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Araneae communities and the functioning of prey—predator system (dipterans—spiders) in the devastated Karkonosze mountain forest

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Prey, predators, Karkonosze Mountains, forest damage, Araneae and Diptera communities, functional response, numerical response, anthropogenical changes

Abstract. In the Karkonosze Mountain region, investigations were conducted on spiders and their dipteran prey. These investigations included three different spruce forest habitats: old spruce forests, open areas after the disappearing of damaged spruces, and young spruce woods.

The analysis included the structure of spider and dipteran communities (number of species, abundance, biomass), the distribution of animals examined in all these three habitats and the function of prey—predator systems.

The numerical relations of dipterans and spiders demonstrated that only in the old spruce forests there is a probability of regulatory action of prey—predator system. New habitats (young spruce woods and devastated areas) have no such possibilities.

INTRODUCTION

Our research in the Karkonosze mountain region was part of a major scientific project. A scientific project to evaluate the causes and ecological consequences of mountain forest degradation in the Karkonosze Mountain region in South-West Poland, was undertaken by the Institute of Ecology PAS and by other scientific institutions. The project included environmental studies (geological, soil, climatological), biocoenotical studies (vegetation, soil and overground animals) and functional aspects (prey—predator relations, decomposition of dead organic matter in the soil, matter cycling). Within the framework of this project, we studied the structure and the functioning of field-layer spiders and dipterans.

Our investigations were conducted in 1992 and 1993 at 13 sites. Spiders and dipterans were caught with a sweep-net, a method often used in entomology: at each site and date a series of ten samples was taken, each sample consisting of 25 strokes. The sites were concentrated in the western (most polluted) part of Karkonosze at Mumlawski Wierch (1240 m above sea level), at the foot of a mountain in the valley of Kamienna river (900 m), and for comparison also at Szrenica mountain (1362 m). In this paper, we present general results of our investigations carried out in the region of Mumlawski Wierch and the Kamienna river valley. We differentiated there three types of forest habitats: old spruce forests (2 sites), areas with a destructed tree layer (4 sites), and young regenerating spruce woods about 15 years old (3 sites) (Fig. 1). In all these habitats, the herb layer typical for spruce forests was preserved (Wasiłowska, 1992, 1994). These three types of habitats were represented both on the slope of Mumlawski Wierch and in the Kamienna river valley (Fig.1). In this way our investigations were made in all phases of spruce forest transformations, characteristic for this region.

REACTIONS OF SPIDERS TO SPRUCE FOREST TRANSFORMATIONS

In the Karkonosze spruce forests, a significantly reduced species number, smaller species abundance and a much smaller biomass, compared to the forests of the other regions, was observed.

It seems that the reasons for the quantitative and qualitative poverty of the field-layer arachnofauna in the Karkonosze region (Table 1) lie both in the weak development and differentiation of the spruce forest herb vegetation (which make constructing webs difficult) and in the sharp climatic conditions; there may be also an influence of the high industrial emission flowing in from other regions of Poland as well as from Germany and Czech Republic.

The investigations were carried out in three types of forest habitats representing different forms of environmental transformation: (1) remains of old spruce forest complexes, (2) open areas formed after the disappearing of damaged spruce trees, and (3) the regenerating young small spruce woods, the early stages of natural forest succession.

Remains of old forest complexes are about 80 years old and have a structure of plant communities typical of old montane spruce forests. In the herb layer of these forests there are 11 species of vascular plants and mosses, and species characteristic of spruce forests, such as *Vaccinium myrtillus, V. vitis idaea* and *Trientalis europaea.* They have the highest sum of cover indices for spruce forest characteristic species and the lowest for grass species. Treeless areas formed after the decay of damaged spruce are covered

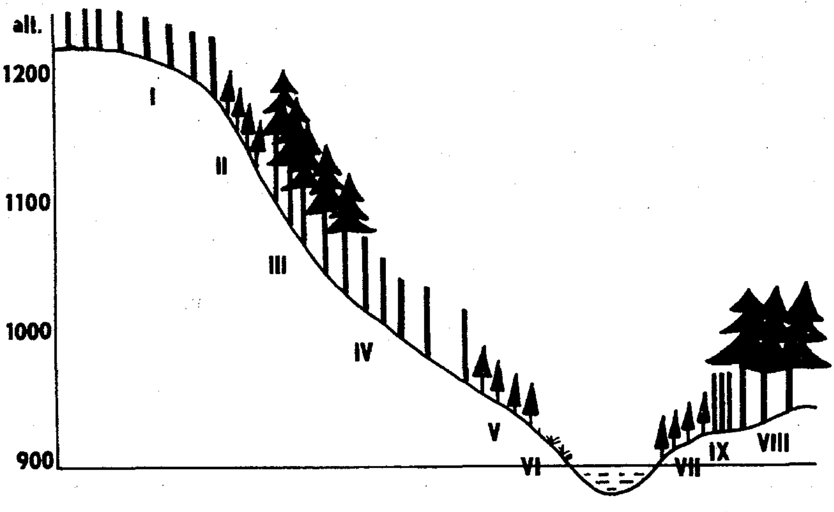

Fig. 1. Distribution of habitats at the Mumlawski Wierch (Western part of Karkonosze Mountains). I–IX examined sites.

Table 1. Characteristics of field-layer spider communities in three types of mountain spruce forest habitat (values for the whole season).

	Living old spruce forests (80 years old)	Open areas after devastated spruce forests (without trees)	Young, regenerating spruce woods (about 15 years old)
Number of species	27	28	32
Abundance of spiders	296	74	222
Biomass of spiders (mg w.w.)	670	290	667
Dominating ecological groups and % of total	Linyphiidae (68) Metidae (14)	Araneidae (32) Linyphiidae (29)	Linyphiidae (50) Araneidae (26)
Dominating species	*Lepthyph. mughi* (54)	*Araneus marmoreus*	*Pityohyph. phrygianus*
(22)			
and % of total	*Meta mengei* (10)	only young inds (10)	*Lepthyph. mughi* (17)
	Tetragnatha sp. (10)		*Araneus marmoreus*
(15)			*Tetragnatha* sp. (11)
% of all dominating species	74	10	65

luxuriantly by grasses with *Calamagrostis villosa* and *Deschampsia flexuosa* which predominants. Their vegetation has the lowest sums of cover indices of spruce forest species and the highest of grasses. This vegetation is the richest floristically because it is already invaded by species associated with clearings, such as *Rubus idaeus, Chamaenerion angustifolium.*

On small areas of young (about 15 years old) regenerating spruce woods there is a great density of trees. These woods are characterized by a greater proportion of spruce forest species in the herb layer as compared with treeless plant communities but smaller than the old spruce forests. Also the cover of spruce forest species in these woods is intermediate between old spruce forests and treeless plant communities.

The destruction of the spruce forests causes a qualitative transformation of the spider community but does not change the total number of species (Table 1). The structure of the herb vegetation maintains itself for some years after the moment of the disappearance of the trees (Wasiłowska, 1992, 1994) and makes it possible to maintain there the same number of other web-building species, although with a very small number of individuals. The appearance of the regenerating young spruces enriches the spider community by about 20% of the species.

The reaction of spiders to the environmental damage was primarily numerical. In damaged open habitats the abundance of spiders was significantly reduced compared to the old spruce forests and the young spruces: number of spiders there was only 25% of the level achieved in the old spruce forest and 35.5% of the level in the young spruces and their biomass had about 43% of the level in two other types of habitats (see Table 1).

The species characteristic of mountain regions, *Lepthyphantes mughi* (Fickert), was the dominant species (54% of the total spider numbers) in old well preserved spruce forest. There were also two other minor dominant species (Table 1). *L. mughi* disappeared in the open damaged habitats, which revealed a new dominant species: immature stages of *Araneus marmoreus* Clerck (10% of the total spider numbers). The lack of other predominant species and even of more numerous species is the testimony of bad environmental conditions for maintaining greater populations of spider species in this habitat.

In young spruce woods, a qualitative and quantitative reconstruction of the field-layer spider communities was observed. *L. mughi* appears there again and also the three other predominant species with *Pityohyphantes phrygianus* (C. L. Koch), which accounted for about 22% of the total spiders in this habitat (see Table 1). This last species was found also in small numbers in the old spruce forests.

The seasonal dynamics in spider biomass and numbers were studied. The investigations were carried out in the hot and dry vegetative season of 1992 and in the colder and rainy season of 1993.

The distribution pattern of spiders in the season is very characteristic (Fig. 2). In the spring of both years, spiders were most numerous in the young spruce woods. It is interesting to note that in the hot dry summer they concentrated chiefly in old spruce forests, but in the colder rainy summer in young spruce woods. In autumn, there follows a decrease of spider numbers and biomass in damaged open areas and in young spruce woods and their concentration in the old spruce forests. It is interesting that in both seasons (contrasting in weather), numbers and biomass of spiders at the end of the season (beginning of October) are high and similar in old spruce forests (Fig. 2).

Generally, the habitats whose tree layer had been destroyed had the poorest spider faunas throughout the season, whereby their numbers were decreasing in the course of the season (Fig. 2). An analogous seasonal trend was observed in terms of spider biomass (Fig. 2).

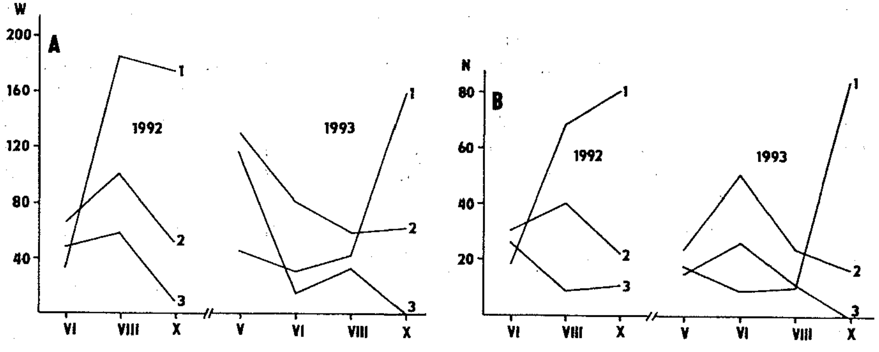

Fig. 2. Seasonal changes of biomass (A) and numbers (B) of field-layer spiders at the Mumlawski Wierch. 1—old spruce forests, 2—young spruce woods, 3—devastated open forest areas. W—biomass (means) in mg w.w. per site; N—numbers (means) per site.

PREDATOR—PREY SYSTEM

Spider predation upon insects is a much studied subject. Previously published investigations show that the most common prey of web-building spiders are the dipterans, in some cases amounting up to 80% of the spiders diet (Dąbrowska-Prot & Łuczak, 1968; Kajak, 1978; Riechert & Łuczak, 1982, and others).

The fundamental question regarding predation is: does the spider—dipteran system have the self-regulatory character? Do predators exhibit functional and numerical responses?

We recall that "the functional response is defined as the change in the rate at which an individual predator captures prey as prey density changes. The numerical response is the change in population density of predators as a function of changing prey density" (Wise, 1993). Some researchers state that the spiders exhibit a functional response to prey density (Haynes & Sisojevic, 1966; Kiritani & Kakiya, 1975; Kajak, 1978; Mansour, Rosen, Shulov & Plant, 1980; Riechert & Harp, 1987); others found evidence for a numerical response to prey density (Turnbull, 1964, 1966; Riechert, 1976, and others). These reactions may suggest the regulatory character of predation, maintaining the abundance of both components of the predator—prey system on relatively stable levels. The importance of these reactions for prey control by predators was widely discussed in the literature following Holling's studies (1959, 1965). Ecologists suggest that only one type of functional response (the sigmoid type) may indicate the regulatory function of predators.

There is a disagreement among ecologists which type of functional response is exhibited by the spiders to their prey. After the analysis of many papers Wise (1993) arrived at the conclusion that functional responses in spiders are very weak, and numerical responses, well known in many spider species, influence only the actual size of the prey populations. Nevertheless, Wise and other arachnologists underline the importance of spiders as strong predators in some types of habitats and in the relation to definite types of prey. The sigmoid type of functional response of spiders was demonstrated by Dąbrowska-Prot, Łuczak & Tarwid (1968) in field experiments with some spider species and flies.

An ecological principle in connection with functional response of general predators says that visible effects of these predators on their prey are exhibited in a narrow range of relative numbers of both components of the system. Outside of this range, when the relative numbers of prey are either too large or too small, the effects of the predation on prey populations are weak. The above mentioned experimental field investigations of Dąbrowska-Prot, Łuczak & Tarwid (1968) on the reduction of Diptera populations by spiders demonstrated that there exists an optimal range of numerical relations of prey to predators, at which the dipteran reduction is most intensive (Fig. 3). It is narrower (1–2 individuals per one predator) in the case of wandering spiders such as *Dolomedes fimbriatus* (Clerck) and broader (1–4 individuals/predator) in the case of web-building species such as *Tetragnatha montana* Simon (Fig. 3) (Dąbrowska-Prot, 1968).

In the Karkonosze Region the numerical relations between the spiders and the dipterans (as evidenced in the case of spiders in the previous chapter) depend on the degradation of the habitats which determines the spatial distribution of both components of the

Table 2. Spatial distribution (in %) of prey numbers (Diptera) and their potential predators (Araneae) in the region of devastated mountain spruce forests in Karkonosze (1992, 1993).

	Living old spruce forests (80 years old)	Open areas after devastated spruce forests (without trees)	Young, regenerating spruce woods (about 15 years old)
Diptera	32.5	18.5	**49.0**
Araneae	**52.0**	13.0	35.0
Diptera : Araneae numbers	1.85	4.50	4.0

predator—prey system. Therefore, in order to establish the probability of prey number regulation by predators a very detailed analysis of their distribution pattern is required.

Our investigations have demonstrated that web-building spiders tend to concentrate in old, well preserved spruce forests, and the dipterans chiefly in young, regenerating spruce woods (Fig. 4) (Table 2). Analyses of the seasonal distribution of spider and dipteran numbers and biomass show the high disproportion in abundance of both groups of animals and differences in eveness of spatial distribution (measured by index of variation —standard deviation to mean number) in the Mumlawski Wierch (Fig. 4). This means that we observe here some spatial avoidance of both components of the prey—predator system (Table 2).

These phenomena indicate that the regulation of dipterans by spiders is unlikely in some habitats. This supposition is confirmed also by the fact that the numerical relations of both groups of species (index of prey-predator relations, i.e. relation of prey individuals to predator individuals) are above the optimal range in two important habitats in the investigated region: in the devastated forest area as well as in young, regenerating spruce woods (Fig. 5). Only in the old spruce forests the numerical relations of both components allow the control of prey population by their spider predators (Fig. 5).

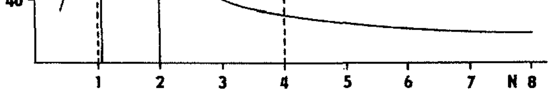

Fig. 3. Dependance of Diptera reduction (in %) on the number of prey per one predator (N) fot two kinds of spider species (Dąbrowska-Prot, Łuczak & Tarwid, 1968; Dąbrowska-Prot, 1968). Most intensive reduction by wandering spider *Dolomedes fimbriatus* (——) and web spider *Tetragnatha montana*(----).

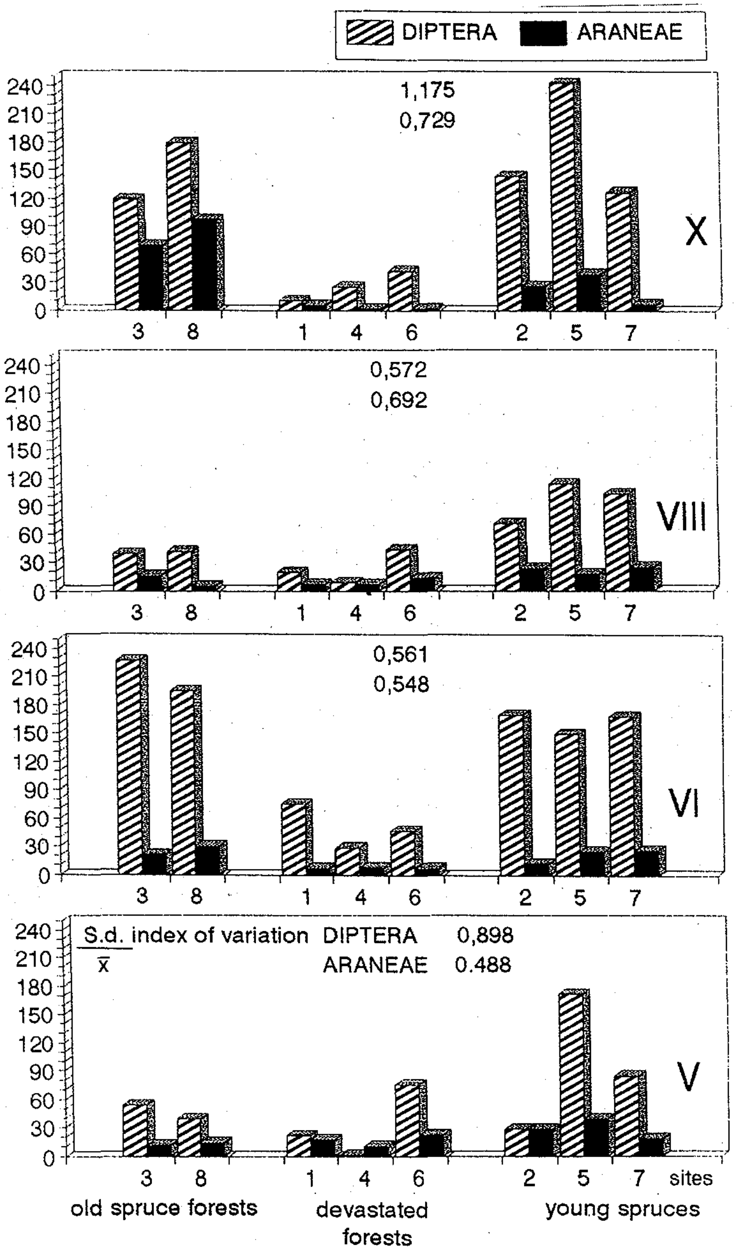

Fig. 4. Differences in seasonal spatial distribution of prey and predator numbers (Diptera—Araneae) in the region of Mumlawski Wierch (1993).

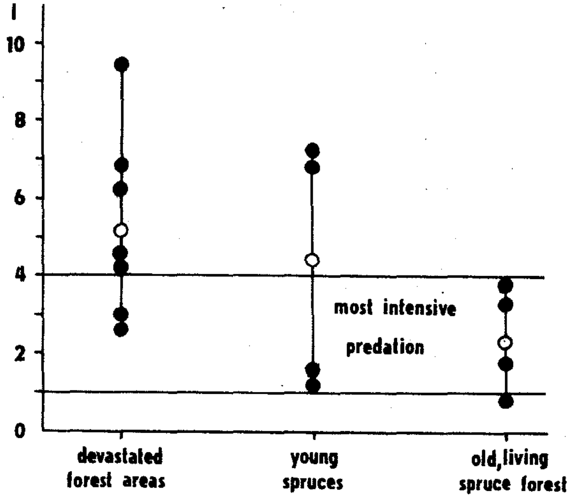

Fig. 5. Changes of prey—predator number relation (●) in devastated forest areas (three sites), young spruces (three sites) and old living spruce forests (two sites) in Karkonosze Mountains in two years (1992, 1993). I mean index of prey—predator relations; ○ means values of indices.

CONCLUSIONS

1. Quantitative and qualitative poverty of spider communities in the spruce forests of the Karkonosze Mountains (region of Mumlawski Wierch) compared to the communi-ties in other types of forests and regions was observed.
2. It was stated that qualitative changes of spider communities depend on the type of spruce forest habitat as well as the variation of their seasonal dynamics under the influence of the destruction of spruce trees.
3. In different stages of the season, either old, healthy spruce forests or young spruce woods are the most important habitats for the maintainance of rich, differentiated spider communities.
4. In open habitats after the disappearance of spruces, the abundance of spider communities always decreases strongly in the course of the season (from spring to autumn).
5. Only in old spruce forests, the numerical relations of dipterans and spiders are optimal from the point of view of prey control by predators. In the new habitats (damaged and regenerating forests), the numerical relations make effective control unlikely.

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