

## Ecotonal systems on the border of the Kampinos Forest and their importance to spiders

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### ABSTRACT

Two ecotonal systems were examined: mixed forest 1 (ecotone 1) meadow and mixed forest 2 (ecotone 2) woodlot. The abundance of herb-layer spiders, their biomass, number of species, and number and abundance of species common to the whole systems and to six habitats were analysed. The ecotone was characterized as transition zone (spiders could pass from mixed forest to meadow or woodlot) opposed to a barrier zone found in the forest-island ecotone in the Masurian Lakeland (spider could not pass from forest to field).

### INTRODUCTION

Various ecotones differ in their function. Earlier studies conducted in the forest-island ecotones (Łuczak 1995) suggest that they can act as a barrier preventing dispersion of spiders to the adjoining crop fields.

Studies on spiders of forest-islands ecotones in the Masurian Lakeland were performed in 1988, 1989 and 1991. Forest islands were of two types: 1) remainders of an old mixed forest (*Pino-Quercetum* Kozł. 1925 em. Mat. et Polak. 1955) and birch-aspen woodlots being in the early stages of the succession to a mixed forest. They all were surrounded by arable fields. The number of species was highest in the forest ecotone and lowest in the crop fields. The abundance of spiders was highest in the interiors of forest islands and lowest in crop fields. The comparison of species common to each of the two types of forest islands demonstrated some isolation of the ecotone spiders from the interiors in mixed forest islands and a high isolation of ecotone spiders from arable fields. This paper compares preliminary results of the ongoing research in the Kampinos Forest to the results from the Masurian Lakeland.

## MATERIAL AND METHODS

Spiders occurring on plants were examined by using the quantitative sweeping method: 10 x 25 strokes of a sweep-net taken in each habitat, every month from May to October. Each sample (1 x 25 strokes) was preserved in alcohol and then weighed after several minutes of drying for obtaining the wet biomass of spiders.

## RESULTS

### Characteristics of the habitats

Mixed forest 1 represented the stage of succession between a pine monoculture and a mixed forest *Pino-Quercetum*. In the upper layer there was only *Pinus silvestris* but in the undergrowth there were species typical of mixed forests: *Frangula alnus*, *Sorbus aucuparia* and *Quercus robur*. Pine was also in the undergrowth. In the herb layer there were many forest species but with small cover: *Melampyrum pratense*, *Trientalis europea*, *Vaccinium myrtillus*, *V. vitis-idaea* and *Calluna vulgaris*. The stratum of mosses typical of mixed forests, consisted of *Dicranum undulatum* and *Entodon schreberi* was well developed.

The meadow had two parts: one, of the class *Molinio-Arrhenatheretea*, was wetter and floristically very rich with dominance of *Deschampsia caespitosa* and many meadow species such as *Ranunculus acer*, *Potentilla erecta* and *Juncus effusus*. The second, dryer part, was dominated by *Nardus stricta* and *Calluna vulgaris*.

Ecotone 1 between mixed forest 1 and meadow (6 m wide) comprised three distinct parts: 1) Zone with a high proportion of meadow plants, specially *Nardus stricta*, *Hypericum perforatum* and *Potentilla erecta*. 2) Zone typical of ecotones with *Calluna vulgaris* and *Polytrichum commune*. The cover of meadow species was small. 3) Zone with preponderance of forest species: shrubs of *Sorbus aucuparia*, *Frangula alnus*, *Quercus robur*, *Juniperus communis*. In the herb layer there were: *Festuca ovina*, *Melampyrum pratense* and the moss *Entodon schreberi*, but less of *Calluna vulgaris* and *Polytrichum commune*. There were no meadow species.

Mixed forest 2 also represented the stage of succession between a pine monoculture and a mixed forest. The stratum of undergrowth was weaker developed and made up only of *Juniperus communis* and *Frangula alnus*. *Quercus robur*, *Sorbus aucuparia* and pine were present only in the herb layer which was poorer than in the mixed forest 1. There were no *Melampyrum pratense*, *Trientalis europea* and *Vaccinium vitis-idaea*. Only *Entodon schreberi* was in the moss layer.

The birch woodlot was a 14-year old forest growing spontaneously. In the lower tree layer there were *Betula verrucosa* and pine. The herb layer was poor, generally consisting of grasses and sedges.

Ecotone 2 (5 m wide) had two zones: 1) A zone typical for ecotones, with high proportion of *Calluna vulgaris*, *Calamagrostis epigeios*, *Athyrium filix-femina*, *Dryopteris filix-mas* and *Rubus caesius*. 2) A zone with forest species such as *Festuca ovina*, *Polygonatum odoratum*, moss *Entodon schreberi* and shrubs of *Sorbus aucuparia*, *Frangula alnus* and *Juniperus communis*.

**Number of species**

A total number of 100 species were recorded, including 85 in system 1 and 72 in system 2. In both years, the number of species in individual sites was lower in system 2. In system 1 there was almost the same number of species in the two years. In system 2 there were some differences between years (Tab. 1).

Tab. 1. Number of spider species and their percentage in the habitats of two ecotonal systems in 1994 and 1995.

		1994			1995		
		N. of species	Percent of species	All species	N. of species	Percent of species	All species
s y s t e m 1	Mixed forest 1	48	34	74	47	33	63
	Ecotone 1	49	35		49	35	
	Meadow	45	31		45	32	
s y s t e m 2	Mixed forest 2	30	30	55	38	33	55
	Ecotone 2	35	35		42	37	
	Woodlot	35	35		35	30	

All species caught: 100  
 System 1 in two years: 85 species  
 System 2 in two years: 72 species

If the sum of species in the three habitats of each system is taken as 100 %, then the percentage number of species was similar in all the habitats; for both systems, it was 30-35 % in 1994 and 30-37 % in 1995 (Tab. 1). This means that the number of species was high also in the ecotone.

#### **Numbers and biomasses of spiders**

A total of 12,827 spiders were captured, including 3,213 and 4,918 in system 1, 1,723 and 2,973 in system 2.

In both years, the number of individuals and biomass of spiders were considerably higher in system 1, with the meadow than in the system 2, with the woodlot. In 1995 the abundance of spiders was considerably higher than in 1994.

In system 1, the number of spiders was highest in the ecotone, showing so called edge effect, and large differences among habitats were observed. In system 2, number of spiders were similar in different habitats.

The number of individuals and biomass of spiders were increasing during the season, reaching the highest values in August and/or in September, declining in October. Spiders living in the ecotone followed a similar pattern as those living in the mixed forest, meadow and woodlot.

The biomass of spiders in system 1 was highest in the meadow because of the presence of large species of spiders. The other habitats were predominated by juveniles.

If we consider the sum of the number of individuals and the biomass in the two systems and two years, the following pattern can be noted (Tab. 2a, 2b):

- the abundance of spiders in systems 1 and 2 in 1994 was highest in the ecotone, accounting for 41 % and 39 % of the total spider abundance respectively,

- the biomass of spiders in system 1 was highest in the meadow and it accounted for 52 % of the total biomass, whereas in system 2 it was highest in the ecotone, accounting for 45 % of the total.

Tab. 2a. Number of individuals and percentage in two ecotonal systems in both years combined.

	<b>N. of individuals</b>	<b>%</b>
Mixed forest 1	2,556	31
Ecotone 1	3,336	41
Meadow	2,239	28
Mixed forest 2	1,230	26
Ecotone 2	1,821	39
Woodlot	1,645	35

Tab. 2b. Biomass of spiders and percentage in two ecotonal systems in both years combined.

	Biomass mg w. w.	%
Mixed forest 1	5,102	19
Ecotone 1	7,475	29
Meadow	13,601	52

  

Mixed forest 2	1,989	21
Ecotone 2	4,391	45
Woodlot	3,325	34

#### Species common to the systems and habitats

There were 13 species common to the two systems in both the study years (Tab. 3). They accounted for 80 % and 77 % of system 1 and 85 % and 77 % of system 2 in 1994 and 1995, respectively. Almost all of them were eurytopic species, showing preference for insolated sites, in forests.

Tab. 3. List of the common species to all systems and their abundance in each ecotonal system in two years

Species	System 1	System 1	System 2	System 2
	1994	1995	1994	1995
<i>Mangora acalypha</i>	1,766	2,472	994	1,564
<i>Agalenatea redii</i>	253	79	4	5
<i>Araneus diadematus</i>	9	11	5	13
<i>Tetragnatha pinicola</i>	79	154	78	184
<i>Meta segmentata</i>	18	32	87	115
' <i>Araneus</i> ' sp.	119	575	8	47
<i>Enoplognatha ovata</i>	6	22	14	37
<i>Theridion bimaculatum</i>	28	47	20	39
<i>Linyphia triangularis</i>	69	79	168	167
<i>Microlinyphia pusilla</i>	31	44	12	27
<i>Dictyna</i> sp.	98	136	7	7
<i>Philodromus</i> sp. ( <i>aureolus</i> ?)	45	53	43	48
<i>Evarcha falcata</i>	49	93	31	42
	2,570	3,797	1,471	2,295
%	80	77	85	77

All spiders caught in two years - 12,827

*Mangora acalypha*: 53 % of all spiders in two years

Species common to 4 systems - 79 %

Also the species common to the three habitats of each ecotonal system were analyzed (Tab. 4). In system 1 in 1994 there were 23 such species and they accounted for 87.6 % of the total spider community, in 1995 the number of such species was 28, or 87.8 % of the total numbers of individuals in the community. In system 2, there were 14 common species (91 %) in 1994 and 20 (88 %) in 1995.

Tab. 4. Spider species common to two ecotonal systems in 1994 and 1995, their relative abundance and percentage of the total number of spiders in two ecotonal systems.

	Ecotonal systems			
	System 1 1994	System 1 1995	System 2 1994	System 2 1995
Number of spider species common to the system	23	28	14	20
Abundance of common spider species	2,816	4,336	1,568	2,618
Percent of numbers of common species in total spider numbers of the systems	87.6	87.8	91.0	88.0

Number of individuals and proportions of the common spiders were calculated for each of the habitats in two years (Tab. 5). It has been shown that the abundance of the common species was highest in the ecotone.

A group of species showing preference for the ecotone, that is, living there in higher densities in the ecotone than in the adjoining habitats, was selected from the species common to each habitat of two years (Tab. 6).

There were 8 such species in system 1 in 1994: *Mangora acalypha* (Walck.), *Dictyna* sp. (most likely mainly *arundinacea* (L.)), *Araneus* sp. (young, small spiders of the former genus *Araneus*), *Theridion bimaculatum* (L.), *Microlinyphia pusilla* (Sund.), *Misumena vatia* (Clerck), *Pisaura mirabilis* (Clerck) and *Theridion sisyphium* (Clerck) or *impressum* L. Koch (juveniles) (Tab. 6).

Tab. 5. Seasonal relative abundance of the spiders common to different habitats of two ecotonal systems in two years.

Systems	Years	Mixed forest	Ecotone	Meadow or woodlot	Total
System 1	1994	1,030	<b>1,136</b>	650	2,816
System 1	1995	1,314	<b>1,870</b>	1,152	4,336
System 2	1994	397	<b>599</b>	572	1,568
System 2	1995	672	<b>1,036</b>	910	2,618
Total		3,413	<b>4,641</b>	3,284	11,338

Tab. 6. The abundance of species common to three habitats of system 1 in 1994 (species names after Roberts 1985, 1987).

Species 23	Mixed forest	Ecotone	Meadow
<i>Tetragnatha pinicola</i>	<u>44</u>	33	2
<i>Evarcha falcata</i>	<u>26</u>	13	12
<i>Xysticus</i> sp. (non <i>cristatus</i> )	18	10	16
<i>Araniella cucurbitina</i>	12	4	7
<i>Linyphia triangularis</i>	<u>45</u>	21	3
<i>Theridion bimaculatum</i>	5	<u>20</u>	4
<i>Philodromus</i> sp. ( <i>aureolus</i> ?)	15	19	9
' <i>Araneus</i> ' sp.	23	<u>65</u>	24
<i>Mangora acalypha</i>	<u>772</u>	<u>764</u>	230
<i>Enoplognatha ovata</i>	3	2	2
<i>Misumena vatia</i>	6	<u>16</u>	3
<i>Clubiona</i> sp.	2	3	1
<i>Dictyna</i> sp. ( <i>arundinacea</i> ?)	20	<u>83</u>	48
<i>Agalenatea redii</i>	12	24	<u>192</u>
<i>Tibellus oblongus</i>	1	11	12
<i>Meta segmentata</i>	<u>11</u>	1	2
<i>Hypsosinga pygmaea</i>	1	4	<u>62</u>
<i>Cercidia prominens</i>	2	1	1
<i>Microlinyphia pusilla</i>	1	<u>18</u>	12
<i>Pisaura mirabilis</i>	2	<u>9</u>	1
<i>Theridion sis.-impressum</i>	1	<u>11</u>	5
<i>Xysticus cristatus</i>	3	3	1
<i>Meioneta rurestris</i>	5	1	1
	1,030	1,136	650 = 2816
%	36.5	40.4	23.1

Species preferring ecotone (8 species, 992 inds.), forest (5,898), meadow (2,254)

In system 1 in 1995, there were 10 such species. The same four species were most abundant in the ecotone in both years.

In system 2 in 1994, 4 species showed preferences for the ecotone: *Mangora acalypha* (Walck.), *Tetragnatha pinicola* L. Koch, *Evarcha falcata* (Clerck) and *Cyclosa conica* (Pallas).

In system 2 in 1995, there were 8 such species. The same three species were most abundant in the ecotone in both years.

Ecotones are colonized by many species common to the ecotone and adjoining habitats and by species showing preferences for this habitat type. It means that the ecotones are 'normal' habitats for spiders. Spiders immigrate there from the adjoining habitats, and remain, grow and develop.

#### The dominance structure

The dominance structure of the spider community in both systems and years was highly predominated by *Mangora acalypha*, which accounted for 68 % and 69 % in system 1 and for 58 % and 53 % in system 2.

In 1994, the dominance was more differentiated and the number of dominant species was higher. In 1995, when numbers of spiders markedly increased, only *Mangora acalypha* was the dominant species although in the meadow its dominance was reduced to 30 %, so that it co-dominated with *Agalenatea redii* (Scop.), which accounted for 27 % of the community (Tab. 7).

Tab. 7. Dominance structure of the spiders in 6 habitats of ecotonal systems in 1994 and 1995

1994	forest 1	<i>Mangora acalypha</i>	- 68 %
	ecotone 1	<i>Mangora acalypha</i>	- 62 %
	meadow	<i>Mangora acalypha</i>	- 27 %
		<i>Agalenatea redii</i>	- 26 %
	forest 2	<i>Mangora acalypha</i>	- 65 %
		<i>Zilla diodia</i>	- 9 %
	ecotone 2	<i>Mangora acalypha</i>	- 58 %
		<i>Linyphia triangularis</i>	- 10 %
	woodlot	<i>Mangora acalypha</i>	- 52 %
		<i>Linyphia triangularis</i>	- 14 %
1995	forest 1	<i>Mangora acalypha</i>	- 69 %
	ecotone 1	<i>Mangora acalypha</i>	- 51 %
	meadow	<i>Mangora acalypha</i>	- 30 %
		<i>Agalenatea redii</i>	- 27 %
	forest 2	<i>Mangora acalypha</i>	- 53 %
	ecotone 2	<i>Mangora acalypha</i>	- 47 %
	woodlot	<i>Mangora acalypha</i>	- 57 %

## DISCUSSION

In earlier papers (Łuczak 1990, 1995) I analyzed spiders of ecotonal system between forest islands and arable fields in the Masurian Lakeland. The conclusions were similar concerning the ecotone as a distinct habitat where many invertebrate species live, feed, and multiply during their whole life after migration.

The main difference is in the role of forest ecotone for spiders. In the Masurian Lakeland it is rather a barrier for spiders, preventing many forest species from spreading to adjoining field ecosystems. While in the Kampinos Forest, ecotones between mixed forest and meadow or birch woodlot are rather a transition zone for many spider species. In the first case there is no edge effect, in the second one the edge effect is seen in spider numbers.

Ecotonal phenomena were also analyzed by Dąbrowska-Prot and Łuczak (1968) and Dąbrowska-Prot *et al.* (1973).

## GENERAL CONCLUSIONS

The ecotone has a similar number of species like the two adjoining habitats. Specific characteristics of the ecotone are reflected not only in the mixture of species from two adjoining habitats but also in the preferences of some species for the ecotone, where their populations are more dense than in their typical habitats. Such species may change from year to year depending on weather and other abiotic and biotic factors as they do in their proper habitats.

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