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BUG (HETEROPTERA) ASSOCIATIONS IN THE AGRICULTURAL LANDSCAPE OF GREAT POLAND

ABSTRACT: The four trophic groups found in the agricultural landscape of Great Poland include: zoophages — 12, zoo-phytophages — 16, phytophages — 46, and saprophages — 2 species. In potato and rye plantations, and in the shelterbelt herb-layer the specific composition of these trophic groups, and the dominant species in particular, are similar. In spring and in summer, after the harvest season, the numbers of the particular associations are under the influence of migration phenomena. The richest and most abundant are the bug associations in potato plantations, where the post-harvest migrations from cereal fields restore the fauna destroyed by pesticides. The abundance of cropfield Heteroptera is affected by the shelterbelts.

KEY WORDS: Heteroptera, associations, migrations, role of shelterbelts.

1. INTRODUCTION

The aim of the research presented in the paper was to determine the effect of intensive agriculture applied to large-area fields on the formation of the fauna of agrocoenoses and on the numbers of its main components.

In the region under study these phenomena are primarily affected by the consequences of agrocoenose simplification. Chemical treatment and cultivating practices reduce to occurrence of weeds, due to which a crop plant, dominant in a plantation is rarely accompanied by other plant species. Subject to simplification are also horizontal and vertical structures. The sowing technique results in a uniform distribution which eliminates the horizontal-structure patchiness found in all natural ecosystems. The vertical structure of cropfields also consists of one layer, which is an extremely rare phenomenon in temperate-zone natural ecosystems.

Ecosystem diversity within an agricultural landscape provides another important element influencing the formation of communities and their dynamics in individual fields. A landscape represents a mosaic made up of croplands, woods, mid-field shelterbelts, shrubbelts and hollows, often with small water bodies in them. In areas unsuitable for farming, and constituting wastelands, plant and animal communities develop spontaneously. Meadows are connected with river valleys, due to which their habitat specificity – related to higher moisture levels – is different; they have not been covered by the research.

Agrocoenose structure specificity shapes the faunistic communities found in the area under study. It is manifested by a species-composition enrichment or impoverishment of the communities, and their peculiar structure. The number of species making up the communities, and the quantitative relations between them, defined here as the community dominance structure, are of paramount importance to the regulatory role played by the communities in the homeostatic mechanisms of the ecosystem (Trojan 1984).

Bugs (Heteroptera) represent a good model group for studies of this kind. Their taxonomy, faunistics and bionomy are well known. They include phytophagous, predatory and saprophagous species, as well as zoo-phytophagous species of a diverse diet. Thus, within heteropterans all basic animal community types are represented except parasites.

Due to the structural simplification of agrocoenoses, there are conditions favouring the growth in number of phytophages connected with crops: agrophytophages. Predatory bugs affect the numbers of small insects living in cropfields.

The study covered bugs found in rye and potato fields, and in the ground vegetation of shelterbelts and wastelands. The subject of analyses was the structure of communities, as well as their diversity and abundance dynamics. A trial was made to estimate the density of these animals by using two catching methods of which the sweep net better represents diversity, while the biocenometer makes it possible to relate numbers to the area. Another subject for analyses was the distribution of bugs in plantations in relationship to mid-field shelterbelts which, according to Melnichenko (1937) represent, in an agricultural landscape, a strong regulatory factor.

2. STUDY AREA, METHODS AND MATERIAL

The research was carried out in the period 1965 – 1968 in the southern part of Great Poland, in the Leszno voivodship near the Department of Agroecology, Polish Academy of Sciences, at Turew. The area is a plain, located in the catchment area of the Obra river. In the 19th century it was reclaimed owing to the building there of a drainage-canal system. One of the canals, the Wyskoć Ditch, runs across the southern part of the study area. The proportion of wooded area in the Turew region is low, not exceeding 13%. At the beginning of the 19th century, due to gen. D. Chłapowski's efforts, a system of mid-field wooded strips, mainly of the shelterbelt type were laid out. Treated as protective wooded strips, the shelterbelts run along roads. Over the past century the specific composition of the tree stands has changed. At present the dominant species is *Robinia pseudoacacia* L., whereas the ground cover vegetation layer is primarily made up of grasses. The soils in the arable lands there represent medium sands on clay. Agriculture has been developed throughout the area. Most of the land belongs to State-owned Farms that conduct large-crop-stand agriculture with fields as a rule of several dozen hectares each. The level of agricultural science used is good, and the yield per hectare is over 10% higher than the mean for the whole country (according to data for 1966).

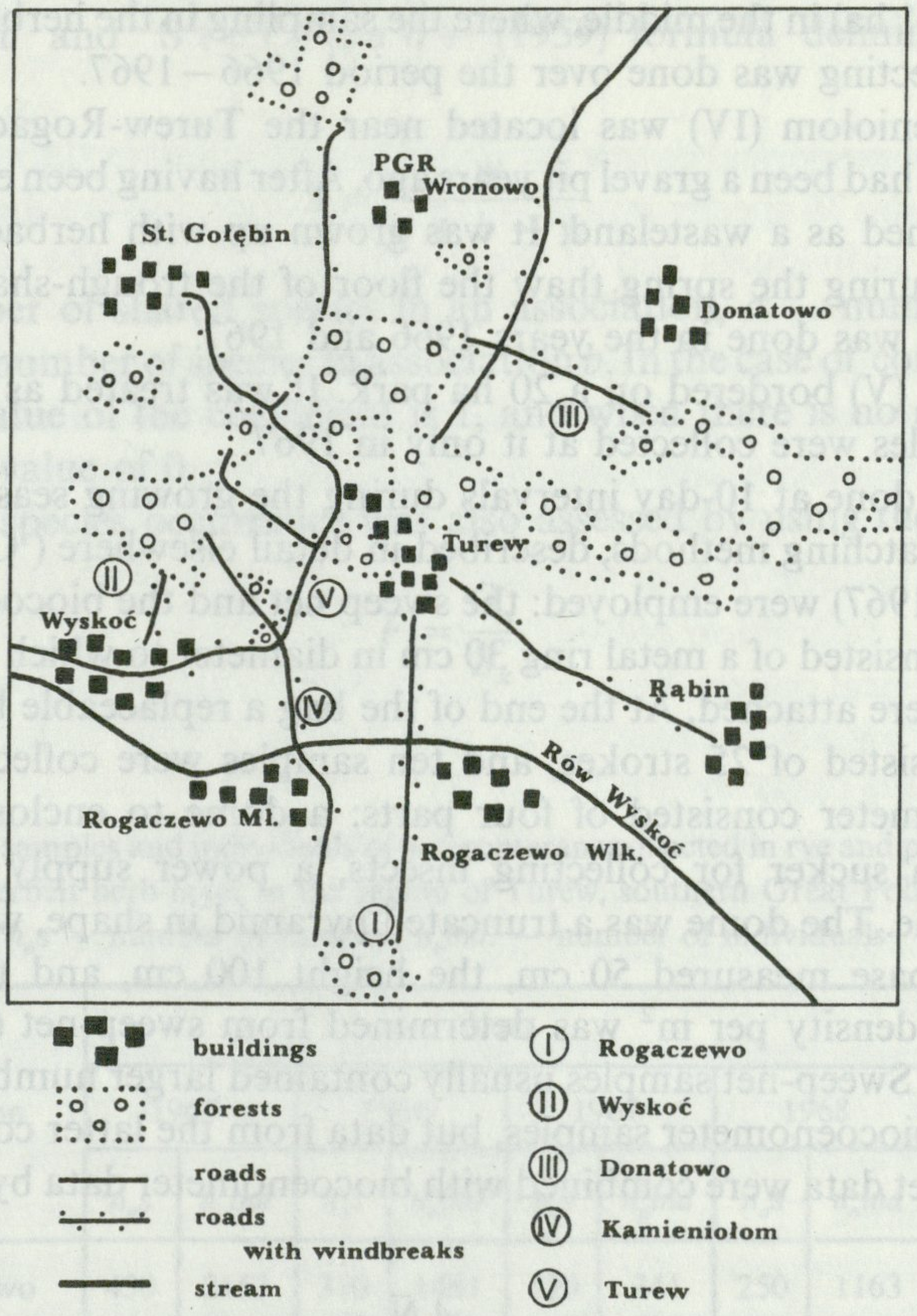

Fig. 1. Sketch map of sampling stations (I – V) location in the region of Turew

Five sampling stations were established (I – V) (Fig. 1). At each of the stations there were crops bordering on a shelterbelt or wasteland. Samples were taken from potato and rye plantations, as well as from the herb layer of adjacent shelterbelts. The stations were named after the localities, woods or a range closest to them. At each of the stations entomofauna was sampled at seven sites: (1) in the shelterbelt herb layers, (2) at the shelterbelt-rye field interface, (3) at the shelterbelt-potato field interface, (4) in rye plantations 50 m from a shelterbelt, (5) in potato plantations 50 m from a shelterbelt, (6) rye plantations 150 – 200 m from a shelterbelt, (7) potato plantations 150 – 200 m from a shelterbelt.

Station Rogaczewo (I) was situated on either side of a shelterbelt running along the Turew-Kopaszewo road. At that station a study of the effect of shelterbelts on the climate was carried on for 10 years (Kamiński 1968). The material-collecting programme covered the period 1965–1968.

Station Wyskoć (II) was located near the village of the same name. It included, as a wooded area, a stretch of a mid-field mixed coniferous forest and the adjacent croplands. The material-collecting programme covered the period 1966–1967.

Station Donatowo (III) comprised sites in fields surrounded by shelterbelts. There was a small forest (1 ha) in the middle, where the sampling in the herb layer was carried out. Material collecting was done over the period 1966–1967.

Station Kamieniołom (IV) was located near the Turew-Rogaczewo road, in a region where there had been a gravel pit years ago. After having been exploited, the area had been abandoned as a wasteland. It was grown up with herbaceous vegetation, mainly grasses. During the spring thaw the floor of the trough-shaped gravel pit is flooded. Sampling was done in the years 1966 and 1967.

Station Turew (V) bordered on a 20 ha park. It was treated as a supplementary station, and samples were collected at it only in 1967.

Sampling was done at 10-day intervals during the growing season, from May to November. Two catching methods, described in detail elsewhere (Gromadzka and Trojan 1967) were employed: the sweep net and the biocoenometer. (1) The sweep net used consisted of a metal ring 30 cm in diameter to which a linen bag and a wooden handle were attached. At the end of the bag a replaceable bag was attached. Each sample consisted of 25 strokes, and ten samples were collected at every site. (2) The biocoenometer consisted of four parts: a dome to enclose the insects, an electrically driven sucker for collecting insects, a power supply and a crane for dropping the dome. The dome was a truncated pyramid in shape, with a square base. The side of the base measured 50 cm, the height 100 cm, and the area 0.25 m^2.

Heteropteran density per m^2 was determined from sweep-net (e) and biocoenometer (b) samples. Sweep-net samples usually contained larger numbers of species and individuals than biocoenometer samples, but data from the latter could be referred to the area. Sweep-net data were combined with biocoenometer data by using the density index (I_d):

$$I_d = \frac{4\bar{N}_b}{\bar{N}_e}$$

where: $\bar{N}_b$ – mean numbers of a particular species or association in biocoenometric samples, $\bar{N}_e$ – mean numbers of a particular species or association in sweep-net samples.

Density indices were calculated separately for each sampling site and for each catching series covering one season.

For sweep-net samples density ($N \cdot m^{-2}$) was calculated in the following way:

$$N \cdot m^{-2} = I_d \cdot N_e$$

where: N_e – numbers in a particular sweep-net sample.

Diversity within associations was estimated by using Shannon's estimator (H'):

$$H' = \sum_{i=1}^{S} p_i \ln p_i$$

where: $p_i - N_i \cdot N_t^{-1}$, N_i – mean numbers of the i species at a station, N_t – total of mean numbers of all species at a particular station, S – total number of species found at a particular station.

Comparisons of the specific composition at different stations were based on the Marczewski and Steinhaus (1959) formula defining the similarity coefficient (S):

$$S = \frac{w}{a + b - w}$$

where: w – number of shared species in an association, a – number of species in association a, b – number of species in association b. In the case of complete identity of associations the value of the coefficient is 1, and when there is no similarity among them, it takes the value of 0.

The fidelity of species occurrence was also assessed by using the coefficient (F):

$$F = \frac{O_x}{S_x}$$

Table 1. Number of samples and individuals of heteropterans collected in rye and potato fields and in shelterbelt herb layer in the region of Turew, southern Great Poland

n_os – number of samples, $n_o$ind. – number of individuals

Samples	Station	Year								Total	
		1965		1966		1967		1968			
		$n_o s$	$n_o ind$	$n_o s$	$n_o ind$	$n_o s$	$n_o ind$	$n_o s$	$n_o ind$	$n_o s$	$n_o ind$
Net	Rogaczewo	430	2153	370	1481	320	341	250	1163	1370	5138
	Wyskoć	–	–	70	421	40	140	–	–	110	561
	Donatowo	–	–	250	1085	110	117	–	–	360	1202
	Kamieniołom	–	–	225	1267	125	100	–	–	350	1367
	Turew	–	–	–	–	220	151	–	–		
Total		–	–	–	–	–	–	–	–	2190	8268
Biocenometric	Rogaczewo	679	197	540	518	700	388	330	338	2249	1441
	Wyskoć	–	–	370	718	270	69	–	–	640	787
	Donatowo	–	–	400	384	700	457	–	–	1160	841
	Kamieniołom	–	–	400	365	140	26	–	–	540	391
Total		–	–	–	–	–	–	–	–	4589	3460

where: O_x — number of stations at which a particular species was found to occur, S_x — total number of stations.

The value of the coefficient varies from 1 for ubiquitous species to almost 0 for species sporadically occurring at single stations. Over the four-year study period a total of 2190 sweep-net and 4589 biocoenometric samples were collected at the above-described five stations (Table 1). They included almost 12000 heteropterans.

3. HETEROPTERAN ASSOCIATIONS IN AGROCOENOSES

On the basis of numerical data a list of the species found in the study area has been drawn up. It includes 76 species representing 14 heteropteran families. An insignificant number of larval individuals and of those damaged during the catching have been identified to the genus or family. The list contains species known before, mentioned in faunistic papers, so they do not require separate descriptions.

The composition of the heteropterans found in the study area consists of species differing in their bionomy and food specialization. For further analyses they were divided according to their diet. The classification defines the place of a particular species group in the food web of the biocoenose. In earlier studies such a group was defined as sharing a common ecological niche (Elton 1927, Odum 1959). In more recent ecological papers, however, this concept is not defined as unequivocally as it was earlier on, mainly because of the introduction of the multidimensional niche concept (Patten and Auble 1978).

In this situation, a group of species sharing common food resources and having the same group of enemies, predators and parasites has been described with a narrower definition (Trojan 1980), according to which they are species holding a similar position in a food chain; they are also referred to as trophic groups. The numbers-controlling processes that go on in such a group lead on to the formation of specific structures termed the dominance structures. The composition and structure of an association are of fundamental importance to the maintenance of such ecological systems as food chains (Trojan 1984). Such assemblage of species can be defined as uniform from the viewpoint of the theory of ecosystem homeostasis, and as more suitable for statistical analyses than are assemblages identified on the basis of taxonomical criteria, and called taxocoens.

The heteropterans found in the neighbourhood of Turew belong to four different associations. The most abundant is the phytophage group (46 species), followed by zoo-phytophages (16 species), and zoophages (12 species). Saprophages are the least numerous group (2 species). Estimates of the numeric ratios of the three principal heteropteran associations (saprophages are only found sporadically outside cropfields) to some extent depend on the catching method used (Table 2). Numerically dominant, both in the sweep-net and biocoenometer samples, was the saprophage group, including species of diversified diets and capable of changing from vegetable to animal food and vice versa. Herbivores represent $\frac{1}{3}$ of the numbers of zoo-phytophages. This relationship is similar in sweep-net samples and biocoenometrical samples. Divergent

Table 2. Number of individuals and species in three bug associations on rye plantations at Rogaczewo in 1965–1968
$\bar{N}$ – mean number of individuals per sample, $\bar{S}$ – mean number of species per year, S_t – total number of species in all samples

Association	Net samples			Biocenometric samples		
	$\bar{N}$	$\bar{S}$	S_t	$\bar{N}$	$\bar{S}$	S_t
Zoophages	0.022	1	4	0.097	2.6	6
Zoo-phytophages	0.545	2.6	4	0.249	3.6	5
Phytophages	0.149	3.2	8.	0.076	3.8	8

values are obtained from comparisons of the quantitative ratios between zoo-phytophages and zoophages assessed by both the methods. In biocoenometric samples the zoophage to zoo-phytophage abundance ratio is 0.39 : 1, and in sweep-net samples 0.04 : 1 – tenfold lower. The number of zoophagous species found in biocoenometric samples is also higher than in net samples. Such differences probably result from the fact that the collecting of samples with the sweep-net flushes out the predaceous forms, and the samples are not, therefore, fully representative for the assessment of the quantitative ratios between associations.

Cropfield insect association structure is additionally affected by migrations. In spring, cropfields are colonized by insects that leave their wintering places in the litter of forests and shelterbelts. In autumn, bugs emigrate from fields into wooded areas. The winter reduction in numbers of these insects is not known. The number of species present in each cropfield in summer is lower than this one found for the whole area. The problem that requires elucidation in this situation is the species-composition repeatability of the associations in cropfields in successive years. It has been exemplified by the Rogaczewo station where samples were collected for four consecutive years. In rye plantations the following species-composition pattern of three bug associations was obtained.

For biocoenometric-sample zoophages the following species repeatability is found: for four years – 1, for three years – 1, for two years – 2, for one year – 2.

In sweep-net samples the repeatability is lower: in two years – 1, in one year – 3. The highest repeatability is found for *Nabis ferus* L.

Zoophytophages are represented here by 5 species. Repeatability in sweep-net samples is as follows: in four years – 1, in three years – 1, in two years – 1, in one year – 1.

In biocoenometric samples a higher repeatability is found: in four years – 3, in one year – 2.

Lygus rugulipennis, *L. pratensis* and *Aelia acuminata* L. are species of the highest repeatability.

The phytophages here are represented by 9 species. Sweep-net sample species repeatability is as follows: in four years – 1, in two years – 1, in one year – 5.

In biocoenometric samples a higher species repeatability is found: in four years – 1, in three years – 1, in two years – 2, in one year – 3. The highest-repeatability species include *Trigonotylus pulchellus* H. Hahn, *Notostira erratica* L. Other species appear in one or in two years.

To level the differences resulting from an incomplete repeatability of the specific composition in particular years, for the analysis all the samples taken at a particular site throughout the study period were pooled. An analysis has been undertaken to explain the species composition and structure of associations in plantations and shelterbelts. Plantations are described via samples collected at a distance of 150 m from a mid-field shelterbelt.

Table 3. Fidelity of occurrence (*F*) of predatory bugs in agrocoenoses of the region Turew

Seq. no.	Species	Shelterbelt	Potato	Rye	*F*
1.	*Himacerus apterus* F.	2/4	1/4	0/4	0.25
2.	*H. mirmicoides* Costa	2/4	0/4	0/4	0.17
3.	*Nabis flavomarginatus* Schultz	2/4	1/4	0/4	0.25
4.	*N. ferus* L.	0/4	4/4	2/4	0.50
5.	*N. pseudoferus* Rem.	3/4	4/4	3/4	0.83
6.	*N. limbatus* Dhlb.	1/4	0/4	0/4	0.08
7.	*Anthocoris pilosus* Jak.	1/4	0/4	0/4	0.08
8.	*A. nemorum* L.	0/4	2/4	0/4	0.17
9.	*A. nemoralis* F.	2/4	0/4	0/4	0.17
10.	*Orius niger* Wolff	1/4	4/4	2/4	042
11.	*O. minutus* L.	1/4	2/4	1/4	0.33
12.	*Saldula saltatoria* L.	1/4	1/4	1/4	0.25

The zoophage association consisting of 12 species throughout the study area is represented at individual sites by 0–8 species. Thus the occurrence of species at the different sites is variable. The largest number of predatory species has been found in the herb layer vegetation of the mid-field shelterbelts (10 species). In potato plantations there are 8, and in rye 5 such species. A question therefore arises as to whether we are dealing with one or several separate predaceous bug associations. The fidelity of occurrence of the species of this group has been analysed (Table 3) by using the fidelity coefficient (*F*) indicating the proportion of a particular species at every station. Species arranged according to the fidelity coefficient make up the core of an association, and are in principle present at every station. Their sequence is as follows: (1) *Nabis pseudoferus*, (2) *N. ferus*, (3) *Orius niger*, (4) *O. minutus*, (5) *Saldula saltatoria*. Of these 5 species only *N. ferus* is not present in the herb layer under the tree canopy of the shelterbelts, and *S. saltatoria* should be considered to be immigrant from the sides of water bodies. Other species are more sporadic in the different cropfields.

The phytophage association is richer than other associations. In the study area it includes 46 species, 37 of which occur in the shelterbelt herb layer and in the middle parts of rye and potato fields. The largest number of species are found in the shelterbelt herb layer — 33 species; in potato fields there are 18, and in rye fields — 8. It is difficult

Table 4. Fidelity of occurrence (*F*) of phytophagous bugs in agrocoenoses of the region of Turew

Seq. no.	Species	Shelterbelt	Potato	Rye	*F*
1.	*Lygus punctatus* Zett.	0/4	1/4	0/4	0.08
2.	*L. kalmi* L.	1/4	0/4	0/4	0.08
3.	*Adelphocoris lineolatus* Gz.	1/4	2/4	0/4	0.25
4.	*A. annulicornis* K. Sahlb.	2/4	2/4	0/4	0.33
5.	*Stenodema laevigatum* L.	4/4	1/4	3/4	0.67
6.	*S. virens* L.	4/4	1/4	3/4	0.67
7.	*S. calcaratum* Fall.	4/4	2/4	0/4	0.50
8.	*Notostira erratica* L.	4/4	1/4	2/4	0.58
9.	*Leptopterna ferrugata* Fall.	3/4	0/4	0/4	0.25
10.	*Acetropis carinata* H-S.	4/4	0/4	0/4	0.33
11.	*Trigonotylus pulchellus* H. Hahn.	3/4	1/4	1/4	0.42
12.	*T. ruficornis* Goeffr.	1/4	1/4	0/4	0.17
13.	*Capous ater* L.	1/4	1/4	0/4	0.17
14.	*Orthytylus flavosparsus* C. Sahlb.	0/4	3/4	1/4	0.33
15.	*Charagochilus gyllenthali* Fall.	1/4	0/4	0/4	0.08
16.	*Plagiognathus chrysanthemi* Wolff.	4/4	3/4	1/4	0.67
17.	*Polymerus unifasciatus* F.	2/4	0/4	0/4	0.17
18.	*Chlamydatus pullus* Reut.	1/4	0/4	0/4	0.08
19.	*Megalocoleus molliculus* Fall.	1/4	0/4	0/4	0.08
20.	*Dimorphopterus spilonai* Sign.	1/4	0/4	0/4	0.08
21.	*Stenotus binotatus* F.	1/4	1/4	0/4	0.17
22.	*Monanthia echii* (Schr.)	1/4	0/4	0/4	0.08
23.	*Tingis reticulata* H-S	1/4	0/4	0/4	0.08
24.	*Piesma maculatum* Lap.	4/4	2/4	2/4	0.67
25.	*P. quadratum* Fieb.	1/4	0/4	0/4	0.08
26.	*Nysius lineatus* Costa	2/4	0/4	0/4	0.17
27.	*N. ericae* Schill.	2/4	1/4	0/4	0.25
28.	*Kleidocerys resedae* Pz.	3/4	0/4	0/4	0.25
29.	*Cymus claviculus* Fall.	3/4	1/4	0/4	0.33
30.	*Bathysolon nubilus* Fall.	1/4	0/4	0/4	0.08
31.	*Coreus marginatus* L.	0/4	1.4	0.4	0.08
32.	*Syromastus rhombeus* L.	1/4	0/4	0/4	0.08
33.	*Myrmus miriformis* Fall.	1/4	0/4	1/4	0.17
34.	*Rhopalus parumpunctatus* Schill.	0/4	2/4	1/4	0.25
35.	*Brachycarenus tigrinus* Schill.	1/4	0/4	0/4	0.08
36.	*Strictopleurus punctatonervosus* Gz.	1/4	0/4	0/4	0.08
37.	*Trigomegas bicolor* L.	1/4	0/4	0/4	0.08
38.	*Elasmucha betulae* Deg.	2/4	0/4	0/4	0.17
39.	*Carpocoris fuscipinus* Boh.	0/4	1/4	0/4	0.08
40.	*Eurydema oleracea* L.	0/4	1/4	0/4	0.08
41.	*Aelia klugi* Hahn.	2/4	0/4	0/4	0.17
42.	*Sciocoris deltocephalus* Fieb.	1/4	0/4	0/4	0.08

to determine the number and distinctness of the associations of phytophages, firstly because the number of species in the different cropfields and in the shelterbelt herb layer varies considerably, and secondly because there are monophagous and oligophagous phytophage species, mainly connected with a specific host plant. This problem ceases to be important when the species considered are more common in a particular cropfield. This also applies to those species that have been found at least at a half of the sampling sites in a cropfield. There are 4 such species in rye fields, and 6 in potato fields. All the species more common in both crops, except *Orthotylus flavosparsus*, are also present in the shelterbelt herb layer. Thus, as regards the more common species making up an association, they appear to be common to the shelterbelt herb layer and potato and rye fields. As assessed by the Marczewski and Steinhaus (1959) coefficient, the similarity of the associations is not great. Comparisons of the associations of the three cropfield types considered give the following results:

shelterbelt herb layer-potato fields	$S = 0.378$	(0.609)
shelterbelt herb layer-rye fields	$S = 0.206$	(0.304)
potato fields-rye fields	$S = 0.241$	(0.438)

Similarity coefficient (*S*) values are thus far from unity. The result obtained may, however, arouse doubts, because it is biased by 14 phytophage species that appeared to be present only at one of the 12 sampling sites. In Table 4 all such species have the value $F = 0.08$. If they are rejected, as accessory, from the analysis of the similarity of associations, the similarity coefficients have much higher values. In the above-presented summary they are represented by numbers in brackets. Owing to the clear similarity of the most common species, the phytophage association can also be regarded as uniform in respect of its component species, enriched at each site and in every cropfield with a pool of accessory species.

Present in the shelterbelt herb layer and rye and potato fields are the following: (1) *Stenodema laevigatum*, (2) *S. virens*, (3) *Notostira erratica*, (4) *Trigonotylus pulchellus*, (5) *Plagiognathus chrysanthemi*, (6) *Piesma maculatum*. These species make up the body of the phytophage association, the first four of them being associated with grassses and grains, and the remainder with weeds of the region of the shelterbelt-cropfield interface.

The base of the high similarity between the phytophage association of the shelterbelt herb layer and that of potato fields is 14 shared species. Only four phytophagous bugs, of which three were only once found at Rogaczewo station, are not present in the shelterbelt herb layer. Even more marked is the situation when the composition similarity is analysed between the association of rye fields and that of the shelterbelt herb layer, as only one of the species present on rye was not found in the shelterbelt herb layer.

From the above findings it may be concluded that in the agricultural landscape there occurs one association of phytophagous bugs, its composition being the richest in the shelterbelts. Its impoverished forms occur in rye and potato fields.

In the shelterbelt herb layer the zoo-phytophagous association (Table 5) includes 12 species, in potato fields — 7, in rye — 4. In the three plant associations mentioned 16 zoo-phytophagous bug species are found. Five of them occurred only in one crop, and only at one sampling site, 5 were found at two sampling sites of the same crop, or

Table 5. Fidelity of occurrence (*F*) of zoo-phytophagous bugs in agrocoenoses of the Turew region

Seq. no.	Species	Shelterbelt	Potato	Rye	*F*
1.	*Lygus rugulipennis* Popp.	4/4	4/4	4/4	1.00
2.	*L. pratensis* L.	4/4	4/4	1/4	0.75
3.	*L. gemellatus* H-S.	2/4	0/4	0/4	0.17
4.	*Calocoris fulvomaculatus* Deg.	2/4	0/4	0/4	0.17
5.	*C. quadripunctatus* Vill.	2/4	0/4	0/4	0.17
6.	*Campylomma verbasci* Mey.	0/4	3/4	0/4	0.25
7.	*Cyllecoris flavoquadrimaculatus* Deg.	1/4	0/4	0/4	0.08
8.	*Deraecoris punctulatus* Schill.	0/4	1/4	0/4	0.08
9.	*Macomma ambulans* Fall.	1/4	1/4	0/4	0.17
10.	*Neides tipularius* L.	2/4	1/4	0/4	0.25
11.	*Scolopsthetus decoratus* Hahn.	1/4	0/4	0/4	0.08
12.	*Drymus sylvaticus* F.	1/4	0/4	0/4	0.08
13.	*Dolycoris baccarum* L.	1/4	1/4	0/4	0.17
14.	*Aelia acuminata* L.	3/4	0/4	4/4	0.58
15.	*Eurygaster maura* L.	0/4	0/4	1/4	0.08
16.	*Deraecoris ruber* L.	1/4	1/4	0/4	0.17

in two crop types, but at one sampling site. Those 10 species can be defined as accessory ones. Their value in Table 5 is $F = 0.08$ or 0.17. The remaining 5 species form the body of the zoo-phytophage association. They are the following: (1) *Lygus rugulipennis*, *L. pratensis*, (3) *Aelia acumunata*, (4) *Campylomna verbasci*, (5) *Neides tipularius*. A comparison of the associations by means of the Marczewski and Steinhaus (1959) coefficient gives results similar to those obtained for phytophages:

shelterbelt herb layer-potato fields $S = 0.356$ (0.556)
shelterbelt herb layer-rye fields $S = 0.231$ (0.300)
potato fields-rye fields $S = 0.222$ (0.286)

If accessory species with coefficient values $F = 0.08$ are left out, the coefficient of similarity of the zoo-phytophage associations of the shelterbelt herb layer and potato fields is clearly higher (values in brackets). In spite of this, the similarity of these associations must be regarded to be low. The value of the *S* coefficient has been significantly affected by the considerable difference in the number of species found in the shelterbelts and in the cropfields. As many as 6 zoo-phytophage species present in the shelterbelt herb layer do not spread into cropfields. Only two zoo-phytophage species were found exclusively in potato fields, and one exclusively in rye fields. This lack of specificity of the species composition of the cropfield zoo-phytophage associations permits the assumption that in this case also the association of these bugs found in cropfields is the same as that present in the sherterbelt herb layer, where it is the richest in species. The enrichment of associations with specific species, seen in cropfields does not take place in the shelterbelt herb layer, or is low there, and does not lead to the appearance of distinct features in an association.

In the study area the saprophage association includes only two species found in the shelterbelt herb layer, and does not play any important role in the agroecosystem economy.

Table 6. Species diversity in three bug associations in the Turew region
H' — index of diversity, *S* — number of species, *N* — mean annual numbers of association per sample

Association	Sampling station	Net samples			Biocenometric samples		
		H'	*S*	*N*	*H'*	*S*	*N*
Zoophages	Rogaczewo	1.8393	11	47.9	1.0996	8	22.2
	Wyskoć	1.8053	8	8.6	1.1114	5	4.3
	Kamieniołom	1.5817	6	10.6	1.4921	6	3.0
	Donatowo	1.4407	6	15.6	1.2457	6	6.6
Phytophages	Rogaczewo	2.3978	22	86.7	1.8125	19	27.6
	Wyskoć	1.8221	20	181.0	2.2899	16	7.9
	Kamieniołom	1.8359	18	80.2	1.9988	10	5.2
	Donatowo	1.7515	19	143.8	2.5799	21	9.0
Zoo-phytophages	Rogaczewo	0.7786	14	600.6	0.6365	8	86.3
	Wyskoć	0.9836	9	52.6	0.9334	5	23.7
	Kamieniołom	0.8698	5	195.6	0.9932	7	25.2
	Donatowo	0.6889	7	134.6	0.7313	5	67.0

Species diversity of the particular associations at four sampling stations was analysed in pooled samples from cropfields and shelterbelt herb layers, from seven sites at each station (Table 6). The highest diversity is found in phytophage associations, both in sweep-net and biocoenometer samples. The lowest species diversity is recorded in zoo-phytophage associations that were most numerous at all stations.

4. BUG ABUNDANCE DYNAMICS IN AGROCOENOSES

Changes in numbers of the epiphytic fauna in agrocoenoses is on the one hand a natural process connected with the reproduction and mortality in populations, and on the other hand it is caused by migrations related to the growth cycles of annual crop plants and the cultivating operations that accompany them. The latter factor plays a significant role in the case of potato and rye plantations. The shelterbelt ground-layer vegetation provides a stable cover. Sown in September, rye comes up in autumn when it is cool, and when insects do not migrate to cropfields. For this reason, rye fields are colonized by them in spring, and their populations can grow there till July or August.

Harvest brings about a complete change of habitat conditions for epihytic animals, and they seek food in aftercrops or stubble weeds. If post-harvest ploughing is done, the epiphytic species are left without food resources, and they emigrate or die. Planted in spring, potatoes develop leaves and shoots from May to September. In the second half of summer and early in autumn potato-plants most often wither, and then in potato fields there begin to grow weeds associated with root crops. In this period also the living conditions of epiphytic fauna change drastically.

In particular years the sampling period was adjusted to the weather conditions and the plant growing cycle. At station Rogaczewo samples were collected for four years, and at other stations only in the years 1966, 1967. Sampling was begun as soon as freezing weather had subsided and plant growing had started, at the earliest on 3.04.1967, at the latest on 12.05.1966. It was terminated at the end of October. In some cases sampling was continued until the last days of November. In 1967, at stations: Wyskoć, Donatowo and Kamieniołom sampling was terminated at the end of July.

The course of abundance dynamics of the bugs in the shelterbelt ground cover vegetation is as follows. Bugs begin to appear in May. If the spring weather is warm, the first specimens are captured from mid-April on, and if it is cold — in June. The earliest to appear, in April, are phytophages. Predatory forms very rarely become active before other bugs do so. In many cases representatives of all the three associations appear simultaneously. Zoo-phytophages are the earliest to cease their activity, often as early as September, and they seldom continue to be present till the beginning of November.

Table 7. Mean annual numbers of three bug associations in Rogaczewo shelterbelt herb layer, biocoenometric data

Association	Year			
	1965	1966	1967	1968
Zoophages	0.339	0.171	0.225	0.071
Zo-phytophages	0.828	0.350	0.120	0.029
Phytophages	0.717	0.489	0.645	0.247

The mean annual numbers of bugs, determined from sweep-not samples, varied considerably over the four consecutive years (Table 7). The highest variation was recorded for zoo-phytophates, whose numbers at the same site may be in different years over 28 times higher or lower. In the shelterbelt herb layer the lowest variation in numbers is found for phytophagous bugs, their highest abundance being about 3 times higher than their lowest numbers. For zoo-phytophagous species this value comes up to 4.8. It must be noted that analogous data obtained on the basis of biocoenometric samples show much lower abundance oscillations. For zoophages they amount to 1.7, for zoo-phytophages 4.0, and for phytophages 3.5. Only in this case was the difference higher than in the case of sweep-net samples.

Periods of highest numbers are shifter in time. For zoophages it is usually July, rarely June. Zoo-phytophages attain peak numbers in June, and in some years at the turn of August. Phytophages have one or two abundance peaks. The first — the spring peak occurs every year in June, and is sometimes extended over the beginning of July, and the second one usually appears in the second half of August, sometimes extending over the beginning of September. A similar picture was obtained from the analysis of the bug associations found in the herb layer of the remaining three shelterbelts.

A separate problem is the uniform occurrence in time. Among sweep-net samples, and especially among biocoenometric samples there are samples in which no bugs are found. The case of this may be the weather conditions, catching method, mobility of the bugs and their distribution. The three associations analysed differ considerably in this respect. Zoophages were present in only 30.6% of a total of 157 sweep-net sample series, and zoo-phytophages in 45.2%. The highest sample-cover uniformity has been found for phytophages – 73.3%.

Abundance dynamics in rye fields. Bugs first appear in April or May, depending on the beginning of the phenological spring. Of the zoophage group the first to appear are species of the genus *Nabis*: *N. ferus* and *N. pseudoferus*. The zoo-phytophage *L. rugulipennis* begins its activity in March, April or May. Other spring zoo-phytophages begin to colonize rye fields in May. Among them is *Aelida acuminata*, *Dolycoris baccarum*, *Calocoris quadripunctatus* and *Eurygaster maura*. The first phytophages that appear in April are *Notostira erratica*, *Nysius ericae* and *Stenodema virens*. In May there occur besides them other species of the genus *Stenodema*, and *Plagiognathus chrysantemi*, *Eurydema oleracea* and *Piesma maculatum*. In rye fields, the number of species present during the growing season at particular sampling sites is not high. The mean and extreme numbers of species found at the sampling sites over the growing season were as follows:

zoophages	1.36	(0–4)
zoo-phytophages	2.79	(0–4)
phytophages	4.14	(1–8)

The above numbers indicate that in some rye fields not a single individual of predatory or zoo-phytophageous bugs was captured during the growing season with the catching methods used. Such a situation has been recorded five times. Phytophages, too, are represented by a small number of species that occur in larger numbers in May. The growing season of rye ends in July–August, so the whole period of association formation lasts two months. Consequently, bugs never succeed in buildng a complete association here. Rye-field colonization continues throughout the time, but is limited. The attractiveness, to phytophagous bugs, of ripe and partly dried plants is not high. It may, therefore, be stated that the development rate of rye is faster than the formation rate of bug associations. As a result, changes in their numbers are to a considerable extent fortuitous. Abundance peaks are difficult to establish, and often they do not occur at all. Sometimes it is only after the harvest that bugs attain a stabilized, as a rule low, level of numbers.

Table 8. Mean annual numbers of three bug associations in rye fields, biocoenometric data

Association	Number of individuals per m^2		
	mean	max.	min.
Zoophages	0.18	0.88	0.00
Zoo-phytophages	0.50	2.20	0.01
Phytophages	0.23	0.44	0.04

Assessed by the biocoenometric method, bug density in rye fields appears to be low (Table 8). There is one predatory bug per over 5 m^2, one zoo-phytophage per 2 m^2, and one phytophage per over 4 m^2. Between spring and the harvest rye fields are not treated with pesticides, so it can be assumed that the importance of phytophagous bugs as pests is insignificant. A similar view can be expressed with regard to both the remaining associations.

Abundance dynamics in potato fields. The appearance of bugs in potato fields is spread over three months – from the early days of May until the end of July. Earlier occurrences of bugs in fields are not connected with the growing of the potatoes, but with the weeds growing in the fields.

Table 9. Mean annual numbers of three bug associations in potato fields, biocoenometric data

Association	Number of individuals per m^2		
	mean	max.	min.
Zoophages	0.30	1.06	0.08
Zoo-phytophages	2.40	5.97	0.20
Phytophages	0.31	0.91	0.08

In June, all the three associations are already represented. Potato-field colonization proceeds very quickly, and in July there are, most often, already stable associations and levels of numbers. They are fairly high (Table 9) and clearly dominated by the zoo-phytophage association, whose numbers are eight times as high as those of each of the remaining associations. Abundance dynamics is on the increase, this process extending over August and September when the populations, particularly of zoo-phytophages, attain peak numbers. This phenomenon is only in part caused by local factors associated with the potato fields themselves, which in high-precipitation years stay green until September. There is also the effect of the disappearance of cereal crops that causes insect migration, within agrocoenoses, into crops that are still in the growing phase. Hence the gathering of bugs in potato plantations.

5. EFFECT OF SHELTERBELTS ON BUG DISTRIBUTION

The first data gathered in 1965 at station Rogaczewo (Table 10) already revealed considerable differences in numbers between associations at different sites. The number of bugs in the shelterbelt-cropfield interface differed from that in the shelterbelt. Considerable differences in numbers were also found between the bug associations in the central parts of the cropfields, distant from the shelterbelts, and those in the shelterbelts and the interface zone.

To explain this phenomenon, samples were collected at sites forming a line, from a shelterbelt to the middle of a cropfield. For this purpose sampling sites were located in

Table 10. Numbers of three bug associations at different distances from shelterbelt

Annual mean, sweep-net data, Rogaczewo, 1965

Association	Potato		Shelter-belt	Rye	
	150 m	contact zone		contact zone	150 m
Zoophages	0.266	0.127	0.339	0.061	0.011
Zoo-phytophages	6.866	0.683	0.828	0.038	0.794
Phytophages	0.543	0.094	0.717	0.299	0.177

the shelterbelts, in the shelterbelt-cropfield interface zones, where samples were taken from the cropfield area close to a belt, and within cropfields — two sites in each: the first one, 50 m from the belt, which corresponds to 3–4 shelterbelt heights, was in the zone of a strong influence of the shelterbelt on the microclimate, the second one was situated 150–200 m from the shelterbelt, that is over 10 shelterbelt heights, in the zone of a weak effect of the shelterbelt on the microclimate. The above sampling system was used at four stations: Rogaczewo, Wyskoć, Donatowo and Kamieniołom over a two-year period. Sampling was done both with the sweep-net and biocoenometer in two potato and two rye fields, which gave a total of 16 yearly capture series. The numeric data obtained from them demonstrate considerable variation between stations and sampling sites, as well as from year to year. To increase their comparability, the mean annual numbers in the shelterbelt herb layer were adopted as the basis, and other data were presented as percentages of that quantity. This made it possible to level part of the variation resulting from the weather conditions prevailing during a particular season, and the different abundance levels found at individual sites, or the catching methods used. Percent data make it possible to analyse differences in the abundance of cropfield bugs by comparing their numbers to those observed in a habitat representing a departure habitat for the formation of a cropfield fauna.

Table 11. Numbers of three bug associations at different distances from shelterbelt

Data calculated as per cent of numbers in shelterbelt

Association	Potatoes			Rye		
	contact zone	50 m	150 m	contact zone	50 m	150 m
Zoophages	193.2	115.5	112.2	89.7	50.0	71.2
Zoo-phytophages	882.6	1195.2	1736.0	78.9	208.4	162.1
Phytophages	37.8	80.9	75.6	36.4	73.0	56.9

The effect of shelterbelts on the numbers of bugs in cropfields depends on the crop plant and competitive association(Table 11). Potato plantations are more attractive to the zoophage association than the shelterbelt herb layer is. A considerable concentration of predators occurs there, particularly high in cropfield areas adjacent to shelterbelts, decreasing with the distance from them. Less attractive to predators are rye fields in which their numbers are lower than in the belt.

Zoo-phytophages migrate almost completely into cropfields. To them also potatoes are more attractive than rye is. Zoo-phytophages occur in potato plantations in 9–17 times higher numbers than in the shelterbelt herb layer. In rye fields higher numbers of zoo-phytophages are found in field parts distant from shelterbelts. In the cropfield contact zone directly bordering on a shelterbelt smaller numbers of zoo-phytophages occur than in field parts far from the belt.

Phytophagous species in cropfields show lower levels of numbers than in the shelterbelt herb layer. In the interface zone their abundance represents only $\frac{1}{3}$ of that recorded for shelterbelts. In more distant field parts it is higher, but it never attains the level of numbers characteristic of the shelterbelts.

Thus, the effect of mid-field shelterbelts on the quantitative relations both within particular associations and among associations is quite clear. A shelterbelt represents a factor that organizes the biocoenotic relations in cropfields.

6. DISCUSSION OF RESULTS

Ecological studies of bugs in agrocoenoses, begun by Tischler (1938, 1939), have a 50-year tradition. In Poland they have been developed by Strawiński (1955, 1956, 1964, 1966) and Bilewicz-Pawińska (1959, 1961, 1965). They undertook problems related to the specific composition, role and natural reduction of bugs.

The methods used in this study do not require a broader description. They have been described in detail in a separate paper (Gromadzka and Trojan 1967). An extensive survey of the literature concerning both the sweep-net and biocoenometer methods had been prepared earlier by Jürisoo (1964). It must only be emphasized here that the biocoenometric catching method used in our studies differs from those employed earlier on at least in two points: (1) the surface area of our biocoenometer (0.25 m^2) is larger than that usually used in other studies (0.1 m^2), (2) the biocoenometer hood is not placed on plants by hand, as it is done by other investigators, but with the aid of a long extension arm. These modifications reduce the flushing of the insects sitting on plants, and the determination of density is more accurate.

The assessment of bug associations, presented in this paper, is based on the competitive association concept. The point of departure adopted by other students of the ecology of bugs is their taxonomic classification. The assemblages distinguished are usually called taxocoens or zooms (Jürisoo 1964). Phytophagous forms are often combined with zoo-phytophages, although the role of the latter in agrocoenoses can, at least temporarily, be different from that of the phytophages. In spite of the different assumptions adopted, the findings of this study as regards the dominant species in cereal crops and potatoes to a large extent agree with the data reported by

Bilewicz-Pawińska (1965, 1976). Similar data concerning the specific composition of the bugs of Schleswig-Holstein have been published by Afschapour (1960), for agrocoenoses of Slovakia by Štepanovicova (1963, 1966), and for Sweden by Jürisoo (1964).

A comparison of data on the specific composition of potato-plantation bugs in Great Poland and in the Lublin region, made possible by Strawiński's papers (1955, 1966), indicates considerable differences even in the set of species defined by Strawiński (1955) as peculiar to potato fields. It seems that the cause lies not only in differences in the climatic and soil conditions between these two regions. Most important is the presence in the Lublin region of small-area cropfields, a large proportion of boundary strips with a natural vegetation, and a considerable abundance of weeds within the cropfields. Because of these factors, the ecological conditions under which bugs in the two regions live are different.

The abundance dynamics of bugs observed in our studies shows a diversity similar to that presented by Jürisoo (1964) with regard to cereals in Sweden. The periods of appearance, the occurrence and duration of peak numbers vary in the case of most species, even the dominants, such as *Lygus rugulipennis*, between years at the same site, and between sites of the same cropfield in the same year. This diversity is most conspicuous in low-abundance species. Presented in this paper is a trial for explaining these differences by accepting the concept of colonization of agrocoenoses, especially of annual crops, anew every spring. In the case of potato fields the process lasts a longer time – there occurs an additional migration wave, following by treatment with pesticides. As a result, both the species composition of potato-field bugs and the course of changes in their numbers indicate a considerable stabilization. In cereal fields the situation is different, because the period of cereal ripening and harvesting is shorter than that of potatoes.

A comparison of data on the numbers of bugs in the shelterbelt herb layer and in cropfields demonstrates that in summer zoophagous species migrate into potato fields more readily than into cereal fields. Almost all zoo-phytophages move into cropfields, clearly preferring potato fields. The same applies to the association of phytophages. In summer, the level of numbers of bug associations staying in the shelterbelts is low. Due to bug migrations within the agricultural landscape, the structural and dynamic phenomena within associations are highly variable in time and space.

7. CONCLUSIONS

(1) In the agrocoenoses of southern Great Poland there occur four trophic groups of bugs, including: zoophages – 12, zoo-phytophages – 16, phytophages – 46 and saprophages – 2 species. (2) The species compositions of the trophic groups of zoophages and zoo-phytophages are similar in cropfields and in the shelterbelt herb layer. They form two uniform associations within the agricultural landscape of Great Poland. (3) The phytophage association has a similar set of dominant species making

up the association. Differences are mainly found in the composition of accessory species. This association can also be considered uniform within the landscape. (4) The saprophage association is in the study area represented by small numbers, and only in the shelterbelt herb layer. (5) In plantations, bug associations and populations are restored every year through migration from wintering grounds in the litter of shelterbelts and forests. Apart from this, their abundance dynamics is affected by migrations between cropfields, due to cultivating operations. (6) In summer the highest numbers of bugs are recorded in potato fields after the harvest of cereals; in rye fields and shelterbelts the density of heteropterans is low. (7) In potato plantations there form richer bug associations due to the longer growing season and immigration from cereal fields after harvest. In rye fields the process is not completed before harvest. (8) Mid-field shelterbelts influence the distribution of the associations of zoophages, zoo-phytophages and phytophages. The attractiveness of the particular crop plants to bugs has a considerable effect on the level of numbers of the associations.

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8. SUMMARY

In the period 1965 – 1968 the author carried out studies of bugs in the Turew region (Leszno voivodship) (Fig. 1), using the sweep-net and biocoenometer methods. He collected material at five stations in rye fields, potato fields and in the herb layer of mid-field shelterbelts.

A total of 76 bug species belonging to 14 families have been found to occur in the study area. The species have been included in three associations (trophic groups) of which zoophages are represented by 12 (Table 3), zoo-phytophages by 16 (Table 5), phytophages by 46 (Table 4) and saprophages by 2 species. An analysis of dominant and shared species has shown that within the whole agricultural landscape each of the three groups: zoophages, zoo-phytophages and phytophages forms only one association. Their species compositions are subject to slight modifications, depending on the station and year. Species fidelity (Tables 3 – 5) and association diversity (Table 6) among stations were analysed.

Individual bug species, and even associations vary considerably in numbers (Table 7). The phenomenon has been described extensively in the relevant literature. Considerable differences seen in the variation of numbers are caused by migration phenomena and a diverse, varying with time, attractiveness of particular agrocoenose segments to bugs. Spring migration from wintering places in the shelterbelt litter into fields has the strongest effect on the level of numbers of the associations. Potato fields are more attractive to bugs than rye fields (Tables 8, 9). Due to this, in potato fields higher numbers and a more complete composition of bug associations are found than in rye fields. Differences found in the course of abundance dynamics concern the beginning of occurrence, end of colonization and abundance peaks. The highest oscillations are recorded for the numbers of zoo-phytophages, the lowest for phytophagous heteropterans. There is a clear effect of shelterbelts on the numbers of particular associations at different distances from the shelterbelts (Tables 10, 11).

9. POLISH SUMMARY

W latach 1965–1968 autor przeprowadził badania pluskwiaków w rejonie Turwi (woj. leszczyńskie) (rys. 1) stosując czerpak ilościowy i biocenometr. Materiał zbierano na pięciu stanowiskach w uprawach żyta, ziemniaków i w runie zadrzewień śródpolnych.

Na badanym obszarze ustalono występowanie 76 gatunków pluskwiaków należących do 14 rodzin. Gatunki te zaliczono do trzech zespołów (grup troficznych), z których zoofagi liczą 12 (tab. 3), zoofitofagi 16 (tab. 5), fitofagi 46 (tab. 4) i saprofagi 2 gatunki. Analiza dominantów i gatunków wspólnych wykazała, że w obrębie całego krajobrazu rolniczego występuje tylko po jednym zespole zoofagów, zoofitofagów i fitofagów. Ich składy gatunkowe ulegają nieznacznym modyfikacjom zależnie od stanowiska i roku. Zbierano wierność (tab. 3–5) gatunków i różnorodność zespołów (tab. 6) na poszczególnych stanowiskach.

Liczebność poszczególnych gatunków, a nawet zespołów pluskwiaków wykazuje znaczną zmienność (tab. 7). Zjawisko to jest obszernie opisane w literaturze przedmiotu. Przyczyny znacznych różnic w przebiegu zmian liczebności mają u podstaw zjawiska migracyjne oraz zróżnicowaną, zmienną w czasie atrakcyjność poszczególnych odcinków agrocenoz dla pluskwiaków. Największy wpływ na kształtowanie się poziomów liczebności poszczególnych zespołów ma migracja wiosenna z zimowisk w ściółce zadrzewień śródpolnych na pola. Większą atrakcyjność dla pluskwiaków mają uprawy ziemniaka niż żyta (tab. 8, 9). Dzięki temu na plantacjach ziemniaczanych mamy do czynienia z wyższymi poziomami liczebności i pełniejszym składem zespołów pluskwiaków niż na uprawach żyta. W przebiegu dynamiki liczebności występują różnice w początku pojawu i końcu zasiedlenia oraz w szczytach liczebności. Najwyższe wahania wykazuje liczebność zoofitofagów, najmniejsze pluskwiaków roślinożernych. Zaznacza się wyraźny wpływ zadrzewień śródpolnych na liczebność poszczególnych zespołów w różnych odległościach od tych zadrzewień (tab. 10, 11).

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