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## THE EFFECT OF THE PROPERTIES OF FOREST ISLAND ECOTONES IN AGRICULTURAL LANDSCAPE ON THE FECUNDITY OF SPIDER *ENOPLIGNATHA OVATA* (CLERCK)

**ABSTRACT:** Study was made of the effect exerted on the reproduction of spider *Enoplognatha ovata* (Clerck) by forest island ecotones and their differentiation resulting from island size, type of vegetation and exposure (southern and northern ecotones). Evaluation was made of female density and numbers of cocoons, as well as of female fecundity characterized by the following indices: cocoon size (number of eggs laid), cocoon validity (percentage of fertilized eggs) and cocoon viability (percentage of young spiders which left the cocoon). Reproduction losses at the embryonic development stage in the cocoon, caused by embryo mortality, were calculated. The birch-aspen woodlot ecotones and ecotones with southern exposure, as compared with the Pino-Quercetum forest island ecotones, were characterized by higher individual fecundity and smaller losses in *E. ovata* reproduction. The differences between the ecotone and forest island interior in spider reproduction were more clear-cut in the case of the larger islands (13.5 ha).

**KEY WORDS:** spiders, ecotones, reproduction, *Enoplognatha ovata*.

### 1. INTRODUCTION

The present studies of the reproduction of the spider *Enoplognatha ovata* were carried out in an agricultural-forest terrain in the Masurian Lakeland (north-eastern Poland). They concerned the importance of forest island ecotones and their differentiation related to the forest island vegetation type, exposure of the ecotone and forest island size. In the study area the spider community consisted exclusively of the species *Enoplognatha ovata*, without any addition of

*Enoplognatha latimana*. In the spider material collected in 1992, as well as in a control sample of 600 females caught in second half of July 1993 at the investigated forest islands and their vicinity, not a single *Enoplognatha latimana* individual was present.

The investigated ecotones constituted the forest margin zone separating two different ecosystems: forest and crop field. These habitats display great diversity of the vegetation derived from both adjoining ecosystems (W ó j c i k 1991, W ó j c i k and W a s i ł o w s k a 1995) and considerable variation of the microclimatic conditions (W ó j c i k and W a s i ł o w s k a 1995). For many animal groups this type of habitat creates favourable developmental conditions so that not only species richness but also the density of the fauna are greater (Ł u c z a k et al. 1995). Many predator species, including spiders, find there an abundant food supply (D a b r o w s k a - P r o t 1995) This is testified to by high spider numbers in the ecotone zone; some species even attain higher densities in the ecotone than in forest interior (Ł u c z a k 1995). They include *Enoplognatha ovata*, a web spider of the *Theridiidae* family, often occurring more abundantly in forest ecotones than in forest interiors (Ł u c z a k 1984, 1991, T a r w i d 1987, 1991); as a rule, the density of its mature female population is higher in the ecotones. This species is one of the dominants of the spider communities living on plants in the investigated forest ecosystems (Ł u c z a k 1991).

## 2. STUDY AREA, MATERIAL AND METHODS

The study area consisted of a fragment of a hilly post-glacial landscape (Masurian Lakeland) characterized by a big number of woodlots situated among crop fields; these woodlots are either remainders of greater forest complexes or have developed spontaneously on wasteland unsuitable for agriculture.

The present studies concerned the ecotones of eight forest islands differentiated in the origin of the plant community and in size. Four of them (nos 1–4; 35, 13.5, and 1 ha, respectively) are remainders of old mixed Pino-Quercetum forest, and four (nos 5–8; 1.5, 1, 0.5 and 0.125 ha in size respectively) are young birch-aspen woodlots formed spontaneously in the course of plant succession on barrens (W ó j c i k 1991) (Fig. 1).

The ecotones studied were differentiated phytosociologically (different origin of forest islands), as well as in forest island size, ecotone width (2–6 m) and ecotone exposure: insolated southern ecotones and shadowed northern ones.

The object of studies consisted of the spider *Enoplognatha ovata*, very suitable for investigations on individual fecundity and population reproduction. During its whole life, the female lays only one cocoon (S e l i g y 1971) which is, therefore, a measure of total individual fecundity. Moreover, the cocoons are easy to find because they are coloured blue and the females lay them in characteristically folded leaves of the herb layer. They remain near them until hatching of the young.



Fig. 1. Distribution of the forest islands under study in the landscape  
Numbers from 1 to 8 denote the forest islands

During the *E. ovata* reproduction period, i.e. from July until September, cocoons were several times collected from the herb layer of the ecotones of all islands (detailed description of the methods has been presented by Tarwid 1984). Cocoons were kept at the laboratory until complete hatch of young spiders. For each cocoon counts were made of the spiders which left the cocoon, embryos remaining

in the cocoon and fully formed young spiders unable to leave the cocoon, as well as unfertilized eggs, i.e. those without any traces of embryonic development.

Female fecundity and reproduction level of the *E. ovata* population in the investigated ecotones were characterized by the following indices: 1) female density per m<sup>2</sup>, 2) cocoon density (no. of cocoons collected during 10 min.), 3) cocoon size (no. of eggs laid in it), 4) cocoon validity (percentage of fertilized eggs in the cocoon), 5) cocoon viability (percentage of young spiders which left the cocoon).

Since in spiders the number of eggs in cocoons is very variable, even within the same species, the sample size (i.e. the number of cocoons), from which the fecundity indices of females in a given habitat are calculated, is essential. Cocoon collection by the method "per time", i.e. evaluation of cocoon density per collection time unit was applied on account of the possibility of collecting a greater number of cocoons, and because of the differences between ecotones in length, resulting from the differentiation in forest island size (0.125–35 ha). Cocoon density per m<sup>2</sup> was used for evaluation of the numbers and reproduction level of the population inhabiting a given habitat.

The material was collected in the years 1986–1988 and 1991–1993. More than 2000 cocoons were examined. Cocoons in which the eggs could not be counted accurately were eliminated; they include mouldy cocoons, cocoons laid by sick females (in which the individual eggs could not be singled out) and cocoons damaged by parasite larvae.

### 3. RESULTS

#### 3.1. *ENOPLIGNATHA OVATA* REPRODUCTION IN THE ECOTONES OF PINO-QUERCETUM AND BIRCH-ASPEN FOREST ISLANDS

*Enoplognatha ovata* is a plant-dwelling web spider living mainly in the herb layer, but also in low undergrowth. Since the females lay cocoons in leaves of many plant species, the vegetation structure significantly influences the reproduction of this spider.

Analysis of the reproduction indices in the ecotones of 1-ha Pino-Quercetum and birch-aspen forest islands showed that the *E. ovata* population was more numerous in the former than in the latter ecotone. This was testified to by higher female density and cocoon numbers greater by 50% (Table 1). More abundant *E. ovata* inhabiting the ecotones of the Pino-Quercetum forest islands persisted throughout all 6 years of studies.

In contrast to the density of the *E. ovata* population, in the ecotone of the Pino-Quercetum forest island the indices of the female individual fecundity were lower. Mean size of cocoon, evaluated by the number of eggs laid in it, was usually lower in the ecotone of the Pino-Quercetum forest island, as compared

with the birch-aspen forest island of a similar size (Table 1). Although in the ecotone of the Pino-Quercetum forest island there were more cocoons of the greatest size (containing more than 180 eggs per cocoon), the percentage of the smallest cocoons was by 10% higher; there were by 14% less cocoons of medium size, which are usually represented most frequently (Table 2). The variation range of cocoon size was much wider in the ecotone of the Pino-Quercetum forest island, as compared with the birch-aspen woodlot (Table 1). This points to greater differentiation of females in fecundity in the ecotone of the Pino-Quercetum forest island.

Table 1. *E. ovata* fecundity indices in the ecotones of Pino-Quercetum forest islands (P-Q) and birch-aspen woodlots (B-As) (years 1991–1993)

Type and no. of forest island*	Female density per m <sup>2</sup>	Density of cocoons collected during 10 min.	Mean number (and range) of eggs per cocoon	% of reproduction losses**
P-Q (no. 3) 1-ha	4.3	16.8	110 (21–277)	5.0
B-As (no. 7) 1-ha	3.2	11.2	125 (40–264)	2.0

Explanations to all Tables: \*the localisation and numbers of forest islands are presented in Fig. 1; \*\*the difference between the validity and viability indices.

Table 2. Percentage of cocoons of different size classes in the ecotones of Pino-Quercetum forest islands (P-Q) and birch-aspen woodlots (B-As)

No. of eggs per cocoon	0–80	81–140	141–180	181 and more
1-ha forest islands P-Q (no. 3)*	22.0	55.0	15.0	8.0
B-As (no. 7)	12.0	69.0	15.0	4.0

Such a large range of cocoon size occurs only in the ecotones. Forest interior and interiors of the greater forest islands are characterized by less wide a variation range of cocoon size, because there occur mainly cocoons of medium size, whereas the percentages of small and large cocoons are low. Very large cocoons do not occur at all. It is difficult to interpret this phenomenon. Presumably, it is related to the more stable environmental and trophic conditions of forest interior. Variable abiotic and biotic conditions in the ecotones may hinder or promote reproduction of *E. ovata*, but at the same time owing to the greater abundance of food (that stimulates female fecundity – Tarwid, unpublished) apart of females attain high fecundity and lay very large cocoons, this increasing the range of cocoon size.

This is particularly evident for the ecotone of the Pino-Quercetum forest island, where the cocoon size range is much wider than in the ecotone of the birch-aspen woodlot.

Also the viability index of cocoons tended to assume lower values in the Pino-Quercetum forest island ecotone; it is noteworthy that there occurred greater differences between the indices of validity and viability, which inform about the reproduction losses at the stage of the development of eggs and young spiders in the cocoon (Table 1).

In general it may be stated that the ecotones of the Pino-Quercetum forest islands are more abundantly inhabited by *E. ovata*, in view of the higher numbers of the local populations; on the other hand, female fecundity measured by the number of eggs per cocoon and by egg viability is superior in the birch-aspen woodlot ecotones.

### 3.2. FOREST ISLAND SIZE AND *E. OVATA* FECUNDITY IN THE ECOTONE

The investigated forest islands were differentiated in size: the greatest and smallest had an area of 35 and 0.125 ha, respectively. Evaluation of the effect of forest island size on female fecundity in the ecotone was exemplified by mixed forest islands 1, 2 and 3 (35, 13.5 and 1 ha, respectively) and birch-aspen forest islands 5, 7 and 8 (1.5, 1 and 0.125 ha, respectively).

The results showed that in the case of the Pino-Quercetum forest islands the ecotone of the 13.5-ha forest island was inhabited by *E. ovata* in greatest numbers (Table 3). During 5 years of studies there was the highest density of females and cocoons. In the ecotones of both the larger (35 ha) and smaller (1-ha) forest islands, cocoon density was lower by more than 40% (Table 3).

Table 3. Comparison of the *E. ovata* fecundity indices in the ecotones of Pino-Quercetum forest islands and birch-aspen woodlots of different size (means for 5 years: 1986–1988, 1991–1992)

Size and vegetation type of forest island*	Female density indiv. per m <sup>2</sup>	Cocoon density (no. of cocoons collected during 10 min)	No. of eggs per cocoon (mean value)	% of reproduction losses**
Pino-Quercetum forest islands	35-ha (no 1)	5.1	108	8
	13.5-ha (no 2)	9.5	111	7
	1-ha (no 3)	4.2	125	5
Birch-aspen woodlots	1.5-ha (no 5)	4.8	117	6
	1-ha (no 7)	3.2	120	2
	0.125-ha (no 8)	3.1	114	8

The largest cocoons were laid by females in the ecotone of the 1-ha Pino-Quercetum forest island. There the mean cocoon size was greater than in the ecotones of both larger forest islands (Table 3), and there occurred the greatest

number of the very big cocoons (more than 180 eggs per cocoon) (Table 4). Moreover, the viability of the hatching young spiders was high because the weak spider individuals (unable to leave the cocoon) accounted for only 5% of the fertilized eggs. In the ecotone in this 1-ha forest island, as compared with the other island, the reproduction losses were by 2–3% lower (Table 3).

Table 4. Percentage of cocoons in different size classes in the ecotones of Pino-Quercetum forest islands and birch-aspen woodlots differing in area

Forest islands	No. of eggs per cocoon				
	0–80	81–140	141–180	181 and more	
Pino-Quercetum	35-ha (no. 1)	23	65	7	5
	13.5-ha (no. 2)	20	56	21	3
	1-ha (no. 3)	26	44	18	12
Birch-aspen woodlots	1.5-ha (no. 5)	14	63	15	8
	1-ha (no. 7)	19	60	16	5
	0.125-ha (no. 8)	11	68	21	0

For the group of birch-aspen woodlots, comparison was made of the female fecundity indices in the ecotones of the forest islands nos 5, 7 and 8 (1.5, 1 and 0.125 ha, respectively). In the ecotone of the smallest 0.125-ha forest island, the reproduction losses of the *E. ovata* population (percentage of not developed fertilized eggs) were greatest (Table 3). As compared with the ecotones of the other forest islands, there the cocoon density was lower, mean cocoon size was smaller (Table 3), and no largest cocoons (containing more than 180 eggs per cocoon, and being characteristic of the ecotones) were present (Table 4).

The female fecundity indices showed no significant differences between the ecotones of both larger birch-aspen woodlots. Only the reproduction effectiveness was lower in the ecotone of the 1.5-ha woodlot than in that of the 1-ha woodlot (reproduction losses amounted to 6 and 2% respectively) (Table 3).

For evaluation whether the described differences in *E. ovata* female fecundity between the ecotones of the investigated forest islands could be related to forest island size, the female fecundity indices found for the ecotones and interiors of these islands were compared (Table 5). Namely, it is known that the ratio of the ecotone zone area to the interior area depends on forest island size, and that the proportion of ecotone area rises with a decrease in forest size. Earlier studies (Tarwid 1984, 1987) have shown that in forest interiors, as compared with the ecotones, there are lower numbers of females and cocoons, the cocoons are smaller, the group of the largest cocoons is absent, and the differences between the validity and viability indices are smaller (i.e. there are smaller losses in population reproduction).

Analysis of the changes in *E. ovata* fecundity indices in the ecotone and interior of the Pino-Quercetum forest islands indicates that, with a reduction of forest island size, the differences between the ecotone and forest island interior in the values of various indices decrease (Table 5). These differences are smallest in

Table 5. Comparison of the *E. ovata* fecundity indices in the interiors (Int.) and ecotones (Ec.) of Pino-Quercetum forest islands and birch-aspen woodlots of different size (means for the years 1986–1988)

Type and no. of forest island		Reproduction indices							
		Female density per m <sup>2</sup>		Density of cocoons collected during 10 min.		No. of eggs per cocoon		Reproduction losses	
				Int.	Ec.				
Pino-Quercetum forest islands	35-ha (no. 1)	0.2	4.8	3.2	13.8	93	110	4	9
	13.5-ha (no. 2)	1.5	10.4	4.8	20.2	106	112	5	8
	1-ha (no. 3)	1.4	8.7	5.5	16.2	109	119	6	7
Birch-aspen woodlots	1.5-ha (no. 5)	0.9	6.0	5.7	12.7	118	132	3	8
	1-ha (no. 7)	3.7	3.4	13.0	13.2	109	121	11	7
	0.125-ha (no. 8)	2.7	2.8	8.5	10.8	117	114	17	10

Table 6. Percentage of cocoons in different size classes in the interior of Pino-Quercetum forest islands and birch-aspen woodlots differing in area

		No. of eggs per cocoon			
		0–80	81–140	141–180	181 and more
Pino-Quercetum forest islands	35-ha (no. 1)	0	100	0	0
	13.5-ha (no. 2)	23	61	16	0
	1-ha (no. 3)	29	58	10	3
Birch-aspen woodlots	1.5-ha (no. 5)	15	60	25	0
	1-ha (no. 7)	26	56	15	3
	0.125-ha (no. 8)	23	57	9	11

the case of the 1-ha forest island. Only this forest island displayed an interior characterized by the occurrence of very large cocoons containing more than 180 eggs per cocoon, this being specific for the ecotones (Table 6). No such big cocoons were found in the interiors of both larger forest islands. Moreover, in the interior of only this (1-ha) forest island the reproduction losses were similar to those in the ecotone (Table 5). The disappearance of the differences in the *E. ovata* reproduction indices between the ecotone and interior of a small forest island was even more evident in the case of the 1-ha birch-aspen woodlot. In this case there were nearly no differences in the female and cocoon density between the ecotone and interior of the forest island (Table 5); the largest cocoons occurred also in forest interior (Table 6), where also the reproduction losses were greater than in the ecotone (Table 5).



In the ecotone of the smallest birch-aspen woodlot (0.125 ha), the cocoons were even smaller than in the interior, where the largest cocoons accounted for 11% of all cocoons (Table 6). In this forest island, as compared with all other ones, the percentage of reproduction losses in the ecotone and interior was highest (Table 5). During the 3-year studies there died in the embryonic period ca. 17%, on the average, of *E. ovata* spiders. So high mortality of the young spiders in this forest island could have been related to its situation near a mid-field road. It was shown that so small a forest island assumes in total the nature of an ecotone habitat.

The 13.5-ha Pino-Quercetum forest island exemplified the island size at which the ecotone and interior are evidently distinguishable. In both these habitats the *E. ovata* fecundity indices display features characteristic of the habitats: in the ecotone the spider and cocoon density is several times greater than in the interior (Table 5), and there occur the largest cocoons absent from forest interior (Table 6). The mortality of hatching young spiders is higher in the ecotone than in interior (Table 5).

It seems, therefore, that with respect to *E. ovata* reproduction, the 13.5-ha forest island and the larger one are more evidently differentiated into the ecotone and interior than the other smaller islands.

### 3.3. REPRODUCTION OF THE *ENOPLIGNATHA OVATA* POPULATION IN RELATION TO ECOTONE EXPOSURE – SOUTHERN AND NORTHERN ECOTONES

The exposure of the ecotones differentiates them with respect to the microclimatic conditions, because of the dissimilarities in their insolation; moreover, depending on exposure the ecotones differ in vegetation structure and species composition (Wójcik and Wasilowska 1995). The southern and northern ecotones are particularly contrasting.

The high *E. ovata* fecundity indices in the warm southern ecotones indicate that most often these habitats afford more suitable reproduction conditions for *E. ovata* populations. In the southern ecotones, as compared with the shadowed and colder northern ones, usually the density of females and cocoons was greater, irrespective of the vegetation type and forest size (Table 7). Furthermore, the females tended to lay larger cocoons (Table 7). In the southern ecotones of both the Pino-Quercetum forest islands and birch-aspen woodlots there occurred ca. 20% of the large cocoons (140–180 eggs per cocoon) and very large cocoons (more than 180 eggs/cocoon) which were particularly numerous in the ecotone of Pino-Quercetum forest island (Table 8). In contrast, in the northern ecotones the largest cocoons were absent and the large ones were less abundant (Table 8).

Reproduction losses caused by spider mortality in the embryonic period were also lower in the southern than in the northern ecotones (Table 7).

Analysis of the individual forest islands pointed, however, to deviations from the above-mentioned regularities. In two birch-aspen woodlots (5 and 6) formed

Table 7. Fecundity indices of *E. ovata* females in the southern and northern ecotones of Pino-Quercetum forest islands and birch-aspen woodlots, 1-ha in size

	Female density indiv. per m <sup>2</sup>		Density of cocoon collected during 10 min.		Cocoon size (no. of eggs)		Reproduction losses	
	P-Q	B-As	P-Q	B-As	P-Q	B-As	P-Q	B-As
Southern ecotones	6.2	5.3	23.6	17.5	127	140	3	2
Northern ecotones	1.7	1.1	18.2	3.0	98	122	7	5

Table 8. Percentage of cocoons in different size classes in the southern and northern ecotones of Pino-Quercetum forest islands and birch-aspen woodlots

		No. of eggs per cocoon			
		0-80	81-140	141-180	181 and more
Pino-Quercetum forest islands	southern ec.	20	40	20	20
	northern ec.	24	64	12	0
Birch-aspen woodlots	southern ec.	14	57	22	7
	northern ec.	8	84	8	0

in depressions and containing small pools, in the northern ecotone, as compared with southern ones, the cocoon density was smaller (similarly as in two dry woodlots 7 and 8), but the cocoons were the largest. *E. ovata* is a hygrophilous mesophilic species, and thus the presence of water and the resulting higher air humidity are beneficial factors. In the wet forest islands, as compared with the dry ones, in both the southern and northern ecotones the reproduction losses tended to be smaller. However, also in the wet forest islands somewhat higher mortality persisted in the northern ecotones (Table 9).

Table 9. Comparison of the *E. ovata* fecundity indices in southern and northern ecotones of dry (nos 7 and 8) and wet (nos 5 and 6) birch-aspen woodlots

	Density of cocoons collected during 10 min		Cocoon size (mean no. of eggs)		Reproduction losses, %	
	Dry islands	Wet islands	Dry islands	Wet islands	Dry islands	Wet islands
Southern ecotones	12.5	14.5	114	115	4	3
Northern ecotones	8.7	7.3	105	135	6	4

Data obtained in 1992 may exemplify the changes in the microclimatic conditions in the ecotones (caused by weather in the given growing season) and the effect of these changes on the course and effectiveness of *E. ovata* reproduction in these habitats. In summer of 1992 long-lasting heat and drought prevailed; for example, in the Mikołajki district the sum of precipitation for: May,

June, July and August was 133 mm, whereas for the years 1990, 1991 and 1993 the respective sums were 260, 227 and 321 mm (data supplied by Bajkiewicz-Grabowska). As a result, the shadowed and more moist northern ecotones became a more appropriate habitat for spiders than the southern ecotones. In this year, in the northern ecotones (particularly in those of the Pino-Quercetum forest islands) cocoon density (which rose with a decrease in forest island size) was higher than that in the southern ecotones (Table 10). In the "dry" birch-aspen islands in the northern ecotones the cocoon density increased but it did not exceed that in the southern ecotones; in contrast, in the ecotones of the "wet" forest islands no effect of heat and drought was observed. In the northern ecotones of these islands the cocoon density was as usually lower than in the southern ones (Table 10).

Table 10. Differentiation of cocoon density in different exposure and origin, in dry and hot year 1992 (means for July, August, September)

	Cocoon density (no. of cocoons collected during 10 min.)						
	Pino-Quercetum forest islands			Dry birch-aspen woodlots		Wet birch-aspen woodlots	
	35-ha	13,5-ha	1-ha	1-ha	0.125-ha	1.5-ha	0.5-ha
Southern ecotones	11.9	15.2	13.0	11.1	13.9	12.7	13.8
Northern ecotones	13.4	19,7	18,6	11.4	13.7	10.7	7.6

In 1992 the reproduction period was markedly accelerated and shortened. In the area of the present studies *E. ovata* reproduction usually began in the second half of June. Most cocoons were present in August, and only few – in September. In contrast, in 1992 nearly all of the females laid cocoons in July. In August there occurred only single cocoons, but not at all sampling sites; in September no cocoons were found.

In general it may be stated that the final effect of *E. ovata* reproduction, i.e. the numbers of young spiders leaving the cocoons, is better in the southern ecotones of forest islands but it may be modified by humidity conditions of the terrain (in this case – of the individual forest islands). In ecotone habitats *E. ovata* reproduction may be modified also by the weather conditions in the growing season. A type of weather greatly departing from the normal one may even change the suitability of these habitats for *E. ovata* reproduction.

#### 4. DISCUSSION

Many years' studies of *E. ovata* reproduction lead to the conclusion that the ecotones of forested areas play a very important role in life of the individuals of this species. This common spider species, being a dominant or one of the

dominants in spider communities in many regions of Poland, often occurs in a greater number of individuals in the interiors and margins of insolated forest.

This paper presents a detailed description of the populations of this spider, inhabiting the hilly landscape of north-eastern Poland (Masurian Lakeland). There *E. ovata* occurs abundantly in forest islands of mixed forest and birch-aspen woodlots. The species *E. latimana* which has been distinguished from the *E. ovata* population and described by Hippa and Oksala (1982), did not occur simultaneously with *E. ovata*. In other regions of Poland, e.g. in the Kampinos Forest and other regions adjacent to Warsaw (central-eastern Poland), as well as in lower Silesia (south-western Poland), an addition of *E. latimana* was found. However, in certain parts of lower Silesia only *E. ovata* was present (Dr. M. Woźny – personal communications), though usually both species occurred in proportions from 1 : 3 to 1 : 6, in favour of *E. ovata* (Kwiecień-Wrotniewska et al. 1993).

Comparison of the interior and margins (ecotones) of forest islands in the Masurian Lakeland showed that female density and cocoon size (number of eggs) were greater in the ecotones. Moreover, in the ecotones the variation range of the number of eggs per cocoon was wider, because there occurred the group of very large cocoons which failed to be present in the forest island interior. These differences were clear-cut in the case of the larger forest islands whereas they decreased with reduction of island size.

Ecology of *E. ovata*, which often occurs also in meadows (Dąbrowska-Prot et al. 1973, Kwiecień-Wrotniewska et al. 1993), predisposes it to abundant occurrence in the ecotones. The fact that particularly large cocoons are laid in the ecotones may be due to the local abundance of food (Dąbrowska-Prot 1995, Tarwid, unpublished). Variation of different ecological (e.g. meteorological) factors leads, however, to instability of this habitat; probably for this reason in the ecotones the fecundity indices decrease, and in the first place the differences between the cocoon validity and viability indices rise, this testifying to increased mortality of the hatching young spiders.

The interior of forest and of forest island offers to spiders a more stable habitat, where as a matter of fact no very large cocoons are present, but cocoon viability is improved; as a result, the population reproduction is more effective in the interior than in the ecotone (Tarwid 1987, Tarwid and Łuczak in print). The present studies fully confirm this conclusion.

*E. ovata* "cares" for its survival in a given habitat in different ways; for example, in the ecotone the number of eggs laid is increased to a maximum, for compensation of the higher mortality of the embryos and hatching young spiders. The fact that the mortality of hatching young spiders is lower in the interiors than in the ecotones allows for laying a smaller number of eggs; i.e. for reduction of the expenditure of the population for reproduction. This may be termed "ecological strategy of the species" which may replace the "physiological strategy

of the species" reported by Kessler (1971) with respect to the *Pardosa* genus. This author has discussed four species of this genus; in the case of a food deficiency two of them maintained an unchanged number of eggs in the cocoon at the expense of own body tissues (loss of weight), whereas two other species laid smaller cocoons, adjusting the fecundity level to the supply of food. This diversity of the means for species survival is extremely interesting phenomenon, not yet fully elucidated in population life of spiders.

Population studies of *E. ovata* in Silesia, Kampinos Forest near Warsaw and Masurian Lakeland (Tarwid 1984, 1987) have resulted in some general conclusions. It has been found that the forest ecosystem of Upper Silesia (most degraded by the impact of the coal industry), as compared with the other regions studied, was characterized by the widest range of the number of eggs per cocoon, occurrence of so-called zero cocoons (empty cocoons) and highest mortality of hatching young spiders. Moreover, in the terrains polluted by industrial emissions, in contrast to those free from pollution, in the ecotones of mixed forest islands and birch-aspen woodlots (i.e. with increasing exposure to pollutions) the cocoon density has been found to decrease, the number of eggs per cocoon dropped and the mortality of hatching young spiders rose. In the vicinity of pollution emitters, i.e. in the most pollution-loaded habitats, the strategy of population reproduction has been observed to change. In forest interiors, i.e. in habitats better shielded from the action of pollution than the ecotones, the cocoons have been shown to be larger and the losses in population reproduction were smaller than in the ecotones, in contrast to nonpolluted ecosystems.

These earlier studies have testified to high sensitivity of *E. ovata* to environmental factors, in this case to industrial pollution of the environment.

According to the present results, the reproducing *E. ovata* populations react similarly to varying conditions of the forest island ecotones. The effect of variation of the conditions prevailing in the ecotone on *E. ovata* populations manifests itself evidently in the ecotones with southern and northern exposure. This problem was investigated in the years 1988 and 1991–1992. Analysis of *E. ovata* fecundity as a function of ecotone exposure showed that the ecotones with southern exposure afford better developmental conditions for spiders than the shaded ones with northern exposure (Tarwid and Łuczak in print). In the southern ecotones the female and cocoon densities are higher, large cocoons are more abundant and the mortality of hatching young spiders is lower; thus, the effectiveness of reproduction is higher. It is stressed that the above differences in female fecundity between the southern and northern ecotones are more pronounced in warm and sunny seasons, whereas they disappear in cold and rainy seasons, when climatic factors are more uniform in both types of ecotones.

In general, high sensitivity of *E. ovata* to changes in the environments conditions in the ecotones and forest interiors, as well as different reproduction strategies "applied" by this species for survival in a definite habitat were observed.

## 5. SUMMARY

Analysis was made of population numbers, female fecundity indices (size, validity and viability of cocoons) and losses in *E. ovata* population reproduction in forest island ecotones (Fig. 1). The objective of the studies was to evaluate the importance for *E. ovata* reproduction, of ecotone differentiation related to vegetation type, forest island size and ecotone exposure.

The results showed that the density of females and cocoons is higher in the ecotones of mixed forest islands than in these of the birch-aspen woodlots, whereas female fecundity measured by the number of eggs laid and their viability is higher in the birch-aspen forest island ecotones (Tables 1, 2, 3 and 4). Comparison of the fecundity indices for the forest island interiors and ecotones indicated that in the case of the investigated forest islands of different sizes, the reproduction indices preserve the properties characteristic of these habitats at a 13.5-ha forest island size. With a reduction of forest island size, the differences in the values of the indices between forest island ecotone and interior are found to decrease (Tables 5 and 6). Irrespective of the vegetation type and forest island size, the southern ecotones, characterized by greater female and cocoon density, larger cocoons and lower mortality of hatching young spiders, as compared with the northern ecotones, were usually more advantageous for *E. ovata* reproduction (Tables 7 and 8). Moisture conditions of forest islands may modify some *E. ovata* fecundity indices in these habitats (Table 9). Moreover, a type of weather greatly departing from the normal conditions (long-lasting heat and drought) may lead to a situation when the northern ecotones become more suitable for *E. ovata* reproduction than the southern ones (Table 10).

## 6. POLISH SUMMARY

Analizowano liczebność populacji, wskaźniki płodności samic: wielkość, wartościowość i żywotność kokonów i straty w rozrodzie populacji *Enoplognatha ovata* w ekotonach wysp leśnych (rys. 1). Celem pracy była ocena znaczenia zróżnicowania ekotonów, wynikającego z typu roślinności, wielkości wyspy i położenia ekotonu w stosunku do stron świata dla rozrodu tego pająka.

Badania wykazały, że w ekotonach wysp boru mieszanego występuje większe niż w ekotonach wysp brzoźowo-osikowych zagęszczenie samic i kokonów, natomiast płodność samic mierzona liczbą składanych jaj i żywotnością jest korzystniejsza w ekotonach wysp brzoźowo-osikowych (tabele 1, 2, 3 i 4). Porównanie wskaźników płodności w ekotonach i wnętrzach wysp wykazało, że spośród badanych wysp, wielkością przy której wskaźniki rozrodu zachowują cechy charakterystyczne dla tych środowisk jest 13,5 ha. W miarę zmniejszania się powierzchni wyspy, zmniejszają się różnice w wartościach wskaźników pomiędzy ekotonem a wnętrzem wyspy (tabele 5 i 6). Stwierdzono też, że niezależnie od typu roślinności i wielkości wyspy, dla rozrodu *E. ovata* na ogół korzystniejsze niż ekotony północne są ekotony południowe, gdzie występowało większe zagęszczenie samic i kokonów, większe kokony i mniejsza śmiertelność wylęgających się młodych pajaków (tabele 7 i 8). Warunki wilgotnościowe danej wyspy mogą modyfikować niektóre wskaźniki płodności *E. ovata* w tych środowiskach (tabela 9); a także odbiegający w znacznym stopniu od normy typ pogody (długotrwałe upały i susza) mogą powodować, że ekotony północne stają się dla rozrodu tego pająka środowiskiem dogodniejszym niż ekotony południowe (tabela 10).

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