Laufener Seminarbeiträge 7/91, 61-67 • Akad. Natursch. Landschaftspfl. (ANL) – Laufen/Salzach 1991

Monitoring of insect diversity and abundance in large areas.

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1. Introduction

In studies on a spatial structure of animals in the landscape it is important to estimate their resources in various ecosystems, the attractiveness of which to some particular species or groups of animals may be of different type and may vary to a different degree. Some habitats, for instance, may be very attractive to certain animals on account of essential food resources, whereas others may serve as refuge places suitable for reproduction or hibernation. In this aspect, the fact certain ecosystems are present or absent in the landscape mosaics or that they constitute some portion of the landscape may result in the impoverishment or enrichment of the landscape in definite groups of animals, which is particularly important in the case of trophic groups, and may also affect the proportion of variation and diversity of the fauna in this landscape (BANASZAK 1985, RYSZKOWSKI and KARG 1986).

The amount of fauna in agricultural landscape may also depend to a significant degree on the scale of a pressure exerted by man on various ecosystems. On this account, classification of animal resources in a landscape is frequently adequate to the extent of man's interference mainly in the form of a widely understood agrotechnical activities.

Studies on a spatial structure of the density of animals in a landscape are very difficult to carry out for methodical reasons. In view of that, the so-far monographs concern only some species or taxonomic groups, the density of which could be estimated by methods specially worked out for them. The necessity of a simultaneous taking of a considerable number of samples from large areas causes that the biocenometric method, for instance, widely applied for estimations of epigeic invertebrates, is of little use in this case.

In order to estimate a spatial diversity of flying insects in the aspect of absolute values of their density an original method consisting in a rapid capture of a considerable number of samples on a large area has been elaborated (KARG 1975, 1980). This method called a motorcycle-net has been tested in the course of several year studies on the structure of flying insect fauna in the agricurtural landscape in central-west Poland.

2. Description of method

Insect flying over individual studies ecosystems were captured by nets arranged at the field motorcycle mast. Samples were taken when driving a motorcycle through the studies habitat at a definite speed (averagely 35 km/h). Insects were captured in three layers of air: at the height of 0.5, 1.5 and 2.5 m from the ground surface. The density of flying insects per unit air volume (100 m^3) was counted on the basis of the known ride length and of a capturing diameter of each net using the formula for cylinder volume.

This method differs from the remaining ones first of all by the fact that insects in this case are captured in an active way. It is also important that this method is based on a simple construction very easy in use and that it is very operative in the field, which differs it from various other types of stationary suction traps (TAYLOR 1955, JOHNSON 1969, TAYLOR and PALMER 1972). This method is similar to traps erected on airplanes and used for estimation of insects present in the higher layers of the atmosphere (GLICK 1939), and to truck traps (TAKAHASHI 1988).

Testing studies were carried out with the aim of choosing the most optimal parameters concerning the influence of the speed of the motorcycle while taking samples and of the wind as well as of the net size. It has been found that the speed of driving ranging within 20-50 km/h while taking samples has no influence on reliability of results. This also concerns the speed of wind below 2 m/sec. A capturing net surface 0.5 m in diameter was taken as an optimal net size.

Very important factors, which can be significantly reflected on results obtained in studies on flying insects, are a daily activity of insects and weather conditions, chiefly thermal conditions. A higher temperature generally causes an increase in the activity of insects. Also during the day the activity of various species is different, an extreme example of which are species flying exclusively at night as some *Lepidoptera* or beetles. On the basis of the performed daily estimations of insects density in the air and estimations concerning the influence of temperature on their density (KARG 1980, KARG and RYSZKOWSKI 1985) as well as on the basis of data obtained by other authors (TAYLOR 1963) the time from 11^{00} to 16^{00} was taken as optimal for taking samples. At this time interval under comparable weather conditions the highest densities of the majority of insect species occurring in the studied area are noted. In addition to that samples are taken only in sunny and warm days, when the wind does not exceed the speed of 2 m/sec.

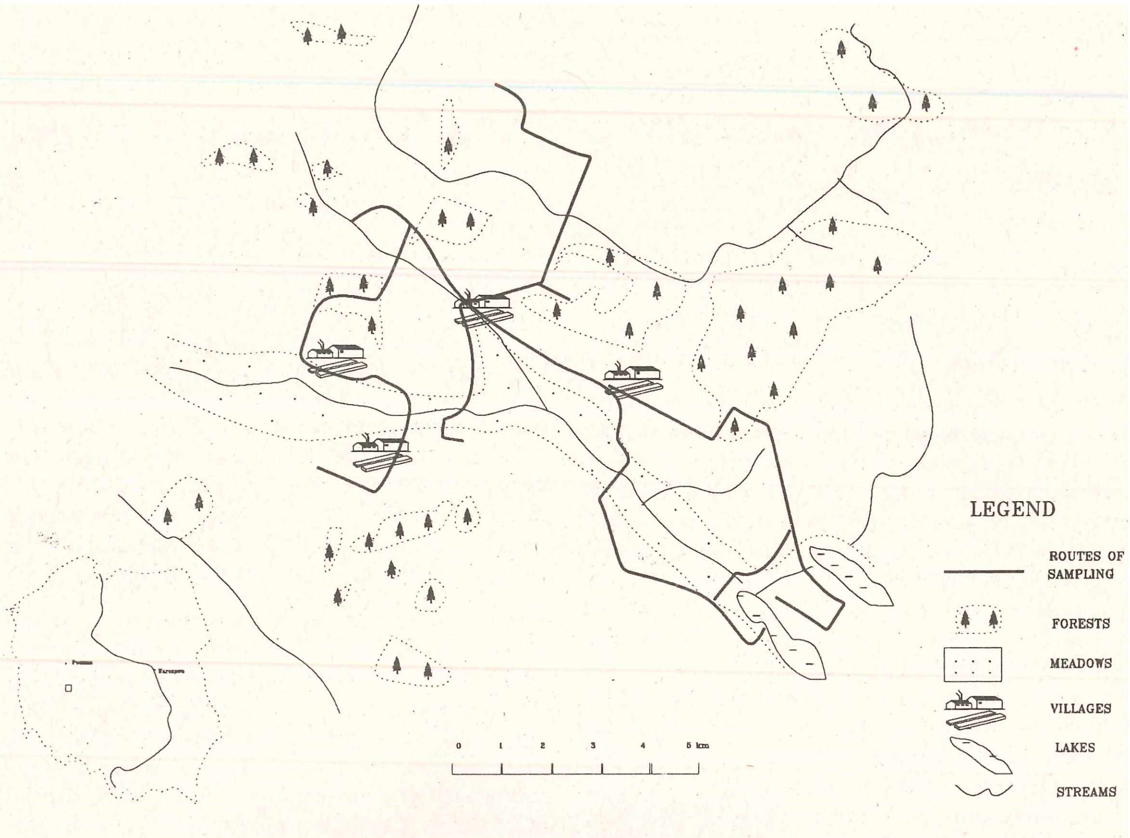

Figure 1

Terrain of investigation

A single sample consists of insects captured during one drive through a given habitat within the marked transect. The length of the drive route within the studied habitat was determined by its size.

In the studies conducted in the agricultural landscape samples were taken averagely each 20 days during the entire vegetation season. During the entire period of studies totally 1161 samples from each of the three studied layers of air (3483 samples together) were taken obtaining the material numbering 479 087 insects.

In the field, transects were marked in all types of ecosystems, along which samples were taken (Fig. 1). Eight groups of habitats were separated: roads, village buildings, spring crops, winter crops, perennial crops, meadows, ecotones of forests and forests.

3. Results

3.1 Density of flying insects

An average density of insects present in the air layer from 0.5 to 2.5 m above the ground surface amounts to about 55 ind/100 m^3 in the entire landscape (when taking into consideration landscape structure weighed mean). The largest density is noted on annual (winter) crops as well as on perennial (alfalfa) crops. In the remaining types of ecosystems the insect density is lower. The lowest values of insect density were found in the habitat of village buildings. A significant part of insects are dominant families associated with agricultural crops (*Chironomidae, Sphaeroceridae*) (Table 1).

When grouping individual families of insects according to their largest portions in the density of different habitats, three main groups of families characteristic of definite types of habitats can be distinguished. The first group related with forest habitats consists of about 20 families including the majority of parasitic *Hymenoptera*, the second group covers more or less synanthropic species belonging to the families *Sphaeroceridae, Scatopsidae, Ephydridae* and to the suborder *Aphidodea* attaining the highest degree of dominance in village habitats and above communication roads. The third group is definitely assiociated with the habitat of grass ecosystems (meadows) and is representend by insects of thirty families. This last group also includes the family *Chironomidae* dominant in the aeroentomofauna of the entire landscape.

In the course of vegetation season the insect density in the air significantly changes. The lowest values are generally noted in the entire studied landscape in the spring period (from the end of February to the beginning of May). The density then is averagely about 21 ind/100 m^3 During full vegetation season (from May to August) it attains 73 ind/100 m^3, but at the end of this period (from September to December) it remains on a quite high level of about 45 ind/ 100 m^3 on account of a mass occurrence of autumn

Table 1

Mean density of dominating orders and families of flying insects in different types of ecosystems (ind/100 m^3).

order, family	villages	roads	spring crops	winter crops	perennial crops	meadows	ecotons	forests
Dominating orders								
Diptera	22,65	28,42	33,87	53,81	60,75	47,03	36,04	26,50
Coleoptera	2,28	3,58	2,79	4,72	4,11	2,79	4,72	2,39
Homoptera	3,46	1,82	1,47	5,00	2,18	2,64	3,25	2,35
Hymenoptera	1,61	2,30	2,15	4,11	2,97	3,40	3,66	4,00
Thysanoptera	0,78	1,31	1,62	2,76	2,33	2,21	1,86	2,85
Psocoptera	0,24	0,39	3,27	3,88	1,29	0,41	1,01	0,45
Heteroptera	0,06	0,09	0,11	0,17	0,28	0,18	0,10	0,16
other orders (11)	0,03	0,04	0,04	0,05	0,26	0,24	0,04	0,61
Dominating families								
Chironomidae	6,20	12,60	21,19	25,70	35,73	27,18	13,89	5,70
Sphaeroceridae	7,89	5,59	3,60	6,86	12,23	2,98	4,35	2,49
Staphylinidae	1,63	2,54	1,96	3,16	3,06	1,81	3,10	1,93
Aphidodea	3,35	1,70	1,27	4,66	1,69	2,31	2,98	2,14
Anthomyiidae	1,03	1,28	0,20	4,93	1,86	2,69	5,18	4,79
Scatopsidae	1,73	2,46	2,12	3,12	2,39	2,04	2,05	1,36
Thripidae	0,67	1,13	1,40	2,37	2,00	1,90	1,60	2,45
Sciaridae	1,06	1,24	1,23	2,04	1,58	1,96	2,05	1,89
Empididae	0.38	0,32	0,31	2,61	0,42	2,58	1,34	2,07
Chloropidae	0,57	0,75	1,00	1,75	1,35	1,38	1,32	1,04
Phoridae	0,70	0,56	0,56	1,03	0,85	0,56	1,20	2,25
Ceccidomyiidae	0,64	0,41	0,82	1,50	1,11	0,75	1,25	0,74
Ephydridae	0,67	1,33	0,57	1,06	0,62	0,78	0,40	0,23
Bibionidae	0,08	0,24	0,75	0,39	0,36	0,65	0,43	0,26
Eulophidae	0,29	0,47	0,50	0,86	0,63	0,81	0,78	0,56
Pteromalidae	0,15	0,19	0,18	0,26	0,37	0,35	0,45	0,61
Ceratopogonidae	0,50	0,42	0,34	0,48	0,41	0,81	0,51	0,49
Braconidae	0,26	0,31	0,30	0,56	0,43	0,61	0,50	0,50
Scelionidae	0,17	0,22	0,28	0,70	0,32	0,38	0,44	0,56
other families (154)	3,14	4,19	6,73	11,45	6,53	6,39	6,86	7,29
total	**31,11**	**37,95**	**45,31**	**74,49**	**73,94**	**58,92**	**50,68**	**39,35**

generations of many insect species and of their late-summer and autumn migrations. During full vegetation season the amount of insects in the studies landscape is threefold larger than during the spring period and 1.6- fold larger than in the autumn period (Fig. 2).

3.2 Vertical stratification

The highest insect density in the entire landscape is generally on the level of the lowest layer and the lowest on the level of the highest layer. It averagely amounts to 78.4, 42.5 and 32.3 ind/ 100 m^3, respectively, which is expressed by the ratio 1 : 0.54 : 0.41. An interrelation of insect density in different air layers significantly differs in individual types of studied ecosystems (Fig.3). This relation is strongly limited in the habitats of village buildings, communication roads as well as in forest habitats. From the entire material three groups of insects differing by the density structure in the vertical stratification can be separated, which may be indicative of the extent of their tendency to migration (Fig.4). The first group includes species attaining the highest density near at the ground surface and diminishing with the height increase. This concerns the majority of insects and the most striking examples are species

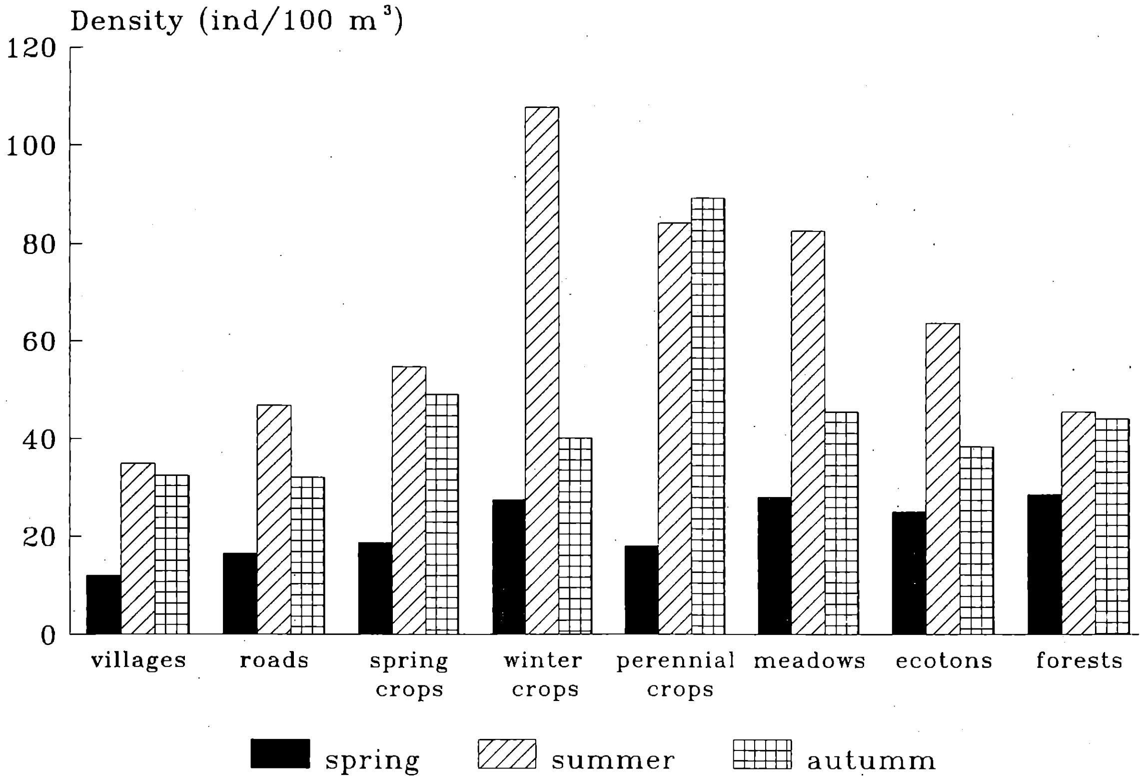

Figure 2

Density of flying insects in three period of vegetation season (Average in the air layer of 0,5 - 2,5 m)

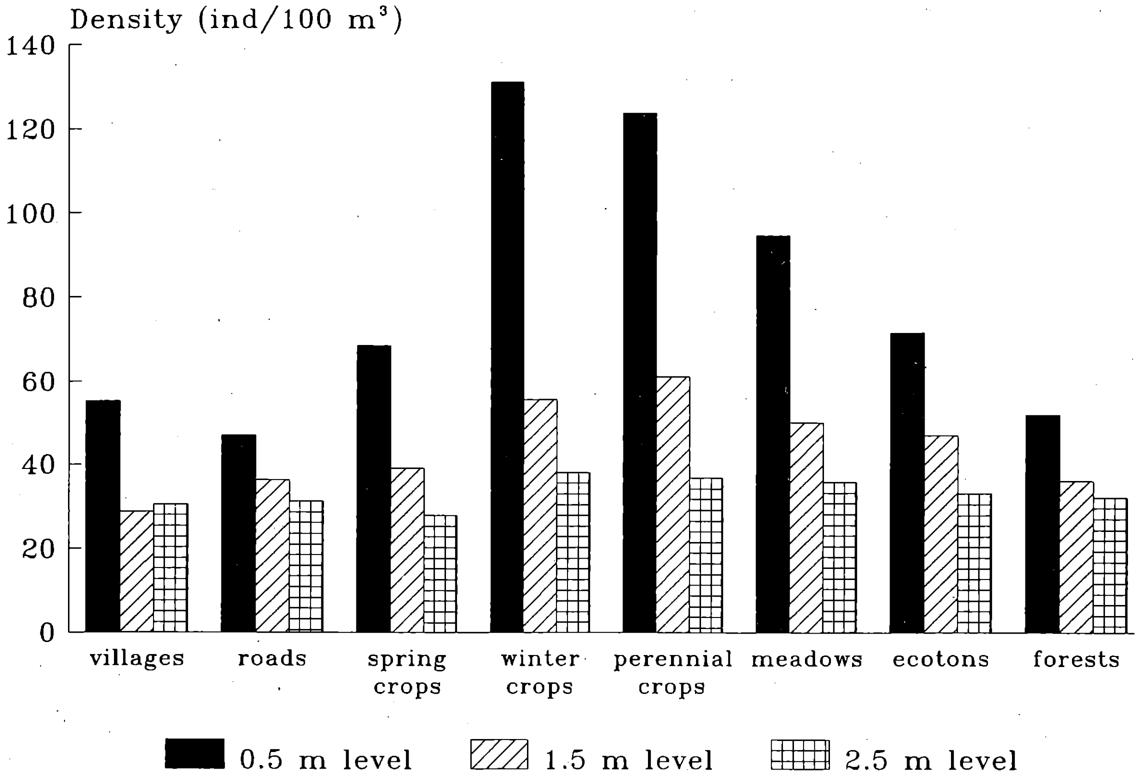

Figure 3

Density of flying insects at different heights

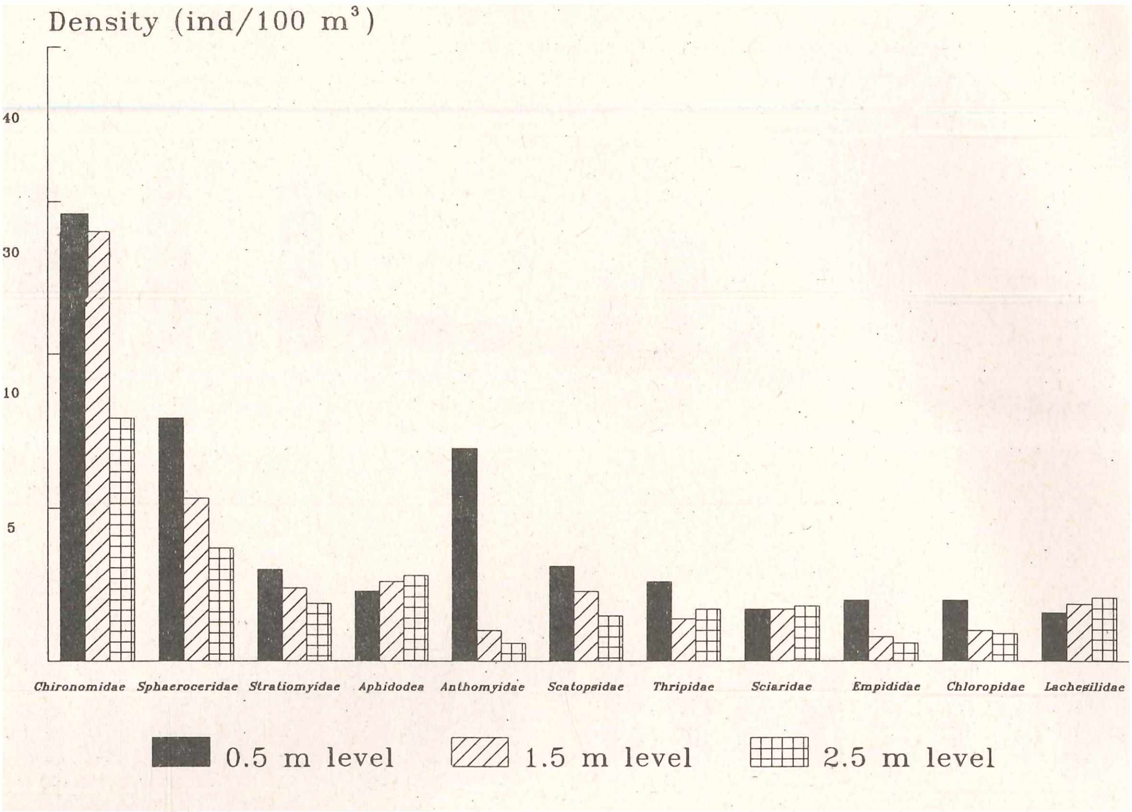

Figure 4

Density of dominating families of flying insects at different heights (Average of the landscape)

from the family *Anthomyiidae* (*Diptera*) grouping in the predominant majority on the level of 0.5 m. The density ratio of insects from this family in the air layers from the lowest to the highest ones (in the entire landscape) is as 1 : 0.14 : 0.07. These differences are statistically significant in the majority of the studied habitats. The second group consists of families with similar insect densities in the entire air layer which are mainly represented by saprophagous species including several of them belonging to the group of subdominants, like for example *Sciaridae* (*Diptera*), whose density distribution in vertical stratification is 1 : 0.98 : 1.13 and these differences are not statistically significant. Finally, the third group is a family characterized by a reversal of the above relationships, attains the highest density in the highest layer of air. This concerns species from so numerous taxa as *Aphidodea*, *Lachesillidae* as well as from several families of a small population (e.g. *Ptilidae*). As an example, the distribution of densities in the case of *Lachesillidae* is 1 : 1.16 : 1.34. These differences are statistically significant in most studied habitats chiefly having the character of open fields.

Table 2

Trophic structure of the flying insects (percentage share in total material)

trophic group	percentage
saprovores	68,4
herbivores	18,0
predators	3,9
parasites	5,7
omnivores	4,0

3. 3 Trophic structure

Saprophagous insects are decisively predominant in the entire studied landscape. On the average they constitute about 68.4 % of the total number of flying insects. The portion of phytophagous insects in the whole of aeroentomofauna constitutes about 18.0 %. The portion of parasites (5.7 %) is also relatively high, whereas that of predator (only 3.9 %) is the lowest (Table 2).

The mean density of saprophages and phytophages differs significantly in different types of the studied ecosystems. Insects from these both groups attain higher density in typically agricultural ecosystems (spring and winter as well as perennial crops). The highest density of saprophages was noted on perennial crops (57.8 ind/100 m^3), while the highest density of phytophages (14.8 ind/100 m^3) was noticed on winter crops (Fig. 5). Predaceous and parasitic species occur with the highest density in the ecosystems of meadows and forests.

3.4 Diversity

In all studied types of ecosystems the index of diversity (H') calculated for density has comparatively high values ranging from 2.19 (perennial crops) to 3.29 (forest inside). A low insect diversity was noted in winter and spring crops. Also in

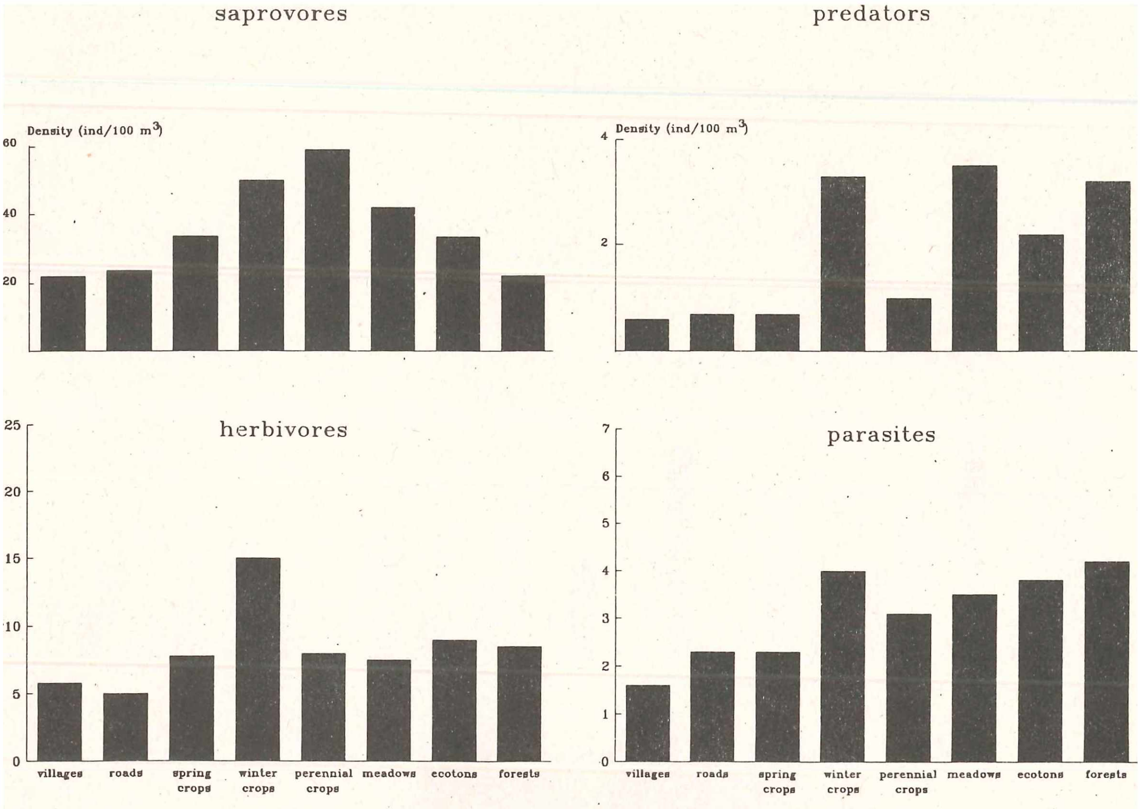

Figure 5

Density of trophic groups of flying insects

meadow habitats it is smaller than might be expected (Table. 3). Therefore, even in faunistically very rich habitats there are pronounced tendencies to a dominance of a small number of species. Differencies between individual groups of ecosystems in the value of the index of diversity in the most cases are statistically significant (at $P<0.01$). In vertical stratification of insects the index of diversity characterized by higher values in the highest air layer as compared to the remaining ones. In other words, the higher is the air layer, the larger is insect diversity and the more pronounced is domination of a narrow group of species. The index of diversity in the entire landscape is 2.36 in the lowest layer (0.5 m), 2.60 in the higher layer (1.5 m) and 2.75 in the highest layer (2.5 m) (Table 3).

A larger diversity of the insect fauna in the higher layers of air than in the lowest layer results probably from an increase at larger heights of the portion of insect groups weakly related with a given habitat, i.e. migrating groups. For that reason at larger heights there also increases the degree of dominance of certain insect groups, because insects with migrating tendencies frequently occur in mass.

3.5 Regularities of flying insect distribution in the landscape

About 70% of the area in the structure of the studied landscape are annual agricultural crops characterized by a relatively high density (about 60 ind/100 m^3) of aeroentomofauna. Its composition is, however, little differentiated, and is charakterized by a significant dominance of a small number of species, chiefly sapro and phytophagous insects. Particularly simplified in this respect are spring crops, not speaking of the habitats of village buildings. These last ones are also extremely poor regarding the attained values of insect densities. Like annual crops, perennial alfalfa (3.5% of the area), probably on account of

Table 3

Diversity index (H') of flying insects in vertical stratification

air layer	villages	roads	spring crops	winter crops	perennial crops	meadows	ecotons	forests
0,5 m	2,48	2,25	2,32	2,31	1,79	2,40	2,59	2,78
1,5 m	2,56	2,54	2,50	2,67	2,14	2,31	2,82	3,24
2,5 m	2,64	2,72	2,67	2,70	2,55	2,47	2,95	3,32

a large intensity of agricultural work drastically interfering into the stability of food basis (frequent cuts), are characterized by a small diversity of entomofauna. Habitats, which are faunistically rich, are forests and afforestations (9.9% of area). The lowest level of insect numbers was noted in the habitats of village buildings. They occupy only about 2.4% of the area of the studies.

On the basis of a dendrite cluster analysis, taking into consideration similarity of insect density in individual ecosystems, three groups of ecosystems differing decisively from one another have been separated. The first group included ecosystems of village buildings, communication roads and field ecosystems covering spring crops. Between these habitats practically no significant differences occur in the density of the whole of insects. These habitats are exposed to a strong pressure of agrotechnical treatments (spring crops) or are specyfically developed by man (villages, communication roads). Ecosystems of winter crops (cereals, rapes), ecosystems of perennial crops (alfalfa) and ecosystems of stable crops (mowing meadows) form the second group of ecosystems characterized by a relatively high density of aeroentomofauna at its large variation and small taxonomic diversity. These are ecosystems, where the pressure of a man undoubtedly exists, but it is significantly smaller than that in the ecosystems of the first group. These ecosystems last significantly longer, particularly perennial alfalfa or stable meadows. On the last ones there is almost a complete lack of agrotechnical treatments, such as ploughing, ridging, weeding, etc. The last, third group is formed by the habitats of forest enterier and afforestations and it is very markedly distinct as compared to the others. This group includes also forest ecotones.

Diversity of the fauna of flying insects in three separated groups of ecosystems forming the studied landscape manifests itself in many characteristics features. First of all, the third group consisting of forests and afforestations as well as of their ecotones, due to its generally the largest taxonomic abundance differs from the remaining groups. The habitats belonging to that group were found to have from 126 to 150 families of insects, i.e. by about 20% more insect families than other habitats. These differences are reflected in the values of the diversity coefficient calculated on the basis of the number of families and their density. In the ecosystems of the third group the diversity coefficient ranges from 2.9 to 3.3, whereas that in the first and second groups ranges from 2.4 to 2.7 and from 2.1 to 2.7, respectively. Mean insect densities are the highest in the second group (averagely 69.1 ind/100 m^3). The density in the third group is 45.0 ind/100 m^3, and its lowest values are in the habitats of the first group (averagely 38.1 ind/100 m^3).

4. Conclusions

1. It has been shown that the method of motorcycle net is perfectly suitable for monitoring of the resources entomofauna in the scale of the landscape due to a possibility of collecting samples in a required number of replications easily and rapidly.

2. Using the method of motorcycle net the density of flying insects in the typical agricultural landscape was estimated at 55.0 ind/100 m^3

3. It has been found that enrichment of a landscape in forest ecosystems has its influence on the increase of a qualitative and quantitative richness of flying insects, whereas the increase of the number of annual ecosystems of agricultural crops impoverishes landscape faunistically.

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