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PRODUCTIVITY INVESTIGATION OF TWO TYPES OF MEADOWS IN THE VISTULA VALLEY

VI. PRODUCTION AND POPULATION DENSITY OF LEAFHOPPER (*HOMOPTERA-AUCHENORRHYNCHA*) COMMUNITIES

(Ekol. Pol. 19: 151–172). A comparison of leafhopper (*Homoptera-Auchenorrhyncha*) communities in two meadows differing in the degree of their diversification showed that the more diversified habitat was richer in species, and the number of individuals in it was doubled. However, as a result of the strong pression of the predators (numerous in all layers of the diversified habitat) the average life span of the leafhoppers was several times shorter, ınd their population density was less than a half of that in the meadow with simpler trophic relationship.

1. INTRODUCTION

The leafhoppers (*Homoptera-Auchenorrhyncha*) present in a meadow form an ecologically uniform group of herbivorous insects. They all feed on plant sap and the biology of the different leafhopper species, occuring in the meadows under study, is very similar. In meadow habitats, leafhoppers constitute an important component of the meadow fauna, and especially of the herbivorous fauna, closely associated with and directly affecting the primary production of the meadow.

The investigation described in this paper was carried out during the years 1966 to 1968. Its aim was to compare and analyse: 1) the leafhopper communities, 2) the production and population density of leafhoppers, 3) the causes, and the rate of elimination of leafhoppers from a meadow.

The study area consisted of two meadows located above ten kilometres apart. One of these is a cultivated meadow in which the association *Arrenatheretum* occurs, and the other is a nature reserve meadow with the association *Stellario-Deschampsietum*. A detailed botanical description of the meadows concerned can be found in the papers by Traczyk (1966, 1971), and the soil characteristics in Czerwiński's study (1971).

The meadow designated by KII is a typically fertile meadow, cultivated, sown, and harvested twice during the growing season. Over 90% of the plant crop is taken by man (Traczyk 1971).

Up to 1965, the nature reserve meadow (SM) was mown once a year, and grazed sporadically. This extensive utilization was a protection against the invasion of shrubs and trees from the adjacent areas. The presence if intact deposits of litter, the natural plant communities, characteristic of these habitats and the low utilization of the meadow, that had not been changed for many years, permitted for a relatively stable plant species composition to be maintained. In 1965 the meadow was included into the nature reserve area under strict conservancy law, and its utilization was stopped entirely. In consequence, the whole plant crop produced remains in the meadow, where it forms a thick layer of dead matter persisting till the next growing season. Each the habitats, with so many fundamental differences between them, naturally has a different fauna of predators (Kajak, Breymeyer, Pętal 1971, Pętal, et al. 1971), *Diptera* (Olechowicz 1971), and saprophages (Nowak 1971).

2. METHODS

To estimate the population density and species composition of the leafhoppers in the meadow, samples were collected by means of a biocenometer, at several days' intervals, from early spring (end of April) until October. A series of samples consisted of 10 samples collected from random selected areas in the meadow, and covered with a biocenometer (of the size 0.8 by 0.8 m). The insects captured in the biocenometer were taken out of it with a sucking apparatus.

The biocenometer samples so collected provided a recording of the standing crop (N) of leafhoppers on different days during the growing season. For the calculation of the average density for the season ($\bar{N}$) the "weighed average" method suggested by Petrusewicz and Macfadyen (1970) was used.

In this method, the calculation of $\bar{N}$ is not affected by the irregularities of the intervals between the successive samples. The area beneath the curve of variations in abundance represented by the number of individual-days ($\bar{N}T$), has been divided by the number of days (T) between the first and the last catches $\left(\frac{\bar{N}T}{T} - \bar{N}\right)$. In the same way the average leafhopper density for the four periods ($\bar{N}_{I}$, $\bar{N}_{II}$, $\bar{N}_{III}$, $\bar{N}_{IV}$) corresponding to four periods of intenser hatching of larvae during the growing season was calculated.

Simultaneously with the recording of the density of the leafhoppers all insects hatching and appearing in the litter, and chiefly in the grass layer, were captured and collected from under the "permanent" biocenometers (Olechowicz 1970). At the end of April in each meadow 15 biocenometers were placed, from under which insects were collected every several days by means of a sucking apparatus. Every 4 weeks the biocenometers were translocated to new areas and set up in places from which all the insects present had been collected. Continuous collecting of insects considerably reduces the number of eggs laid, thus affecting the abundance of the next generations. Due to the repeated translocating of the biocenometers it was possible to estimate the real number of insects hatched in the meadows throughout the season.

The samples taken out from under the "permanent" biocenometers mainly included adult forms and the final larval stages of the leafhoppers. From these samples the number of insects emerged during the several days' periods between the succesive catches was estimated. By adding the values together an aggregate quantity is obtained, this being the measure of the production of the leafhoppers (adults) during the season, expressed as the number of individuals per 1 m^2 of the meadow. In their studies Petrusewicz (1966), Petrusewicz and Macfadyen (1970) define this quantity as the "number of discrete individuals" – ν occuring in the community during study time T, as calculated per unit area.

The youngest larval stages, almost exclusively remaining in the deeper layers of the litter, were not represented in the samples. Therefore the records did not cover number of the hatching eggs and the youngest larval stages very intensely reduced by the predators living in the litter (Pętal, et al. 1971). The number of larvae hatched was determined from the number and fecundity of the females that occurred in the meadows during the previous summer (1967). The average number of eggs for each species was estimated by dissecting the females. As the eggs mature successively and are laid in portions, the estimates of the average fecundity, based on the number of eggs found in the females, are no doubt lower than the real fecundity. The average fecundity, being the smallest possible number of eggs that the leafhopper females present in the meadow could have laid, was adopted in the calculations that followed. The

Percentages of individual species in the community of leafhoppers hatching and occurring in the natural meadow SM

Tab. I

Percentage class	Species hatching in the meadow (v)	% of abundance	% of biomass	Species occurring in the meadow ($\overline{N}$)	% of abundance	% of biomass
1	2	3	4	5	6	7
Above 10%	1. *Calligypona pellucida* (Fabr.)	18.2	8.3	1. *Macrosteles laevis* (Rib.)	21.7	7.6
	2. *Arthaldeus pascuellus* (Fall.)	14.7	7.9	2. *Delphacodes venosus* (Germ.)	14.8	2.85
	3. *Delphacodes venosus* (Germ.)	12.9	5.7	3. *Arthaldeus pascuellus* (Fall.)	11.5	5.4
3–10%	4. *Calligypona straminea* (Stol.)	7.3	3.5	4. *Dicraneura citrinella* (Zett.)	8.5	1.9
	5. *C. spinosa* (Boh.)	7.0	3.4	5. *Sorhaonus assimilis* (Fall.)	4.3	4.2
	6. *Lepyronia coleopterata* (L.)	4.4	29.6	6. *Philenus spumarius* (L.)	3.7	18.8
	7. *Arthaldeus strüfrons* (Kbm.)	4.3	2.9	7. *Lepyronia coleopterata* (L.)	2.6	23.9
	8. *Neophilenus lineatus* (L.)	3.2	8.3	8. *Neophilenus lineatus* (L.)	3.4	5.2
				9. *Psammotettix alienus* (Dhlbm.)	3.2	1.6
				10. *Cicadula quadrinotata* (F.)	3.0	1.6
1–3%	9. *Sorhoanus assimilis* (Fall.)	2.9	2.0	11. *Mocydiopsis parvicauda* (Rib.)	2.5	2.0
	10. *Kellysia pallidula* (Boh.)	2.8	1.2	12. *Kellysia pallidula* (Boh.)	2.3	0.9
	11. *Macrosteles laevis* (Rib.)	2.5	0.8	13. *Calligypona pellucida* (Fabr.)	2.3	0.9
	12. *Cicadula quadrinotata* (F.)	2.4	1.6	14. *Athysanus argentarius* Metc.	1.7	4.9
	13. *Dicraneura citrinella* (Zett.)	2.4	0.5	15. *Arthaldeus strüfrons* (Kbm.)	1.7	0.8
	14. *Euscelis obsoletus* (Kbm.)	2.1	2.6	16. *Euscelis obsoletus* (Kbm.)	1.5	1.4
	15. *Athysanus quadrum* (Boh.)	2.0	6.2	17. *Athysanus quadrum* (Boh.)	1.3	3.6
	16. *Philenus spumarius* (L.)	1.8	6.0	18. *Calligypona straminea* (Stol.)	1.15	0.5
	17. *Agalia brachyptera* (Boh.)	1.5	0.5	19. *Macrosteles 6–notatus* (Fall.)	1.15	0.3
	18. *Calligypona albostriata* (Fieb.)	1.1	0.5	20. *Cicadella viridis* (L.)	1.1	3.7
				21. *Strongylocephalus agrestis* (Fall.)	1.0	3.2
				22. *Calligypona spinosa* (Boh.)	1.0	0.4

	19. *Kellysia ribauti* Wagner	0.9	0.3	23. *Eupteryx atropunctata* (Goeze.)	0.9	0.9
	20. *Megamelus notula* (Germ.)	0.9	0.3	24. *Calligypona marginata* (Macr.)	0.65	0.2
	21. *Strongylocephalus agrestis* (Fall.)	0.9	0.3	25. *Kellysia ribauti* Wagner	0.6	0.2
	22. *Mocydiopsis parvicauda* (Rib.)	0.8	0.7	26. *Megamelus notula* (Germ.)	0.6	0.3
	23. *Athysanus argentarius* Mect.	0.6	3.7	27. *Rhopalopyx preyssleri* (H.–S.)	0.5	0.4
	24. *Doratura stylata* (Boh.)	0.5	0.2	28. *Kellysia vittipennis* (Schlb.)	0.45	1.3
	25. *Cicadella viridis* (L.)	0.3	1.3	29. *Doratura stylata* (Boh.)	0.4	0.4
	26. *Hardya tenuis* (Germ.)	0.2	0.15	30. *Emposca flavescens* (F.)	0.4	0.4
	27. *Calligypona* sp.	0.2	0.1	31. *Notus flavipennis* (Zett.)	0.3	0.3
	28. *Notus flavipennis* (Zett.)	0.2	0.05	32. *Agallia brachyptera* (Boh.)	0.2	0.1
	29. *Aphrodes bicinctus* (Schrk.)	0.2	1.1	33. *Conomelus limbatus*	0.2	0.2
Below	30. *Rhopalopyx preyssleri* (H.–S.)	0.15	0.7	34. *Calligypona albostriata* (Fieb.)	0.1	0.05
1%	31. *Eupteryx atropunctata* (Goeze.)	0.12		35. *Agallia venosa* (Fall.)	0.1	0.1
	32. *Aphrodes trifasciatus* (Geoffr.)	0.2		36. *Limmotettix striola* (Fall.)	0.1	0.1
	33. *Kellysia vittipennis* (Schlb.)	0.1	0.02	37. *Cicadula flori* (Fieb.)	0.1	0.1
	34. *Psammostettix alienus* (Dhlbm.)	0.1		38. *C. saturata* (Edw.)	0.1	0.1
	35. *Macrosteles 6-notatus* (Fall.)	0.06	0.03	39. *Balclutha punctata* (Thnb.)	0.1	0.1
	36. *Empoasca flavescens* (F.)	0.05	0.02	40. *Hardya tennuis* (Germ.)	0.1	0.1
	37. *Balclutha punctata* (Thnb.)	0.05	0.03	41. *Metalimnus formosus* (Boh.)	0.1	0.1
	38. *Agallia venosa* (Fall.)	0.05				
	39. *Metalimnus formosus* (Boh.)	0.02	0.01			
	40. *Calligypona marginata* (Macr.)	0.02				
	41. *Conomelus limbatus*	0.01	0.01			

Percentages of individual species in the community of leafhoppers hatching and occurring in the cultivated meadow K II

Tab. II

Percentage class	Species hatching in the meadow (ν)	% of abundance	% of biomass	Species occurring in the meadow ($\overline{N}$)	% of abundance	% of biomass
Above 10%	1. *Arthaldeus pascuellus* (Fall.)	36.5	24.6	1. *Arthaldeus pascuellus* (Fall.)	24.55	11.1
	2. *Calligypona pellucida* (Fabr.)	14.3	9.4	2. *Macrosteles laevis* (Rib.)	23.58	10.8
	3. *Streptanus sordidus* (Zett.)	11.0	15.2	3. *Calligypona pellucida* (Fabr.)	13.8	8.0
	4. *Macrosteles laevis* (Rib.)	10.7	4.6	4. *Cicadella viridis* (L.)	10.3	43.0
3–10%	5. *Cicadella viridis* (L.)	6.6	30.4	5. *Dicraneura citrinella* (Zett.)	9.6	2.5
	6. *Calligypona albostriata* (Fieb.)	5.7	3.2	6. *Streptanus sordidus* (Żett.)	5.9	8.8
	7. *C. straminea* (Stol.)	5.7	3.2	7. *Cicadula quadrinotata* (F.)	3.0	2.5
	8. *C. spinosa* (Boh.)	3.4	2.0			
1–3%	9. *Dicraneura citrinella* (Zett.)	1.7	0.4	8. *Calligypona straminea* (Stal.)	2.8	1.6
	10. *Elymana sulphurella* (Zett.)	1.1	0.4	9. *Psammotettix alienus* (Dhlbm.)	1.3	0.8
	11. *Megamelus notula* (Germ.)	0.6	0.4	10. *Philenus spumarius* (L.)	0.9	4.95
	12. *Philenus spumarius* (L.)	0.7	2.9	11. *Calligypona albostriata* (Fieb.)	0.8	0.5
	13. *Arthaldeus strifrons* (Kbm.)	0.3	0.2	12. *Elymana sulphurella* (Zett.)	0.8	1.0

	14. *Deltocephalus pulicaris* (Fall.)	0.3	0.2	13. *Calligypona spinosa* (Boh.)	0.6	0.3
	15. *Cicadula quadrinotata* (F.)	0.5	0.5	14. *Deltocephalus pulicaris* (Fall.)	0.55	0.2
	16. *Psammotettix alienus* (Dhlbm.)	0.3	0.2	15. *Arthaldeus striifrons* (Kbm.)	0.3	0.2
	17. *Aphrodes fuscofasciatus* (Goeze.)	0.2	1.2	16. *Megamelus notula* (Germ.)	0.2	0.02
	18. *Calligypona marginata* (Macr.)	0.1	0.06	17. *Aphrodes bicinctus* (Schrk.)	0.2	1.3
	19. *Aphrodes bicinctus* (Schrk.)	0.05	0.3	18. *Euscelis obsoletus* (Kbm.)	0.15	1.6
	20. *Agalia brachyptera* (Boh.)	0.05	0.03	19. *Conomelus limbatus*	0.15	0.2
Below 1%	21. *Errastunus ocellaris* (Fall.)	0.05	0.04	20. *Empoasca viridis*	0.1	0.1
	22. *Agalia venosa* (Fall.)	0.05	0.03	21. *Eupteryx atropunctata* (Goeze.)	0.1	0.15
				22. *Neophilenus lineatus* (L.)	0.08	0.3
				23. *Athysanus argentarius* (Mtc.)	0.05	0.2
				24. *Rhopalopyx preyssleri* (H.–S.)	0.03	0.05
				25. *Agalia brachyptera* (Boh.)	0.03	0.02
				26. *Calligypona marginata* (Macr.)	0.03	0,02
				27. *Balclutha punctata* (Thnb.)	0.03	0.05
				28. *Strongylocephalus agrestis* (Fall.)	0.03	0.15
				29. *Psammotettix confinis* (Dhlbm.)	0.03	0.05
				30. *Calligypona marginata*	0.03	0.05
				31. *Calligypona* sp.	0.03	0.02
				32. *Errastunus ocellaris* (Fall.)	0.03	0.05

adult leafhoppers (ν d) caught by the "permanent" biocenometers represent 33% of the larvae hatched in the meadow KII, and 24% in the SM meadow.

3. RESULTS

3.1. Species composition of leafhopper communities

The majority of the leafhopper species occurring in the meadows, can feed on the sap of various plants, hence the same species may be found in different meadow communities. However, the structure of each layers of vegetation, their species composition, and whole complex of environmental factors create specific conditions determining the occurrence of particular species leafhoppers.

In the nature reserve meadow SM, with its well-developed litter layer, the group represented by a large number of species comprises the litter species, that is species which remain in this layer throughout their life, or for the greater part of their life (*Delphacodes venosus, Kelysia vittipennis, K. pallidula, Athysanus quadrum*). The most numerous in the grass layer (in 1968) were: *Macrosteles laevis, Calligypona pellucida* and *Arthaldeus pascuellus*. Species which as a rule are numerous in plant communities of this type (*Lepyronia coleopterata, Philenus spumarius, Neophilenus lineatus, Cicadella viridis, Arthaldeus pascuellus*) appeared not to be numerous, except *A. pascuellus*, in this meadow but were represented by a larger amount of biomass (Tab. I).

In the KII meadow, virtually without any litter, the litter species were found to be missing. Numerous in the grass layer were species associated with cropfields, that is habitats which are frequently damaged by cultivation (*Calligypona pellucida, Macrosteles laevis, Streptanus sordidus, Arthaldeus pascuellus*) (Tab. II).

The number of leafhopper species hatching in the nature reserve meadow SM appeared to be almost twice as large as the number of species hatching in the cultivated meadow KII (41 and 22 species respectively). The basic differences found between these two meadows were differences in the number of those species which constitute small percentages in the community. In the class 1–3% and less than 1%, 33 species were found to hatch in the SM meadow, and only 14 species in the KII meadow (Tab. III).

In the KII meadow, the number of species occurring during the growing season is larger by 10, in comparison with the number of species hatching there. Those leafhoppers hatched outside the meadow concerned, and they got there during their migratory flights. This group consists entirely of species of low abundance (in the percentage class below 1% – Tab. III).

It may be presumed that also in the groups including those species which hatch in the meadow there occur migrations between surrounding habitats. Young

Number and percentages of leafhoppers hatching and occurring in the natural and cultivated meadows

Tab. III

Percentage classes in relation to the community		Adult leafhoppers emerging on 1 m² of the meadow during the growing season (ν d)				Mean (for the season) density of adult leafhoppers ($\bar{N}$)			
		number of species	percentages of species	abundance according to classes	% abundance according to classes	number of species	percentage of species	average density	% average density
Natural meadow SM	above 10%	3	7.3	214	45.8	3	7.3	6.3	47.00
	3–10%	5	12.2	122	26.2	7	17.1	3.8	28.75
	1–3%	10	24.4	100	21.5	12	29.3	2.5	18.80
	below 1%	23	56.1	31	6.7	19	46.3	0.8	6.00
	total	41		467		41		13.4	
Cultivated meadow K II	above 10%	4	18.2	268	72.5	4	12.5	21.7	72.20
	3–10%	4	18.2	79	21.4	3	9.4	5.5	18.50
	1–3%	2	9.1	10	2.8	2	6.2	1.2	4.10
	below 1%	12	54.5	12	3.3	23	71.9	1.5	5.20
	total	22		370		32		29.9	

adult forms, of nearly all the leafhopper species, showed a tendency to migratory flights, and were found in light traps set up far from the hatching grounds of these insects. However, as indicated by earlier investigations (Andrzejewska 1962), the rate of migration varies with the species. Also the direction of migration appears not to be accidental, but dependent on the type of habitat Cropfields and man-changed natural habitats are quickly infested by leafhopper species some of which have their hatching grounds in distant areas (Andrzejewska 1962). Mass migrations do not occur in habitats undergoing slow natural changes.

In the reserve meadow SM the number of species occurring is the same as the number of species hatching there (41) (Tab. I and III). There are only some slight shifts in the dominance structure of the leafhoppers. The fact that as many species occur in the meadow as there are hatched (except for two species – *Calligypona pellucida* and *Macrosteles laevis*), and the similar dominance structure may indicate that migratory flights to and from the meadow are insignificant, or that emigration flights are balanced by immigration flights.

Two of the species (*M. laevis* and *C. pellucida*) considerably differ, by their percentage in the leafhopper communities in the meadow SM, from the remainder of the leafhopper species. They will be discussed later in the paper.

In both meadows the density of the leafhoppers and the percentage of individual species at particular time periods during the growing season vary. Over the time period from the end of April to October the density of the leafhopper population undergoes variations, and several emerging periods of the different species can be distinguished.

In the spring, the fast growth of vegetation in the two meadows considered occurs at the end of April and at the beginning of May. At that time in meadow K II the biomass of the green parts of the vascular plants is over 10 times greater than that in the SM meadow. At this time numerous leafhoppers of the genus *Calligypona*, notably *C. pellucida*, emerge from the larvae overwintered in the meadows. This species alone represents 71% of the spring community ($\overline{N}_I$) of the meadow K II, with a maximum density of 33.4 individuals/m². In the SM meadow $\overline{N}_I$ = 1.1 individual/m². *C. pellucida*, a species associated with cropfields, and cultivated meadows does not occur in large densities in natural habitats. The number of individuals emerging during the spring in meadow SM is large, ν = 36 individuals/m² per 10 days. In spite of this, the spring community is not abundant, although its species composition is similar to that of the spring community of leafhoppers in the cultivated meadow K II.

At the end of June the vegetation attains its biomass peak. This is also the time of the mass emergence of the leafhoppers of the second, the summer community. Their outbreak occurs about 10 to 15 days earlier in the cultuvated meadow K II than in the reserve meadow SM. Similar acceleration can be observed in the growth of vascular plants which also attain their green-biomass peak at an earlier time (Fig. 1)[1]. This probably is associated with the fact that in the nature reserve meadow snow and ice persist for a longer time in the spring and the soil-water conditions are different from those in the meadow KII. In spring, the water-logged litter remains cold and its warming is slower than in the KII meadow.

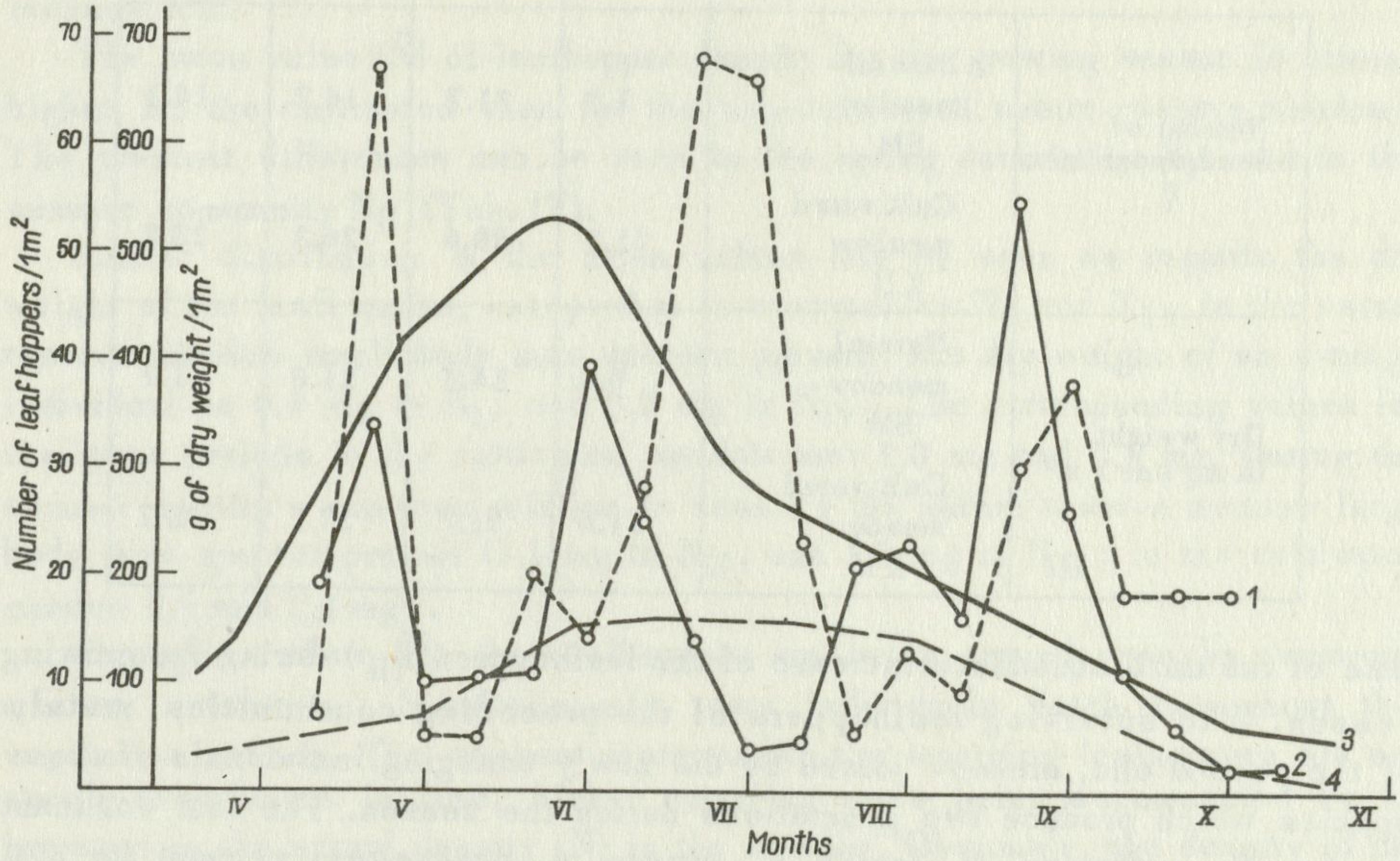

Fig. 1. Variation in numbers of the leafhoppers hatching in the meadow, and green plant parts production during the growing season

Number of leafhoppers in: *1* – natural meadow SM, *2* – cultivated meadow KII; production of green parts of vascular plants: *3* – in the cultivated meadow, *4* – in the natural meadow

The summer ($\bar{N}_{II}$) community of leafhoppers in the two meadows under study appears to be the richest of all, in regard of the number of leafhoppers emerging (ν) and those occurring ($\bar{N}_{II}$) in the meadows (Tab. IV). At this time there occurred 25 species in meadow KII. Six most mumerous of these species (*C. pellucida, M. laevis, A. pascuellus, Dicraneura citrinella, S. sordidus, C. viridis*) constituted 77.2% of the abundance ($\bar{N}_{II}$), and 81.2% of the biomass of the entire community. During the same period in meadow SM there were only 17 species, 6 most numerous of which (*M. laevis, D. citrinella, A. pascuellus, P. spumarius, L. coleopterata, N. lineatus*) accounted for 85.3% of the abundance, and 82.5% of the biomass of the community.

Following the mowing of the meadow KII in June, another growth peak of the vegetation is attained during the second half of August, this being the

[1] According to Traczyk (1971).

Average density and dry weight of the leafhoppers in particular periods during the growing season

Tab. IV

		Period			
		I $\bar{N}_I$	II $\bar{N}_{II}$	III $\bar{N}_{III}$	IV $\bar{N}_{IV}$
Number of leafhopper/m² $\bar{N}$	Natural meadow SM	1.1	31.7	16.7	10.1
	Cultivated meadow KII	21.3	80.6	26.3	28.2
Dry weight in mg per 1 m²	Natural meadow SM	0.4	34.4	21.8	1.7
	Cultivated meadow KII	21.6	51.7	27.7	25.7

time of the third abundance increase of the leafhopper ($\bar{N}_{II}$) during the growing season. The surviving leafhoppers of the preceding communities, mainly of the second one, are now joined by the newly emerging individuals of those species which produce two generations during the season. The four dominant species (*C. pellucida, M. laevis, C. viridis, A. pascuellus*) account for 62% of the abundance and about 66% of the community biomass.

During this period, in the nature reserve meadow SM the increase of the green vegetable biomass ceases, while the amount of dead parts of plants begins to grow rapidly, adding up to the litter already present there. The second generation of leafhoppers that emerges ($\bar{N}_{III}$) is not abundant. This community, the third one in succession, includes 22 species, four of which (*L. coleoptera*, *P. spumarius*, *N. lineatus*, *M. laevis*) constitute 36% of the abundance, and 63% of the biomass of the community.

At the end of September, and in October, in the accumulating litter-layer in the SM meadow there appear species which only sporadically occur in the upper vegetation layers, and larvae of those leafhopper species whose wintering stage is the larva.

In the cultivated meadow KII the litter species are missing, and the autumn community, the fourth one ($\bar{N}_{IV}$), consists of the surviving leafhopper individuals of the preceding communities, and the hatching larvae of the genus *Calligypona*.

3.2. Leafhopper density and production

In the two meadows considered the density of leafhopper populations is subject to considerable variations during the growing season: 1.4 up to 42.5 individuals/m², with a mean value of density for the season $\bar{N}$ = 16 individuals/m², in the SM meadow, and 2.5 up to 131.6 individuals/m², with a mean value of density for the season $\bar{N}$ = 46 individuals/m², in the cultivated meadow KII.

The mean value ($\bar{N}$) of leafhopper density for the growing season is always higher for the cultivated than for the non-cultivated nature reserve meadows. The greatest differences can be seen in the spring community N_I, and in the summer community N_{II} (Tab. IV).

Similar distribution of the mean values can be seen as regards the dry weight of the leafhoppers, except that in communities N_I and N_{IV} in the nature reserve meadow small body size species prevail. The dry weight of an average individual is 0.4 mg in N_I, and 0.2 mg in N_{IV}, The corresponding values for the same periods in the cultivated meadow are: 1.0 mg and 0.9 mg. During the summer months a converse relation is seen. In the nature reserve meadow large body size species prevail (1.1 mg in N_{II}, and 1.3 mg in N_{III} ; in the cultivated meadow 0.6 and 1.0 mg) .

Throughout their life the leafhoppers are being preyed upon by numerous meadow predators . Simultaneously, new individuals hatch throughout the vegetation season. The numbers representing the emerging leafhoppers are not evenly distributed in time, higher emerging rates being accompanied by an increase in the actual density (N) in the meadow. Obviously, the density of the leafhoppers in the meadow is always lower than the total of individuals produced (Fig. 2, 3). During the growing season, that is from the end of April to October, of 1968 a total of 1931 leafhopper individuals hatched per 1 m² in the reserve meadow, and 1155 in the cultivated meadow. Only about 20% of this number of larvae (ν) produced attains the stage of imago in the SM meadow, and about 30% in KII.

The highest reduction rates are recorded for the larval period, although this period is short – about 10 to 14 days under favourable conditions (except the species wintering at the larval stage[2]). A relatively high rate of elimination of young adult forms is also observed during a short period immediately following their emergence. At this time about 4% of the individuals produced survive in the cultivated meadows, and only 0.8% in the nature reserve meadow. Young imagines show a migratory flight tendency, hence their rapid elimination may be caused not only by the predatory activity, but also by emigration.

[2]The elimination (reduction) of leafhoppers is calculated as a percentage from the ratio of the number of insects which hatched during period "t" by the number of those occurred at the end of the same period$\left(\frac{\nu t}{N_t} \times 100\right)$.

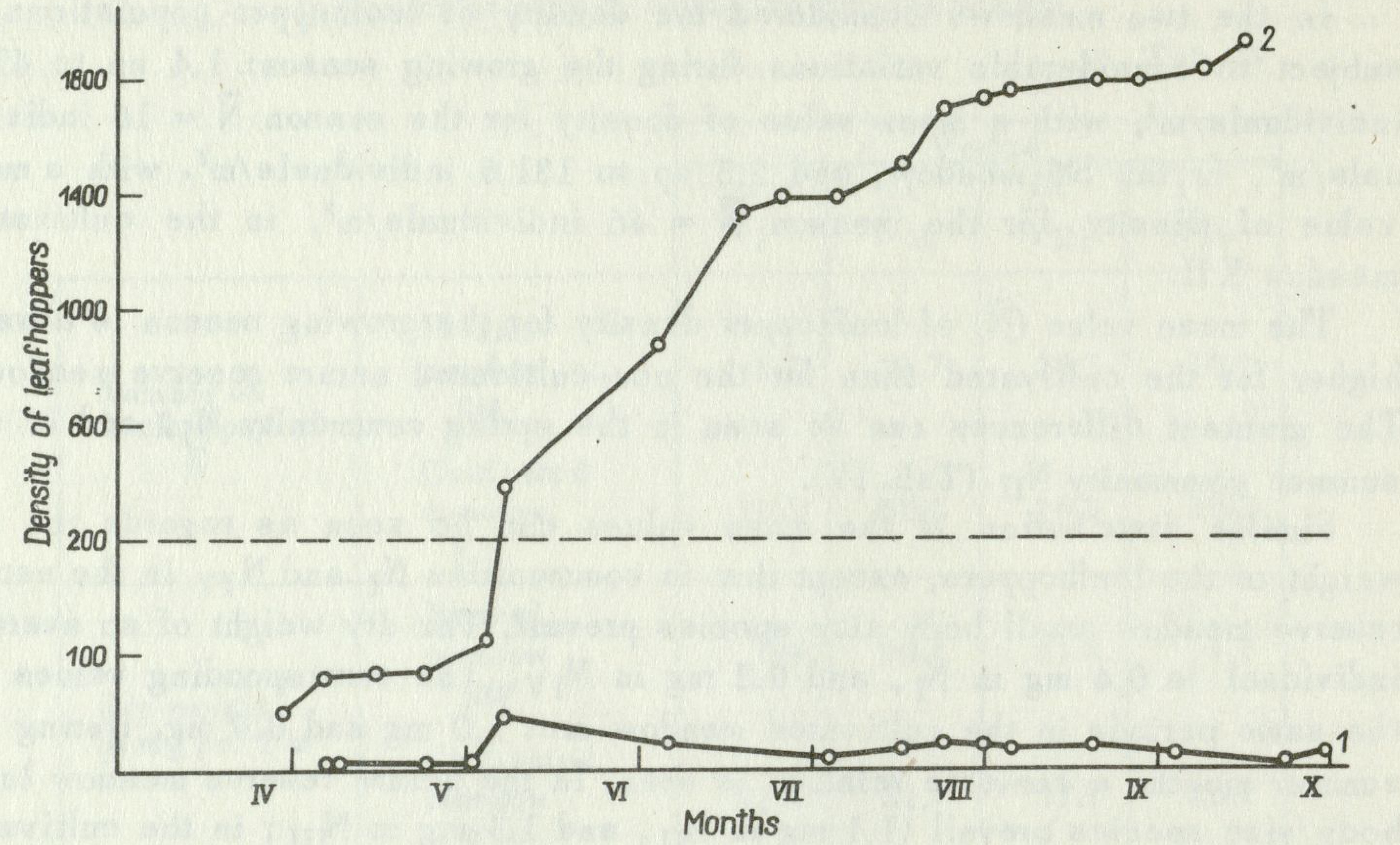

Fig. 2. Production and density of leafhoppers in the natural meadow SM

1 – density of leafhoppers during the season, *2* – number of individuals hatched in 1 m^2 during the whole season

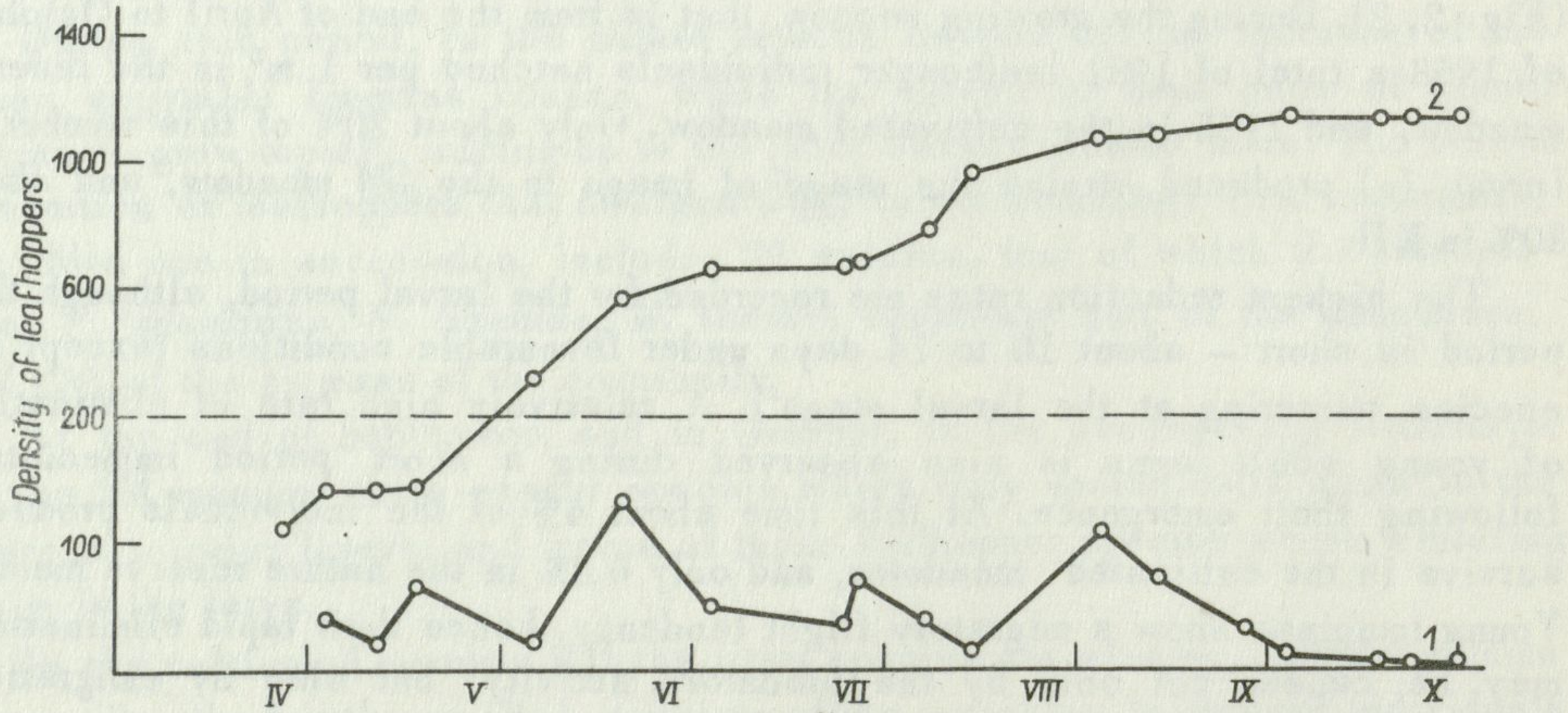

Fig. 3. Production and density of leafhoppers in the cultivated meadow K II

1 – density of leafhoppers during season, *2* – number of individuals hatched in 1 m^2 during the whole season

In the cultivated meadow KII, the reduction of the leafhopper community proceeds primarily at the expence of the 4 dominant species. Their percentage in the community is 62%. The less abundant species are being reduced at a slower rate (Fig. 4).

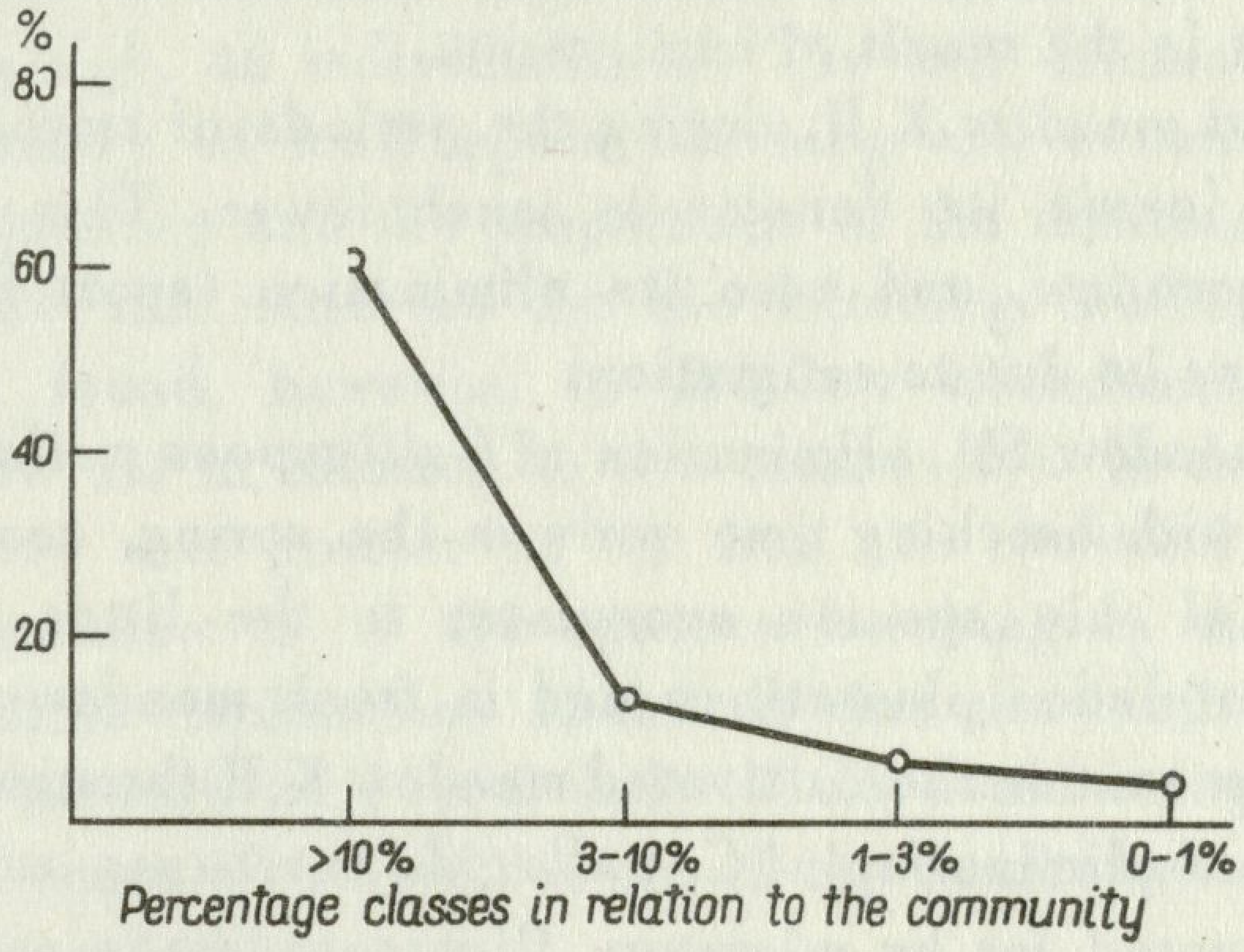

Fig. 4. Percentage elimination of leafhoppers (as estimated for the season) according to 4 abundance classes of the community in the cultivated meadow KII

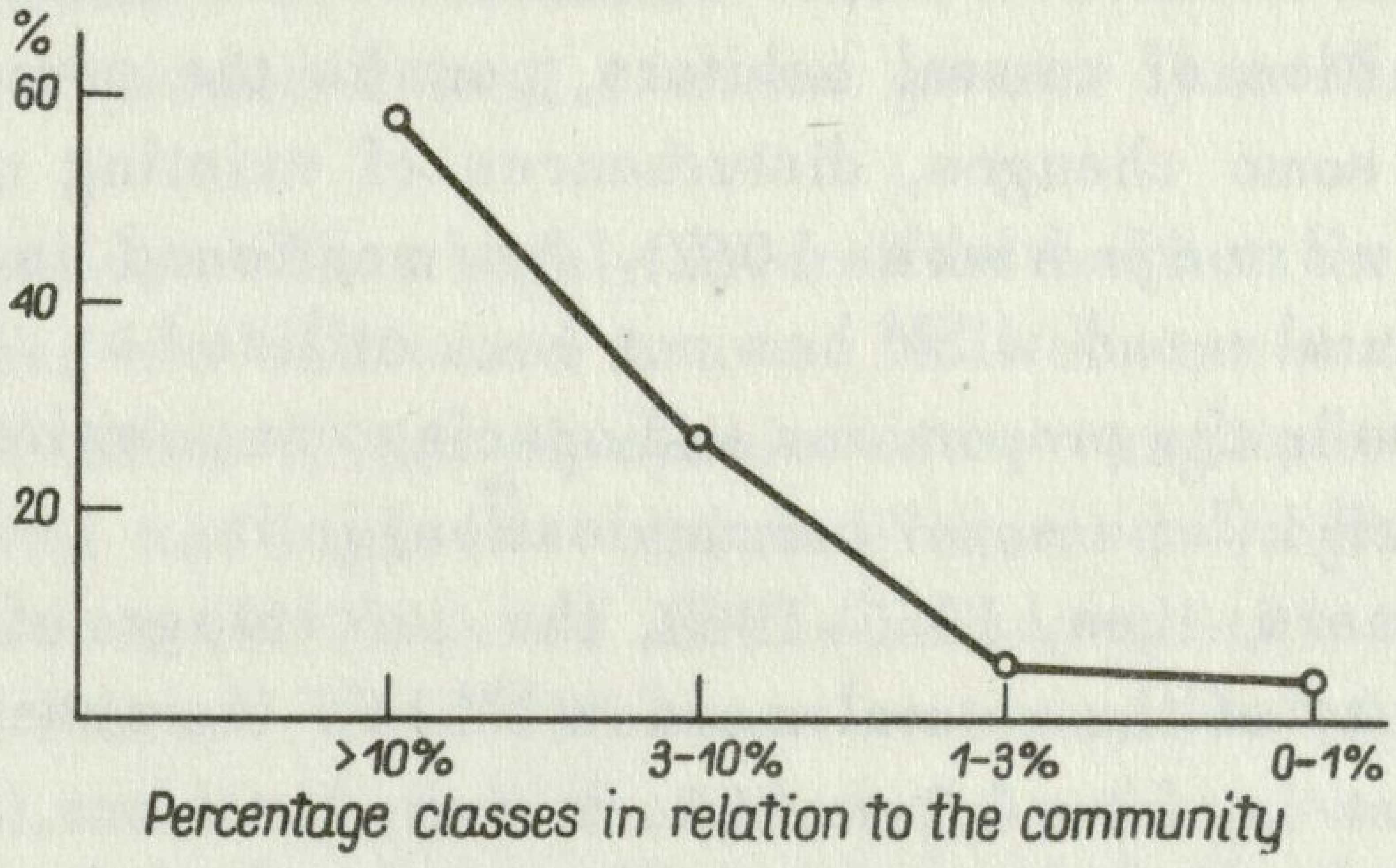

Fig. 5. Percentage elimination of leafhoppers (as estimated for the season) according to 4 abundance classes of the community in the natural meadow SM

In the SM meadow reduction more evenly involves all the leafhopper species, yet it is higher for the more abundant species and lower for those species whose percentage in the community is smaller (Fig. 5). Of the three hatching dominant species *Calligypona pellucida* is most rapidly eliminated from the meadow, and represents only a small percentage (2.3%) in the community that persists in the meadow, the most numerous dominant species there is *Macrosteles laevis* (about 22%), a species which hatches in the meadow in small numbers (2.5%). The existing relations may be the result of migration alone. This is possible during the migratory flights which usually occur after the emerging periods: in *M.laevis* in June and August, in *C. pellucida* at the beginning of May and at the end of August.

In the natural meadow SM *M. laevis* appears in June, then is numerous though emerges in the meadow in low numbers, which means that the high density of *M. laevis* is the result of immigration.

In the cultivated meadow K II, during the periods of emerging and of a high value of *v* for *M. laevis* its density is much lower. This species does not immigrate to this meadow, and even its elimination (apart from the reduction by the predators) may be due to emigration.

In the natural meadow SM, elimination of *Calligypona pellucida*, an abundant dominant species, with hatching time early in the spring, continues for several days. The larvae of this species overwinter in the litter. It is particularly abundant in monocotyledon plantations and in fresh meadows. It is one of the dominant species present in the cultivated meadow K II throughout the vegetation season. The index of eliminating of *C. pellucida* increases at the end of August which may be accounted for by migratory flights to areas with a thicker litter layer, more suitable for the larvae to winter over. In the natural meadow SM the reduction of *C. pellucida*, which emerges in large numbers in the spring, is fast and it is probably from there that the species migrates to cropfields.

The behaviour of *Macrosteles laevis*, which occurs in large numbers in the leafhopper communities of natural habitats, permits the conclusion that in the habitat concerned some changes, disturbances of existing natural conditions, have occurred (Andrzejewska 1962). As mentioned in the introduction, since 1965 the natural meadow SM has not been utilized at all. Since that time progressive changes in the proportions and species composition of the vegetation have occurred (Traczyk – personal communication) in it.

Within the 2-years, time, 1966–1968, the percentage of *M. laevis* in the leafhopper community of the natural meadow SM has increased from 0.1 to 10.7 individuals/m^2, that is, from 0.3 to 33%. It may, therefore, be presumed that although the community has remained stable (in regard of the number of species, and species composition), the change in the way of utilization of the meadow has caused some changes in this stability of the leafhopper community.

4. DISCUSSION OF RESULTS

The two meadows under study, fundamentally differing from each other in habitat type, species composition, structure of particular layers of vegetation, as well as in their agricultural development and utilization, also have different communities of leafhoppers, which are herbivorous insects closely associated with the habitat.

In the cultivated meadow K II, as a result of the poor stratification of vegetation, absence of the litter layer, agricultural treatment, and harvesting, the number of leafhopper species hatching during the season is not large (22). The litter species are missing, and the number of species characteristic of meadows with more diversified vegetation, is small, the abundance of these species ($\bar{N}$) being high, 46 individuals/m². The four dominant species represent 73% of the community of leafhoppers hatching and occurring in the meadow. The species composition and the proportions of the dominant species occurring in the meadow are the same as for the hatching leafhoppers. Considerable differences were found, however, in the low abundance species, captured sporadically (below 1% in relation to the community). In this group the number of species captured was greater by 13 than the recorded number of species hatching in the meadow (3 of the species hatching in the meadow were not caught). The possible explanation of this is that the leafhopper species represented during the season by 1 or 2 individuals avoid being caught, or get into the sample by change. Possibly, some of the leafhoppers immigrated to the meadow from adjacent habitats.

Of the total 1155 leafhoppers/m² (ν), produced in the cultivated meadow, on an average 46 individuals/m² (the $\bar{N}$ for the season – from end of April to October) survive. It follows that the number of individuals produced is 25 times as large as the number of individuals which remain in the meadow, and the amount of biomass produced is 7.4 times greater than the biomass that will eventually remain.

The reserve meadow SM, a highly diversified habitat, is much richer in leafhopper species than the cultivated meadow K II. Between the end of April and the beginning of October (1968) 41 species were caught, but their total density for the season was not high ($\bar{N}$ = 16 individuals/m²). During the same time just as many species (41) hatched in the meadow, with a total number of individuals ν = 1931/m². Thus 120 times as many leafhoppers (and 34 times as much biomass) are hatched in the meadow as there remain in it during the season. The ratio of the number to the biomass of the leafhoppers produced and remaining in the meadows (SM and K II) shows that species of large body size more readily persist in the meadow. The elimination of species of smaller body size and smaller biomass is faster.

The meadows discussed, K II and SM, appeared to differ in the ratio of the number of leafhoppers hatched in the meadow (ν) to the number of those remaining in it ($\bar{N}$). The number of leafhoppers hatched in the natural meadow was about twice as large as that in the cultivated meadow, whereas the mean of abundance ($\bar{N}$) and the number of individual-days (during time period T = $\bar{N} \cdot T$) was about 3 times smaller (Tab. V). The number of individuals hatched in the meadow K II is smaller, but the abundance is greater. It may, therefore, be assumed that the effect on primary production is also greater. This is illustrated by the

Number parameters of leafhopper population in the meadows

Tab. V

	Number of leafhoppers hatched in 1 m² ν	Number of imagines emerged in 1 m² $\nu\alpha$	Density for the season as per 1 m² $\overline{N}$	Number of individual-days $\overline{NT}$	Average duration of presence in meadow t	Average duration of presence of adults $t\alpha$
Cultivated meadow K II	1155	369	46	7360	6.4	19.9
Natural meadow SM	1931	467	16	2560	1.3	5.4

number of individual-days ($\overline{N} \cdot T$). The $\overline{N}T$ value for the cultivated meadow is about 3 times as large as that for the reserve meadow (Tab. V), hence the consumption rate is as many times higher.

Average density of predators per 1 m² in the meadows (After Pętal et al.1971)

Tab. VI

		Natural meadow SM	Cultivated meadow KII
Predators of litter	ants	142.0	46.4
	epigeal spiders	45.3	10.0
		= 187.3	= 56.4
Predators of upper herb layer	web spiders	52.0	4.4

The opposite relations between the production and density in the two meadows considered result from the fact that they differ in the elimination rate of the leafhoppers, their ecological longevity. Petrusewicz (1967) has found that the value of abundance ($\overline{N}$) and $\overline{N} \cdot T$ depends on the number of individuals hatched, and on the duration of their presence in a population. $\overline{N} = \frac{\nu \cdot \overline{t}}{T}$; $\overline{N} \cdot T = \nu \cdot \overline{t}$, where $\overline{t}$ is the average duration of presence in the meadow during time T. In the given case T denotes the entire growing season, thus it may be assumed that t is the average presence of individuals in the meadow (not taking the eggs into account): $\overline{t} = \frac{\overline{N} \cdot T}{\nu}$. Value $\overline{t}$ may be overestimated when there is leafhopper immigrations. These occur in both meadows, but the species immigrating to the cultivated meadow are not abundant, their aggregate abundance ($\bar{N}$) being 1 individual /m^2 or less. Generally, only one species immigrates to the natural meadow, but since this is an abundant species, the value of $\bar{t}$ is slightly incremented.

Only a small percentage of the leafhoppers hatched in the meadow remain in it. The highest reduction rate is observed at the larval stage. The average lifetime calculated for all the developmental stages of the leafhoppers is much smaller than that calculated for the adult forms alone (Tab. V). The larvae hatch and remain mainly in the litter, where they are preyed upon by predators the most abundant of which are ants and epigeal spiders (Pętal et al.1971) (Tab. VI). Adults are reduced particularly by the predators living in the upper layer of vegetation, web spiders (Kajak 1971). There is a close relationship between the average density – of the predators mentioned and the average lifetime of the leafhoppers (Fig. 6).

As a result of the reduction rate, different in each of the two meadows, the density of the leafhoppers in the natural meadow SM is about 3 times lower (and the number of eggs laid is accordingly as many times smaller) than in the cultivated meadow K II, in spite of the fact that the production of leafhoppers in meadow SM is about twice as great as in the cultivated meadow. It may be assumed that the fecundity of the females is the same in both meadows; if so, then the relationship observed (a lower density accompanied by a higher production) may only be maintained when part of the eggs laid in the meadow K II becomes destroyed, or when due to migrations eggs are laid in a different habitat. Both these situations occur. The cultivated meadow K II is moved twice during the growing season, and part of the eggs laid may be taken away with the hay. Besides, the lack of the litter layer, the winter flooding and freezing may cause considerable losses to the eggs laid.

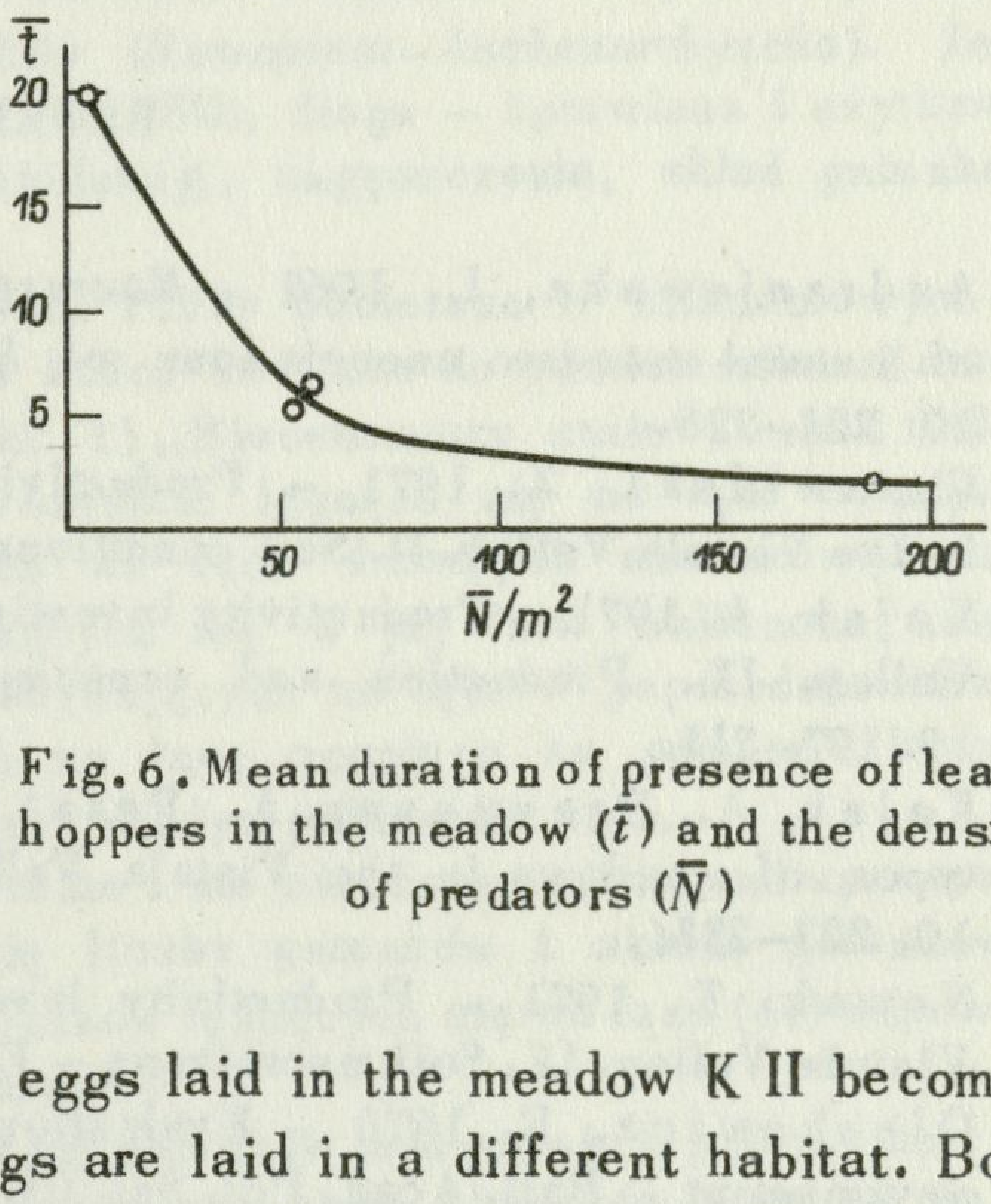

Fig. 6. Mean duration of presence of leafhoppers in the meadow ($\bar{t}$) and the density of predators ($\bar{N}$)

5. SUMMARY

From the analysis of the leafhopper community in the nature reserve meadow SM and the cultivated meadow K II the following conclusions can be drawn:

1. A higher diversity of the habitat (SM) is accompanied by a larger number of species.

2. A larger number of species in the meadow (SM) corresponds to a lower average density.

3. In the more complex habitat (SM) the production of leafhoppers is higher while the density of individuals is smaller.

4. For this reason the number of individuals-days, and the consumption rate are lower (SM).

5. In the more diversified habitat (SM) the average duration of presence of leafhoppers (ecological longevity) is shorter.

6. The average lifetime of the leafhoppers depends on the density of predators in the meadow.

7. Between the habitats migrations, varying in intensity, occur.

8. Under the conditions of a diversified habitat there exists a strong pression of the ecosystem on the leafhopper community living in it.

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BADANIA PRODUKTYWNOŚCI DWÓCH TYPÓW ŁĄK W DOLINIE WISŁY

VI. PRODUKCJA I ZAGĘSZCZENIE ZGRUPOWAŃ SKOCZKÓW *HOMOPTERA–AUCHENORRHYNCHA*

Streszczenie

Na dwóch łąkach różniących się typem siedliska i sposobem eksploatacji została przeprowadzona analiza zgrupowań skoczków (*Homoptera–Auchenorrhyncha*). Jedna łąka była nie uprawiana, położona w rezerwacie (SM), druga – uprawiana i użytkowana (K II). Na badanych łąkach porównano produkcję, zagęszczenie, skład gatunkowy, wielkość i przyczyny redukcji skoczków.

Badania prowadzono w latach 1966–1968. Próby pobierano w kilkudniowych odstępach w ciągu całego sezonu, to jest od końca kwietnia do października. Zastosowano dwie metody wyłowu skoczków z łąki: 1) „Biocenometry stałe", spod których przy użyciu aparatu ssącego wybierano wszystkie lęgnące się na łące owady. Tą metodą uzyskano liczbę wyprodukowanych na łące dorosłych skoczków i część ostatnich stadiów larwalnych. Liczba lęgnących się z jaj larw obliczona została na podstawie płodności i liczby samic przebywających na łące w poprzednim okresie; 2) Zagęszczenie skoczków przebywających na łące oceniano za pomocą „biocenometrów chwilowych" zarzucanych na trawę przy każdym pobieraniu prób.

Stwierdzono, że środowisko łąkowe naturalne i nie niszczone zabiegami uprawowymi (SM), charakteryzuje się większą stałością liczby gatunków i składu gatunkowego zgrupowania skoczków. Liczba gatunków skoczków lęgnących się na łące (41) odpowiada liczbie utrzymujących się na niej w całym sezonie.

Na łące uprawianej KII liczba lęgnących się gatunków jest prawie o połowę mniejsza (22), ale na skutek nalatywania na łąkę ilość gatunków skoczków wzrasta do 32. Na łące rezerwatowej (SM) większej ilości gatunków odpowiada większa liczba lęgnących się skoczków (1931/m^2) w porównaniu z łąką uprawianą KII (1155/m^2). Jednak średnia liczebność jest przeszło dwukrotnie mniejsza niż na łące uprawianej (16 osobników/m^2 i 46 osobników/m^2). Stąd liczba osobniko-dni, a więc i konsumpcja skoczków jest przeszło dwukrotnie większa na łące uprawianej w porównaniu z łąką rezerwatową.

Większa liczba wylęgających się skoczków przy ich mniejszym zagęszczeniu na łące rezerwatowej (SM) jest wynikiem silniejszej redukcji spowodowanej działalnością drapieżców. Są one liczniejsze na łące rezerwatowej zarówno w warstwie ściółki (pająki epigeiczne i mrówki) jak i w piętrze roślin (pająki sieciowe). Efektem redukcji, różnej na obu badanych łąkach, jest różna długość życia skoczków – na łące rezerwatowej około czterokrotnie większa niż na łące uprawianej.

Produkcja skoczków na badanych łąkach i ich zagęszczenie w sezonie zależy głównie od związków z innymi piętrami troficznymi ekosystemu, a w mniejszym stopniu od typu siedliska.

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