

## Spiders as indicator species : lessons from two case studies

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**Spiders as indicator species: lessons from two case studies.** - Spiders have been used as indicator species in at least two ways. The first approach examines spiders at the species level, using known ecological preferences in order to determine how spider communities react to environmental change or disturbance. In the second approach, species richness of spider communities is used as a synthetic indicator of the quality of natural habitats. An example for the first approach is the analysis of the tyrphobiont species of a series of European peat-bogs; the second approach is illustrated by the analysis of a case study on the effect of reed bed burning and mowing on species richness and composition. Both case studies are discussed and the following lessons are drawn :

- when individual species are used, excellent basic information on their distribution and ecology is a prerequisite for the choice of indicator taxa;
- a high standard in sampling design is needed for indicator species applications;
- precise definition of the kinds of perturbations that are expected to influence the indicator taxa is to be recommended.

**Key-words:** indicator species - Arachnida - Araneae - conservation - community structure - sampling design.

### INTRODUCTION

For environmental applications, spiders have been used as indicator species in at least two ways. The first approach examines spiders at the species level, using known ecological preferences of species in order to determine how spider communities react to environmental change or disturbance. This approach is illustrated by the work of BUCAR (1983), MAELFAIT *et al.* (1990), MCIVER *et al.* (1990) and PLATEN (1993). In the second approach, species richness of spider communities is used as a

Manuscript accepted 18.01.1996.

Proceedings of the XIIIth International Congress of Arachnology, Geneva, 3-8.IX.1995.

synthetic indicator of the quality of natural habitats (ALLRED 1975; KROMP & STEINBERGER 1992; POZZI 1994). A study by CLAUSEN (1986) on use of spiders for the monitoring of pollutants can also be associated with this second approach.

While most authors agree that spiders should be appropriate as ecological indicators (ALLRED 1975; BUCAR 1983; MAELFAIT & BAERT 1988a, b; MAELFAIT *et al.* 1990; MCIVER *et al.* 1990; FÜRST *et al.* 1993; PLATEN 1993), only very few studies report supportive evidence in the context of applied ecological questions or environmental impact assessment procedures (MAELFAIT & BAERT 1988b; MAELFAIT *et al.* 1990; POZZI 1994). Moreover, no study has so far critically examined the limitations in the use of spiders as ecological indicators. Therefore, this work examines two case studies in order to improve the answers to the following questions:

- can spiders be successfully used as ecological indicator species ?
- what are the advantages and limitations in the use of spiders as indicator species ?
- which conditions should be fulfilled in order to develop standard use of spiders as ecological indicators ?

#### FIRST CASE STUDY: THE INDICATOR VALUE OF TYRPHOBIONT SPECIES

The term tyrphobiont was coined by PEUS (1928) to define species living only in peat-bogs and mires. Reviewing a series of papers dealing with the spider fauna of European peat-bogs, CASEMIR (1976) lists 8 tyrphobiont spider species: *Heliophanus dampfi*, *Pirata uliginosus*, *Clubiona norvegica*, *Theonoë minutissima*, *Aphileta (Hillhousia) misera*, *Drepanotylus uncatulus*, *Hilaira excisa* and *Maro lepidus*. As peat-bogs are nowadays often perturbed or altered by exploitation, pollution or inappropriate management, one may expect to use such tyrphobiont species as indicators of good-state peat-bogs.

#### MATERIALS AND METHODS

This brief analysis is based on a review of published reports on peat bog spiders (11 papers were examined). Lists of tyrphobiont species and general characteristics of seven European peat-bogs were retained from papers having sufficiently complete informations for data analysis (area, state of the habitat). The state of each peat-bog was estimated from published information and defined as having a low or high level of degradation and a low or high level of geographic isolation.

#### RESULTS

Table 1 illustrates the number of tyrphobiont species found in the seven peat-bogs. It appears that most published studies were carried out on lowly modified peat-bogs and that the two smaller and degraded or isolated peat-bogs have fewer tyrphobiont species than the five larger and well-conserved peat-bogs (Wilcoxon signed-rank  $z = -1.706$ , one-tailed  $p < 0.05$ ). However, as shown in Fig. 1, there is a

TABLE I

Number of tyrophobiont spider species (n) found in seven European peat-bogs, with habitat area (S) and estimated state (level of habitat degradation D : low or high; level of habitat isolation I : low or high).

n	S (ha)	state (D/I)	country	reference
0	5	low/high	Switzerland	Holzappel (1937)
2	50	high/high	Switzerland	Mulhauser <i>et al.</i> (1987)
5	630	low/low	Germany	Rabeler (1931)
1	4000	low/low	UK	Cherret (1964)
5	10000	low/low	Belgium	Baert & Kekenbosch (1982)
8	10000	low/low	Belgium/Germany	Casemir (1976)
6	31500	low/low	Estonia	Vilbaste (1980)

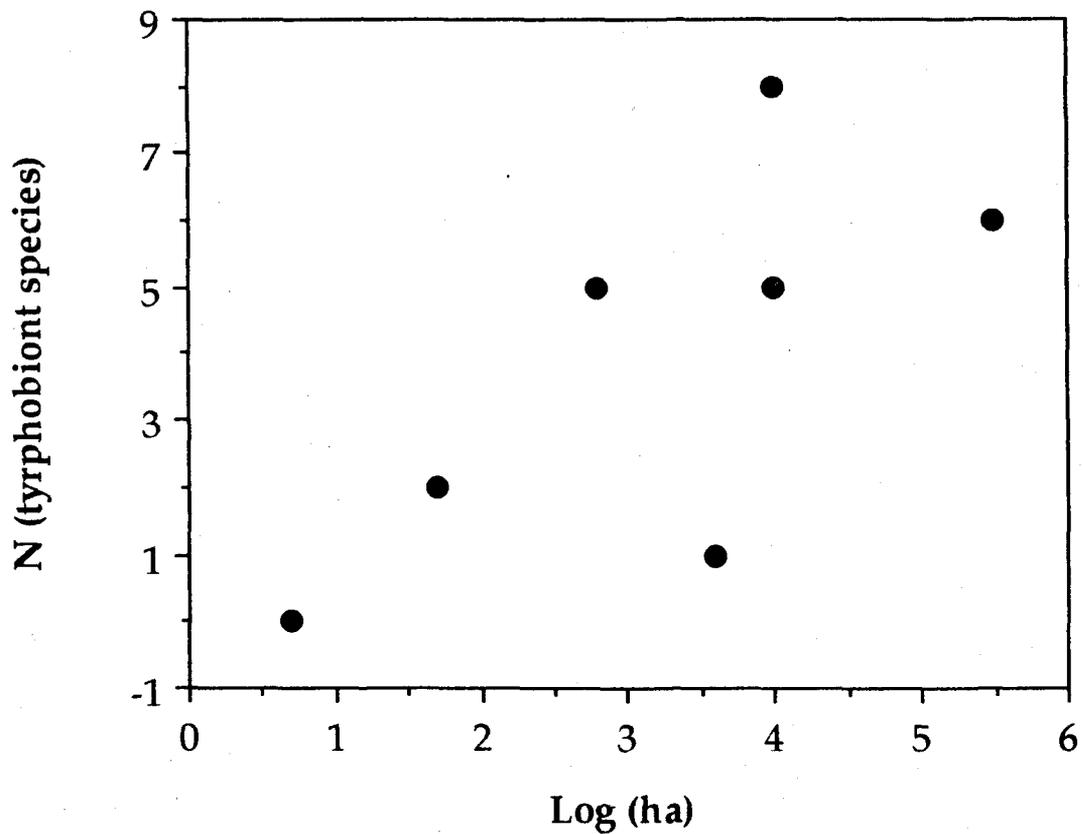


FIG. 1

Relationship between peat-bog area (Log values) and the number of tyrophobiont spider species. Kendall's rank correlation Tau = 0.65,  $p < 0.05$ .

significant correlation indicating that the number of tyrphobiont spiders found is directly influenced by habitat area (Kendall's rank correlation  $\text{Tau} = 0.65$ ,  $z = 2.05$ ,  $p < 0.05$ ).

#### DISCUSSION

The results of this simple analysis indicate that the use of tyrphobiont spiders as indicators is problematic. While the presence of tyrphobiont species is informative and may confirm that the habitat is not highly modified, the absence of such species cannot be used for assessments without care. The reason for this is that indicator species may be missing :

- because of insufficient sampling effort,
- due to the biogeographical effects of small habitat area and isolation (natural local extinctions due to the spatial and patchy distribution of the peat-bog habitats),
- because the peat-bog habitat is perturbed and altered (local extinctions due to habitat degradation and human influences).

Thus, unless one can control for the effects of habitat size and isolation and ensure appropriate sampling, it will not be possible to conclude that a peat-bog habitat is seriously modified simply because some tyrphobiont species are not found. Another more general problem regarding the use of known ecological preferences of spiders is that most species are associated with several habitat types when one considers currently used habitat classification systems. In a recent synthesis by HÄNGGI *et al.* (1995), which characterizes the habitats of 384 Central European species, most are found in a series of different habitats and only very few appear to be strictly associated with a given habitat type. This can be explained by the fact that spiders depend not only on microclimate and vegetation characteristics but also on the physical structure of habitats and may therefore appear in quite different habitats if appropriate physical structures are present (e.g. DUFFEY 1966). In the case of tyrphobiont species, although for some cases there is evidence that they are strictly related to peat-bogs, e.g. *Heliophanus dampfi* (NEET 1987), recent evidence shows for example that *Pirata uliginosus* and *Drepanotylus uncatulus* also occur in other habitats (HÄNGGI 1987; HÄNGGI *et al.* 1995) and thus are not strict tyrphobionts.

#### SECOND CASE STUDY: THE EFFECT OF FIRE AND MOWING ON A WETLAND SPIDER COMMUNITY

An alternative to assessments based on autecological data of individual species is to look for more synthetic indicators such as species richness. The data presented here are taken from a study that was carried out in the wetlands of the natural reserve of "Les Grangettes" on the Eastern end of the Lake Lemán (Switzerland). Invertebrates were collected in order to assess the effects of a fire that occurred in May 1992. Since the fire affected mown and unmown areas of the reed bed, this analysis examines both effects of burning and mowing on species richness and composition.

## MATERIALS AND METHODS

The sampling design included four sampling sites organized as follows.

Site 1 : control plot 1, burned plot 1; Site 2 : control plot 2, burned plot 2; Site 3 : mown plot 1, burned & mown plot 1 ; Site 4 : mown plot 2, burned & mown plot 2. In site 4, there was also an intermediate plot between the two other ones. Hereafter, "burnt" and "mown" are considered as two treatments. All sites were situated along one border of a large burnt area of 30 ha, with a more or less uniform cover of *Phragmites australis*, *Carex lasiocarpa* and *C. elata*; the sites 1 and 2, which were not mown, included dense patches of *Carex* sp. The distance between sites varied between 60 and 200 m. Sites were situated at increasing distances from the Lake Lemman, site 1 being closest to the lake and site 4 most distant. On each plot 6 pitfall and 2 emergence traps were placed. Sampling started 5 days after the fire and specimens were collected every 7 days during 9 periods (from May to September 1992). A detailed report on the study site (HOFMANN *et al.* 1994), as well as an analysis of the spider fauna, with detailed species lists and different analyses at the species level (ECOCONSEIL 1994) are available.

TABLE 2

Total species richness and number of species per family for the most abundant spider families according to different treatments of the habitat (tests after SIEGEL & CASTELLAN 1988)

	No*	Treatment			test (Fisher exact or Chi-square)
		Burnt	Mown	B+M**	
Species richness :					
Total	35	33	38	36	Chi-square = 0.53 NS
Araneidae	3	2	2	0	Fisher ex. = 0.52 NS
Clubionidae	5	4	2	4	Fisher ex. = 0.61 NS
Linyphiidae	8	5	12	10	Chi-square = 7.0 p < 0.01
Lycosidae	6	8	10	10	Chi-square = 3.2 NS
Salticidae	3	4	2	5	Fisher ex. = 1.00 NS

\* Control \*\*Burnt and Mown

## RESULTS

Table 2 indicates that total species richness did not differ between the different treatments. Among the most abundant families, a significant difference in species richness per family was found only for Linyphiidae, where the effect of mowing appears to be an increase of richness.

In order to examine whether species composition was influenced by treatments, a cluster analysis of plot similarity was performed using the species abundances of each sampling plot as descriptors.

Following the recommendations of LEGENDRE & LEGENDRE (1979), similarity was measured by the chi-square distance and the UPGMA clustering method was

selected (Fig. 2). The plots are grouped according to spatial proximity rather than to treatment, indicating that the spatial distribution of the plots has a major influence on species composition. A Mantel test (MANLY 1986) was used to evaluate this indication, by estimating the correlation between the similarity matrix and inter-plot distance classes (distance matrix). Among the four distance classes tested (one intra-site and three intersite), only one intersite distance class is significantly correlated with similarity ( $r = -0.59$   $p < 0.05$ ). This suggests the presence of a spatial structure in the data, i.e. differences between sampling sites related to spatial position.

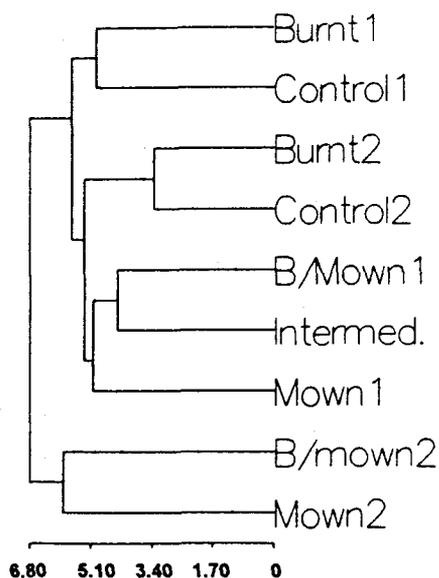


FIG. 2

Cluster analysis of plot similarity using species abundances as descriptors (Chi-square distance and UPGMA clustering).

These results show that treatments did only affect richness of some groups of species (Linyphiidae) without affecting total richness and without deeply modifying community structure. An important aspect was unfortunately not taken into consideration in the sampling design: water level. In wetlands situated on lakeshores, when sampling occurs over several weeks, the water level may vary and influence species richness on local plots as well as pitfall trapping efficiency. Given the positions of sampling sites, a gradient of water level is one of the probable factors that may explain the spatial structure detected in the data.

## DISCUSSION

The conclusion that burning or mowing did not globally diminish species richness is consistent with the results obtained by DITLHOGO *et al.* (1992), who showed that total number of invertebrates, species-richness, diversity and evenness

show no relationship with cutting or burning reed-beds. USHER & SMART (1988) have even found increases of species richness after a heathland fire. From the results presented here, one could thus conclude that spider species richness can be used as an indicator of the non-harming effect (no reduction of species richness) of burning and mowing. This kind of conclusion has important practical consequences as reed bed mowing and protection against fire are current issues for local managers. However, alternative interpretations can be found :

- the results could be biased if sampling insufficiently covered species living in the upper layers of the herbaceous cover (Araneidae, Clubionidae); therefore some important components of species richness and composition may have been missed,
- the presence of a spatial structure in the data indicates that uncontrolled factors such as the influence of water level may affect sampling design and results,
- if, after the treatments, some species are definitely lost and others newly invading the community, effects on species richness may be delayed in time due amongst other reasons to modifications in interspecific interactions.

Delayed effects have actually been found by MERRETT (1976) who noticed an evolution of community composition over ten years after heathland fires. Therefore, species richness alone as an indicator could be somewhat limited : if species richness remains constant but with ordinary species progressively replacing rare ones, the effect would actually be negative for conservation.

## CONCLUSIONS

Returning to the questions of the introduction, following answers can be suggested. First, there is evidence that spiders can be used as ecological indicators (see also MAELFAIT & BAERT 1988a and MULHAUSER 1990 for other discussions). Besides published results mentioned above, the non-harming effect of reed-bed burning and mowing is an illustrative example. Advantages of spiders as ecological indicators are their abundance in all ecosystems, the fairly easy identification and, as predators, their integrative trophic level. One major disadvantage is the limited association between currently used habitat classifications and the actual patterns of spider habitat selection, resulting in a very limited number of spider species selecting a unique habitat (HÄNGGI *et al.* 1995), even in the case of presumable habitat specialists such as tyrphobionts. Regarding limitations in the use of spiders as indicators and the conditions which should be fulfilled in order to develop standard use of spiders as ecological indicators, the following lessons can be drawn from the examples presented here :

- when individual species are used, the availability of excellent basic information on their distribution and ecology cannot be overlooked and should be considered as an important prerequisite for the choice of indicator taxa,
- a high standard in sampling design is needed, in order to control as much as possible for confounding situations and alternative explanations to the patterns observed.

The interest of ecological indicators is to replace very detailed studies of community ecology by simplified approaches that permit to organize monitoring over larger spatial and time-scales. To monitor river ecosystem pollution such tools have been developed with success, in particular due to the fact that the perturbation under test is clearly defined and has obvious detrimental consequences (water pollution). If terrestrial indicators are to be used in practice, a last recommendation would therefore be to take care to define exactly what kind of perturbations are under test and which are their expected consequences. This will help clarifying problems of sampling design by clearly separating the different effects that may occur simultaneously, as in the peat-bog example where habitat isolation and habitat degradation by exploitation may occur, or in the second case study, where an important factor such as water level was not controlled for.

#### ACKNOWLEDGEMENTS

I am very grateful to Pierre-Alain Fürst, Najla Naceur, Sébastien Sachot and Michel Sartori for their important contributions to this work. The data concerning the Granges natural reserve are part of a wider project designed to monitor the effects of reed-bed burning on arthropods. I would like to thank the Fondation des Granges and the Museum of Zoology, Lausanne, who are leading this project and in particular Claire Hofmann, Geneviève l'Eplattenier and Dominique Chautemps who have done most of the field work.

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