

EKOLOGIA POLSKA (Ekol. pol.)	39	4	481—516	1991
---	-----------	----------	----------------	-------------

Eliza DĄBROWSKA-PROT

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

THE ROLE OF FOREST ISLANDS IN THE SHAPING OF THE STRUCTURE AND FUNCTIONING OF ENTOMOFAUNA IN AN AGRICULTURAL LANDSCAPE

ABSTRACT: Analyses were done of the influence of origin, size and location in landscape of forest islands, on the structure and functioning of entomofauna. It was ascertained that birch-aspen woodlots which form natural overgrowths in wastelands, are significant for the fauna. They have been more intensively inhabited by entomofauna than forest islands of the Pino-Quercetum type, which are the remnants of larger forest complexes from the watershed of the Jorka river in the Masurian District. Between the birch-aspen woodlots and the surrounding cropfields there was a continuous exchange of fauna, particularly in the periods of changing and deteriorating environmental conditions in the agricultural landscape. We think, that this type of woodlots can play an important role in determining the structural and functional character of the fauna.

KEY WORDS: forest islands, agricultural landscape, migration, dispersion, bio-coenotical relations.

1. INTRODUCTION

Each area undergoes characteristic changes and natural (i.e. resulting from progressive aridity) or anthropogenic reshaping, which result from management activities of man. These changes lead to the formation of environmental mosaics which determine the structural character of the entire area and which make the basis for its functioning. Over centuries, in the Masurian lakeland, in northern Poland, the basic unit of space formation has been a forest landscape which, with the development of settlements, the intensification of hunting, forestry and agriculture, has gradually changes into a forest-agricultural or even agricultural-forest landscape. In the latter case, the dominant elements of the landscape structure over large areas are crop fields,

together with a small contribution of larger forest complexes, but mainly with woodlots of different sizes, shapes and origin (Dzieje (...) 1965).

In spite of intensification of agriculture and of other forms of management by man, the proportions of the basic elements of a landscape structure in the agricultural Masurian region are still showing the important contribution of forest environments. Thus, over an area of 35 km² of the watershed of Jorka river, in the vicinity of Mikołajki, in a terrain where small and medium farms dominate, 10% of the surface area is taken by lakes and waterways, 6% by roads settlements, 23% by meadows and pastures, 43% by cropfields, and 18% by forests and woodlots. The latter area makes about one third of the total surface area of fields and pastures (Polakowski et al. 1985). Such structure of the landscape has serious ecological consequences.

Agricultural landscape is characterized by a high variability. Seasonal changes of the cultivated crops structure, management, the maturing and drying of plants in crop fields, will cause, with the passing of the season, deterioration of environmental conditions for the fauna, their intensive migrations within the landscape, and an exchange between different ecosystems. In such a landscape, refuge environments are especially significant for the fauna. They are capable of periodical admittance and sheltering of the migrating fauna, and of its further transfer to other environments during favourable periods of time. In typically agricultural landscapes with prevailing cropfields, such environments are usually found among wastelands, mid-field footpaths, trails and adjacent field roads. In the Masurian agricultural-forest landscape, such role should first of all be taken, by the different types of forest islands which are densely distributed among the cropfields.

A problem arises to identify the role of forest islands in the formation of the structure and functioning of the fauna in such a landscape. Literature devoted to forest islands in an agricultural landscape is rather extensive (Dąbrowska-Prot 1987a). However, relatively few works have analysed their importance for the animals in relation to the morphological characteristics of the islands such as size, shape, location in space and origin. In the present work, we discuss this problem in relation to the shaping and functioning of entomofauna, and particularly the Diptera group, the members of which are dominant among entomofauna actively moving in the landscape.

2. AREA, MATERIALS AND METHODS

2.1. RESEARCH AREA

The study was carried out in north-eastern Poland, in the Masurian Lakeland. The area, shaped by a glacier, is characterized by a mosaic of natural environments (forest islands, woodlots and wastelands) and cropfields. It is further modified by a relief and a net of various types of water reservoirs which form specific land-water environments. These water reservoirs are periodical hatcheries for great quantities of



Fig. 1. Distribution of forest islands and cropfields in the agricultural landscape near Lake Jorzec
 1–4 — Pino-Quercetum forest islands, 5–8 — birch-aspen islands
 A–J — natural ecosystems and plantations; denotations as in Table 3

insects, for example, dipterans, which move en masse in the landscape and inhabit land ecosystems.

Eight forest islands located over an area of ca 10 km² in the watershed of the Jorka river are included in the studies (Fig. 1). Extensive investigations on the biological productivity of ecosystems, conducted for many years in this area by the Institute of Ecology, have provided data on the climate, different types of environments, vegetation and animal communities (Hillbricht-Ilkowska 1983, Traczyk 1985a, 1985b). Four of the investigated islands (No. 1–4) are

remnants after clearing of larger forest complexes in a Pino-Quercetum forest (Polakowski et al. 1985, Traczyk and Kloss 1985, Wójcik 1991). The remaining four islands (No. 5–8) are birch-aspen woodlots, naturally developing in wastelands over elevations, or in depressions. In the latter case, the woodlots contain permanent water pools (islands No. 5, 6).

The chosen study islands are characteristic for the region's elements of the agricultural landscape mosaic. They represent two different ecologically environments, that is relatively old (100 years) well phytosociologically formed, the Pino-Quercetum plant associations, and, on the other hand, much younger, dynamically developing birch-aspen woodlots in the early stage of succession. Detailed botanical description of these forest islands has been given by Wójcik (1991).

The forest islands studied, differ one from another mainly by their origin, and thus by the vegetation structure, but also by their size, the length of the ecotone belt, which is an indicator of their contact with the surrounding cropfields, and they also differ by their location in space (Fig. 1, Table 1).

Table 1. Some parameters describing the forest islands

Forest islands	Size (ha)	Length of ecotone (m)	Ecotone area* (m ²)	Percentage of ecotone area in the size of a forest island
Pino-Quercetum, No.:				
1	35.0	2400	4800	1.4
2	13.5	1500	3000	2.2
3	1.0	430	860	8.8
4	1.0	430	860	8.5
Birch-aspen, No.:				
5	1.5	480	960	6.7
6	0.5	320	640	13.5
7	0.5	280	560	11.5
8	0.125	150	300	24.0

* The adopted value of 2 m is the most frequent ecotone zone width between the forest ecosystem and cropfields.

2.2. METHODS AND MATERIALS

The studies were conducted in 1987–1989. In the entire vegetative season of 1987, once a month, between April and November, during 1–2 days, the entomofauna was sampled in 8 chosen forest islands. Collections were made with an entomological net. A series of 10 samples was taken on each forest island, and each sample was obtained with 25 sweeps of the net.

In the years 1988–1989 the studies concentrated on the ecotone problems, and the sampling of entomofauna was done according to the method described earlier, in three chosen forest islands, (No. 3, 5, 7) and their immediate vicinity: in the interior

of the islands, their ecotones, ecotones of the adjacent crop fields, and in the interior of fields. This way ca. 300 m transects were studied, leading from the interior of the islands to the interior of the crop fields. The results of ecotone studies will be subject to a separate publication, and only some of them have been included in the present paper. In order to compare our quantitative data on adult forms of entomofauna, particularly the dominant Diptera, with the results of Paplińska (unpublished data) on larval forms, whose numbers and biomass were estimated with standard methods and calculated for 1 m² of soil, our data on imagines are recalculated for 1 m² surface area, assuming that 10 samples multiplied by 25 sweeps of the net give their quantity over 60 m² of the environmental surface area. These calculations have been adopted following field sampling and a comparison with literature data (Melničenko 1949).

In addition to that, in the forest islands, microclimatic studies (relative humidity, temperature) were done in the soil, herb, and shrub-layers, ca. 2 m above the ground, in all the habitats investigated. For example, Table 2 gives such data for early spring, when small microclimatic differences might be decisive for the commencement of the phenological cycle in plants and animals. These data show, that birch-aspen woodlots in this period are warmer in all strata of the environment, and within the herb and shrub layers, they are somewhat more dry (Table 2).

Table 2. Temperature (°C) and humidity (%) in the soil and in the herb- and underbrush-layers in the forest islands under study, as recorded on 10th Apr. 1987

Forest islands	Soil				Herb layer				Underbrush layer			
	°C	\bar{x}	humidity (%)	\bar{x}	°C	\bar{x}	humidity (%)	\bar{x}	°C	\bar{x}	humidity (%)	\bar{x}
Pino-Quercetum, No.:												
1	0.2		23.7		7.0		85.0		7.25		93.0	
2	1.0	0.8	15.6	19.8	7.0	7.5	98.0	89.0	5.0	6.8	98.0	91.0
3	0.2		18.5		11.0		75.0		11.0		81.0	
4	0.2		21.3		5.0		98.0		4.0		92.0	
Birch-aspen No.:												
5	1.2		43.3		13.0		71.0		12.25		83.0	
6	3.2	2.05	23.0	28.5	13.75	13.5	72.0	66.0	13.25	13.0	77.0	77.0
7	3.0		19.2		14.5		52.0		13.0		77.0	
8	0.8		28.4		12.75		69.0		13.0		71.0	

Physico-chemical data for soil (pH, organic matter content) and data on the density and qualitative structure of soil insect larvae are also included (Paplińska — unpublished data).

The captured entomofauna was identified to orders; the quantitatively dominant Diptera to families; the members of the family Chloropidae which includes many important plant pests were identified to species. Within some other orders, such as Heteroptera and Coleoptera, the families which are important from the ecological or management view point (pests), as well as more numerous forms, have been determined.

3. RESULTS

3.1. THE IMPORTANCE OF THE ELEMENTS OF LANDSCAPE STRUCTURE OF THE JORKA RIVER WATERSHED FOR THE ENTOMOFAUNA ACTIVELY MIGRATING IN SPACE

Earlier studies conducted in the years 1976–1977 in the agricultural landscape of the Jorka river watershed (Dąbrowska-Prot 1980), over an area of ca. 2 km², which included the forest island No. 2 (Fig. 1) have shown, that small forest islands situated among cultivated fields, have a high capacity for concentrating entomofauna. Together with such elements of the agricultural landscape, as natural meadows and perennial crops (alfalfa, clover) they hold the main mass of insects in the landscape. However, it should be noted, that this pertains mainly to 1 ha of a forest island surface area, and not the 13.5 ha of the forest island much less inhabited by insects (No. 2 in the studies of 1987).

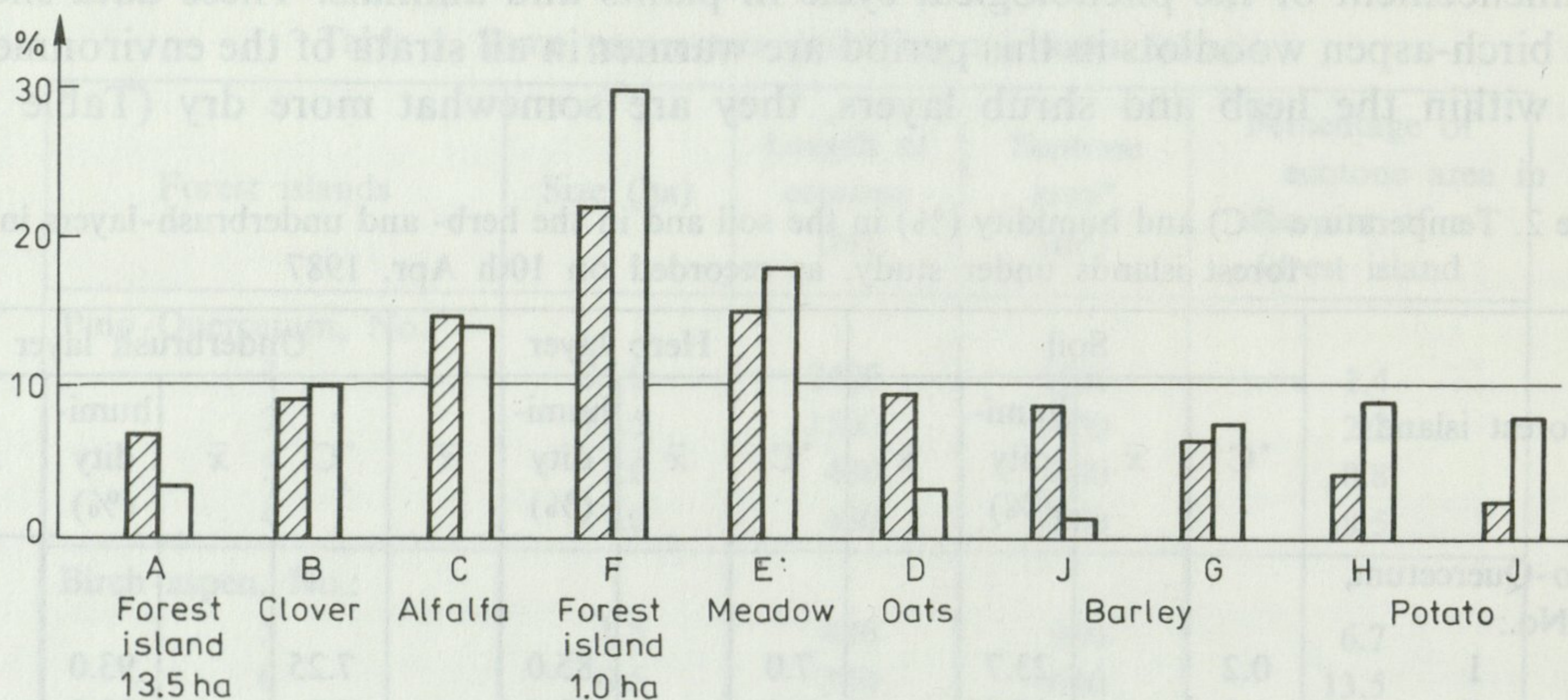


Fig. 2. Rate of colonization of different habitat types in the agricultural landscape by entomofauna in the growing season, expressed by its spatial per cent distribution

Habitat distribution in space as in Figure 1, straight solid line — average population rate, open columns — biomass, hatched columns — abundance

High importance of forest environments for the entomofauna in an agricultural landscape, results from the fact, that in this highly changeable, during the vegetative season, area, influenced by the maturing of grain producing plants, and an intensive cultivation of plants, these environments remain as permanent and little disturbed elements of the landscape's structure, and thus they provide year round favourable habitats for insects. Studies have shown, that in the Masurian lakeland, temperatures above zero are recorded during 8 months (from April to November); the average annual temperature is 6.8°C; in January it is 4.4°C; in July — 17.5°C; there are on the average 77 days with a snow cover; the vegetative season lasts 206 days (Bajkiewicz-Grabowska 1986). In this area, forest islands and meadows were during 7 months of the vegetative season inhabited by actively migrating

Table 3. Seasonal changes in the distribution of entomofauna in the Masurian agricultural landscape. The distribution of cropfields and forest habitats in the landscape has been presented in Figure 1. Crosses indicate the presence of actively moving entomofauna in the ecosystem; double crosses — abundance of entomofauna above the average level assessed for all the habitats studied

Month	A forest island 13.5 ha	F forest island 1.0 ha	E meadow	B clover	C alfalfa	G barley 2.5 ha	I barley 10 ha	D oast	H potato 2.5 ha	J potato 30 ha
March										
Apr.	++	+	+							
May	++	++	++	++	+	+	+	+		
June	+	++	++	+	++	++	+	+	+	+
July	+	+	++	+	++	++	++	++	+	+
Aug.	+	++	++	++	++	+	+	+	++	+
Sept.	++	++	++	++	+					
Oct.	++	+	+							
Nov.										
Presence of actively moving entomofauna	7 months			5 months		4 months			3 months	

entomofauna; perennial crops were inhabited for 5 months; annual grain crops for 4 months, while root plants only during 3 months (Table 3). Thus forest islands and natural meadows were the major refuge environments for the entomofauna during the entire vegetative season. It should be mentioned, that forest islands are also the major habitats for overwintering for many groups of vertebrates and invertebrates in the agricultural areas (M e l n i č e n k o 1949).

The presence of a high number of water reservoirs in the Masurian landscape causes, that the fauna of terrestrial ecosystems is being intensively enriched by insects hatching in them and then migrating over the area. Small forest islands are especially inhabited by these migrants (Table 4).

Table 4. Distribution pattern (in per cent) in the River Jorka watershed of dipterans hatching in water bodies (D a b r o w s k a - P r o t 1980, modified)

Forest island 13.5 ha	Forest island 1.0 ha	Meadow	Crop-fields
16.5	40.0	36.5	7.0

From the view point of a qualitative structure of entomofauna, 1 ha of a modified woodlot was much richer in species than 13.5 ha of a forest island. Thus, for example, it was inhabited by 85% of the Diptera families occurring in the entire agricultural landscape at lake Jorzec, while in the 13.5 ha forest island there were 62%, and in the cultivated fields 45–55% of the families.

At the same time, about 10% of the Diptera families found in the 13.5 ha forest island, had inhabited exclusively this environment and did not occur either in the 1 ha woodlot, nor in the agrocoenosis. In the 1 ha woodlot 5% of such families occurred; in the meadow and clover about 3%: while in the annual grain crops and rooted plants, no such families were found. This suggests, that a small forest island makes a much more favourable environment for insects than a larger island, and it is more exposed to the external influence of the surrounding cultivated ecosystems with which it intensively exchanges the fauna.

It can be taken, that forest islands are important structural elements of the agricultural landscape, which, in various periods of the season, shelter a rich fauna, both quantitatively and qualitatively. This pertains particularly to the spring season when some of the crops have not yet appeared in the landscape, as well as to autumn, when most of the fields are tilled for new sowing and they do not yet form environments suitable for insects.

3.2. PARAMETERS OF THE CHARACTERISTICS OF FOREST ISLANDS AND INTENSITY OF ISLAND'S INHABITATION BY ENTOMOFAUNA

Forest islands are the environments which play an important role in the maintenance of both, the qualitative variability and of the quantitative level of the fauna in an agricultural landscape. A question arises, however, what are the special

properties of a forest island which make it attractive for entomofauna? The forest islands studied, which are characteristics for the Masurian landscape, differ from one another by their origin, size, location in space and the presence, in some of them, of small water reservoirs. Although the number of the islands studied have been limited to 8 (for reasons of time consuming research), and differences between them have been recognized, they can be compared in pairs which differ from one another by only one of the properties mentioned earlier (Fig. 1, Table 1). Thus the comparison of forest islands No. 3 and 4 provides data on the influence of their location in the landscape on the formation of the fauna. They are both of the Pino-Quercetum type, both have an area of 1 ha, and both are dry. However, island No. 3 is situated in the nearest neighbourhood of the remaining forest islands, while island No. 4 is located about 4 km away, among cultivated fields.

Statistical analysis of the significant differences in the intensity of inhabiting both these islands by entomofauna, during different periods of the vegetative season, done by the *t*-student test for small samples (Parker 1978) have shown, that location of the island in the area is an essential factor affecting the quantity of the fauna (Table 5).

On the other hand, forest islands No. 1 (35 ha), No. 2 (13.5 ha) and 3 (1 ha) of the Pino-Quercetum type, the birch-aspen islands No. 5 (1.5 ha) and 6 (0.5 ha) which contain small water pools in the interior, as well as the dry islands No. 7 (0.5 ha) and 8 (0.125 ha) can be compared with respect to the influence of their size on the inhabiting fauna. Statistical analysis of the significant differences in the quantities of entomofauna in forest islands of different sizes has shown the effect of this factor to be rather complex (Table 5). A comparison of very large surface areas of the mixed forests No. 1 and 2 (35 ha and 13.5 ha) has not shown statistically significant differences between the quantities of the insects present. However, such differences were found when both these forest islands were compared with the small (1 ha) island No. 3. In the case of the birch-aspen small class woodlots, no significant differences were found between the forest islands No. 5 and 6 (1.5 ha and 3 times less 0.5 ha). Such differences occurred when both these forest islands were compared with the very small surface area No. 8 (0.125 ha — 4 and 12 times less than the two previous areas).

The forest islands studied represent a rather limited range of sizes, however, the results suggest, that significant differences in the abundance of fauna can be expected, first of all, between different size classes of the forest islands. In the case of the present investigations, these are the differences between very large and small forest islands, and between small ones and very small islands. Of course, the problem remains open, what is the full range of the size classes of forest islands, where significant differences occur in the intensity of inhabiting them by the fauna.

The effect of the presence of a small water reservoir has been estimated by comparing two neighbouring birch-aspen woodlots, one 0.5 ha (No. 6) containing a water reservoir, and another (No. 7) dry woodlot located on an elevation (Table 5). Such effect was noted exclusively at the time of a mass hatching of insects from

Table 5. Assessment of the significance of differences between the abundance of the entomofauna present in forest islands differing by their position in the landscape, size, origin and presence in them of small water body

Student's *t*-test for small samples (Parker 1978). *s.d.* — significantly different, *NS* — not significant, *p* — significance level

Months	Distribution in landscape, islands: No. 3—No. 4 1 ha 1 ha	Size of forest islands					Presence of water		Origin	
		Pino-Quercetum			birch-aspen		No. 6—No. 7 0.5 ha 0.5 ha		No. 3—No. 5 P—Q b—a 1 ha 1.5 ha	
		No. 1—No. 2 35—13.5 ha	No. 1—No. 3 35—1 ha	No. 2—No. 3 13.5—1 ha	No. 5—No. 6 1.5—0.5 ha	No. 7—No. 8 0.5—0.125 ha				
Apr.	<i>s.d.</i> <i>p</i> <0.05	<i>s.d.</i> <i>p</i> <0.05	<i>NS</i>	<i>NS</i>	<i>NS</i>	<i>NS</i>	<i>NS</i>	<i>NS</i>	<i>s.d.</i> <i>p</i> <0.05	
May	<i>s.d.</i> <i>p</i> <0.001	<i>NS</i>	<i>s.d.</i> <i>p</i> <0.05	<i>NS</i>	<i>NS</i>	<i>s.d.</i> <i>p</i> <0.01	<i>NS</i>	<i>s.d.</i> <i>p</i> <0.05		
June	<i>s.d.</i> <i>p</i> <0.01	<i>NS</i>	<i>s.d.</i> <i>p</i> <0.001	<i>s.d.</i> <i>p</i> <0.001	<i>s.d.</i> <i>p</i> <0.05	<i>s.d.</i> <i>p</i> <0.05	<i>NS</i>	<i>s.d.</i> <i>p</i> <0.01		
July Seasonal peak of entomofauna abundance	<i>s.d.</i> <i>p</i> <0.05	<i>s.d.</i> <i>p</i> <0.01	<i>s.d.</i> <i>p</i> <0.001	<i>s.d.</i> <i>p</i> <0.001	<i>NS</i>	<i>s.d.</i> <i>p</i> <0.01	<i>s.d.</i> <i>p</i> <0.05	<i>s.d.</i> <i>p</i> <0.001		
Aug.	<i>s.d.</i> <i>p</i> <0.05	<i>NS</i>	<i>s.d.</i> <i>p</i> <0.001	<i>s.d.</i> <i>p</i> <0.01	<i>NS</i>	<i>s.d.</i> <i>p</i> <0.05	<i>NS</i>	<i>s.d.</i> <i>p</i> <0.001		
Sept.	<i>NS</i>	<i>NS</i>	<i>NS</i>	<i>s.d.</i> <i>p</i> <0.001	<i>NS</i>	<i>s.d.</i> <i>p</i> <0.05	<i>NS</i>	<i>s.d.</i> <i>p</i> <0.05		
Oct.	<i>s.d.</i> <i>p</i> <0.01	<i>NS</i>	<i>s.d.</i> <i>p</i> <0.01	<i>s.d.</i> <i>p</i> <0.001	<i>NS</i>	<i>NS</i>	<i>NS</i>	<i>s.d.</i> <i>p</i> <0.01		

water reservoirs, for example, of dipterans from the families Culicidae, Ceratopogonidae, Chironomidae, etc. For many other groups of invertebrates, for instance, the spiders (Łuczak 1992) this factor is not so significant.

The role of the origin of a forest island in the shaping of entomofauna has been estimated by comparing forest islands No. 3 (1 ha Pino-Quercetum) and No. 5 (1.5 ha birch-aspen woodlot containing water reservoir). The difference in sizes as shown above, is not significant, the more, that both islands are characterized by similar lengths of the ecotone lines, and by similar contributions of the ecotone surface to the entire surface of the islands (Table 1). This creates similar conditions of biological exchange between these islands and the open areas which surround them.

The presence of a water reservoir in the woodlot has, as shown above, a significant effect on the quantities of the entomofauna only at the time of mass hatching of insects from the reservoir (Table 5). This probably results from the fact, that immediately following the hatching from water, insects remain for a short time in the nearest vicinity of the hatchery-water reservoir, and then begin intensive migrations in the area. In the meantime, an analysis of the intensity of inhabiting the forest islands No. 3 and No. 5 by entomofauna, has shown statistically significant differences between these islands during the entire vegetative season, which can be attributed to the differences in the origin of the islands.

Considering the above speculations, one can ask, if any other (besides the quantities) characteristics of the entomofauna, such as the qualitative structure, trophy, predator-prey relations, and first of all the intensity of migration of the fauna between the forest island and the surrounding space, are also being shaped through the influence of the analysed factors. Is the significance of each of these factors, for the development of these phenomena and processes, similar to their influence on the quantitative level of the entomofauna?

3.3. PROPERTIES OF A FOREST ISLAND, AND STRUCTURE AND FUNCTIONING OF ENTOMOFAUNA

3.3.1. Origin of a forest island

In speculations about the role of forest islands, the first question is that of their size, which is sometimes understood as the problem of environmental capacity for the fauna, and sometimes as the size of a spot in the landscape. It is rare, however, that the important question of the forest island's origin is being raised, as well as the related problems of vegetation structure and the stages of its successive development. This is probably caused by the difficulties of finding in one area such forest environments, which would differ in only one characteristic, in this case the origin, and would retain the similarities of other parameters.

In the Masurian lakeland, both types of forest islands studied, the Pino-Quercetum and birch-aspen, are very characteristic and important elements of the landscape. Thus the question arises if both types differ in their degree of

attractiveness for insects. Data presented earlier showed, that 1 ha surface area of Pino-Quercetum (island No. 3), only about 1 km remote from the 1.5 ha birch-aspen lot (No. 5), differed from it significantly by the intensity of inhabiting by entomofauna (Table 5), which, in the birch-aspen woodlot was characterized, during the entire vegetative season, by 1.5 times greater numbers and biomass (Table 6). In the case of Diptera, which were dominant among the entomofauna (comparing up to 70% of the numbers), this prevalence was even somewhat greater (Table 6). Similarly, this environment was attractive for the spiders, whose biomass was 50% higher there than in the Pino-Quercetum island No. 3 (Łuczak 1991).

Table 6. Rate of forest island colonization by insects. Per cent distribution of number and biomass (mg dry wt) of entomofauna and dipterans that are numerically dominant among insects

Indices	Forest islands				Total 1-4	Birch-aspen				Total 5-8
	1	2	3	4		5	6	7	8	
Entomofauna:										
numbers	6.5	7.0	12.5	15.0	40.5	19.5	14.5	13.5	12.0	59.5
biomass	6.0	7.5	12.5	14.0	40.0	17.5	15.5	15.0	12.0	60.0
Diptera:										
numbers	5.0	7.0	13.0	14.0	39.0	20.0	13.5	15.0	12.5	61.0
biomass	5.5	6.5	12.0	13.5	37.5	19.5	14.0	16.5	12.5	62.5

In addition to the intensive inhabiting by insects of the birch-aspen woodlot No. 5, attention has been called to their distribution pattern in this environment (Table 7). Except for the spring (April, May), in other periods of the season, the insects had rather uniformly and in a similar manner, inhabited this woodlot. Their most uniform distribution (June) was not related to the seasonal peak of their abundance in this environment (Fig. 3). In Pino-Quercetum No. 3 woodlot the degree of uniformity of covering the environment by insects was very variable in the season. In addition, in all the forest islands of the Pino-Quercetum type, the lowest values of the coefficient of variability were recorded during the seasonal peak of the insect numbers in the area (Table 7).

Birch-aspen woodlot No. 5 was characterized by fauna richer qualitatively than in the Pino-Quercetum woodlot No. 3. This is illustrated by comparing the numbers of families of mature Diptera (Table 8), soil larvae of Diptera (woodlot No. 3; 11 families, woodlot No. 5; 13 families) and Coleoptera larvae (4 and 7 families, respectively), (Paplińska — unpublished data). In the first type of the environment, forms with greater individual biomass were more numerous (Table 8).

One fourth greater contribution, of the synanthropic forms in Diptera community and 2/3 greater contribution of dipterans hatching in the water reservoirs in the birch-aspen woodlot (Table 9), point out to the processes of qualitative and quantitative enrichment of the fauna of this environment with insects migrating from other types of ecosystems. This is also shown by the development, in both forest islands, of the seasonal dynamics in insect numbers and biomass (Figs. 3, 4), as well as by the migration from water reservoirs (Fig. 5). During the entire

Table 7. Degree of spatial distribution uniformity of insects in forest islands, expressed with the variation coefficient $V = \frac{S}{\bar{x}}$ for 10 sweep-net samples, collected in every habitat in successive periods of the growing season. The dash indicates the lowest, and the cross — the highest coefficient values

Months \ Forest islands	1	2	3	4	5	6	7	8
Apr.	0.578	0.919*	0.734	0.682*	1.415*	1.001*	0.849*	1.450*
May	0.348	0.311	0.889*	0.544	0.962	0.322	0.298—	0.254—
June	0.329	0.397	0.285	0.306	0.254—	0.381	0.377	0.414
July*	0.286—	0.213—	0.242—	0.092—	0.370	0.442	0.412	0.398
Aug.	0.735	0.358	0.383	0.374	0.304	0.254—	0.319	0.910
Sept.	0.588	0.600	0.312	0.327	0.325	0.521	0.526	0.919
Oct.	0.565	0.376	0.559	0.392	0.340	0.630	0.320	0.366
\bar{x}	0.490	0.453	0.488	0.388	0.569	0.507	0.443	0.673

* Seasonal insect abundance peak.

Table 8. Qualitative structure of the dipterans of the forest islands studied

Parameter \ Forest island	Pino-Quercetum				Total 1-4	Birch-aspen				Total 5-8	Total 1-8
	1	2	3	4		5	6	7	8		
% of dipterans in entomofauna	62.0	62.0	71.0	64.0	65.0	68.5	65.0	75.0	68.0	69.0	67.5
Number of dipteran families	32	36	35	40	48	40	40	39	40	50	54
Total number of families co-occurring in all 4 forest islands	2	1	1	6	—	0	2	1	4	—	—
% of families present in all 4 forest islands	—	—	—	—	50	—	—	—	—	64	—
% of families occurring only on one site	—	—	—	—	20	—	—	—	—	14	—
% of the dominant Diptera family	17.0	18.5	25.0	36.5	23.0	41.0	29.5	36.0	37.5	31.0	27.5
	Mycetophylidae	Chironomidae		Culicidae				Chironomidae	Culicidae		
Number of Chloropidae species	5	8	6	11	17	6	5	7	6	13	20
Number of sporadic* Chloropidae species	—	—	—	—	7	—	—	—	—	4	—
Mean individual dipteran biomass (mg dry wt/individ.)	0.949	0.893	0.906	1.064	0.962	1.035	1.083	1.162	1.056	1.082	

* Only one individual caught.

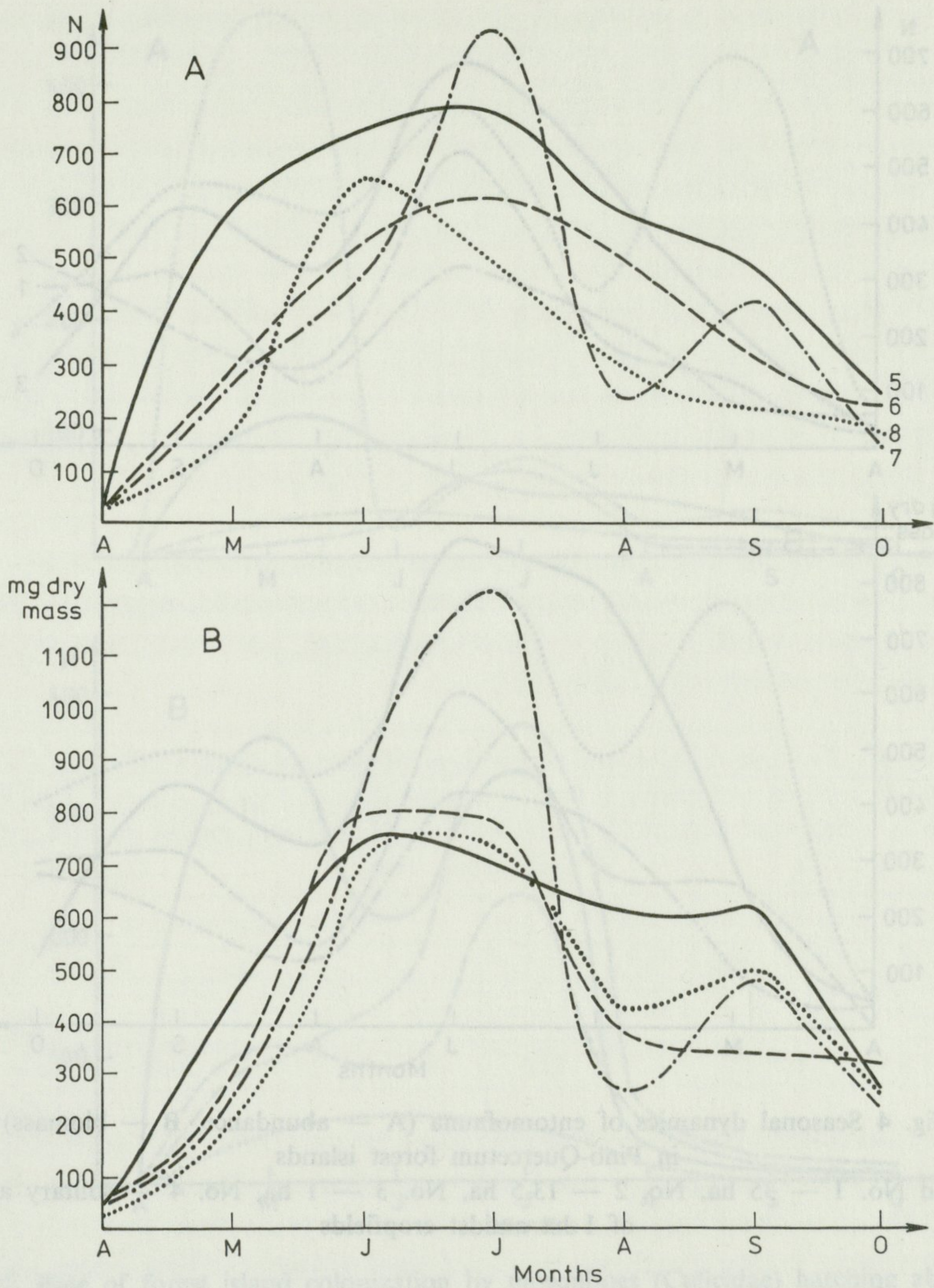


Fig. 3. Seasonal dynamics of entomofauna (A — abundance, B — biomass) in birch-aspen forest islands
 Island No. 5 — 1.5 ha, No. 6 — 0.5 ha with a small water reservoir, No. 7 — 0.5 ha dry,
 No. 8 — 0.125 ha

Table 9. Percentage in dipteran communities of the family Culicidae the members of which hatch in water bodies and then intensively spread in the area, and of synanthropic dipterans

Forest island	Pino-Quercetum				Total 1-4	Birch-aspen				Total 5-8
	1	2	3	4		5	6	7	8	
Group of Diptera										
Migrant	13.8	12.7	13.2	36.5	23.0	41.0	29.5	36.0	10.0	31.0
Synanthropic	4.0	8.5	8.0	15.0	8.0	10.5	13.5	9.5	18.5	13.0

vegetative season, the level of numbers and biomass of the entomofauna, was higher in the birch-aspen woodlot than in the Pino-Quercetum lot. In addition, the seasonal

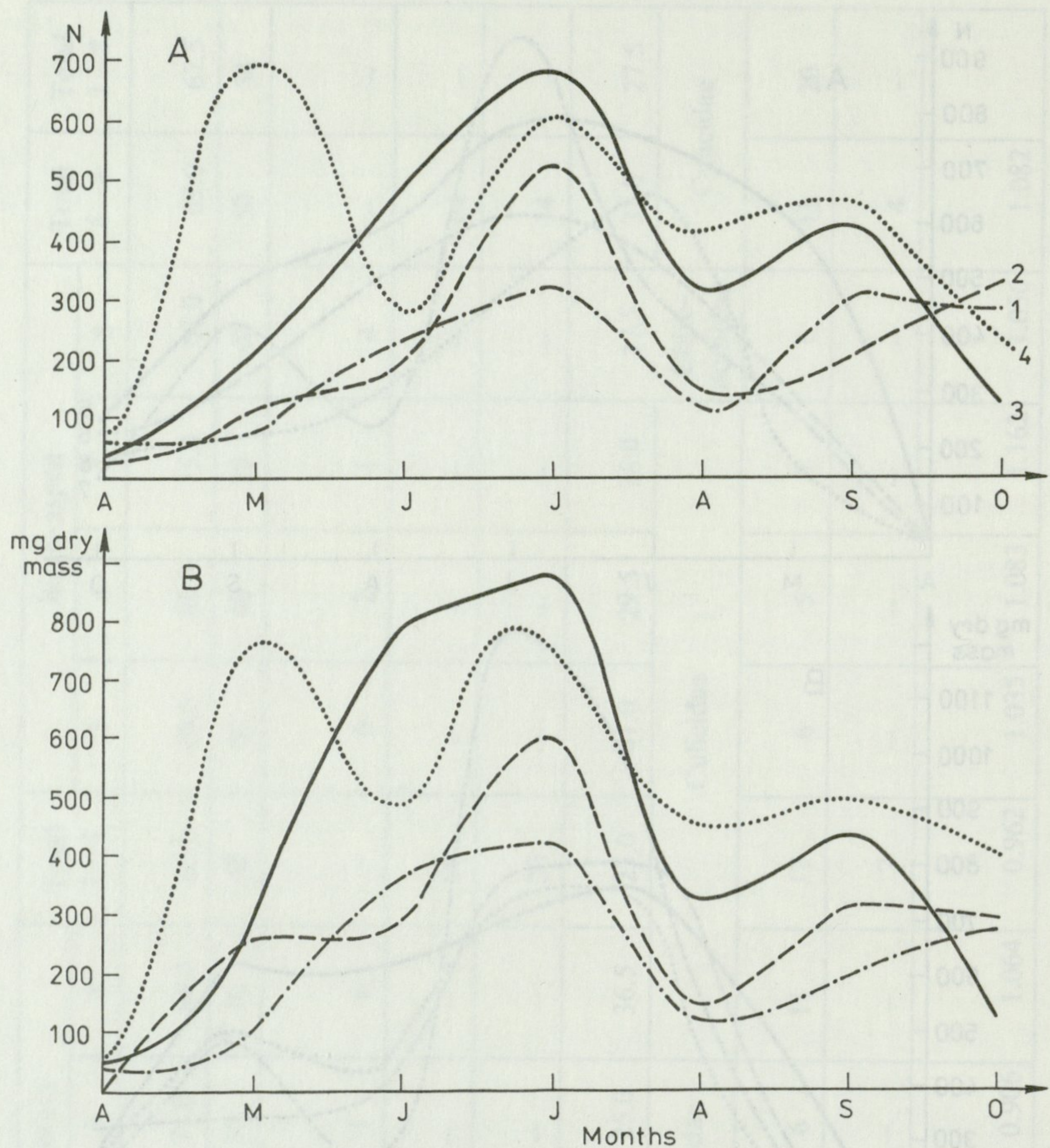


Fig. 4 Seasonal dynamics of entomofauna (A — abundance, B — biomass) in Pino-Quercetum forest islands

Island No. 1 — 35 ha, No. 2 — 13.5 ha, No. 3 — 1 ha, No. 4 — solitary area of 1 ha amidst cropfields

peaks of the insect numbers typical for the forest environment, did not occur in the former type of the island, which was in contrast to the observation in the Pino-Quercetum type of island (Fig. 4). The same has been found by Olechowicz (1984) for the Kampinos mixed forest association. Thus a statement can be made, that the seasonal dynamics in the latter type of the environment, had reflected the natural development cycle of insects with the peaks of numbers and biomass in the periods of their mass hatching (Dąbrowska-Prot and Karg 1975). On the other hand, this development of seasonal dynamics in the birch-aspen woodlot is being distorted by the continuous migrations of animals from other environments. This supposition is corroborated, by the differences in inhabiting the forest islands by dipterans hatching in water reservoirs (Fig. 5).

It should be emphasized, that significant portion of Diptera which inhabit the birch-aspen woodlots studied by us, except for island 8, are the migrating forms,

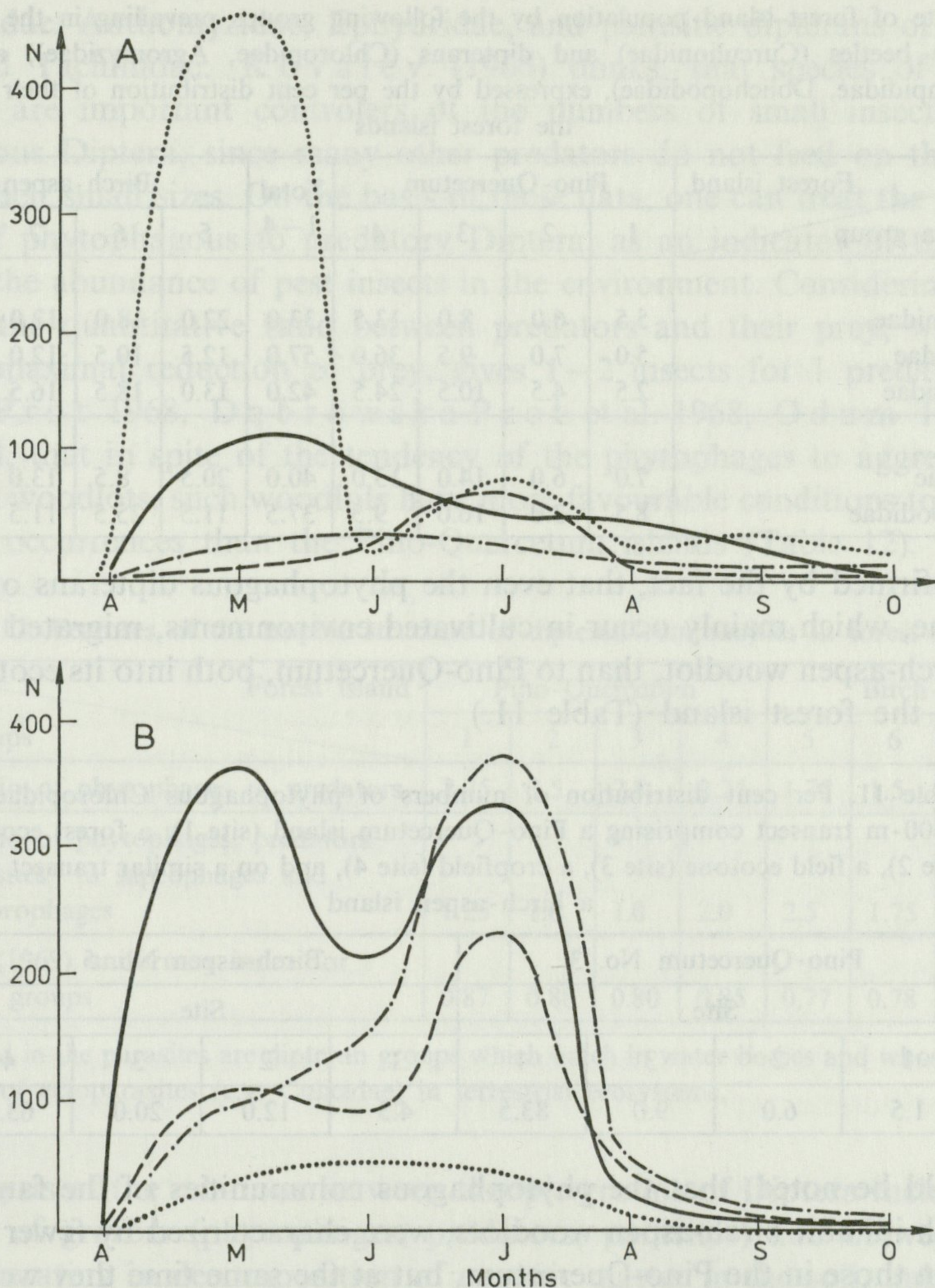


Fig. 5. Rate of forest island colonization by mosquitoes (Culicidae) hatching abundantly in the numerous water bodies of the study areas

A — Pino-Quercetum islands, B — birch-aspen islands. Islands denotation as in Tables 4 and 5

hatching in water reservoirs (Table 9, Fig. 5) The family Culicidae are dominant in the qualitative structure of Diptera in these environments (Table 8). Except for the ecological importance, this fact has also epidemiological consequences, since mosquitoes, being carriers of virus and bacterial diseases are a hazard for the health of both people and animals, in the areas of their mass occurrence in Poland, including the Masurian District.

In the trophic structure of the entomofauna, it is interesting to note the more intensive inhabiting of the birch-aspen woodlot by the dominant groups of phytophagous and predator insects (Table 10). This could suggest a "trap" type of environment at least in relation to certain groups of phytophages and predators. It

Table 10. Rate of forest island population by the following groups prevailing in the entomofauna: phytophagous beetles (Curculionidae) and dipterans (Chloropidae, Agromyzidae), and predatory dipterans (Empididae, Dolichopodidae), expressed by the per cent distribution of their abundance in the forest islands

Forest island Entomofauna group	Pino-Quercetum				Total 1-4	Birch-aspen				Total 5-8
	1	2	3	4		5	6	7	8	
Phytophages:										
Curculionidae	5.5	6.0	8.0	13.5	33.0	22.0	18.0	12.0	15.0	67.0
Chloropidae	5.0	7.0	9.5	36.0	57.0	12.5	10.5	12.0	7.0	42.5
Agromyzidae	2.5	4.5	10.5	24.5	42.0	13.0	18.5	16.5	10.0	58.0
Predators:										
Empididae	7.0	6.0	14.0	13.0	40.0	20.5	8.5	13.0	17.0	60.0
Dolichopodidae	8.5	3.0	16.0	9.5	37.5	11.5	25.5	11.5	14.0	62.5

can be confirmed by the fact, that even the phytophagous dipterans of the family Chloropidae, which mainly occur in cultivated environments, migrated more easily into the birch-aspen woodlot, than to Pino-Quercetum, both into its ecotone and the interior of the forest island (Table 11.)

Table 11. Per cent distribution of numbers of phytophagous Chloropidae on a 300-m transect comprising a Pino-Quercetum island (site 1), a forest ecotone (site 2), a field ecotone (site 3), a cropfield (site 4), and on a similar transect near a birch-aspen island

Pino-Quercetum No. 3				Birch-aspen No. 5			
Site				Site			
1	2	3	4	1	2	3	4
1.5	6.0	9.0	83.5	4.5	12.0	20.0	63.5

It should be noted, that the phytophagous communities of the family Chloropidae which inhabit birch-aspen woodlots, were characterized by fewer numbers of species than those in the Pino-Quercetum, but at the same time they were eurytopic species, permanently tied to these types of environments (few sporadic species), (Table 8). A similar structure of the Chloropidae communities has been observed in areas of intensified agriculture (Dąbrowska-Prot 1984) and industry (Dąbrowska-Prot 1984, 1987b). It was found, that in conditions of a strong anthropopressure, the Chloropidae communities have been mainly formed on the basis of cosmopolitan species, which are numerous and permanently occurring in the environment.

Environmental selectivity of various trophic groups of Diptera, for example, of predators and their potential prey, has its biocoenotic consequences. Many data can be found in the literature on the subject of preying by mature predatory dipterans on other representatives of this group of insects (Lawrence 1952, Smith 1952, Kovaliev 1966, Downes 1970). Crane (1961) stated, that the species *Ramphomyia scutellaris* of the family Empididae had fed on 26 families of insects, twenty of them being Diptera. The prey included the pests of the families

Cecidomyiidae, Anthomyzidae, Ephydriidae, and parasitic dipterans of the Pipunculidae and Tachinidae. K o v a l e v (1966) thinks, that species of the family Empididae are important controllers of the numbers of small insects including phytophagous Diptera, since many other predators do not feed on them for the reason of their small sizes. On the basis of these data, one can treat the ratio of the numbers of phytophagous to predatory Diptera, as an indicator of the potential control of the abundance of pest insects in the environment. Considering literature data, that the quantitative ratio between predators and their prey, which brings about the maximal reduction of prey, gives 1–2 insects for 1 predator (D a b r o w s k a-P r o t 1968, D a b r o w s k a-P r o t et al. 1968, O d u m 1982), it can be assumed, that in spite of the tendency of the phytophages to aggregate in the birch-aspen woodlots, such woodlots have more favourable conditions to counteract their mass occurrences than the Pino-Quercetum islands (Table 12).

Table 12. Features of the trophic structure of dipteran communities in forest islands

Forest island	Pino-Quercetum				Birch-aspen			
	1	2	3	4	5	6	7	8
Numbers ratio of phytophages to predators	2.75	3.5	2.5	2.25	1.75	1.5	1.5	1.0
Numbers ratio of phytophages, predators and parasites* to saprophages and phyto-saprophages	1.25	1.0	1.0	2.0	2.5	1.75	1.5	0.5
Pielou's (1969) uniformity index for 5 trophic groups	0.87	0.88	0.80	0.85	0.77	0.78	0.76	0.77

* Included in the parasites are dipteran groups which hatch in water bodies and whose adult forms play the role of ectoparasites (e.g. Culicidae) in terrestrial ecosystems.

An analysis of the relations between thropic groups of Diptera included in the food chain of grazers (phytophages, predators, parasites) and between saprophages, cooperating in decomposition of organic matter in the soil, indicates, that birch-aspen woodlots contain in majority the insects of the first group, however, excluding the smallest woodlot, with a distinct dominance of the saprophages (Table 12). In the Pino-Quercetum woodlot, there is a tendency to equalize the contribution of both functional groups, however, with the exception of an isolated woodlot among cultivated fields (island No. 4) which takes the role of a refuge environment in the landscape for the representatives of phytophages, predators and parasites.

Earlier studies showed, that the trophic structure of dipterans can be an indicator of the environmental stability (D a b r o w s k a-P r o t 1987b). Thus the values of the uniformity coefficient (P i e l o u 1966) calculated for five trophic groups of Diptera (phytophages, phyto-saprophages, saprophages, predators, parasites) have been lower for the ecosystems of cultivated fields, than for natural (forest, woodlot) and seminatural ecosystems (meadow). For all types of ecosystems they were lower in industrial areas than in non polluted areas. A decrease in the coefficient value was

mainly caused by an increase in the contribution of the phytophagous insects in the communities of Diptera. In environments relatively little disturbed by man, retaining the natural, ecological equilibrium, there is a tendency in this group of insects, to equalize the proportions between the trophic groups. Thus, for instance, this coefficient, calculated for larger forest complexes in so called "clean areas" indicated ca. 0.8–0.9 (Dąbrowska-Prot unpublished data); in industrial areas it decreased to 0.4–0.5, and even to 0.3, in the most altered forest environments (Dąbrowska-Prot 1987b).

Although in both types of forest islands studied in the Masurian Lakeland, the coefficient of uniformity had reached values pointing to a relatively small, man-induced alteration of the environment, however, in all the birch-aspen woodlots its values were lower than in the Pino-Quercetum community, which indicates a tendency of an increase of the importance of some trophic groups (Table 12). The earlier considerations have shown, that this pertains to the functional groups of the grazing food chain.

The essential question is, to what degree the forest islands can enrich other environments of the landscape in both, the individuals and the biomass of insects. Olechowicz (1984) found, that in the Pino-Quercetum community of the Kampinos Forest, the ratios of numbers and biomass of insects which hatch and inhabit this environment, indicated an extensive migration of insects, and an enrichment, through this ecosystem, in biomass and nutrients of more impoverished environments.

Our studies on the quantitative relations between the soil larvae of Diptera (Paplińska — unpublished data) and imagines inhabiting forest islands, point out to the greater role of the Pino-Quercetum islands, than of the birch-aspen woodlots, in the export (but not exchange) of insects to other environments (Table 13.)

Table 13. Value of export of insects from forest islands, measured by the abundance and biomass ratio of the adult forms living in the habitat to dipteran soil larvae (in %) (data on dipteran larvae by E. Paplińska — unpublished data)

Forest island	Pino-Quercetum				Birch-aspen			
	1	2	3	4	5	6	7	8
Numbers: $\frac{\text{imagines}}{\text{larvae}}$	0.8	1.0	1.0	1.0	6.0	—	7.0	5.0
Biomass: $\frac{\text{imagines}}{\text{larvae}}$	1.5	1.75	4.0	5.5	12.5	—	23.5	8.0

3.3.2. Location of a forest island in a landscape

Among the forest islands studied of the Pino-Quercetum type, there were two having 1 ha surface areas; one of them (No. 3) was located in a vicinity of six other investigated woodlots; the second one (No. 4) was located about 4 km away from

them and stood solitary among cultivated fields (Fig. 1). Thus, the latter lot was the only larger element of the natural environment situated in an extensive spacious area of root plants and crop fields.

Statistical analysis showed significant differences between both these environments in the numbers of entomofauna which inhabit them in particular periods of the season (Table 5). Except for June and July, in different periods of the vegetative season, the numbers of entomofauna in Pino-Quercetum No. 4 were 8–20% higher than in Pino-Quercetum No. 3, while the biomass was 23 to 26% greater. This island was an exception among all the Pino-Quercetum woodlots, since ca. 40% of its fauna contained forms which hatch in water reservoirs and migrate in the landscape (Table 8). In Pino-Quercetum No. 3 they made up only about 18%.

Generally, entomofauna in forest island No. 4 was distributed more uniformly than in island No. 3, but it was also more uniformly distributed than in all the remaining Pino-Quercetum islands, as well as in some birch-aspen woodlots, which is shown by the values of the variation coefficient (Table 7). This does not result only from the greater quantitative level of entomofauna in this environment; for example, in a woodlot No. 6 having similar numbers of insects, these coefficients showed a greater range of variation in the season, and their mean value was higher.

Qualitative structure of insects was clearly more variable in the isolated forest island. This pertained to the community structure of mature Diptera (number of Diptera families, number of species Chloropidae), (Table 8); it was even more distinct for Diptera larvae dominant in the soil fauna (Pino-Quercetum No. 4 — 18 families, No. 3 — 11 families) and for Coleoptera (Pino-Quercetum No. 4 — 12 families, No. 3 — 5 families), (Paplińska unpublished data). In addition, attention should be called to the twice greater contribution to this environment, of synanthropic Diptera, which indicates a high disturbance and contamination by man, and grazing by animals (Table 9).

The isolated island was also 2–4 times more intensively inhabited by different groups of phytophagous insects (Table 10), which were also more variable qualitatively, i.e. Chloropidae, (Table 8). In the seasonal dynamics of entomofauna in both environments, the summer and autumn peaks of numbers and biomass were similar, but they differed by the occurrence of a spring peak of numbers in only Pino-Quercetum island No. 4, (Fig. 4). This peak was mainly caused by the mass occurrence of Culicidae (Fig. 5) which migrate into this environment from hatcheries in the nearby bogs. This phenomenon of an intensive immigration of mosquitoes into this forest island makes the island similar to the birch-aspen woodlots, but it pertains exclusively to spring, since subsequent hatchings of these insects during full summer (July) cause their much less intensive concentrations in this environment (Fig. 5).

Three most abundant phytophagous groups of entomofauna, had 2–4 times more intensively inhabited Pino-Quercetum woodlot No. 4 than woodlot No. 3 (Table 10). On the other hand, dominant predatory groups of dipterans (Dolichopodidae and Empididae), although they occurred 1/3 less abundantly in Pino-Quercetum No. 4 than No. 3 (Table 9), they showed there a greater quantitative

uniformity during the entire vegetative season (coefficient of variation for forest island No. 4 — 0.996; for island No. 3 — 1.663). Certain other predatory groups such as spiders (Łuczak 1991) and ladybugs (Gałęcka 1991) had reached there greater quantities and biomass than in island No. 3.

The results shown above suggest, that special localization of a forest island among cultivated fields, causes an increased exchange of the fauna between this type of a natural environment and the surrounding space. In this environment more intensive is the aggregation of insects migrating in the area following their hatching (i.e. mosquitoes), also of those which migrate as a result of seasonal changes in the structure of crops (i.e. Chloropidae), or of those searching for wintering places (ladybugs). More intensive is also the inhabiting of the island by photophages and predators at different times of the season.

However, in spite of the special localization in the landscape, which increased its attraction for the fauna, Pino-Quercetum No. 4 had differed from a similar size birch-aspen woodlot No. 5, by certain properties of the entomofauna. For example, it had not reached the quantitative wealth of the fauna (numbers, biomass) of the latter environment (Table 6). Although in both forest islands a similar number of Diptera families occurred (Table 8), however, in certain periods of the season (April, June, September), the qualitative diversity of dipterans was much greater in the birch-aspen woodlot. Also the contribution to its fauna of forms migrating from water reservoirs was greater (Table 9), as well as the communities of different phytophages and predators were richer in the spring, while of the phytophages also in the autumn.

It should be emphasized, that the Pino-Quercetum island No. 4 represented undoubtedly a more synanthropic environment than the birch-aspen woodlot No. 5. This is shown by the 50% greater contribution of synanthropic dipterans (Table 9), and also by the significant contribution of synanthropic species among the higher plants of this environment (Wójcik 1992). This woodlot was intensively used by people (walking, polluting, trampling).

3.3.3. Size of a forest island

Problem of the effect of the size of a forest island on the degree of its inhabiting by organisms, has been extensively discussed in the literature. However, this pertains first of all to plants (for instance Levenson 1981, Hoehne 1981), and among the animals to birds (e.g. Goszczyński 1985, Gromadzki 1970, Whitcomb et al. 1981). Very few such data pertain to invertebrates. Those existing are mainly on spiders (Łuczak 1987, Tarwid 1987) and dipterans (Dąbrowska-Prot 1987a, 1987b, Paplińska 1987).

Complex investigations carried out in industrial areas showed, that the difference between a large, several tens ha mixed forest, and a small forest island, formed by a deforestation of the large forest, was in the more intensive inhabiting of the latter by entomofauna. This difference reached 20% of the numbers and 40% of biomass

in the island (Dąbrowska-Prot 1987a). In part 3.2 of this paper, attention has been called to the fact, that differences in the fauna, should be first of all looked for, between the size classes of forest islands, and not in proportion to the progressive decrease or enlargement of a forest island. Large forest islands of the Pino-Quercetum type (35 ha and 13.5 ha) did not differ significantly, during the entire vegetative season in numbers of entomofauna, however, such difference did occur, between these islands and a small 1 ha forested surface area (Table 5). Similarly, small birch-aspen woodlots (1.5 ha and 0.5 ha) did not show statistically significant differences in inhabiting them by insects; these differences only occurred after comparing these islands with a very surface area (0.125 ha) (Table 5).

A question arises, if the qualitative structure of entomofauna and the seasonal changes in inhabiting the islands, show a similar kind of dependence on islands of different sizes. A comparison was made of three Pino-Quercetum forest islands of different sizes, which undoubtedly originated from the same larger forest complex divided, as a result of agricultural management, into several smaller neighbouring parts. It was shown, that two larger (35 and 13.5 ha) forest islands, which differed in size by the factor of 2.5, had a very similar fauna, in contrast to a small surface area (1ha) of the third island which was distinctly ecologically different.

The similarities between large forest areas are following:

1. Relatively low (the lowest among all the forest islands studied) levels of numerical abundance and biomass of entomofauna, including Diptera (Table 6).
2. Low (the lowest of all environments investigated) contribution of a dominant species to the quantitative structure of Diptera; also the lowest contribution of Diptera into entomofauna, which points out to the greater relative qualitative richness of entomofauna in both environments (Table 8).
3. Less pronounced inhabitation of both islands by dominant forms of phytophages and predators (Table 10).
4. Less extensive utilization of both environments by migrating forms (Table 9).

However, distinct differences occurred in the degree of synanthropization and the qualitative richness of the fauna in both these environments. The largest forest area of 35 ha was characterized by a twice smaller contribution of synanthropic dipterans than the 13.5 ha forest island: this contribution was many times less compared to all the remaining forest environments (Table 9). In addition, this environment was inhabited by 12% Diptera families less, and 45% Chloropidae species less, compared to the 13.5 ha forest island (Table 8).

The 1 ha surface area of Pino-Quercetum located in the nearest vicinity of forest island No. 1, but separated from in the past after clearing a part of the forest for cultivation of fields, had differed from the two other larger islands by the level of its inhabitation by entomofauna. It was characterized by about twice greater numbers and biomass of insects (Table 6); 1.5 higher contribution of dominant forms (Table 8); and ca. 2.5 greater inhabitation by phytophages and predators dominant in entomofauna (Table 10). In spite of these differences, which point out to a more effective utilization of the small Pino-Quercetum island by entomofauna, the relatively low degree of synanthropization of the fauna, and relatively small

inhabitation by migrating forms, relate the island to the largest forest islands (Table 9).

Interesting is the pattern of spatial distribution of entomofauna in these environments. Dispersion of Diptera families within forest islands has been estimated by Koch (1957) dispersion coefficient according to the equation

$$\frac{(T-S):(n-1)}{S} \times 100,$$

which values are 0 — 100%; n — number of samples taken in different points of a forest island (10 samples; see methods); S — number of species (families) found in a given time over the whole island; T — arithmetical sum of species found in consecutive samples. Mean dispersion coefficient for Diptera families in the whole vegetative season was for forest island No. 1 — 26.0%; during consecutive months it ranged 23.0–33.0%; for island No. 2 — 22.5% (16.5–35.0%); for island No. 3 — 32.5% (16.0–36.5%). Mean values of the coefficient and the range of its seasonal variations, point to the more diversified, aggregation kind of occurrence of Diptera families in the largest forest island. In the consecutive periods of the season their spatial distribution was quite similar. In both remaining forest environments (13.5 and 1 ha) the range of seasonal changes in dispersion of dipterans was high, but the mean values of the coefficient indicate, that island No. 3 (1 ha) had the most homogeneous environment for Diptera families.

No greater differences were found in the degree of uniform cover of the three Pino-Quercetum environments by the whole entomofauna (variation coefficients, Table 7). Only in island No. 4, entomofauna had clearly more uniformly expanded in space, than in the other Pino-Quercetum woodlots.

In addition to numerical abundance and biomass of entomofauna, the seasonal dynamics of changes of these parameters confirmed the significant similarity of both larger islands (Fig. 4) (Spearman rank correlation: Siegel 1956). In the case of the 1 ha island, in spite of dynamics of numbers and biomass of entomofauna similar to that of the two other environments, it is interesting to note, that the island is more intensively inhabited by entomofauna during almost all periods of the vegetative season, exclusive of spring and autumn. This gives an evidence of the high importance of a small forest area in the maintenance of the quantitative and biomass insect richness in the landscape. This pertains, however, mainly to the middle of the vegetative season. In autumn, the level of entomofauna in this environment decreases fast, while in the two large forest islands there still remains rather numerous fauna. It can be assumed, that these islands provide refuge for the fauna during the period of deteriorating environmental conditions in the landscape (tillage of fields) as well as during changing climatic conditions at the end of the vegetative season.

Birch-aspen islands represent the other end of size classes, namely, they form a series of small and very small surfaces. From the quantitative view point of the fauna, only the smallest (0.125 ha) surface area differed significantly from the others (Table 5). Among all the birch-aspen islands, it was a woodlot the least inhabited by

fauna, but it should be emphasized, that both the numbers and biomass of insects there, were twice higher than in the two largest Pino-Quercetum woodlots (Table 6). Similarly, the numbers and biomass of spiders in this smallest environment were 1.5–2.0 times lower than in the remaining birch-aspen woodlots (Ł u c z a k 1991). This smallest island was as rich qualitatively in fauna, as the other birch-aspen woodlots, and it differed from them by the dominance of the saprophagous dipteran family Chironomidae which was also characteristic for two (No. 2 and No. 3) Pino-Quercetum woodlots (Table 8). Three remaining birch-aspen areas were dominated by representatives of the family Culicidae which hatch in water reservoirs.

It is interesting to note, that compared with a birch-aspen woodlot No. 7 (0.5 ha) located on a small elevation, and only about 500 m apart, the dominant phytophagous forms in the smallest lot No. 8 were ca. 15% less numerous. However, they were 15–25% more frequent than in two large Pino-Quercetum areas (Table 10). Thus, both, very large and very small forest surface areas do not provide favourable conditions for distribution of these groups of phytophagous insects. Similarly, the family Culicidae which intensively migrate in this terrain from water reservoirs, had avoided the smallest surface area, and had occurred there 3–4 times less than in other birch-aspen woodlots, and even less than in Pino-Quercetum, which is generally less inhabited by this family of dipterans (Table 9). Statistical analysis (Kendall coefficient of concordance; Siegiel 1956) showed significant differences ($p < 0.001$) in the seasonal dynamics of Culicidae in all the forest islands studied, which points out to their differing importance as habitats for this group of dipterans.

Conspicuous is the fact of a rather high contribution of synanthropic dipterans in birch-aspen woodlots, close to that observed in the Pino-Quercetum woodlot, standing in isolation among cultivated fields and extensively utilized by man (Table 9). This indicates a fast process of synanthropization of the fauna, quicker than in larger in size forest environments. This process of seasonal changes of entomofauna in birch-aspen woodlots, shows that the insects inhabit in the least degree the 0.125 ha surface area during different times of the vegetative season (Fig. 3). The differences were less pronounced in the biomass of insects, whose seasonal changes were similar in all four environments exhibiting summer and autumnal peaks (Fig. 3).

Changes in the numbers of entomofauna clearly divide the woodlots into two groups (Fig. 3). Dry woodlots No. 7 and 8 located on small elevations had distinct seasonal peaks of insect numbers. During summer they were mainly caused by a periodical mass occurrence of dipterans from the families Culidae and Chironomidae (woodlot No. 7), and exclusively of Chironomidae in area No. 8. Another higher occurrence of Chironomidae and Limoniidae could be observed in autumn only over the larger area No. 7.

In woodlots containing small water reservoirs in the interior (No. 5 and 6), there were consecutive occurrences of different groups of entomofauna during the entire vegetative season, which caused, that no peak numbers of insects could be observed in the seasonal dynamics (Fig. 3). Thus, mass occurrences of Culicidae in these woodlots (Fig. 5) were not reflected in the seasonal dynamics of the numbers of

entomofauna, since during the remaining periods of the season, there were observed equally numerous groups of insects, such as, among dipterans, the parasites of the family Ceratopogonidae, predators of the Dolichopodidae and Empididae and the phytophages Opomyzidae. Among other groups of insects there occurred Araneae, Coleoptera, and especially the phytophagous beetles of the family Curculionidae. As a result, the curve of the seasonal dynamics of insects in these both environments, had taken the shape of a parabola.

Summarizing, the size of the smallest birch-aspen woodlot seems to be critical from the view point of its utilization by fauna. It is relatively weakly inhabited both by the entomofauna as by other groups of invertebrates, for instance, the spiders (Ł u c z a k 1991). It is avoided by some groups of phytophages and, for forms migrating from water reservoirs, it is not a competitive environment in relation to four times larger birch-aspen surface areas, which are being inhabited by these insects with a three-fold higher intensity.

The poverty of fauna in this environment is emphasized by the seasonal dynamics of numbers, which shows, that only in the spring-summer period, greater quantities of insects inhabited this forest island. At the same time, fauna inhabiting this environment, does not differ, in its qualitative structure (numbers of dipteran families, numbers of species of the Chloropidae) from other birch-aspen woodlots, and it is undoubtedly richer than that in the largest Pino-Quercetum surface areas.

Rather large contribution of synanthropic forms of the fauna points out to the progressive alteration of this environment by man, and the considerable influence of the surrounding cultivated fields. It should be kept in mind, that the surface of the bordering zone, the ecotone, takes 24% of the entire surface area of this forest island (Table 1). This important influence of the open, near-forest areas is noticeable also in the vegetation structure, where synanthropic species take a significant place, in spite of the fact that dominance of forest species shows the continuous forest character of this environment (W ó j c i k 1991).

3.3.4. Presence of water in the woodlot

The presence of a water reservoir in a woodlot gave only during the full summer statistically significant differences between the quantities of fauna in a dry woodlot No. 7 (0.5 ha), and a wet woodlot No. 6 (Table 5). In the scale of the entire season, there were no greater differences between the numbers and biomass of the fauna in both woodlots (Table 6). The same was ascertained for spiders (Ł u c z a k 1991).

Among different groups of animals, the predatory dipterans of the family Dolichopodidae clearly preferred the humid woodlot No. 6, which results from the ecological properties of this group. Some phytophagous insects, such as Curculionidae, occurred there in greater quantities than in a dry environment (Table 10).

The significant difference pertains, first of all, to the seasonal dynamics of numbers in both woodlots, which was "smoothed" in the case of the moist environment, and having two peaks in the dry woodlot (Fig. 3).

Unexpectedly, in July, in the period of a mass hatching of mosquitoes from water reservoirs, including one in woodlot No. 6, their numbers there were twice lower than in dry woodlot No. 7. Similarly, in woodlot No. 5 with a large water reservoir, which was a permanent hatchery of insects (also during spring), the numbers of mosquitoes in July were lower than in woodlot No. 7 (Fig. 6). This gives an evidence of an extensive migration of these insects from their hatching grounds, and thus it shows the important role of these environments in enriching the entire area in entomofauna.

4. DISCUSSION

A group of problems of the landscape ecology, such as the basis of integration of landscape elements, stability of ecological processes in the landscape, dispersion of animals, role of ecotone and buffer zones, are presently important objects of interest to ecologists. All these problems are closely tied with the spatial structure of a landscape, and therefore, all actions directed towards the changes of this structure, affect the phenomena and ecological processes referred to earlier.

One of the types of man-management activities, seriously affecting the landscape structure, is deforestation, the changing of these areas into cultivated fields, and the leaving of small forest enclaves among the "sea" of crop fields. Burgess and Sharpe (1981) give such an example of the process of deforestation taking place in the State of Wisconsin, where during 120 years (1831—1950), the general forest surface area had diminished in 96.5%, the numbers of forest islands had increased 55 times, while their mean surface area had decreased 1500 times. On the other hand, the distances between forest islands, and the lengths of their edge lines had increased considerably. As a result an entirely new landscape had been created, both with respect to its natural values, as to its structure and functioning, and thus with respect to the exchange of energy, matter and species between the elements of the landscape.

This process of transformation of forest landscapes into agricultural-forest landscapes creates many problems for ecologists, including the particularly important one, pertaining to the role of forest islands in the structure and functioning of an agricultural landscape. Ecological significance of forest islands is integrally tied to their characteristic properties, among which such parameter as size, is especially important in biological investigations.

The size of a forest island is decisive, first of all, about the specific environmental properties; the smaller the island, the more it is influenced by the open space. This causes there the formation of microclimatic conditions, different from those occurring in larger forest complexes. Fleming (1983) compares the microclimate of a small forest island to conditions prevailing in a forest ecotone. The specific property of such microclimatic conditions is their high variation, and at the same time, a greater amount of light, higher temperature and lower humidity compared with the interior of a forest, which may have a significant meaning for many groups of organisms.

According to Levenson (1981) floristic richness of a small forest island increases with its size, but only to a certain threshold which is about 2 ha; above this size it usually decreases. Small capacity of such an environment augments its susceptibility to the action of anthropogenic factors, which at least in the first phase of influence, will cause an increase in floristic diversity (Hoehne 1981).

These particular biotopic conditions, and not the size of the surface area alone, as suggested by some investigators (Petrusewicz and Uchmański 1980) cause, that different groups of animals positively react to small forest areas. Literature on this subject pertains mainly to vertebrates, for instance birds (e.g. Hooper 1976, Gromadzki 1970), small mammals (Yahner 1982), and in a lesser degree to invertebrates such as insects (Dąbrowska-Prot 1987a, 1987b, 1987c, 1987d), spiders, (Łuczak 1987). The article of Simberloff (1982) which summarizes the results of many authors on the subject of the size effect of a forest island on the species richness of the fauna, should also be mentioned. This author concludes that there is some evidence which negates, and evidence which confirms the positive effect of small surface areas on the qualitative richness of the fauna. However, he emphasizes, that there are more works showing that many small refuge sites in the landscape, and not one large one, have an essential meaning to enrich the fauna.

Complex investigations on the functioning of entomofauna in an agricultural landscape, conducted in industrial areas in Silesia in the Rybnik Coal District, and for comparison, in the recreation-farm-forest landscape of the Masurian Lakeland, have shown the important role of small forest islands in the maintenance of the quantitative and qualitative wealth of the fauna in a landscape (Dąbrowska-Prot 1986, 1987c, 1987d, Łuczak 1987). It has been shown, that qualitative differences between a larger forest environment, and the originating from it, as a result of deforestation, small mid-field woodlot, result mainly from the fact of the greater exposure of the woodlot to the influence of the open space (Dąbrowska-Prot 1987c, 1987d). This causes an intensive penetration into the woodlot of animal species from the neighbouring open environments. It increases in the woodlot, compared with the forest, the qualitative wealth of the fauna, in spite of the disappearance of some forest species. Thus, for example, among 60 Diptera families found in the research area in Silesia, 18.5% were common for both large and small forest islands, and did not occur in other types of environments. Only 5% families penetrated from open areas into large forest islands, and twice more (10%) occurred exclusively in small forest islands and in cultivated fields (Dąbrowska-Prot 1987c).

Landscape investigations conducted in the years 1976–1977 in the Masurian Lakeland District showed, that the qualitative similarity of entomofauna inhabiting a small forest island and a cultivated field may become, in certain conditions, even greater (Dąbrowska-Prot 1980). It has been found, for example, that only 11.5% of Diptera families occurred exclusively in large (13.5 ha) and small (1 ha) forest islands, and as much as 23% occurred only in a small island and cultivated fields, and were not found in larger forest complexes.

In small forest islands of Silesia there has been observed, a greater, than in large forest areas, seasonal and multi-year qualitative exchange of the fauna (Dąbrowska-Prot 1987), as well as the variability of certain biocoenotic processes (such as predator-prey relations) and population processes (change in species fecundity), (Dąbrowska-Prot 1987d). This points out to the weaker, than in large forest islands, functioning of the regulation mechanisms, which stabilize natural systems.

Investigations conducted in Silesia have confirmed some literature data, for example those pertaining to the greater qualitative and quantitative richness of the fauna in smaller forest surface areas (Burgess and Sharpe 1981, Simberloff 1982, Dąbrowska-Prot 1987d). However, they have provided also a number of new results, for example, on the subject of the greater amplitude of the seasonal changes in the numbers of fauna, on the higher contribution of phytophages and larger multi-year changes in the structure of the fauna in small forest islands, as compared to larger forest surfaces (Dąbrowska-Prot 1987c, 1987d, Łuczak 1987, Paplińska 1987). There remains, however, the question open of a precise definition, of what small and large forest islands are, from the view point of the observed phenomena and ecological processes.

Masurian investigations allow us to make the very important statement, that one should not look for proportional changes in the numbers and structure of entomofauna on one hand, and the progressive decrease or increase of the size of a forest island, on the other. In this case the size class of the island is decisive; both, very large (35 ha, 13.5 ha) and very small (0.125 ha), forest islands were disproportionately less inhabited by entomofauna, than small (1.5 ha and 0.5 ha) islands.

Changes in the structure of entomofauna, related to the size of the forest island, were noticeable in the higher synanthropization of the fauna of the smallest forest area (0.125 ha), and its greater similarity to the fauna of cultivated fields. In the largest forest areas (13.5 and 35 ha), there was a decrease of the contribution of phytophagous and predatory insects; additionally, in the 35 ha area, there occurred a decrease of synanthropic Diptera and a certain decrease in the qualitative diversity of the fauna (the smallest number of Diptera families, few species of Chlorophidae). Both large forest islands provided better, than the small islands, sources of entomofauna for other ecosystems.

Thus mainly small forest islands (1–1.5 ha) made structural elements of the landscape, which attracted entomofauna, both qualitatively and quantitatively richer. In this respect, very large and very small forest islands provided much less favourable environments, particularly during the full vegetative season. In autumn only large forest islands gave shelter to insects.

The second important element of the properties of forest islands is their origin. The most frequently encountered statement in the literature says, that the more the woodlot differs in its character from natural forest environment, the lower is the contribution of forest animal species to its fauna (Tischler 1975). Vague character of this conclusion results from the fact, that usually an additional

important factor is included, namely the size of the environment. That is why a problem arises, if, for example, the differences in avifauna between the mid-field woodlots in a farm landscape and a natural forest complex (G r o m a d z k i 1970) are related rather to the size, or origin of these environments, or perhaps to both? This author however, tends to relate them mainly to the size of the environment. In investigations conducted in the Masurian Lakeland, appropriately chosen groups of woodlots were compared, and thus the effect of the size of environment could have been excluded.

The factor of origin has very clearly distinguished the forest islands studied into two groups. On the one hand, there was a group of several tens years old islands, well defined phytosociologically, of the Pino-Quercetum mixed forest type; on the other hand, there were the birch-aspen woodlots, young in their successive stage, developing in a natural way on wastelands. These small woodlots, typical elements of the agricultural Masurian landscape make forest associations, which in spite of their origin and size, are not easily susceptible to the process of synanthropization. According to W ó j c i k (1991), they make the intermediate stage of succession between a multi-year fallow land and a climax association, most likely of the mixed forest type. Microclimatic studies showed, that they are warmer and dryer environments than the Pino-Quercetum woodlots. This may have a particularly important meaning in the periods of unfavourable climatic conditions, such as in early spring or in autumn.

It became evident, that from the view point of biomass and species management, the birch-aspen woodlots are important elements of the landscape structure. They are more intensively inhabited by entomofauna than the mixed forest environments. At the same time, they are more similar to each other with respect to abundance (numbers and biomass) and quality of the fauna (high contribution of common species and families). They are also more uniformly inhabited by fauna, including the ecotone zone. In addition to this, birch-aspen woodlots show greater faunistic similarity to the neighbouring open environments. This is shown both by data pertaining to Diptera families inhabiting the two types of environments, as well as by the results of ecotone studies. It has been found in the latter, that in the birch-aspen woodlot (forest island No. 5) only 7.5% of Diptera families inhabited exclusively the interior of the woodlot and its ecotone, and did not occur either in the ecotone of the cultivated field, nor in its interior. In the case of the Pino-Quercetum woodlot (forest island No. 3), more than 20% such families were found (D ą b r o w s k a - P r o t unpublished data).

Greater contribution of synanthropic form in birch-aspen woodlots, both among the plants of the field (herb) layer (W ó j c i k 1991) and in Diptera communities, points out to the possibilities of these forest ecosystems being penetrated by groups of organisms related to cultivated terrains, and other types of environments that remain under man-management. All the ecological characteristics of the birch-aspen woodlots stated earlier, point out to the higher, than in the case of the Pino-Quercetum type, possibilities of exchange of fauna between particular woodlots, and also between them and the adjacent open areas.

Certain phenomena provide a direct evidence of such an exchange. Thus, for example, insects hatching in water reservoirs migrate intensively into birch-aspen woodlots; mosquitoes have been found dominant in Diptera communities occurring in three, among four birch-aspen woodlots studied, and only in one Pino-Quercetum island. Similarly, phytophagous dipterans of the family Chloropidae, more easily migrated from field to ecotone, and on to the interior of a birch-aspen woodlot, than to Pino-Quercetum.

One of the indicators of the intensity of exchange of entomofauna between woodlots and adjacent areas, can be expressed as the relationship between the numbers and biomass of soil insect larvae and their adult forms, which inhabit the over ground layers of the environment during the vegetative season. It turned out, that in the case of Diptera in Pino-Quercetum, the numbers of adult forms made only 1% of the numbers of larvae and ca. 5.5% of their biomass, while in the birch-aspen woodlots the values were 7 and 23.5%, respectively. These data show, that there is an intensive migration of insects to other environments following their hatching in the Pino-Quercetum forest islands, a phenomenon observed earlier by O l e c h o w i c z (1984, 1988) for mixed forest associations of the Kampinos forest complex. Birch-aspen woodlots are also important habitats for this type of fauna.

Phenomena discussed earlier point out to the great role of forest islands, and particularly of the birch-aspen woodlots, in the biomass and species management within the landscape. There is a continuous exchange of fauna between woodlots and the open space. It enriches both the animal communities which inhabit the woodlots and the cultivated fields. It enables survival to part of the fauna, during difficult climatic conditions, in the periods of intensive field agro-technical cultivation, and during winter. This qualitative enrichment in fauna of the agrocoenoses by forest islands, is especially intensive when small cultivated fields dominate the landscape (L e w i s 1970).

One of the problems discussed in relation with woodlots is their role as the environments, which make possible the maintenance in the landscape of many phytophagous populations, and of organisms, such as parasites and predators, which are useful from the view point of man-management. It has been ascertained earlier, that for pests of cultivated fields, such as Chloropidae, the midfield woodlots are only substitute environments, readily inhabited in the periods of agrotechnical works, or at the time of unfavourable climatic conditions (M e l n i č e n k o 1949, D a b r o w s k a - P r o t 1987a, 1987c). On the other hand, woodlots are more extensively inhabited by pests related mainly to wild vegetation, shrubs and trees, and for them, they may provide a more favourable environment than a larger forest complex (D a b r o w s k a - P r o t 1987d). It has been suggested, that the existence of small mid-field woodlots in the landscape, attracting these types of pests, may act as protection to forests. Present investigations show, that birch-aspen woodlots maintain richer, than Pino-Quercetum islands, fauna of phytophages and predators. Thus, adopting the hypothesis about the protective role of woodlots in relation to forests, they provide a good "trap" environment for these both trophic groups of insects, with potentially favourable conditions for the biological reduction of pests.

Except for the size and origin, many other parameters of the characteristics of forest islands, affect their role in the structure and functioning of the landscape. Location in the area, and particularly exclusion of an island from a complex of other woodlots, and its isolated occurrence in the "sea" of cultivated fields, increase the intensity of its inhabiting by entomofauna. This pertains to some groups of phytophagous and synanthropic forms. The latter occur in relation to grazing, polluting and trampling, thus with the increasing alteration of the environment by man. Such environment is also more used as refuge by migrants (i.e. Diptera), and as a wintering place for the fauna, for instance, the Coccinellidae (Gałecka 1991). However, even in the case of the special location in the landscape of an Pino-Quercetum island, it never becomes as attractive for the entomofauna, as the birch-aspen woodlot. The presence of a small water pool in the forest island, affected the extent of its inhabiting by insects only in the period of a mass hatching from that reservoir.

The entire studies show, that birch-aspen woodlots are, from the view point of the numbers, biomass and species management, particularly important structural elements of an agricultural landscape. They are characterized by fauna, which is qualitatively and quantitatively much richer, than in the mixed forest environments. High dynamics of changes in the numbers and biomass of entomofauna in these woodlots during the season, the concentration there of forms migrating in the landscape, and periodical occurrences of certain ecological groups of insects, point out to the extensive exchange of the fauna between birch-aspen woodlots and the adjacent areas. It is made possible to a high degree, by the similarity of fauna in these woodlots and in adjacent agrocoenoses, the small specificity of the environment and thus of the particular birch-aspen woodlots, and a greater, than in Pino-Quercetum, contribution of eurytopic forms capable of existing in a variety of environments.

All these properties of the birch-aspen woodlots, besides the greater capacity of these environments for the fauna, (more uniform distribution of insects) and a lesser differentiation of the ecotone than in Pino-Quercetum, make possible the penetration into them of foreign elements of fauna, and the survival of fauna during unfavourable periods, both in summer, at the time of advanced agrotechnical works, and in winter.

If we assume, following Forman and Godron (1983), that the stability of a landscape is shown by its ability of maintaining a defined level of biomass, numbers and species, then, the birch-aspen woodlots which counteract the escape of these elements from the landscape, may form one of the components of its stability. Our studies showed the high ecological role of these types of forest environments in agricultural landscapes. By foresters and farmers they are unjustly treated as unproductive environments of little biological value.

5. SUMMARY

The studies included eight forest islands which differed one from another by size, origin, the presence of water pools and the location in a landscape (Table 1, Figs. 1, 2). One group of environments was formed by nearly 100-years old, well phytosociologically defined, mixed forest islands of the Pino-Quercetum type; they were remnants after deforestation of larger forest complexes. The second group

was formed by birch-aspen woodlots, young in succession and naturally developing in waste land. The latter make, according to Wójcik (1991), an intermediate stage of succession between a multi-year fallow land and a climax association of, probably, the mixed forest type. Both types of forest islands make typical components of the agricultural Masurian landscape.

The studies showed, that the major properties of forest islands, which are decisive about their role in the structure and functioning of entomofauna are: size, origin, and location in landscape. It was found, that the size class is an important factor of the intensity of inhabiting forest islands by entomofauna, and of the fauna structure (Table 5). Both very large islands (35 ha, 13.5 ha), and a very small one (0.125 ha), were much less inhabited by entomofauna, than small islands (1.5 ha, 0.5 ha) (Tables 5, 6, Figs. 4, 5). Changes in the structure of entomofauna related to the size of a forest island were mainly shown in the smaller contribution of phytophages and predators to both largest forest areas (Table 10), and in the decrease of contribution of synanthropic forms (Table 9), and in the decrease of diversity of the fauna (Table 8) in the 35 ha island. The smallest forest island (0.125 ha) had the most synanthropic type of fauna (Table 9), which qualitatively resembled most the fauna of cultivated fields. Summarizing, mainly the small forest islands (1.5 and 1 ha) were the elements of the landscape structure, which concentrated rich entomofauna, both quantitatively and qualitatively.

The two large forest islands (35 ha and 13.5 ha) were a greater source than small islands, of the entomofauna, which inhabited other ecosystems in the landscape of the Jorka river watershed (Table 13).

1 ha forest island of the Pino-Quercetum type, standing alone among cultivated fields, was clearly more attractive for insects, than an island of a similar origin and size but situated in the vicinity of other forest islands (Figs. 2, 4, Tables 6, 8). It concentrated, first of all, phytophagous forms (Table 10), those migrating in the landscape, and synanthropic insects (Table 9).

It became evident, that from the view point of biomass and species management, small birch-aspen woodlots of the size no less than 0.5 ha, are especially important elements of the landscape structure. They are inhabited by entomofauna which is quantitatively and qualitatively richer than that in a mixed forest environment (Tables 6, 8). Seasonal dynamics of numbers and biomass in birch-aspen woodlots (Table 4), the concentration of insects hatching in water reservoirs there (Fig. 6, Table 9), the intensive inhabiting by predators (Table 10), and the easiness of dispersion through their ecotone zones of some insect groups from cultivated fields (Table 11), all this points out to the possibilities of an extensive exchange of fauna between birch-aspen woodlots and the surrounding open areas. In the strongly changing agricultural landscape, they may provide shelter environments for insects, and thus they can play the role of one of the stability factors in a landscape, which counteracts the escape of biomass and species.

From the view point of management, the protective role of these woodlots in relation to larger forest complexes is significant; they make "traps" for holding certain groups of phytophagous insects (Tables 8, 10, 11). At the same time, they have potential possibilities to reduce their numbers through the abundance of predators (Table 12).

Summarizing, our studies have shown the significant ecological role of small forest enclaves in the landscape, especially those which naturally develop on post-farm waste lands, and which are treated both by foresters and farmers, as unproductive environments having little biological value.

6. POLISH SUMMARY

Badaniami objęto osiem wysp leśnych różniących się wielkością, pochodzeniem, obecnością oczek wody i położeniem w krajobrazie (tab. 1, rys. 1, 2). Jedną grupę środowisk tworzyły cztery około 100-letnie, dobrze określone fitosocjologicznie wyspy boru mieszanego Pino-Quercetum, pozostałości po wycięciu większych kompleksów leśnych. Drugą — sukcesyjnie młode, samorzutnie rozwijające się na nieużytkach zadrzewienia brzoźowo-osikowe. Te ostatnie stanowią według Wójcik (1991) pośrednie stadium sukcesji od wieloletniego odłogu do zbiorowiska klimaksowego, najprawdopodobniej boru mieszanego. Oba rodzaje wysp leśnych stanowiły typowy element rolniczego krajobrazu mazurskiego.

W badaniach wykazano, że głównymi właściwościami wysp leśnych, decydującymi o ich znaczeniu w kształtowaniu struktury i funkcjonowaniu entomofauny są: wielkość, pochodzenie oraz położenie w krajobrazie. Stwierdzono, że o intensywności zasiedlania wysp leśnych przez entomofaunę oraz o jej

strukturze decyduje przynależność do klasy wielkości (tab. 5). Zarówno bardzo duże wyspy leśne (35 ha, 13,5 ha) jak i bardzo mała (0,125 ha) były znacznie słabiej zasiedlane przez entomofaunę niż małe wyspy (1,5 ha, 0,5 ha) (tab. 5, 6, rys. 4, 5). Zmiany w strukturze entomofauny w związku z wiekością wyspy leśnej polegały głównie na mniejszym udziale w entomofaunie fitofagów i drapieżców w obu największych powierzchniach leśnych (tab. 10), a w 35-hektarowej również na spadku udziału form synantropijnych (tab. 9) oraz różnorodności fauny (tab. 8). Najmniejsza wyspa leśna (0,125 ha) miała najbardziej zsynantropizowaną faunę (tab. 9) i jakościowo najbardziej zbliżoną do fauny pól uprawnych. Podsumowując, głównie małe wyspy leśne (1,5 ha, 1 ha) były elementem struktury krajobrazu skupiającym bogatą ilościowo i jakościowo entomofaunę.

Obie duże wyspy leśne (35 ha i 13,5 ha) intensywniej niż małe wyspy wzbogacały w entomofaunę inne ekosystemy w krajobrazie zlewni rzeki Jorki (tab. 13). Jednohektarowa wyspa leśna typu Pino-Quercetum, samotnie występująca wśród pól uprawnych, była wyraźnie atrakcyjniejsza dla owadów niż podobnego pochodzenia i wielkości, położona w pobliżu innych wysp leśnych (rys. 2, 4, tab. 6, 8). Skupiała ona przede wszystkim formy roślinożerne (tab. 10) i migrujące w krajobrazie (tab. 9) oraz synantropijne (tab. 9).

Okazało się, że z punktu widzenia gospodarki biomasą i gatunkami szczególnie ważnym elementem struktury krajobrazu są małe zadrzewienia brzożowo-osikowe, które nie są mniejsze niż 0,5 ha. Zasiedlane są przez bogatszą ilościowo i jakościowo entomofaunę niż środowiska boru mieszanego (tab. 6, 8). Przebieg sezonowej dynamiki liczebności i biomasy w zadrzewieniach brzożowo-osikowych (tab. 4), skupianie się tam owadów wylęgających się w zbiornikach wodnych (rys. 6, tab. 9), intensywne zasiedlanie przez drapieżce (tab. 10) oraz łatwość przenikania przez ich strefę ekotonową niektórych grup owadów z pól uprawnych (tab. 11) wskazują na możliwości intensywnej wymiany fauny między zadrzewieniami brzożowo-osikowymi i otaczającymi je terenami otwartymi.

W intensywnie zmieniającym się krajobrazie rolniczym mogą one stanowić środowiska ostożowe dla owadów, a w konsekwencji pełnić rolę jednego z czynników stabilności krajobrazu, przeciwdziałającego „ucieczce” z niego biomasy i gatunków.

Z punktu widzenia gospodarczego duże znaczenie ma fakt ochronnej roli tych zadrzewień w stosunku do większych kompleksów leśnych, ze względu na przechwytywanie i przetrzymywanie przez tego typu środowiska niektórych grup roślinożerców (tab. 8, 10, 11). Jednocześnie istnieją tam potencjalne możliwości biologicznej redukcji ich liczebności przez występujące licznie drapieżce (tab. 12).

Podsumowując, w badaniach wykazano duże ekologiczne znaczenie małych enklaw leśnych w krajobrazie, szczególnie samorzutnie rozwijających się na nieużytkach porolnych, które zarówno przez leśników, jak i rolników traktowane są jako środowiska nieproduktywne o małych walorach przyrodniczych.

7. REFERENCES

1. B a j k i e w i c z - G r a b o w s k a E. 1986 — Factors affecting nutrient budget in lakes of the Jorka watershed (Masurian Lakeland, Poland). I. Geographical description hydrographic components and mans impact — *Ekol. pol.* 33: 173–200.
2. B u r g e s s R. L., S h a r p e D. M. 1981 — Introduction (In: *Forest island dynamics in man dominated landscape*. Eds. R. L. Burgess, D. M. Sharpe) — Springer-Verlag, New York—Heidelberg—Berlin, 1: 1–5.
3. C r a n e A. E. 1961 — A study of the habits of *Rhamphomyia scutellaris* Coquillett (Diptera: Empididae) — *Wasmann J. Biol.* 19: 247–262.
4. D ą b r o w s k a - P r o t E. 1968 — Zagęszczenie drapieżców i ofiar, a tempo redukcji [Density of predators and prey and rate of reduction] — *Ekol. pol.* B, 14: 337–342.
5. D ą b r o w s k a - P r o t E. 1980 — Ecological analysis of Diptera communities in the agricultural region of the Masurian Lakeland and the industrial region of Silesia — *Pol. ecol. Stud.* 6: 685–716.
6. D ą b r o w s k a - P r o t E. 1984 — Structural and functional characteristic of Chloropidae community in an industrial landscape — *Pol. ecol. Stud.* 10: 111–140.
7. D ą b r o w s k a - P r o t E. 1986 — Diptera in an agricultural landscape (In: *Impacts de la structure des paysages agricoles sur la protection des cultures*) — *Les colloques de l'INRA*, 36: 97–106.

8. Dąbrowska-Prot E. 1987a — Rola zadrzewień śródpolnych w krajobrazie rolniczym [The mid-field woodlots in the agricultural landscape] — *Wiad. ekol.* 33: 48–59.
9. Dąbrowska-Prot E. 1987b — Diptera jako bioindykatory stanu środowiska przyrodniczego [Diptera as bioindicators of the environmental state] — *Wiad. entomol.* 7: 3–11.
10. Dąbrowska-Prot E. 1987c — The effect on Diptera of woodlots in an agricultural landscape — *Pol. ecol. Stud.* 13: 71–94.
11. Dąbrowska-Prot E. 1987d — Woodlots in an agricultural landscape — *Pol. ecol. Stud.* 13: 153–168.
12. Dąbrowska-Prot E., Karg J. 1975 — An ecological analysis of Diptera in agrocenoses — *Pol. ecol. Stud.* 1: 123–127.
13. Dąbrowska-Prot E., Łuczak J., Tarwid K. 1968 — Prey and predator density and their reactions in the process of mosquito reduction by spiders in field experiments — *Ekol. pol. A*, 16: 773–819.
14. Downes J. A. 1970 — The feeding and mating behaviour of the specialized Empididae (Diptera); observation on four species *Rhamphomyia* in the high Arctic and a general discussion — *Can. Entomol.* 102: 769–791.
15. Dzieje lasów, leśnictwa i drzewnictwa w Polsce [The history of forests, forestry and woodcraft in Poland] Eds. A. Żabko-Potopowicz 1965 — Państwowe Wydawnictwo Rolnicze i Leśne, Warszawa, 786 pp. (complete edition).
16. Flemming G. 1983 — Klimat — środowisko — człowiek [Climate — environment — Man] — Państwowe Wydawnictwo Rolnicze i Leśne, Warszawa, 12 pp.
17. Forman R., Godron M. 1986 — Landscape ecology — John Wiley and Sons, New York—Toronto, 618 pp.
18. Gałęcka B. 1991 — Importance of forest islands for populating of agricultural landscape by coccinellids (Coccinellidae, Coleoptera) — *Ekol. pol.* 39: 561–577.
19. Goszczyński J. 1985 — Wpływ strukturalnego zróżnicowania krajobrazu ekologicznego na przebieg interakcji drapieżnik—ofiara [The effect of structural variation of ecological landscape on the predator—prey interaction] — Wydawnictwa SGGW-AR, Warszawa, Rozpr. nauk. Monogr., 79 pp.
20. Gromadzki M. 1970 — Breeding communities of birds in midfield afforested areas — *Ekol. pol. A*, 19: 307–350.
21. Hillbricht-Ilkowska A. (Ed.) 1983 — Biotic structure and processes in the system of river Jorka watershed (Masurian Lakeland, Poland) — *Ekol. pol.* 31: 535–834.
22. Hoehne L. M. 1981 — The ground layer vegetation of forest islands in an urban — Suburban matrix (In: Forest island dynamics in man—dominated landscape. Eds. R. L. Burgess, D. M. Sharpe) — Springer—Verlag, New York—Heidelberg—Berlin, 41–54.
23. Hooper D. M. 1976 — Historical and biological studies on English hedges (In: Les bocages, histoire, écologie, économie) — CNRS — ENSA, Université de Rennes, pp. 225–227.
24. Koch L. F. 1957 — Index of biotal dispersity — *Ecology*, 38: 145–148.
25. Kondracki J. 1972 — Polska północno-wschodnia [North-eastern Poland] — Państwowe Wydawnictwo Naukowe, Warszawa, 271 pp.
26. Kondracki J. 1976 — Podstawy regionalizacji fizyczno-geograficznej [The basis of physical-geographical regionalization] — Państwowe Wydawnictwo Naukowe, Warszawa, 168 pp.
27. Kovalev V. T. 1966 — K faune podsemejstva Tachydrominae (Diptera, Empididae) srednej polosy evropejskoj časti SSSR — *Entomol. oboz.* 45: 774–792.
28. Laurence B. R. 1952 — The prey of some Empididae and Dolichopodidae (Diptera) — *Entomol. mon. Mag.* 88: 156–157.
29. Lewis T. 1970 — Pattern of distribution of insects near a windbreak of tall trees — *Ann. appl. Biol.* 65: 213–220.
30. Levenson J. B. 1981 — Woodlots as biogeographic island in Southeastern Wisconsin (In: Forest island dynamics in man—dominated landscapes. Eds. R. L. Burgess, D. M. Sharpe) — Springer—Verlag, New York—Heidelberg—Berlin, 13–39.
31. Łuczak J. 1987 — Spiders of woods and woodlots in an industrial landscape — *Pol. ecol. Stud.* 13 (1): 113–137.

32. Łuczak J. 1991 — The role of forest islands in distribution and dynamics of the Araneae communities — *Ekol. pol.* 39: 517–543.
33. Mělničenko A. N. 1949 — Polezaščitnye polosity rozmnoženija životnych poleznych i vrednych dla selskogo chozjajstva — Nauka, Moskwa, 359 pp.
34. Odum E. P. 1982 — Podstawy ekologii [Fundamentals of ecology] — Państwowe Wydawnictwo Rolnicze i Leśne, Warszawa, 660 pp.
35. Olechowicz E. 1984 — Herb layer entomofauna of different forest ecosystems in the Kampinos Forest and its participation in cycling of elements — *Ekol. pol.* 32: 43–60.
36. Olechowicz E. 1988 — The structure of community of Diptera imagines of different forest ecosystems in the Kampinos Forest — *Ekol. pol.* 36: 509–529.
37. Papińska E. 1987 — Preliminary quantitative and qualitative estimation of soil associations of Diptera larvae occurring in forest ecosystems and in woodlots in the vicinity of Knurów (Silesia) — *Pol. ecol. Stud.* 13: 95–111.
38. Parker R. E. 1978 — Wprowadzenie do statystyki dla biologów [Introductory statistics for biology] — Państwowe Wydawnictwo Naukowe, Warszawa, 162 pp.
39. Petruszewicz K., Uchmański J. 1980 — Density of confined and open population. A model study — *Bull. Acad. Pol. Sci. Sér. Sci. biol.* Cl, II, 28: 49–58.
40. Pielou E. C. 1966 — The measurement of diversity in different types of biological collections — *J. theor. Biol.* 13: 370–383.
41. Polakowski B., Dziedzic J., Hołdyński Cz., Korniak J., Pietraszewski W., Szarejko T. 1985 — Real vegetation of the Jorka River watershed — *Pol. ecol. Stud.* 11: 209–214.
42. Siegel S. 1956 — Nonparametric statistics for behavioral Sciences — McGraw-Hill Company, New York–Toronto–London, 311 pp.
43. Simberloff D. S. 1982 — Teoria ostrovnoj biogeografii i organizacja ochranijajemych territorii — *Ekologia*, 4: 3–13.
44. Smith K. C. V. 1952 — On the prey of two smarms of *Hilaria neura* F. (Diptera, Empididae) — *Entomol. mon. Mag.* 88: 38–39.
45. Tarwid M. 1987 — Fecundity of the spider *Enoplognatha ovata* Cl. in forest ecosystems, their ecotones and mid-field woodlots — *Pol. ecol. Stud.* 13(1): 139–151.
46. Tischler W. 1975 — Zmiany struktury krajobrazu a biosfera [Changes in the landscape structure and biosphere] (In: *Kształtowanie krajobrazu a ochrona przyrody* [Shaping of the landscape and environmental protection] Eds. K. Buchwald, W. Engelhardt) — Państwowe Wydawnictwo Rolnicze i Leśne, Warszawa, 223–237.
47. Traczyk T. (Ed.) 1985a — Matter flow through agricultural landscape. Part I. Environmental characteristics primary production of the Jorka River watershed (Masurian Lakeland) — *Pol. ecol. Stud.* 11: 170–336.
48. Traczyk T. (Ed.) 1985b — Matter flow through agricultural landscape. Part II. Chemical estimation of landscape subsystems of the Jorka River watershed (Masurian Lakeland) — *Pol. ecol. Stud.* 11: 343–466.
49. Traczyk T., Kloss M. 1985 — Spatial structure of land management in the Jorka watershed — *Pol. ecol. Stud.* 11: 239–246.
50. Whitcomb R. F., Robbins C. S., Lynch J. F., Whitcomb B. L., Klimkiewicz M. K., Bystrak D. 1981 — Effect of forest fragmentation on avifauna on the eastern deciduous forest (In: *Forest island dynamics in man—dominated landscapes*. Eds. R. J. Burgess, D. M. Sharpe) — Springer–Verlag, New York–Heidelberg–Berlin, 1: 125–205.
51. Wójcik Z. 1991 — The vegetation of forest islands in the agricultural landscape of the Jorka river reception basin in the Masurian Lakeland (north-eastern part of Poland) — *Ekol. pol.* 39: 437–479.
52. Yahner R. H. 1982 — Microhabitats use by small mammals in farmstead shelterbelts — *J. Mammal.* 63: 440–445.