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PLANT-DWELLING SPIDERS OF THE ECOTONE BETWEEN FOREST ISLANDS AND SURROUNDING CROP FIELDS IN AGRICULTURAL LANDSCAPE OF THE MASURIAN LAKELAND

ABSTRACT: In the years 1988, 1989 and 1991 study was made of the ecotones of forest islands situated in agricultural landscape of the Masurian Lakeland. Spider communities were analyzed from the angle of the number of species, as well as of the numbers and biomass of plant-dwelling spiders. Common species and those exclusive for different zones of the ecotone transect: forest island interior-forest ecotone-crop field, were identified. Dominant species were identified as well. Discussion was made of the importance of the ecotone and its role as a barrier for forest spider species, which prevents the major part of these species from spreading over the crop fields.

KEY WORDS: ecotone, forest island, agricultural landscape, plant-dwelling spiders.

1. INTRODUCTION

The present studies of forest island ecotones in the Masurian Lakeland were performed in the years 1988, 1989 and 1991 in a hilly agricultural landscape characterized by the occurrence, among crop fields, of many remainders of old Pino-Quercetum mixed forests, as well as of birch-aspen woodlots being young stages in the succession to mixed forest.

The objective of these studies was to examine whether and how the spider communities of the forest ecotone differ from those present in both ecotone – forming ecosystems: interiors of forest and crop field, i.e. ecosystems of a completely differ-

ent nature. It was intended to elucidate whether there are differences in the number of species, numbers and biomass of spiders, and dominant species. Studies were aimed also at revealing whether species associated exclusively with the ecotone occurred in this system.

Our earlier studies have shown that the origin of forest islands (either remainders of mixed forest or birch-aspen woodlots growing spontaneously on barrens) situated among crop fields exerts an effect on the numbers and biomass of spiders, no. of exclusive species, no. of common species, composition of the group of dominant species and age structure; the size of forest island was found not to influence these parameters. Species composition of the spider communities inhabiting both types of forest islands was similar, and common species accounted for ca. 75% of the total spider material (Łuczak 1990a, 1991). In a preliminary communication (Łuczak 1990b) dealing with studies of forest island ecotones, it has been reported that the ecotones represent a habitat for many spider species, but at the same time they are a barrier zone preventing many species from spreading over the adjacent crop fields. It has been found that in dependence on the kind of the ecotone-forming ecosystems, the margin effect on spider numbers in the ecotone may be positive or negative.

Whereas many plant-dwelling spider species have been observed to occur in both – forest island interior and ecotone, it was possible to single out on the basis of the population density data the species preferring the interior or the ecotone (Łuczak 1990b).

2. TERRAIN, METHODS AND SPIDER MATERIAL

Out of the earlier studied 8 forest islands (Łuczak 1991), 6 forest islands were selected for the present studies (Fig. 1): 13-ha Pino-Quercetum forest island (no. 2), 1-ha Pino-Quercetum forest island (no. 4), and four birch-aspen woodlots (1.5 ha, 0.5 ha, ca. 1 ha and 0.125 ha, numbered 5, 6, 7, 8, respectively) situated among crop fields and distributed within a small (2 km²) area. Only the forest island no. 4 was located at a ca. 4-km distance from all other sampling sites. The lengths of the forest island ecotones were (Dąbrowska-Prot 1991): forest island no. 2 – 1500 m, no. 4 – 430 m, no. 5 – 480 m, no. 6 – 320 m, no. 7 – 280 m, no. 8 – 150 m. Ecotones were examined along a length of ca. 1/3 of the above values. The birch-aspen woodlots were either "dry" (nos 7 and 8) or "wet" (nos 5 and 6), i.e. without or with a small pool at the centre (Fig. 1).

The ecotone system of the forest island no. 4, isolated among crop fields, was investigated during three vegetation seasons from May until November (in 1988, 1989 and 1991), and the remaining ecotone systems – during one season.

Floristic and phytosociological characterization of the forest islands has been reported by Wójcik (1991).



Fig. 1. Distribution of the investigated forest islands (1–8) in agricultural landscape in the vicinity of the Jorzec Lake

Studies involved only the forest ecotone, but not the field margin zone, because of the spider fauna scarcity in the local fields treated by intensive mineral fertilization and pesticide sprays. The field margin zone failed to appear as a high grass belt standing out sharply (as e.g. in the studies by Kromp and Steinberger 1992), whereas it constituted an integral part of the crop field; namely, there the fields were ploughed to the forest ecotone.

Spiders were collected with a quantitative entomological sweep-net once monthly during the vegetation season in all of the three zones of the ecotone system of each forest island (forest island interior, forest ecotone, field), with application of a "big sample", i.e. 250 sampler strokes ("small sample" = 25 strokes) at each sampling site; this "big sample" corresponds to ca. 60 m² of the herb layer area. In total, every year analysis was made of the material from 6 ecotone systems examined from May until November (7 "big samples") in each habitat (6 ecotone systems x 7 sampling dates x 3 zones = 126 "big samples").

Spider biomass was obtained by weighing each "small sample" (25 strokes) immediately after ethanol evaporation from spider bodies.

3. RESULTS

3.1. SPECIES CHARACTERIZATION

In the years 1988 and 1989 the total number of spider species in the ecotones of the mixed forest and birch-aspen woodlot forest islands, as compared with forest island interiors, was higher by several species (Tables 1 and 2). On the other hand, much fewer species were caught in fields than in forest island interiors and ecotones.

The mean monthly number of species fluctuated in mixed forest interior between 18–22, in birch-aspen forest island interior between 15–19, and in the respective ecotones between 18–23 and 17–20 (Table 3).

Analysis of the total material obtained from all of the investigated ecotone systems, and calculation of the mean number of species per vegetation season gave the following results:

forest island interior – 42 spider species (coefficient of variation 0.120)

forest island ecotone – 50 spider species (coefficient of variation 0.142)

crop field – 24 spider species (coefficient of variation 0.229).

In the agricultural landscape studied, as a rule the number of species inhabiting the field was much smaller than that found for the forest island interior and forest ecotone. It was also a rule that the number of species in the forest margin zone exceeded that in the forest interior (Tables 1a and b, 2).

3.2. NUMBERS OF PLANT-DWELLING SPIDERS AND THEIR SEASONAL DYNAMICS

The total spider material collected in forest island interiors and ecotones, and in the surrounding crop fields consisted of 17476 individuals: 9803 individuals were caught in the forest island interiors, 7078 – in forest ecotones, and 595 – in fields; they accounted for 56, 40 and 4%, respectively, of the total material.

Table 1. Number of spider species, total numbers of individuals, their total biomass and mean individual body weight (mg w.w.) in Pino-Quercetum forest island (mixed forest) and two birch-aspen forest islands: in their interior (Int.), margin parts (Ec.) and adjacent crop fields (Field) (according to Łuczak 1993), for the years 1988 and 1989

	1 ha mixed forest island (no. 4)			0.5 ha birch-aspen forest island (no. 6)			1 ha birch-aspen forest island (no. 7)		
	Int.	Ec.	Field	Int.	Ec.	Field	Int.	Ec.	Field
A – Year 1988									
No. of species	44	56	21	35	38	21	40	48	27
% in transect	37	46	17	37	41	22	35	42	23
Total numbers	1173	1199	46	1522	978	88	1586	1354	109
% in transect	48	50	2	59	38	3	52	44	4
Total biomass	7607	6454	204	11735	8501	358	10936	9248	369
% in transect	53	45	2	57	41	2	53	45	2
Mean individual weight	6.48	5.38	4.43	7.71	8.69	4.07	6.89	6.83	3.38
B – Year 1989									
No. of species	49	58	29	45	49	16	48	52	30
% in transect	36	43	21	41	44	15	37	40	23
Total numbers	1237	735	92	1423	646	87	1057	1180	112
% in transect	60	35	5	66	30	4	45	50	5
Total biomass	9739	6612	297	13686	6516	165	9583	14010	438
% in transect	58	40	2	67	32	1	40	58	2
Mean individual weight	7.87	8.95	3.23	9.62	10.10	1.90	9.07	11.87	3.91

Table 2. Number of spider species, total numbers of individuals and total biomass (mg w.w.) of plant-dwelling spiders in the interior (Int.) and ecotone (Ec.) of the investigated forest islands Means per month in the season (period of studies from May until November)

		Pino-Quercetum				Birch-aspen			
		Forest islands							
		4	4	4	2	5	6	7	8
		Years							
		1988	1989	1991	1991	1989	1988	1988	1989
No. of species									
Mean per month	Int.	18	19	22	18	17	15	15	19
	Ec.	23	21	20.3	18	17	19	19	20
Total	Int.	44	49	51	53	45	35	40	48
	Ec.	56	58	54	50	49	38	48	52
Numbers									
Mean per month	Int.	168	177	105	153	203	207	226	151
	Ec.	171	106	72	68	92	140	193	168
Total	Int.	1173	1237	735	1070	1429	1522	1586	1057
	Ec.	1199	740	505	477	646	978	1354	1180
Biomass									
Mean per month	Int.	1087	1391	539	1101	1955	1676	1562	1369
	Ec.	922	944	404	520	930	1214	1321	2001
Total	Int.	7607	9739	3775	7708	13686	11735	10936	9583
	Ec.	6454	6612	2826	3644	6516	8501	9248	14010

Table 3a. Species common to pairs of habitats: common species number and its percentage in the total number of all species in ecotone systems of these forest islands (in the whole season)

	1-ha birch-aspen forest island				1-ha mixed forest island			
	Total ecotone system	Island interior and ecotone	Island interior and field	Ecotone and field	Total ecotone system	Island interior and ecotone	Island interior and field	Ecotone and field
Number of common species	17	31	20	24	17	36	21	20
Percentage of the number of common species in the total number of all species	29	53	34	41	24	51	30	29

Table 3 b. Species common to pairs of habitats: common species numbers and their percentage in the total numbers of all species in ecotone systems of these forest islands (in the whole season)

	1-ha birch-aspen forest island				1-ha mixed forest island			
	Total ecotone system	Island interior and ecotone	Island interior and field	Ecotone and field	Total ecotone system	Island interior and ecotone	Island interior and field	Ecotone and field
Numbers of common species	1793	2852	900	935	1615	1760	1153	623
Percentage of the numbers of common species in total numbers in different ecotone system transect zones (%)	forest interior	54	90		59	64	93	
	ecotone	47			36	36		87
	field	48	46	89	5		7	13
Percentage of the numbers of common species in total numbers of spiders in the total ecotone system	5		10	11	5		7	13
	59	93	29	30	78	85	56	30

The birch-aspen forest islands, as compared with the mixed forest islands, were characterized by higher numbers of spiders; for the forest ecotone and forest interior the numbers were greater by 50 and 33%, respectively.

In all years of studies, on the whole in all forest islands spiders were more abundant in island interior than in the ecotone (Tables 1a and b, 2). However, the difference in spider numbers between the interior and ecotone of forest islands failed to be large (Fig. 2). In contrast, in crop fields adjacent to forest islands, as compared with forest ecotone, spider numbers were 7–12 times (in one case 25 times) smaller. Low spider numbers in fields were due to intensive agrotechnical

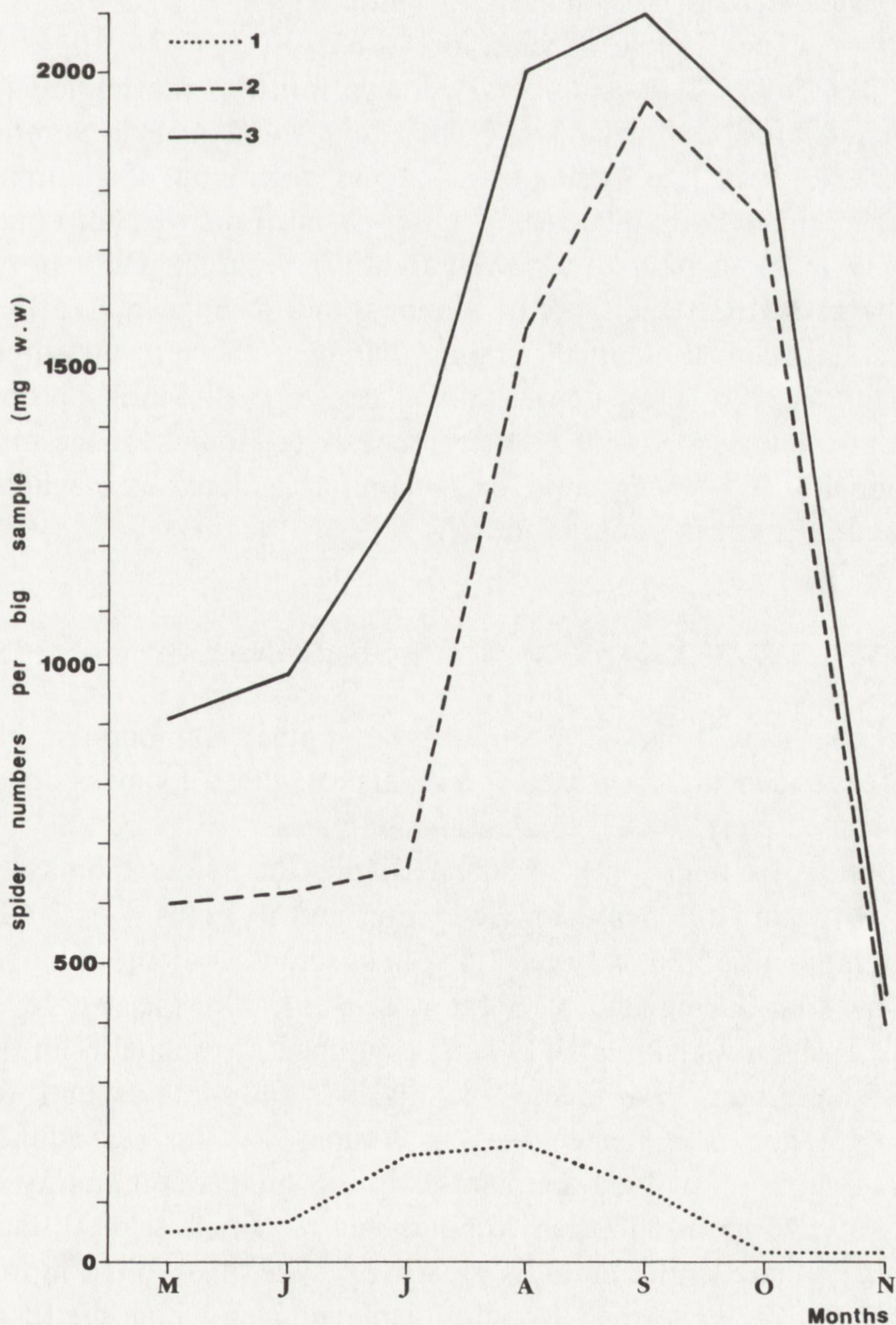


Fig. 2. Seasonal dynamics of spider numbers (seven dates of sampling in the vegetation season) in forest island interior, ecotone and crop field
1 – crop field, 2 – ecotone, 3 – forest island interior

treatments and absence of plants in certain periods of the vegetation season (harvesting of the crop).

Marked differences in spider numbers between "wet" forest islands (birch-aspen woodlots nos 5 and 6, with a small pool in the centre) and "dry" ones (birch-aspen woodlots nos 7 and 8, without water and marshes), in favour of the latter, were found only for the ecotones of these forest islands.

Mean spider numbers per season, calculated for the 6 investigated ecotone systems, were:

forest island interior – 1226 (coefficient of variation 0.229)

forest ecotone – 885 (coefficient of variation 0.383)

crop field – 74 (coefficient of variation 0.462).

Seasonal dynamics of the numbers were as follows: the numbers of plant-dwelling spiders were low in spring (May, June), and rose in summer (July), attaining a maximum in late summer and at the beginning of autumn (August, September), whereupon they decreased (in dependence on weather conditions) in October or only in November to a few individuals (Fig. 2). Only in crop fields the spiders attained earlier the peak of numbers and disappeared earlier. Spiders of the forest island interior attained maximal numbers, those of the forest ecotone – high ones, and those of crop fields – low ones (Fig. 2). Similar proportions of spider numbers in the three ecotone system zones were found for the mixed forest and birch-aspen forest island groups, each being considered as a whole or upon setting apart the individual forest islands.

3.3. SPIDER BIOMASS AND ITS SEASONAL DYNAMICS

Spider biomass (wet weight), similarly as spider numbers in birch-aspen forest islands exceeded that in mixed forest islands; these biomass accounted for 64 and 36%, respectively, of the total spider biomass.

In the interiors of both types of forest islands the spider biomass amounted to 74769 mg w.w., in ecotones – to 57811 mg, and in fields – to 2002 mg (this accounting monthly for 55.5, 43 and 1.5%, respectively, of the total biomass in the ecotone system during the vegetation season). On the whole, with one exception, spider biomass, similarly as spider numbers, was smaller in the ecotone than in forest island interior; in mixed forest islands and birch-aspen forest islands it was lower by 50 and 20%, respectively, as compared with forest island interiors.

The only exception involved the plant-dwelling spiders community in the ecotone of the dry 0.125-ha birch-aspen woodlot (no. 8) (smallest of all the forest islands examined), where spider biomass greatly exceeded that found in forest island interior (Tables 1b, 2). This small woodlot displayed as a whole the features of an ecotone. It was inhabited by larger-size species, and there occurred individuals of a greater body weight, as pointed to by the fact that in this habitat the mean individual body weight was higher than in all other habitats studied (Table 1b).

Spider biomass, similarly as spider numbers, was much lower in the crop field than in the ecotone; they differed by at least one order of magnitude. Spider biomass in fields and ecotone was 165–369 and 6454–14010 mg w.w. per season, respectively (Table 1a, b, Fig. 3).

Mean seasonal biomass of spiders in six ecotone systems running across the forest islands under study amounted to:

forest island interior – 9346 mg w.w. (coefficient of variation 0.323)

forest ecotone – 7226 mg w.w. (coefficient of variation 0.483)

crop field – 305 mg w.w. (coefficient of variation 0.483).

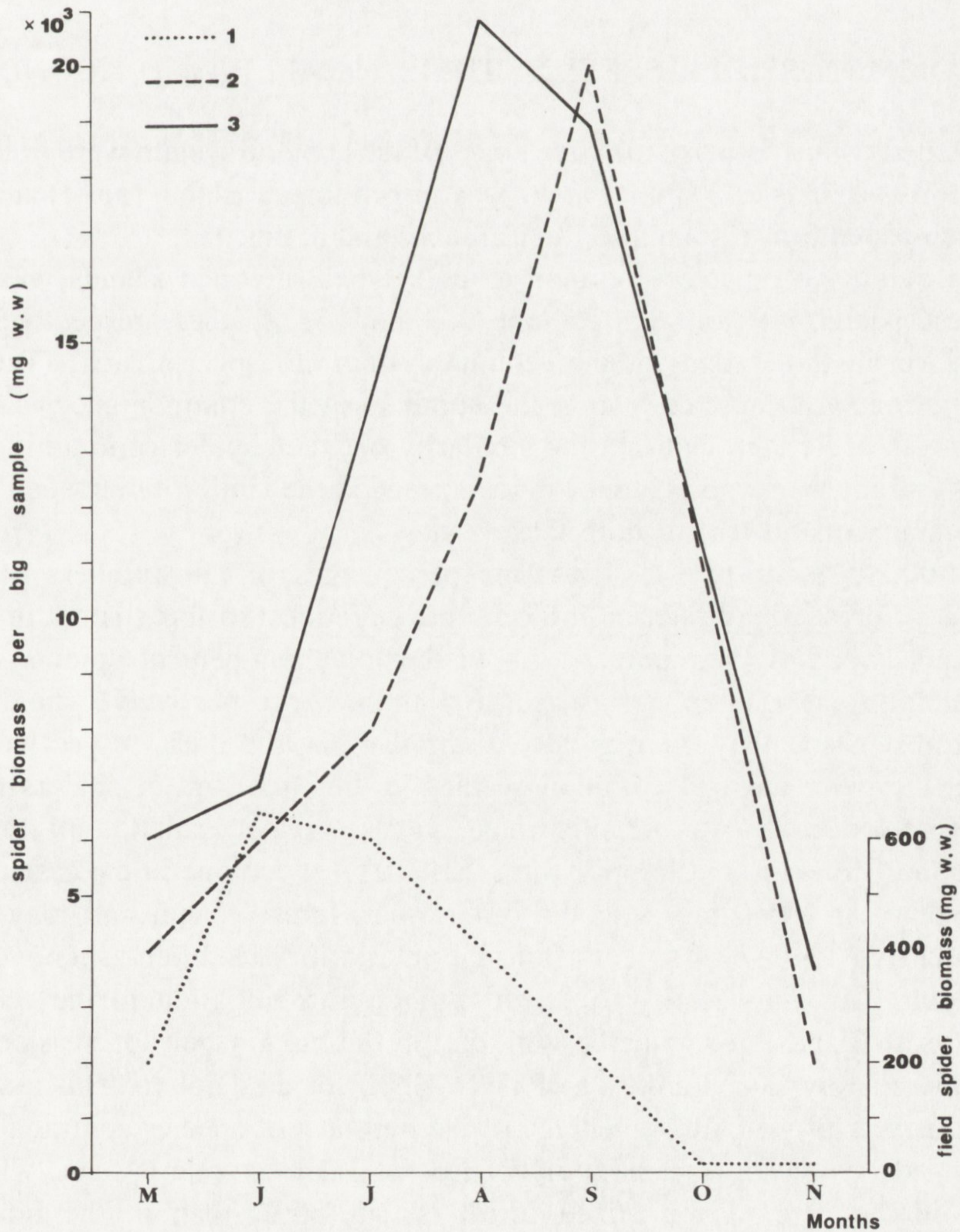


Fig. 3. Dynamics of the herb layer spider biomass (seven dates of sampling in the vegetation season) in forest island interior, ecotone and crop field
 Note – another scale for field spider biomass (mg w.w.)
 1 – crop field, 2 – ecotone, 3 – forest island interior

Seasonal dynamics of spider biomass changed during the vegetation season, exhibiting (similarly as spider numbers) fairly small values in spring, a peak at the end of summer or at the beginning of autumn (August, September) and small values in October or November (Fig. 3). Similarly as in the case of the numbers, spider biomass in the crop field, as compared with the forest island interior and ecotone, decreased earlier in the season.

The highest biomass level was attained by spiders of the forest island interiors, a lower level (though still fairly high) by ecotone spiders, and a very low one by crop field spiders (Note: scale in Fig. 3).

3.4. COMMON SPIDER SPECIES: THEIR NUMBER AND ABUNDANCE

Detailed comparisons of all three zones of the ecotone system were exemplified by two forest islands of a similar area: 1-ha mixed forest island (no. 4) and nearly 1-ha birch-aspen forest island (no. 7) (Table 3 a and b, Fig. 1).

The number of species common to both types of forest islands was highest for forest island interior and ecotone (53 and 51 species, respectively), and smallest for all three zones of the ecotone system (17 species each) (Table 3 a). The same regularity applied also to the numbers of the common species (Table 3 b). This was due to the fact that the similarity between spider communities of the forest island interiors and ecotones much exceeded the similarity between the crop field community and that of both these zones.

In both types of forest islands the percentages of the numbers of spiders common to forest island interior and ecotone, were most differentiated. In the 1-ha birch-aspen woodlot their percentages in the total numbers of spiders in forest island interior and ecotone were similar (54 and 46%, respectively) whereas in the mixed forest island they were greatly dissimilar (64 and 36%, respectively). The fact that the percentage of common species in the numbers of spiders from the mixed forest ecotone was smaller may suggest greater isolation of the spider population of forest island interior from that of forest ecotone in the case of mixed forest island, as compared with the birch-aspen forest island, and may indicate more intensive passage of spiders from the interior of the birch-aspen woodlot to its ecotone. This may testify to greater spider differentiation in the ecotone of mixed forest islands, as compared with that in the birch-aspen forest islands. This was found also by Dąbrowska - Prot (1995) for the Diptera. This assumption was confirmed also by the percentage of the numbers of species common to forest interior and ecotone in spider numbers for the total ecotone system, which was smaller in the case of the mixed forest island (85%) than of the birch-aspen woodlot (93%). On the other hand, the proportion of the numbers of species common to all three zones of the ecotone system in spider numbers in the total ecotone system was higher in the case of the mixed forest island (78%) than of the birch-aspen woodlot (59%) (Table 3 b).

The proportion of species common to other zones of the ecotone system (forest island interior and field, ecotone and field) was very similar in both types of forest islands. Numbers of common species in fields were low, and their proportions in all three zones of the ecotone system were always low.

3.5. SPECIES OCCURRING EXCLUSIVELY IN DEFINITE ZONES OF THE ECOTONE SYSTEM

3.5.1. Species exclusive for the interiors and ecotones of mixed forest islands and birch-aspen islands

Exclusive species are defined as species which in a given year occur exclusively in the interior or ecotone of a definite habitat. With few exceptions nearly always their numbers are very low. Nevertheless, they are very important as one of the constant elements of all spider communities, amplifying the biodiversity of the community.

In the interiors of the mixed forest islands in four investigated spider communities a total of 26 exclusive species occurred in the vegetation season. They accounted for 2–4% of the numbers of all spider species. *Helophora insignis* (Blackw.), never found in the ecotones, was the only species which could be defined most certainly as being exclusive for the interior. *Linyphia emphana* (Walck.) and *Linyphia peltata* (Wider) could be regarded as species preferring the interior of the Pino-Quercetum forest islands. On the other hand, it was difficult to evaluate from this standpoint the other 24 identified species, because of the very small number of individuals (on the whole, 1–3 individuals).

In the ecotones of the mixed forest islands 44 species occurred exclusively; they accounted for 3–11% of the spider community: *Microlinyphia pusilla* (Sund.), *Zygiella atrica* C. L. Koch, *Araneus marmoreus* Clerck, *Araeoncus humilis* (Blackw.), *Clubiona terrestris* Westr., *Singa hamata* (Olivier), *Pachygnatha degeeri* Sund. and *Tibellus* sp. (most certainly *Tibellus oblongus* (Walck.) could be considered to prefer the ecotone (under the conditions of the present studies). The other 36 identified species could not be assessed on account of a minimal number of individuals.

It is noteworthy that nearly two times more species exclusive for a given year and habitat were caught in the ecotones, as compared with forest interiors.

In the interiors of the birch-aspen woodlots there occurred 28 species exclusive for a given year and habitat. They included also in this case *Helophora insignis* (exclusive species of the interior of both forest island types), and the species *Cyclosa conica* (Pallas), *Linyphia emphana* and *Linyphia peltata*, preferring the forest island interiors. In total, they accounted for 2–9% of the numbers of spider community.

In the ecotones of the birch-aspen woodlots 45 species exclusive for a given year and habitat occurred; they accounted for 3–7% of the spider community. The

following species could be listed as preferring the ecotone: *Microlinyphia pusilla*, *Zygiella* sp., *Tibellus* sp. (similarly as in the case of the mixed forest islands) and *Linyphia clathrata* (Sund.) (perhaps because in the interior it was less accessible to catches, since it was located low in the herb layer), *Neottiura bimaculata* L.), *Pachgnatha clercki* Sund. and *Misumena vatia* (Clerck) (rather a meadow spider).

It is stressed that in the birch-aspen woodlots, similarly as in mixed forest islands, many more exclusive species were found in the ecotones than in the forest interiors.

As an example Table 4 presents the number of the exclusive species and their percentages in the total numbers of spiders in the 3 zones of both ecotone systems: that with 1-ha mixed forest island (no. 4) and that with nearly 1-ha birch-aspen woodlot (no. 7), for one year. On the whole, these numbers and proportions were similar for both forest island types; there stood out only the greater proportion of exclusive species in the mixed forest ecotone than in the birch-aspen island ecotone (29 and 17%, respectively) (Table 4). This testified to greater species richness of the mixed forest island.

Table 4. Exclusive species: their number, percentage of their number in the total number of species, and percentage of their numbers in total spider numbers in different ecotone system zones (1988)

Forest islands		Number of exclusive species	Percentage of the number of exclusive species in total number of species	Percentage of the numbers of exclusive species in total spider numbers
Ca. 1-ha birch-aspen forest island (no. 7)	Number of exclusive species of the total ecotone system	20	34	4
	Forest island interior	8	20	3
	Forest island ecotone	8	17	5
	Crop field	4	14	4
1-ha Pino-Quercetum forest island (no. 4)	Number of exclusive species of the total ecotone system	28	40	3
	Forest island interior	7	16	2
	Forest island ecotone	17	29	4
	Crop field	7	13	5

The proportions of the exclusive species in total spider numbers was in both above mentioned forest islands very low (2–5%). In the other forest islands this proportion was similar though for some of them it was slightly higher, but it never exceeded 10%.

3.6. DOMINANT SPECIES

In four investigated plant-dwelling spider communities from the mixed forest islands and in four communities inhabiting the birch-aspen woodlots, in total 12 species were dominant, including 8 species dominant both in the interiors and ecotones of forest islands. Species accounting for 10% (or more) of the sum of all spiders of a given habitat were regarded as dominant. The following dominant species were common for forest island interior and ecotone: *Meta segmentata* (Clerck), *Linyphia triangularis* (Clerck), *Gongylidium rufipes* (Sund.), *Enoplognatha ovata* (Cl.), *Tetragnatha montana* Simon, *Tetragnatha extensa* (L.) (though as a rule it was dominant in the ecotones) and *Neriene montana* (Clerck). Apart from the above species, *Helophora insignis* (Blackw.) was dominant and even occurred exclusively in the forest island interiors (see Part 5), *Mangora acalypha* (Walck.) was present only in the ecotone of the mixed forest island isolated from the other islands and in one year; *Neottiura bimaculata* (L.) was dominant only in the ecotone of the smallest birch-aspen woodlot, and *Hylyphantes graminicola* (Sund.) was dominant only in the forest island no. 4. isolated among crop fields in 1988.

These results indicate that the groups of species dominant in forest island interiors and ecotones were very similar, though there were some differences; for example, some species occurred as dominants only in forest island interior or only in the ecotone.

It is stressed that the numbers of the group of dominant species accounted for a high percentage of the numbers of the total spider community (Table 5); this percentage was, however, smaller for the spider communities of the ecotones, as compared with forest island interiors (Table 5).

It is also noteworthy that the groups of dominant species in spider communities inhabiting the mixed forest islands, as compared with the birch-aspen islands, accounted for a lower percentage of the total numbers of spiders.

Analysis of the occurrence of individual dominant species pointed to differences in the distribution of their numbers between the interior and ecotone of a given forest island in different periods of the vegetation season. Mostly (in 5 out of 7 cases) the proportion of the numbers of the dominant species group was lower in the ecotone (as exemplified in Fig. 4).

Dynamics of the numbers of dominant species were characterized by a dissimilar course of the seasonal changes in forest interior and ecotone (Figs 5 and 6).

In crop fields *Tetragnatha extensa* (young individuals) was the only dominant species with numbers of 15–52 individuals per season. Other species accounting for 10% (or more) of the total spider community occurred in numbers of 5–10 individuals per season. The latter number concerned young individuals of the *Tetragnatha montana* species.

Table 5. The number of dominant species and the percentage of their numbers in total spider numbers in forest island interiors, ecotones and adjacent crop fields

Vegetation type of forest island	Description of forest island	No. of forest island and year of studies	Number of dominant species and percentage of their numbers in total spider numbers			
			Forest island interior	Ecotone	Mean ecotone width (m)	Crop field
Pino-Quercetum forest islands	1-ha Pino-Quercetum forest island isolated from the other-ones, surrounded by crop fields	No. 4 – 1988	4 (70%)	4 (47%)	1.5–2	3 (37%)
		No. 4 – 1989	5 (68%)	3 (39%)	1.5–2	2 (39%)
		No. 4 1991	3 (43%)	3 (26%)	1.5–2	No dominants
	13-ha Pino-Quercetum forest island situated near other islands	No. 2 – 1991	5 (79%)	3 (32%)	6	1 (34%)
Birch-aspen forest islands	1.5-ha forest island situated near other islands, with a water pool	No. 5 – 1989	5 (80%)	1 (44%)	3.5	1 (60%)
	0.5-ha forest island located near other islands, with a water pool	No. 6 – 1988	5 (68%)	3 (64%)	2	3 (48%)
	ca. 1-ha forest island situated near other islands, "dry"	No. 7 – 1988	5 (76%)	4 (54%)	2	2 (38%)
	Smallest 0.125-ha forest island located near other islands, "dry"	No. 8 – 1989	5 (70%)	3 (44%)	2	2 (43%)

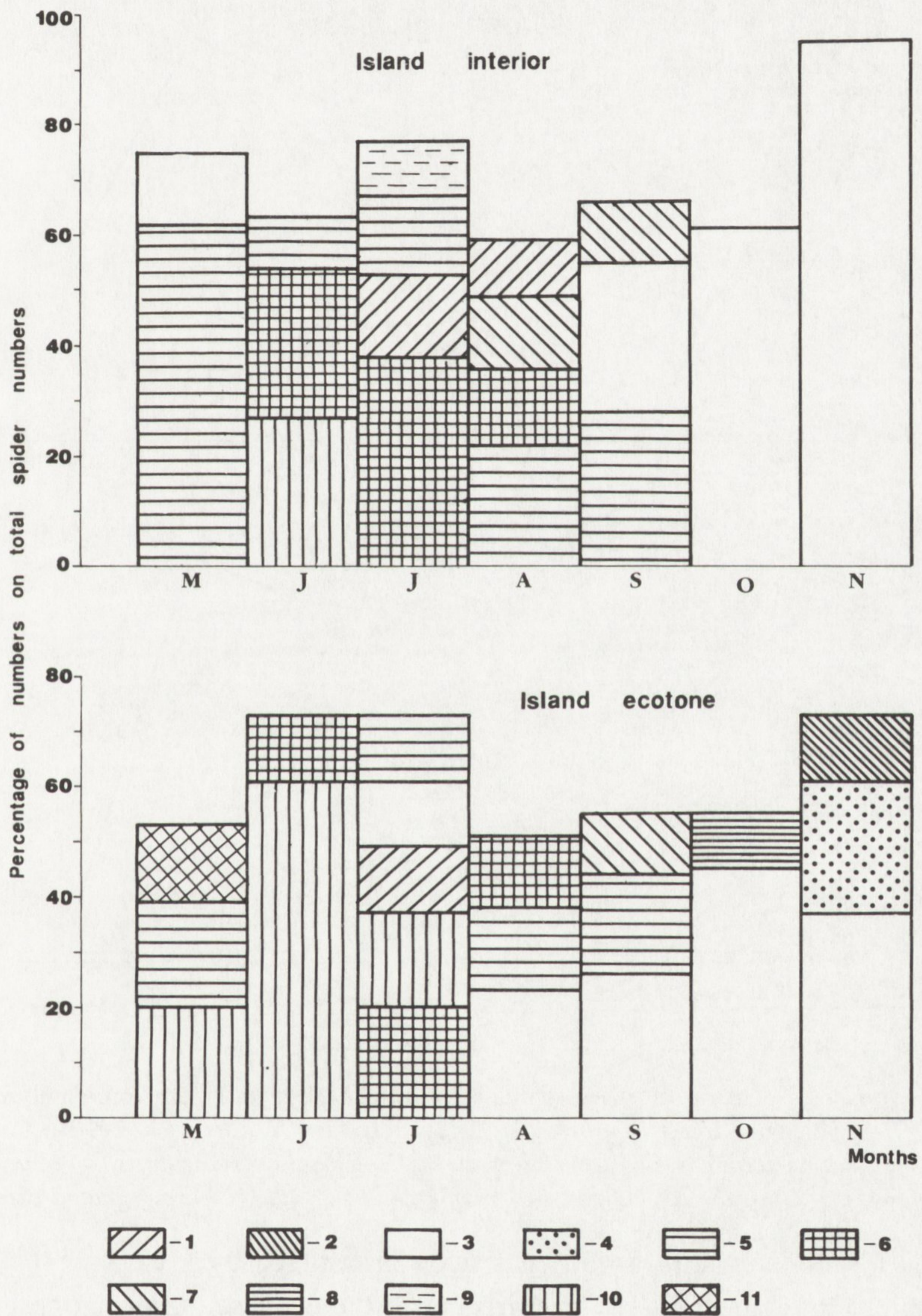


Fig. 4. Dominant species in spider communities (percentage of their numbers in total community numbers) in the interior and ecotone of forest island no. 7, in consecutive months of 1988
 1 - *Meta segmentata*, 2 - *Araneus cucurbitinus*, 3 - *Tetragnatha montana*, 4 - *Tetragnatha extensa*, 5 - *Gongylidium rufipes*, 6 - *Linyphia triangularis*, 7 - *Linyphia montana*, 8 - *Hylyphantes graminicola*, 9 - *Bolyphantes alticeps*, 10 - *Enoplognatha ovata*, 11 - *Theridion saxatile*

3.7. FOREST ISLAND INTERIOR SPECIES AND ECOTONE SPECIES

Spider species were divided into three groups: 1) preferring the forest island interior, 2) preferring the forest ecotone (see Fig. 7, and 3) neutral, i.e. at times occurring more abundantly in the forest island interior and at times - in the

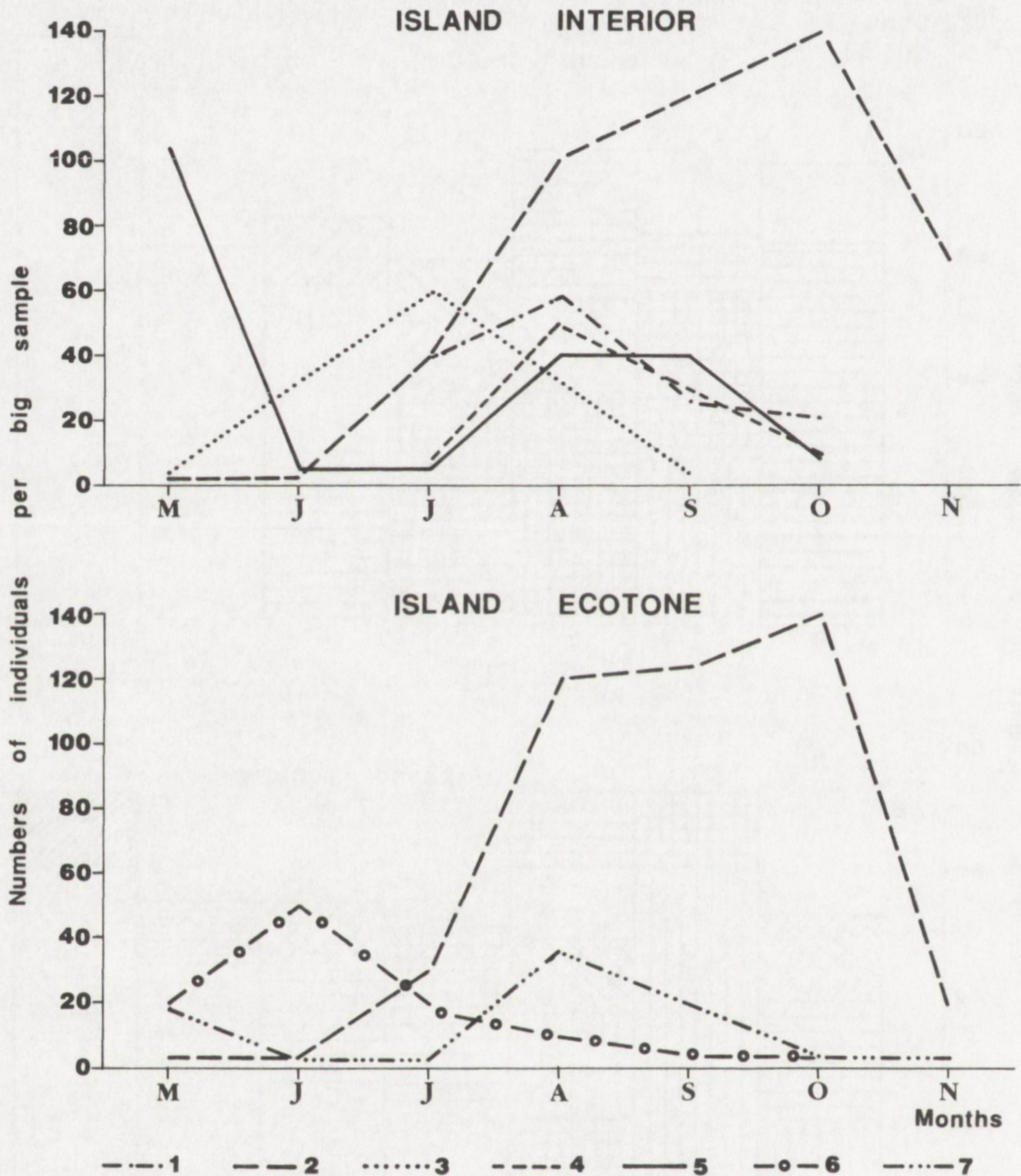


Fig. 5. Dynamics of dominant species numbers in the herb layer spider community of the birch-aspen forest island no. 6 (1988) (according to Łuczak 1990)

1 - *Meta segmentata*, 2 - *Tetragnatha montana*, 3 - *Linyphia triangularis*, 4 - *Linyphia montana*, 5 - *Gongylidium rufipes*, 6 - *Enoplognatha ovata*, 7 - *Tetragnatha extensa*

ecotone. This division into groups has been introduced by Łuczak (1993). As an example, Fig. 7 presents the occurrence, in the ecotone system zones, of three species, two of which are ecotone species (one is an ecotone - field species), and one is a forest island interior species (Fig. 7).

Among the more abundantly represented species, six occurred in greater numbers in the forest island interiors (*Meta segmentata*, *Linyphia triangularis*, *Linyphia montana*, *Gongylidium rufipes*, *Bolyphantes* sp., *Helophora insignis*), and other eight species were present in the ecotones (*Tetragnatha extensa*, *Araniella cucurbitina* (Clerck), *Larinioides patagiatus* (Clerck), *Microlinyphia pusilla* (Sund.), *Neottiura bimaculata*, *Philodromus aureolus* (Clerck), *Xysticus ulmi* (Hahn), *Enoplognatha ovata* (Clerck) (with no addition of *Enoplognatha latimana* Hippa and Oksala). Three species did not display this type of preference.

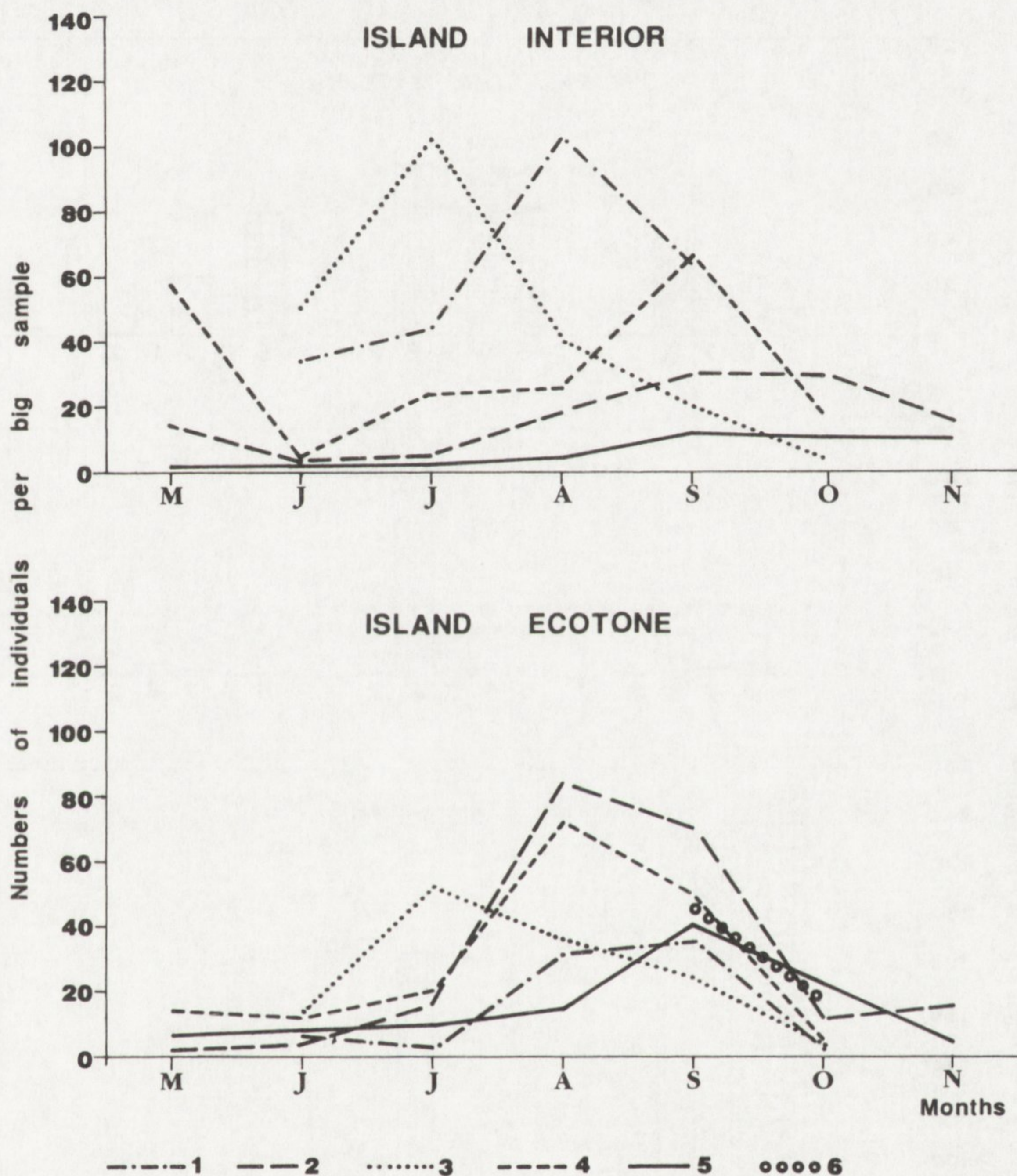


Fig. 6. Dynamics of dominant species numbers in the herb layer spider community of the mixed forest island no. 4 (1988) (according to Łuczak 1990)

1 – *Meta segmentata*, 2 – *Tetragnatha montana*, 3 – *Linyphia triangularis*, 4 – *Gongylidium rufipes*, 5 – *Tetragnatha extensa*, 6 – *Hylyphantes graminicola*,

4. DISCUSSION

The southern ecotone dealt with in this paper represents a narrow (1.5–6 m) margin zone of forest islands distributed in a hilly agricultural landscape among crop fields. The ecotone differs from forest island interior and crop fields in the structure and species composition of the vegetation (Wójcik 1991, Wójcik and Wasilowska 1995). The question arises what are the differences in the composition and structure of the communities of selected invertebrate groups, including spiders, between the ecotone and interiors of the ecotone-forming ecosystems.

Arachnological studies point to a marked qualitative similarity between the spider communities of the interior and margin of the forest island in the case of both – the Pino-Quercetum forest islands and birch-aspen woodlots (Łuczak

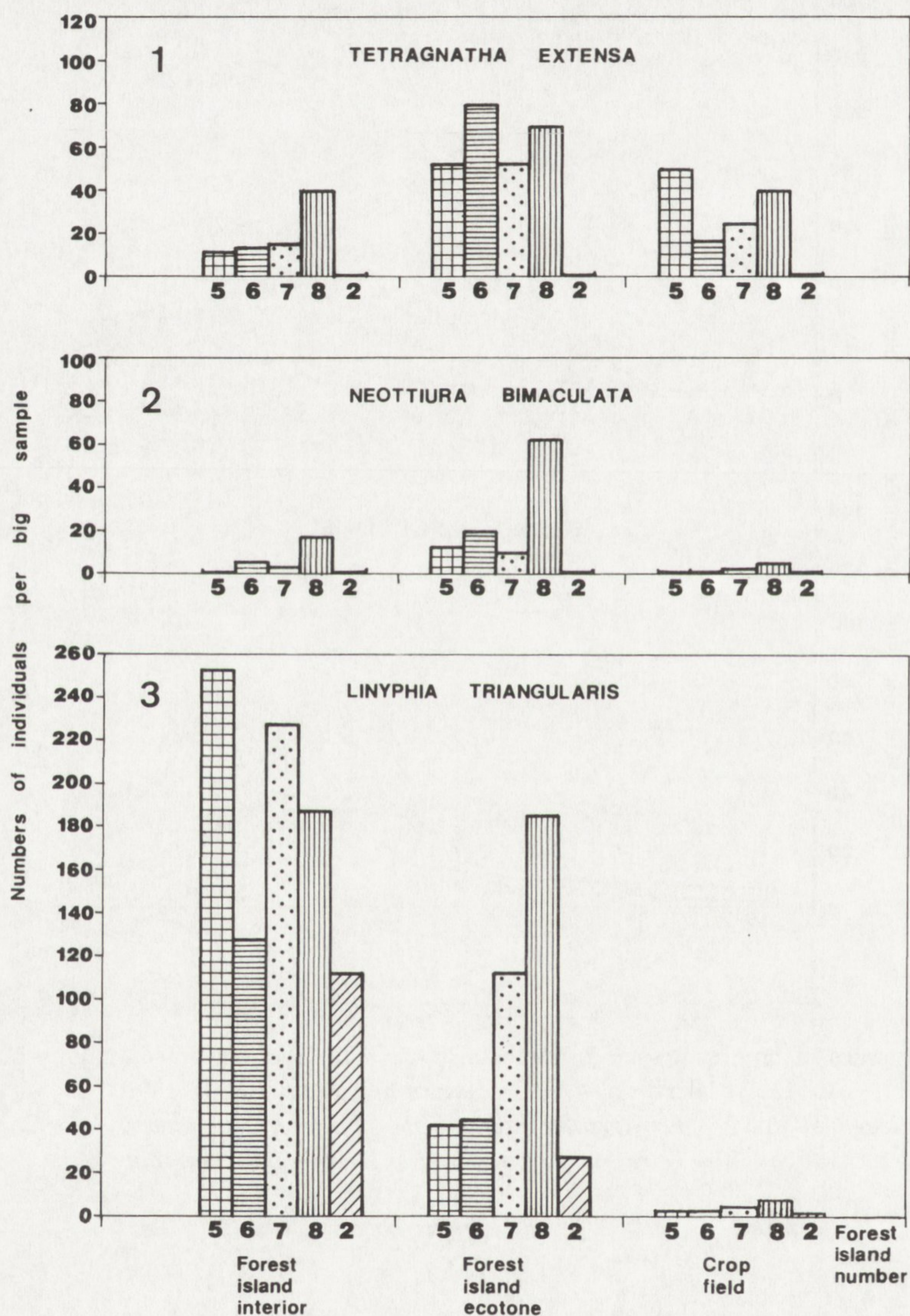


Fig. 7. Numbers of three spider species differing in habitat preference
 1 – species preferring the ecotone and being fairly abundant in fields, 2 – species preferring evidently the ecotone, 3 – species preferring the forest island interiors and also abundant in the ecotone

Nos of forest islands (see Fig. 1)

1991) (Tables 1 a, b). When considering the similarity of the structure of spider communities, it is necessary to stress the striking similarity of the number of species found exclusively in the ecotones (44 and 45) and exclusively in the interiors (26 and 28) of the mixed forest islands and birch-aspen woodlots, respectively. Despite the considerable similarity in the structure of spider

communities there are also clear-cut differences: 1) in total numbers and particularly in the biomass of spiders between the interiors and ecotones (Tables 1 a, b and 2; Figs 2 and 3); 2) in the distribution of the numbers of species occurring both in the forest island interiors and ecotones; these differences have been interpreted as resulting from the preference of spider species to one of these habitats (Łuczak 1990 b), and the respective species were referred to as "interior species" and "ecotone species" (Fig. 7); 3) in the composition and dynamics of the numbers of dominant species groups (Figs 4, 5 and 6); 4) in the composition and numbers of the groups of species common to the ecotone system zones (Table 3); 5) in the composition, number of species and exclusive species numbers (Table 4); 6) in the differentiated dominance of ecological groups, i.e. of various spider families (Łuczak, unpublished) (e.g. the Metidae are a dominant family in forest island interior, and the Tetragnathidae – in the ecotones).

The above findings indicate that the ecotone may, on account of the specific nature of its ecological conditions (meteorological, vegetation, soil etc. conditions) constitute a distinct ecological unit; this fact exerts an effect on the shaping of the ecotone spider communities which – though strongly influenced by the forest island interior communities – are changed by the specific ecotone conditions. The same applies to the Diptera communities (Dąbrowska-Prot 1995) and to the course of spider reproduction exemplified by web spider (*Enoplognatha ovata* (Clerck)) (Tarwid 1995).

In the present studies there occurred species which in the case of all of the forest islands formed much greater populations in the forest island interiors, as well as other species present much more abundantly in the ecotones of these islands (Fig. 7). It seems that the habitat preferences of spider species in the ecotone system zones (forest island interior–ecotone–crop field) are based on ecological factors (presence of vegetation and its structure, meteorological factors) rather than on biotic factors (predation or interspecies competition); nevertheless, it cannot be ruled out that the biotic factors exert an effect within the spider community (competition of families and species) and, moreover, act on the spider community from the outside (other predators, parasites, competitors belonging to other invertebrate groups).

It is necessary to emphasize the strong effect of both the habitat conditions prevailing in the forest island interiors and spider communities inhabiting these interiors on the shaping of the ecotone spider communities. This causes the similarity between plant-dwelling spiders inhabiting the forest island interiors and ecotones. Klimeš and Špičáková (1984) have found a marked similarity between the litter spider communities of the forest and its ecotone, and at the same time – big differences between these communities and spiders inhabiting open meadow terrains.

The margin effect may be either positive or negative from the standpoint of the number of species, species numbers and total spider numbers, in dependence on the ecological properties of the species and character of the ecotone. A positive

margin effect leading to greater spider numbers has been observed in the ecotone between an alder forest and woodland meadow in the Kampinos Forest (Dąbrowska-Prot et al. 1973) and in the ecotone between an alder forest and pine forest in the Kampinos Forest (Dąbrowska-Prot and Łuczak 1968 a); on the other hand, according to the present results no such effect occurred in the ecotone of the forest islands situated among crop fields in the Masurian Lakeland. This may indicate that in the case of very contrastive ecosystems the positive quantitative margin effect may be absent.

The clash of the abiotic and biotic conditions of the forest island interior and ecotone gives rise to a phenomenon which may be defined as the barrier effect of the ecotone. Namely, the ecotone is at the same time: 1) the living place for many invertebrate species (including spiders), 2) a transition zone for many species (e.g. some species of the *Diptera* and other insect groups, and even a few spider species), allowing them to penetrate and colonize other habitats, and 3) a barrier zone for many forest species, e.g. for many spider species living in the investigated ecotone system and never moving beyond it (Łuczak et al., in print, Łuczak 1990 b).

In the present studies, there occurred no spider species living exclusively in the ecotone and there was only one species inhabiting exclusively the forest island interiors. Nevertheless, in the consecutive years we found species occurring only in a given year, only in a given forest island and only in a definite zone of the ecotone system. Thus, some species found exclusively in the ecotone may occur in very low numbers in other years and in other forest islands; the major part of these exclusive species occur in numbers too low to enable the determination of their habitat preference.

Crop fields are completely open terrains, with periodic crop harvest, i.e. with destruction of the ecosystem and chemicalization (mineral fertilization and pesticidal sprays). As compared with forest island interiors and ecotones, crop fields are much less stable ecosystems, to which some species (groups) of invertebrates, and even spiders, become adapted periodically. Crop fields have their own spider communities which differ from those inhabiting forests and meadows (Łuczak 1979, Nyffeler 1982, and many other authors). If the field margin is grassy, spiders are more abundant there than in the field (Kromp and Steinberger 1992). These authors have reported a low exchange of the spider fauna between the grassy field margin and crop field; they divided spider species into those migrating to the field margin and those remaining in the crop field interior. Kajak (1990) has investigated the spider species richness in the ecotones and crop fields, as well as the ecological diversity of spiders.

Under the conditions of the Masurian Lakeland, crop fields are inhabited by a very scanty spider fauna. The number of species is smaller than in other regions of Poland, but in the first place their numbers and biomass are small (Tables 1 a, b and 2). There live in low numbers mainly the young forms of spiders and

species with small biomass. In the present author's opinion, spider species do not occur there (with few exceptions) in the form of populations, but rather as single individuals which have found there appropriate ecological niches for a certain period of their life. Moreover, the major part of the spider species inhabiting the Masurian Lakeland crop fields consist of aeronauts arriving by air from distant terrains (Duffey 1956, Kajak 1959), instead of migrating from the forest island interior across the ecotone to the crop field. The forest island appears as "an isolated cage" with spiders rather than as a spider propagator onto fields. It is of interest, however, that the birch-aspen woodlots, as compared with the mixed forest islands, have more common species with fields. This has been found also for the Diptera (Dąbrowska-Prot 1991).

This isolation rules out the possibility of regarding plant-dwelling spiders as significant predators of field pests. Perhaps the communities of the litter and soil spiders (a completely distinct community not dealt with in the present studies) are more effective predators in fields, as suggested by Nyffeler (1982). Attempts at introducing spiders onto fields or at initiating environmental changes beneficial for spiders (Riechert 1990) (e.g. herb vegetation belts) seem to be useless, because of chemicalization of the environment.

On the other hand, in forest islands the web spiders of the herb layer may be of importance for reducing the population of the Diptera which are abundant in the whole ecotone system (Dąbrowska-Prot 1995) and thus also in the forest islands, where they are the most important prey of the web spiders. Preying of spiders on mosquitoes, which are mainly associated with forest island interiors, may be of special significance; field studies and field experiments (e.g. Dąbrowska-Prot and Łuczak 1968 b, Łuczak and Dąbrowska-Prot 1986) have shown that the mosquitoes are important preys of many spider species.

5. SUMMARY

Spiders of six forest-field ecotone systems were studied. The number of species was greatest in the ecotones and smallest in crop fields; it accounted, on the average, in the forest ecotone, forest island interior and crop field for 44, 36 and 20%, respectively, of the total number of species (Tables 1 a, b and 2).

On the other hand, the numbers of spiders were greatest in the forest island interiors where they accounted for 56% of the total spider numbers in the ecotone system, whereas in the forest ecotones and crop fields the respective percentages were 40 and nearly 4%, respectively. The percentages of spider biomass in the total spider biomass were fairly similar in the forest island interior and its ecotone, while in crop fields they were only 1.8% (Tables 1 a, b and 2). The dynamics of spider numbers and biomass in the vegetation season (from May until November) were determined (Figs 2 and 3). It was found that for plant-dwelling spiders August and September are the period of maximal occurrence and biomass.

For an analysis of the species common to different ecotone system zones, two forest islands of a similar size: birch-aspen woodlot (no. 7) and mixed forest island (no. 4), were observed (Fig. 1, Tables 3 a and b). In both types of forest islands the number of common species is greatest for the

forest island interior and its ecotone (53 and 51 species, respectively). The percentages of the numbers of spiders common to forest island interiors and their ecotones in total spider numbers in both these habitats are most differentiated between both types of forest islands; namely, in the birch-aspen woodlot these percentages are similar (54 and 46%, respectively, whereas in the mixed forest island they are different (in the interior and ecotone 64 and 36%, respectively). This indicates that in the birch-aspen forest island spiders pass easier from the interior to the ecotone. This also testifies to greater isolation of the ecotones from the interiors in mixed forest islands (Table 3 a).

In both types of forest islands there are less species exclusive for forest island interiors than those exclusive for the ecotones (Table 4). In this case the exclusiveness is not regarded as absolute, and is considered only for a given year and a given forest island. In the interiors and ecotones of the mixed forest islands there occurred 26 and 44 exclusive species, respectively; for the birch-aspen forest islands the respective values were 28 and 45.

In both types of forest islands 12 dominant species (i.e. those with the percentage in total spider community numbers equalling or exceeding 10%) were found. Groups of species dominant in the forest island interiors or in their ecotones are very similar, though there are qualitative differences; namely, a few species occur as dominants either only in the forest island interior or only in its ecotone (Table 5, Figs 4, 5, 6). The percentages of the group of dominant species account in forest island interiors and their ecotones for 43–80 and 26–64%, respectively, of total spider numbers in the ecotone system.

According to the division introduced by Ł u c z a k (1993), spider species were divided into three groups: 1) species preferring forest island interiors, 2) species preferring forest ecotones, 3) neutral species. Names of spider species which can be classed among these groups are listed in Fig. 7 and in the text.

In the discussion the causes of the similarities and differences between spider communities in the ecotone system zones were analyzed. The importance of the ecotone for spiders of forest islands in a hilly agricultural landscape, as well as the significance of forest island spiders for insects were discussed.

6. POLISH SUMMARY

W pracy omówiono wyniki badań nad pająkami sześciu układów ekotonowych. Analizowano liczbę gatunków stwierdzając, że jest ona największa w ekotonach, a najmniejsza na polach uprawnych, stanowiąc w ekotonie średnio 44% ogólnej liczby gatunków, we wnętrzu wyspy leśnej 36% a na polu uprawnym 20% (tabele 1 a, b i 2).

Liczebność pająków była największa we wnętrzach wysp leśnych, stanowiąc 56% ogólnej (całkowitej dla układu) liczebności pająków, w ekotonach leśnych – 40%, a na polu uprawnym – niecałe 4%. Biomasa pająków wnętrza wyspy i jej ekotonu osiągała podobne udziały w biomacie pająków, ale na polach stanowiła tylko 1,8% (tabele 1 a, b i 2). Przedstawiono dynamikę liczebności i biomasy (rys. 2 i 3) w sezonie od maja do listopada. Stwierdzono, że sierpień i wrzesień są dla pająków naroslinnych okresem szczytowego występowania i najwyższej biomasy.

Analizę gatunków wspólnych dla różnych stref układu ekotonowego wykonano przykładowo na podobnych wielkością dwóch wyspach: brzożowo-osikowej (nr 7) i boru mieszanego (nr 4) (tabele 3 a i b). Liczba gatunków wspólnych w obu typach wysp jest największa dla wnętrza wyspy i jej ekotonu (53 i 51 gatunków). Najbardziej zróżnicowane na obu typach wysp leśnych są udziały liczebności pająków wspólnych dla wnętrza wysp i ich ekotonów w całej liczebności tych środowisk: na wyspie brzożowo-osikowej ich udziały są podobne (54 i 46%), a na wyspie boru mieszanego – różne (64 – we wnętrzu i 36% – w ekotonie). Oznacza to, że pająki mogą łatwiej przechodzić na ekoton na wyspie brzożowo-osikowej. Wskazuje to na większą izolację ekotonów wysp boru mieszanego od jej wnętrza. Udział gatunków wspólnych dla wszystkich stref układu ekotonowego w liczebności pająków całego układu jest większy w borze mieszanym (tabela 3 a).

Gatunków wyłącznych dla wnętrza wysp jest mniej niż gatunków wyłącznych dla ekotonu w obu typach wysp (tabela 4). Wyłączność nie jest tu traktowana jako bezwzględna: tylko w danym roku i dla danej wyspy. We wnętrzach wysp boru mieszanego znaleziono 26 gatunków wyłącznych, a w ekotonach tego boru – 44: analogicznie dla wysp brzożowo-osikowych – 28 i 45.

Na obu typach wysp leśnych znaleziono 12 gatunków dominujących, czyli takich, których udział w zgrupowaniu stanowił 10 i więcej procent. Grupy gatunków dominujących we wnętrzach wysp leśnych i na ekotonach są bardzo podobne, chociaż istnieją różnice jakościowe: nieliczne gatunki występują jako dominanty tylko we wnętrzu wyspy lub tylko w jej ekotonie (tabela 5, rys. 4, 5 i 6). Udział gatunków dominujących stanowi we wnętrzu wysp leśnych 43–80%, w ich ekotonach – 26–64%.

Gatunki podzielono na trzy grupy: 1) gatunki preferujące wnętrza wysp, 2) gatunki preferujące ekoton wysp, 3) obojętne (wg Łuczak 1993). Podano nazwy gatunków, które można zaliczyć do poszczególnych grup (rys. 7 i tekst).

W dyskusji przeanalizowano przyczyny podobieństw i różnic zgrupowań pajaków w poszczególnych strefach układu ekotonowego oraz omówiono znaczenie ekotonu dla pajaków wysp leśnych w pagórkowatym krajobrazie rolniczym oraz znaczenie pajaków wysp leśnych dla owadów.

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