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The seasonal distribution of litter coleopteran population and its relationship with edaphic factors in a tropical evergreen forest of West Bengal, India.

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Abstract

A lot of work has been done on seasonal variation in insects abundances in many tropical forests all over the world. This study centre's round the comparison of seasonal changes of order Coleopteran population under the gradients of edaphic factors, which include moisture, temperature, pH, organic carbon, inorganic nitrogen, phosphorus, sodium and potassium contents of an anthropogenous tropical forest, Bibhutibhushan sanctuary in West Bengal. This study also examines the seasonal occurrence of different species of Coleoptera and their relationship with particular edaphic factors where little research has been done. A total of 2538 specimens representing 15 families 26 genera and 31 species were recorded. The variation in abundance of Coleoptera is significant during the study period. The higher numbers of insects were collected in December and August which are in winter and monsoon seasons respectively while the lowest numbers were observed in August and June, both of which are in the monsoon season, in the first and second study year, when soil temperature and soil nitrogen content had shown remarkable variations. . In the study area, some species were moderately distributed in different seasons, while the distribution of the others species were found to be irregular and discrete in nature. The present study helps to distinguish the actual cause of seasonal variation of Coleopteran populations i.e. the effect of particular edaphic or other factor on them.

Keywords: Forest litter, coleoptera, population abundance, seasonal variation, significant correlation, Pearson's correlation, canonical correspondence analysis.

Introduction

In forest litter, leaf content is very high along with bark, stems, root, fruits, and flowers. The decomposition of such organic matters starts with the infestation of micro organisms . Their activities help to change the chemical composition of the litter soil as well as decaying organic matter . Litter fall is an inherent part of nutrient and carbon cycling and it forms a protective layer on the soil surface that also regulates microclimatic conditions of soil. Long term litter removal, increased soil bulk density, overland flow, erosion and temperature fluctuations and upset of the soil water balance cause lower soil water content during dry season. The direct effect of rainfall arises from the physical effects of large amount of water falling on litter fauna and forest floor litter (Chiba *et. al.* 1975, Boinski and Fowler 1989). In some tropical dry forest an inhibition of decomposer community results in a transient accumulation of litter on the forest floor during the dry season (Swift and Anderson, 1989). Factors such as litter temperature, moisture, other edaphic factors and slope of the terrain have been shown to be influencing abundance and distribution of the litter insects as observed by Samson *et al.* 1997; Bruhl *et al* . 1999; Kaspari *et al* 2000; Fisher and Robertson 2002; Sanders *et al.* 2003; Vineesh *et al.* 2007. These generally occur due to seasonal variation. The amount of litter fall may change on a seasonal basis or based on the forest vegetation type resulting in litter depth peaking perhaps once or twice throughout the year (Ananthakrishnan, T.N .,1996). Among Coleoptera the population of family Carabidae, Scarabadae, Tenebryonidae, Scydminidae, Curculionidae, Ptilidae, Cerumbicidae, Anthicidae, Selaphidae, Dytiscida and Nitidulidae are found in forest litter. Normally they exhibit maximum varieties of species.

As such present investigation has been initiated with the objectives like (i) To know the diversity of coleopteran insects and its seasonal variations in forest litter ecosystem of BibhutiBhushan sanctuary, (ii) To study the edaphic factors of the litter and their relation to insects fauna in these ecosystem and (iii) To study the seasonal variations in respect of edaphic factors in this study area.

Materials and Methods

The present work has been carried out in Bibhutibhushan Sanctuary (District North 24 parganas) which is categorized as a northern tropical moist deciduous forest. The Geographical location is between 88.45°East longitude and 23.12°North latitude. It is characterized by an oppressive hot summer and high humidity all around the year, particularly during the rainy season . The mean annual soil temperature ranges from 17.7°C-38.5°C. Soil moisture is higher during late monsoon, autumn months and comparatively less during summer months.

Samples were collected from December' 2006 to December' 2008 and were taken fortnightly. The mean observed value of six seasonal samples were used to evaluate the abundance of insects' fauna for a particular season. For analysis of edaphic factors and for population study, litter soil was collected from each plot throughout the period of sampling. Factors like temperature, pH, soil moisture content and inorganic factors like sodium, potassium, phosphorus, nitrogen and organic carbon are analyzed by means of standard methods. Temperature of the soil was measured by a centigrade thermometer inserting directly into the soil at each sampling plot. Its pH value was measured in room temperature by using a digital pH meter (Systematics-121, India). For analyzing carbon (organic) matter, Walky and Black method was applied. Total nitrogen content of the soil was analyzed using micro-Kjeldahl distillation method (Jackson, 1958). Phosphate content of the soil was determined by molybdate- stannous chloride method (Jackson, 1958). Potassium and sodium content were analyzed by flame photometry method of ASA (1965).

Faunal Composition and Seasonal Variation

The study year had been divided in to four seasons.

Winter….December to February, Summer …..March to May, Monsoon ….. June to August, Autumn…. September to November.

Seasonal variation in abundance of tropical insects is a common phenomenon (Wolda 1988; Pinheiro *et al.* 2002). Season wise variation in the population of Coleopteran and other edaphic factors in different sites , as observed during the study period, are as follows .

Monthly distribution of insects varied in number during the collection period due to its differences in microhabitat (Table1 & Fig.1). During the period 2006-07 and 2007-08 the season wise distribution of insect's population revealed that Coleopteran represents 26 genera and 31 species. It showed maximum population during winter (December) in 2006-07 and monsoon (August) in 2007-08 and minimum during the period of Monsoon in 2006-07 and 2007-08 (June and August respectively) (Fig.-1).

Table-1: Edaphic factors along with abundance of Coleoptera throughout the years.

Month	Coleoptera	Temperature ^0C	Moisture %	pH	Na mg/kg	K mg/kg	P mg/kg	N %	C %
Dec.2006	210	17.75	19	7.84	15	86	45	3.4	4.2
Jan,2007	116	18	11.5	7.13	10	90	39	1.95	4.7
Feb,2007	108	20.75	17.75	7.9	12	91	54	0.81	3.4
March,2007	80	25.25	14.75	7.3	16	80	55	0.84	1.43
April,2007	92	28.5	11.5	7.29	11	78	56	1.1	2.9
May,2007	32	28.75	10.1	7	17	79	55	1.94	4.5
June,2007	28	29.75	13.75	6.8	20	86	52	2.25	5.2
July,2007	100	31	20.25	6.7	32	89	55	3.05	5
Aug,2007	20	38.5	24.1	6.75	103	93	56	4.08	4.8
Sept,2007	108	36	34	6.77	162	90	57	0.77	5.6
Oct,2007	88	27.75	35.5	6.73	128	96	58	1.02	5.3
Nov,2007	84	27	29.3	7.77	17	92	58	2.18	5
Dec,2007	98	18	18	7.93	7	88	60	13.65	4.8
Jan,2008	130	18.25	14.3	7.2	8	91	56.5	2.17	5.4
Feb,2008	89	21	18.1	7.04	11	96	55	0.77	3.8
March,2008	138	26.25	12.6	7.14	9	85	56	0.86	2.8
April,2008	114	29.25	12	7.08	8	77	57	1.33	3.4
May,2008	97	29.75	11.5	7.05	16	84	56	2.17	4.8
June,2008	20	29.5	12	6.85	22	89	55	2.65	5.6
July,2008	96	30.25	19	6.78	38	94	53	3.37	5
Aug,2008	242	32	22	6.72	152	95	54	13.51	5.2
Sept,2008	98	30.25	20	6.82	160	91	56	1.15	5.4
Oct,2008	135	28	30.1	7	139	99	57	0.49	5.2
Nov,2008	215	24.75	27.5	7.38	8	90	61	10.92	5.1

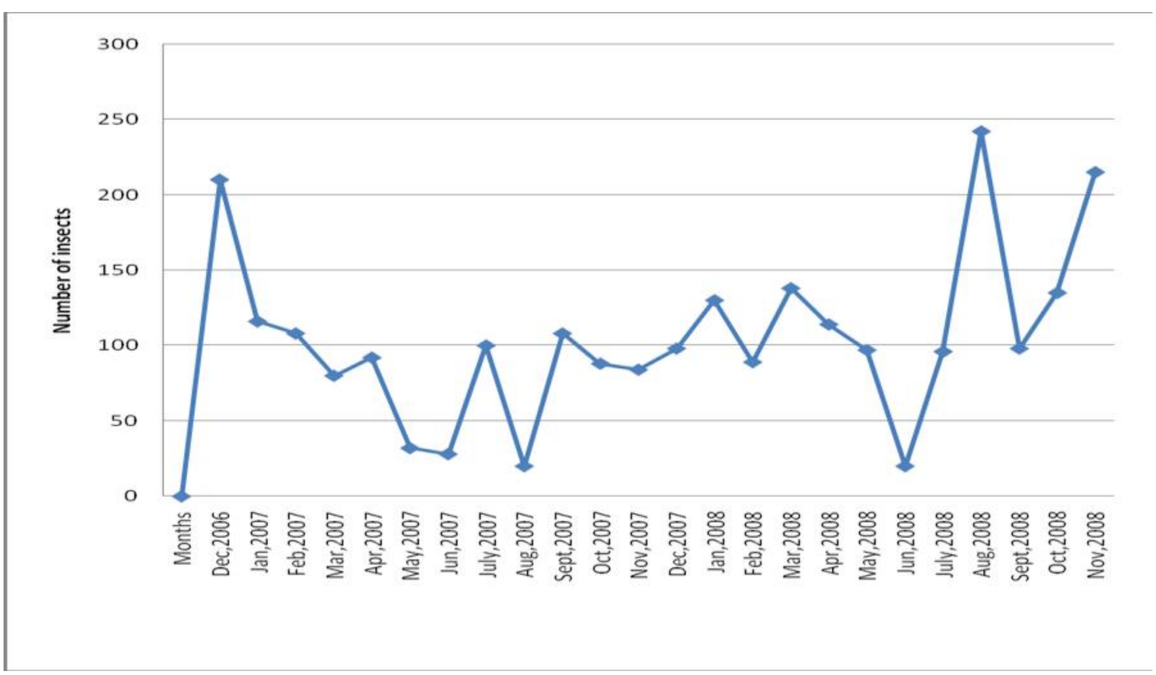

Fig.1: Seasonal abundance of order Coleoptera at Bibhutibhushan sanctuary.

At Bibhutibhushan sanctuary Coleopteran species like *Scaphisoma agaricinum* showed maximum abundance during winter 2007. But *Osorius loptuensis*, *Trogophlius calcuttanus*, *Scydmineus* sp. showed maximum abundance during 2007-08 (Fig.2). These are present in almost all the months throughout the study period. However, *Copeletus mysorensis*, *Copeletus indicus*, *Apogonia area*, *Hypothenium areccae* , *Hippocaccus sinae* , *Phloebius alternans* and *Cypturus bengalensis* showed minimum abundance throughout the study period (Table-1A & Fig.2).

Others species like *Osorius loptuensis*, *Osorius gardneri*, *Xanthilinus ruficaudatus*, *Xantholinus aenius*, *Stilicus pygmius*, *Staphylinus bengalensis*, *Trogophlius calcuttanus*, *Gonocephalum depresum*, *Scaphisoma agaricinum*, *Scydmineus* sp, *Coccotrypes carpophagus*, *Dyscherius globosus*, *Onthophagus orientalis* , *Agonotrichus dicranoides*, *Bembidion notatum* were widely distributed throughout the year (Table-1A & Fig.2). Some species are moderately distributed in different seasons. The distribution of these species were found to be irregular and discrete in nature, which are *Philonthus carbonarius*, *Acupalp usmeridians*, *Stenus sikkimensis*, *Anomola bengalensis*, *Apogonia aerea*, *Staphylinus sikkimensis*, *Staphylinus bengalensis*, *Clivina fasciata* among Coleoptera. (Table-1A & Fig.2).

Table-1A: Seasonal abundance of order Coleoptera at Bibhutibhushan sanctuary.

Species	Winter		Summer		Monsoon		Autumn	
	2007	2008	2007	2008	2007	2008	2007	2008
Osorius loptuensis	12	12	16	8	4	4	68	156
Osorius gardneri	8	12	8	20	0	12	8	28
Philonthus carbonarius	12	16	0	0	0	8	0	4
Philonthus bengalensis	8	16	0	0	0	0	0	0
Xantholina aeneus	20	12	12	28	4	4	0	0
Xanthilina ruficaudatus	8	4	12	6	0	0	0	0
Stilicus pygmicus	4	5	8	4	0	0	0	0
Staphylinus bengalensis	8	4	16	37	12	24	16	12
Staphylinus sikkimensis	0	3	0	5	0	0	12	6
Trogophleus Calcatanus	4	9	0	31	28	100	16	20
Adoretus bengalensis	0	0	16	9	0	0	0	0
Onthopnagus orientalis	8	4	0	5	4	8	4	0
Apogonia aerea	0	0	0	0	0	4	4	0
Anomala bengalensis	0	0	4	0	12	4	4	0
Copelatus mysorensis	0	0	0	0	0	4	0	4
Copelatus indicus	0	8	0	0	0	0	0	0
Coccotrypes carpophagus	108	118	40	16	4	0	28	83
Scydmineus sp.	28	4	20	104	12	130	20	20
Gonocepnalum depressum	20	27	4	28	0	4	16	0
Scaphisoma agaricinum	138	27	20	7	0	0	4	19
Dyschirius sp.	20	8	16	8	8	12	40	76
Bembidion notatum	8	8	0	4	0	0	20	8
Agonotrechus dicranoides	4	12	12	4	0	12	0	0
Liodaptus biramunus	4	8	0	16	28	28	4	12
Meligethis tilurani	4	0	0	4	8	0	4	0
Hypotheniums areccae	4	0	0	0	0	0	0	0
Hipocaccus sinae	0	0	0	4	0	0	0	0
Aphthonoides himalayensis	4	0	0	4	8	0	4	0
Phloebius alternans	0	0	0	0	8	0	0	0
Macrotoma spinosa	0	0	0	0	0	0	0	4
Cypturus bengalensis	0	0	0	0	8	0	0	0

Table- 1B Mean abundance (square root) indifferent of location in order Coleoptera.

SPECIES	OBS(TRAN)	OBS(TRNS)	OBS(TRNS)	OBS(TRNS)
	SEASON			
	Autumn	Monsoon	Summer	Winter
Osorius loptuensis	10.33(2.29)	0.83(0.64)	1.71(1.07)	2.63(1.31)
Osorius gardneri	3.04(1.37)	0.67(0.51)	1.17(0.67)	2.33(1.29)
Philonthus carbonarius	0.83(0.65)	0.33(0.39)	0.0(0.22)	2.50(1.23)
Philonthus bengalensis	0.0(0.22)	0.0(0.22)	0.0(0.22)	1.00(0.58)
Xantholina aeneus	0.83(0.61)	0.33(0.42)	4.00(1.57)	179(0,90)
Xanthilina ruficaudatus	0.17(0.32)	0.17(0.32)	1.08(0.68)	0.50(0.45)
Stilicus pygmius	1.0(0.59)	0.50(0.47)	1.33(0.80)	1.38(0.81)
Staphylinus bengalensis	1.33(073)	1.50(0.84)	5.04(177)	1.67(0.93)
StaphylinuJs sikkimensis	075(0.65)	0.0(0.22)	2.08(075)	0.13(0.29)
Trogophleus manh kolkatanus	3.17(1.39)	6.33(1.65)	2.46(1.20)	3.54(1.45)
Adoretus bengalensis	0.0(0.22)	0.0(0.22)	1.04(0.60)	0.00(0.22)
Onthopnagus orientalis Harold	1.17(075)	0.67(0.57)	0.87(0.63)	0.83(0.69)
Apogonia aerea	0.17(0.32)	1.50(0.90)	1.17(0.62)	0.0(0.22)
Anomala bengalensis	0.17(0.32)	0.67(0.56)	0.17(0.32}	0.0(0.22)
Copelatus mysorensis	0.17(0.32)	0.0(0.22)	0.0(0.22)	0.33(0.37)
Copelatus indicus	00.0(0.22)	0.0(0.22)	0.0(0.22)	0.33(0.37)
Coccotrypes carpophagus	4.62(1.14)	1.00(0.63)	2.67(1.22)	10.25(2.12)
Scydminus sp.	2.83(1.33)	5.92(135)	5.83(1.69)	2.17(0.93)
Gonocepnalum depressum	0.67(0.51}	0.17(0.32)	1.33(0.67)	2.13(1.04)
Scaphisoma agaricinum	1.13(0.75)	2.50(1.10)	2.63(1.12)	7.87(2.11)
Dyschirius sp.	4.83(1.24)	0.83(0.55)	1.33(073)	2.67(1.17)
Bembidion notatum	1.17(0.77)	0.17(0.32)	3.33(0.91)	1.83(1.15)
Agonotrechus dicranoides	1.67(070)	0.50(0.41)	2.83(1.15)	1.33(0.80)
Liodaptus biramunus	1.83(0.96)	0.33(0.86)	2.17(0.98)	0.67(0.57)
Meligethis tilurani Easton	0.33(0.42}	0.50(0.46)	0.83(0.61}	0.83(0.64)
Hypothenimus areccae	0.50(0.41)	0.17(0.32)	0.0(0.22)	0.83(0.66)
Macrotoma spinosa	0.17(0.32)	0.0(0.22)	0.00(0.22)	0.17(0.32)
Aphthonoides himalayensis	0.00(0.22)	0.50(0.47)	0.0(0.22)	0.0(0,22)
Phloebius alterans	0.13(0.29)	0.38(0.41)	0.17(0.32)	0.33(0.37)
Hipocaccus sinae	0.0(0.22)	0.0(0.22)	0.17(0.32)	0.0(0.22)
Cypturus bengalensis	0.0(0.22)	0.33(037)	0.0(0.22}	0.0(0.22)

OBS=Observed value, TRAN = Transformed value.

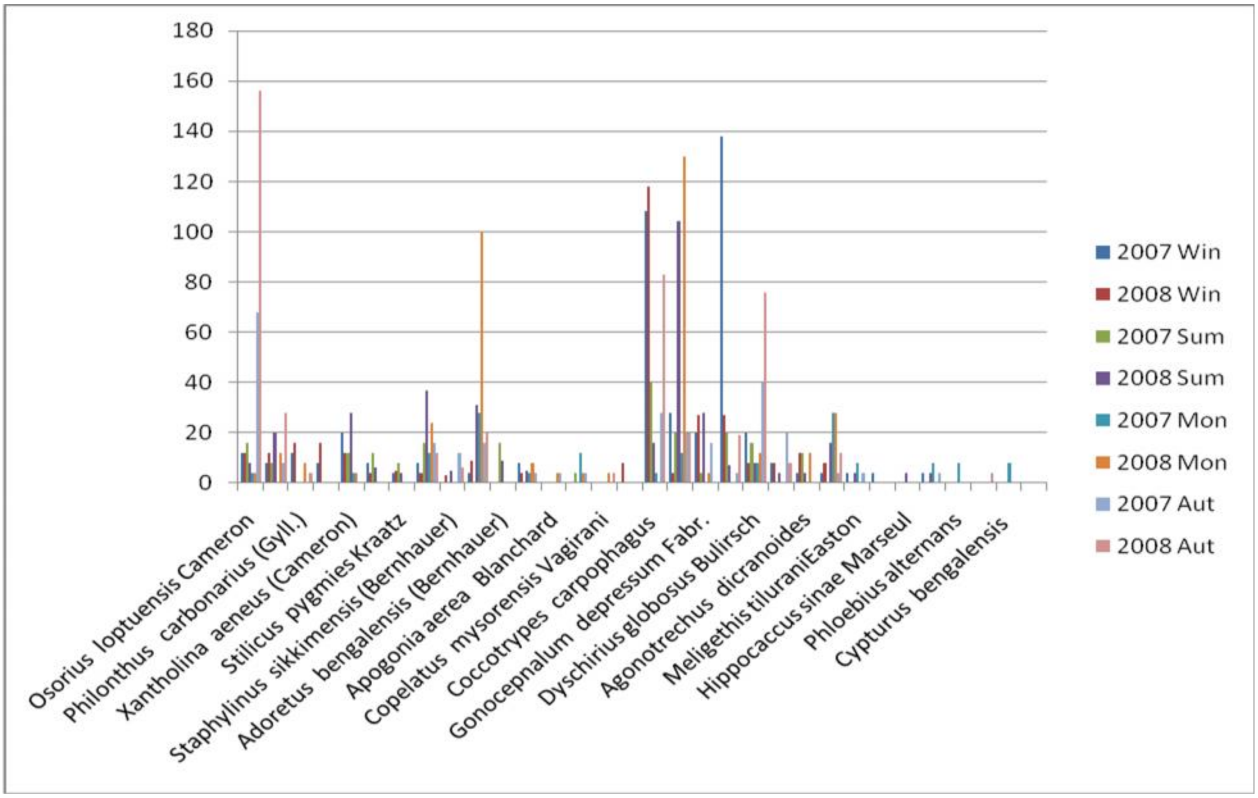

Fig.2: Seasonal fluctuation of population of different species in Coleoptera at Bibhutibhushan Sanctuary.

Soil temperature at Bibhutibhushan sanctuary showed its regular peak during August, 2007 and 2008. From Table- 1, it was found that the average temperature of soil at Bibhutibhushan sanctuary showed a regular pattern of winter minima and summer maxima. Soil moisture showed its regular peak during October in 2007 and 2008 (Table-1). Soil pH concentration showed its highest peak during December in the study period. Though little drop have been recorded during July and August in both 2007 and 2008. Month wise changes in pH at Bibhutibhushan sanctuary showed little variations. The soil was found to be weekly alkaline at all the sites during entire period of study, with few exceptions, when it became neutral. Sodium concentration showed its usual peak during September in 2007 and 2008 (Table-1). Potassium showed very little differences in concentration throughout the study period (Table-1). Phosphorus showed its usual peak during December in 2007 and November in 2008 (Table-1). Nitrogen showed unusual peak during December in 2007 and August in 2008 respectively (Table-1).

Statistical Analysis:

Pearson's Correlation technique and Canonical Correspondence Analysis (CCA) were used in this investigation. Pearson's correlation and analysis highlighted the difference in preferences towards edaphic factors of forest litter and thus influences the insects' abundance on the variability of edaphic factors. Canonical Correspondence Analysis can describe actual reason of seasonal fluctuation of insects' species. This occurs due to different loading between species abundance and edaphic factors

Canonical Correspondence Analysis:

Canonical Correspondence Analysis was used on transformed (square root of X+0.05) mean abundance data with many missing values for non-availability of all coleopteran species where such analysis assumes Gaussian relationship between groups of variables. During Canonical Corresponding Analysis, an assumption was made that species abundance in different population would be Gaussian function of environmental edaphic factor concentration. Canonical Correspondence Analysis technique using unimodal response model was followed to explain the species abundance concentration in response to different edaphic factors through bi-plot type of scaling. A test of significance of both first canonical axis and all canonical axes were made under Monte Carlo test with 499 permutations under reduced model. Relationship of species abundance with -environmental loading in different population has been presented in ordination diagrams (bi-plot) for first two axes.

Results

According to Pearson's correlation of study (Table-2) at Bibhutibhushan sanctuary, among the members of order Coleoptera the abundance of species of *Phillonthus industenus* , *Gonocephalum depressum, Cypturus bengalensis, Staphylinus bengalensis* significantly correlate only with temperature. *Dyschirius globosus* showed significant correlation with only moisture. *Anomala bengalensis* showed significant correlation with pH. *Liodaptus biramanus*, *Scydmineus* sp. showed significant correlation with only N. *Onthophagus orientalis* significantly correlates with P. *Macrotoma spinosa* population significantly correlates with Na. *Stinus sikkimensis*, *Agonotrechus dicranoides* and *Hipocaccus sinae* population significantly correlate with C. *Phloebius alterans* showed significant correlation with temperature and Na. *Xantholina ruficaudatus* and *Adoretus bengalensis* showed significant correlation with C and K. *Staphylinus sikkimensis*, *Copeletus mysorensis* showed significant correlation with moisture and Na. *Coccotrypes carpophagus* significantly correlates with temperature and pH. The population of *Hypothenium arrecae* significantly correlates with temperature and P. *Scaphisoma agaricinum* showed significant correlation with temperature, pH and P. The abundance of species *Osorius loptuensis* significantly correlates with moisture, N and P. *Xantholina aeneus* showed significant correlation with Moisture, Na and C .*Copeletus indicus* showed significant correlation with temperature, pH and N. *Bembidion notatum* showed significant correlation with moisture, pH and P. The population of *Phillonthus carbonaria* significantly correlates with temperature, K and P . *Trogophleus manh* significantly correlates with temperature, pH, N and Na . *Apoginia aerea* showed significant correlation with temperature, Na, moisture and N. At Bibhutibhushan sanctuary, relationship of species abundance with environmental loading in different population has been proved its actual reason of seasonal fluctuation.

Table-2: Correlation of abundance of Coleopteran species and edaphic factors with level of significance.
Pearson`s correlation analysis: Significant<0.05=*=Association/Correlation is Significant at 5%level. Significant<0.01=**=association/correlation is significant at 1% level (* = P<0.05, ** = P<0.01).

Species		Temp.	Moisture	pH	N	P	K	Na	C
Osorious loptuensis	Corr.	-0.080	0.405**	0.232	0.355*	0.341*	0.166	-0.038	0.161
osorious gardneri	Corr.	0.059	-0.009	-0.122	0.101	0.181	0.091	0.267	0.196
Philonthus carbonarius	Corr.	-0.350*	-0.056	-0.052	-0.022	-0.338*	0.284*	0.004	0.252
Philonthus bengalensis	Corr.	-0.439**	-0.211	0.070	-0.080	-0.261	0.093	-0.188	0.172
Xantholina aeneus	Corr	-0.219	0.322*-	0.160	-0.086	0.081	-0.230	-0.313*	-0.336*
Xantholina ruficaudatus	Corr.	-0.112	-0.253	0.120	-0.223	0.059	-0.337*	-0.250	-0.475**
Stilicus pygmicus	Corr.	0.224	0.000	-0.088	-0.223	-0.110	-0.275	0.085	0.059
Staphylinus bengalensis	Corr.	0.353*	-0.163	-0.273	-0.084	-0.041	-0.205	0.221	-0.04
Staphylinus sikkimensis	Corr.	0.155	0.431**	-0.115	-0.259	0.204	0.273	0.43 **	0.182
Trogophleus calcuttanus	Corr.	0.298*	0.126	-0.353*	0.406**	0.010	0.306	0.372**	0.135
Adoretus bengalensis	Corr.	-0.077	-0.185	0.125	-0.176	0.032	-0.337*	-0.168	-0.714**
Onthophagus orientalis	Corr.	-0.163	-0.108	-0.106	-0.106	-0.39**	0.116	-0.129	0.224
Apogonia aerea	Corr.	-0.374**	0.314*	-0.272	0.299*	0.041	0.185	0.56**	0.241
Anomala bengalensis	Corr.	0.203	-0.055	-0.355*	-0.099	0.014	-0.053	-0.038	0.243
Copelatus mysorensis	Corr.	0.031	0.439**	-0.211	-0.121	0.148	0.263	0.304* *-	0.157
Copeletus indicus	Corr.	-0.316*	-0.016	0.452**	0.565**	0.235	-0.025	-0.144	0.055
Coccotrypes carpophagus	Corr.	-0.53**	0.056	0.333*	-0.018	-0.129	0.259	0.002	-0.059

Species		Temp.	Moisture	pH	N	P	K	Na	C
Scydmineus sp.	Corr.	0.224	-0.072	-0.068	0.427**	-0.015	-0.090	0.149	-0.026
Gonocephalum depressum	Corr.	-.412**	-0.112	0.169	-0.172	-0.187	0.068	-0.175	-0.182
Scaphisoma agaricinum	Corr.	-0.44**	-0.030	0.503**	0.015	-0.467**	-0.113	-0.198	-0.121
Dyscherius sp. Bonelli	Corr.	0,094	0.293*	-0.024	0.063	0.118	0.023	0.270	0.125
Bembidion notatum	Corr.	-0.166	0.518**	0.448**	0.175	0.302*	0.081	-0.008	0.194
Agonotrechus dicranoides	Corr.	-0.180	-0.265	-0.046	-0.206	-0.120	-0.040	-0.248	-0.378**
Liodaptus biramanus	Corr.	0.110	0.081	-0.238	0.361 *	0.020	0.159	0.150	0.099
Meligethis tilurani	Corr.	0.211	0.063	-0.200	-0.123	0.047	-0.007	0.028	0.088
Hypotheniums areccae.	Corr.	-0.308**	-0.176	-0.012	-0.061	-0.666**	0.041	-0.122	0.032
Macrotoma spinosa	Corr.	0.107	0.009	-0.118	-0.101	0.048	0.074	0.378 **	0.158
Aphthonoides himalayensis	Corr.	0.145	0.048	-0.201	-0.006	0.006	0.009	-0.049	0.086
Phloebius alterans	Corr.	0.464**	0.003	-0.277	0.176	0.083	0.013	0.339 *	0.059
Hipocaccus sinae	Corr.	-0.060	-0.127	-0.009	-0.115	0.048	-0.119	-0.126	-0.309*
Cypturus bengalensis	Corr.	0.294*	0.185	-0.197	0.021	0.030	0.083	0.078	0.077

According to transformed values of CCA, Axisi-1 of bi-plot (Fig.-3,Table-3) proved that the edaphic factors like moisture, temperature, Na, N and C are highly associated with the increasing population of *Phloebius alterans, Cypturus bengalensis, Apogonia aerea, Aphthonoides himalayensis* , *Anomala bengalensis* , *Staphylinus bengalensis, Scydmineus* sp, *Stilicus Pygmius, Trogophleus calcuttanus, Meligethis tilurani, Liodaptus biramanus* , *Dyschirius globosus* , *Osorius loptuensis, Macrotoma spinosa, Staphylinus sikkimensis* due to positive loading. But in high pH concentration these showed decreasing population. At the same time *Adoretus bengalensis*, *Hipocaccus sinae*, *Stenus sikkimensis*, *Xantholina ruficaudatus* , *Agonotrechus dicranoides, Xantholina aeneus*, *Gonocephalum depressum*, *Coccotrypes carpophagus*, *Scaphisoma agaqricinum*, *Hypothenium arrecae*, *Philonthus industenus*, *Copeletus indicus* , *Onthophagus orientalis* , *Osorius loptuensis*, *Bembidion notatum*, *Philonthus carboneria* and *Copeletus mysorensis* showed decreasing population in presence of the same factors but showed increasing population in presence of high pH concentration.

Table-3: Canonical Correspondence Analysis (CCA) results involving effect of edaphic factors on abundance of species under Coleoptera.

	Axis-1	Axis-2	Axis-3	Axis-4
Sum of all Eigen values=2.592				
Env. vs Abundance correlation	0.88	0.91	0.87	0.8
Cumulative percentage variance				
Abundance of species	9.5	16	22.1	25.2
Abundance-Env.relation	32.1	54.2	74.5	85
P value=0.038				
Inflation factors<20				
Omitted env. Variables: K and P				

Four axes are extracted which could explain 85% of variance. Out of these, two axes were further used to draw the biplot diagram to explore the relation between two sets *viz.* edaphic factors and species abundance.

Axis-2 of bi-plot (Fig.-3) revealed that the Coleopteran species like *Copeletus mysorensis, Philonthus carbonerius, Copeletus indicus, Bembidion notatum, Philonthus carbonerius, Osorius loptuensis, Onthophagus orientalis, Macrotoma spinosa, staphylinus sikkimensis, Dyschirius globosus, Osorius gardener, Trogophleus manh, Meligethis tilurani* , *Liodaptus biramanus*, *Anomala bengalensis, Aphthonoides himalayensis, Cypturus begalensis* and *Apogonia aerea* showed increasing population in presence of temperature, moisture, Na, N and C. But in high pH concentration these showed decreasing population. On the other hand *Adoretus bengalensis*, *Hipocaccus sinae* , *Stenus sikkimensis* , *Xantholina ruficaudatus* , *Agonotrechus dicranoides* , *Xantholina aenius*, *Gonocephalum depressum*, *Staphylinus sikkimensis*, *Scydmineus* sp, *Phloebius alterans*, *Stilicus pygmies*, *Coccotrypes carpophagus* and *Scaphisoma agaricinum* showed increasing population in presence of high concentration of pH but showed decreasing population in presence of high concentration of moisture, temperature, Na, N and C. In the bi-plot of transformed values, concentration of P and K do not show any significant relationship with the population fluctuation. In biplot , quadrant-wise position of species and nearness to each of these, describe the co-existence of those species in a given environment.

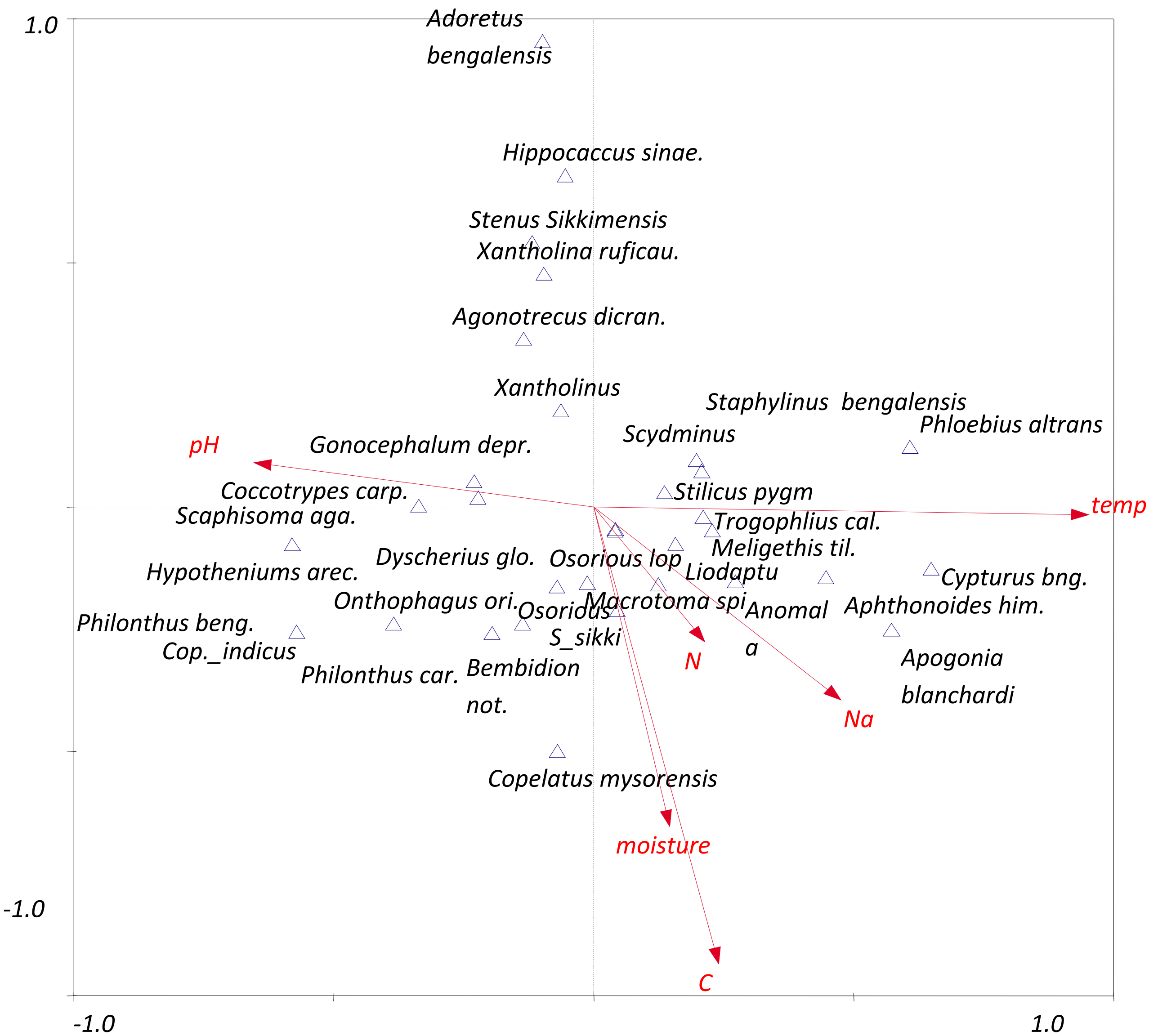

Fig.3: Biplot showing the divergence of species under coleoptera explained by edaphic factors at Bibhutibhushan sanctuary.

Discussion

The seasonal variation showed significant relation throughout the study period. All the Coleopteran insect populations showed a sharp reduction in their number in the study area. Several groups of coleopteran insects showed to decline during wet season though there is no direct relationship of rain fall with the population fluctuation . Rainfall also did not have any significant effect directly on faunal abundance in the study area. A sharp reduction of insect abundance during the dry season seems to be restricted due to tropical habitats that have a severe dry season which concur with the opinion of Jangen, D.H, Schoener, T.W. 1986, Wolda H., 1977.

Several families of insects are known to decline in number during the dry season and, the onset of rain is the major factor which has a direct effect on the population of these insects. Several are known to decline during the mid-wet season, sometimes exhibiting an abundance that is lower than that of observed during the dry season as suggested by Robinson, M.H. and Robinson. B.1970, Boinski and Fowler 1989, Pinheiro et.al. 2002 .Here Coleoptera showed its significant abundance during winter at Bibhutibhushan sanctuary. Macfadyen (1952) and Murphy (1953) had the observation that the population size of soil fauna was maximum during winter and that also on upper layer . In the study area the dominant Coleopteran species throughout the year are *Osorius loptuensis*, *Liodaptus biramanus*, *Scydminus* sp., *Coccotrypes carpophagus* and *Scaphisoma agaricinum*. In addition to these, a few representatives of other families of Coleopteran like Cerumbicidae, Histeridae , Curculionidae , Nitidulidae , Pselaphidae and Ptilidae are found in a low density . The abundance of Staphylinid beetles are present here, which are known for their preference for wet litter conditions. Carabids depend on several abiotic and biotic factors. These include temperature, humidity, food conditions, present and distribution of competitors , life history and season (Lovei and Sunderland 1996). It seems that some of the species are more dependent on these factors than others. This species level difference to drought/moisture also has been observed in other study (Kadar F, Szentkiralyi F. 1997).

In the study area the maximum soil temperature ranges from 30.2^{0}C to 38.5^{0}C, during July to September in the years 2006-2007 and 2007-2008 whereas minimum (18^{0}C to 23^{0}C) during December to February. From the population it is evident that temperature is inversely proportional to the abundance of Coleopterans.

Mean abundance of observed values of moisture showed significant differences in various season. Soil moisture showed maximum range during October 30.1% to 35.5% and minimum 10.1% to 11.5% during May in both the years. The values of moisture have a positive effect over the population of coleopteran insects. The abundance is directly proportional to the percentage of soil moisture. The abundance of Hydrophilyd and Staphylinid beetles, known for their preference for wet litter conditions are further evidence for this hypothesis (Borrer *et al.*1996; Lawrence. 1999).

The abundance of Coleoptera showed highest population when soil is alkaline in nature. The mean observed pH values showed significant differences in various seasons. The population of insects in different seasons is significantly related with the pH value of the soil.

N concentration increased suddenly due to some abnormalities during the experiment. Increase in the N concentration of leaf litter have been found in other studies as stated by Melillo *et al .(*1982), Babbar and Ewel (1989). The abundance of various coleopteran species is significantly related with N content . N concentration in leaf litter increased to a maximum range during August , then declined and again increased in December. The lowest concentration of N was noticed during February. A significant rise in the abundance of population occurs during this time.

C showed no significant difference in its concentration in the study area. Soil organic C showed the maximum range of concentration during June and September and lowest in March during the study period. This had a positive effect on population of a few species.

Mean observed values of P revealed that significant differences were recorded in different seasons. Higher values in P concentration were observed during November, December and lowest during June. The higher K concentration was noticed during August and October . According to

Pearson's correlation of study it is observed that the population of a few species is significantly correlated with the concentration of P and K .It is significant to note that according to the transformed results of CCA (Fig.-3) it has appeared that concentration of K and P could not affect the population abundance, which ware more specific.

The mean observed values of Na revealed significant difference in its concentration throughout the study period. Its rise in concentration initiated from August and retained up to October then declined. Na has the significant effect on the abundance of a few species of Coleopteran.

Sloping of the terrain helps to move different chemical element by the bulk removal of the litter by heavy water flow or other physical procedure. The presence of fallen branches and rotting logs added to the structural diversity and so influenced the numbers and types of species. Trampling and compression by intensive grazing by cattle and forest management staffs is also equally important. In addition to these factors mentioned , the insect populations of forest litter become fluctuate season-wise according to their life cycle and favorable environments.

Various macro and micro climatic changes *viz.* temperature, moisture content, rain fall, humidity, pH concentration, decomposition rates of litter and variation in the availability of the food resources are important factors in triggering seasonal activity of coleopteran insects of this particular ecosystem.

Conclusion

This investigation can provide knowledge on seasonal variation of insect populations in response to physico-chemical structure of forest litter, which has been seen in the study area .Finally, it is hoped that the present investigation may provide a base line data to the future workers and can help to formulate in a more sophisticated pattern of investigation on interaction of insects and litter ecosystem, where ever may be the study area.

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