

## Structure and dynamics of aphid communities connected with trees in selected forest associations

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**ABSTRACT.** This study describes the aphid consortia connected with the following seven tree species: *Betula pendula*, *Quercus robur*, *Carpinus betulus*, *Pinus sylvestris*, *Picea abies*, *Alnus glutinosa* and *Sorbus aucuparia*. The species composition, domination structure and dynamics of dominant species on particular trees were depicted. Furthermore, this study identifies changes in the structure of the aphid consortia caused by anthropopressure.

**KEY WORDS:** Hemiptera, Aphidinea, aphid communities.

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### INTRODUCTION

About 40% of world aphids (Hemiptera, Aphidinea) are trophically connected with trees during a part of or throughout their life cycle. Groups of aphid species connected with particular trees form unique communities. Zoocenotic studies involving tree species are rather rare and have been undertaken, among others, by GĘBICKI et al. (1977), KLIMASZEWSKI et al. (1980a, 1980b, 1989), CZYŁOK (1983), and WOJCIECHOWSKI et al. (1991). Most of them focused on areas strongly affected by antropopressure and were concerned with species composition of aphid communities rather than with their domination structure. However, it is on the basis of the domination structure that the condition of the fauna and the extent to which it deviates from the norm can be determined (TROJAN et al. 1982, TROJAN 2000). Research of this kind undertaken on the remains of the former Sandomierz Forest would

enable a thorough examination of the condition of the area. Hence, the aims of this study were as follows:

1. to determine the species composition, structure and dynamics of aphid communities connected with selected trees of the Sandomierz Forest; and
2. to identify changes in the structure of these communities induced by anthropopressure.

### STUDY AREA

The research was conducted in woods which once formed Sandomierz Forest (EA 87). Four forest associations were selected for the analysis: *Quercus roboris-Pinetum*, *Leucobryo-Pinetum*, *Tilio-Carpinetum*, and *Fraxino-Alnetum*. The study focused on trees characteristic of these associations: *Betula pendula*, *Quercus robur*, *Carpinus betulus*, *Pinus sylvestris*, *Picea abies*, *Alnus glutinosa*, and *Sorbus aucuparia*. For each plant association 2-3 localities were selected so as to ensure that the collected material was representative of the type.

### MATERIAL AND METHODS

Material for the study was collected in the years 1999-2001, from the beginning of May through the end of September, by means of shaking and using a scoop. One series involved shaking 10 branches chosen at random (GĘBICKI et al. 1977). Sampling took place at the interval of 14 days. To determine the structure of aphid communities, the domination coefficient (GÓRNY & Grüm 1981) was calculated.

Five domination classes were distinguished:

- I. eudominant species – with the coefficient value of 20.01% and more;
- II. dominant species – with the coefficient of 10.01-20,00%;
- III. subdominant species – with the coefficient of 5.01-10.00%;
- IV. receding species – with the coefficient of 1.01-5.00%;
- V. subreceding species – with the coefficient of 1.00% and less.

$\chi^2$  test was used to evaluate the significance of differences in dominance structure of different type of forests.

### RESULTS

A total of 10 742 specimens of 31 aphid species were collected from the seven tree species. Seven separate aphid communities connected with the tree species were determined. These communities differ from each other in terms of species composition of aphids between various tree species. The results revealed significant differences between the

domination structures of the communities connected with the same tree species in a different type of forest. The domination structure of aphid communities connected with the tree species is presented in Table.

#### **Aphid community connected with the birch (*Betula pendula*)**

The aphid community connected with the birch is composed of 9 species in the mixed coniferous forest and 10 species in the fresh coniferous forest. A total of 4 743 of specimens were collected. Although the species composition of these communities was similar, some vital differences in the domination structure ( $\chi^2=1676.7$ ;  $p<0.001$ ) resulting from a different percentage of particular species appeared. In the mixed coniferous forest the eudominant species were *Betulaphis quadrituberculata* and *Calaphis betulicola*, whereas in the fresh coniferous forest *Symydobius oblongus* and *Calaphis betulicola* were eudominant (Table).

The average dynamics of all dominants on the birch in the mixed coniferous forest is presented in Fig. 1. For *B. quadrituberculata* an average of one peak was noted in the middle of June. For *C. betulicola* an average of two peaks of occurrence were observed, one in the middle of May, the other in the middle of June. The average dynamics of dominants in the *Leucobryo-Pinetum* forest association is presented in Fig. 2. For *S. oblongus* an average of three peaks were noted, one in the middle of June, next at the end of July, and the third at the end of August. Also for *C. betulicola* and *C. calliptera* an average of three peaks were observed – in the middle of May, in the middle of June, and in the middle of September.

#### **Aphid community connected with the oak (*Quercus robur*)**

A total of 2529 specimens were collected from oaks. The aphid community connected with the oak consisted of 6 species in the mixed coniferous forest, 4 species in the dry-ground forest and 4 in the riparian forest. *Tuberculatus annulatus* was the eudominant species in all communities (Table). It was shown that the quality composition of aphids connected with oaks in various forest associations was similar. As regards the domination structure of the community, there was a significant differences between various forest associations ( $\chi^2=170.82$ ;  $p<0.001$ ).

The dynamics of dominant species on oaks in the mixed coniferous forest, dry-ground forest and riparian forest are presented in Figs. 3-5. For *T. annulatus* an average of two peaks were noted, one in the middle of June, and the other in the middle of September. In the dry-ground forest For *T. annulatus* one peak was noted, lasting from the middle of June through the middle of July. Also for *T. annulatus* in *Fraxino-Alnetum* an average of two peaks of occurrence were recorded, one in the middle of June, and the other in August.

#### **Aphid community connected with the hornbeam (*Carpinus betulus*)**

From hornbeams in the dry-ground forest, 455 specimens of *Myzocallis carpini* were collected (Table). An average of two peaks of occurrence were recorded, one at the end of

June, and the other lasting from the middle of September through the end of the research span (Fig. 6).

#### **Aphid community connected with the pine (*Pinus sylvestris*)**

From pines, a total of 1492 aphids of 3 species were collected. *Schizolachnus pineti* and *Eulachnus agilis* were eudominant, while *Cinara pinea* was dominant in this community (Table).

The dynamics of dominants on pines in the *Leucobryo-Pinetum* forest association is presented in Fig. 7. For *S. pineti* an average of four peaks were noted – in the middle of May, in the middle of June, in the middle of August, and in the middle of September. For *E. agilis* an average of two peaks were recorded, one in the middle of May, and the other in the middle of July, from which point the number of representatives of this species remained stable till the end of the research.

#### **Aphid community connected with the spruce (*Picea abies*)**

From spruces in the *Fraxino-Alnetum* (riparian forest), a total of 435 aphids of 5 species were collected. *Elatobium abietinum* and *Sacchiphantes abietis* were eudominant, and *Cinara costata* and *Cinara pilicornis* were dominant in this community (Table).

For *E. abietinum* an average of one peak was noted, lasting from the end of August through the middle of September. For *S. abietis* an average of two peaks were recorded, the first one more clearly marked at the end of May, and the other at the end of July (Fig. 8).

#### **Aphid community connected with the alder (*Alnus glutinosa*)**

From alders in the *Fraxino-Alnetum*, 419 aphids of 4 species were collected. *Pterocalis alni* was the eudominant species and *Pterocallis maculata* was dominant. (Table).

The average dynamics of dominants on the alder is presented in Fig. 9. For *P. alni* an average of one peak of occurrence was noted at the end of June; from this point the number of representatives of this species gradually fell until the end of the research. Similarly, for *P. maculata* one peak was recorded at the end of June.

#### **Aphid community connected with the rowan (*Sorbus aucuparia*)**

From the rowan in the *Quercu roboris-Pinetum* association 666 specimens were collected. *Aphis pomi* was the eudominant species (Table). An average of two peaks of occurrence were noted for this species, one from the end of May through the end of June, and the other in the middle of September (Fig. 10).

**Table.** The average domination values (D) for aphid species collected from trees.

tree species	forest association	aphid species	D-value (%)	domination class (D)	number of species
-1-	-2-	-3-	-4-	-5-	-6-
<i>Betula pendula</i>	<i>Quercus roboris</i> - <i>Pinetum</i>	<i>Betulaphis quadrituberculata</i>	42.7	E	9
		<i>Calaphis betulicola</i>	25.6		
		<i>Callipterinella callipterae</i>	11.2	D	
		<i>Euceraphis betulae</i>	11		
		<i>Monaphis antennata</i>	5.08	S	
		<i>Calaphis flava</i>	1.79	R	
		<i>Callipterinella tuberculata</i>	1.44		
		<i>Symydobius oblongus</i>	1		
		<i>Hormaphis betulae</i>	0.27	SR	
	<i>Leucobryo</i> - <i>Pinetum</i>	<i>Symydobius oblongus</i>	35	E	10
		<i>Calaphis betulicola</i>	20.6	D	
		<i>Euceraphis betulae</i>	10.3		
		<i>Callipterinella callipterae</i>	9.66	S	
		<i>Monaphis antennata</i>	8.32		
		<i>Callipterinella tuberculata</i>	8.28		
		<i>Betulaphis quadrituberculata</i>	4.88	R	
		<i>Calaphis flava</i>	1.74		
		<i>Hormaphis betulae</i>	0.6	SR	
	<i>Glyphina betulae</i>	0.56			
<i>Quercus robur</i>	<i>Quercus roboris</i> - <i>Pinetum</i>	<i>Tuberculatus annulatus</i>	80.9	E	6
		<i>Tuberculatus querceus</i>	8.79	S	
		<i>Thelexes dryophila</i>	7.6		
		<i>Myzocallis castanicola</i>	2.29	R	
		<i>Lachnus roboris</i>	0.4	SR	
		<i>Tuberculatus neglectus</i>	0.12		
	<i>Tilio</i> - <i>Carpinetum</i>	<i>Tuberculatus annulatus</i>	75.3	E	4
		<i>Thelexes dryophila</i>	19.4	D	
		<i>Myzocallis castanicola</i>	3.28	R	
		<i>Tuberculatus querceus</i>	2.27		
	<i>Fraxino</i> - <i>Alnetum</i>	<i>Tuberculatus annulatus</i>	82.5	E	4
		<i>Thelexes dryophila</i>	10	D	
		<i>Myzocallis castanicola</i>	5.09	S	
<i>Tuberculatus querceus</i>		2.36	R		

-1-	-2-	-3-	-4-	-5-	-6-
<i>Carpinus betulus</i>	Tilio-Carpinetum	<i>Myzocallis carpini</i>	100	E	1
<i>Pinus sylvestris</i>	Leucobryo-Pinetum	<i>Schizolachnus pineti</i>	54.9	E	3
		<i>Eulachnus agilis</i>	34		
		<i>Cinara pinea</i>	11.1	D	
<i>Picea abies</i>	Fraxino-Alnetum	<i>Elatobium abietinum</i>	40.3	E	5
		<i>Sacchiphantes abietis</i>	33.4		
		<i>Cinara costata</i>	12.3	D	
		<i>Cinara pilicornis</i>	11.4		
		<i>Cinara pruinosa</i>	2.56	R	
<i>Alnus glutinosa</i>	Fraxino-Alnetum	<i>Pterocallis alni</i>	88.2	E	4
		<i>Pterocallis maculata</i>	10.9	D	
		<i>Clethrobius comes</i>	0.53	SR	
		<i>Pterocallis albida</i>	0.36		
<i>Sorbus aucuparia</i>	Quercu-roboris-Pinetum	<i>Aphis pomi</i>	81.4	E	2
		<i>Dysaphis sorbi</i>	18.6	D	

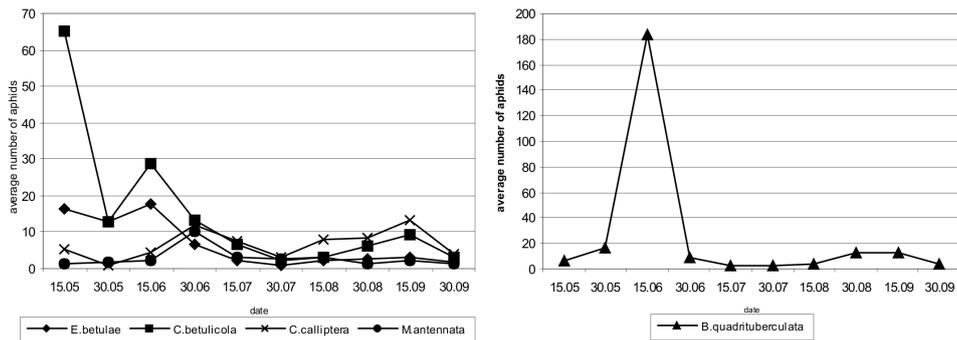
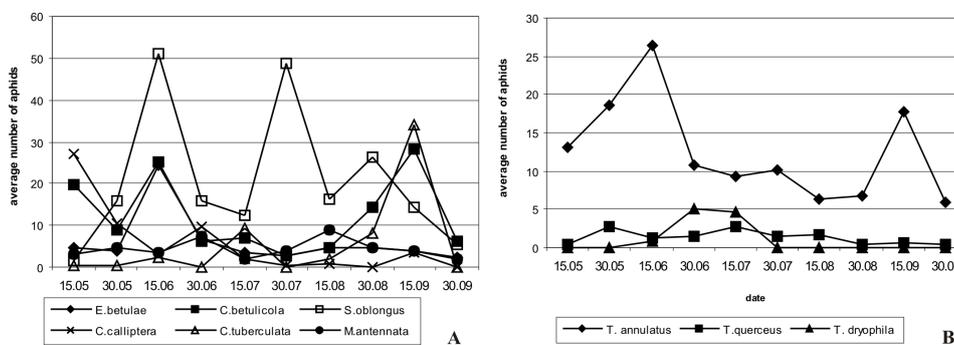
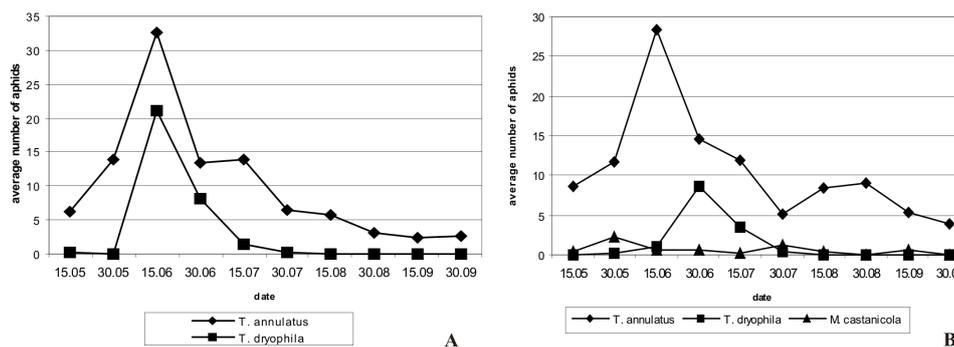


Fig. 1. The average dynamics of dominants on the birch in *Quercu-roboris-Pinetum*.



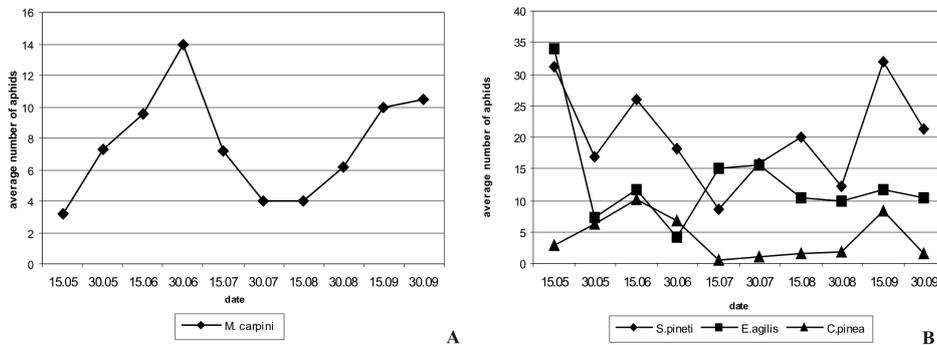
**Figs 2-3.** A – The average dynamics of dominants on the birch in *Leucobryo-Pinetum*; B – The average dynamics of dominants on the oak in *Quercus roboris-Pinetum*.



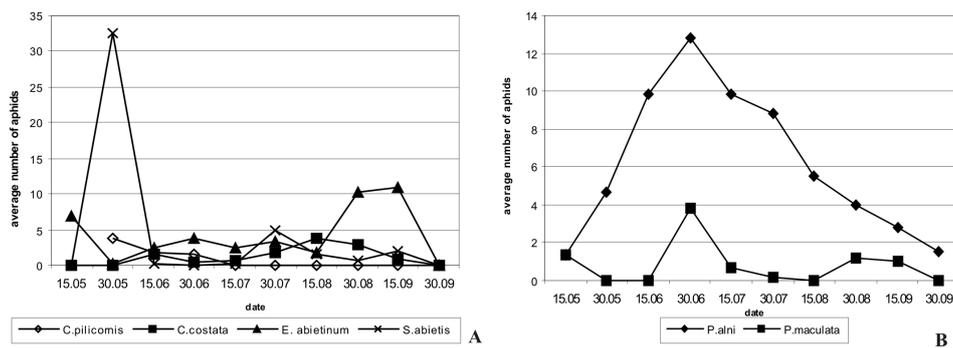
**Figs 4-5.** A – The average dynamics of dominants on the oak in *Tilio-Carpinetum*; B – The average dynamics of dominants on the oak in *Fraxino-Alnetum*.

## DISCUSSION AND CONCLUSIONS

The differences in aphid communities connected with the seven tree species were shown in the conducted research. This bears out the results of the research on arthropod communities in the mixed coniferous forest, which show the strongest relationship between insects and the tree species (SCHOWALTER & GANIO 1998, SCHOWALTER & ZHANG 2005). Insect communities, however, did not differ significantly between the levels of the tree canopy (SCHOWALTER & GANIO 1998). The two



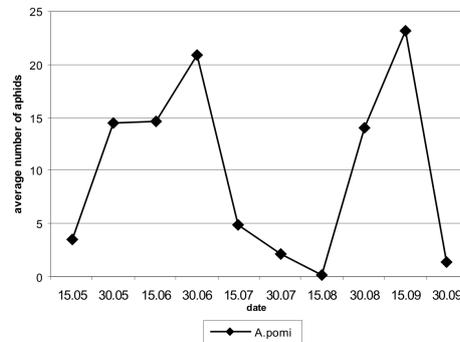
**Figs 6-7.** A – The average dynamics of *Myzocallis carpini* on the hornbeam in *Tilio-Carpinetum*; B – The average dynamics of dominants on the pine in *Leucobryo-Pinetum*.



**Figs 8-9.** A – The average dynamics of dominants on the spruce in *Fraxino-Alnetum*; B – The average dynamics of dominants on the alder in *Fraxino-Alnetum*.

aphid communities (those connected with the birch and oak), showed the difference in the domination structure in terms of forest association. Aphid communities connected with the **birch** in the mixed and fresh coniferous forests were similar in terms of species composition, but their domination structures differed slightly.

The domination structure developed on birches in the mixed coniferous forest was different than the one found in the areas strongly affected by anthropopressure, in which *E. betulae* was the dominant species (GĘBICKI et al. 1977, KLIMASZEWSKI et al. 1980a, (OLSCHOVY 1976, CHARLES & VILLEMANT 1977, VILLEMANT 1981, KLIMASZEWSKI et al. 1980a, 1980b, 1989, CZYŁOK 1983, WOJCIECHOWSKI et al. 1991, HAŁAJ & WOJCIECHOWSKI 1997).



**Fig. 10.** The average dynamics of *Aphis pomi* on the rowan in *Quercus robor*-*Pinetum*.

The five-point scale of environmental distortion (KLIMASZEWSKI et al. 1989) has made it possible to correlate the condition of the environment with the presence of particular aphid species. Thus, huge domination of *Euceraaphis* sp. indicates a considerable distortion of the natural habitat. This correspondence has also been confirmed by research conducted in the area of the Moravian Gate, which forms a channel for pollution from two industrial districts, Polish and Czech (WEĞIEREK & DURAK 2000). The species composition and domination structure of the aphid community on birches in Sandomierz Forest are indicative of a very small degree of environmental distortion (1 class on a five-point scale). The fact that *E. betulae* was absent from the group of dominant species means that the structure of this community was unaffected by anthropopressure. At the same time, the high percentage of *B. quadrituberculata* was probably related with climatic conditions, especially with temperature and humidity.

A very similar structure of an aphid community on birches, with *Betulaphis brevipilosa* among the dominants, has been described by HAJEK and DAHLSTEN (1988) on the basis of research conducted in northern California. The authors demonstrate that the main factor that influences aphid populations on birches is the maximum summer temperature. Thus, the size of summer populations of *B. brevipilosa* increases if the average temperature of May through September does not exceed 20°C in a locality of a relatively high air humidity connected with the activity of gulf streams. This species has not been found in temperatures above 29°C. Conducive temperatures at the time of the research and high humidity in the study area created suitable conditions for an aphid community which bore a close resemblance to that described from California. Also the dynamics of the species proved highly similar. *Betulaphis* sp. feeds on mature leaves of birches throughout the growing season, and changes in the condition of the host plant (from young to aging leaves) do not affect its occurrence (HAJEK & DAHLSTEN 1986a, 1988). Feeding on mature tree leaves is less common among aphids, as most species feed on young leaves and shoots (DIXON 1998), which is why they adapt to changing the host or estivate. *E. betulae* belongs to the species whose

dynamics depends on the presence of young leaves in spring and aging leaves in autumn. *B. quadrituberculata* occurs in large numbers in spring, but its dynamics falls in summer. In California, another peak of occurrence was noted for the population of *Betulaphis* sp. in August and September if the maximum temperature was not higher than 20°C (HAJEK & DAHLSTEN 1988). The domination structure developed on birches in the fresh coniferous forest suggests a very small degree of distortion. A relatively small percentage of *Eucraphis* sp. in the community of the fresh coniferous forest and a large number of species collected on birches in the study area qualify this community as little distorted (1 class).

A unique domination structure of this community and a smaller contribution of *B. quadrituberculata* compared with the results obtained for the mixed coniferous forest may be related to the lower humidity and shading of the area. It has been established that large populations of aphids are more likely to develop on shaded trees (Hajek & Dahlsten 1986b). This is connected with the fact that shaded tree tops provide cooler and more humid habitats, which offer optimum conditions for aphids. In the fresh coniferous forest, birches suffer greater sun exposure, which results in changes in the structure of aphid communities. The percentage of *B. quadrituberculata* was found to be smaller, while the contribution of *S. oblongus* increased. Aphids manifest a number of behavioural and physiological adaptations which help them avoid heat, e.g. they feed in groups on shaded leaves, produce melanin in spring and autumn, and develop non-pigmented forms, which are slower to absorb heat and which remain cooler. The avoidance of heat may also partly explain the variety of aphid species and their distribution on birches depending on the amount of shade (HAJEK & DAHLSTEN 1986b). Thus, *S. oblongus* is trophically connected with branches of birches, which provide better temperature and humidity conditions than leaves.

The aphid community connected with the **oak** comprised six species in the mixed coniferous forest and four species in the dry-ground forest and in the riparian forest. The percentage of the eudominant species helps to monitor the direction of changes in aphid communities, since, as other authors have pointed out, a rise in the number of aphids and in the proportion of the eudominants is the first symptom of degradation (KLIMASZEWSKI et al. 1989, RYCHLIK 1979, WOJCIECHOWSKI et al. 1991). An analysis of the results shows that the aphid community connected with the riparian forest is most distorted, as indicated by the small number of aphid species in the community and the highest value of the domination coefficient calculated for the eudominant. By contrast, the community connected with the mixed coniferous forest proved least distorted. With regard to the communities comprising the same number of aphid species (the dry-ground forest and riparian forest), it is probably the value of the domination coefficient that indicates the advancement of regeneration processes under way. These processes are more advanced in the communities where the coefficient value is lower; in the communities where the domination coefficient calculated for the eudominant is high, regeneration processes have been disrupted. The dynamics of the dominant species on oaks was similar in various growing seasons and differed slightly in particular plant associations.

From the **hornbeam**, *M. carpini* was collected. The dynamics of this species was very similar both in different growing seasons and in various localities. Two peaks were noted, one in spring and the other in autumn, which is connected with the biology of the species. This aphid has also been described from the community connected with the dry-ground forest in the Lublin Upland (BOCHEN 1989) and is treated as one of the species connected with this plant association.

The domination structure on **pin**s was very similar to that of aphid communities connected with the fresh coniferous forest in the Czestochowa Upland (HAŁAJ & WOJCIECHOWSKI 1997), the Little Poland Upland (CZYŁOK 1983) and the Pomerania (PŁACHTA et al. 1996). The domination patterns in aphid communities on pines serve as bioindicators of their condition (KLIMASZEWSKI et al. 1980a, b), and a considerable proportion of *E. agilis* is symptomatic of a distortion of the habitat. The domination structure observed in the study area, with *S. pineti* as the dominant species, may suggest a relatively small degree of environmental degradation. However, compared to natural environments and areas unaffected by anthropopressure, e.g. Białowieża Forest, the White Forest and Tuchola Forest, where aphid communities comprising as many as seven aphid species have been recorded on pines (WINIARSKA & CHOLEWICKA 1990), a reduction of the tail area of the distributional diagram was noted. Research into the seasonal dynamics of entomofauna of the crowns of pines in the fresh coniferous forest in Białowieża Forest and the White Forest (CHUDZICKA 1990) has shown two peaks in the group of Aphidodea, one in early spring and the other beginning in June. It was probably due to heavy rains in June and July, especially in the year 2000, that the dynamics of aphids on pines in the study area was modified, as shown by the fall in the number of insects at this time.

Species composition and the proportion of particular species show that a unique aphid community developed on the **spruce** in the riparian forest. This community differs slightly from those on spruces in their typical plant association of the *Vaccinio-Pinetum* alliance. In spruce forests, aphids can form communities which comprise seven species, with *Cinara pilicornis* and *Cinara costata* as eudominants (KLIMASZEWSKI et al. 1980a). In spruce forests affected by anthropopressure, a reduction of the tail area of the distributional diagram is observed, as well as a rise in the proportion of one of the eudominants (*C. pilicornis*). In the aphid community connected with the riparian forest, species characteristic of spruce forests were found, but their proportion was smaller (dominants). The position of eudominants was taken by other species. Degradation of the habitat results in a fall in the number of aphid species, a decrease in the size of the population and an accidental character of the community (GĘBICKI et al. 1977). In their typical plant association, spruces are inhabited by a characteristic aphid community of a well-defined structure. In other plant associations, spruces are home to a different aphid community, whose structure may be modified in unfavourable conditions, which results in a totally accidental character of the grouping marked by the presence of species trophically unconnected with spruces. The dynamics of dominants on spruces was similar in different growing seasons and was related to the biology of particular aphid species.

The domination structure of species connected with the **alder** indicates that this aphid community was rather well developed. Its species composition was close to that of the aphid community connected with alders in the alder carr described by HAŁAJ and WOJCIECHOWSKI (1997). The existing differences in the proportion of individual species resulted from more advanced synanthropisation of this community, as shown by a higher value of the domination coefficient for *P. alni*. The aphid community described from alders in the vicinity of the Katowice steelworks (GĘBICKI et al. 1977) may serve as an example of an extremely distorted grouping. This community comprised three species, only one of which (*P. alni*) was trophically connected with the alder and acted as the eudominant. The other species (*E. punctipennis*, *A. corni*), the dominant and the subdominant, were present in this community coincidentally. A totally destroyed structure, manifest in the accidental character of this community, is a result of anthropopressure.

The dynamics of dominant species in different growing seasons and in particular localities of the study area was similar and closely resembled that observed in the Czestochowa Upland.

From the **rowan** in the mixed coniferous forest, only two aphid species were collected. The domination structure of this community was similar to that of the community described from the vicinity of the Katowice steelworks (GĘBICKI et al. 1977, KLIMASZEWSKI et al. 1980a). Species composition was typical of the habitat, while the small number of species found on this tree indicated progressing synanthropisation of the community. Species composition of aphid communities on the rowan in other plant associations than coniferous forests is accidental, and their size is small (GĘBICKI et al. 1977).

The research has shown that seven tree species are inhabited by characteristic aphid communities. Species composition and the domination structure of such communities may be affected by distorted habitats. As a result, species composition is impoverished and the proportion of individual species in a community is modified. Because of the correlation between the condition of the habitat and the structure and composition of aphid communities, the latter can be used in monitoring the condition of trees.

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