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Insect species diversity and abundance in oak forest of Kumaun Himalaya, Uttarakhand

Asha Garia*, **Deepika Goswami, Himanshu Lohani and B.R. Kaushal**

Department of Zoology, Kumaun University, Nainital, Uttarakhand 263002, India
Email: yogitagaria@gmail.com; brkaushal01@gmail.com

ABSTRACT: Species richness, abundance and biomass, species diversity, secondary production and herbivore of insects in an oak forest of Kumaun Himalayan were studied during August 2013 to July 2015. A total of 90 species of insects belonging to 32 families under 8 orders were collected. Herbivores were dominant in terms of number of species (68.4%) and number of individuals (76.9%). Shannon-Wiener diversity index H' varied from 0 to 0.3 and Evenness (E) varied from 0 to 0.04. Mean secondary net production of herbivores was 0.638 KJ $m^2 yr^{-1}$. As a proportion of net primary production, secondary production was only 0.033% suggesting that herbivores were not food limited of the 90 species of insects collected.

KEYWORDS: Insect diversity, abundance, secondary net production, oak forest

INTRODUCTION

The Himalaya represents one of the youngest but most complex mountain systems of the world. Forests are universally known to be critically important habitats in terms of biological diversity they contain and in terms of ecological functions such as pollination, herbivore, decomposition and nutrient cycling, predatory/ parasitism of other species (Bond, 1994) and are greatly affected by relentless habitat destruction (Lowman,1997), they provide. Species richness, abundance and diversity of insects in different forest habitats have been intensively studied by many workers (Singh *et al*., 2010; Sarasija *et al*., 2012; Pande, 2013; Bhardwaj and Thakur, 2015; Usha and John, 2015). The present investigation was aimed at understanding certain structural and functional aspects of an oak forest community in Kumaun Himalaya including species richness, abundance and biomass, species and trophic level diversity, secondary net production and role of insects as pollinators in an oak forest during August 2013 to July 2015.

MATERIALS AND METHODS

The study site Naina Devi Himalayan Bird Conservation Reserve is located at Kilbury (29^o 39 'N and 79^o 44'E longitude; altitude 2528m) about 13 km from Nainital. The area studied is approximately 2 ha and is dominated by *Quercus leucotrichophora* A. Camus, *Q. floribunda* Lindl., *Q. semecarpifolia* Smith, *Q. lanuginosa* D. Don *and Q. glauca* Thunb. tree species. Temperature ranged from 4.6^0C to 25.7^0C (June). Maximum rainfall (69.2%) is during the months of July to September. On this basis, the year can be divided into three seasons namely, rainy (July to October), winter (November to February) and summer (March to June).

* Author for correspondence

Sampling of insects was done at an interval of 30 days. The insects were collected by sweep sampling method (Gadagkar *et al*., 1990) and hand-picking (Jonathan, 1990). The collected insects were killed in jars containing ethyl acetate and were oven-dried to constant weight (60^0C for 24 h). Each dried specimen was weighed in a single pan electric balance (0.01 mg accuracy) for biomass estimation. The collected insects were identified at Forest Research Institute, Dehradun.

Species diversity H' (S) was calculated using Shannon-Wiener expression (1963):

$$H'(S) = -\sum_{i=1} pi \log pi$$

Where $P_{i} = n_i/N$; n_i is the number of species present in the season ; and N is the number of individuals, S denotes the number of seasons.

Buzas and Gibson's Evenness (E_2) was calculated using:

$$E2 = e^{H/S}$$

Where, S is the number of taxa and H is the Shannon Index.

Secondary production comprises that portion of energy which is assimilated by the consumer and is transferred into organic matter, useful as source of energy for other organisms in ecosystem. Time series biomass data was analyzed using Wiegert's (1965) equation for the estimation of secondary production:

$$P = S + \sum_{i=2}^{n} \frac{(Ni + Ni-1)}{2} (Wi - Wi - 1)$$

Where,

Ni = Number of insect present at time 1,

Wi = Mean weight per insect at time 1,

i = Sampling time (Date)

S = Standing crop at time when i = 1

It was assumed that Ni $\leq$ Ni-1 and Wi $\geq$ Wi-1. However, when Wi was less than Wi-1, the production was considered to be zero.

RESULTS AND DISCUSSION

Floristic composition: A total of 58 species were recorded in the oak forest of these, 41 species were shrubs and herbs 17 were tree species. Dominant oak species were *Quercus leucotrichopha, Q. floribunda, Q. semecarpifolia, Q. glauca and Q. lanuginosa.* Primary production of shrubs and herbs was 87.6 g m^2 yr^{-1} (Rawat, 1999).

Species richness and trophic components: A total of 90 species were collected of which 80 species were recorded in both years (Table1). Species richness was highest during summer and rainy seasons (Table 2). Species richness was positively correlated with maximum temperature (r=0.904; Pd"0.01, df=12), minimum temperature (r=0.91; Pd"0.01, df=12) and rainfall (r= 0.489; Pd"0.05, df=12). On the basis of number of species collected, 68.4% were herbivore, 20% predators, 4.7% omnivores, 4.5% parasites, 2.4% saprophages, and on the basis of number of individuals, 76.9% were herbivores, 15.3% predators, 3.3% omnivores, 2.6% parasites and 1.9% saprophages.

Gadagkar *et al*. (1990), Moran *et al*. (1994), Arya (2005) and Pande (2013) have reported that herbivores were the dominant insect group in comparisons to other trophic levels in different forest ecosystems. Herbivores in all reported habitats and in the present investigation are not limited by availability of food, and can thus maintain relatively higher abundances, whereas predatory, parasitic and other trophic components of insect communities depend considerably on the existence of refuge habitats. Thus, population or species in all trophic levels are not limited by the abundance of food and by competition for food resources (Sinclair, 1975; Belovsky, 1986).

Abundance and biomass: Abundance of insects ranged from 0 (December) to 89 ind.ha^{-1} (April) (Table 3). Abundance of insects was positively

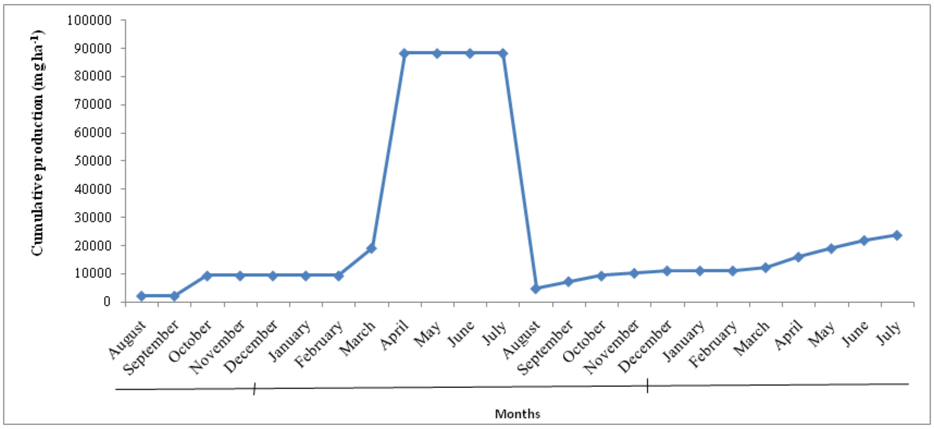

Fig. 1. Cumulative net secondary production of herbivores in oak forest during 2013-2015

Table 1. Species composition, trophic components, number of individuals and their percent contribution in the oak forest during August, 2013 - July, 2015

S. No.	Taxonomic composition	Trophic level	2013-2014		2014-2015	
			No. of individuals	%	No. of individuals	%
	ORDER- LEPIDOPTERA Family-Danaidae					
1.	*Euploea core core* Cramer	Herbivore	2	0.6	4	0.7
2.	*Danaus chrysippus* Linnaeus	,,	2	0.6	2	0.4
	Family-Nymphalidae					
3.	*Lasimmata schakra* Kollar	Herbivore	12	3.5	17	3.1
4.	*Vanessa cashmirensis* Kollar	,,	17	5.0	25	4.5
5.	*Vanessa indica* Herbrt	,,	3	0.9	3	0.5
6.	*Junonia lemonias* Linneaus	,,	1	0.3	2	0.4
7.	*Neptis yerburyi yerburyi* Butler	,,	1	0.3	3	0.5
8.	*Neptis m. mahendra* Moore	,,	4	1.2	6	1.0
9.	*Callerebia nirmala* Moore	,,	14	4.1	18	3.3
10.	*Vanessa cardui* Linnaeus	,,	1	0.3	2	0.4
11.	*Aulocera swaha* Kollar	,,	9	2.6	10	1.8
12.	*Ariadne m.cramer* Cramer	,,	1	0.3	3	0.5
13.	*Lethe verma sintica* Kollar	,,	2	0.6	2	0.4
14.	*Lethe rohria* Fabricius	,,	2	0.6	2	0.4
15.	*Junonia orithya* Linnaeus	,,	1	0.3	2	0.4
16.	*Junonia hierta* Hubner	,,	1	0.3	2	0.4
17.	*Euthalia patala* Kollar	,,	5	1.4	9	1.6
18.	*Phalanta phalantha* Drury	,,	1	0.3	2	0.4
19.	*Euthalia lubentina* Cramer	,,	-	-	6	1.0
	Family-Papilionidae					
20.	*Papilio protenor romulus* Cramer	Herbivore	2	0.6	3	0.5
21.	*Atrophaneura polyeuctes* Doubleday	,,	2	0.6	4	0.7
22.	*Papilio memnon agenor* Linnaeus	,,	1	0.3	2	0.4

S. No.	Taxonomic composition	Trophic level	2013-2014		2014-2015	
			No. of individuals	%	No. of individuals	%
	Family-Pieridae					
23.	*Pieris canidia* Evans	Herbivore	56	16.5	68	12.3
24.	*Catopsilia pyranthe* Linnaeus	,,	3	0.9	7	1.3
25.	*Aporia aganthon.caphusa* Moore	,,	2	0.6	3	0.5
26.	*Colias electo fieldi* Menestries	,,	4	1.2	5	0.9
27.	*Pontia daplidice* Linnaeus	,,	1	0.3	3	0.5
28.	*Eurema herla laeta* Boisduval	,,	5	1.4	7	1.3
29.	*Eurema hecabe* Linnaeus	,,	2	0.6	3	0.5
30.	*Gonepteryx r.nepalensis* Linnaeus	,,	-	-	2	0.4
31.	*Cepora nerissa* Fabricius	,,	3	0.9	6	1.0
	Family-Lycanidae					
32.	*Heliophorous sena* Kollar	Herbivore	9	2.6	20	3.6
33.	*Heliophorous oda* Hewitson	,,	7	2.0	11	1.9
34.	*Lycaena phlaeas* Linnaeus	,,	2	0.6	3	0.5
35.	*Zizeeria* sp.	,,	2	0.6	5	0.9
	Family-Geometridae					
36.	*Rhodostrophia sp.* Moore	Herbivore	-	-	2	0.4
	Family-Riodinidae					
37.	*Dodona durga* Kollar	Herbivore	7	2.0	4	0.7
	Family-Acraeidae					
38.	*Acraea vesta* Fabricius	Herbivore	-	-	2	0.4
	ORDER-COLEOPTERA Family-Coccinellidae					
39.	*Coccinella septumpunctata* Linnaeus	Predator	18	5.2	19	3.4
40.	*Epilachna viginitioctopunctata* Fab.	,,	2	0.6	4	0.7
41.	*Palaeoneda auriculata* Mulsant	,,	2	0.6	6	1.0
42.	*Micraspis univittata* Hope	,,	1	0.3	3	0.5
43.	*Psyllobora bisoctonotata* Mulsant	,,	1	0.3	2	0.4
44.	*Adonia variegate* Goeze	,,	1	0.3	4	0.7
	Family-Chrysomelidae					
45.	*Aulacophora foveicollis* Lucas	Herbivore	1	0.3	3	0.5
46.	*Haltica cyanea* Weber	,,	2	0.6	5	0.9
47.	*Zygogramma bicolorata* Pallister	,,	1	0.3	3	0.5
48.	*Merista quadrifasciata* Hope	,,	4	1.2	7	1.3
49.	*Altica* sp.	,,	16	4.7	31	5.6
	Family-Carabidae					
50.	*Chlaenius* sp.	Predator	2	0.6	4	0.7
	Family-Scarabaeidae					
51.	*Onitis philemon* Fabricius	Saprophagous	1	0.3	4	0.7
52.	*Oxycentonia versicolor* Fabricius	Herbivore	3	0.9	3	0.5
53.	*Anomala dimidiate* Hope	Herbivore	3	0.9	6	1.0

S. No.	Taxonomic composition	Trophic level	2013-2014		2014-2015	
			No. of individuals	%	No. of individuals	%
	Family-Tenebrionidae					
54.	*Lagria* sp.	Omnivorous	3	0.9	5	0.9
	Family-Meloidae					
55.	*Mylabris cichorri* Linnaeus.	Predator	10	2.9	12	2.2
	Family- Cerambycidae					
56.	*Lamiinae* sp.	Herbivore	-	-	1	0.2
	ORDER-HYMENOPTERA Family-Apidae					
57.	*Apis dorsata* Fabricius	Herbivore	5	1.4	7	1.3
58.	*Bombus* sp. Latreille	,,	4	1.2	4	0.7
59.	*Apis* sp.	,,	2	0.6	2	0.4
60.	*Xylocopa* sp.	,,	2	0.6	7	1.3
	Family-Vespidae					
61.	*Vespa cincta* De Geer	Predator	1	0.3	3	0.5
62.	*Vespa ducalis* Smith	Omnivorous	2	0.6	6	1.0
63.	*Polistes* sp.	Predator	-	-	5	0.9
64.	*Eumenes dimidiatipennis* De Saussure	,,	2	0.6	3	0.5
	Family-Formicidae					
65.	*Componotus compressus* Fabricius	Predator	3	0.9	4	0.7
	Family-Ichneumonidae					
66.	*chenumon xanthorious* Forster	Parasite	4	1.2	5	0.9
67.	*Xanthopimpla* sp.	,,	-	-	2	0.4
68.	*Microphthalmia bucephala* Fall.	,,	2	0.6	4	0.7
69.	*Xanthopimpla stemmator* Thunberg	,,	-	-	4	0.7
	Family-Sphecidae					
70.	*Trypoxylon* sp.	Predator	1	0.3	4	0.7
	ORDER-ORTHOPTERA Family-Gryllidae					
71.	*Gryllus* sp.	Omnivorous	5	1.4	5	0.9
72.	*Brachytrupes orientalis* Burmeister	,,	1	0.3	3	*0.5*
	Family-Acrididae					
73.	*P. scabra* Klug	Herbivore	4	1.2	8	1.4
74.	*Phlaeoba* sp.	,,	2	0.6	6	1.0
	Family- Tettigonidae					
75.	*Elimaea* sp.	Herbivore	4	1.2	5	0.9
76.	*Neoconocephalus* sp.	,,	1	0.3	3	0.5
	ORDER-HEMIPTERA Family-Pyrrhocoridae					
77.	*Physoptata gutta* Brum	Herbivore	9	2.6	13	2.4
	Family-Pentatomidae					
78.	*Dolycoris indicus* Stal	Herbivore	2	0.6	4	0.7
79.	*Palomena spinosa* Distant	,,	3	0.9	6	1.0
80.	*Murgantia histrionic* Hahn	,,	6	1.7	8	1.4
81.	*Andrallus spinidens* Fabricius	,,	1	0.3	3	0.5

S. No.	Taxonomic composition	Trophic level	2013-2014		2014-2015	
			No. of individuals	%	No. of individuals	%
	Family-Coreidae					
82.	*Euthochtha galeator* Fabricius	Herbivore	2	0.6	4	0.7
	ORDER-DIPTERAFamily-Asilidae					
83.	*Neoitamus grandis* Ricardo	Predator	1	0.3	1	0.1
84.	*Philodicus femoralis* Ricardo	,,	4	1.2	5	0.9
	Family-Tipulidae					
85.	*Tipula* sp.	Herbivore	-	-	2	0.3
	Family-Tabanidae					
86.	*Tabanus* sp.	Parasite	1	0.3	2	0.3
	Family-Muscidae					
87	*Musca* sp.	Saprophagous	5	1.4	7	1.3
	ORDER-ODONATA					
	Family- Libelluidae					
88.	*Pantala flavescence* Fabricius	Predator	1	0.3	2	0.3
89.	*P. s. sexmaculatata* Fabricius	,,	-	-	2	0.3
	ORDER -MANTODEA					
	Family-Mantidae					
90.	*Mantis* sp.	Predator	2	0.6	2	0.3
		340	100	553	100	

Table 2. Monthly variation in the species content of different taxa, total species and percentage in the oak forest during August, 2013 to July, 2015 (mean of two years)

Taxon/ Months	Lepidoptera		Orthoptera		Coleoptera		Hymeno-ptera		Odonata		Hemiptera		Diptera		Mantodea		Total
	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	%
August	12	38.7	5	16.1	7	22.6	3	9.7	1	3.2	2	6.5	1	3.2	-	-	100
September	10	40.0	4	16.0	5	20.0	2	8.0	1	4.0	1	4.0	2	8.0	-	-	100
October	10	47.6	3	14.3	4	19.0	1	4.8	-	-	2	9.5	1	4.8	-	-	100
November	4	50	-	-	3	37.5	-	-	1	12.5	-	-	-	-	-	-	100
December	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
January	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
February	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
March	8	66.6	-	-	2	16.6	1	8.4	-	-	1	8.4	-	-	-	-	100
April	17	53.1	2	6.3	6	18.7	4	12.5	-	-	2	6.3	1	3.1	-	-	100
May	15	48.3	2	6.4	6	19.5	3	9.6	-	-	2	6.5	2	6.5	1	3.2	100
June	13	43.4	2	6.8	9	30.0	2	6.6	-	-	1	3.3	2	6.6	1	3.3	100
July	10	38.5	2	7.7	9	34.7	2	7.7	1	3.8	1	3.8	1	7.7	-	-	100

Table 3. Shannon-Wiener diversity index (H’) and Evenness (E) of insect fauna in the oak forest during August, 2013- July, 2015

Months	August, 2013- July, 2014				August, 2014- July, 2015			
	S (Richness)	N (Abundance)	H’ (Shannon index)	E (Evenness)	S (Richness)	N (Abundance)	H’ (Shannon index)	E (Evenness)
August	24	38	0.24	0.01	27	76	0.30	0.01
September	22	36	0.23	0.01	23	67	0.24	0.01
October	17	32	0.22	0.01	17	44	0.23	0.01
November	6	12	0.11	0.02	6	19	0.15	0.03
December	0	0	0	0	2	8	0.08	0.04
January	0	0	0	0	0	0	0	0
February	0	0	0	0	0	0	0	0
March	8	29	0.20	0.03	11	42	0.20	0.02
April	28	58	0.30	0.01	21	89	0.27	0.01
May	23	52	0.28	0.01	23	82	0.25	0.01
June	21	44	0.26	0.01	20	77	0.24	0.01
July	21	39	0.24	0.01	18	49	0.21	0.01
Total	**170**	**340**	**2.08**	**0.12**	**168**	**553**	**2.17**	**0.16**

Table 4. Shannon-Wiener diversity index (H') and Evenness (E) of herbivores in the oak forest during August, 2013 to July 2015

Months	August, 2013- July, 2014				August, 2014- July, 2015			
	S (Richness)	N (Abundance)	H’ (Shannon index)	E (Evenness)	S (Richness)	N (Abundance)	H’ (Shannon index)	E (Evenness)
August	9	28	0.28	0.03	10	47	0.25	0.03
September	8	17	0.21	0.03	8	36	0.22	0.03
October	9	25	0.26	0.03	7	21	0.17	0.02
November	3	9	0.14	0.05	3	9	0.11	0.04
December	0	0	0	0	2	8	0.10	0.05
January	0	0	0	0	0	0	0	0
February	0	0	0	0	0	0	0	0
March	4	16	0.21	0.05	6	19	0.23	0.04
April	13	37	0.32	0.02	9	44	0.25	0.03
May	8	20	0.23	0.03	13	37	0.29	0.02
June	6	18	0.22	0.04	11	36	0.27	0.02
July	6	17	0.21	0.04	9	23	0.26	0.03
Total	**66**	**187**	**2.08**	**0.32**	**78**	**280**	**2.15**	**0.31**

correlated with maximum temperature ($r=0.84$; Pd"0.01, df=12), minimum temperature ($r=0.832$; Pd"0.01, df=12) and rainfall ($r=0.42$; $P<<0.05$, df=12). Low and high temperature and rainfall influenced the abundance of insects in the present study. Extremely low and high temperature, rainfall and vegetation cover have been reported to influence the population density of insects (Thomas *et al*., 1998; Zheng *et al*., 2008; Dev *et al*., 2009; Regniere *et al*., 2012). Biomass of insects ranged from 0 (December) to 6385.1 mg ha^{-1} (May). Biomass of insects was significantly and positively correlated with maximum temperature ($r=0.786$; Pd"0.01, df=12), minimum temperature ($r=0.419$; $P<<0.05$, df=12) and abundance ($r=0.966$; Pd"0.01, df=12).

Species diversity and Evenness: The Shannon-Wiener diversity index H' varied from 0 to 0.3 (Table 3). Herbivores had almost similar species diversity (0 to 0.32) because of their higher percent contribution towards total abundance (Table 4). Buzas's Evenness (E) which takes into account the distribution of species and their numbers across gradients have returned low values between 0 to 0.04 during the study period (Tables 3 and 4). Monthly fluctuations recorded could be due to changes in the numerical importance of some of the species. Diversity index (H') and Evenness (E) were zero during the months of December to February when insects were not recorded due to extreme cold climatic conditions.

Low species diversity index H' (0.3) recorded in the present study in comparison to reported values of 1.38 to 3.57 in different forest ecosystems (Torchote *et al*., 2010; Pande, 2013; Arya *et al*., 2015; Bhardwaj and Thakur, 2015 ; Usha and John, 2015) could be due to lower number of species and abundance of insects collected. Human disturbances such as grazing (You and Li, 2006), predatory insects (Boiteau, 1983) and cutting of vegetation (Morris and Plant, 1983) result in serious degeneration of the environment and reduction in the species diversity in different ecosystems.

Secondary net production: The tissue production estimates of herbivores in the present study is the present study is based on the calculations of the mean biomass of herbivores on each sampling data during 2013-2015 (Fig. 1). Cumulative net secondary production was 422.814 g ha^{-1} yr^{-1} (9301.9 KJ $ha^{-1}yr^{-1}$ or 0.93019 KJ m^{-2} yr^{-1}) in the first year when converted to Joules by multiplying with 22 J mg^{-1} (Kaushal and Joshi, 1991), 157.064g ha^{-1} yr^{-1}(3455.4 KJ $ha^{-1}yr^{-1}$ or 0.34554 KJ $m^{-2}yr^{-1}$) (Fig. 1). As a proportion of net primary production, secondary production of 0.033% recorded in the present study fall in the range of reported values of 0.006 to 5.8 % (Blummer and Diemer, 1996; Dev *et al*., 2009).

Insects as pollinators: Of the 90 species recorded, 61 pollinator species were observed to have visited flowers of different plants and trees regularly. Pollinator species belonged to Lepidoptera (40 species), Hymenoptera (9 species) and Coleoptera (12 species). Pollinators are essential for survival of forest ecosystems and strongly influence ecological interactions, floral diversity and genetic variation in the plants community. Although 80% the insect pollination is performed by Hymenoptera, bees in particular (Sihag, 1988; Taha and Bayoumi, 2009; Joshi and Joshi, 2010) but also by Lepidoptera (Hodges *et al*., 2002), Coleoptera (Pande, 2013) and Diptera (Larson *et al*., 2001). Pollinators recorded in the present study could also thus fulfill ecological functions such as pollination and plant-insect interactions.

The present study reveals the species richness and abundance of insects. Herbivores were the dominant group because they were not limited by the availability of food. Low species Diversity (H') and Evenness (E) could be attributed to low species richness and abundance of insects. Natural habitat conservation is very important for the existence of insect species.

REFERENCES

Arya M. (2005) Population dynamics of entomofauna of Pinder valley, part of buffer zone of Nanda Devi Biosphere Reserve in district Bageshwar (Uttaranchal). Ph.D Thesis submitted to G. K. University, Haridwar.

Arya M. K, Joshi P.C. and Badoni V.P. (2015) Species composition, abundance and diversity of grasshoppers (Insecta:Orthoptera) in a protected forest ecosystem in the Western Himalayas, India. International Journal of Fauna and Biological Studies 2(5): 42-46.

Belovsky G.E. (1986) Generalist herbivore foraging and its role in competitive rainforest tree: Abundance of component taxa, species richness and guild structure. Australian Journal Ecology, 17: 89-98.

Bhardwaj D. K. and Thakur K. N. (2015) Diversiy of insects in Sal (*Shorea robusta*) forest at selaqui region, Dehradun (India). International Journal Pharma and Biological Science 6(1) (B) :793-800.

Blummer P. and Diemer M. (1996) The occurrence and consequences of grasshopper herbivory in alpine grassland, Swiss central Alps. Arctic and Alpine Research 28: 435-440.

Boiteau G. (1983) The Arthropod community of potato fields in New Brunswick. Canadian Entomologist 115: 847-853.

Bond W. J. (1994) Do mutualism matter? Assessing the impact of pollinator and disperser disruption of plant extinction. Philosophical Transactions of the Royal Society of London B 344: 83-90.

Dev P., Tewari M. and Kaushal B. R. (2009) Diversity and abundance of insects in a cropland of central Himalayan Bhabar region of Kumaun, Uttarakhand. Entomon 34(1): 11-21.

Gadagkar R., Chandrashaekara K. and Nair P. (1990) Insect species diversity in the tropics: sampling method and case study. Journal of Bombay Natural History Society 87(3): 328-353.

Hodges s.A., Whittal J.B., Fulton M. and Yang J.Y. (2002) Genetics of floral traits influencing reproductive isolation between *Aquilegia formosa* and *A. pubescens*. American Naturlist 159: 51-60.

Jonathan J. K. (1990) Collection and preservation of animals (Hymenoptera). Zoological Survey of India, Calcutta. 147-150.

Joshi N.C. and Joshi P.C. (2010) Foraging behavior of Apis sp. on Apidae on Apple flowers in a subtropical environment. Newyork Science Journal 3(3): 71-76.

Kaushal B.R. and Joshi P.C. (1991) Energy dynamics of grasshopper population in a temperate grassland community. Australian Journal Ecology 16(3): 295-300.

Larson B.M.H., Kevan P.G. and Inouye D.W. (2001) Flies and flowers: The taxonomic diversity of anthophiles and pollinators. Canadian Entomologist 133(4): 439-465.

Lowman M.D. (1997) Herbivory in Forest- From Centimeters to Megametres. In : Forests and Insects, Watt A.D., Stork N.E. and Hunter M.D (Eds.). Chapman and Hall, London. 135-149.

Moran V. C., Haffaman J H, Impson F. A. C. and Jenkins J. F. G. (1994) Herbivorous insect species in the tree canopy of a relict South African Forest. Ecological Entomology 19: 147- 154.

Morris M.G. and Lakhani K.H. (1979) Responses of grassland invertebrates to management by cutting. I. Species diversity of Hemiptera. Journal of Applied Ecology 16: 77-98.

Pande P.K. (2013) Population dynamics of insects and their role in sustaining forest ecosystem in Askot Wildlife sanctuary of District Pithoragarh. Ph.D Thesis, Kumaun University, Nainital. 206 p.

Rawat S. (1999) Population dynamics and nutrient content of aboveground arthopods in Pine, Oak and Mixed-oak forests. Ph.D. Thesis, Kumaun University, Nainital, India. 190p.

Regniere J., Powell J., Bentz B. and Nealis V. (2012) Effects of temperature on development, survival and reproduction of insects: Experimental design, data analysis and modeling. Journal of Insect Physiology 58: 634-647.

Sarasija P., Remadevi O. K. and Srinivasa Y. B. (2012) Comparison of saproxylic insect diversity in three forest types of Rajiv Gandhi National Park, Nagarahole (Nilgiri Biosphere Reserve, India). Current Biotica 5(4): 413-420.

Shannon C. E. and Weiner W. (1949) The Mathematical Theory of Communication. University Illinois Press, Urbana, IL.

Sihag R.C. (1988) Characterization of pollinators of cultivated cruciferous and leguminous crops of sub-tropical Hisar, India. Bee World 69: 153-158.

Sinclair A.R.E. (1975) The resource limitation of trophic levels in tropical grassland ecosystems. Journal Animal Ecology 44: 479-520.

Singh O. T., Chakravorty J., and Varatharajan R. (2010) Entomofauna of Kane Wildlife Sanctuary, Arunachal Pradesh, North Eastern India. Journal of Threatened Taxa 2(13): 1392-1400.

Taha E.A. and Bayoumi Y.A. (2009) The value of honey bees (*Apis mellifera*, L.) as pollinators of summer sed watermelon (*Citrullus lanatus colothynthoides* L.) in Egypt. Acta Biologica Szegediensis 53(1); 33-37.

Thomas J. A., Simcox D. J., Wardlaw J. C. and Clarke R. T. (1998) Effect of latitude, altitude and climate on the habitat and conservation on the endangered butterfly *Maculinea arion* and its

Myrmica ant host. Journal of Insect Conservation 2: 39-46.

Torchote P., Sitthicharoenchai D. and Chaisuekul C. (2010) Ant species diversity and community composition in three different habitats: Mixed deciduous forest, Teak plantation and fruit orchards. Tropical Natural History 10(1): 37-51.

Usha A.U. and John V.K. (2015) A study on insect diversity of a selected area in Wadakkanchery (Thrissur, Kerala). Journal of Zoology Studies 2(3): 38-50.

Wiegert R. G. (1965) Energy dynamics of the grasshopper population in an Oldfield and alfalfa ecosystems. Oikos 16: 161-176.

You P. and Li Houhun (2006) A study on the diversity of the month community in the North Dagang Wetland Nature Reserve Tianjin, China. Acta Ecologia Sinica 26 (4): 999-1003.

Zheng F. S., Du Y. Z., Wang Z. J. and Xu J. J. (2008) Effect of temperature on the demography of *Galerucella birmanica* (Coleoptera: Chrysomelidae). Insect Science 15: 375-380.

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