Memoirs of the Museum of Victoria 56(2):331–337 (1997) 28 February 1997
https://doi.org/10.24199/j.mmv.1997.56.21

SPIDERS AS ECOLOGICAL INDICATORS: AN OVERVIEW FOR AUSTRALIA

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Abstract

Churchill, T.B., 1997. Spiders as ecological indicators: an overview for Australia. *Memoirs of the Museum of Victoria* 56(2): 331–337.

Spiders operate as a dominant predator complex which can influence the structure of terrestrial invertebrate communities. The potential use of spiders as indicators of ecological change, amongst a suite of selected taxa, is worthy of further research. Indicator taxa need to be diverse and abundant, readily sampled, functionally significant, and to interact with their environment in a way that can reflect aspects of ecological change. This paper examines the attributes of spiders in terms of these criteria, with an Australian perspective, and proposes the use of families as functional groups to represent divergent foraging strategies and selection of prey types. With such information gain, and reduced impact of the "taxonomic impediment", the cost-benefit of surveys is enhanced to encourage the wider collation of quantitative spider data for management or conservation purposes.

Introduction

Invertebrates have an important role to play in achieving effective conservation and management of biodiversity for three reasons:

1. they dominate fauna in terms of species richness and abundance;
2. they are linked to critical ecological processes and;
3. they can provide quantitative data from small spatial scales (Greenslade and Greenslade, 1984; Yen and Butcher, 1992; Kitching. 1993; Norton, 1994; New, 1995).

As it is impossible to assess all invertebrate taxa, however, the pragmatic approach is to select major taxa on which to focus research efforts (New, 1994).

In the case of using certain faunal groups to reflect and monitor environmental conditions, the term "indicator taxa" is frequently employed (Greenslade and Greenslade, 1984; Andersen, 1990; New, 1995), as here. In the indicator context, observed differences or shifts in the relative abundance of particular taxa can be interpreted to reflect more general ecological attributes or changes in a system. For invertebrates, this has been primarily developed using aquatic or marine taxa to characterise water quality or more specifically, the effect of pollutants (e.g., reviews by Warwick, 1993; Bunn, 1995; Fairweather et al., 1995). For Australian terrestrial invertebrates, parallel approaches have been limited to the established use of ants to evaluate processes of land restoration after mining (Majer, 1983; Andersen, 1990, ms.). To gain a wider understanding of patterns of biodiversity and ecological change in invertebrate communities, however, a range of taxa need to be adopted (Beattie et al., 1993; Kitching, 1994; New, 1995; Noss, 1990).

The potential of spiders

In selecting a suite of taxa, arguments for choosing those which are functionally important (Yen and Butcher, 1992; New, 1994) are the most convincing. Due to their ecological importance as dominant predators, spiders have been promoted as one of several priority groups for research (Kitching, 1994; Yen, 1995). In terms of their use as ecological indicators, spiders need to fulfil specified criteria, namely they must:

1. be diverse and abundant;
2. be readily sampled;
3. be functionally significant and;
4. interact with their abiotic and biotic environment in a way that can reflect ecological change (Greenslade and Greenslade, 1984; Andersen, 1990; Cranston, 1990; Beattie et al., 1993; Yen, 1995).

The attributes of spiders with respect to these criteria are reviewed below.

1. Diversity and abundance

The order, Araneae, which comprises spiders, is among the six or seven most speciose orders worldwide, with one hectare of tropical forest estimated to contain 300–800 species (Coddington et al., 1991). In Australia, a total of 1876 described species from 430 genera in 68 families has been tallied (Raven, 1988). With notable increases in taxonomic effort over the last eight years, the number of species described has risen by 26% to 2357 (R. Raven, pers. comm., Jan 1996). With only an estimated 30% (Davies, 1985) or 20% (Raven, 1988) of the fauna formally described, these figures clearly demonstrate that Australia is rich in spider taxa. However, the levels of richness are not unmanageable. In the north-east of Tasmania, a coastal heathland survey over 16 months revealed 130 species over a maximum sampled area of 1.2 ha (Churchill, 1993).

Across Australia, spiders have ranged between the most, to the sixth most, abundant invertebrate order from surveys in rainforest and *Eucalyptus* forest canopies using a number of sampling methods (Majer and Recher, 1988; Basset, 1991; Majer et al., 1990; Yen and Lillywhite, 1990; Abbott et al., 1992; Coy et al., 1993; Kitching et al., 1993; Kitching, 1994; Majer et al., 1994). In a subtropical Queensland rainforest tree canopy where spiders dominated the entire arthropod assemblage sampled, they were responsible for 85% of total abundance and 65% of the total biomass (Basset, 1991).

2. Functional significance

As a predator complex, spiders are among the most abundant and important invertebrate consumers across a range of natural and disturbed habitats (Turnbull, 1973; Reichert, 1974; Humphreys, 1988). Levels of predation upon the arthropod biomass of temperate forests have been estimated at 43.8% annual consumption (Moulder and Reichle, 1972). Spiders are often classed as polyphagous (Reichert, 1974; Turner and Polis, 1979), yet, they include specialist predators such as ant mimics and those that simulate pheromones or odours to attract certain prey species (Stowe, 1986, Pollard et al., 1987). Spiders also interact directly as competitors, mutualists, predators, and particularly as prey, with higher order taxa such as birds (Gunnarsson, 1996), fish (Bleckmann and Lotz, 1987), and lizards (Schoener and Spiller, 1987). Consequently, spider assemblages can play a major role in ecosystem function by directly and indirectly regulating the abundance of taxa which determine rates of herbivory, pollination, decomposition, soil production, nutrient cycling or energy flow (Riechert, 1974; Wise, 1993). The value of spiders as indicators relates, therefore, to their being dominant invertebrate predators, with observed changes in spider faunas having the potential to reflect ecological impacts at lower trophic levels, and across relatively small spatial scales.

3. Ease of sampling

Due to their abundance and diverse behaviours, spiders can be easily sampled by a range of techniques (e.g., Coy et al., 1993). Vagrant ground hunters are readily captured by the cost-effective pitfall trap (Canard, 1982; Merrett and Snazell, 1983; Churchill, 1993). Foliage dwelling taxa are more susceptible to capture by sweep net (Canard, 1982; Churchill, 1993), beating bushes (Canard, 1982; Hatley and MacMahon, 1980); branch clipping (Majer and Recher, 1988; Abbott et al., 1992); chemical knockdown (Majer and Recher, 1988; Yen and Lillywhite, 1990; Kitching et al., 1993) or restricted canopy fogging (Basset, 1991). Spiders that are sedentary and cryptic, or conspicuous by their webs, size or behaviours, are effectively sampled by visual searching and hand collection (Canard, 1982; Coddington et al., 1991; Churchill, 1993). To target spiders in leaf litter, sifting and extraction techniques such as Berlese or Tullgren funnels can provide standardised and quantitative samples (Canard 1979; Coyle, 1981; Coddington et al., 1991).

4. Interaction with their abiotic and biotic environment

For any invertebrate taxon to be considered as an indicator of ecological change, it needs to display a sensitivity to changes in environmental variables which are associated with stress and disturbance (Andersen, 1990; Noss, 1990; New, 1995). Research in the Northern Hemisphere has revealed that habitat structure and/or associated microclimatic factors, which can be altered by many land use practices, strongly influence patterns of spider distribution (reviews by Turnbull, 1973, Uetz, 1991; Wise, 1993). Across environmental and successional gradients the diversity and relative abundance of spider taxa has been shown to exhibit clear shifts (Uetz, 1976; Bultman et al., 1982; Klimes, 1987; Gibson et al., 1992). The relative importance of different variables can change over time (Uetz, 1979), however, with the availability of prey resources another important factor (e.g., Reichert, 1974). In terms of specific responses to environmental disturbance, characteristic changes in spider faunas have been documented in Europe and America for the effects of metal pollution (Bengtsson and Rundgren, 1984;

Clausen, 1986), fire (Merrett, 1976), grazing (Gibson et al., 1992), pasture improvement (Luff and Rushton, 1989) and clearcutting, burning, mowing and plowing (Huhta, 1971; Coyle, 1981; Haskins and Shaddy, 1986). Clearly, the composition of spider communities of different habitat types is affected by certain changes in environmental conditions, the challenge is now to develop a predictive understanding for management purposes.

Australian research

In Australia, comparable research into spider communities has been minimal. In Western Australia, Mawson (1986) studied the richness and diversity of the arachnid fauna in rehabilitated minesites and surrounding undisturbed eucalypt forest in Western Australia. The result included recommendations for improving the rehabilitation process based on the fact that a more complex habitat structure favoured a richer spider fauna. Research beyond community indices, however, is required to evaluate whether Australian spider faunas display patterns of variation in relation to change in key environmental factors.

With the recent expansion of multivariate techniques it is now easier to analyse complex ecological patterns (Gauch, 1982), with indicator properties of invertebrate communities being determined specifically by ordination (Kremen, 1992). Consequently, these techniques have been applied to pitfall trap data derived from a 16 month survey of a coastal heathland spider community in Tasmania, across three nested spatial scales, with the minimum scale 18 × 18 m (Churchill, 1993, 1995). Correlation coefficients for spider vectors from HMDS ordination (Belbin, 1991), using the Bray Curtis association measure (Bray and Curtis, 1957), revealed strong associations of both spider families and species (correlation coefficients > 0.6 for 85% and 80% vectors, respectively) with patterns of spatial variability across the community (Churchill, 1995). These patterns were strongly associated with changes in habitat structure, particularly the mean cover of plant species. Significant correlations between changes in the abundance of taxa and abiotic variables (e.g., temperature and rainfall) over time were also documented at both the family and species level (Churchill, 1995). These results illustrate that Australian spiders can display a sensitivity to variation in environmental factors, even at the family level. Given that spider faunas have been shown to respond faster to anthropogenic disturbance than vegetation (Klimes, 1987), they have the potential to reveal early, and more subtle, ecological changes, which characterises the main value of an indicator group (New, 1995).

Spider families as functional groups

The information value of using certain indicator taxa is greatly enhanced if combined with a functional group approach. This approach has been advocated to increase an understanding of the dominant processes which maintain biodiversity (Lambeck, 1992; Walker, 1992) and underly environmental change (Andersen, 1990). The fact that most spider families differ in their primary foraging mode, has facilitated their classification into broad functional groups (e.g., Canard, 1990; Coyle, 1991). Patterns of relative abundance of key spider families, however, are here proposed as the basis of a functional group approach in Australia given the following:

1. the paucity of ecological knowledge at lower taxonomic levels (Humphreys, 1988);
2. that taxonomic characters at family level have ecological relevance (see below);
3. that prevailing ecological patterns in spider communities can be detected at the family level (Churchill, 1995);
4. an increasing demand for ecologically useful data at finer spatial scales than previously used (Norton, 1994);
5. the need for protocols to assess anthropogenic change on invertebrate faunas that apply to various habitat types and regions (New, 1995);
6. an urgent need to collate this information cost-effectively (New, 1994; Yen, 1993); and
7. the successful development of a parallel approach using ant genera (Andersen, 1990; ms).

As the ecology of Australian spider genera and species is increasingly understood, as for spiders of European heaths (Canard, 1990), this approach can be further refined.

To distinguish families, important morphological characters relate to the size and arrangement of eyes, legs and silk producing organs (e.g., Davies, 1986). These anatomical features directly reflect the perception and use of important environmental components, including prey. In addition, the size of particular taxa and their spatial distribution within a habitat defines the part of the prey spectrum utilised and hence, their function in the system (Canard, 1990). For example, the family Thomisidae, or crab spiders, have evolved to be ambush hunters, typically cryptic and preying upon small insects attracted to flower heads (Main, 1976). Moreover, the spatial distribution patterns of thomisids are significantly correlated to a high abundance of arthropod pollinators (Turner and Polis, 1979). An observed shift in the relative abundance of a given family, therefore, can indicate more specifically the range of resources being altered by processes of change in the system.

Additional advantages of investigating spider communities *at least* to family level relate to current concerns for rationalising the costs and benefits of surveys (Margules and Austin, 1991; Yen, 1993). In the case of invertebrate surveys, an increasing demand for taxonomic resources to identify genera and species has accentuated the decline in available expertise (Richardson and McKenzie, 1992; Gaston and May, 1992). This issue has been termed the "taxonomic impediment" to effective invertebrate assessment (Cranston, 1990; Kitching, 1993; New, 1994), with which high costs can be associated. Means to circumvent this have focused on development of procedures of "Rapid Biodiversity Assessment" (RBA) where specimens are taken to "morphospecies" or "Recognisable Taxonomic Units" in lieu of specific taxonomic resolution (Cranston and Hillman, 1992; Kitching, 1993; Oliver and Beattie, 1993). The separation of RBA procedures from taxonomy and associated phylogenies (Beattie et al., 1993), however, involves an asssociated loss of biological and biogeographic data which limits ecological applications.

Alternatively, the use of higher taxonomic levels may suffice for certain survey goals as suggested for stream invertebrate assemblages (Wright et al., 1995). To assess land degradation and restoration processes, Australian ant genera have successfully been used as the basis of a functional group approach (Andersen, 1990). In detecting human impacts on marine faunal communities, responses of higher taxonomic levels have presented an advantage by operating "above the noise of natural variability" (Warwick, 1993). In this context, spiders can offer an additional resilience to "noise" by tolerating notable periods of starvation (Nakamura, 1987), to possibly provide a strong signal when interpreted as an ecological impact lower down the trophic pathway.

To evaluate broad scale ecological patterns in spider assemblages, family level analysis has been suggested (Yen, 1995) and shown to be as effective as the use of species in Tasmanian coastal heath (Churchill, 1995). Since spiders display a sensitivity to variation in environmental parameters, even at the family level, there is a opportunity to investigate, cost-effectively, general responses to various agents of ecological change. Efforts to further refine the data set can be directed at investigating dominant taxa in families which indicate the strongest trends with respect to the specific disturbance, or variables, under study. Relationships between the observed patterns with other biotic/abiotic components can then offer an insight into the key processes behind ecological change for more specific testing.

Acknowledgments

The research on Tasmanian heathland spiders was supported by the Queen Victoria Museum in Launceston, an Australian Post-graduate Research Award at Griffith University, and the Arachnology section of the Queensland Museum, in Brisbane. Michael Arthur and Dr Stuart Bunn, at Griffith University, assisted with the multivariate analyses. I am very grateful to Dr Robert Raven, (Queensland Museum) for his invaluable support, and to Dr Alan Andersen, (CSIRO, Darwin), and an anonymous reviewer, for comments on the manuscript.

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