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THE VEGETATION OF THE TRANSITION ZONES BETWEEN FOREST ISLANDS AND CULTIVATED FIELDS

ABSTRACT: The investigation embraces several forest islands characteristics of the agricultural landscape of Masurian Lakeland – as well as their border zones. The investigated islands differ in their size and origin. Part of them represents the remnants of pine plantations that – in the course of their 100-year-old development – became transformed into a mixed forest (Pino-Quercetum). The other part represents spontaneously developed birch and aspen woods – the transition stages of the succession from the fallow land to the mixed forest.

We analysed the structure of the vegetation and the floristic composition of transition zones that develop between the investigated forest islands and the surrounding cultivated fields.

We noted that the above characteristics depend on the type of the island's vegetation and that of the cultivated field; on the size of the island and on the exposure of the island's border to various points of the compass.

KEY WORDS: forest island, mixed forest, birch and aspen wood, transit or transition zone (ecotone), synanthropic species.

1. INTRODUCTION

This report concerning the vegetation in the transition zones of forest islands in agricultural landscape of Masurian Lakeland (north-eastern Poland) is a continuation of our earlier research concerning those islands' vegetation (Wójcik 1991) that contained the characterization of eight forest islands chosen as representative of this region – as well as the estimation of their degree of synanthropization. The information about their border zones representing the transition to the cultivated fields was of a preliminary character only. We mentioned there that – among other things – there were structural and floristic

differences between the vegetation of transition zones of various type of forest islands and also some kind of this vegetation's dependence on the relation of the forest border to the points of the compass.

In the agriculturally cultivated regions of the forest zone, where forests appear mainly as small remnants and still smaller spontaneously grown woods – the length of forest borders and the share of transition zones in the whole forest area is growing continuously in the course of the forest's devastation. The importance of transition zones in the landscape structure is also growing and this is the main reason for our undertaking the present study.

According to our definition, the transition zone (or the contact zone) of two phytocenoses is a narrow belt of vegetation between two phytocenoses that represent two different types of plant communities and most often occupy greater areas. In the floristic composition of the vegetation, elements of both communities are found. That is why it has – both in the floristic and ecological sense – a transitory character between those two communities (e.g. Traczyk 1960, Matuszkiewicz 1972).

In a more general, ecosystemic formulation, the transition zone (ecotone) is a variable (depending on time and space) zone of exchange between neighbouring ecological systems (ecosystems). The exchange concerns both, species and the matter and energy (di Castri et al. 1988).

In the Polish literature, there are many publications dealing with the vegetation of transition zones between natural forest communities (Krankowska-Sznajder 1952, Traczyk 1960, Polakowska 1966, Matuszkiewicz 1972, Kotowska 1988), but much less works about the ecotones that develop between the forest and the open space (forest-meadow, forest-field) (Dąbrowska-Prot et al. 1973).

In phytosociological reports we only find the information about plant communities that develop on forest borders because those reports are concerned with those very communities and not with the transition zones. From the works dealing with mid field shelter belts one can deduce the islands' influence on the yield of surrounding fields and on the change of microclimatic and hydrologic conditions in their immediate neighbourhood. But those reports lack the quantitative and qualitative appraisal of floristic changes within the transition zone and they do not attempt to define the limits of this zone. The American authors (Levenson 1981, Ranney et al. 1981, Wales 1972) pay more attention to the problems of transition zone between the forest and the open space.

With the aim of gaining a more accurate information about the transition zone between forest islands and the fields, we tried to answer the following questions:

1. What is the structure of the vegetation, its floristic composition and the species richness in the transition zones and whether it is possible to differentiate the latter from plant communities they separate? Whether it is possible – on this basis – to accurately define the limits between forest islands and transition zones?

2. Whether there is any dependence – and of what kind – of the transition zone characteristics on the following factors:

a) microclimatic conditions connected with the exposure of the forest border to the various quarters of the compass,

b) the type of the plant community of the forest island that in our case depends on the island's origin (whether it is a remnant of a mixed forest or a spontaneously grown wood),

c) the type of the plant community that develops on the surrounding cultivated field,

d) the size of the forest island in whose neighbourhood the investigated transition zone has developed.

3. What significance have the transition zones for the synanthrophization of forest islands?

2. THE INVESTIGATED AREA AND THE OBJECT OF OUR RESEARCH

This area is located within the Masurian Lakeland (north-eastern Poland). Its geographic coordinates are: 53°7' of the northern latitude and 21°3' of the eastern longitude. It is a region of the last glaciation, hilly and with many lakes. It has diversified soils and a continental, rather chilly climate (the average annual temperature = 6.8° C), with a short vegetation season (180–190 days) (Bajkiewicz-Grabowska 1985).

In the geobotanical classification of Poland's territory (Szafer 1972) this area belongs to the Northern Division whose flora and vegetation considerably differ from those of the whole rest of the country. It lies directly beyond the north-eastern limit of the beech-tree range and on the south-western extremity of the boreal reach of the spruce.

The investigated area is much deforested. Some forest remnants form forest islands whose size oscillates from some tens of m^2 to several dozen ha. They represent remnants of the planted pine forests or birch and aspen woods spontaneously grown on wastelands. usually they develop in places unsuitable for cultivation.

The remnants of old pine forests have already – in the course of their 100-year old development – achieved an accordance of their community with the occupied space and now represent a mixed forest (Pino-Quercetum Kozł. 1925 em Mat. et Polak. 1955). The birch aspen woods – as deduced from their floristic composition – are in a relatively early stage of regenerative development that tends in the same direction (Wójcik 1991).

As the object of our investigation we took five forest islands of various size, some chosen of mixed forests and same of birch and aspen woods. The position of those islands within the investigated area is shown on the enclosed map (Fig. 1).

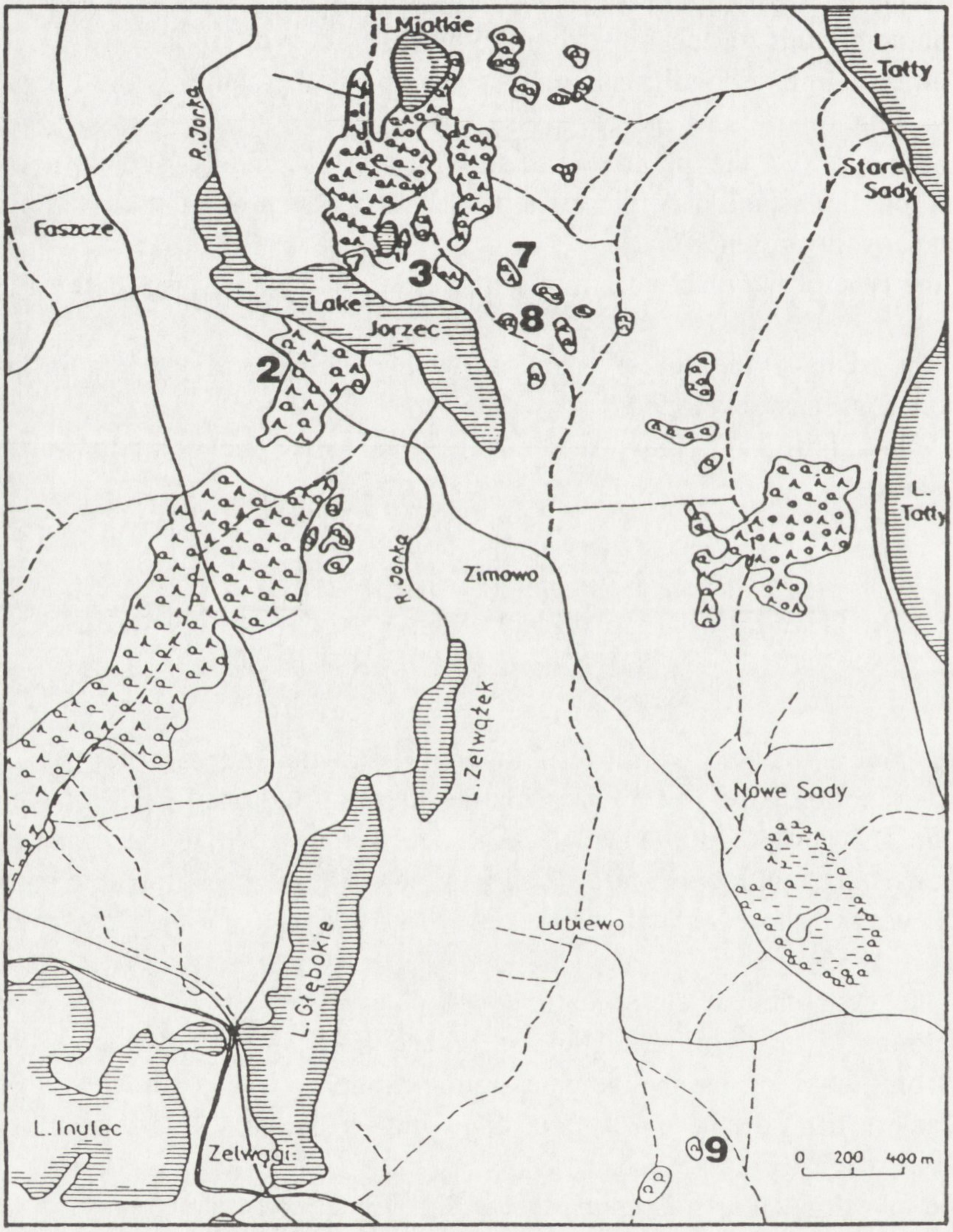


Fig. 1. Distribution of forest islands on investigated areas; 2, 3 and 9 – mixed forest islands, 7 and 8 – birch and aspen wood islands

Out of the three chosen mixed-forest islands, two (of the surface 13.5 and 1 ha) were described earlier (Wójcik 1991) as islands no. 2 and 3, and the third, newly chosen, is smaller (about 0.2 ha). Both spontaneously grown birch and aspen woods (1 and 0.1 ha) were also described in the previous report (islands no. 7 and 8). On the greatest island (13.5 ha), a narrow tongue of forest deeply jutting out into the fields was the object of our investigations concerning the transition zone. Its width was similar to the diameter of other investigated islands. All those islands were situated in places slightly raised above the surrounding cultivated fields.

3. METHODS

When conducting our investigations within this glacial lakeland landscape we tried to chose – whenever possible – the islands that occupied similar positions in the earth's surface. In order to compare transition zones of a mixed forest and those of birch and aspen woods we chose for our research the islands on small elevated places of the terrain, stony and not suited for cultivation, since in those conditions, both the remnants of mixed forests and birch and aspen woods could be found.

In the field research the method of a belt transect was used. It is a method universally accepted in the investigations of the vegetation of transition zones between the phytocenoses (Traczyk 1960, Polakowska 1966, Matuszkiewicz 1972, Ranney et al. 1981, Kotowska 1988). The transects cut through forest islands from the south to the north and from the west to the east (Fig. 2). The stripe of sample surfaces runs from the middle of the field

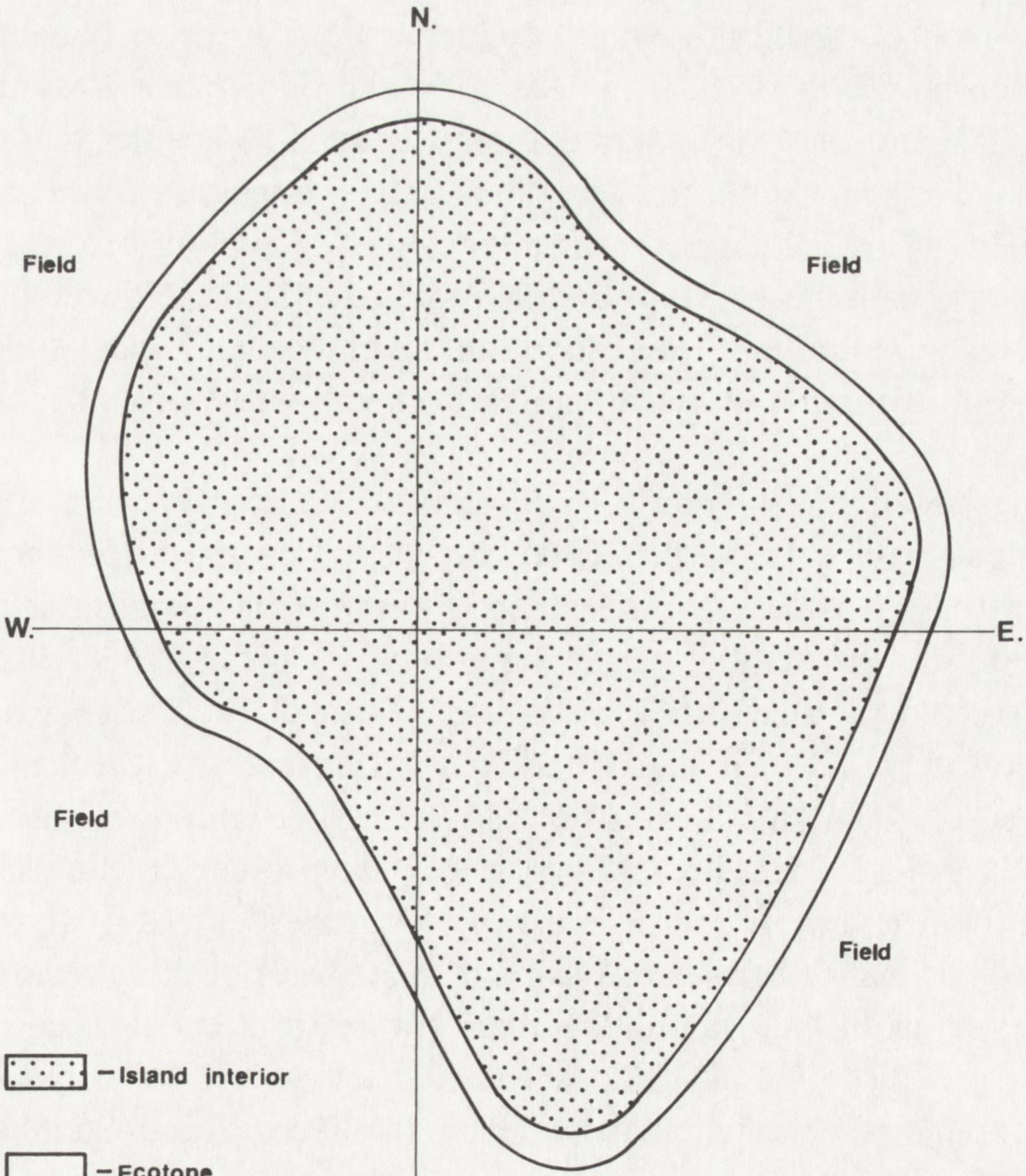


Fig. 2. Schema of transect course across the investigated forest islands

adjoining the island, passes through the transition zone between the field and the forest island, then through island's interior and the opposite transition zone, to finally end in the opposite cultivated field. In the transition zone the transects were continuous and on the cultivated field and in the interior of forest islands the phytosociological records were made only in those places where the vegetation was different from that on the earlier investigated site.

The sizes of record surfaces were so chosen that they were considerably greater than the largest found in the islands of individual plants of the ground layer – and at the same time were small enough so that in the transition zone they were relatively numerous (Faliński 1962, Matuszkiewicz 1972). That is why, in the transition zone those surfaces totaled 2 x 1 m but in the fields and inside the islands 2 x 2 m for the ground layer and 6 x 10 m for the tree-and-shrubbery layer. The number of records made in individual transects varied. Depending on the island's size and the width of the transition zone, it amounted to 17–29.

The embrace all possible vascular plants and mosses, the investigations on the transect were repeated a number of times at different times at different dates. In the vegetation season of 1991 they were conducted from April to November, in the middle of each month. In 1992 – in May, July and September, toward the end of each month. The enclosed tables and diagrams contain all species that were found. In July 1993 we conducted our investigations only in transition zones and adjoining cultivated fields. This year, for the first time from beginning of our research, all fields were sown with winter crops and this fact equalized the development conditions of segetal communities. That is why, in the phytosociological tables and derivative tables and diagrams we used records from cultivated fields of this particular year 1993.

The phytosociological records made along the transects were compiled into phytosociological tables. In those table the records are arranged from the south to the north and from the west to the east – exactly in the sequence of their making. We show in them only the number of species according to the Broun-Blanquet scale, universally accepted in the Central and Western Europe. The presence of trees, both high (a_1) and lower (a_2), that exceed the record's surface (2 x 2 = 4 m^2) is marked with the letter V. The sign V means that the tree grows within the record's surface and v – that only its branches reach its surface. The presence of tree species in the shrub and ground layers (b and c) is expressed in the degrees of Braun-Blanquet scale, similarly as that of herbaceous plants. On the basis of those records, the diagrams of coefficients of their floristic similarity were worked out (according to Czekanowski, after Kulczyński 1940). The coefficients of similarity of the records to those diagrams were calculated by using the Jaccard and Steinhaus formula (Sławiński 1950). On the basis of those diagrams it was possible to define the limits between the transit zone and the interior of islands more precisely and to divide transition zones into narrower belts. The results were presented in the form of tables and figures but it was impossible to include all of them in our necessarily short

report. That is why, some of them were represented only by examples. One of the chosen examples was a mixed-forest island no. 3 and the other – a birch and aspen wood no. 7 (Fig. 1). Those two islands – of different origin and, consequently, of different vegetation – have the same surface (about 1 ha). Their comparison seems thus to be most reliable.

In order to evaluate the microclimatic conditions inside the islands, in the transition zones and in the surrounding fields, we measured temperatures and air humidity by means of psychrometers, at the altitude of 2 m (in the forest – the shrub layer) and of 20 cm (the ground layer). In 1991, the measurements on the south-north transects were made on two islands: one of the mixed forest (no. 3) and one of the birch and aspen (no. 7). They were made in April, June, September and October, between hours 10:00 and 11:00. In July of the same year we made similar measurements on the same islands – every hour from 10:00 to 16:00. In 1992, we made measurements at 12:00 noon each day from the 21th to the 24th of July, in all five investigated forest islands along the south-north and west-east transects. In the two chosen islands (of mixed forest no.3 and of birch and aspen wood no. 7) – also in the morning at 9:00 and in the afternoon at 18:00.

4. RESULTS

4.1. MICROCLIMATIC CONDITIONS OF FOREST ISLANDS AND TRANSITION ZONES

Our investigations show that there are differences in the microclimatic conditions between mixed forest islands and birch and aspen woods: differences between the conditions inside the islands, in their transition zones and in the adjoining cultivated fields – and also at different distances from the earth surface. Differences between microclimatic conditions are most distinct in spring (Figs 3 and 4) but also in summer, particularly about noon and in the afternoon (Table 1). In the fall, the air temperature along the transects becomes almost equalized (Fig. 5). Microclimatic differences also depend on the type of weather conditions – they become particularly conspicuous in sunny weather, in dry and windless days (Figs 3 and 4) and are less marked during chilly and windy days (Fig. 5). It was found – among other things that:

1. Mixed-forest islands are usually more chilly and humid than the birch and aspen woods – and not only in their interiors but also in their transition zones (Figs 3 and 4).

2. Transition zones exposed to the south are warmer than the inside parts of islands and the adjoining cultivated fields. In early spring those differences can be as large as 5–6° C. The temperatures in transition zones exposed to the north are similar to those in the island's center (Fig. 3).

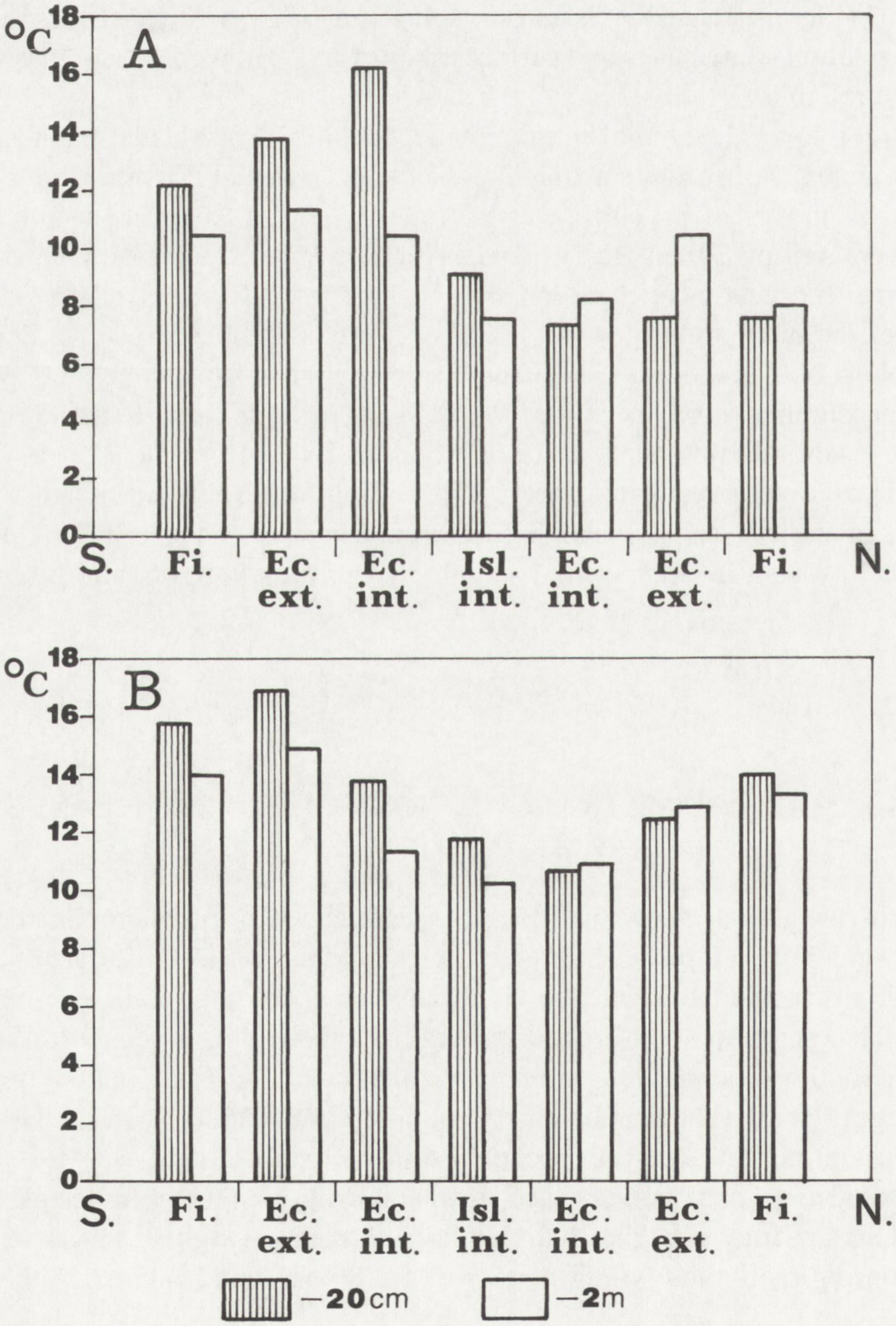


Fig. 3. Variability of temperature (° C) along the transects S-N across forest islands, measured 24 April 1992 at 10 a.m. (sunny, dry and windless day) at the altitude of 20 cm and 2 m above the ground; A – across 1 ha island of mixed forest no. 3; B – across 1 ha birch and aspen wood island no. 7

Fi. – field, Ec. ext. – exterior transit zone, Ec. int. – interior transit zone, Isl. int. – island interior

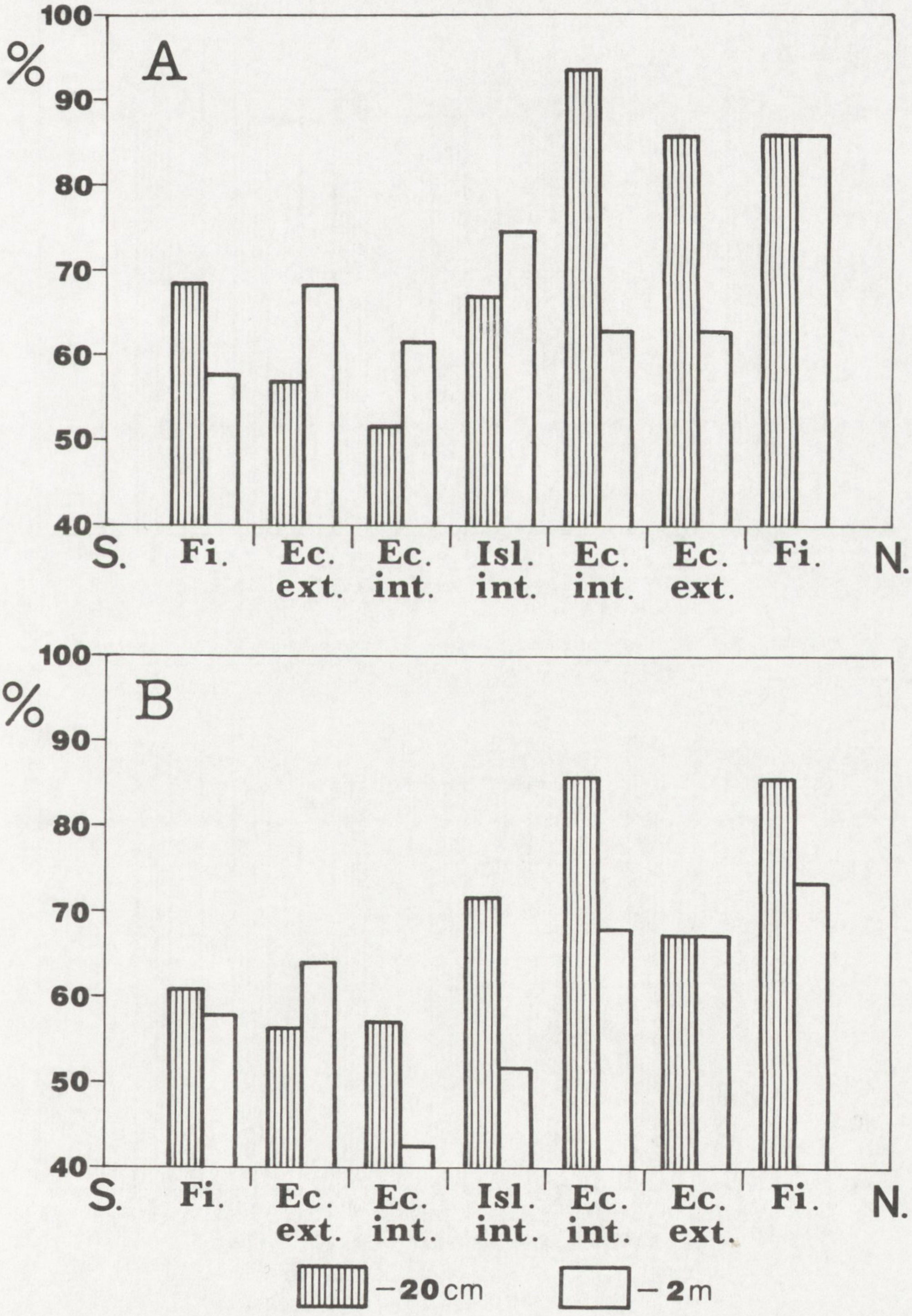
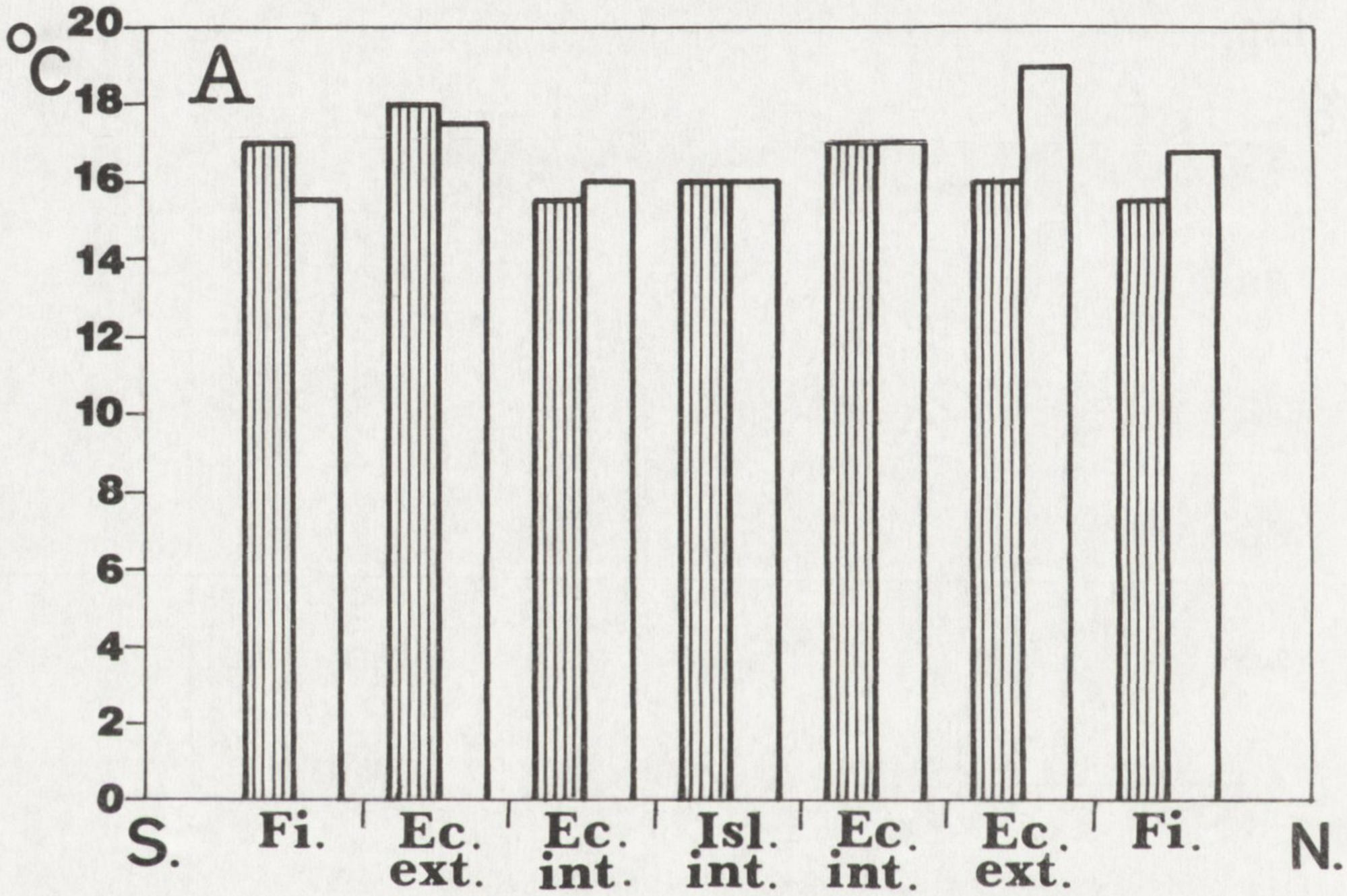


Fig. 4. Variability of air humidity (%) along the transects S-N across forest islands measured 24 April 1992, at 10 a.m. (sunny, dry and windless day) at the altitude of 20 cm and 2 m above the ground; A – across 1 ha mixed forest island no. 3; B – across 1 ha birch and aspen wood island no. 7

Abbreviations see Fig. 3



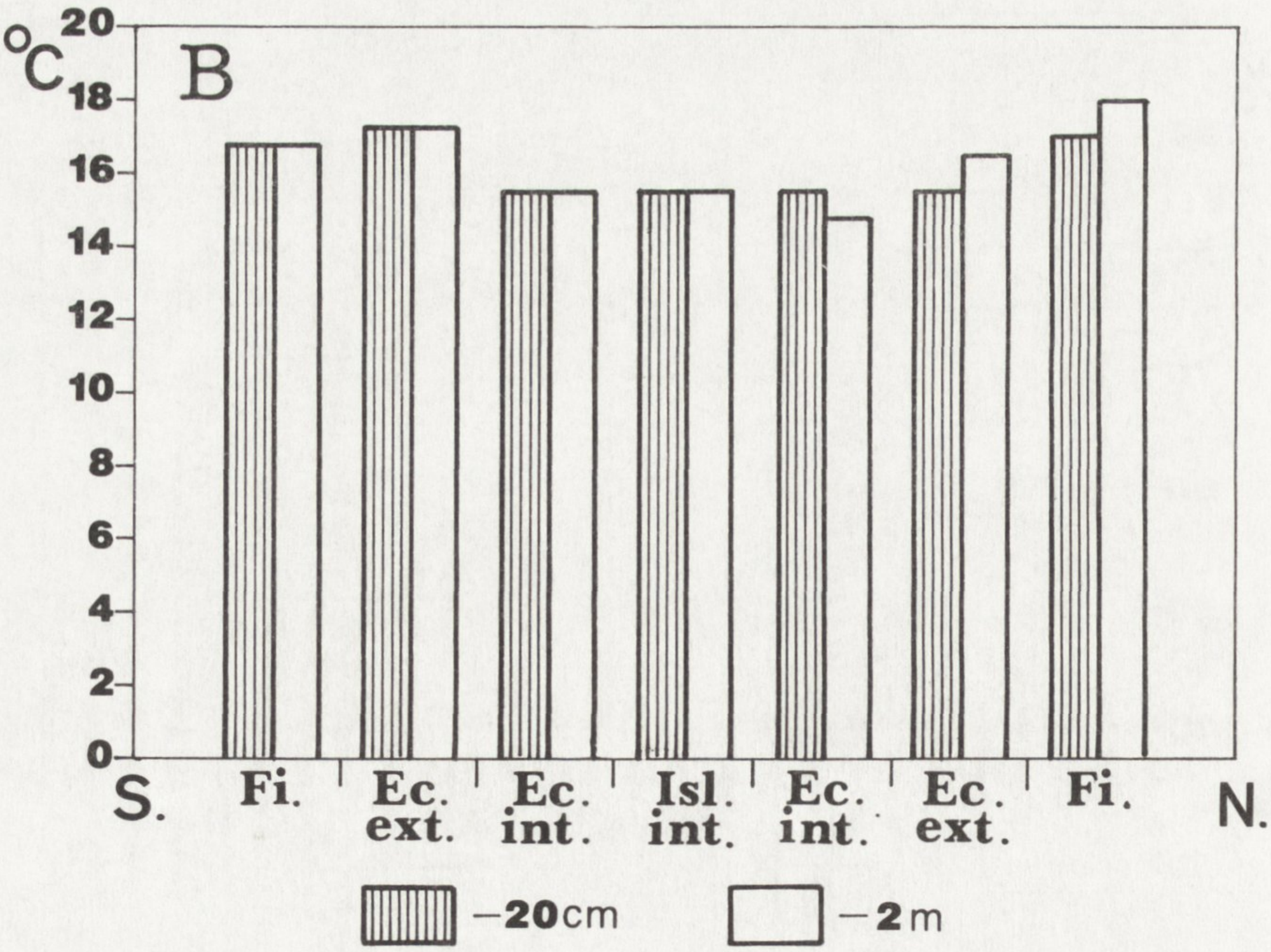


Fig. 5. Variability of temperature along the transects S-N across forest islands, measured 19 September 1992 at 10 a.m. (sunny, dry and windy day) at the altitude of 20 cm and 2 m above the ground; A – across 1 ha island of mixed forest no. 3; B – across 1 ha birch and aspen wood island no. 7
Abbreviations see Fig. 3

Table 1. Temperature and relative air humidity on the transect West-East (measured 26 July 1992) at the altitude of 20 cm):
A – across the mixed forest island (no. 3); B – across the birch and aspen wood (no. 7)

Measured parameter			Temperature (° C)			Air humidity (%)		
Exposure	Forest zone		Hour					
			9:00	12:00	16:00	9:00	12:00	16:00
A								
West	Field		19.5	26.0	30.0	67.5	69.0	65.0
	Transit zone	External belt	18.5	24.0	30.0	71.0	68.0	65.0
		Interior belt	19.5	23.0	28.0	67.5	71.0	64.0
	Interior of forest island		17.5	20.5	23.0	80.0	77.5	67.0
East	Field		26.0	28.0	26.0	62.0	64.0	62.0
	Transit zone	External belt	22.0	29.0	26.5	62.0	68.0	62.0
		Interior belt	22.0	24.0	25.5	66.0	68.0	61.5
	Interior of forest island		21.5	21.0	21.0	69.5	82.0	69.0
B								
West	Field		23.0	26.0	31.5	63.0	62.0	65.0
	Transit zone	External belt	22.5	24.5	31.0	70.5	71.5	65.0
		Interior belt	20.5	23.5	29.0	73.0	79.0	65.0
	Interior of forest island		20.0	22.5	26.0	77.0	83.0	69.0
East	Field		26.0	28.0	26.0	62.0	64.0	69.0
	Transit zone	External belt	26.5	30.5	25.5	62.5	65.0	72.5
		Interior belt	22.0	24.0	26.0	66.0	67.0	76.0
	Interior of forest island		21.5	22.0	25.0	69.0	74.0	80.0

3. The differences between temperatures at the altitude of 2 m and in the ground layer (20 cm) were usually larger in the mixed forest than in the birch and aspen woods. They were also larger on the southern sides of islands than on the northern ones (Figs 3 and 4). In the interiors of islands and on their southern transition zones as well as on the cultivated fields the temperatures were usually higher in the ground layer than at the altitude of 2 m. On the northern side of islands the situation was usually the opposite: the lower layer was more chilly (Figs 3 and 4).

4. Air humidity in mixed forest islands is usually higher than in the birch and aspen woods (Fig. 4). Particularly large differences in air humidity were noticed in the northern transition zone of the mixed forest in the ground layer and at the altitude of 2 m.

5. The differences between microclimatic conditions in eastern and western transition zones and those in the forest islands' interiors are much lesser (Table 1).

4.2. THE VARIABILITY OF THE VEGETATION ALONG THE TRANSECTS "FIELD – FOREST ISLAND – FIELD (MEADOW)"

4.2.1. The width of transition zones and the structure of their vegetation

The phytosociological records made along the transects that cut across islands from south to north and from west to east and that embrace adjacent parts of cultivated fields revealed a considerable variability of the vegetation. This variability manifests itself in the structure of the vegetation, its floristic composition and the richness of species. It makes possible to define more precisely the limites of transition zones. The latter were initially fixed on the basis of structural characteristics of the vegetation, easily observable without detailed research.

The width of the investigated transition zones varies but it lies within the limits of 1 to 7 m. Those of the birch and aspen woods are somewhat narrower than those of the remnants of the mixed forest (Table 2). They depend – among other things – on the steepness of slopes of the hillock on which the remnants of the mixed forest or a deciduous wood has developed. On a more steep slope (mixed forests no. 2 and 9) the transition zone is wide and not disturbed by ploughing. The flat borders of islands (like the wood no. 7) have a narrow transition zone as a result of frequent ploughing. This ploughing of islands' borders brings about also a certain variability of the width of transition zones from year to year and influences the floristic composition of the vegetation in the most exterior belt of this zone.

Table 2. The width of transition zones and the length of transects (m)

Quality of the island	Mixed forest						Birch and aspen wood			
No of the island	2		3		9		7		8	
Year of the measurement	1992	1993	1992	1993	1992	1993	1992	1993	1992	1993
South transit zone	7.0	5.0	3.0	3.0	6.0	6.0	2.0	2.0	2.0	4.0
North transit zone	6.0	6.0	3.0	3.0	3.0	3.0	2.0	6.0	2.0	4.0
Length of transect N–S	144.3		113.5		70.3		108.3		68.3	
West transit zone	4.0	4.0	3.0	3.0	2.0	3.0	2.0	3.0	3.0	3.0
East transit zone	2.0	4.0	3.0	4.0	5.0	3.0	3.0	4.0	3.0	3.0
Length of transect W-E	185.0		105.8		61.1		104.9		32.6	

The belt-like structure of transition zones of mixed forest and birch and aspen woods was first called to attention by Wójcik (1991). Our detailed phytosociological research made on transects across islands show how the vegetation structure varies from the forest wall to the field. On borders of mixed forests (e.g. no. 2 and 3) the transition zone usually comprises two belts. In the inner belt, adjoining the forest,

the pine (*Pinus silvestris*) still appears. Over the exterior belt that adjoins the field, the branches of the forest wall reach only in some places. In the case of the birch and aspen woods, the forest wall is composed of aspen (*Populus tremula*) and birch (*Betula pubescens*). In the inner belt of the transition zone there is the undergrowth of trees – not only of those growing in the island's interior but also of some others as well as some shrubs. Their density is, however, inconsiderable – sometimes smaller than that of the shrub layer in the island's interior. On the other hand, the layer of herbs and grasses is dense and it usually forms a solid carpet that reaches under the crowns of the forest wall trees and even farther. The appearance of this belt in no way resembles the dense shrub belt on the edges of deciduous forests that was described in various reports (e.g. Faliński and Falińska 1965, Faliński 1966). The external belt of the transition zone is covered with herbaceous vegetation of a considerably differentiated floristic composition and – consequently – of a differentiated physiognomy. It changes along the forest wall and is different in the vicinity of different islands. The ploughed belt of the field closest to the island differs somewhat from the field's interior. Nevertheless, on the basis of its structure and its floristic composition we recognize it as the field and not the transition zone.

4.2.2. The variability of the floristic composition of the vegetation in the mixed forest islands on the "south-north" transects

The variability of the floristic composition of the vegetation of forest islands and of their closest neighbourhood is reflected as well in the tables of phytosociological records made along the transect across the islands (Tables 3 and 4), as in the tables of the share of species of different ecological groups in individual zones of the transect (Tables 5 and 6) and in the diagrams of coefficients of similarity put together on the basis of those records (Figs 6 and 7).

On the Table 3 (transect across a 1 ha mixed-forest island No. 3) we see several groups of records of different floristic composition and of various species richness. Records 1–3 from the cultivated field sown with winter rape represent a plant association Papaveretum argemones with four characteristic species of this association and two differentiating ones. The community is dominated by synanthropic species (almost 70% of its species composition) and have some admixture of grassland ones (25%). The share of other species is infinitesimal. For the light soils of northern Poland, the community is comparatively rich in the floristic sense; the average number of species in a record is 22.7 and the total number on 3 records is 36 species (Fig. 8A).

Records 4 and 5, made in the southern transition zone, are conspicuous for their floristic richness: they contain 34 and 33 species in one record, that is 33.5 on the average. We find here the same characteristic and differentiating species of the Papaveretum argemones plant association as on the adjoining cultivated field but the total number of species from the Centaureenalia cyani suborder is smaller

(only 5, while on the field it reaches 9). It thus become evident that in the transition zone exposed to the south, not shaded by the branches of trees and often disturbed by ploughing and other agricultural activities, this field community finds excellent conditions for development in places where the sod is destroyed. However, the grassland species (38.5 and 45.5%) that form separate clumps (Fig. 8A) dominate over the synanthropic species. Those records represent the exterior belt of the transition zone.

Table 3. List of phytosociologic recors made along the S–N transect across 1 ha mixed forest island (no. 3)

Transect zone	South field			Transit zone ext.			Transit zone int.		Interior of the island						Transit zone			North field		
No of records in the transect	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Cover of tree crowns (%)	0	0	0	0	0	10	30	20	50	75	80	85	50	60	30	25	0	0	0	0
Cover of shrub layer(%)	0	0	0	0	40	40	60	50	40	25	50	15	20	30	60	0	0	0	0	0
Number of plant species in the record	28	18	22	34	33	20	25	25	14	16	14	14	12	13	21	25	23	15	13	16
Trees																				
Pinus silvestris a_1							V	V	V		V	v	v				v			
Pinus silvestris c																	+			
Quercus robur a_1														V						
Quercus robur a_2									V	V	V	v	V	v						
Quercus robur b					1	+	1	1			1		+		2					
Quercus robur c						+	+		+											
Populus tremula a_1						V								V						
Populus tremula b					3	1	2													
Populus tremula c		+		+																
Betula pubescens a_1										V				V	V					
Betula pubescens a_2										V			V							
Betula pubescens b								1												
Sorbus aucuparia b							1	1	1											
Sorbus aucuparia c									+						+					
Acer platanoides b													1							
Acer platanoides c														1						
Ch. Vaccinio-Piceetea																				
Veronica officinalis										1										
Vaccinium myrtillus														4	+	2				
Ch. Querco-Fagetea																				
Frangula alnus b								1	1	1	1	1	1	1	2					
Frangula alnus c				+											+	1				
Eurynchium stratum					+	1	+		3	+		3	1	3						1
Ribes schechtendali b							+	1												
Ribes schechtendali c										1	+	+	1							
Moehringia trinervia							+	1	1	1	1	1	+	+						

No of records in the transect	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Polystichum lobatum									+		+									
Other forest species																				
Juniperus communis b							+	+	+											
Entodon schreberi							2	2							4	4	1			
Geum urbanum								+		+	+	+					+			
Urtica dioica									1		1									
Mycelis muralis										1										
Humulus lupulus											2									
Majanthemum bifolium												2								
Oxalis acetosella												2	1	+						
Mnium affine															+					
Rhytidiadelphus squarosus																1	2			
Hylocomnium splendens																	1			
Ch. Rhamno-Prunetea																				
Rhamnus catartica						2	1	1		+										
Crataegus monogyna						1	+		1			+								
Rosa canina											+									
Ch. Trifolio-Geranietea																				
Medicago falcata	1			2	3	1	+	+												
Ch. Epilobietea angustifolii																				
Rubus idaeus					1	2	2	3		2	1	2	1		1	+	1			
Fragaria vesca						1	1	+	1	1	1				1	1	1			
Sambucus racemosa										1	+	1								
Sambucus nigra												1								
Rubus suerectus													2	2		1	+			
Calamagrostis villosa																+				
Ch. Molinio-Arrhenatheretea																				
Taraxacum officinale	+																			
Medicago lupulina	+																			
Achillea millefolium	+			1	1	1+										1	1	+		
Festuca pratensis				3																
Phleum pratensis				1	2										+	+				
Galium molugo				2	2	1	2	2	+	+				+	1	1	1			
Dactylis glomerata				+	+	1	1	+		+				+	2	1	1			
Knautia arvensis				1	1	1	1	1							+	+	1			
Festuca rubra				1	1	2	1	3								1	+	+		
Poa pratensis					+	+	1	+								+	1			
Veronica chamaedrys					1	1	1	1	1							+	1			
Agrostis vulgaris							1								2	2	1			
Plantago lanceolata															+					
Daucus carrota															+					
Trifolium pratense															1					
Rumex acetosa																+	1			

No of records in the transect	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Cerastium vulgatum																1	1	+		
Ch. Festuco-Brometea																				
Artemisia campestris	+			2	2	1														
Centaurea scabiosa				1	+	+	+													
Pimpinella saxifraga				1		+	1	+							1	1	1			
Ch. Sedo-Scleranthetea																				
Arenaria serpillifolia	1	+	+	+																
Erophila verna	+		+		+															
Veronica dilleni	2		1	+																
Myosotis micrantha	+	+	+	+	+															
Rumex acetosella	1																	1	+	+
Sedum acre				2	+															
Trifolium arvense				1	2															+
Hieracium pilosella					2															
Festuca ovina							4		+					+						
Hypericum perforatum															+	+	+			
Ch. Nardo-Callunetea																				
Potentilla erecta					1															
Viola canina																	1			
Ch. Ruderali-Secalietea																				
Lithospermum arvense	+																			
Sonchus arvensis	+																			
Melilotus officinalis	+																			
Anthemis arvensis	+		+																	
Papaver argemone	1	1	+	+																
Arabidopsis thaliana	+	2	1	1	2															
Erodium cicutarium	+	2	2	+	+															
Scleranthus annus	+	1	+																	
Equisetum arvense	2		+	1	+										+	+	+			
Polygonum convolvulus	1							+												
Viola arvensis	2	1	1	1														+	1	
Veronica arvensis	+		+	+														+	+	
Capsella bursa-pastoris	1	2	3	1	1	1													+	+
Papaver dubium	2	+	1		+															+
Vicia angustifolia	+	+		1	+														+	+
Tripleurospermum inodorum	1	1	1	1														1	3	3
Myosotis arvensis	1	1	1		+													3	3	2
Agropyron repens	3	1	1	2	+	2	2	+							1	2	2	3	2	1
Artemisia vulgaris		+		+	1			+												+
Digitaria ischaemum		+																		
Lycopis arvensis		2	2																	
Stellaria media		+	1															1	1	2
Poa annua		1																+	+	+
Vicia hirsuta			+	+	1															

No of records in the transect	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Veronica triphyllos			+	+	+															
Polygonum aviculare				+															+	+
Convolvulus arvensis				+	+	+														
Cerasus avium							+													
Galeopsis tetrahit											+	+								
Chenopodium album																		+	+	+
Spergula arvensis																				1
Papaver rhoeas																				+
Centaurea cyanus																				+
Other species																				
Viola sp.															+	+				

Table 4. List of phytosociologic recors made along S-N transect across 1 ha birch and aspen wood island (no. 7)

Transect zone	South field		Trans. zone		Interior of the island								Transit zone						North field			
No of records in the transect	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
Cover of tree crowns (%)	0	0	20	40	50	50	40	40	30	50	30	20	30	0	0	0	0	0	0	0	0	0
Cover of shrub layer (%)	0	0	0	0	0	10	30	50	70	60	10	20	0	0	0	0	0	0	0	0	0	0
Number of plant species in the record	8	19	11	19	15	19	31	29	30	37	24	20	10	9	13	10	14	15	18	18	18	16
Trees																						
Betula pubescens a_1			v	v	V	V		V		V												
Betula pubescens a_2							V	V		V												
Betula pubescens b							+	1														
Betula pubescens c					1		1	1														
Populus tremula a_1						V	V		V	V	v	v	v									
Populus tremula a_2										V		v	v									
Populus tremula b									2	1		2										
Populus tremula c					1	+		1														
Quercus robur b									+													
Quercus robur c					2						+											
Sorbus aucuparia b							+	1	+	1												
Sorbus aucuparia c					+	+	+	1	1		+	+										
Frangula alnus b							1	1	3	3												
Frangula alnus c						+	1	1	1		+	+										
Acer platanoides b						+																
Acer platanoides c											+											
Padus avium b							1															
Padus avium c							1															
Acer pseudoplatanus c									+													

No of records in the transect	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
Picea excelsa											+											
Ch. Vaccinio-Piceetea																						
Juniperus communis c									+													
Solidago vigra-aurea						1	1	1	2	1	1	+										
Vaccinium myrtillus							1	2	1	+												
Peucedanum oreoselinum								1	1													
Majanthemum bifolium									1													
Ch. Querco-Fagetea																						
Ribes schechtendali b							+															
Ribes schechtendali c							+		1													
Eurynchium striatum					+	1	1	2				2										
Atrichum undulatum						1	+	1	+	+												
Actea spicata									+													
Lonicera xylosteum										1												
Other forest species																						
Mnium affine					+	2	2	2	2	2		2										
Geum urbanum							1		+													
Mnium undulatum									+													
Rhytidiadelphus squarosus									+													
Entodon schreberii									1	2												
Moehringia trinervia									+		1											
Rubus saxatilis										3	2											
Convalaria majalis												+										
Rhysobium roseum												+										
Tuidium sp.												+										
Ch. Rhamno-Prunetea																						
Crataegus monogyna b						+	1			1	1	+										
Crataegus monogyna c						+	1															
Rosa canina b								+	+													
Rosa canina c								+	+													
Rhamnus catartica b										+												
Ch. Trifolio-Geranietea																						
Picris hieracioides						+	1			1												
Hieracium ubellatum										2	1											
Astragallus glycyphyllos										2												
Polygonatum odoratum											+											
Medicago falcata			+	+																		
Ch. Epilobietea angustifolii																						
Viburnum opulus b									+													
Viburnum opulus c									1	+												
Fragaria vesca						+	1	1	1	1	1		1	1								
Epilobium angustifolium										1												

No of records in the transect	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
Torilis japonica										+												
Rubus suerectus												1										
Galeopsis tetrahit				1																		
Ch. Molinio--Arrhenetharetea																						
Medicago lupulina	+																					
Agrostis vulgaris		1			+					+	+							+				
Trifolium pratense			1					1		+												
Rumex acetosa					+																	
Poa pratensis					1		3	2	2	2	1											
Galium molugo					1	1	1	1	1	1	1	1										
Dactylis glomerata					2	2	3	2	2	1	2	2										
Veronica chamaedrys					+	1	1			+		1	1	1								
Achillea millefolium						+		+		+												
Anthoxanthuum odoratum						2		1		1												
Phleum pratense						+	+				+	1	1	1	+							
Ranunculus acer							+															
Festuca rubra							2	3			2	2										
Antriscus silvestris							2	1	1	+	1	1	1	+								
Taraxacum officinale							1	+	1		1	+	+		+							
Knautia arvensis							+	+		+			1	1	+							
Cerastium vulgatum								+											+			
Molinia coerulea										+												
Chrysanthemum leucanthemum										1												
Trifolium repens										r												
Vicia cracca												+										
Ch. Festuco-Brometea																						
Bromus inermis	1	1			2																	
Pimpinella saxifraga					+	+	1	+		+	1	1	2	2								
Allium oleraceum							+	1														
Ch. Sedo-Scleranthetea																						
Festuca ovina					1		2	1	1	2												
Hypericum perforatum							+	1														
Ch. Nardo-Callunetea																						
Viola canina							+			+												
Ch. Ruderali-Secalietea																						
Melandrium album	+			1																		
Cirsium arvense	+	+													1			+				
Equisetum arvenis	+	1				+									+	+		1				
Veronica arvensis	+	+																	+			
Sonchus arvensis	1														+	1	1	1	2	2		
Erodium cicutarium	+	+																		+	+	
Agropyron repens	3	1	1	+	+		+						2	2	2	2	3	3	3	3	2	2

No of records in the transect	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
Artemisia vulgaris	3	+	3	2									1	1	1	1	2	2	+	+	+	+
Tripleurospermum inodorum	+	+	2	2												1	1	1	+	1	1	2
Polygonum convolvulus	1	1	+	+								+				+	1	1	1	1	1	+
Chenopodium album	+		1	2													+	1	+	+	1	2
Myosotis arvensis	2	2		1											1		1	1	+	+	+	+
Vicia angustifolia	+	1												2	1	+	+			+	+	+
Vicia hirsuta	1	1													+	1		+	+	+	1	1
Crepis tectorum	1	1															+	+		+	+	+
Papaver rhoeas	+															+		+				+
Centaqurea cyanus	1																					
Aethusa cynopium agrestis		+																				
Tussilago farfara		1													1	1	1	1	1			
Viola arvensis		1															+	+		1		
Capsella bursa-pastoris		+	+	+															+	+	+	+
Stellaria media		+		+															+	+	+	+
Convolvulus arvensis			+	+																		
Polygonum tomentosum			+																+	+	1	2
Rumex crispus				+																		
Lycopsis arvensis				+																+		
Polygonum aviculare				+													+		+	+		
Spergula arvensis				+															+	1	3	1
Lapsana communis																			+		+	
Sinapis arvensis																			+		+	
Raphanus raphanistrum																					+	1
Avena fatua																						+

Records 6, 7 and 8 form the inner belt of the transition zone. Their floristic richness is much smaller (20–25 species on a record – on the average 23.3 species). In their floristic composition grassland species dominate; there are many species characteristic of clearings and shrubbery but the presence of forest species is clearly visible (35.5%). For a part of the day this zone is in shade of forest-wall trees.

The transition zone is thus wide and forms two belts: the first, adjoining the field, devoid of trees and shrubs, is rich in species and submitted to a strong anthropopressure. The other, adjoining the forest, is somewhat poorer in species, less anthropophized and already contains some forest species like shrubs and young trees.

Records 9 to 14 represent the interior of a forest island. Here, forest species dominate (60.6%). If we also count the clearing and shrub communities species, they represent 85% of species. There are also grassland species to be found; a consideable share of non-forest species bespeaks a certain degeneration of the mixed-forest community inside a small forest island submitted to a strong anthropopressure. But one can easily recognize the type of the community (Pino-Quercetum). In the layer of

high-tree crowns (a_1), the pine dominates, sometimes with the admixture of birch. The lower-tree layer (a_2) is composed of oaks and birches.

Table 5. Share of species belonging to different ecological groups in the vegetation of successive zones of transects going from south to north
A – across 1 ha island of mixed forest (no. 3); B – across 1 ha island of birch and aspen wood (no. 7); 1–3 – winter rape, 18–20 – winter wheat

A

Successive No of records in transect		1–3	4–5	6–8	9–14	15–17	18–20
Transect zone		South field	Transit zone		Interior of the island	Transit zone	North field
			external	interior			
Total number of plant species		36	44	34	33	36	26
Average number of species		22.7	33.5	23.3	13.8	23.0	16.0
Number of species "from – to"		18–28	33–34	20–25	12–16	21–25	15–18
Synanthropic species	N	25	17	5	1	2	19
	%	69.4	38.5	14.7	3.0	5.7	73.1
Meadow and dry grassland species	N	9	20	12	4	17	6
	%	25.0	45.5	35.3	12.1	48.8	23.1
Clearing and brushwood species	N	1	2	5	8	4	–
	%	2.8	4.5	14.7	24.3	11.4	–
Forest species	N	1	4	12	20	11	1
	%	2.8	9.1	35.3	60.6	31.4	3.8
Other species	N	–	1	–	–	1	–
	%	–	2.3	–	–	2.9	–

B

Successive No of records in transect		1–2	3–4	5–6	7–11	12–14	15–18	19–22
Transect zone		South field	Transit zone		Interior of the island	Transit zone		South field
			external	interior		external	interior	
Total number of plant species		24	19	26	62	26	22	27
Average number of species		18.0	15.0	17.0	30.0	13.0	13.0	17.5
Number of species "from – to"		18	11–19	15–19	24–37	9–20	10–15	16–18
Synanthropic species	N	22	15	2	1	4	16	26
	%	91.7	78.9	7.7	1.6	15.4	72.7	96.3
Meadow and dry grassland species	N	2	1	12	23	11	6	1
	%	8.3	5.3	46.1	37.1	42.3	27.3	3.7
Clearing and brushwood species	N	–	2	2	12	2	–	–
	%	–	10.5	7.7	19.4	7.7	–	–
Forest species	N	–	1	10	26	9	–	–
	%	–	5.3	38.5	41.9	34.6	–	–
Other species	N	–	–	–	–	–	–	–
	%	–	–	–	–	–	–	–

Table 6. Share of species belonging to different ecological groups in the vegetation of successive zones of transects going from west to east
A – across 1 ha island of mixed forest (no. 3); B – across 1 ha island of birch and aspen wood (no. 7) (1–3 – winter rape, 18–19 – winter barley)

A

Successive No of records in transect		1–3	4	5–6	7–10	11–13	14	15–17	18
Transect zone		West field	Transit zone		Interior of the island		Transit zone		East field
			external	interior			interior	external	
Total number of plant species		29	27	13	20	12	18	23	16
Average number of species		18.7	27.0	9.0	8.5	7.0	18	14.3	16.0
Number of species "from – to"		11–25	27	7–11	5–12	6–8	18	0–19	16
Synanthropic species	N	21	18	1	1	–	1	3	15
	%	72.4	66.7	7.7	5.0	–	5.6	13.0	93.8
Meadow and dry grassland species	N	2	8	5	2	–	6	13	–
	%	27.6	29.6	38.45	10.0	–	33.3	52.2	–
Clearing and brushwood species	N	–	1	1	4	2	5	4	–
	%	–	3.7	7.7	20.0	16.7	27.8	17.4	–
Forest species	N	–	–	5	12	9	6	2	–
	%	–	–	38.45	60.0	75.0	33.3	8.7	–
Other species	N	–	–	1	1	1	–	2	1
	%	–	–	7.7	5.0	8.3	–	8.7	6.2

B

Successive No of records in transect		1–3	4–6	7–9	10–14	15–21	22–23
Transect zone		West field	Transit zone	Interior of the forest island		Transit zone	East field
Total number of plant species		26	19	33	39	40	31
Average number of species		16.0	10.7	18.3	17.7	13.6	16.7
Number of species "from – to"		13–18	9–12	16–20	15–22	10–20	12–21
Synanthropic species	N	22	13	–	1	16	22
	%	84.6	68.4	–	2.6	40.0	71.5
Meadow and dry grassland species	N	3	1	9	11	15	8
	%	11.5	5.3	27.3	28.2	37.5	25.3
Clearing and brushwood species	N	–	2	6	11	2	–
	%	–	10.5	18.2	28.2	5.0	–
Forest species	N	1	2	17	15	6	1
	%	3.9	10.5	51.5	38.4	15.0	3.2
Other species	N	–	1	1	1	1	–
	%	–	5.7	3.0	2.6	2.5	–

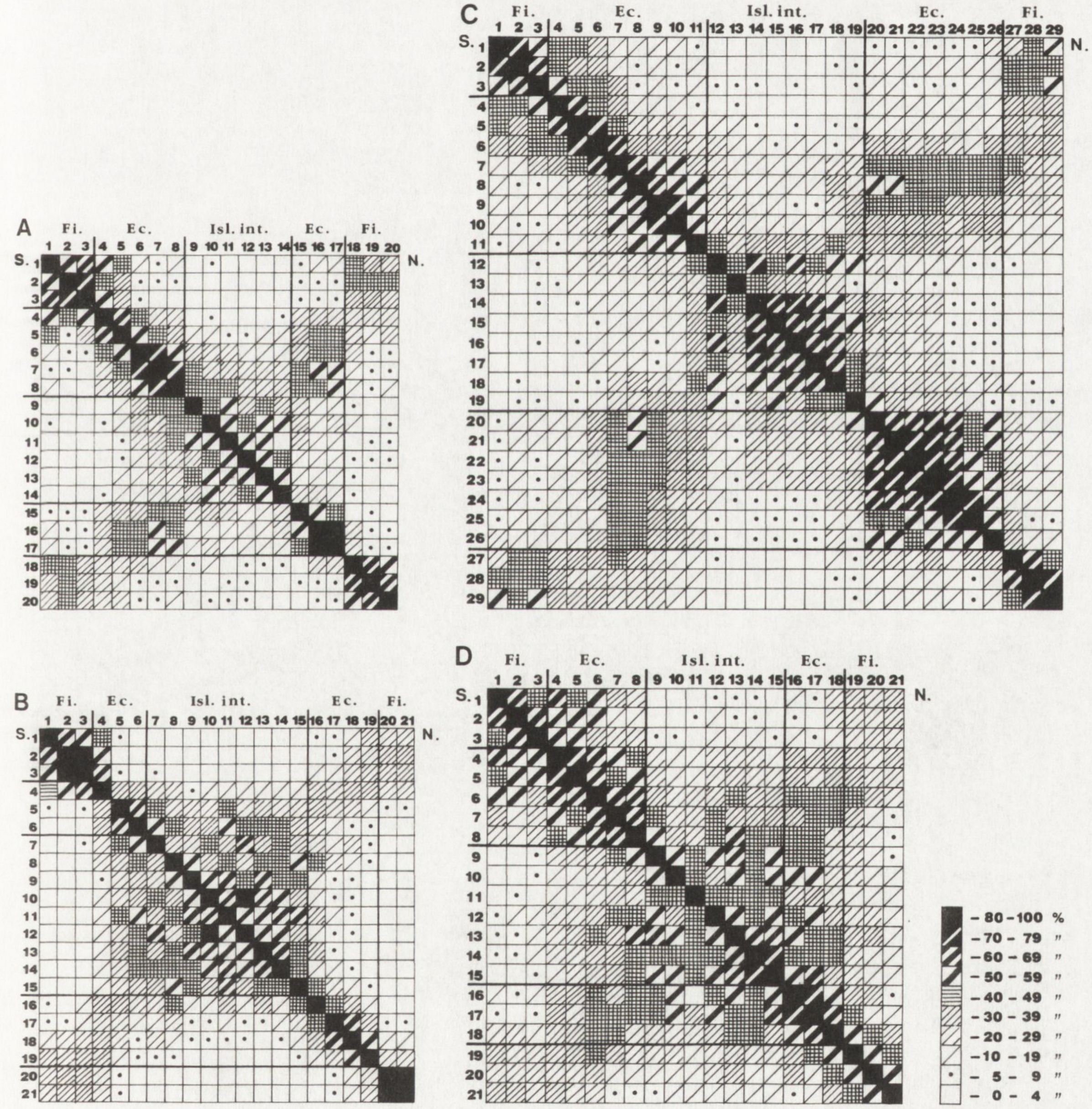


Fig. 6. Floristic similarity diagrams of successive phytosociologic records done along the transects across islands of mixed fores
A – across 1 ha island no. 3 from S to N; B – across 1 ha island no. 3 from W to E; C – across 13.5 ha island no. 2 from S to N; D – across 0.2 ha island no. 9 from S to N
Abbreviations see Fig. 3

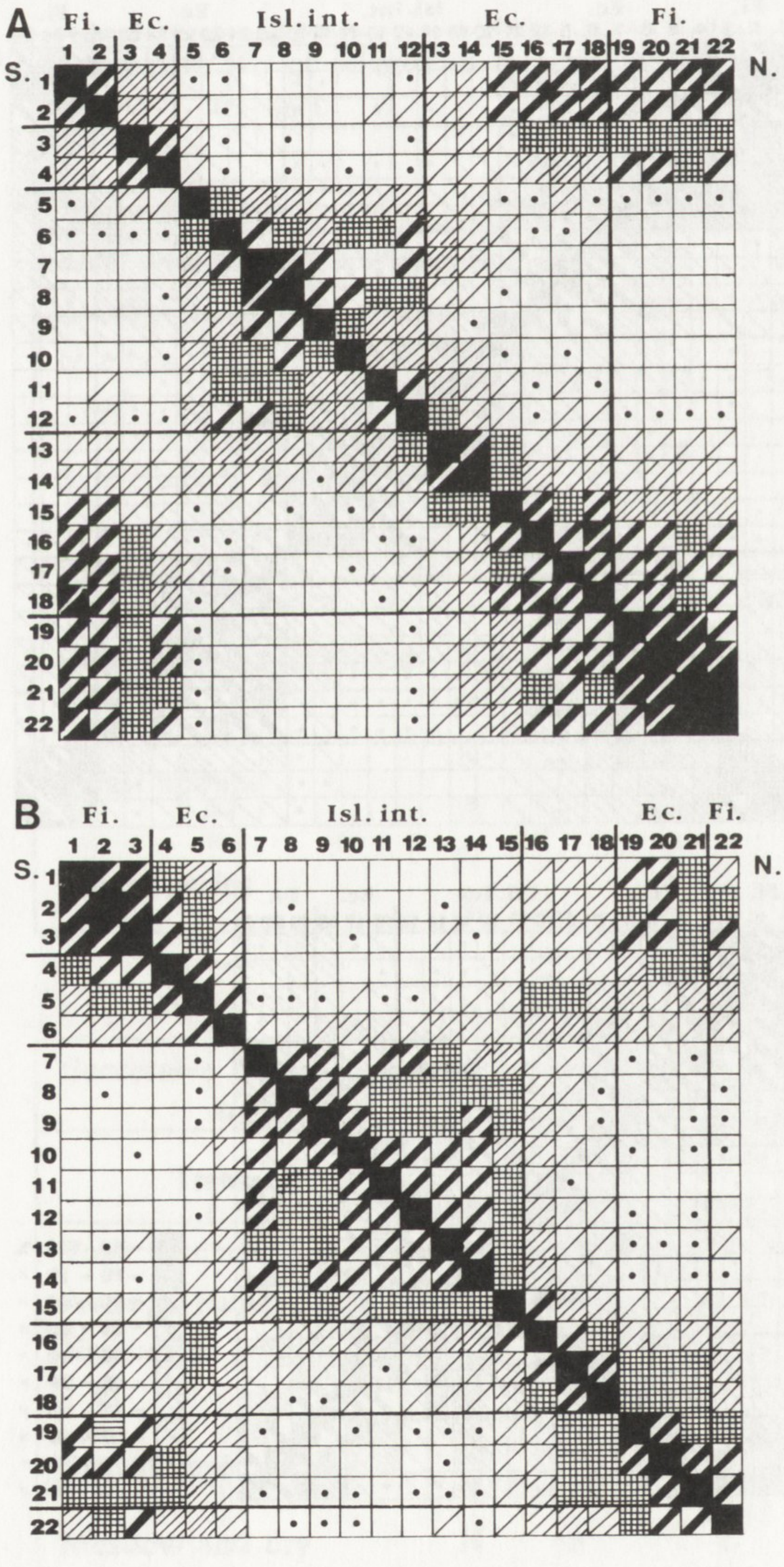


Fig. 7. Floristic similarity diagrams of successive phytosociologic records done along the transects across the islands of birch and aspen woods
A – across 1 ha island no. 7 from S to N; B – across 1 ha island no. 7 from W to E; C – across 0.2 ha island no. 8 from S to N
Abbreviations see Fig. 3

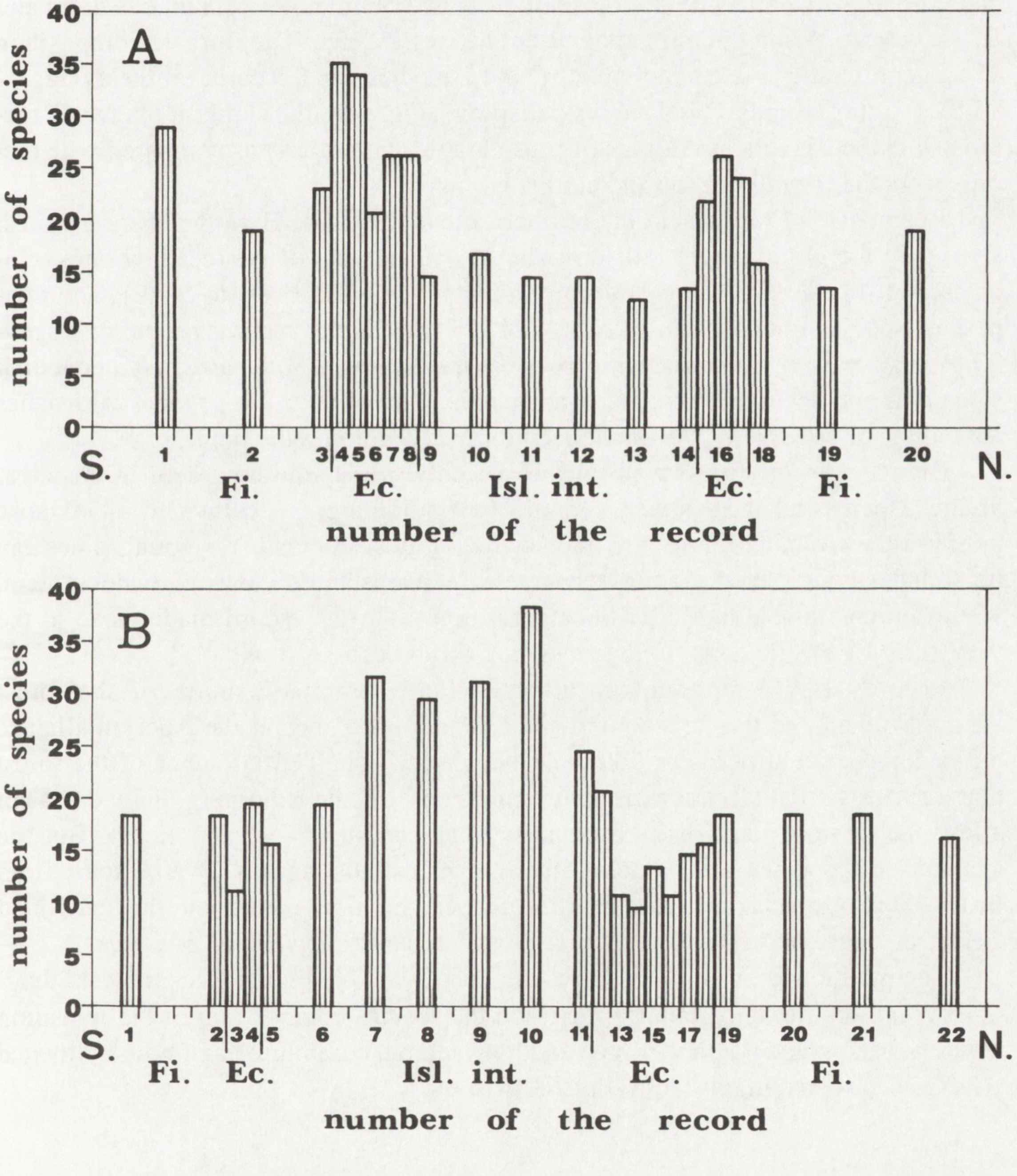


Fig. 8. Variability of species number in successive records along the transects from S to N
A – across the mixed forest no. 3; B – across the birch and aspen wood no. 7
Abbreviations see Fig. 3

In the shrub layer, apart from young oaks and birches, mountain-ash and alder buckthorn, species characteristic of shrub communities appear (*Rhamnus cathartica* and *Crataegus monogyna*) and those of clearing communities (*Sambucus nigr*a and *S. racemosa*). Young maples and current bushes are rare. The floristic composition of this community is extremely poor (12–16 species per 1 record; on the average – 13.8). Judging from the Czekanowski diagram (Fig. 6A), the similarity between records from the island's interior is not considerable, particularly as compared with records from the transition zone and cultivated fields.

Records 15–17 represent the northern transition zone. Here the share of forest species in the ground layer falls down to 31.4% and that of the meadow ones – increases to 48.8%. The share of synanthropic species also rises (to 5.7%). The richness of species goes up considerably (21–25 species per record; on the average – 23.0). The mosses (*Entodon schreberi, Rhytidiadelphus squarosus, Hylocomnium splendens* and *Mnium affine*) are conspicuous. One of them (*R. squarosus*) reaches the degree of cover = 3 even on the record directly adjoing the field.

Branches of the forest-wall trees reach only to the adjoining belt. In this area, young aspens and oaks appear. In the belt adjoining the cultivated field those young trees are much more rare and – what is most interesting – young pines can be found (though they do not regenerate in the island's centre). Besides them, young mountain-ash and alder buckthorn appear. In the record made close to the very limit of the field no young trees nor shrubs can be found.

Records 18–20 represent a cultivated field community north of the forest island. Similarly to the field south of this island, it belongs to the Aperion alliance but cannot be identified as a definite plant association. The influence of the forest that creates particular microclimatic conditions on the adjoining field does not allow the development of a community characteristic of segetal fields. But the synanthropic species are numerous here (19, and that means 70%). Apart from them, there are meadow species (23.1%). In the first record on the cultivated fields, in the extreme furrow, even a moss appears (*Eurynchium striatum*).

The mentioned groups of records are clearly visible on the Czekanowski diagram. What's more, the similarity between the species composition of the transition zones (northern and southern ones) and between the communities of both cultivated fields is clearly distinguishable (Fig. 6A).

4.2.3. The variability of the vegetation of birch and aspen woods on the south-north transect

On the birch and aspen wood no. 7 transect, the vegetation also gradually changes (Tables 4 and 5B, Fig. 7A) but it looks somewhat different than on the transect across the mixed forest no. 3.

The cultivated field south of the investigated forest island, sown with winter barley (records 1–2) represents a plant community of average floristic richness

(18 species). There appear 7 species of the Centaureenalia cyani suborder but those species are characteristic only of higher syntaxonomic units. That is why, this community cannot be classified as belonging to any definite association. One can only suppose that it belongs to the Aperion alliance composed mainly of synanthropic species (92%) (Table 5B).

In the narrow transition zone adjoining the fields (records 3–4), the vegetation is composed of high grass and herbs (*Artemisia vulgaris, Bromus inermis, Agropyron repens, Chenopodium album, Tripleurospermum inodorum* and other). Among them smaller species, such as field weeds, hide. In total, there are only 19 species in this zone out of which 15 are synanthropic. Among those high herbs on the verge of the field, *Artemisia vulgaris* clearly dominates and in the next belt (records 5–6), *A. vulgaris* is totally absent but *B. inermis* clearly dominates.

Records 5–12 show the interior of this forest island. It is a plant community, usually rich floristically, particularly in its central part: in those records we found 24–37 species, on the average 30.2 in a record. Together, we found 62 species – and this is a great deal in comparison with the interior of the mixed forest (33 species together).

Records 13–14 represent an interior belt of the northern transition zone. Its vegetation is different from that of the island's interior and from that of its exterior belt. The greatest share belongs to the grassland species (42.3%) but the synanthropic ones also appear (15.4%). The floristic richness is much lesser than in the island's interior (9–20 species in a record).

Records 15–18 represent the external belt of the northern transition zone. Its vegetation does not distinctly differ from that of the previous belt from the point of view of the richness of species (10–15 species in a record, on the average 13.0). But it differs from it in the floristic composition. The grassland species are less numerous but the synanthropic ones are more and more strongly represented. Finally, their shares balance. The influence of the adjoining cultivated field is already noticeable. as well as that of the frequent human interference that disturbs the zone's exterior belt, in the course of agricultural interventions.

Records 19–22 describe the vegetation of a cultivated field sown with the winter barley and lying on the northern side of a birch and aspen wood. The segetal community is composed almost exclusively of synanthropic species (96%). The grassland ones are very scarce (4%) and other species are completely absent. There are only 4 species characteristic of cereal associations. They are characteristic of the alliance and the suborder only, so that it is difficult to identify the plant association. The floristic richness of the community is a bit larger than in previous zones (16–18 species by record; on the average 17.5; the total number of species on the field is 27). Those quantities are very similar to those found on the southern field (Tables 4 and 5B).

In the diagram showing the floristic similarity of records from this transect (Fig. 4A) we see a greater similarity of plant communities of cultivated fields and

transition zones on the southern and northern side of the island (similarly on the diagram of the wood 8) – than it is visible on the south-north diagrams of mixed forest islands (Figs. 6A, B, C).

4.2.4. The variability of vegetation on the west-east transects

On the west-east transect across the mixed-forest island no. 3 (Fig. 6B), the changes in the vegetation on the western, warmer side take place in a similar way as on the southern side of the same island. On the field (records 1–3), the same segetal community, Papaveretum argemones, develops. The transition zone can also be divided in two belts. The first, rich in synanthropic species and devoid of the forest ones, well illuminated and disturbed during agrotechnical interventions, is represented only by one record (no. 4). The second belt, almost devoid of synanthropic species, and in which the meadow plants predominate and a considerable number of forest species are present, is more shadowed and not disturbed by ploughing (records 5 and 6). The western transition zone is thus narrower than the southern one. The border between the inner belt of the transition zone and the island's centre is less distinct and this suggests a gradual transition. The records 7 and 8 still show some similarity to those of the transition zone but are more similar to those from the island's interior. On the eastern side, the transition zone is a bit wider; it more distinctly differs from its center and the changes occur more gradually there. When one goes in the direction of cultivated field, the forest species become less and less numerous and the meadow ones and even the dry grassland ones become more numerous. Finally, their place is taken by synanthropic species.

The plant community of the eastern cultivated field (records 19–21) is as poor in species as that of the field on the northern side of this island (on the average 16 species).

About the transect "west-east" across the birch and aspen wood no. 7 (Fig. 7B) the same can be told as about the mixed forest no. 3. The changes on the western side are similar to those on the southern one. On the eastern side, the changes occur more gradually. As we move away from the forest meadow species become less numerous and the synanthropic ones – more numerous.

4.3. THE CHARACTERISTICS OF TRANSITION ZONES (ECOTONES) IN RELATION TO THE MICROCLIMATIC CONDITIONS AND TO THE VEGETATION OF FOREST ISLANDS AND CULTIVATED FIELDS

When analysing the variability of the forest islands' vegetation across the transects we found certain regularities, concerning, firstly, the differences in the floristic richness of the islands' interiors and their transition zones and, secondly, the differences in the floristic composition of transition zones that depend on their exposure to the points of the compass.

4.3.1. The floristic richness of the ecotones – the edge effect

It was ascertained that such transect zones as field interiors, transit zones and island interiors very distinctly differ in their floristic richness. In the interiors of the islands that represent remnants of mixed forests we found a comparatively small number of species. In their transition zones into cultivated fields the number of species were much larger – also in comparison with those on adjoining cultivated fields (Fig. 8A). Only in the vicinity of a small mixed-forest island no. 9 (about 0.2 ha) the differences were less clear.

In the spontaneously grown birch and aspen woods we observe an opposite phenomenon. The floristic richness inside them is even larger than that on their borders (Fig. 8B). The reason is that – as stages of succession from the clearing communities to the forest ones – they contain not only forest species but also many of the previous stages of succession, namely those characteristic of clearings and shrubs communities, as well as of grasslands. It was found that in the final effect, the transition zones of those woods were much poorer than their interiors and also poorer than the adjoining cultivated fields (Fig. 5B). This is also true of the wood no. 7 (almost 1 ha large) and of the almost ten times smaller wood no. 8 (about 0.1 ha).

4.3.2. The differentiation of the vegetation of transition zones between forest islands and cultivated fields, depending on their exposure

In our earlier observations (W ó j c i k 1991) we already found differences between the vegetation of transition zones with various exposure. In our present, detailed investigation we ascertained that they show in the structure of the vegetation, in its species composition and in the floristic richness. They particularly show in the share of species from various ecological groups in the vegetation of transition zones with different exposure (Tables 3 and 4).

In southern transition zones of the mixed forest (Table 3), in the direct vicinity of cultivated fields (1–2 records; a belt 1–2 m from the external furrow) the vegetation does not cover the earth's surface with a solid carpet. It forms clumps of rather high plants of grasslands, such as *Artemisia vulgaris*, *A. campestris, Centaurea scabiosa,* sometimes *C. rhenana; Knautia arvensis, Gallium molugo, Medicaga falcata, Achillea millefolium. Agropyron repens, Phleum pratense* and *Dactylis glomerata* are the most common herbs and grasses. Clusters of trailing *Sedum acre, Thymus serpyllumor, Hieracium pilosella* also appear.

Thus, as we see, it is a rather dense sod (Table 3). Vacant spaces between clusters of those perennial plants are occupied by the annual ones, mainly synanthropic – among others by the field weeds (e.g. the species characteristic of Papaveretum argemones). The whole has thus the appearance of a dry steppe, described long ago by P a c z o s k i (1925), who distinguished in it some durable elements of the association (components) and some ephemeral ones (ingredients).

In the farther belts of the transition zone, closer to the forest wall, the sod becomes more dense. It is composed mainly of *Festuca rubra* which reaches here a high degree of cover (= 3). Sometimes there is also *F. ovina* (in the form of dense clusters). Clumps of some dicotiledone plants also densely cover the ground (*Veronica chamaedrys*, *Fragaria vesca* and others). This turf is made still more dense by the first appearance of mosses (*Entodon schreberi* and *Eurynchium striatum*). The latter become more and more dense in the direction of the forest. In this turf, some other species also appear (*Mycelis muralis, Moehringia trinervia, Geum urbanum*) and – among them – seedlings of trees and shrubs (*Quercus robur, Sorbus aucuparia, Populus tremula, Frangula alnus*). This dense, low turf penetrates deeply under tree crowns of the forest wall, sometimes even farther. There are no more field weeds nor such thermophilous species as for example *Centaurea scabiosa* or *Artemisia capestris*, so conspicuous in the neighbouring belt of the transition zone.

On the northern borders of mixed-forest islands, meadow species prevail. They represent more than the half of their floristic composition. The ground layer is composed of mosses that form large pillows and vast carpets. To name at least a few: *Rhytidiadelphus squarosus, Hylocomnium splendens, Mnium affine.* They develop mainly in the part of the transition zone closest to the forest. *Entodon schreberi* could also be found farther from the forest. In the northern transition zones of the mixed forest some young pines can be found, though they are not to be seen anywhere in the islands' centers nor in their transition zones with a different exposure.

Southern transition zones of birch and aspen woods (Table 4) are narrow. Their vegetation consists of tall grasses or dicotyledones plants. Those communities are composed of such species as *Agropyron repens, Bromus inermis, Artemisia vulgaris* and also *A. absinthium.* Among them meadow – and synanthropic species are found. Some of them are high and – in their blossoming season visible from a long way away: *Tripleurospermum inodorum, Melandium album, Antriscus silvestris, Galium molugo.* Beside them, there are many smaller and inconspicuous ones. The synanthropic species are almost as numerous as the meadow ones, but the cover of the majority is poor and they can easily pass unnoticed unless – like *Convolvulus arvensis, Polygonum convolvulus* or *Galium aparine* – they climb the stems of other plants. The clearting- and shrub communities species are rare or totally absent. Only seedlings of forest trees such as *Populus tremula* or *Sorbus aucuparia* can be spotted (Table 4).

In northern transition zones of those woods, meadows species dominate (characteristic of the Arrhenatheretalia order) and also some synanthropic ones. When going farther from the forest, the first become more scarce and the second more numerous. The shrub- and clearing community species, as well as the forest ones are very scarce and all are found in records closest to the forest. The whole aspect of those transition zones brings to mind an old field or a weed-infested wayside.

The differences between the vegetation of transition zones on the western and eastern side of islands are less conspicuous than those between the southern and

northern side, but are still noticeable (Fig. 6A, 7B). For instance, on the western border of a mixed-forest island no. 3, the belt directly adjoinng the field is similar in its appearance to an analogous belt of the southern transition zone. The synanthropic species here are most numerous and among them we find species characteristic of the Papaveretum argemones association. On the whole, however, the species of the cereal association (Centaureenalia cyani) are more scarce. Considerably less numerous are large clumps of *Artemisia vulgaris*; *A. campestris* and *Centuerea scabiosa* are absent. In the belts of this zone farther from the field, the synanthropic species gradually disappear. Meadow species dominate but without *Festuca rubra*, typical of the transition zone, forming grassy patches on the south. Forest species are numerous and among them some mosses. In the eastern transition zone of this island, in the first belt of the transect adjoining the field, the weeds are less numerous and the species characteristic of the Papaveretum argemones are totally absent. Farther toward the forest, meadow species become dominant over the synanthropic ones. Some clearing species appear and the forest ones are more numerous than on the western side of the island. The mosses were not found at all.

Western borders of birch and aspen woods (for instance no. 7) are – like the northern ones – covered with high grasses and herbs: *Argopyron repens, Calamagrostis epigeios, Artemisia vulgaris* and *Antriscus silvestris.* The community is poor in species: the synanthropic ones prevails but they gradually become less numerous when one goes toward the forest. Species of other ecological groups are few (1 meadow one, 2 clearing ones and 2 forest ones).

On eastern borders of this woods the transition zone is wider and generally richer in species. The synanthropic ones are slightly more numerous than the meadow ones. Similarly as on the northern border, they get gradually more numerous in the direction of the field. On the other hand, the meadow species (order Arrhenatheretalia) get less and less numerous in this direction. Worth of notice is the fact that in the direction of the field the density of such species as *Agropyron repens* and *Artemisia vulgaris* grows – and in the direction of the forest – the same is true of such species as *Festuca rubra, Phleum pratense* and *Dactylis glomerata*. Owing to all this, in the part of the transition zone close to the forest, there is a quite dense sod, similar to that in the part of mixed-forest remnants close to the forest.

4.4. THE POSSIBILITIES OF THE VEGETATION'S SYNANTHROPIZATION THROUGH TRANSITION ZONES

The investigations of the transition zone vegetation of two different types of forest islands with a different exposure to the cardinal points created the possibility of estimating the richness and the differentiation of the synanthropic flora close to the islands' borders and – by the same token – the number and quality of foreign species that could invade their center.

The data about the synanthropic flora of forest islands and of their surroundings we establish here solely on the basis of the investigations made on transects and not on some particular floristic investigations. Plant communities of cultivated fields were defined in 1993 at the time when all fields were sown with winter crops.

On southern and western borders of a mixed forest (islands no. 2 and 3) the communities of Papaveretum argemones develop in fields sown with winter crops. This relatively thermophilous and xerophilous community finds excellent conditions of development on warmer, early drying sides of forest islands – all the more so, as the terrain raises slightly in the direction of the islands – and this increases the warming influence of their exposure. The conditions are so favourable to the association that the characteristic species of the Papaveretum argemones invade even the gaps between clumps of plants of the belt that lies closest to the field. The field community on the northern and eastern side of the islands could have been identified only as belonging to the order Aperion.

The topographical situation in the vicinity of birch and aspen wood islands is somewhat different from that in the vicinity of mixed forest islands. The terrain raises only in the island's interior or the field is inclined toward the island. Segetal communities developing around those woods do not show any distinct differentiation that would depend on the points of the compass.

In the closest vicinity of forest islands and in their interiors we found 70 synanthropic species. Among them there were 38 species of fields weeds (species characteristic of Secali-Violetalia arvensis). Out of them, 20 species belonged to those appearing in grain fields (characteristic of the sub-order Centaureenalia cyani), 32 – represented ruderal plants belonging to various syntaxonomic units. A great majority of those species grow on cultivated fields (60 species – 84% of their total number). In the transition zones they are not much less numerous (53, that is 74.5%).

Notwithstanding considerable potential possibilities of synanthropic species from a very weed-infested closest vicinity to invade the forest islands, very few of those species were found in their interior. We counted only 13 (that is 18.4% of all synanthropic species we registered there, and about 7% of the investigated island's flora). There are, among others, three species of field weeds not characteristic of any definite type of cultivation and very common in the whole country. The rest represent ruderal plants of various syntaxonomic affiliation and they appear in the transition zones. Only one species, *Quercus rubra*, probably planted or brought to the islands' center, was not found in the transition zone (Table 7). Nevertheless, the appearance of synanthropic species in forest islands' interiors does not depend on their abundance in the ecotone (Wójcik 1991).

Both, the field weeds and the ruderal plants that appear in forest islands' interiors, belong to species not very particular about the biotope conditions and thus very common in the whole country.

In the Thellung's geographical and historical classification (as modified by Kornaś 1968), the majority of synanthropic species that appear in the islands'

Table 7. Number of synanthropic species in vegetation of investigated forest islands and their surroundings

Zone of their appearance	Groups of synanthropic species				
	Species of grain field	Species of rootcrop fields	Species found in all fields	Ruderal species	Synanthropic species jointly
On fields jointly	20	6	13	21	60
On fields only	7	3	3	4	17
On transit zones jointly	13	3	10	27	53
On transit zones only	–	–	–	10	10
On fields and transit zones	13	3	10	17	43
In forest island interiors jointly	–	–	3	10	13
In forest island interiors only	–	–	–	1	1
On transit zones and in forest island interiors	–	–	3	9	12

interiors are classified as apophytes (native synanthropic ones); the three field--weed species – to the archeophytes (foreign synanthropic ones that came here not later than during the Middle Ages) – and three – to the kenophytes (species brought here in modern times – XVI–XX cent.). Among them we find two tree species (*Quercus rubra* and *Cerasus avium*) and one – a fugitive from flower gardens (*Lilium bulbiferum*).

The distribution of synanthropic species in transition zones is not uniform on their whole width. They grow less and less frequent when one goes from the border of the field towards the forest wall (Table 8). In some transition zones, like for instance in the southern sides of mixed-forest islands, this decrease goes by leaps and jumps. For instance, in the southern transition zone of a mixed-forest island no. 2, on the first three records (that is, on the first three meters of the transect) 27 synanthropic species were found (12–27 species in each record). In the next five records (that is in the further 5 meters of the transect) there were only 8 synanthropic species (2–6 in each record). The similar situation obtains on the southern side of the mixed-forest island no. 3. A still more abrupt quantitative leap occurs on the western side of this island (Table 8). In other transition zones, for instance in the vicinity of the birch and aspen woods no. 7, the decrease of the number of synanthropic species occurs gradually (Table 8).

In the last records of the transition zone, under tree crowns of the forest wall, the synanthropic species are always rare: from 0 to 6. Generally speaking, they are less frequent in the vicinity of mixed forests (0–3) and a bit more frequent in that of birch and aspen woods (4–6).

Table 8. The share of synanthropic species in

Consec. No of island		Zone of transect	South field			South transit zone						
Mixed forest islands	2	No of record in transect	1	2	3	4	5	6	7	8	9	10	11
		Total number of species	22	21	22	30	23	22	19	21	18	10	17
		Number of synanthropic species	17	19	18	27	20	12	6	3	4	2	4
		% of synanthropic species	77	86	82	90	97	55	53	14	22	20	24
	3	No of record in transect	1	2	3	4	5	6	7	8			
		Total number of species	28	18	22	34	31	19	22	21			
		Number of synanthropic species	18	16	17	15	12	2	2	3			
		% of synanthropic species	64	88	77	44	39	11	9	14			
	9	No of record in transect	1	2	3	4	5	6	7	8			
		Total number of species	22	21	16	26	24	19	18	12			
		Number of synanthropic species	15	12	9	10	8	6	6	4			
		% of synanthropic species	68	57	56	38	33	32	33	33			
Birch and aspen wood islands	7	No of record in transect	1	2					3	4			
		Total number of species	18	18					10	18			
		Number of synanthropic species	17	17					8	14			
		% of synanthropic species	94	94					80	78			
	8	No of record in transect	1	2	3	4	5	6	7				
		Total number of species	14	14	11	20	6	4	15				
		Number of synanthropic species	9	10	11	12	3	2	3				
		% of synanthropic species	64	71	100	60	50	50	20				
			West field			West transit zone							
Mixed forest island	3	No of record in transect	1	2	3	4	5	6					
		Total number of species	11	20	25	27	7	6					
		Number of synanthropic species	11	16	19	18	1	0					
		% of synanthropic species	100	80	76	64	14	0					
Birch and aspen wood island	7	No of record in transect	1	2	3	4	5	6					
		Total number of species	18	17	13	12	11	9					
		Number of synanthropic species	15	17	12	11	7	4					
		% of synanthropic species	83	100	92	92	64	44					

successive records of transects across forest islands

Interior of forest island								East transit zone							East field			
12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	
9	6	7	7	12	5	12	10	19	19	23	23	30	28	20	10	20	17	
0	0	0	0	0	0	0	1	3	2	2	3	4	4	6	11	16	15	
0	0	0	0	0	0	0	10	16	11	9	13	13	14	30	58	80	88	
	9	10	11	12	13	14				15	16	17			18	19	20	
	11	13	11	11	6	9				13	25	23			15	15	18	
	1	0	1	1	0	0				2	3	3			10	13	16	
	9	0	9	9	0	0				15	12	13			87	87	89	
	9	10	11	12	13	14	15			16	17	18			19	20	21	
	12	13	15	17	10	12	14			17	16	24			26	14	12	
	3	2	2	2	3	2	2			4	2	5			9	4	7	
	25	15	13	12	30	17	14			24	13	21			35	29	38	
5	6	7	8	9	10	11	12		13	14	15	16	17	18	19	20	21	22
15	17	21	29	30	30	2	8		9	9	13	10	14	15	18	18	18	16
1	1	1	0	0	0	0	1		2	3	9	10	14	15	17	16	18	16
7	6	5	0	0	0	0	13		22	33	69	100	79	33	94	100	100	100
	8	9	10	11	12	13				14	15	16	17			18	19	
	22	18	19	20	17	17				18	17	16	21			15	15	
	1	0	1	1	1	0				6	6	11	13			15	15	
	5	0	5	5	6	0				33	25	69	62			100	100	

Interior of forest island									East transit zone						East field		
7	8	9	10	11	12	13	14	15	16	17	18	19			20	21	
12	8	5	9	6	7	8	18	11	20	21	28	16			16	16	
0	1	0	0	0	1	0	1	2	3	2	11	15			15	15	
0	13	0	0	0	14	0	6	18		15	10	39	94			94	94
7	8	9	10	11	12	13	14	15	16	17	18	19	20	21		22	
16	20	19	16	16	22	22	19	20	10	10	15	14	13	13		12	
0	0	0	0	0	0	0	0	4	4	6	5	11	11	11		10	
0	0	0	0	0	0	0	0	20	40	60	33	79	85	85		83	

We observed a certain dependence of the number of synanthropic species in the forest island interior on its size. In the islands of the surface from 1 ha upwards, they are less numerous than in the smaller ones. On both transects that crossed the two mixed-forest islands (no. 2 and 3) and went across the birch and aspen woods we found 2 to 3 synanthropic species in each interior. Among them, there was only one archeophyte (*Polygonum convolvulus*) that very often appears in Polish shrub communities (Wojterska 1990).

On the other hand, on smaller islands (0.1–0.2 ha) more synanthropic species were found. On the mixed-forest island no. 9 (0.2 ha) they numbered 7, with 4 apophytes, 1 archeophyte (*Viola arvensis*) and 2 kenophytes (*Quercus rubra* and *Lilium bulbiterum*). Moreover, one of the apophytes (*Carex hirta*) was found in almost all record – and its cover was rather considerable (1–2). From the point of view of the degree of synanthropization, in the second places was the birch and aspen island no. 8 (0.1 ha). where 5 synanthropic species were found, but two of them were archeophytes (*Veronica arvensis* and *Capsella bursa pastoris*) and one was a kenophyte (*Cerasus avium*). Those archeophytes were not yet found in our previous investigations (1987–1988).

There are certain differences between the occurrence of synanthropic species in the transition zones of various exposure. On southern sides of mixed-forest islands we found much more synanthropic species than on their northern sides (Table 9). Around the birch and aspen islands the situation is entirely different. The synanthropic species are as numerous – or even more so – on the northern side than on the southern one and as numerous on the east as on the west.

Table 9. Numbers of synanthropic species in transit zones of investigated forst islands

Exposure	Vegetation of forest islands				
	Mixed forest			Birch and aspen woods	
	No of forest island				
	2	3	9	7	8
South	27	17	15	16	14
West	12	18	16	13	6
East	11	14	9	17	29
North	8	2	9	15	19

5. SPECIFICATION AND DISCUSSION OF RESULTS

The most important results of the investigations conducted on transects across the forest islands from the south to the north and from the west to the east can be summarized in the following manner:

1) On the basis of the differences in the floristic composition and in the richness of species, it is possible to discern, in the vegetation of forest islands,

their interiors from their exterior belts that belong to their transition zones to cultivated fields.

2) The interiors of islands no. 2 and 3 represent a mixed forest (Pino--Quercetum Kozł. 1925 em. Mat. and Polak. 1955). In the high-tree layer the pine dominates; the presence of the oak becomes marked only in the low-tree and shrubbery layers, where mountain ash and alder buckthorn and sometimes hazel dominate. The ground layer is not uniform – it barely covers the bottom of the forest and is poor in species. In its floristic composition forest species dominate (about 50%). The presence of clearing species, of the shrubbery ones and of those characteristic of grasslands proves that the forest roof is transparent in consequence of uncontrolled felling of trees. But this does not yet prevent the identification of the association. The most modified island is the small one no. 9.

3) Usually, the transition zones of a mixed forest can be divided into two parallel belts. The vegetation of the inner belt, close to the forest and to some extent shadowed by the branches of the forest wall, is similar to that of the island's interior – it shows the presence of shrubbery, sometimes of trees, of the ground-layer species (including mosses), a larger number of meadow species and a lack of synanthropic ones. But it is not a dense bank of shrubbery and young trees but rather a loose belt of grasses and shrubbery. The vegetation of the exterior belt adjoining the field, not shadowed and often disturbed by agrotechnical interventions shows some similarity to the vegetation of the adjoining field – a similarity due particularly to the presence of synanthropic species such as field weeds. This differentiation is usually more noticeable in the southern zones than in the northern ones.

It is significant that the American scientists who described the transition zones (for instance Gysel 1951, Wales 1972, Levenson 1981, Ranney et al. 1981, Williams-Linera 1990 and others) are concerned only with the inner parts of those zones and do not go outside forest wall.

4) The inner parts of birch and aspen woods stand out very clearly on the diagrams of the floristic similarity (Figs. 4A and B) and form compact units (Table 5). But they cannot be classified with any type of forest community. They can only be regarded as stages of succession leading toward some community (most probably toward a mixed forest). In the composition of those woods a large number of non-forest species shows, mainly of the meadow ones.

Levenson (1981) regarded such small islands, rich in non-forest species, as composed of transition zones only and deprived of the interiors. Ranney et al. (1981) describe the situation more precisely: in small forest islands, similarly as in the disturbed ones, forest communities characteristic of the investigated region, cannot persist for any longer time. They only represent intermediate stages of succession, similar to those on the forest border. In exactly the same situation are the investigated birch and aspen woods: they represent intermediate stages of succession from the fallow land to the forest. Their standing timber is still composed of pioneer species mainly; in our case of birches and aspens.

5) The transition zones of birch and aspen woods vary: they are often formed of two belts but if they are very narrow, as for instance the northern side of woods no. 7, it is difficult to discern these two belts. The zones are sharply separated from the island's interior, particularly in the south and west.

6) The difference between the number of species in the transition zone and that in the island's interior is an important indicator of its vegetation's stage of development. It was found that inside the remnants of the mixed forest – that is of the community consistent with its biotope, few species can be found. They are much more numerous in their transition zones to the cultivated fields (Fig. 8). This is in agreement with the earlier results of investigations by Gysel (1951) and Levenson (1981) who ascertained that in Michigan and Wisconsin (North America), in the interior of deciduous forests only a small number of species occur; only the shade-loving ones; on the borders of those islands a great wealth of species was found, resulting both from the ecological variety of species occupying the transition zone and also from the share of synanthropic ones.

In the spontaneously developed birch and aspen woods the situation is different. Those woods, as stages of succession toward a forest community, have in their floristic composition not only forest species but a large number of non-forest ones and – consequently, a great richness of species. Their transition zones, composed of open-space species (in the south and west the synanthropic and the dry grassland ones – and in the east and north – the synanthropic and the meadow ones) are poor in species. One can thus infer that the edge effect consisting in the fact that in the transition zone the number of species increases – becomes manifest only on the extreme border of final communities (exactly like in the already mentioned investigations of the mixed forests).

7) Some differences between the vegetation of transition zones with different exposure to the points of the compass that were already noticed earlier (Wójcik 1991) were fully confirmed in the case of mixed-forest islands. The biggest floristic differences consisted in a much larger share of grassland- and synanthropic species, including field weeds, in the vegetation of southern transition zones of mixed forest islands and in the plaentiful occurrence of mosses in the northern sides of those islands. This resulted – among other things – in the differences in the vegetation structure; in the south, field weeds occupied all gaps between clumps of perennial plants that develop in the external belts of the transition zone as a consequence of agricultural interventions on the adjoining field. In the north, soft cushions of mosses spread under grassland plants forming a dense carper similar to that of a humid meadow. The range of transition zones was also different. In the south, the plants different from those in the island's interior invaded far under the tree crowns of the forest wall. In the north, some moss species that occupied the whole transition zone crossed even its range and entered the adjoining field or meadow. Moreover, the forest species including shrubs and young trees (among others, the pine seedlings) could be found also in the external belt, in contradistinction to the southern side.

In the vicinity of the birch and aspen woods the south transition zones are composed of high grass and herbs – the species that are rather thermophilous. Among them we find many synanthropic species. Northern zones are formed of grassland species with some synanthropic ones. The share of the latter grows in the direction of the cultivated field. Forest species, including shrubs and trees, are found mainly in the interior belts of those transition zones.

Western and eastern transition zones of both types of forest islands differ less one from the other but the western zones are somewhat similar to the southern ones, and the eastern ones – to the northern ones.

Wales (1972) drew the attention to the floristic and structural differences between transition zones with a different exposure. When investigating transition zones in an oak-and-hickory forest (New Jersey, North America) he found some differences in density and in the thickness of trunks of some trees – not only between the interior of the forest and its ecotone but also between the northern and southern ecotone. Those differences could have been explained by the microclimatic conditions. This factor also produced some changes in density of the vegetation in the shrubbery and ground layers. Wales also found a certain dependence of the spatial distribution of the undergrowth species and the shrubbery and ground layers in the forest island, on its position in the island (the northern ecotone, the southern one, the interior) and on the age of trees: a total independence of that factor in seedlings and the biggest dependence – in old trees that were for a long time subject to the environmental selection. When comparing his own results with those of other authors (Cantlon 1953, Smith 1966 – cited after Wales) he came to the conclusion that the reactions of species to the conditions on the northern and southern border of the forest are weaker from those to the different exposure of mountain sides and even of hill sides. It is interesting that Ranney et al. (1981) regarded the data concerning the exposure of the investigated transition zones only as a justification of a good representativeness of obtained results concerning a general characteristics of the ecotones and not as the basis for the analysis of their heterogeneity.

8) The potential threat to the island's interior of the invasion of synanthropic species through the transition zones is mainly represented by the species developing in the closest vicinity of the islands. Usually, around each of them, about 40 synanthropic species were found. Around all investigated islands we found – together – 70 synanthropic species. Among them – 38 species of field weeds and 32 – of ruderal ones that occurred on adjoining fields and transition zones between those fields and the investigated forest islands. The weeds characteristic of cereal fields and root-crop fields are found in the transition zones only on records closed to the cultivated field (Table 7). That is why, they do not represent any threat to the centers of islands. Farther from the field only common field weeds indifferent to the type of cultivation can be found, and also many ruderal species. From among those species come those found in the forest island's

interior. Out of the 38 registered field weeds, only 3 were found in the island's centres and out of 32 synanthropic species occupying other sites disturbed by man – 10 species were found. Together, they number 14, that is 20% of all synanthropic species occurring in the island's vicinity. One of those species, *Quercus rubra*, geographically foreign, was probably planted there.

9) The distribution of synanthropic species around the investigated islands is not uniform. In the vicinity of the mixed forest they are most frequently found in the southern transition zones; they are slightly less numerous in the western ones, still less frequent in the eastern ones and the least numerous – in the northern ones (Table 9). In the case of birch and aspen woods this regularity was not recognized.

The distribution of synanthropic species is not uniform within the transition zones. They become less numerous when we go from the field's border to that of the forest. Often it changes by leaps, as for instance in the southern transition zones of mixed-forest islands no. 2 and 3. Sometimes it changes gradually, as in the northern transition zone of the wood no. 7 (Table 9).

10) In the investigated islands larger than 1 ha very few synanthropic species occur: 2–3 at the most (mixed-forest islands no. 2 and 3, the birch and aspen wood no. 7). Smaller islands, of the surface 0.1–0.2 ha, have more of those species. In the mixed-forest island no. 9 they number 7 and in the birch and aspen wood no. 8 – as many as 5. It should be added that in the last island we did not find any synanthropic species in our previous investigations (1987–1989). We cannot rule out the fact that the invasion of synanthropic species was induced by some drainage works that were carried out on the island's border or by cutting of several trees. About the reasons for a large number of synanthropic species in mixed forest no. 9 we can only say that this island is small and its standing timber is thinned out.

11) Summing up, we can venture an opinion that the transition zones around the investigated forest islands are not yet fully developed (as Faliński expressed it in 1966) – and in any case they are not as well developed as the deciduous forest borders described by Polish phytosociologists (Faliński and Falińska 1965, 1966, Wojterska 1990) or the American ones (for example Ranney et al. 1981). They regard as mature only such forest border in which tree branches of the forest wall are – in the transition zone – in contact with the tops of dense shrubbery and young trees and in this way they prevent both the wind and the brilliant sunshine as well as seeds from outside the island to invade its centre. In the investigated islands the belt of shrubbery and young trees is sparce and in places does not exist at all. The transition zone is covered mainly with dense vegetation of grasses. It seems that notwithstanding the lack of a dense belt of shrubbery, the investigated transition zones are impervious to such an invasion and protect very well the islands' interior. The situation is similar to that described by other authors who chose for their research only islands with well developed forest border (Hoehnae 1981, Ranney et al. 1981).

6. SUMMARY

We investigated the vegetation of five forest islands, their border zones and adjaoining cultivated fields. The investigated islands represented typical elements of the agricultural landscape of the Masurian Lakeland. Three of those islands (of the size of 0.2, 1 and 13.5 ha) were remnants of old pine plantations that in the course of their about one hundred year development became transformed, in accordance with their site, into mixed forests: two of them – of the size 1 and 0.1 ha, were birch and aspen woods, spontaneously developing on fallow land (Fig. 1).

The floristic composition and the structure of vegetation were analysed in the transition zones that develop between above-mentioned forest islands and neighbouring cultivated fields – depending on the type of the plant community of the island and that of the cultivated field, on the size of the island and on its exposure to the points of the compass. The investigation was carried on along the transects going accross the islands from the South to the North and from the West to the East (Fig. 2).

It was established that:

1. In the mixed-forest islands of the size of 13.5 and 1 ha the structure and the floristic composition of the vegetation in the islands' interior distinctly differ from that of their border zones (Table 3, Figs 6A and 6B).

The border vegetation of mixed-forest islands has often a two-belt aspect. The vegetation of the interior belt is composed mainly of lower trees, shrubs, forest undergrowth and meadow species. In the exterior belt that adjoins the cultivated fields, many meadow- and synanthropic species are found, including field weeds (Tables 3 and 5A).

2. The vegetation of the interiors of birch and aspen woods is different from that of their borders, though the first represents only intermediate stage of succession from the fallow land to the mixed forest (Tables 4 and 5, Figs 7A and 7B).

Transition zones of birch and aspen woods more narrow and distinct than those of mixed forests (particularly in the South and West). Their two-belt aspect is not always recognizable (Table 5, Figs 7A and 7B).

3. Transition zones of mixed-forest islands are richer in species than those of their interiors. On the other hand, in the borders of birch and aspen woods there is much less species than in their interiors (Fig. 8).

4. There are well marked differences in the floristic zomposition and in the vegetation structure between the investigated forest islands' borders that depend on their exposure to the points of the compass.

Those differences are particularly sharp on borders of mixed-forest islands: in the vegetation of souhern borders grassland and synanthropic species dominate (including field weeds), and in that of northern borders the forest species (mainly mosses) are conspicuous, as well as some fresh meadow species (Tables 3 and 5).

Southern transition zones of birch and aspen woods are composed of high grasses and herbs; among them many synanthropic species are found. Northern sides are composed of meadow and dry grassland species as well as of the synanthropic ones and here also the share of the synanthropic ones diminishes with the distance from the cultivated field (Tables 4 and 5).

The differentiation of the vegetation on west-east transects is not so clearly visible.

5. The synanthropic species that grow in the islands' immediate vicinity represent a potential threat to their interiors – a threat that they may become infested by them. The specialized weeds of cereal and root-crop fields are – in their transition zones – found only in belts directly adjoining cultivated fields (Tables 3 and 4). This group of species does not thus represent any threat to the interiors of forest islands. Farther from the field, only common weeds indifferent to the type of cultivation appear. Here also numerous ruderal plants are found. To those groups belong the synanthropic species found in the investigated forest-islands' interiors. From among the 70 synanthropic species registered in the islands' vicinity, only 13 were found in their interiors.

The distribution of synanthropic species around the forest islands is not uniform. In the vicinity of mixed forests the majority of them are found in the southern transition zones, less in the western ones, still less in the eastern ones and even less in the northern ones (Table 9). As far as the birch and aspen woods are concerned, such regularity cannot be established.

7. POLSKIE STRESZCZENIE

Badano roślinność pięciu wysp leśnych, ich stref brzeżnych i przyległych pól uprawnych. Badane wyspy reprezentowały typowy element krajobrazu rolniczego Pojezierza Mazurskiego. Trzy z nich (o powierzchniach 0,2, 1 i 13,5 ha) stanowiły pozostałość starych nasadzeń sosnowych, w toku około stuletniego rozwoju przekształconych już zgodnie z siedliskiem w bory mieszane, dwie zaś samorzutnie rozwijające się na nieużytkach zagajniki brzozowo-osikowe o powierzchniach 1 i 0,1 ha.

Analizowano skład florystyczny i strukturę roślinności stref przejścia tworzących się między wyżej opisanymi wyspami leśnymi a sąsiadującymi z nimi polami uprawnymi w zależności od: typu zbiorowiska roślinnego wyspy i pola uprawnego, wielkości wyspy oraz ekspozycji jej skraju ku różnym stronom świata. Badania prowadzone były wzdłuż transektów przebiegających przez wyspy z południa na północ i z zachodu na wschód.

Stwierdzono, że:

1. Struktura i skład florystyczny roślinności wnętrza wysp leśnych boru mieszanego o pow. 13,5 i 1 ha wyraźnie różni się od roślinności ich stref brzeżnych (tab. 3, rys. 6A i 6B).

Roślinność skrajów wysp boru mieszanego ma często dwupasowy charakter. Roślinność pasa wewnętrznego, przyleśnego, tworzą głównie niższe drzewa, krzewy, gatunki runa leśnego i gatunki łąkowe. W pasie zewnętrznym, graniczącym z polem uprawnym, występuje dużo gatunków murawowych i synantropijnych, w tym chwastów polnych (tab. 3 i 5A).

2. Roślinność wnętrz zagajników brzozowo-osikowych, mimo że są dopiero pośrednimi stadiami sukcesji od odłogu do boru mieszanego, różni się od roślinności ich skrajów (tab. 4 i 5, rys. 7A i 7B).

Strefy przejścia zagajników brzozowo-osikowych są ostrzejsze niż strefy przejścia borów mieszanych (zwłaszcza na południu i zachodzie). Dwupasowości tych stref nie zawsze można się dopatrzeć (tab. 5, rys. 7A i 7B).

3. Strefy przejście wysp boru mieszanego są bogatsze gatunkowo niż wnętrza tych wysp. Natomiast na skrajach zagajników brzozowo-osikowych gatunków jest znacznie mniej niż w ich wnętrzach (rys. 8).

4. Istnieją wyraźne różnice w składzie florystycznym i strukturze roślinności skrajów badanych wysp leśnych zależne od ich ekspozycji do stron świata.

Różnice te są szczególnie wyraźne na skrajach wysp boru mieszanego: w roślinności skrajów południowych przeważają gatunki murawowe i synantropijne, w tym chwasty polne, na północnych zaś gatunki leśne (głównie mchy) oraz gatunki łąk świeżych (tab. 3 i 5).

Przy zadrzewieniach brzozowo-osikowych południowe strefy przejścia tworzą wysokie trawo- i ziołorośla, wśród których występują liczne gatunki synantropijne. Strefy północne tworzą gatunki łąkowe i murawowe, ze zwiększającym się w kierunku pola uprawnego udziałem gatunków synantropijnych.

Zróżnicowanie roślinności na transektach zachód-wschów jest mniej wyraźne.

5. Potencjalne zagrożenie wnętrz wysp leśnych inwazją synantropów stanowią przede wszystkim gatunki występujące w najbliższym otoczeniu tych wysp. Wyspecjalizowane chwasty pól zbożowych i okopowych spotyka się w strefach przejścia tylko w pasach bezpośrednio przylegających do pól uprawnych (tab. 3 i 4). Ta grupa gatunków nie stanowi zatem zagrożenia dla wnętrz wysp leśnych. Dalej od pola występują tylko pospolite chwasty obojętne na rodzaj uprawy oraz liczne rośliny ruderalne. Z tych grup właśnie rekrutują się gatunki synantropijne spotykane we wnętrzach badanych

wysp leśnych. Z 70 zarejestrowanych w otoczeniu wysp leśnych gatunków synantropijnych w ich wnętrzach znaleziono tylko 13.

Rozmieszczenie gatunków synantropijnych dokoła wysp nie jest jednolite. Przy borach mieszanych najwięcej spotyka się ich w południowych strefach przejścia, mniej w zachodnich, jeszcze mniej we wschodnich, a najmniej w północnych (tab. 9). Przy zagajnikach brzozowo-osikowych tej prawidłowości nie daje się zauważyć.

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