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Spiders as ecological indicators in the Australian tropics: family distribution patterns along rainfall and grazing gradients

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Summary

Spiders are among five invertebrate taxa being investigated for their potential to be cost-effective indicators of ecological change and land-use impacts for the sustainable management of Australian tropical savannas. Surveys have been conducted along the Northern Australian Tropical Transect, a 500–1500 mm rainfall gradient, which includes clay, loam and sand soil types, and along a specific grazing gradient. Preliminary results reveal significant variation in the abundance of dominant spider families, across both rainfall and grazing gradients. Along the rainfall gradient, numerically dominant families revealed different patterns of abundance, which were not always the same across soil types. Family trends contrasted most on clay soils: the Lycosidae showed decreasing abundance, and the Zodariidae increasing abundance, across sites with decreasing annual rainfall. Within the lower rainfall region, the numerically dominant zodariids also displayed a distinct increase in abundance with decreasing grazing pressure.

Introduction

The composition of spider communities has been shown to vary with respect to a range of environmental gradients (see review by Wise, 1993), including those related to anthropogenic disturbance (e.g. Klimes, 1987). The effects of various management practices, including grazing, on changes in spider faunas have also been the focus of an increasing number of studies in Europe (e.g. Luff & Rushton, 1989; Maelfait *et al.*, 1990; Gibson *et al.*, 1992). As a result, these authors recognized spider communities as a worthy indicator group for monitoring the effects of different types of disturbance. In Australia, however, comparable research at the community level has been minimal, with a recent study on impacts of livestock grazing on invertebrates in temperate woodlands having considered only three spider families (Abensperg-Traun *et al.*, 1996).

Across the Australian monsoonal tropics, characterized by a summer wet season (95% total rainfall) and a warm winter dry season, savannas are the dominant habitat type, which vary structurally and floristically (see Williams *et al.*, 1996). Land use is characterized by extensive pastoral leases, a lucrative tourist industry, mining, and Aboriginal and conservation reserves. However, compared with savannas worldwide, and with other *Eucalyptus*-dominated habitats in Australia, the levels of disturbance are still relatively low (Woinarski & Braithwaite, 1990). With pressure increasing to expand and diversify land-use patterns, it is important that sustainable land-management practices are developed. Accordingly, a federally funded Co-operative Research Centre for the Sustainable Development of Tropical Savannas (Tropical Savannas CRC) was established in 1995 to integrate expertise and provide a multi-disciplinary approach to land use in the region. One aspect of the research (Sub-program 3: Indicators for Sustainable Land Use: Anon, 1995) addresses the need to develop cost-effective indicators of ecological change and biodiversity. As part of this, our project targets five invertebrate taxa, including spiders, which have recently been identified in Australia as a priority group for ecological research (Kitching, 1994; Yen, 1995)

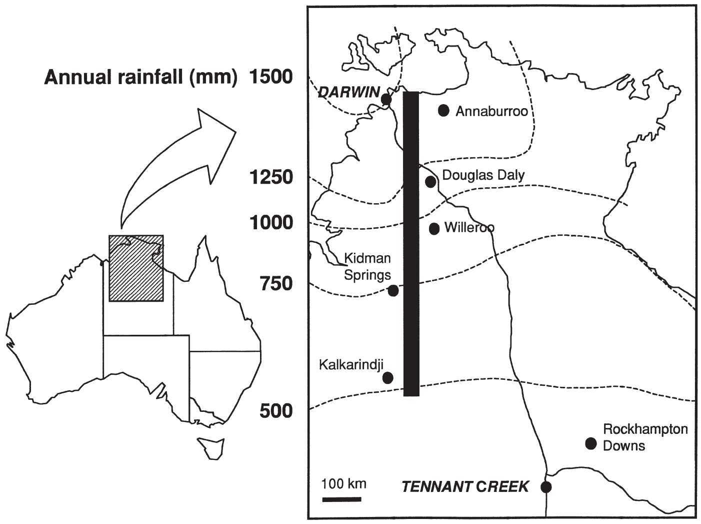

Fig. 1: Position of the five survey sites along the rainfall gradient (Northern Australian Tropical Transect: black bar), and of Rockhampton Downs, with respect to the annual rainfall (mm), isohyets, and major cities.

and as potential indicators of ecological change (Churchill, 1997).

The initial goals of the invertebrate project are: (1) to characterize community structure in relation to variation in rainfall, soil and vegetation; (2) to relate this to different types of disturbance and land use; and (3) to develop effective protocols for the use of key taxa as indicators for assessing ecological change and monitoring land use. Surveys have been conducted along the Northern Australian Tropical Transect (NATT), a rainfall gradient (500–1500 mm average annual rainfall) which includes clay, loam and sand soil types. The NATT was established by the Australian Commonwealth Industrial and Scientific Research Organization (CSIRO) as one of a series of international transects under the auspices of the Global Change in Terrestrial Ecosystems project of the International Geosphere-Biosphere Program (Steffan & Walker, 1992). Surveys have also been carried out across grazing gradients by the Parks and Wildlife Commission of the Northern Territory as part of Tropical Savanna CRC projects to investigate impacts of grazing on the regional biota.

This paper presents preliminary family-level results from spider surveys, along the NATT and a grazing gradient, to introduce the use of spiders as ecological indicators, as part of a

NATT sites	**1**	**2**	**3**	**4**	**5**	**Total**
Average annual rainfall	**1500**	**1250**	**900**	**750**	**500**	
Filistatidae	17	22	11	3	10	63
Gnaphosidae	16	33	40	21	23	133
Lycosidae	74	22	8	11	7	122
Miturgidae	2	1	7	8	22	40
Oonopidae	11	6	59	73	42	191
Prodidomidae	0	1	8	30	10	49
Salticidae	18	53	18	32	21	142
Theridiidae	1	52	9	13	42	117
Zodariidae	30	36	20	43	91	220
Rest	35	38	26	25	16	140
Grand totals	**204**	**264**	**206**	**259**	**284**	**1217**

Table 1: The total number of spiders collected for nine families where $n > 2\%$, and for the remaining 20 families (Rest), across all five NATT sites.

broader protocol for land-management needs in Australia. Further resolution of the data to address species-level and temporal variability is currently under way and will be presented in later publications.

Methods

Rainfall gradient: sites and sampling

Five study sites, established as part of the Northern Australian Tropical Transect, represent variation across a distinct rainfall gradient (Fig.1) and across soil textures. Clay, loam and sand soil types were included in the vicinity of each site: Annaburroo (12°40'–12°50'S, 131°21'–131°49'E); Douglas Daly (13°49'–13°53'S, 131°13'–131°15'E); Willeroo (150°5'–15°11'S, 131°40'–131°43'E); Kidman Springs (160°5'–130°7'S, 130°53'–131°56'E); Kalkarindji (17°18'–17°21'S, 130°45'–130°49'E). The tropical savanna habitat, with a forest or woodland overstorey dominated by *Eucalyptus* and an understorey of annual or perennial grasses, varies structurally and floristically along this gradient (Williams *et al.*, 1996).

At each of the five sites, and for each soil type, spiders were surveyed at a one hectare scale by the use of two sampling grids. A grid comprised 15 pitfall traps, of 8 cm diameter, arranged in three rows of five, all at 10 m intervals. Traps were opened for a one week period during the mid dry season, in July 1996, and partially filled with an ethylene glycol solution. Spiders collected from 30 traps across both grids were pooled to provide a total records for each rainfall and soil type combination.

Grazing gradient: sites and sampling

The grazing impact study was conducted at Rockhampton Downs station (19°17'S, 135°14'E: Fig. 1), a 5080 km^2 property used for extensive cattle production, with the study sites subjected to low to moderate grazing pressure. Located on the Barkly Tableland, the region is characterized by perennial tussock grasslands on cracking clay soils, known as the Mitchell grasslands, which are typically dominated by species of the genus *Astrebla*. During the survey period, the area had poor wet season growth, but a moderate grass cover persisted.

Eight sample sites were selected that ranged from 0.6 km to 6.3 km along an easterly transect from a cattle trough fed from a raised earth dam, forming a gradient of grazing intensity (Fisher, 1996). At each site, spiders were sampled using one grid of 15 pitfall traps, of 7 cm diameter, arranged as above. Traps were opened with a killing solution for a 48 hour period during the late dry season, in October 1995, and partially filled with an ethylene glycol solution. Spiders collected from 15 traps across one grid were pooled to provide a total records for each site, and identified to family according to the current state of taxonomic knowledge defined by Platnick (1989).

Results

Rainfall gradient

In total, 1217 spiders, from 29 families, were collected in pitfall traps over a one-week period across all 15 NATT sites. Zodariidae was numerically dominant (18%) and, with Oonopidae (16%), Salticidae (12%) Gnaphosidae (11%) and Lycosidae (10%), comprised 67% of total abundance (Table 1).

Patterns of distribution across the rainfall gradient in the total number of spiders caught in pitfall traps, varied between dominant ground active spider families (e.g. Lycosidae, Zodariidae, Oonopidae: Fig. 2). Lycosids were more abundant at the higher rainfall sites, whereas zodariids were predominant at sites with lower annual rainfall. Oonopids were more abundant at sites with intermediate rainfall levels.

The extent to which these patterns varied across soil type also differed between these families (Fig. 2). Trends in lycosid abundance were more consistent across clay, loam and sand soils compared to, for example, those in oonopid abundance. Clay soils revealed the strongest constrasts in trends along the gradient between these dominant families. For this soil type, the relationship between spider abundance and increasing rainfall for the Lycosidae (correlation coefficient = 0.73) contrasted with that for the Zodariidae (–0.89).

Grazing gradient

In total, 603 spiders, from 13 families, were collected in pitfall traps over a 48-hour period across the 8 sites. Zodariidae was distinctly numerically dominant (71%) and, with Prodidomidae (8%), Oonopidae (8%), and Salticidae (7%), these families comprised 94% of total abundance.

For the dominant Zodariidae, the pattern of distribution in total spiders caught varied across the gradient (Fig. 3). A clear trend towards increasing zodariid abundance in traps with increasing distance from the artificial water source (and therefore with decreasing grazing intensity) was evident (correlation coefficient of 0.8: Fig. 3).

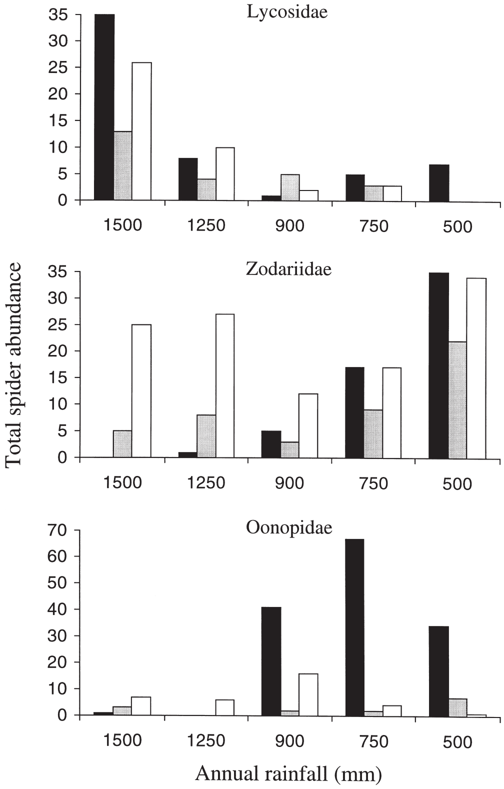

Fig. 2: The distribution of total spider abundance for the Lycosidae, Zodariidae and Oonopidae, across five sites along the rainfall gradient, on clay (black), loam (stippled) and sand (white) soil types.

Discussion

General

Across the five sites utilized in this study to represent a strong rainfall gradient, and across three soil types, the numerical dominance of different spider families varied.

On clay soils, the contrast between the dominant families, Lycosidae and Zodariidae, in the distribution of abundance, was particularly marked. Moreover, for a given family, the distribution patterns along the rainfall gradient, were not always consistent across soil types (e.g. Lycosidae, more consistent than Zodariidae), which suggests that different families are responding to different environmental parameters. This accords with our knowledge that spiders, even when considered at the family level, exploit different prey resources and have particular ecological requirements, supporting their suggested use as functional groups across broad spatial scales, in Australia (Churchill, 1997).

The observed pattern of increasing zodariid abundance with decreasing annual rainfall on clay soils was consistent with their typical distribution in drier habitats (Jocqué, 1993), exploiting ant and termite prey. This trend was also consistent with research in temperate Australia that revealed a significant negative correlation with changes over time in zodariid abundance and (1) rainfall, and (2) soil moisture, at the wettest site studied (Churchill, 1995). Along the NATT on sand soils, however, a greater number of zodariids were caught at the higher rainfall sites, which may relate to the better drainage of sand, compared to clay and loam, soils.

At the northern NATT sites, the intensity and extent of rainfall in the "wet" season would induce substantial surface flows of water. As the foraging mode of lycosids is ground based, and they were caught in greater numbers at high rainfall sites (1500 mm), lycosids may be well adapted to this type of environmental disturbance. Previous observations across a flood gradient revealed that lycosids increasingly dominated sites towards the floodplain, which was associated with decreasing leaf litter depth (Uetz, 1976). The 1500 mm clay site, was not characterized by significant amounts of leaf litter when compared to more southern sites, so

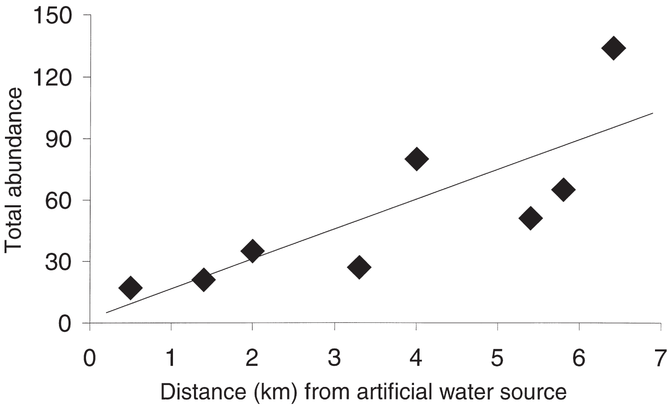

Fig. 3: The distribution of zodariid abundance across 8 sites along the grazing gradient, represented by distance (km) from the artificial water source ($r = 0.8$).

this may be worthy of further investigation. Lycosid distributions have been related to small scale variation in ground cover: to low densities of grass and leaf litter in eastern tropical Australia (Churchill, 1985); and to patches of bare sand in eastern USA (Marshall, 1997).

Ground cover patchiness varied along the NATT, with a threshold in the distribution of patches around the 1000 mm isohyet (Ludwig *et al.*, in review). This coincides with a notable decline in zodariid abundance between the 1250 and 900 mm sand sites, and a contrasting increase in the abundance of Oonopidae caught on clay sites below 1000 mm annual rainfall. It could be expected that the extent and composition of ground cover would influence the distribution of such taxa across a range of scales. Small nocturnal hunters like oonopids depend on leaf litter (Main, 1976) and, most likely, the associated microclimate and prey resources, which are, in turn, influenced by the availability of nutrients. The savanna landscape is characterized by nutrient-poor soils, with the activites of invertebrates contributing to critical soil enrichment processes (Andersen & Braithwaite, 1996). Hence, these results support a role for exploring relationships between micro-habitat features of the environment and changes in spider communities in relation to landscape processes that can be modified by disturbance, such as grazing.

In Europe, changes in plant architecture induced by grazing played an important role (more so than changes in floristics) in altering spider assemblages (Gibson *et al.*, 1992). Maelfait *et al.* (1990) also found the composition of the spider community to be strongly dependent on associated changes in the vertical and horizontal structure of the vegetation subjected to different management regimes of burning, mowing and grazing. In temperate Australia, recent work has shown that lycosids were most abundant in areas subject to “moderate disturbance” by livestock grazing, with only a relationship to decreases in shrub cover significant among nine disturbance-related variables tested (Abensperg-Traun *et al.*, 1996).

On the Barkly Tableland grazing gradient site (below the 500 mm isohyet), the Zodariidae dominated (71% total spiders) the ground-active spider community, particularly at sites with lowest grazing intensity. This supported the trend observed along the NATT, suggesting that they are characteristic of the spider fauna of the semi-arid regions. The strong trend observed in the zodariids, with respect to grazing intensity, was indicative of taxa that have been termed “decreasers”, which respond with a significant decrease in abundance with decreasing distance from an artificial water source (Landsberg *et al.*, 1997). Decreaser trends have been recognized in ant taxa from a series of grazing gradients across semi-arid Australia, preliminary results from which identified spiders as a promising indicator group, worthy of further analysis (Landsberg *et al.*, 1997). Given that data are now required to assess the impacts of pastoralism on Australian native biodiversity (James *et al.*, 1995), there is a clear role for the use of spider communities as indicators of ecological change.

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