Mirosława TARWID

Department of Bioindication, Institute of Ecology, Polish Academy of Sciences,
Dziekanów Leśny (near Warsaw), 05—092 Łomianki, Poland

FECUNDITY OF THE SPIDER *ENOPLOGNATHA OVATA* CL. IN WOODLOTS OF THE AGRICULTURAL LANDSCAPE OF NORTH-EASTERN POLAND

ABSTRACT: Fecundity of females and reproduction rate of a population of the spider were examined in woodlots situated in different agricultural landscapes of the Masurian Lakeland. For each woodlot the following variables were determined: seasonal changes in the rate of reproduction, population density, fecundity of females in terms of three indices such as the size, validity, and viability of cocoons, also potential and realized productivity of the population, and percentage losses as a result of egg and young mortality.

It has been found that birch-aspen woodlots as compared with pine-oak woodlots provide more suitable conditions for survival and reproduction of *Enoplognatha ovata* populations. Also small forest islands, or these located close to other islands or large forests, are more suitable for reproduction of this spider.

KEY WORDS: spiders, fecundity, woodlots, landscape.

1. INTRODUCTION

Enoplognatha ovata is a common spider living in the herb layer and even in the shrub layer of many forest in Poland. It is one of the dominant species in spider communities of these habitat types. With respect to the way of reproduction, this is a suitable object for the study of fecundity. Females lay only one cocoon (S e l i g y 1971), thus it represents the total fecundity of an individual. Moreover, cocoons are easy to find as females lay them on leaves folded in a characteristic way, and stay nearby. Due to their blue colour, it is easy to distinguish them from the cocoons of other spiders. Thus, this spider can be used as a model species in the studies of the effects of various factors such as site conditions, food, and man-produced disturbances due to industrial or agricultural developments on the reproduction of individuals

and population size. In addition, Ł u c z a k (1984, 1991) has found that *E. ovata* is one of the main dominants in the study area.

In earling years, the effect of habitat quality on the fecundity of *E. ovata* was analysed in the areas polluted with industrial emission in the Rybnik Coal Basin (T a r w i d 1984). Also preliminary studies were conducted on the effect of habitat and food conditions on the reproduction of this species in a forest ecosystem, its ecotone, and mid-field woodlots (T a r w i d 1987). Thus, when the study on *E. ovata* fecundity was initiated in the Masurian Lakeland, preliminary results from various types of forest ecosystems were already available.

Urban, industrial, and agricultural developments account for a deep transformation of the natural landscape of Poland. Large forests disappear, and they are replaced by small woods, various kinds of tree clumps and forest islands increasing the mosaic character of the environment. This gives rise to the problem of the importance of these transformations to survival and reproduction of animal populations. It is known that small wooded areas are more affected by the surrounding areas than large forests. They are characterized by a greater variability of climatic conditons, including temperature, humidity, and winds. They are also more exposed to various kinds of pollution (F l e m m i n g 1983). Their vegetation is highly diversified as some forest species disappear, and they are replaced by plants from surrounding habitats and by synanthropic species (T i s c h l e r 1971, W ó j c i k 1991). This is followed by changes in animal communities, including species composition, distribution, numbers, and densities (G ó r n y 1968, G r o m a d z k a 1970, G r o m a d z k i 1970 and others). Woodlots are inhabited by more insect species than forests (D ą b r o w s-k a-P r o t 1980, 1987, 1991). They also provide sites for daily and seasonal migrations of various species and groups of insects, e.g. coccinellids (G a ł e c k a 1991), or for migrations caused by agrotechnical treatments. The density and biomass of spiders are much higher in woodlots than in crop fields. However, only some species reach higher abundance in woodlots than in forests (Ł u c z a k 1984). Thus, woodlots, like forests, are an important component of the landscape structure for spiders.

The purpose of the present study was an analysis of fecundity of *Enoplognatha ovata*, an indicator spider species, in forest islands differing with respect to the origin of plant community, size, and location in the landscape. The literature data show that many factors can affect fecundity of spiders, including the number of cocoons laid by female, number of eggs per cocoon, and the weight of eggs. These factors involve body weight of the female (B r i s t o w e 1939, M i k u l s k a and J a c u ń s k i 1968, K e s s l e r 1971), secretive mode of life and intervals between successive cocoons (M i k u l s k a and J a c u ń s k i 1968, V a l e r i o 1976), and food, the role of which has no consistent interpretation (B r i s t o w e 1939, T u r n b u l l 1962, K e s s l e r 1971, T o f t 1974, V a l e-r i o 1976, W i n g e r d e n 1977). Some authors noted the role of the timing of cocoon laying in the season (E d g a r 1971), also weather conditions and habitat structure (T o f t 1974).

The effect of these factors on spider fecundity was occasionally estimated from egg weight, but typically from the number of eggs per cocoon and their hatchability, using frequently only first cocoons. M i y a s h i t a (1969) also estimated the percentage of dead embryos and unhatched egg. K i r i t a n i and K a k i y a (1975) employed a population approach, and they determined factors affecting the percentage of females in the population. There are also data on the reduction of eggs in cocoons by egg parasites and predators (R o l l a r d 1989).

The indices calculated in the present paper, closley relating individual fecundity with population productivity, are rather unique in the arachnological literature. And I do not know of any so detailed description of different stages of reproduction of *E. ovata*.

2. STUDY AREA AND METHODS

The study was carried out in the river Jorka basin in the Region of Great Masurian Lakes, north-eastern Poland. This area represents a mosaic of habitats due to its relief, different kinds of water bodies, and small farms. According to K o n d r a c k i (1972), forests cover 29.6%, crop fields 48.4% meadows and pastures 11.3%, and lakes 7% of the total area. Forest communities and other vegetation on this area are largely diversified with respect to site conditions, species composition and plant associations. The vegetation ranges from water and shore communities, through meadows, pastures and forests to synanthropic communities. A characteristic feature of this landscape is a large number of woodlots in farmland, which are remnants of large forests, or spontaneously developed as a result of succession on wasteland.

Eight woodlots were selected for this study, of which four were remnants of a one-hundred-years old mixed pine-oak forest (Pino-Quercetum), and the other four were young spontaneously growing birch-aspen woods. Their floral and phytosociological description is given by W ó j c i k (1991). Two of the pine-oak sites had areas of 35 ha and 13.5 ha, the other two were small 1-ha forest islands, which differed in their location: one was close to the two large sites, and another one was isolated in crop fields. The birch-aspen woodlots covered small 0.125−1.5-ha patches located close to each other. Two of them were dry, on moraine hills, two others had small depressions always filled with water.

Cocoons of *Enoplognatha ovata* were collected from all these sites over the breeding period, that is, in July−September. The samples were taken in the interior and at ecotones of different exposures (east, south, etc.) and bordering on different habitats such as another woodlot or crop fields. The importance of ecotones and their diversity for the reproduction of *E. ovata* will be the subject of another paper. Here, the importance of forest islands as a whole is analysed.

To obtain information on the population size of adult spiders, the density of females was estimated several times prior to the onset of breeding. Also the rate of the initiation of breeding was estimated by calculating the percentage of females that

already laid their cocoons. This was done at several time points at the beginning of the breeding season.

Cocoons were collected several times over the breeding period of *E. ovata*, and raised in laboratory until they hatched. The following variables were counted: young spiders leaving cocoons, embryos and fully developed young spiders unable to hatch, and unhatched eggs without traces of embryos, considered as unfertilized. The method is described in detail by T a r w i d (1984).

The following indices were used for the analysis: (1) number of cocoons collected over a specified time from a given site, (2) the size of cocoons i.e., the number of eggs
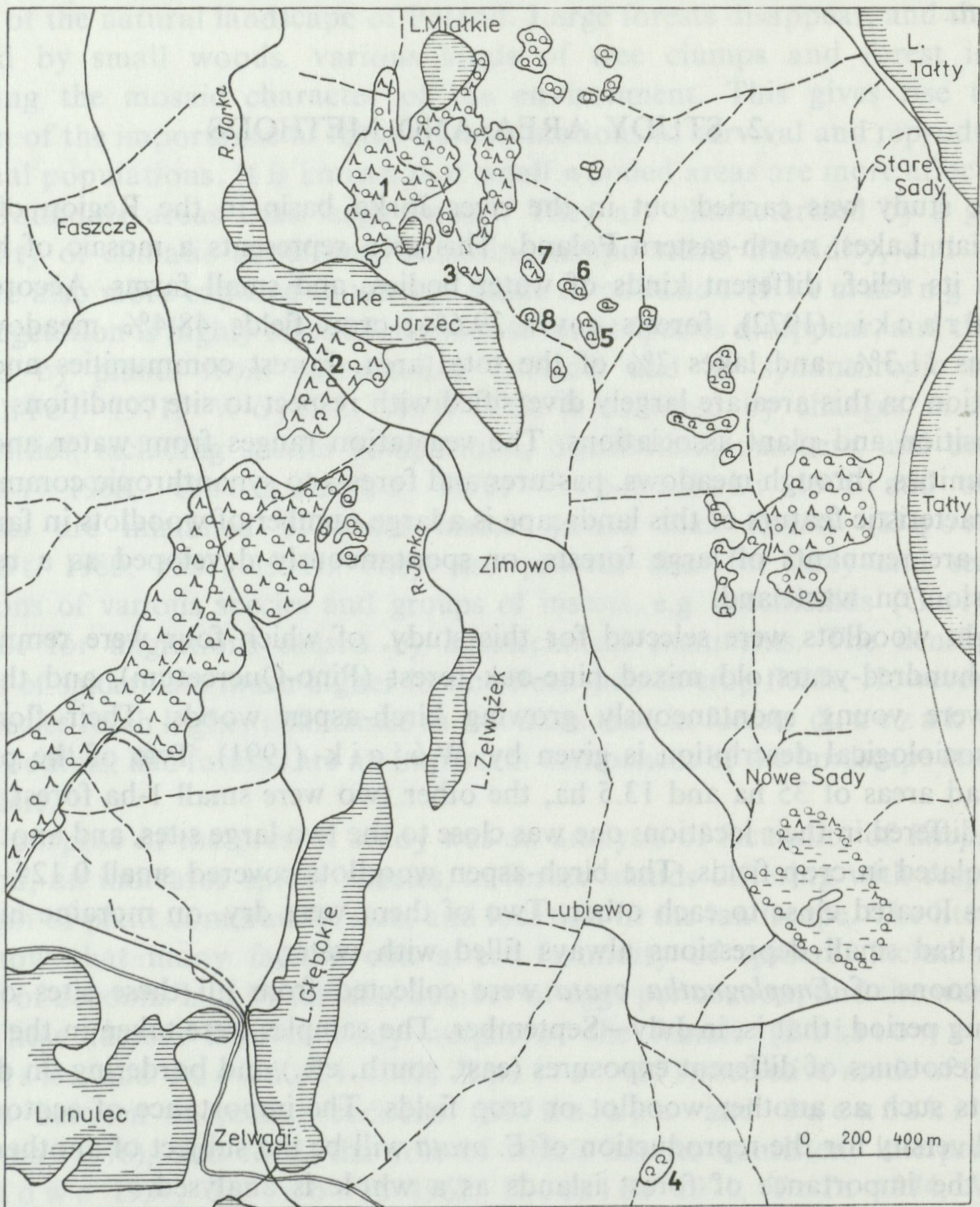

Fig. 1. Distribution of the forest islands under study in the landscape (after D ą b r o w s k a-P r o t 1991)
Numbers from 1 to 8 denote study woodlots

per cocoon, (3) the validity of cocoons, defined as the percentage of fertile eggs (also called valid eggs) in a cocoon (potential fecundity), (4) the viability of cocoons, defined as the percentage of the young spiders hatched in the total number of eggs in a cocoon (realized fecundity).

Also percentage losses were calculated in the reproduction of the population due to (1) embryonal mortality (difference between the validity and viability of cocoons), and (2) total losses (dead embryos and unfertile eggs), that is, the difference between the number of eggs in a cocoon and the number of spiders hatched from this cocoon.

As cocoons were collected throughout the breeding period, it was possible to follow changes in intensity of laying over time. The materials were collected in 1986 – 1988. A total of 1381 cocoons and 149 427 eggs were examined. Cocoons damaged, mildewed, laid by ill females (eggs lumped, sometimes forming a clod of egg matter), thus in which it was not possible to count eggs, were excluded from the analysis. Also the cocoons damaged by Hymenoptera, a rare event in the study area (1 or 2 cocoons per season), were not analysed.

The fecundity of *Enoplognatha ovata* was compared for all pine-oak woodlots (sites 1 – 4) combined and all birch-aspen woodlots (sites 5 – 8) combined (Fig. 1), and then individual sites were compared within each of these two habitat groups, taking into account their size and location.
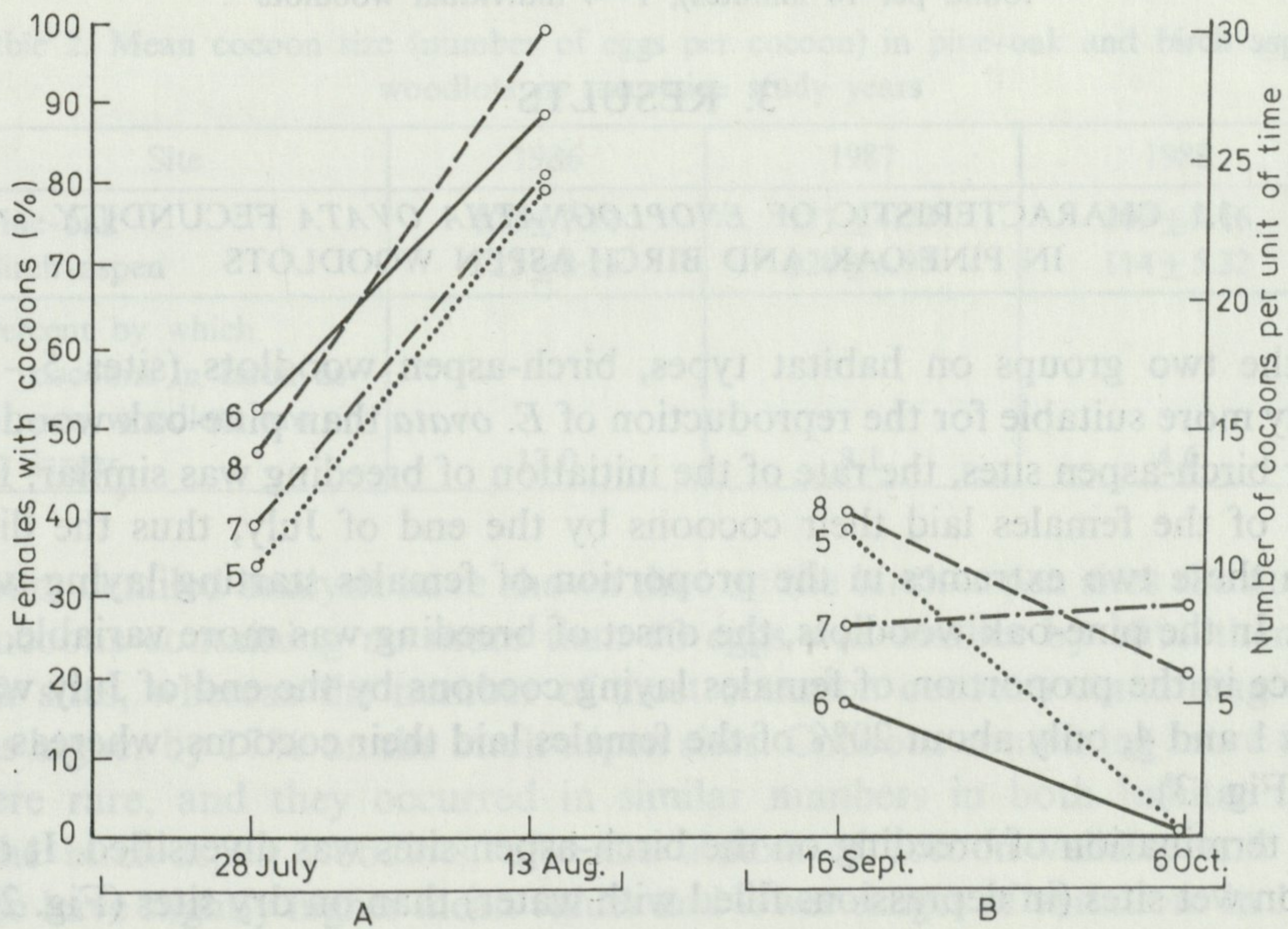

Fig. 2. Seasonal changes in the rate of reproduction of *Enoplognatha ovata* in birch-aspen woodlots in 1987

A — intensity of reproduction at the beginning of the season (estimated as the percentage of females with cocoons), B — intensity of reproduction at the end of the season (estimated as the number of cocoons found per 10 minutes), 5–8 — individual woodlots
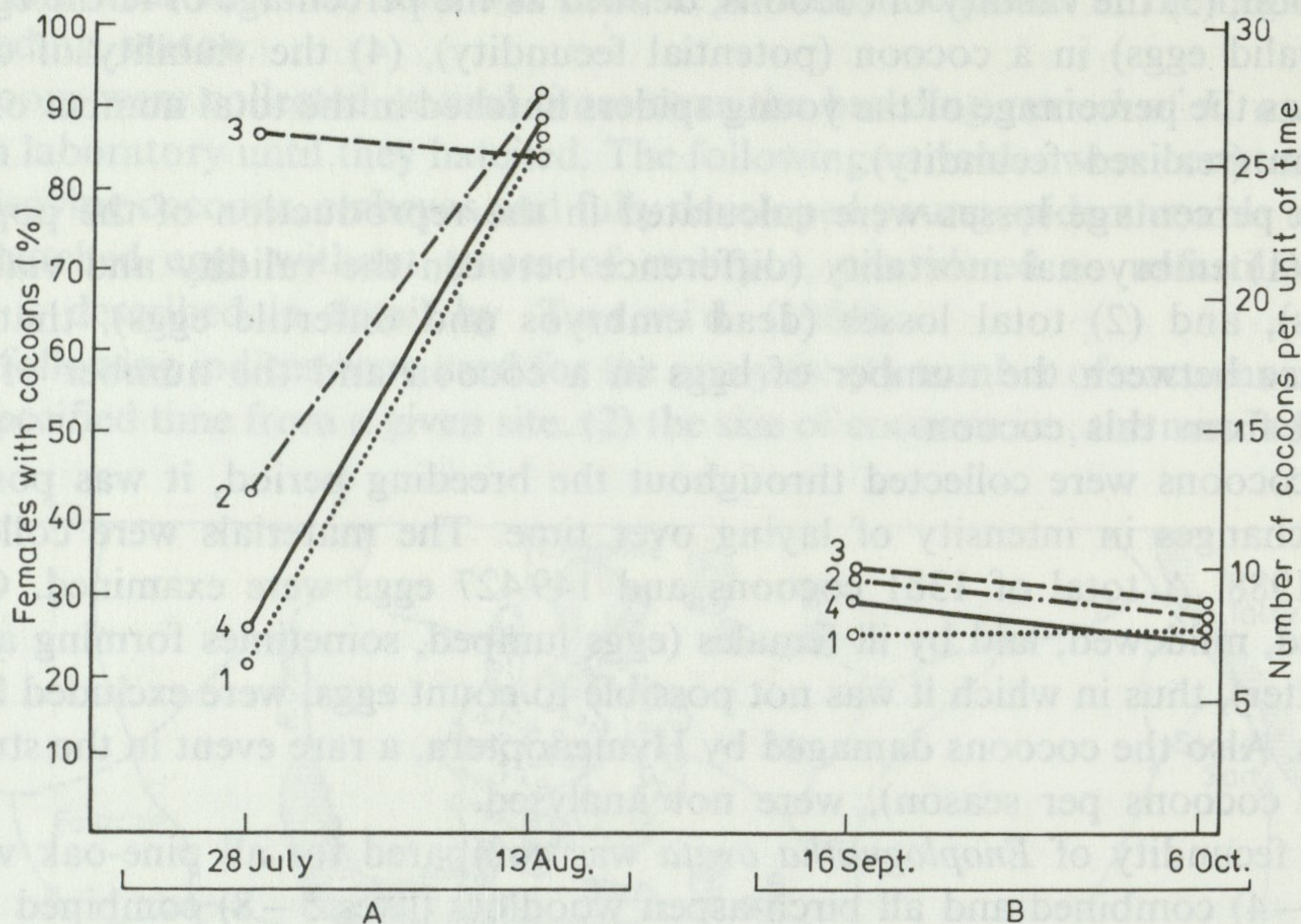
Fig. 3. Seasonal changes in the rate of reproduction of *Enoplognatha ovata* in pine-oak woodlots in 1987 A — intensity of reproduction at the beginning of the season (estimated as the percentage of females with cocoons), B — intensity of reproduction at the end of the season (estimated as the number of cocoons found per 10 minutes), 1—4 individual woodlots

3. RESULTS

3.1. CHARACTERISTIC OF *ENOPLOGNATHA OVATA* FECUNDITY IN PINE-OAK AND BIRCH-ASPEN WOODLOTS

Of the two groups on habitat types, birch-aspen woodlots (sites 5—8) were generally more suitable for the reproduction of *E. ovata* than pine-oak woodlots. On the four birch-aspen sites, the rate of the initiation of breeding was similar. From 33 to 52% of the females laid their cocoons by the end of July, thus the difference between these two extremes in the proportion of females starting laying was 19% (Fig. 2). In the pine-oak woodlots, the onset of breeding was more variable, and the difference in the proportion of females laying cocoons by the end of July was 65%. On sites 1 and 4, only about 20% of the females laid their cocoons, whereas 86% on site 3 (Fig. 3).

The termination of breeding on the birch-aspen sites was diversified. It occurred earlier on wet sites (in depressions filled with water) than on dry sites (Fig. 2). In the pine-oak woodlots, the termination of reproduction followed a similar pattern on all the sites, and it was more extended in time than on the birch-aspen sites (Fig. 3). The delayed onset of cocoon laying and the prolongation of the breeding period could have been related to environmental conditions over winter and spring, as it is known that they affect individual development and maturation of females. The pine-oak

sites are cooler than birch-aspen sites, especially in spring, and this can account for a delayed beginning of the active life and, consequently, for a delayed cocoon laying.

It has also been found that in the birch-aspen woodlots the density of females and cocoons tended to be higher than in the pine-oak woodlots. Also the mean size of cocoons was larger in the former habitats (Table 1). This tendency persisted over the three-year study period, when the mean cocoon size in the birch-aspen sites exceeded than in pine-oak sites by 4.6−13.0% (Table 2).

Table 1. Density of female *Enoplognatha ovata* and fecundity indices on pine-oak and birch-aspen woodlots in 1988

Site	Site No.	Density of females per m²	Number of cocoons found per unity time = 10 min	Mean cocoon size (number of eggs per cocoon)	Cocoon validity (% developing eggs)	Cocoon viability (% young hatched
Pine-oak	1	1.1	5.2	102 ± 20.99	93	86
	2	4.4	9.9	117 ± 10.52	94	88
	3	5.1	10.5	110 ± 14.57	90	86
	4	2.2	4.3	106 ± 20.89	98	90
Birch-aspen	5	4.6	9.9	124 ± 9.80	96	91
	6	7.7	13.7	119 ± 8.60	94	88
	7	2.8	12.2	104 ± 10.85	95	88
	8	1.1	8.2	107 ± 13.00	99	93

Table 2. Mean cocoon size (number of eggs per cocoon) in pine-oak and birch-aspen woodlots in successive study years

Site	1986	1987	1988
Pine-oak	108 ± 7.71	111 ± 4.77	109 ± 8.16
Birch-aspen	122 ± 8.13	120 ± 6.77	114 ± 5.32
Percent by which cocoons in birch-aspen woodlots are larger	13.0	8.1	4.6

A more detailed analysis have shown that on the birch-aspen sites the number of small cocoons containing no more than 60 eggs was smaller by 10% than on the pine-oak sites, whereas the number of most common cocoons containing 60−150 eggs was higher by 17% on the birch-aspen sites. Cocoons containing more than 150 eggs were rare, and they occurred in similar numbers in both habitat types.

In the birch-aspen woodlots, also the indices of cocoon validity and viability tended to have slightly higher mean values and lower ranges of variation. In 1988, the range of the validity index was 94−99% and that of the viablility index 88−93%, whereas in the pine-oak woodlots the respective figures were 90−98% and 86−90% (Table 1). Table 3 shows the results for the three successive study years.

It should be remembered than individual sites within each of the two site groups differed in their size, location, and relief, and these factors, as will be shown later,

Table 3. Ranges of the validity and viability indices (in percent) in pine-oak and birch-aspen woodlots

Site		Indices	1986	1987	1988
Pine-oak	1—4	validity	88—96	72—92	90—98
Birch-aspen	5—8		91—97	82—92	94—99
Pine-oak	1—4	viability	82—93	62—83	86—90
Birch-aspen	5—8		77—91	65—82	88—93

have an effect on the reproduction of *E. ovata* population. Fecundity indices depend not only on population factors and biotic characteristics of the environment, but also on weather conditions and anthropogenic factors, especially in the case of viability index.

Thus, although differences in the mean values of fecundity indices between the two habitat groups were small, they were persistent, and it may be suggested that the validity and viability of cocoons tended to be higher in the birch-aspen woodlots. Presumably, this was related to better food conditions in these habitats. D ą b-r o w s k a - P r o t (1991) has found that the potential prey of spiders (insects) were richter there than in pine-oak woodlots.

Table 4. Reproductive losses in *Enoplognatha ovata*, calculated as the difference between the number of eggs laid and the number of spiders hatched (A), and as the difference between the number of fertilized eggs and the number of spiders hatched (B)

Site No. of site	A. Total reproductive losses			B. Losses in potential reproduction (difference between cocoon validity and viability)		
	1986	1987	1988	1986	1987	1988
1	18	32	14	6	14	7
2	11	17	12	6	9	6
3	7	24	14	3	13	4
4	18	38	10	8	10	8
5	14	33	9	5	15	5
6	9	19	12	5	7	6
7	13	32	12	4	15	7
8	33	27	7	26	15	6

Analysing losses in population reproduction due to the mortality of embryos and young developing spiders and also due to unfertile eggs, two categories of losses were distinguished: total losses, calculated as the difference between the total number of eggs in cocoons and the number of spiders hatched from them (in percentage), and losses in the potential fecundity, calculated as the difference between the indices of cocoon validity and viablility (Table 4). These two categories of losses did no show relationship to the vegetation type of the study sites. No clear and recurrent differences were observed between pine-oak and birch-aspen wood-lots. Thus, the losses were dependent on other factors than the origin and type of plant cover. In both habitat categories there were sites where percentage losses were

small and little variable from season to season (e.g. sites 2 and 6) and sites where losses were very high and variable from season to season.

It seems, however, that adverse weather increased losses in reproduction. Such an increase was observed in the rainy and cold season of 1987 on all the sites, except for site 8. The total losses ranged from 5 to 20%, and the losses in the potential fecundity ranged from 1 to 11% (Table 4).

Based on the fecundity indices such as cocoon size and viability and the density of females on individual sites, the number of young hatchet and living on these sites was estimated (Table 5). It was higher by about 30% in the birch-aspen woodlots as compared with pine-oak woodlots.

Table 5. Density (individuals per m²) of young *Enoplognatha ovata* in woodlots in 1988, estimated from the indices of female densities, mean number of eggs per cocoon, and mean viability of a cocoon

Parameter \ Site	Pine-oak					Birch-aspen				
	1	2	3	4	x̄	5	6	7	8	x̄
Number of eggs laid per m² (density of females times mean cocoon size)	112	515	561	233	355	570	916	291	118	474
Numbers of young leaving cocoons (per m²)	96	453	482	210	310	519	806	256	110	423

Table 6. Density of female *Enoplognatha ovata* (individuals per m²) in the interiors and ecotones of forest islands

No. forest island	Pine-oak				Birch-aspen			
	1	2	3	4	5	6	7	8
Interior	<1	0.3	0.7	1.3	0.5	2.0	0.8	0.7
Ecotone	2.2	8.5	7.7	3.0	8.7	13.3	4.8	1.5
Ratio $\frac{ecotone}{interior}$	>2.2	28.3	11.0	2.3	17.4	6.7	6.0	2.1

Table 7. Numbers of *Enoplognatha ovata* cocoons in the interiors and ecotones of forest islands (mean values per 10 min)

No. forest island	Pine-oak				Birch-aspen			
	1	2	3	4	5	6	7	8
Interior	<1	1.9	3.9	3.1	5.3	4.4	12.2	5.8
Ecotone	10.1	17.7	13.3	5.8	11.9	19.0	12.1	10.0
Ratio $\frac{ecotone}{interior}$	>10.0	9.5	3.5	2.0	2.0	4.5	1.0	1.5

Although, as already noted, the role of ecotones in the reproduction of *E. ovata* will be analysed in a separate paper, it should be emphasized here that ecotones are preferred to habitat interiors by this spider. The density of females at the ecotones was 2 – 28 times that in the interiors (Table 6), and numbers of cocoons were about

Table 8. Cocoon size (number of eggs) in the interior and ecotone of forest islands
(mean values for three years)

Site	Pine-oak				Birch-aspen			
	1	2	3	4	5	6	7	8
Interior	94.6	106.9	107.1	108.2	116.6	130.5	107.9	113.3
Ecotone	108.3	112.9	119.0	101.5	130.1	132.8	123.8	115.4
Percent by which cocoons at ecotone are larger	14.5	5.6	11.1	0	11.6	1.8	14.7	1.9

1.5 — 10 times higher (Table 7). The cocoons are larger at the ecotones, too (Table 8).
It should be noted, however, that only in large forests the situation is clear, cocoons
being much larger than in the interior, whereas in forest islands, especially small, the
reproductive output of *E. ovata* depended on the quality of the ecotone (i.e., whether
it was cool or warm), weather, and island size.

A comparison of the density of cocoons at the ecotone and in the interior of forest
islands (Table 7) shows that the ratio of these densities is lower in the birch-aspen
woodlots than in the pine-oak woodlots. This implies that the interiors of the
birch-aspen habitats are more similar to their ecotones in terms of their suitability for
the reproduction of *E. ovata* than are the interiors of the pine-oak habitats.

3.2. SIZE AND LOCATION OF WOODLOTS VERSUS THE REPRODUCTION OF *ENOPLOGNATHA OVATA*

As stated above, pine-oak woodlots differed in their size and location in the
landscape. Analysing the effect of habitat size on fecundity and productivity of
E. ovata, sites 1, 2, and 3 were compared in the gradient of their size (35 ha, 13.5 ha,
and 1.0 ha), and also sites 1 and 3 (the largest and the smallest). In both cases no
significant differences were found for the cocoon size, and of validity and viability
(Table 1). Large differences were found, however, in the density of females, cocoons,
and young spiders hatched (Tables 1, 5). As compared with the largest site 1, the
density of females on site 2 was 4 time higher and the number of young hatched was
about 4.5 times higher. The respective values on site 3 were 4.6 and 5.0 times higher.
Such a situation was observed in two successive study years, although they differed
in weather conditions. It can thus be suggested that smaller woodlots provide more
suitable conditions for the reproduction of this species. Of the two large forest
islands, that is, sites 1 and 2, reproduction was better on site 2. Moreover, the
E. ovata population living on this site showed a high stability and resistance to
adverse weather conditions that occurred in 1987 and caused high fecundity losses
on other sites (Table 4).

The effect of the location of forest islands on the reproduction of *E. ovata* was
analysed by comparing two pine-oak sites of the same size (1.0 ha). One of them, site
3, was located close to a large forest. Presumably, it was a part of this forest, isolated

as a result of human activity (W ó j c i k 1991). The other one, site 4, was located in crop fields, far from other forest islands. It was more than other sites exposed to agricultural treatments such as chemical plant protection (it is known that potatoes were sprayed in 1988). As a result, the condition for spider life and reproduction could have been poorer than on site 3, this being reflected in lower numbers of mature females and lower density of cocoons (Table 1), generally lower fecundity indices (Table 3), and also in fecundity losses (38% in 1987) which were highest on site 4 of all the pine-oak and birch-aspen sites (Table 4). The number of young spiders hatched on site 4 was lower by half than on site 3 (Table 5), and this was the case from year to year. Moreover, fecundity indices showed large variation from year to year. Thus, it seems that among pine-oak sites, more suitable conditions for the reproduction of *E. ovata* were in smaller habitats of forest islands and in those situated close to other woodlots.

The group of birch-aspen sites was also diversified with respect to their size (from 0.125 to 1.5 ha), and, in addition, with respect to the presence of water and relief. Two of them (sites 7 and 8) were dry and situated on a small elevation. Two others (sites 5 and 6) had depressions with stagnant water, surrounded with a rather narrow belt of trees and shrubs. The analysis of *E. ovata* fecundity on individual sites of this group showed that the most suitable conditions for reproduction were on site 6. In the three study years, the density of adult females and the density of cocoons were highest here (Table 1), and also the density of the young spiders hatched was the highest (Table 5). Moreover, like on site 2 in the first group, the reproduction on site 6 showed a high stability as reflected in a low percentage of losses when they were very high on other sites (Table 4).

Sites 5 and 7 differed with respect to the reproductive success of *E. ovata* (Table 5). Spider populations on these sites differed in the density of females and cocoons, and also in the values of validity and viability indices, which showed annual differences. As a result, the reproductive output, that is, the density of young spiders, also differed. The number of spiders hatched in 1986 and 1987 was much higher on site 7 than on site 5. The validity and viability indices were similar, but due to a higher density of females and cocoons on site 7, numbers of young spiders were higher on this site. In 1988, however, the number of spiders hatched on site 7 was lower by half than on site 5 (Table 5), as the density of females was lower, cocoons were smaller, and the indices of validity and viability were smaller as well (Table 1).

In view of the fact that site 5 is three time larger than site 7, and site 7 equals site 6, the habitat size did not affect the reproduction.

Among the birch-aspen sites, site 8 was least suitable for *E. ovata* population. The densities of females and cocoons were the lowest there (Table 1), and numbers of spiders hatched were lowest too (Table 5). There were different reasons for a poor reproduction on this site. For example, in 1987, high losses were due to a high mortality of embryos (Tables 4 and 3), whereas in 1988 a low number of females laid cocoons (Table 1). Thus, the population was reduced at different stages of its existence. In the first case at early stages of development and in the second case at the adult stage.

The reasons for low and variable indices of *E. ovata* fecundity should be looked for in the size and location of this site. This was a tiny 0.125 ha stony forest island, located in crop fields, bordering on a road, and used as a damping place for various kinds of wastes. Perhaps these perturbations can provide an explanation for a sudden occurrence of extremely high mortality of embroys and young hatching spiders (the difference between the validity index, that is, potential fecundity, and the viability index, that is, realized fecundity) in 1986 (Table 4). But generally low densities of the population on this site over the three study years, and a high variability of fecundity indices could also result from a small food capacity of this habitat. It had a limited capacity of retaining the fauna immigrating from surrounding habitats and, consequently, it did not support many insects, the potential prey of spiders (D ą b r o w-s k a-P r o t 1991). Also other species of spiders were less abundant on this site than on the other forest islands (Ł u c z a k 1991).

It should be noted, however, that *E. ovata* population on site 8 showed a great capacity to recover. In 1986, reproductive losses were very high. As many as 26% of fertile eggs did not hatch (Table 4). On the other sites, this proportion ranged from 3 to 8%. The following year was unsuitable with respect to weather conditions, and on most sites the proportion of losses increased 2−4 times, except for sites 2 and 3 where this proportion was low, being resistant to adverse conditions, as stated above. Losses on site 8, however, were reduced by 11%, levelling with the losses on the other sites. In 1988, further improvement took place (Table 4). Thus, it seems that the high variation in the reproductive output of this population on site 8 was determined by biotic conditions such as food, also by the habitat size, and anthropogenic factors such as littering, pollution, etc.

4. DISCUSSION

The present study shows that birch-aspen woodlots are more abundantly inhabited by *Enoplognatha ovata* populations than pine-oak woodlots (see also Ł u c z a k 1991). Birch-aspen woodlots provide more suitable conditions for survival and reproduction as reflected in higher numbers of females and cocoons, and higher indices of fecundity, including cocoon size, validity, and viability, and, consequently, in a higher production of young spiders entering the population. These habitats, therefore, constitute as important component of the landscape with respect to the development of these populations.

It has also been found that the size of woodlots is important to the reproduction of this species. Both very big and very small forest islands are unsuitable, as population numbers and fecundity of this spider are clearly lower there. A similar pattern with respect to entomofauna was found by D ą b r o w s-k a-P r o t (1991).

Smaller woodlots were more suitable for *E. ovata* population probably due to a more suitable ratio of the ecotone area to the interior area. It is know that *E. ovata* in general is more abundant and lays larger cocoons at ecotones. In the largest,

35-ha pine-oak woodlot, the density of females, number of cocoons, and number of eggs per cocoon were low, whereas reproductive losses were high. Consequently, the number of young spiders hatched in this habitat was lagerly reduced. In the very small 0.125-ha woodlot, its interoir resembled the ecotone in many respects, but this habitat could not provide stable conditions for the development of this species because of a reduced food supply and heavy anthropogenic transformation.

With respect to the location in the landscape, more suitable conditions for the development of this spider seem to occur on forest islands situated close to each other than in isolated woodlots in crop fields, far from wooded areas.

5. SUMMARY

Fecundity of *Enoplognatha ovata* was examined on pine-oak and birch-aspen forest islands differing in size and location within the landscape (Fig 1). The estimates comprised seasonal changes in the rate of cocoon layng (Figs. 2, 3), density of females (individuals per m²), and numbers of cocoons per unit time (10 minutes) (Table 1). The cocoons collected were kept in the laboratory until they hatched. Then the number of young spiders leaving a cocoon was determined, as well as the number of embryos and fully developed spiderlings unable to leave the cocoon, and unhatched eggs.

The following indices were used to characterized the fecundity of females: cocoon size, that is, number of eggs per cocoon, cocoon validity defined as the percentage of fertilized eggs per cocoon (potential fecundity), and cocoon viability defined as the percentage of young spiders leaving the cocoon in the total number of eggs per cocoon (realized fecundity). Also total losses in reproduction (dead embryos and unfertilized eggs) were calculated as a difference between the number of eggs laid per cocoon and the number of young spiders leaving cocoons, as well as losses due to embryonal mortality (difference between the validity and viability indices).

It has been found that *E. ovata* populations in birch-aspen woodlots as compared with those in pine-oak woodlots tend to reach higher densites of females and cocoons, females lay slightly larger cocoons (Tables 1 and 2) which have a little higher validity and a smaller range of variation in the validity and viability indices (Tables 1 and 3). Also the density of young spiders hatched is approximately by one-third higher in birch-aspen woodlots (Table 5).

It has also been found that the size of woodlots and their location play an important part. On the largest and smallest forest islands (35 and 0.125 ha, respectively), densites of females and cocoons were lower (Table 1), and numbers of spiders hatched were low (Table 3). Also the location of forest islands in crop fields far from other woodlots (size 4) is unsuitable, as they are more exposed to the effects of surrounding areas and farming treatments, including chemical plant protection. This impairs the survival and reproduction of spiders, as reflected in lower densities of adult females in the population, lower density of cocoons (Table 1), typically lower fecundity indices and higher reproductive losses (Table 4), and, consequently, lower numbers of spiders hatched (Table 5).

6. POLISH SUMMARY

Badano płodność *Enoplognatha ovata* w wyspach leśnych typu Pino-Quercetum i brzozowo-osikowych, zróżnicowanych pod względem wielkości i usytowania w krajobrazie (rys. 1). Na każdej z nich wyznaczono tempo przystępowania do rozrodu (rys. 2, 3), oceniano zagęszczenie samic (osobniki na 1 m²) i liczebność kokonów na jednostkę czasu (10 min.) (tab. 1). Zebrane na stanowiskach kokony hodowano w laboratorium aż do całkowitego wylęgu młodych pająków. W każdym kokonie liczono młode pająki, które opuściły kokony, embriony i ukształtowane już pająki niezdolne do opuszczenia kokonu i pozostałe w kokonie niewylęgłe jaja.

Płodność samic charakteryzowano stosując następujące wskaźniki: wielkość kokonu czyli liczba jaj w nim złożonych, wartościowość kokonu — procentowy stosunek liczby jaj zapłodnionych do ogólnej liczby jaj w kokonie (płodność potencjalna) i żywotność kokonu — procentowy stosunek liczby młodych pająków, które po wylęgu opuściły kokon do ogólnej liczby jaj w kokonie (płodność zrealizowana). Wyliczono także wielkość strat całkowitych w rozrodzie (martwe embriony i niezapłodnione jaja) — różnica między liczbą wszystkich złożonych jaj a liczbą młodych pająków, które opuściły kokony i straty poniesione w wyniku śmiertelności embrionów (różnica między wskaźnikiem wartościowości i żywotności).

W przeprowadzonych badaniach wykazano, że populacje *E. ovata* w zadrzewieniach brzozo-wo-osikowych mają tendencję do większego zagęszczenia samic i kokonów, nieco wyższej średniej wielkości kokonów (tab. 1, 2), nieco wyższych średnich wartościowości oraz mniejszego zakresu zmienności wskaźników wartościowości i żywotności (tab. 1, 3). Również zagęszczenie młodych wylęgających się pająków jest o około 1/3 większe w zadrzewieniach brzozowo-osikowych niż w Pino-Quercetum (tab. 5).

Stwierdzono także, że wielkość zadrzewienia i jego usytuowanie odgrywa istotną rolę. W największej i najmniejszej wyspie leśnej 35 ha i 0,125 ha, występuje mniejsze zagęszczenie samic i kokonów (tab. 1) i niewielka liczebność młodych, wylęgających się pająków (tab. 5). Niektorzystne jest też samotne położenie wśród pól uprawnych z dala od innych zadrzewień (stanowisko 4), gdyż zwiększa to ekspozycję na wpływy otaczającej je przestrzeni i zabiegi związane z uprawą i ochroną roślin. Stwarza to gorsze warunki życia i rozrodu dla pająków, co znajduje odzwierciedlenie w niższej liczebności populacji dojrzałych samic, mniejszym zagęszczeniu kokonów (tab. 1), na ogół niższych wskaźnikach płodności i większych stratach w płodności (tab. 4), a w konsekwencji mniejszej liczebności młodych, wylęgających się pająków (tab.5).

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