http://www.pjbs.org

PJBS

ISSN 1028-8880

Pakistan Journal of Biological Sciences

ANSInet
Asian Network for Scientific Information
308 Lasani Town, Sargodha Road, Faisalabad - Pakistan

Pakistan Journal of Biological Sciences 8 (1): 13-19, 2005
ISSN 1028-8880

Invertebrates as a Potential Food Source of Brown Bears on the Deosai Plateau, Northern Pakistan

[1]O.B. Kok, [1]C.R. Haddad, [1]D.J. Van Niekerk, [1]H.J.B. Butler and [2]M.A. Nawaz
[1]Department of Zoology and Entomology, University of the Free State, P.O. Box 339, Bloemfontein 9300, South Africa
[2]Himalayan Wildlife Foundation, Centre One, Street 15, F-7/2 Islamabad, Pakistan

Abstract: The ground-dwelling invertebrate fauna was collected using pitfall traps to sample four habitat types on the Deosai Plateau, Northern Pakistan, during the boreal summer of 1999 (mid-June to mid-October). A total of 43751 specimens were collected, representing four classes, 13 orders and 102 determined families (Lithobiomorpha and Basommatophora not determined). The Insecta were predominant in overall abundance and total biomass. At order level, members of the Coleoptera dominated numerically (n = 25 173, 57.5%), followed by the Araneae (n = 8 757, 20.0%), Hymenoptera (n = 3 316, 7.6%), Acari (n = 2 113, 4.83%) and Orthoptera (n = 1 880, 4.3%). At family level, larger arthropods of the Acrididae, Tenebrionidae, Lycosidae, Carabidae and Anthophoridae contributed most to total dry mass. Arthropod families displayed divergent patterns of activity during the brief boreal summer. Overall habitat preference is skewed in favour of the drier, more open habitat types. Based on their relative abundance, arthropods represent a potentially important food source for brown bears inhabiting the Deosai Plateau and contribute to the overall functioning of the Deosai ecosystem.

Key words: Arthropods, pitfall trapping, brown bears, food source, Deosai Plateau

INTRODUCTION

The Deosai National Park was primarily established for the protection of the last remaining viable breeding population of Himalayan brown bears (*Ursus arctos* Linnaeus, 1758) in Pakistan[1,2]. The focal point of the park is the Deosai Plateau, an uninhabited mountain wilderness surrounded by deep valleys and snowy peaks in the rugged northern region of the country. Despite its high elevation, cold climate, abundant snow-fall and windy conditions, the plateau is rich in biodiversity, serving as a refugium for many species of plants and animals[2-7]. Numerous terrestrial and aquatic vertebrate key species occur in the Deosai, including the burrowing vole *Hyperacrius fertilis* True, 1894, the long-tailed marmot *Marmota caudata* Geoffroy, 1842 and the slate-coloured snow trout *Diptychus maculatus* Steindachner, 1866. These species form an important food source for opportunistic omnivores such as the Himalayan brown bears (Personal Observation). A large number of locally migratory birds from surrounding areas are supported on the Deosai by the population explosions of insects and other invertebrates during the brief boreal summer[7]. Based on scat analysis, insects may also serve as a food source for the local bear population (Personal Observation).

As part of an ongoing study on the dietary composition of brown bears inhabiting the plateau, an ecological survey was conducted to gather some basic information on the invertebrate ground fauna of the Deosai. Here we report on the terrestrial invertebrates collected in pit traps over a continuous period of four months. This is the second ecological study of the invertebrate fauna of the Deosai National Park and follows a study on the ground-dwelling spider fauna of the park[8].

MATERIALS AND METHODS

Study area: The Deosai Plateau (35°N, 75°E) is located in the rugged northern region of Pakistan at the junction of four major mountain ranges, namely the Karakoram, Ladakh, Zanskar and Himalaya. The plateau is situated approximately 30 km south-west of Skardu, the capital of the state of Baltistan. It stands apart as an expansive open area of alpine vegetation, grassy valleys, spring-fed nullahs, rivers and lakes. Topographically the area is

Corresponding Author: O.B. Kok, Professor, Department of Zoology and Entomology, University of the Free State, P.O. Box 339, Bloemfontein 9300, South Africa
Tel: +27 51 401 2489 Fax: +27 51 448 8711 E-mail: kokob.sci@mail.uovs.ac.za

characterised by rolling plains surrounded by deep valleys and snowy peaks. The elevation of the plateau ranges from 3 400 to 4 300 m above sea level and with some peaks exceeding 5 000 m, the plains are amongst the highest plateaus in the world and cover a surface area of approximately 700 km^2. Due to the rigorous climate, with the area being snow-bound throughout most of the year, the plateau is only accessible by four-wheel drive vehicles during the short summer season extending from mid-June to mid-October.

For comparative purposes four different habitat types were characterised and selected for sampling:

- Grassy marshes, characterised by a pattern of hummocks densely overgrown by *Agrostis vinealis* Schreh. interspersed with water-filled hollows approximately 0.5 m deep.
- Flat grassland, consisting of drier patches of grass and star tulips (*Tulipa stellata* Hook.f.) on relatively flat surfaces in the valleys.
- Grassland slopes, consisting of perennial alpines such as *Androsace mucronifolia* Watt and *Eremurus himalaicus* Baker.
- Relatively dry, stony floodplains scattered with low growing alpine plants such as *Bistorta affinis* (D. Don) Green, *Rhodiola himalensis* (D. Don) S.H. Fu and *Saxifraga hirculus* L.

Methods: Ground-dwelling invertebrates were collected using pitfall traps with radiating veins on the Deosai Plateau during the brief boreal summer (mid-June to mid-October) of 1999. Owing to logistic problems in the rugged terrain, light-weight plastic cups, 130 mm high and 80 mm in diameter, were used as pitfalls. These were set out level with the dense carpet of grass in the marshy areas, or flush with the ground surface in the other habitats. Four radiating wooden planks, 35 cm in length, were placed in the surrounding substrate of each pit trap to increase the effective trapping area[9]. All pit traps were filled approximately one quarter with glycerol, which does not evaporate easily, has a high viscosity and does not attract or repel insects[10].

Initially (mid-June), 160 pitfall traps were set in 16 line transects of 10 traps each. Five trap transects were set out each in the marshes and grassland flats and three transects each in the stony floodplain and grassland slopes, for the first week of the study. Subsequently, sampling was standardised to one line transect of ten traps set out at 5 m intervals in each of the four habitat types selected and collected on a weekly basis till the 15th successive week of sampling in early October.

Samples obtained were stored in 70% ethanol for later analysis in the laboratory, where the samples were sorted macroscopically. Using various keys[11-16], all specimens were identified to family level and enumerated. After drying in an Inc-O-Mat oven at 70°C for 48 h, the dry mass of each taxon was determined separately using an electric balance (Mettler P100N). This was done in order to determine whether the size distribution of specimens shifted to larger individuals towards the end of the summer, when bears become hyperphagous in preparation to the onset of extreme winter conditions.

Statistical analyses (Spearman’s rank correlation coefficient) were performed using Statistica for Windows, Release 4.0.

RESULTS

Numbers and diversity: A total of 43751 invertebrate specimens, representing four classes, 13 orders and 102 determined families, were collected in the study. At the class level, the fauna was dominated strongly by the Hexapoda (79.5%) and Arachnida (20.0%), with less than a half percent for the Chilopoda and Gastropoda combined (Table 1). Based on dry mass, the predominance of the Hexapoda is even greater (85.2%). Of the 13 invertebrate orders collected, the Coleoptera dominated in terms of numerical abundance (57.5%) and biomass (37.1%), followed by the Araneae and Hymenoptera (numerically) or the Orthoptera and Araneae (dry mass). The nine remaining orders made lesser contributions to the community structure, representing only 10.6% of the total numbers and 5.7% of the overall biomass.

Although members of 102 arthropod families were identified, only nine, namely the Erythraeidae (Acari), Linyphiidae and Lycosidae (Araneae), Cleridae, Curculionidae, Dermestidae, Melyridae and Tenebrionidae (Coleoptera) and the Acrididae (Orthoptera), are represented by more than a thousand individuals each (Table 1). More than 80% of the remaining families contributed less than a hundred specimens per family, while almost half of all the families are represented by less than ten individuals each.

Phenology and biomass: On a temporal basis, the five most important families, as judged by their relative contribution of both numbers and dry mass, experienced divergent patterns of activity during the brief boreal summer. The Lycosidae showed a prominent peak at the onset of the summer season, followed by a progressive decrease in numbers till the end of the 15th week of sampling (Fig. 1). A similar but less pronounced and more

Table 1: Terrestrial invertebrates collected in pit traps on the Deosai Plateau during the boreal summer of 1999

Taxon	n (n=43751)	%	g (212.81 g)	%
Arachnida				
Acari	2113	4.83	0.495	0.23
Anystidae	315	0.72	0.060	0.03
Caeculidae	3	<0.01	0.005	<0.01
Erythraeidae	1771	4.05	0.420	0.20
Trombidiidae	24	0.05	0.010	<0.01
Araneae	8757	20.02	30.010	14.10
Clubionidae	3	<0.01	0.020	<0.01
Corinnidae	33	0.08	0.050	0.02
Gnaphosidae	826	1.89	4.030	1.89
Hahniidae	14	0.03	0.070	0.03
Linyphiidae	1113	2.54	0.460	0.22
Lycosidae	6610	15.11	24.890	11.70
Salticidae	85	0.19	0.200	0.09
Theridiidae	62	0.14	0.220	0.10
Thomisidae	11	0.03	0.070	0.03
Opiliones	74	0.17	0.230	0.11
Oncopodidae	55	0.13	0.190	0.09
Phalangiidae	19	0.04	0.040	0.02
Chilopoda				
Lithobiomorpha	198	0.45	0.615	0.29
Gastropoda				
Basommatophora	11	0.03	0.070	0.03
Hexapoda				
Collembola	1	<0.01	0.001	<0.01
Entomobryidae	1	<0.01	0.001	<0.01
Coleoptera	25173	57.54	78.853	37.05
Anthicidae	6	0.01	0.130	0.06
Attelabidae	1	<0.01	0.004	<0.01
Bostrychidae	1	<0.01	0.002	<0.01
Carabidae	921	2.11	23.227	10.91
Chrysomelidae	941	2.15	5.903	2.77
Cleridae	5602	12.80	3.802	1.79
Coccinellidae	24	0.05	0.258	0.12
Cryptophagidae	2	<0.01	0.001	<0.01
Curculionidae	1030	2.35	5.636	2.65
Dermestidae	6872	15.71	3.153	1.48
Dytiscidae	1	<0.01	0.020	<0.01
Histeridae	1	<0.01	0.005	<0.01
Hydraenidae	8	0.02	0.006	<0.01
Languriidae	4	<0.01	0.005	<0.01
Melyridae	8257	18.87	6.519	3.06
Scarabaeidae	17	0.04	0.722	0.34
Staphylinidae	133	0.30	0.082	0.04
Tenebrionidae	1307	2.99	29.105	13.68
Trogidae	30	0.07	0.235	0.11
Unidentified larvae	15	0.03	0.038	0.02
Diptera	518	1.18	1.414	0.66
Agromyzidae	1	<0.01	0.001	<0.01
Asilidae	9	0.02	0.070	0.03
Athericidae	12	0.03	0.004	<0.01
Bibionidae	2	<0.01	0.001	<0.01
Bombyliidae	1	<0.01	0.002	<0.01
Calliphoridae	14	0.03	0.094	0.04
Cecidomyiidae	1	<0.01	0.003	<0.01
Culicidae	4	<0.01	0.002	<0.01
Dolichopodidae	1	<0.01	0.001	<0.01
Drosophilidae	27	0.06	0.013	<0.01
Empididae	56	0.13	0.082	0.04
Ephydridae	1	<0.01	0.001	<0.01
Lauxaniidae	2	<0.01	0.001	<0.01
Muscidae	239	0.55	0.453	0.21
Mycetophilidae	2	<0.01	0.008	<0.01

Table 1: Continued

Taxon	n (n=43751)	%	g (212.81 g)	%
Phoridae	2	<0.01	0.002	<0.01
Piophilidae	1	<0.01	0.001	<0.01
Psilidae	1	<0.01	0.004	<0.01
Sarcophagidae	1	<0.01	0.010	<0.01
Scathophagidae	6	0.01	0.010	<0.01
Sciaridae	84	0.19	0.100	0.05
Syrphidae	13	0.03	0.076	0.04
Tabanidae	4	<0.01	0.022	0.01
Tachinidae	14	0.03	0.071	0.03
Therevidae	1	<0.01	0.001	<0.01
Tipulidae	19	0.04	0.381	0.18
Hemiptera	872	1.99	1.444	0.68
Aphididae	12	0.03	0.009	<0.01
Cicadellidae	79	0.18	0.059	0.03
Delphacidae	2	<0.01	0.002	<0.01
Lygaeidae	272	0.62	0.258	0.12
Miridae	3	<0.01	0.003	<0.01
Pentatomidae	13	0.03	0.080	0.04
Piesmatidae	2	<0.01	0.002	<0.01
Psyllidae	339	0.77	0.131	0.06
Reduviidae	95	0.22	0.830	0.39
Thaumastocoridae	51	0.12	0.060	0.03
Unidentified nymphs	4	<0.01	0.010	<0.01
Hymenoptera	3316	7.58	27.224	12.79
Andrenidae	411	0.94	1.417	0.67
Anthophoridae	352	0.80	19.983	9.39
Apidae	7	0.02	0.027	0.01
Bethylidae	4	<0.01	0.005	<0.01
Braconidae	21	0.05	0.029	0.01
Chalcididae	11	0.03	0.011	<0.01
Chrysididae	10	0.02	0.027	0.01
Colletidae	989	2.26	2.242	1.05
Formicidae	995	2.27	0.759	0.36
Halictidae	51	0.12	0.180	0.08
Ichneumonidae	10	0.02	0.024	0.01
Megachilidae	6	0.01	0.050	0.02
Melittidae	2	<0.01	0.001	<0.01
Plumariidae	1	<0.01	0.001	<0.01
Pompilidae	23	0.05	0.220	0.10
Pteromalidae	3	<0.01	0.012	<0.01
Sphecidae	411	0.94	2.181	1.02
Tiphiidae	3	<0.01	0.015	<0.01
Vespidae	6	0.01	0.040	0.02
Lepidoptera	827	1.89	7.926	3.72
Gelechiidae	7	0.02	0.032	0.02
Hesperiidae	4	<0.01	0.130	0.06
Noctuidae	22	0.05	0.490	0.23
Papilionidae	26	0.06	1.690	0.79
Pieridae	4	<0.01	0.050	0.02
Tortricidae	194	0.44	0.646	0.30
Unidentified larvae	570	1.30	4.888	2.30
Orthoptera	1880	4.30	64.519	30.32
Acrididae	1674	3.83	52.278	24.57
Gryllacrididae	204	0.47	12.106	5.69
Gryllidae	2	<0.01	0.135	0.06
Trichoptera	11	0.03	0.011	<0.01
Phryganeidae	11	0.03	0.011	<0.01

prolonged period of activity was maintained by the Tenebrionidae and Carabidae. By contrast, both the Acrididae and Anthophoridae experienced their greatest activity towards the end of the summer. Pit traps disturbed and damaged by the Tibetan fox *Vulpes vulpes*

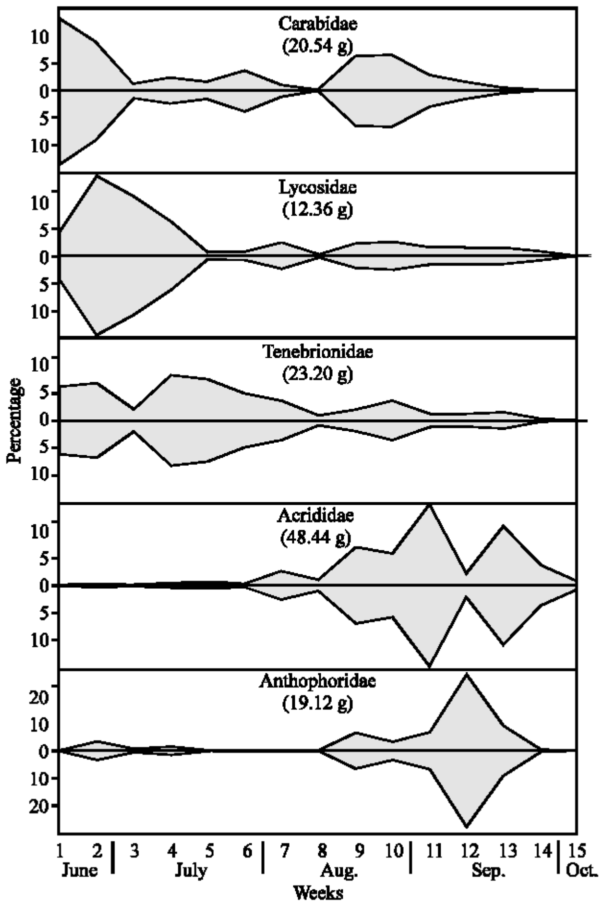

Fig. 1: Temporal variation of the most important arthropod families collected in pit traps on the Deosai Plateau during the boreal summer of 1999

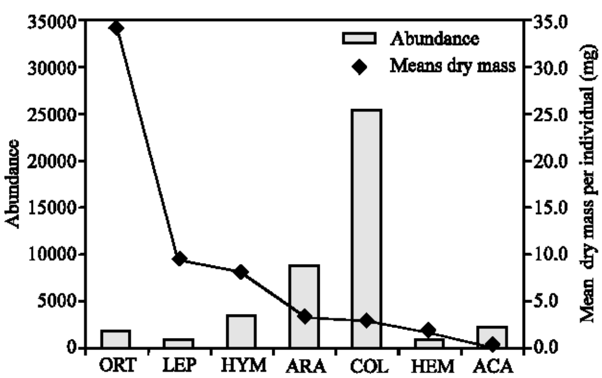

Fig. 2: Representation of abundance and mean dry mass per individual in milligrams of the seven most abundant invertebrate orders collected on the Deosai Plateau during the boreal summer of 1999 (ORT-Orthoptera; LEP-Lepidoptera; HYM-Hymenoptera; ARA-Araneae; COL-Coleoptera; HEM-Hemiptera; ACA-Acari)

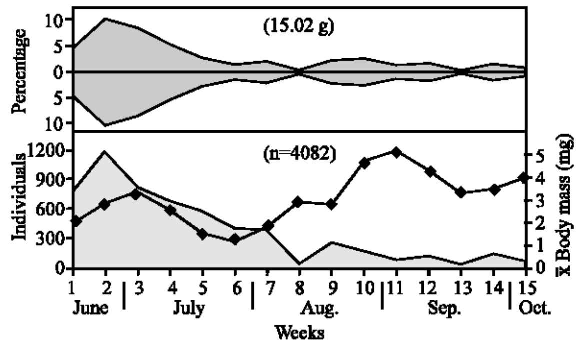

Fig. 3: Temporal variation of the Araneae (number of individuals-light hachuring; dry mass in g-dark hachuring; average body mass per specimen captured-solid squares) collected in pit traps on the Deosai Plateau during the boreal summer of 1999

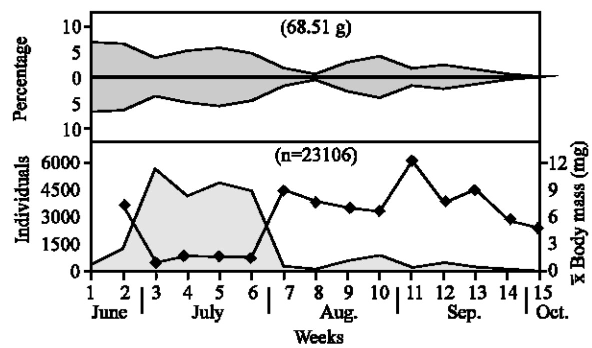

Fig. 4: Temporal variation of the Coleoptera (number of individuals-light hachuring; dry mass in g-dark hachuring; average body mass per specimen captured-solid squares) collected in pit traps on the Deosai Plateau during the boreal summer of 1999

(Linnaeus, 1758), possibly attracted to the glycerol preservative used in the traps, accounted for the reduced catch during the 8th week of sampling.

At the order level, the dry biomass contribution of invertebrates is dominated by the orders Coleoptera, Orthoptera and Araneae (Table 1). However, three moderately abundant orders (Orthoptera, Lepidoptera and Hymenoptera) contribute relatively more to biomass than they do to abundance (Fig. 2), indicating that larger invertebrate prey species, which are more easily captured by brown bears and other predators, are considerably less abundant that smaller prey species. Other orders (e.g. Acari and Hemiptera) form a sizable portion of the invertebrate fauna numerically, but contribute very little to total dry biomass due to their very small size (Fig. 2) and are likely to only form a very small proportion of the

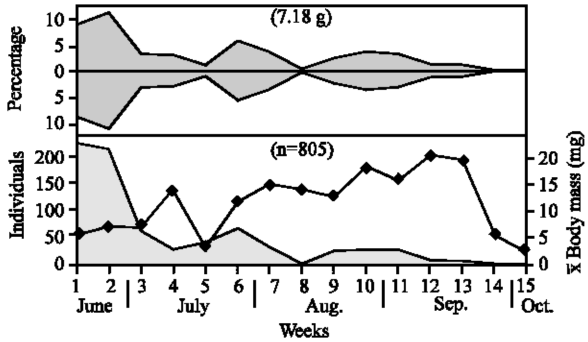

Fig. 5: Temporal variation of the Hymenoptera (number of individuals-light hachuring; dry mass in g-dark hachuring; average body mass per specimen captured-solid squares) collected in pit traps on the Deosai Plateau during the boreal summer of 1999

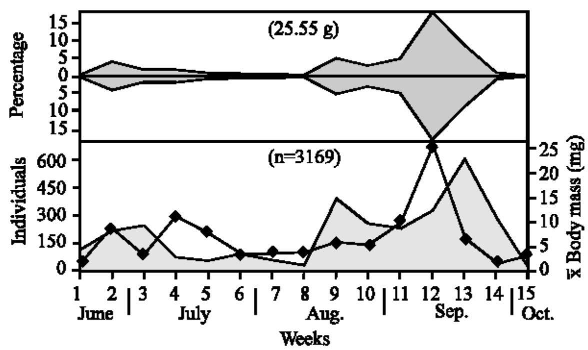

Fig. 6: Temporal variation of the Lepidoptera (number of individuals-light hachuring; dry mass in g-dark hachuring; average body mass per specimen captured-solid squares) collected in pit traps on the Deosai Plateau during the boreal summer of 1999

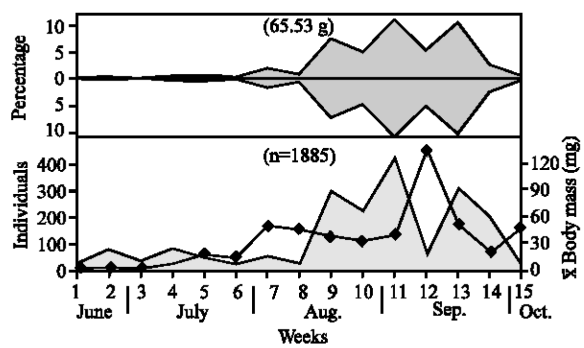

Fig. 7: Temporal variation of the Orthoptera (number of individuals-light hachuring; dry mass in g-dark hachuring; average body mass per specimen captured-solid squares) collected in pit traps on the Deosai Plateau during the boreal summer of 1999

diet of vertebrate predators. Consequently, prey size may impact on the foraging decisions that bears make regarding selection of invertebrate prey relative to their size and abundance.

Based on dry mass, the Acrididae (24.6%), Tenebrionidae (13.7%), Lycosidae (11.7%), Carabidae (10.9%) and Anthophoridae (9.4%) contributed most to the overall biomass of the invertebrate ground fauna collected (Table 1). Despite their relatively low abundance, the Gryllacrididae (Orthoptera) and unidentified larvae of the Lepidoptera also made a fair contribution to overall biomass. Abundant groups, including the Cleridae, Dermestidae and Melyridae (Coleoptera) and to a lesser extent also the Erythraeidae (Acari), Linyphiidae (Araneae) and Formicidae (Hymenoptera), contributed disproportionately less to the overall biomass than expected.

Judging by the relationship between numbers and dry mass of the five arthropod orders where sufficient data are available (Araneae, Coleoptera, Hymenoptera, Lepidoptera and Orthoptera), the relative size distribution of individuals can be seasonally determined. In all cases concerned (four p-values being <0.01 and one <0.05) a gradual increase in the average body mass per specimen collected was observed towards the end of the summer (Fig. 3-7). This is of particular interest, as it coincides with the time when brown bears become hyperphagous, broadening their food selection in order to compensate for the low food energy of their mostly vegetarian diet.

Relation to habitat: Using occurrence alone, the habitat preference of the invertebrate ground fauna collected on the Deosai Plateau may seem to be skewed in favour of the more vegetated wet areas. In this regard, members of 13 and 11 orders, three exclusively so (Basommatophora, Collembola and Trichoptera), are represented in the grassy marsh and grassland plain, respectively. This compares with only ten orders each for the two other habitat types distinguished (Fig. 8). Clearly this is also the case for the Araneae, which show a progressive reduction in numbers and dry mass from the densely vegetated grassy marshes to the more open stony floodplain[8]. The opposite trend is, however, shown by other major taxa such as the Coleoptera and Orthoptera. As indicated in Fig. 8, the stony floodplain (highest numbers) and grassy slope (largest biomass) also contributed most to the overall abundance and dry mass of invertebrate ground fauna, either separately or combined.

Further support for the overall preference of the drier, more open habitats comes from the incidental capture of a few small vertebrates in pit traps. Five Tibetan red-toothed shrews (*Sorex thibetanus* Kastschenko, 1905

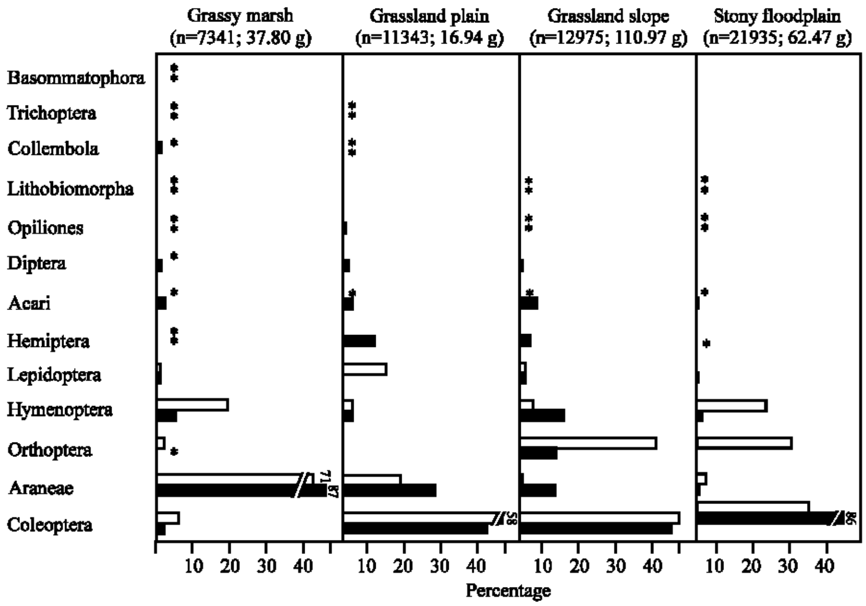

Fig. 8: Habitat preference of terrestrial invertebrates collected in pit traps on the Deosai Plateau during the boreal summer of 1999. Asterisk, <1%; open bars, numbers; solid bars, dry mass

[Insectivora]) and one Himalayan ground skink (*Scincella ladacensis* Günther, 1864 [Squamata]) were caught on the floodplain and five shrews on the grassland slope, but none in either the grassland plain or marshy area. Since these vertebrates are primarily insectivorous, their capture in the pitfalls may possibly be related to the abundance of insects in these two habitats.

DISCUSSION

Surprisingly little is known about the ecology of the invertebrate ground fauna inhabiting the relatively simple ecosystem of the Deosai Plateau[16] (V. Zakaria, Personal Communication). The present study presented the first data on the ecology of the ground invertebrate fauna, which should create a better understanding of the role that invertebrates play in ecological functioning of the Deosai. They fulfil this by pollinating flowers, preying on other invertebrates, breaking down organic waste and serving as food for larger vertebrate predators, among others[11,17].

Owing to the rigorous climate, the Deosai evidently experiences a very short period of intense biological activity, amply demonstrated by the explosion of major taxa such as the Araneae, Coleoptera and Lepidoptera during the onset of the boreal summer when structurally complex plants can provide a diversity of microhabitats for exploitation[18]. The abundance of insects attracted by flowering plants during this time could also serve as an invaluable source of food, partly explaining why the plateau is considered a high altitude refugium of great importance for large numbers of resident small mammals and migratory birds[7]. Although the community composition of invertebrates may remain relatively constant over the duration of an alpine summer[19], this study found that the seasonal fluctuations in numbers of different invertebrate taxa varies considerably through the season. This may partly be determined by the presence of suitable host plants for herbivorous taxa and the time of season at which different plant species flower[20,21]. Despite this, invertebrates ensure a fairly constant supply of prey to insectivorous predators throughout the boreal summer.

Although the diet of brown bears on the Deosai Plateau consists predominantly of roots and grasses[22], scat analyses undertaken during 1999 indicated that small amounts of animal matter occurred in more than half of all samples (n = 74) investigated. While vertebrates constituted 81% of the animal remains (72% small mammals, 6% fish and 3% birds), insects, represented by prey items from the Acrididae, Andrenidae, Formicidae and Tenebrionidae, amongst others, also made a substantial contribution (19%). Being a relatively abundant, if less energy-rich, food source than meat[23], arthropods evidently contribute to the general well-being of brown bears inhabiting the Deosai by contributing towards their accumulation of a copious supply of fat prior to the onset of winter. This is supported by the peak in abundance of Orthoptera and Hymenoptera towards to the end of the boreal summer, taxa which are common in the scat of the bears. Therefore, arthropods form an integral part of the diet of Himalayan brown bears and other insectivorous predators and form an important component in the overall functioning of the Deosai ecosystem.

ACKNOWLEDGMENTS

Thanks are due to Prof. T.C. van der Linde (University of the Free State, Bloemfontein) and Dr. E.A. Ueckermann (ARC-Plant Protection Research Institute, Pretoria) for the identification of some insects and Acari, respectively. Messrs S. Malek, A.H. Siddiqui, S. Ullah and M. Yonus, as well as other members of the Deosai field staff, provided invaluable assistance in the field. The logistic support and sincere interest shown by Mr. V. Zakaria and Dr. A. ur Rehman, project coordinators of the Himalayan Wildlife Project, are gratefully acknowledged.

REFERENCES

1. Anonymous, 1999. Deosai National Park project, 1998. Final report. Himalayan Wildlife Foundation, Islamabad, Pakistan, pp: 76.
2. Khan, A.A. and V. Zakaria, 1995. Management plan for Deosai National Park. Himalayan Wildlife Project, Islamabad, Pakistan, pp: 52.
3. Khan, A.A., R.A. Rajput and U. Khalid, 1996. Birdlife at Deosai: A source of sustenance and sustainability for local people. Abstract, Birdlife Asia Conference, 9-16 November 1996, Coimbatore, India.
4. Roberts, T.J., 1991. The Birds of Pakistan, Vol. 1. Oxford University Press, Oxford, pp: 598.
5. Roberts, T.J., 1992. The Birds of Pakistan, Vol. 2. Oxford University Press, Oxford, pp: 617.
6. Roberts, T.J., 1997. The Mammals of Pakistan. Oxford University Press, Oxford, pp: 525.
7. Woods, C.A., C.W. Kilpatrick, M. Rafique, M. Shah and W. Khan, 1997. Biodiversity and conservation of the Deosai plateau, Northern Areas, Pakistan. In: Biodiversity of Pakistan (Mufti, S.A, C.A. Woods and S.A. Hasan, Eds.), Pakistan Museum of Natural History, Islamabad, Pakistan, pp: 33-61.
8. Kok, O.B., L.N. Lotz and C.R. Haddad, 2004. Diversity and ecology of spiders (Arachnida: Araneae) of the Deosai Plateau, Northern Pakistan. Pak. J. Biol. Sci., 7: 1689-1694.
9. Uys, V.M. and R.P. Urban, 1996. How to collect and preserve insects and arachnids. Plant Protection Research Institute Handboek no. 7. Agricultural Research Council, Pretoria, pp: 73.
10. Wishart, M.J., 2000. The terrestrial invertebrate fauna of a temporary stream in southern Africa. Afr. Zool., 35: 193-200.
11. Borror, D.J., C.A. Triplehorn and N.F. Johnson, 1989. An introduction to the study of insects, 6th Ed. Saunders College Publishing, Philadelphia, pp: 875.
12. Dippenaar-Schoeman, A.S. and R. Jocqué, 1997. African Spiders. An identification manual. Plant Protection Research Institute Handbook No. 9. Agricultural Research Council, Pretoria, pp: 392.
13. Krantz, G.W., 1978. A Manual of Acarology, 2nd Edn. Oregon State University Book Stores, Inc., Corvallis, pp: 509.
14. Meyer, M.K.P., G.C. Loots, R. Van Pletzen, C.M. Engelbrecht and J.B. Walker, 1973. Acari of the Ethiopian region. Entomological Memoir 29, Department of Agricultural Services, Republic of South Africa, pp: 45.
15. Nentwig, W., A. Hänggi, C. Kropf and T. Blick, 2002. Spinnen Mitteleuropas-Bertimmungsschlüssel (www.araneae.unibe.ch)
16. Scholtz, C.H. and E. Holm, 1985. Insects of southern Africa. Butterworths, Durban, pp: 502.
17. Dennis, P., 2003. Sensitivity of upland arthropod diversity to livestock grazing, vegetation structure and landform. J. Food Agric. Environ., 1: 301-307.
18. Visser, D., M.G. Wright, A. van den Berg and J.H. Giliomee, 1999. Species richness of arachnids associated with *Protea nitida* (Proteaceae) in the Cape fynbos. Afr. J. Ecol., 37: 334-343.
19. Kaufmann, R., M. Fuchs and N. Gosterxeier, 2002. The soil fauna of an alpine glacier foreland: colonisation and succession. Arct. Antarct. Alp. Res., 34: 242-250.
20. Hodkinson, I.D. and J. Bird, 1998. Host-specific insect herbivores as sensors of climate change in Arctic and Alpine environments. Arct. Antarct. Alp. Res., 30: 78-83.
21. Medan, D., N.H. Montaldo, M. Devoto, A. Mantese, V. Vasellati, G.G. Roitman and N.H. Bartoloni, 2002. Plant-pollinator relationships at two altitudes in the Andes of Mendoza, Argentina. Arct. Antarct. Alp. Res., 34: 233-241.
22. Anonymous, 1997. Deosai brown bear project, 1996. Final report. Himalayan Wildlife Project, Islamabad, Pakistan, pp: 14.
23. Van Tighem, K., 1999. Bears. Altitude Publishing, Canmore, pp: 160.