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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 7 (10): 1689-1694, 2004
ISSN 1028-8880

Diversity and Ecology of Spiders (Arachnida: Araneae) of the Deosai Plateau, Northern Pakistan

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Abstract: Surface-dwelling spiders (Arachnida: Araneae) were collected using pitfall traps to sample four distinct habitat types on the Deosai Plateau, northern Pakistan, during the boreal summer of 1999 (mid-June to mid-October). Traps with radiating veins significantly increased the catch. A total of 8757 spiders were collected, representing 23 species from 19 genera and nine families. Numerically, members of the Lycosidae dominated in all habitat types sampled, followed by the Linyphiidae and Gnaphosidae. Members of the lycosid genus *Pardosa* C. L. Koch, 1847 dominated the fauna, collectively accounting for 75.5% of the total spiders collected. Overall, the sex ratio of adult spiders is biased in favour of males. A conspicuous population peak for the spider community was experienced early in summer, followed by a progressive decrease in numbers and dry mass. Spider assemblages differed significantly amongst the four habitat types distinguished, with some families showing a distinct preference to habitats relative to the substrate, vegetation composition and inclination of the habitat (e.g. Linyphiidae and Gnaphosidae). Based on their relative abundance, arachnids represent a potentially important component in the overall functioning of the Deosai ecosystem.

Key words: Araneae, abundance, Deosai Plateau, ecology

INTRODUCTION

The Deosai Plateau forms the focal point of the Deosai National Park, established primarily for the conservation of the endangered Himalayan brown bear *Ursus arctos* Linnaeus, 1758 and its habitat in the remote mountainous region of northern Pakistan[1,2]. 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]. Little is, however, known about the invertebrate fauna of the region. Apart from two recent short surveys of Lepidoptera[8] and Orthoptera (Zakaria, personal communication) for taxonomic purposes, no comprehensive long-term study on arthropods inhabiting the plateau has been undertaken.

As part of an ongoing study on the feeding behaviour of the approximately 30 brown bears inhabiting the Deosai National Park, an ecological survey was conducted to gather some basic information on the invertebrate ground fauna of the Deosai Plateau. Here the diversity and ecology of spiders (Arachnida: Araneae), an abundant and widespread group of predatory arthropods, are reported on. Spiders are bound to play an important ecological role in the unique high altitude ecosystem of the Deosai. This is also the first report of its kind on this group of arthropods in the northern mountain regions of Pakistan.

MATERIALS AND METHODS

Study area: The Deosai Plateau (35°N, 75°E) is located at the junction of four major mountain ranges, the Karakoram, Ladakh, Zanskar and Himalaya in the rugged northern region of Pakistan. Situated approximately 30 km south-west of Skardu, the capital of Baltistan, the plateau stands apart as an expansive open area of alpine vegetation, streams and lakes. Topographically the area is characterised by rolling plains surrounded by deep valleys and snowy peaks. The elevation of the plateau ranges between 3 400 and 5000 m above sea level, and with most areas above 4 000 m above sea level, the plains are amongst the highest plateaus in the world, covering a surface area of approximately 700 km^2. Being snow-bound throughout most of the year, the area is only accessible by four-wheel drive vehicles during the short summer

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season extending from mid-June to mid-October. Terrestrial and aquatic vertebrate key species inhabiting the Deosai include the burrowing vole *Hyperacrius fertilis* True, 1894, long-tailed marmot *Marmota caudata* Geoffroy, 1842 and slate-coloured snow trout *Diptychus maculatus* Stiendachner, 1866. These species, together with the invertebrate ground fauna, form an important food source for opportunistic omnivores such as the Himalayan brown bears concerned, as shown by scat analyses.

For comparative purposes, four different habitat types were selected for sampling. Firstly, marshes, characterised by a pattern of hummocks densely overgrown by *Agrostis vinealis* Schreh. interspersed with water-filled hollows approximately 0.5 m deep. Secondly, flat grassland, consisting of drier patches of grass and star tulips (*Tulipa stellata* Hook.f.) on relatively flat surfaces in the valleys. Thirdly, grassland slopes, consisting of open grassy hillsides with perennial alpines such as *Androsace mucronifolia* Watt and *Eremurus himalaicus* Baker. Lastly, 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.

Collecting period and methods: Arachnids were collected using pitfall traps 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 pit traps. These were set with the opening of each container flush with the ground surface or level with the dense carpet of grass in marshy areas. Each pit trap was filled approximately one quarter with glycerol which does not volatilise easily, has high viscosity and does not attract or repel insects[9]. Samples obtained were stored in 70% ethanol for later analyses in the laboratory, where the samples were sorted macroscopically.

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. For experimental purposes, four radiating wooden planks, 35 cm in length, were placed in the surrounding substrate of half (5 traps) of each transect. Based on the results obtained, wooden planks were subsequently (second week of sampling) added to all traps to increase their effectiveness. Sampling was then standardised to one line transect of ten traps set out at 5 m intervals in each habitat, emptied till the end of the 15th week of sampling in mid-October.

Specimens were identified to family[10], and if possible, species level[11], enumerated and also sexed. Due to the unresolved taxonomy of certain families and the number of immature spiders collected in some species, some taxa could only be identified to genus level.

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 spiders 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 (chi-square tests and Spearman's rank correlation coefficient) were performed using Statistica for Windows, Release 4.0.

RESULTS

Numbers and diversity: A total of 8757 spider specimens representing 23 species, 19 genera and nine families were collected during the period of study (Table 1). Three species of the wolf spider genus *Pardosa* C.L. Koch, 1847 (Lycosidae) dominated the fauna, collectively representing 75.5% of the total spiders collected. These are *Pardosa nigra* (C. L. Koch, 1834) (45.7%), *P. luctinosa* Simon, 1876 (16.1%) and *P. cincta* (Kulczynski, 1887) (13.7%). Among the remaining families, only the Linyphiidae (12.7%) and Gnaphosidae (9.4%) formed more than 5% of the total spider fauna (Table 2).

Numbers per habitat were dramatically different, with the wetter marshy areas capturing significantly more spiders ($p<0.001$) than any other habitat (n = 6 305, 72.0%). Grassland slopes captured the second greatest number of spiders (n = 1 502, 17.2%), which was significantly more ($p<0.001$) than the numbers captured in the floodplain (n = 564, 6.4%) and grassland flats (n = 386, 4.4%). Numbers captured in the floodplain were significantly greater than in the grassland flats ($p<0.05$). Differences in the numbers captured in the two grassland types can most likely be attributed to the inclination of each habitat.

Both the Gnaphosidae and Linyphiidae were represented by five species each, while only three congeneric species could be identified from the dominant Lycosidae family. The relatively low number of spiders sampled from the six remaining families may have contributed to their low species representation (Table 1).

Statistically significant differences were recorded in the number of spiders collected from pitfall traps with or without radiating wooden planks. In 11 of the 16 original

Table 1: Arachnids collected in pitfall traps on the Deosai Plateau during the boreal summer of 1999

	Individuals		Dry Mass	
	n	%	g	%
Clubionidae				
Clubiona diversa (O.P. Cambridge, 1862)	3	0.03	0.02	0.07
Corinnidae				
Cetonana sp.	33	0.38	0.05	0.16
Gnaphosidae				
Callilepis sp.	11	0.13	0.05	0.16
Gnaphosa rufula (L. Koch, 1866)	339	3.87	1.66	5.40
Haplodrassus signifer (C.L. Koch, 1839)	323	3.69	1.58	5.14
Micaria sibirica (Danilov, 1993)	114	1.31	0.56	1.82
Nomisia sp.	38	0.43	0.18	0.59
Hahniidae				
Hahnia picta (Kulczynski, 1897)	14	0.16	0.07	0.23
Linyphiidae				
Centromerus silvicola (Kulczynski, 1887)	367	4.19	0.15	0.49
Dismodicus sp.	334	3.81	0.13	0.42
Entelecara congenera (O.P.Cambridge, 1879)	11	0.13	0.01	0.03
Erigone atra (Blackwall, 1833)	390	4.45	0.16	0.52
Savignia sp.	11	0.13	0.01	0.03
Lycosidae				
Pardosa cincta (Kulczynski, 1887)	1198	13.68	4.50	14.64
Pardosa luctinosa (Simon, 1876)	1411	16.11	5.33	17.34
Pardosa nigra (C.L. Koch, 1834)	4001	45.69	15.06	49.01
Salticidae				
Chalcoscirtus brevicymbialis (Wunderlich, 1980)	2	0.02	<0.01	0.03
Chalcoscirtus infimus (Simon, 1868)	9	0.10	0.02	0.07
Pellenes moreanus (Metzner, 1999)	62	0.71	0.15	0.49
Sitticus saltator (O.P. Cambridge, 1868)	12	0.14	0.03	0.10
Theridiidae				
Steatoda albomaculata (De Geer, 1778)	29	0.33	0.10	0.33
Steatoda phalerata (Panzer, 1801)	33	0.38	0.12	0.39
Thomisidae				
Xysticus sp.	11	0.13	0.07	0.23
Total	8757	~100.00	30.01	~100.00

Table 2: Family composition of spiders in four habitats sampled on the Deosai Plateau during the boreal summer of 1999

	Grassland plains		Grassland slopes		Marshes		Stony floodplain		Total	
Family	n	%	n	%	n	%	n	%	n	%
Clubionidae	-	-	-	-	3	0.05	-	-	3	0.03
Corinnidae	-	-	31	2.06	-	-	2	0.35	33	0.38
Gnaphosidae	26	6.74	254	16.91	330	5.23	216	38.30	826	9.43
Hahniidae	-	-	1	0.07	6	0.10	7	1.24	14	0.16
Linyphiidae	120	31.09	-	-	982	15.57	11	1.95	1113	12.71
Lycosidae	236	61.14	1140	75.90	4974	78.89	260	46.10	6610	75.48
Salticidae	1	0.26	49	3.26	2	0.03	33	5.85	85	0.97
Theridiidae	3	0.78	22	1.46	6	0.10	31	5.50	62	0.71
Thomisidae	-	-	5	0.33	2	0.03	4	0.71	11	0.13
Total	386	100.00	1502	100.00	6305	100.00	564	100.00	8757	100.00

line transects where planks have been added to half of the pitfall traps to increase the effective trapping area, the pooled data from the latter revealed significantly more individuals captured (p-values for chi-square tests ten times <0.01 and once <0.05).

Phenology and biomass: The sex ratio of adult spiders, grouped according to family, is mostly biased in favour of males (Fig. 1). The numerical dominance of the Lycosidae, with a sex ratio of 1.00 males: 0.32 females, strongly influenced the overall sex ratio, which amounts to 1.00 males: 0.44 females. Egg sacs were recorded from nearly 17% of the lycosid females. Unsexed individuals (immatures) accounted for less than 10% of the total population, but varied from 0% (Clubionidae and Hahniidae) to 31.0% (Gnaphosidae) for specific families of spiders.

On a temporal basis, the Araneae showed a prominent peak at the onset of the summer season, followed by a progressive decrease in numbers till the end of the 16th week of sampling (Fig. 2). The relatively low numbers recorded during the initial survey compared to that of the second week can be attributed to the lesser effectiveness of the 80 pitfalls originally installed without

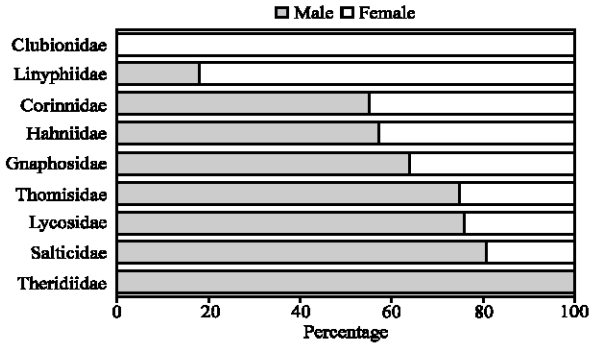

Fig. 1: Sex ratio of spiders collected in pitfall traps on the Deosai Plateau during the boreal summer of 1999

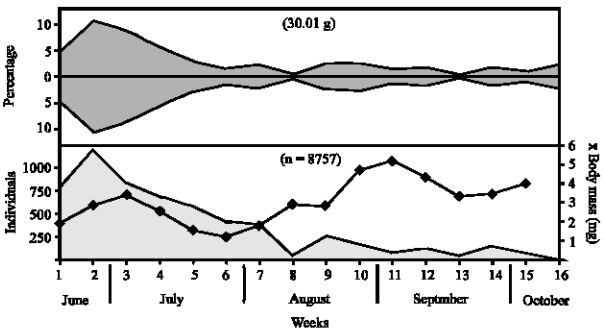

Fig. 2: Temporal variation of spiders (number of individuals-light hachuring; dry mass in grams-dark hachuring; average body mass per specimen captured-solid squares) collected in pitfall traps on the Deosai Plateau during the boreal summer of 1999

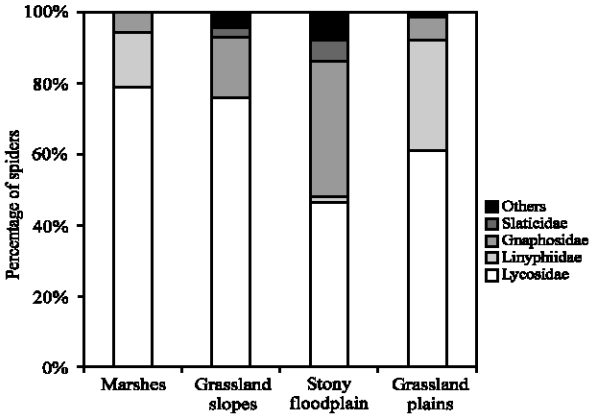

Fig. 3: Habitat preferences of selected ground-dwelling spider taxa collected in pitfall traps on the Deosai Plateau during the boreal summer of 1999

radiating planks. Pitfall traps disturbed and damaged by the Tibetan red fox *Vulpes vulpes* (Linnaeus, 1758), possibly attracted to the glycerol preservative used in the traps, accounted for the reduced catch during the 8th and 13th weeks of sampling.

Of the nine spider families, the Lycosidae dominated dry biomass (81.0%), followed by the Gnaphosidae (13.1%) and Linyphiidae (1.5%) (Table 1). The remainder of the families made little contribution to community structure. The total biomass of the spiders collected decreased from the start of the third week, but remained relatively constant from week six (Fig. 2). Despite the marked decrease in spider numbers from the seventh week onwards, there was a gradual, but insignificant (r^2 = -0.5214, $p>0.05$), increase in the mean biomass per specimen (Fig. 2) indicating that most species mature near the end of the season.

Relation to habitat: The habitat preferences of the arachnids collected is skewed in favour of the more vegetated, wet areas (χ^2_{39}= 2 940, $p<0.01$). This is clearly demonstrated by the Lycosidae, numerically the most abundant family, which showed a progressive reduction in relative abundance from the densely vegetated marshy area to the dry, stony floodplain (Table 2 and Fig. 3). Although most frequently collected in the marshes, the relative abundance of the Linyphiidae was highest in the grassland plains. This family was absent from grassland slopes and was scarce on the stony floodplain, which indicates a preference for flat, vegetated habitats in which they can construct their horizontal sheet webs. The Gnaphosidae showed a preference for the grassland slopes and floodplain habitats and were considerably less abundant in the other two habitats.

DISCUSSION

Surprisingly little is known about the ecology of arachnids inhabiting relatively undisturbed conservation areas in Pakistan such as the Deosai Plateau. Owing to the rigorous climate, the Deosai experiences a very short period of intense biological activity, amply demonstrated by the explosion of arachnids during the onset of the boreal summer when structurally complex plants can provide a diversity of microhabitats for exploitation[12]. Numerous insects attracted by flowering plants during this time[7] could also serve as an invaluable source of food for predatory spiders. Based on their general abundance, the Araneae represent a potentially significant source of high-quality food, clearly forming an important component in the overall functioning of the Deosai Plateau ecosystem.

The diversity of spiders in the Himalayas appears to be strongly influenced by altitude and vegetation structure, with only 23 species collected in this study. In different parts of Africa, spider diversity is much higher in mountain ranges situated at lower altitudes. Sørensen[13] collected 149 species in forest canopies in the Uzungwa

mountains of Tanzania at altitudes of 1800-1900 m above sea level. Haddad[14] collected 109 species in montane grassland in the central Maluti mountains of Lesotho (altitude 1900-2300 m a.s.l.), and 152 species in montane grassland during a more extensive study in the Maluti mountains of southern Lesotho, at altitudes ranging from 1700 to 3000 m a.s.l.[15]. Foord *et al.*[16] recorded 127 species in the Soutpansberg mountains of South Africa at altitudes ranging from 1300 to 1900 m a.s.l. Similarly, more than 28 families were collected in each of the aforementioned studies, while only nine families are represented here. This data would thus suggest that only selected taxa are able to adapt successfully to the extreme climatic conditions and limited habitat diversity and structure of the Deosai Plateau.

Vegetative characteristics often have a strong effect on the species composition and abundance of individual species in different habitats[17-20], which was evident from the four habitats studied here. Certain families, namely Clubionidae, Corinnidae, Hahniidae, Linyphiidae and Thomisidae, were absent from at least one habitat each. This may have partly been due to their general scarcity, but also as a result of vegetation characteristics or habitat inclination. The latter cause most likely explains the absence of one of the more common families, the Linyphiidae, from grassland slopes, whose inclination may have been too steep for these spiders to construct their horizontal sheet webs. The families Clubionidae, Corinnidae and Thomisidae are all active hunters[10] and consequently their absence from certain habitats is most likely due to vegetative characteristics of each habitat.

The strong dominance of Lycosidae in this study may partly be attributed to the exclusive use of pitfalls as a sampling method. It has been found that pitfalls overestimate the abundance of this family, particular in spring and summer, and that Linyphiidae may be underestimated by pitfalls[21]. However, other methods such as D-Vac or hand collecting may have been impractical and difficult to carry out considering the topography and altitude at which this study took place. Therefore, pitfalls were the easiest and most effective sampling method to use in such a structurally simple ecosystem.

Female lycosids are frequently less common than males in surveys as they are considerably less active and need to maximise their energetic intake for reproduction[22,23]. This pattern of high male activity was also demonstrated in this study and contributed largely to the dominance of males in the total sex ratio of the spiders captured in this study. The vegetative structure of a habitat and moisture levels affects abundance and sex ratios of lycosid spiders[9,24,25]. Similarly, the present study found a progressive decline in numbers of *Pardosa* from the moist, vegetated swamps to the dry, stony floodplain, supporting the findings of the aforementioned authors.

ACKNOWLEDGMENTS

Messrs, H.J.B. Butler, P.S. le Roux and D.J. van Niekerk (University of the Free State, Bloemfontein), as well as S. Malek, A. Nawaz, A.H. Siddiqui, S. Ullah, M. Yonus and other members of the Deosai field staff, provided invaluable assistance in the field. The logistic support and sincere interest shown by V. Zakaria and A. ur Rahman, project coordinators of the Himalayan Wildlife Project, are gratefully acknowledged. D.J. van Niekerk is thanked for his assistance with the statistical analysis and production of figures.

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