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SPIDERS AND MOSQUITOES OF THE ECOTONE OF ALDER FOREST (*CARICI ELONGATAE-ALNETUM*) AND OAK-PINE FOREST (*PINO-QUERCETUM*)

Attempts have been made to analyze communities of spiders and mosquitoes in the alder forest (*Carici elongatae-Alnetum*), oak-pine forest (*Pino-Quercetum*), and in the ecotone environment. The specific composition, abundance, and distribution of spiders and mosquitoes in the three environments investigated were analyzed from spring to autumn. Differences in the structure of spider and mosquito communities of the ecotone as compared with typical environments were recorded. Seasonal periods with simultaneous highest abundance of spiders and mosquitoes in these environments were analyzed. Dominating species were singled out, and the seasonal dynamics of their abundance was analyzed. On the basis of these data species of spiders – potential predators of mosquitoes – were singled out, as well as periods of their most intensive pressure on those preys.

The ecotone as a transitional zone between two or more different biocenoses has been defined already long time ago. Generally it is accepted that the composition of the ecotone biocenose comprises a number of organisms occurring in each of the edge biocenoses, and besides organisms characteristic for, and limited exclusively to the ecotone. Already in 1917 Cameron, investigating insects of pastures in England concluded that the bordering zone between the woodland and the meadow is settled by species of both the habitats.

Quite often the number of species and the density of populations of some of them is higher in the ecotone than in the surrounding biocenoses. The occurrence of this phenomenon, called the "edge effect" was recorded by a number of investigators (e.g. Beecher 1942, and Johnston and Odum 1956 for birds). A significant number of animals displays just the opposite tendencies – they stay in the depth of their habitats. It was recorded by Barick (1950) in deer and grouse from the Adirondack mountains.

Arnoldi (1957) drew attention to a different than the change of density reaction of animals on the ecotone environment. He concluded that very often in the ecotone we have not recorded changes in the abundance of a population but only changes in their activity as a reaction on particular conditions of the environment.

Odum (1959) supposes that the ecotone can have a particular significance in such places where man considerably transformed natural biocenoses. Then a mosaic-like composition of habitats, comprising a number of biocenoses, covering small areas, and numerous ecotones, is formed. It is reasonable to suppose that the ecotone together with its characteristic fauna and ecological phenomena will keep on increasing its significance.

The authors investigated the effect of the ecotone of the alder and oak-pine forests on the distribution and structure of the communities of spiders and mosquitoes.

STUDY AREA

Studies in spiders and mosquitoes were carried out from May to October 1965 in Kampinos Forest in the *Carici elongatae-Alnetum* and *Pino-Quercetum* ecotone (Fig. 1). Within this area field experiments on the preying of spiders upon mosquitoes were carried out.

In the wet environment of the alder forest (*Carici elongatae-Alnetum*) *Alnus incana* Moench. with a small participation of *Betula verrucosa* Ehrh. constituted the main part of the tree stand; the density of the canopy amounted to about 70%. Only a small number of species occurred in the shrub layer (undergrowth); of higher shrubs – *Frangula alnus* Mill. and *Padus avium* Mill. and of lower ones – *Ribes nigrum* L., *Rubus idaeus* L., *Salix rosmarinifolia* L., *Humulus lupulus* L. and *Solanum dulcamara* L. (two climbers). Besides some oaks (*Quercus robur* L.) which did not reach the level of tree layer also occurred in the undergrowth. There was no sharp line dividing the undergrowth and herb layer in view of various heights of shrubs from the undergrowth and luxuriant growth of herb vegetation. Of reedswamp plants the following occurred there: *Phragmites communis* Trin., *Scirpus silvaticus* L., *Iris pseudoacorus* L. and *Juncus effusus* L.; of grasses the following were recorded: *Deschampsia caespitosa* L., *Agrostis canina* L., *Poa trivialis* L.; and *Equisetum palustre* L., *Dryopteris thelypteris* (L.) A. Gray, *Urtica dioica* L. From the top of the highest shrubs

(e.g. *Frangula alnus*) to small plants creeping along the ground (e.g. *Ranunculus repens* L.) the space was filled more or less regularly with plants forming splendid conditions for species of web spinning spiders and supplying a suitable resting places for mosquitoes.

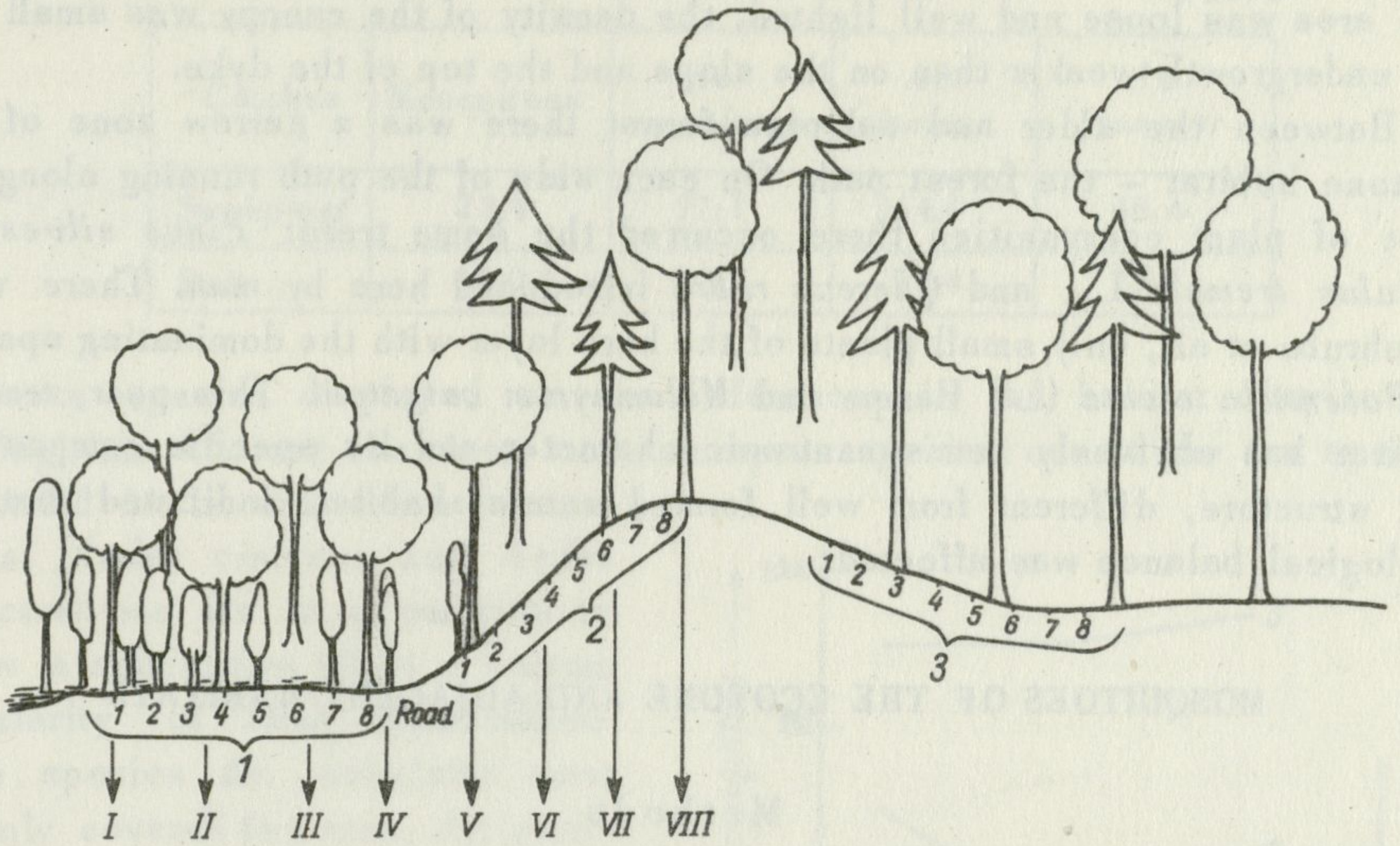

Fig. 1. Plan of the area
1, 2, 3 – stations, *I–VIII* – belts of the habitat (spiders), *1–8* – belts of the habitat (mosquitoes)

In the tree layer of the oak-pine forest growing on the slope of a dune dyke two species were dominating: *Pinus silvestris* L. and *Quercus robur;* besides there was a small admixture of *Carpinus betulus* L. and *Betula verrucosa.* In the undergrowth there occurred very rare, scattered in single shrubs *Corylus avellana* L., and *Sorbus aucuparia* L., *Evonymus verrucosa* Scop., and *Juniperus communis* L. In the herb layer the dominating species was *Pteridium aquilinum* (L.) Kuhn, and besides there also occurred *Polygonatum multiflorum* (L.) All., *Convallaria majalis* L., *Maianthemum bifolium* (L.) F. W. Schm., *Melica nutans* L., *Melampyrum vulgatum* Pers., *Rubus saxatilis* L., *Peucedanum oreoselinum* (L.) Moench., *Sedum maximum* Sut., *Hieracium* sp. L. Generally the herb layer was scarce and not uniform; there were small tufts of herbaceous plants, some turfs of mosses and bare patches.

Higher to the peak of the dune dyke there appeared first seedlings of *Tilia cordata* L., and then grown trees. The top itself was covered with *Quercо-Carpinetum* vegetation, with the oak, hornbeam, and lime in the tree layer; in the shrub layer hornbeams and limes, while in the herb layer *Galeobdolon luteum* Huds., *Aegopodium podagraria* L., and some mosses.

On the other side of the dune there occurred parts of the oak-pine forest

(*Pino-Quercetum*), without the undergrowth, with the species *Melampyrum vulgatum* dominating in the herb layer and parts of the oak-wood with *Quercus robur* in the tree layer; in the shrub layer *Juniperus communis* and in the herb layer *Festuca ovina* L. and here and there turfs of mosses. The tree stand of this area was loose and well lighted, the density of the canopy was small and the undergrowth weaker than on the slope and the top of the dyke.

Between the alder and oak-pine forest there was a narrow zone of the ecotone habitat – the forest path. On each side of the path running along the edge of plant communities there occurred the same trees: *Pinus silvestris*, *Populus tremula* L., and *Quercus rubra* introduced here by man. There were no shrubs at all, only small plants of the herb layer with the dominating species – *Potentilla erecta* (L.) Hampe and *Melampyrum vulgatum*. This poor, trodden habitat has obviously semisynantropic character and its specific composition and structure, different from well formed natural habitat, indicated that the ecological balance was affected.

MOSQUITOES OF THE ECOTONE AND ADJACENT HABITATS

Methods

In our investigation on mosquitoes the following three stations were chosen: a wet alder forest (station *1*), the slope of the dune (station *2*), and the area behind the dyke of the dune (station *3*), the two latter ones much drier than the first (Fig. 1). Two methods of capture were applied: sweep-net and bait-catching. At each of the three stations eight sweep-net samples were carried out (each sample was formed by 25 sweeps with a sweep-net over the herb layer and shrubs) along eight belts running from the depth of station *1* to the ecotone and from the ecotone to the depth of station *2* and *3*, covering in such a way the environment of the edge of both the biocenoses (Fig. 1).

15-minute human-bait captures were carried out before the sweep-net captures at each of the three stations. It should be accepted that in the study area the ecotone for mosquitoes, particularly active ones, is the station *2* as a transitional one between the wet area of *Carici-elongatae Alnetum* and the dry area of *Pino-Quercetum* in the centre of which station *3* was chosen.

In all 54 samples with baits (3,556 mosquitoes were collected) and 432 sweep-net samples (2,010 mosquitoes were collected) were carried out.

Results of the investigation

The space distribution of mosquitoes was uneven in the study area (Tab. I), and inactive mosquitoes (those captured by sweeping) were distributed in the area more unevenly than active mosquitoes (those captured by human-bait).

Uniformity of the quantitative distribution of mosquitoes in the given area, expressed by the values of standard deviation (in per cent)

Tab. I

Catches	Mosquitoes	*Ae. maculatus*	*Ae. cinereus*	*Ae. punctor*
Sweep-net	23.4	27.1	64.6	46.4
Bait	17.0	13.2	54.4	27.0

Separate species displayed certain differences in the habitat distribution. Taking into account the three most numerous species out of the ten species recorded in the area (*Aedes maculatus*, *Aedes cinereus* and *Aedes punctor*) we are in a position to draw a conclusion about a certain regularity of their distribution. The species *Ae. maculatus* most evenly covered the area, *Ae. punctor* covered less evenly and the least even distribution was recorded in the case of *Ae. cinereus*. The same order was preserved both in the case of active and inactive mosquitoes (Tab. I).

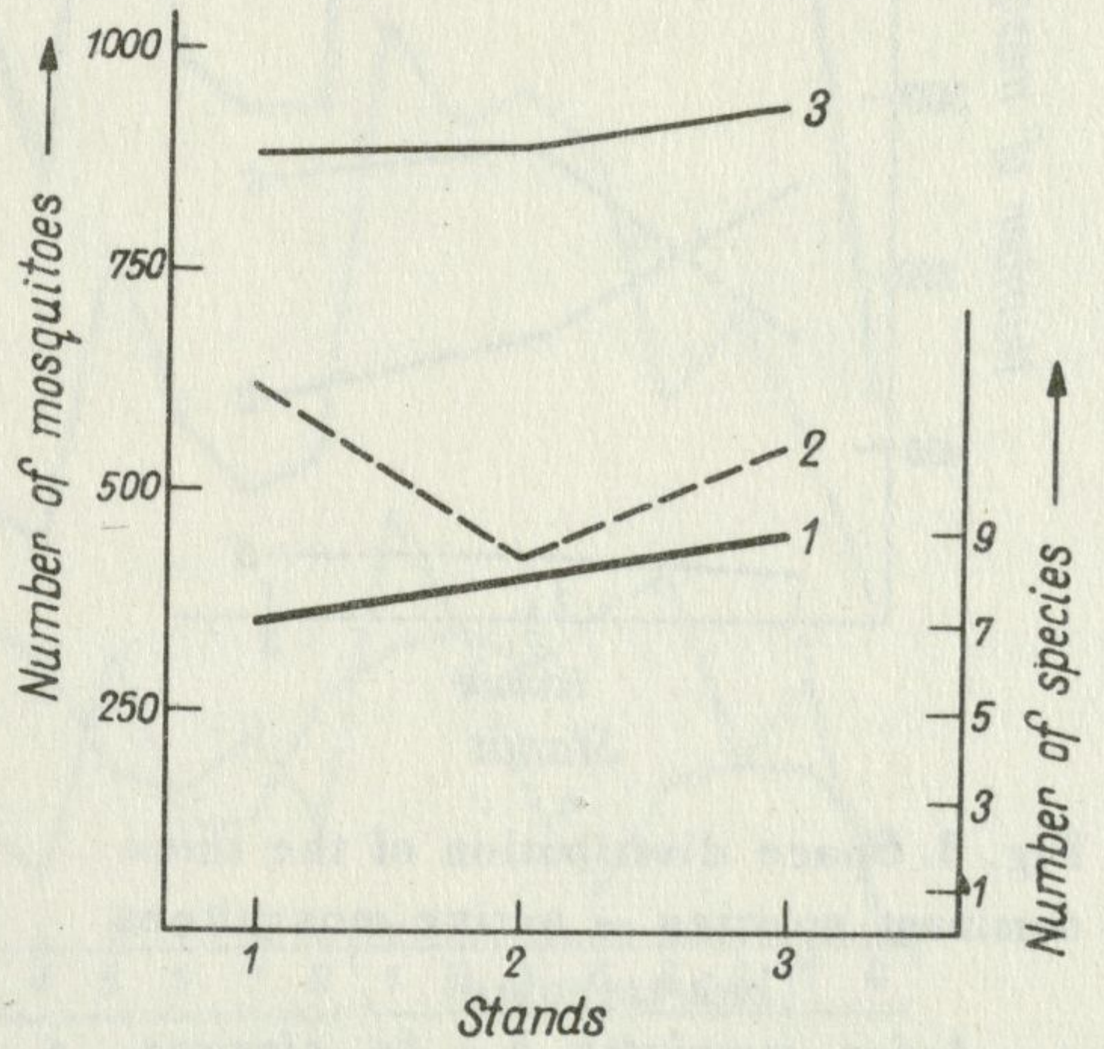

Fig. 2. Space distribution of mosquitoes
1 – number of species, *2* – sweep-net catches, *3* – bait-trapping

Individual stations differed from each other both in the number of species and in the number of mosquitoes (Fig. 2). The three most numerous species of mosquitoes were recorded at all the three stations. The remaining less numerous species dominated first of all at the drier stations (stations *2* and *3*). At station *1 Ae. flavescens*, *Anopheles claviger*, and *Culex pipiens* were not recorded; at station *2 C. pipiens* and *Theobaldia morsitans* were not recorded, while in the case of station *3* only one species (*Th. morsitans*) was not recorded.

The list of species recorded and their percentage occurrence in the mosquito fauna of the area may be presented as follows:

1. *Aedes* (*Ochlerotatus*) *maculatus* Meig. 54%,
2. *Aedes* (*Aedes*) *cinereus* Meig. 21%,
3. *Aedes* (*Ochlerotatus*) *punctor* Kirby 20%,
4. *Aedes* (*Ochlerotatus*) *annulipes* Meig. 3.5%,

5. *Aedes* (*Aedimorphus*) *vexans* Meig. 0.7%,
6. *Aedes* (*Ochlerotatus*) *excrucians* Walk. 0.6%,
7. *Aedes* (*Ochlerotatus*) *flavescens* Müller 0.1%,
8. *Anopheles* (*Anopheles*) *claviger* Meig. 0.04%,
9. *Culex pipiens* Linn. 0.04%,
10. *Theobaldia* (*Culicella*) *morsitans* Theob. 0.02%.

Stations were also differentiated in the number of mosquitoes. The active mosquito fauna was most numerous at station *3*, and slightly less numerous

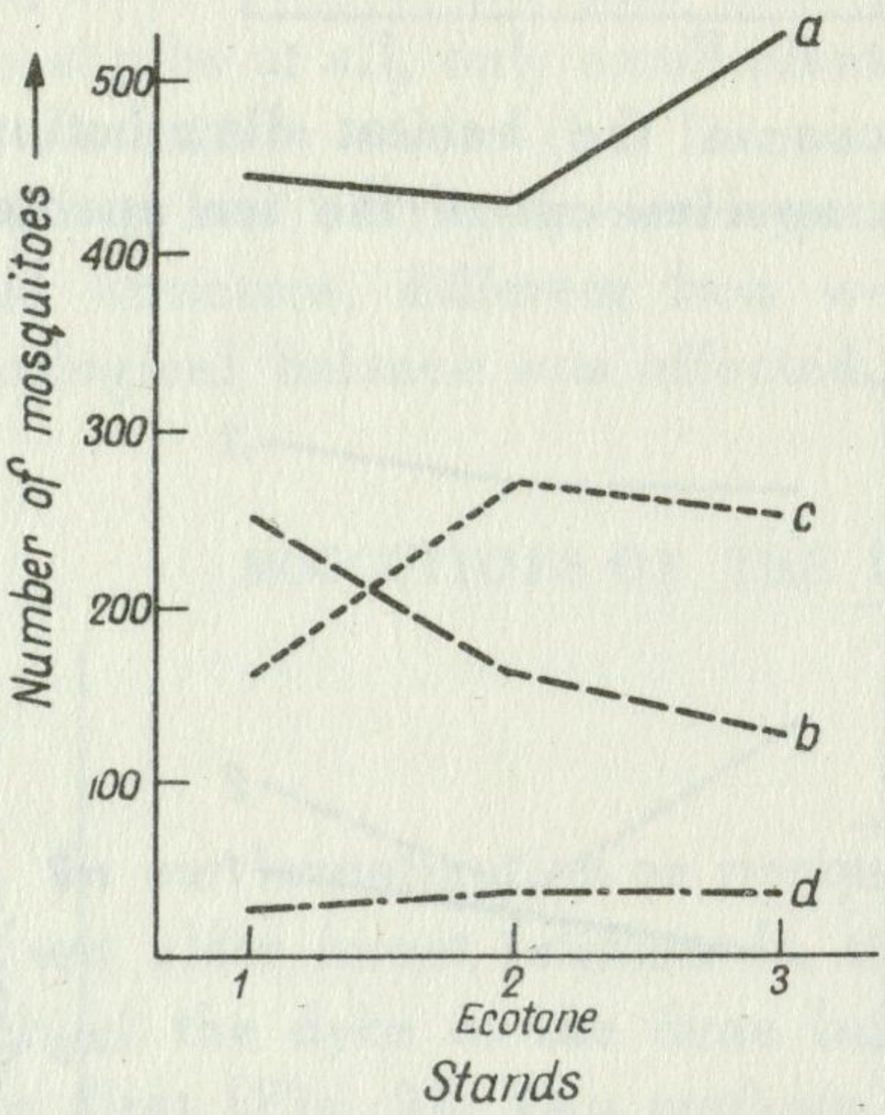

Fig. 3. Space distribution of the three dominant species – active mosquitoes (bait-trapping)
a – *Aedes maculatus*, *b* – *Ae. cinereus*, *c* – *Ae. punctor*, *d* – other species

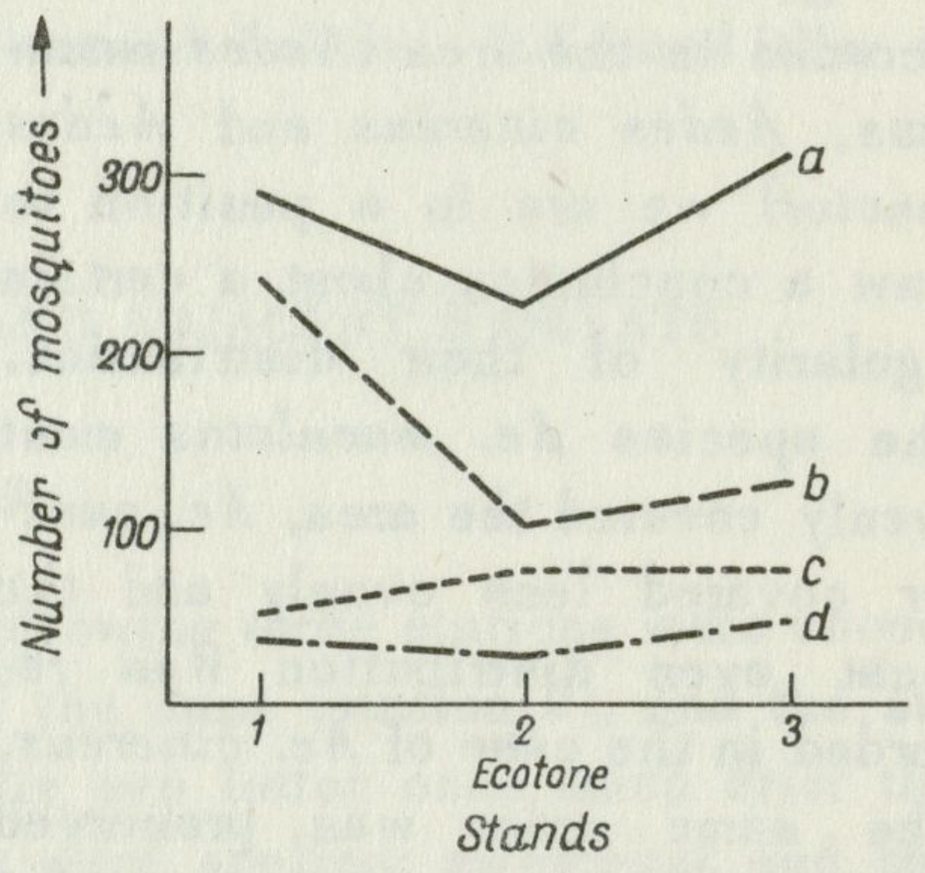

Fig. 4. Space distribution of the three dominant species – inactive mosquitoes (sweeping)
Explanations as in Fig. 3

at the other two stations. Inactive mosquitoes most clearly avoided the ecotone and were considerably more numerous in typical habitats (Fig. 2).

The space distribution of the three most numerous species was affected in an even more marked way by the ecotone. *Aedes maculatus*, the dominating species of this area, clearly preferred typical habitats (stations *1* and *3*), and avoided the ecotone which was evident both in the case of its active and inactive individuals (Figs. 3 and 4). Inactive individuals of *Ae. cinereus* behaved in a similar way (Fig. 4); active individuals of this species were most numerous in a wet habitat, and their numbers in dry habitats decreased with the increasing distance from the marsh. *Ae. punctor* on the other hand preferred dry habitats and in particular the ecotone one (Figs. 3 and 4).

For inactive mosquitoes we have obtained, by the study of the sweep-net captures from the different belts, more particular and detailed data about

their reaction to the ecotone (Fig. 5). The smallest number of inactive mosquitoes was recorded in the case of all the belts of station *2*. A detailed analysis concerning the three most numerous species showed certain specific

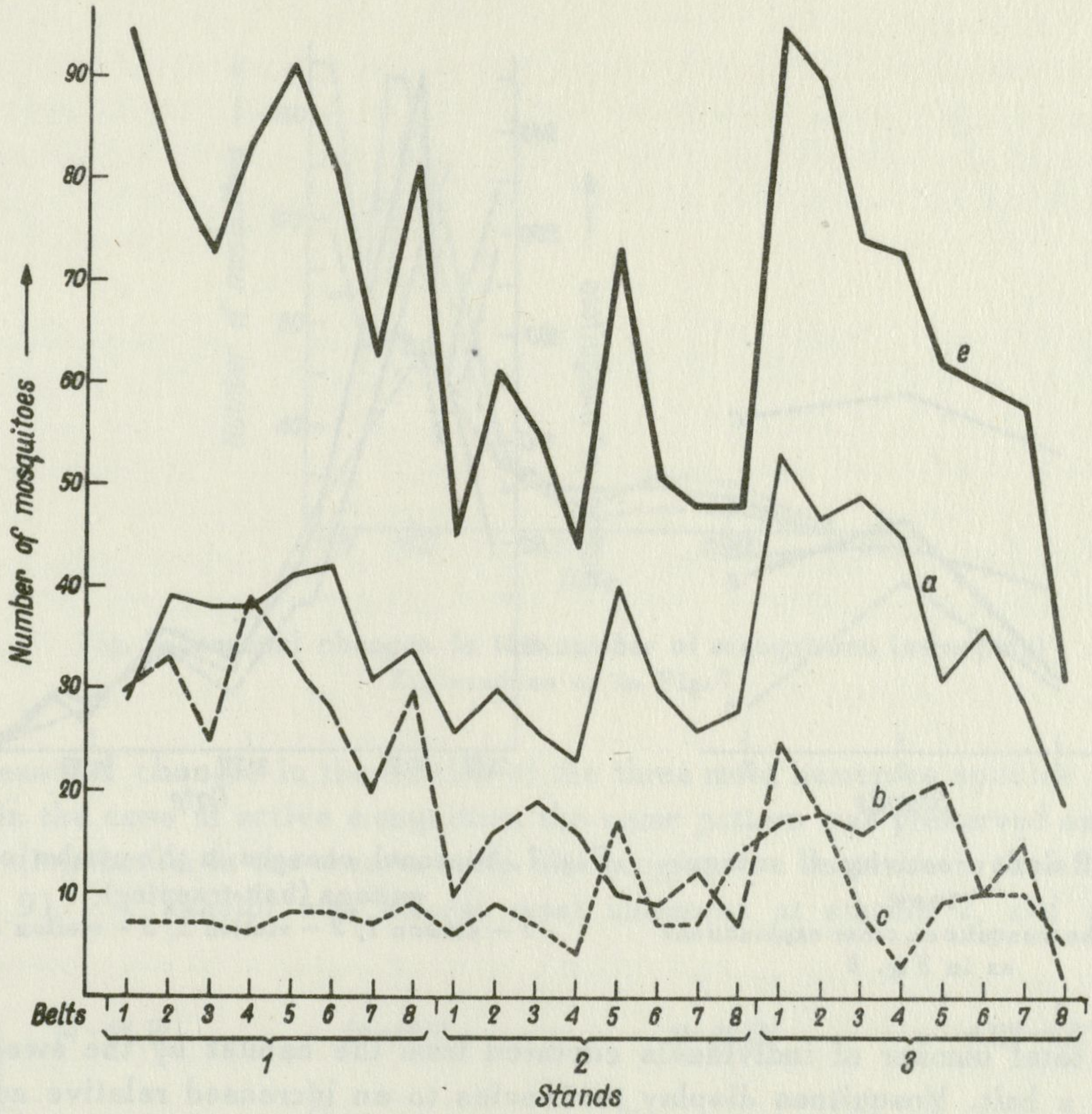

Fig. 5. Space distribution of inactive mosquitoes (sweeping) in the belts in the course of the entire season

e – all the mosquitoes, other explanations as in Fig. 3

differences. *Ae. cinereus* repeated the general pattern of the mosquito distribution, that is it was the least numerous species in all the belts of station *2*. The dominating species of the area – *Ae. maculatus* – was considerably less numerous in all the belts of station *2*, and in the adjoining to the road belts of station *1* (belts *7* and *8*). On the other hand *Ae. punctor* clearly avoided station *1* and dry areas, directly adjoining to this station (belts *1–4* of station *2*).

The results mentioned above underline in an even more deciding way

the negative reaction of *Ae. maculatus* and *Ae. cinereus*, and the positive reaction of *Ae. punctor* to the ecotone.

Interesting results can be obtained when we compare the relative activity of mosquitoes (Fig. 6) expressed by a percentage relation of active individuals

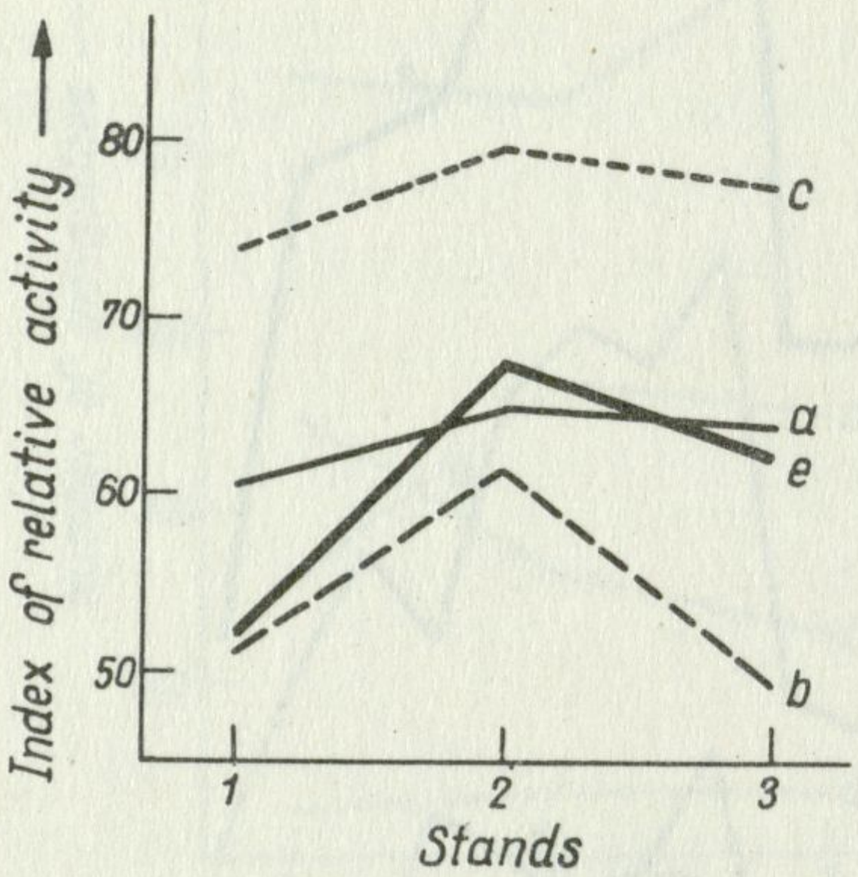

Fig. 6. Relative activity of mosquitoes
e – all the mosquitoes, other explanations as in Fig. 3

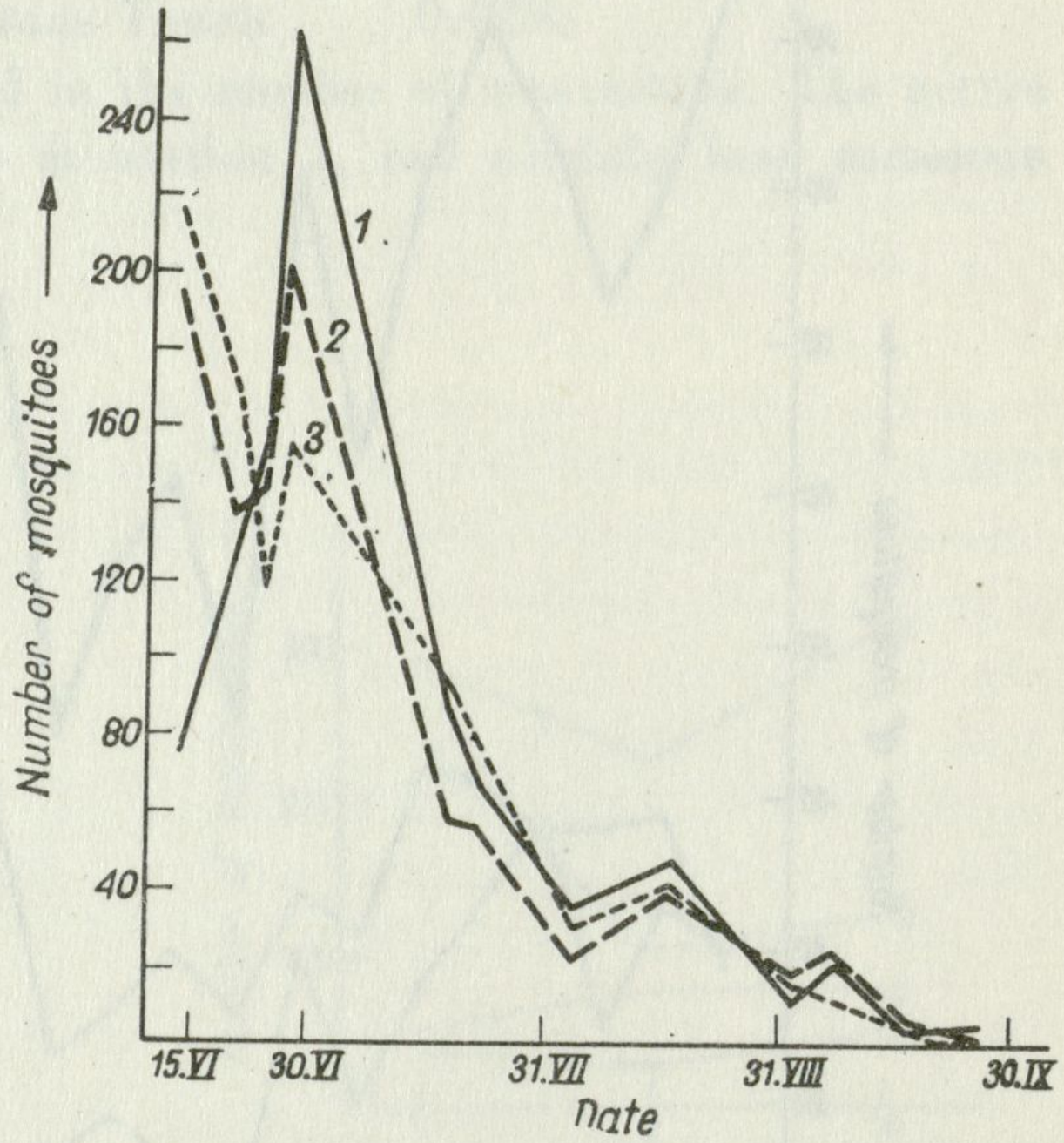

Fig. 7. Seasonal changes in the number of mosquitoes (bait-trapping)
1 – station *1*, *2* – station *2*, *3* – station *3*

to the total number of individuals captured from the habitat by the sweep-net and by a bait. Mosquitoes display tendencies to an increased relative activity in the ecotone. These tendencies are displayed by all the three most numerous species in spite of the specific differences in the level of their activity. A particularly significant increase in the relative activity in the ecotone was displayed by the species *Ae. cinereus*.

Seasonal changes in the number of mosquitoes at the stations examined generally occur in the first part of the year, in the period of their highest abundance (Figs. 7 and 8). The level of mosquito abundance recorded in the middle of June was similar (high) in both the ecotone and dry habitat (stations *2* and *3*), and different (low) at station *1*; this applied to both active and inactive mosquitoes. The increase in the number of mosquitoes recorded at the end of June concerned all the stations but was most clearly seen in the case of station *1*. At the ecotone the increase in the number of active mosquitoes was the smallest one in this period and the number of inactive mos-

quitoes remained at the same level. In spite of these differences, occurring in the period of the peak number of mosquitoes in the season, the progressive decrease in the number of mosquitoes in the second half of the summer and in autumn looked similarly at all the stations.

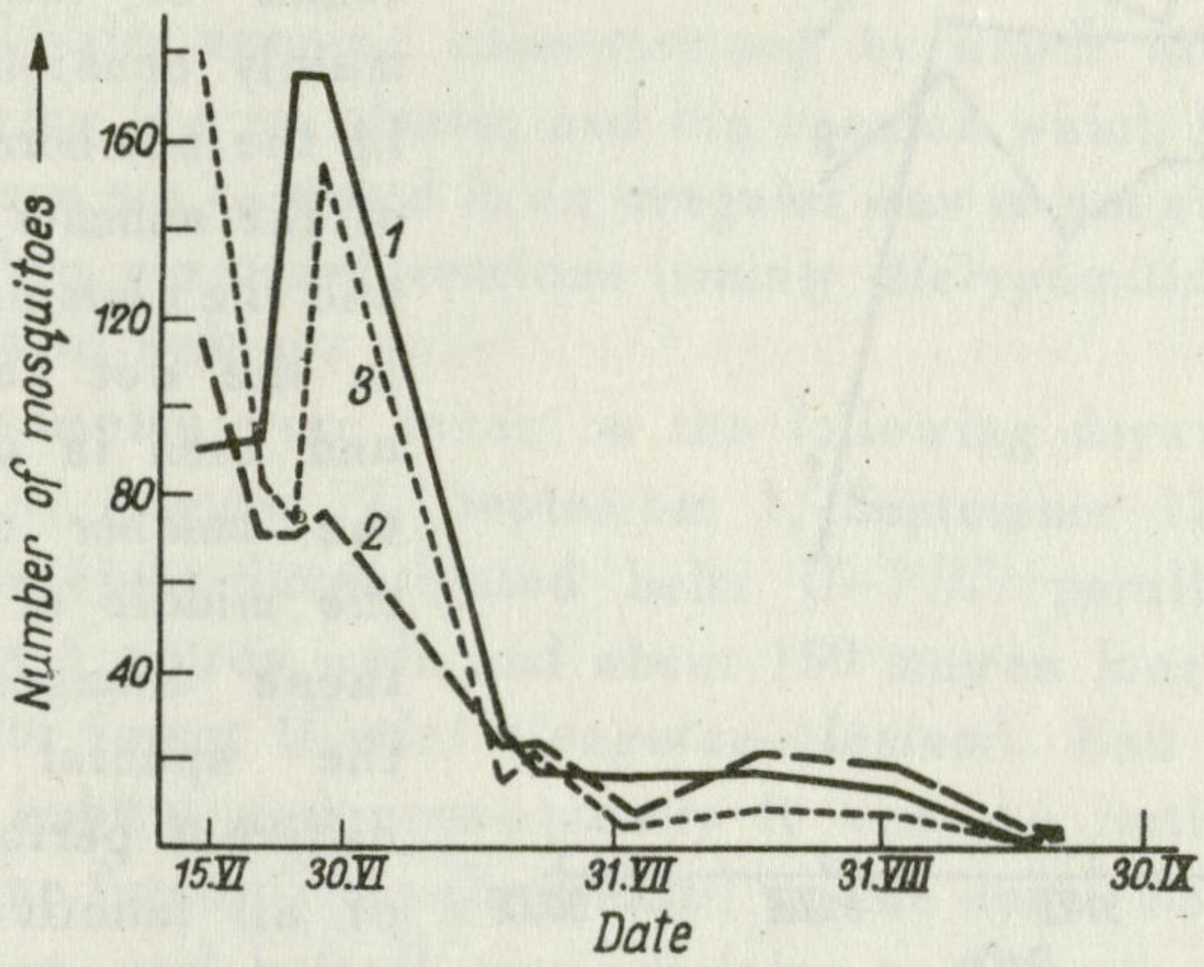

Fig. 8. Seasonal changes in the number of mosquitoes (sweeping)
Explanations as in Fig. 7

Seasonal changes in the number of the three most numerous species showed that in the case of active mosquitoes the same pattern was preserved as far as their distribution in the area in spite of a progressive decrease in their numbers (Fig. 9). *Ae. punctor* was always most numerous at station 2, and then at

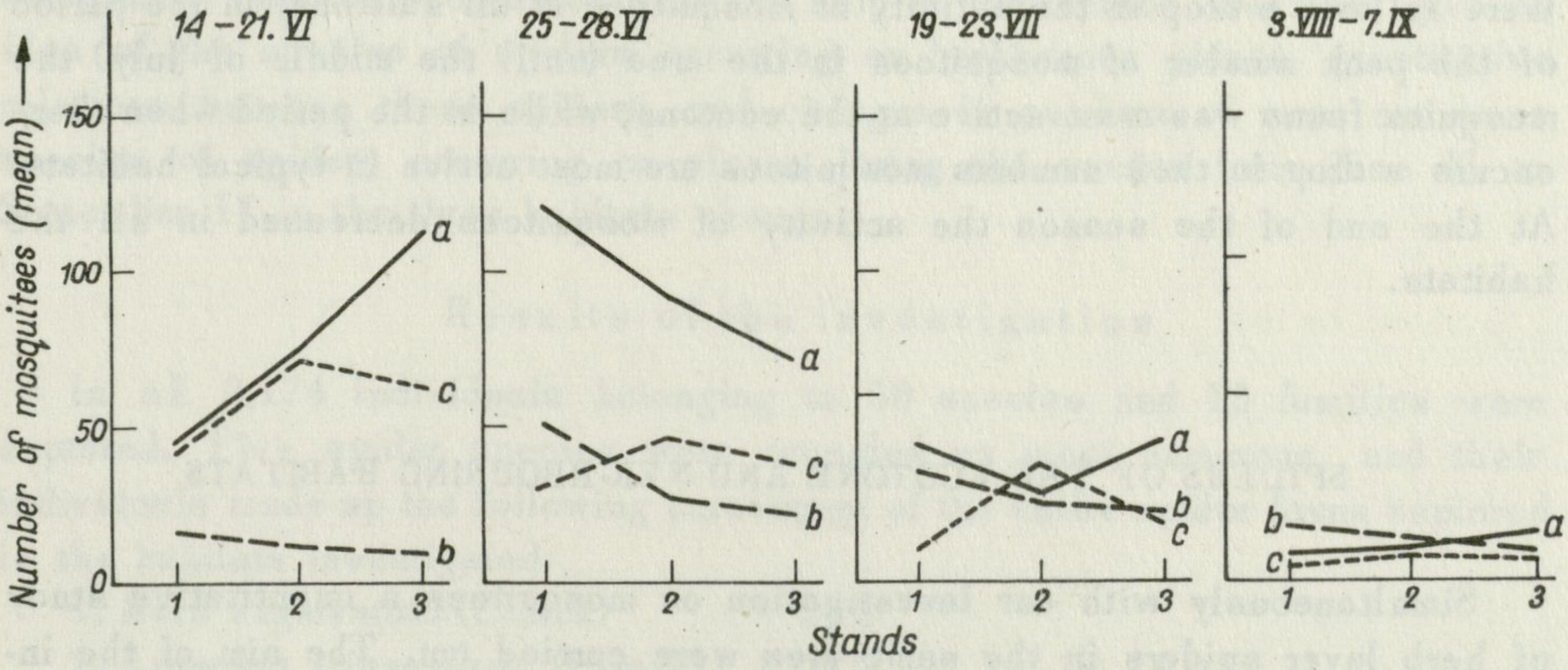

Fig. 9. Seasonal changes in the number of the three dominant species of mosquitoes (bait-trapping)
Explanations as in Fig. 3

station *3*. *Ae. cinereus* always preferred station *1*, and it was least numerous at station *3*. *Ae. maculatus* in different periods of the season was most numerous at station *1* or *3*, or both, but it never preferred the ecotone.

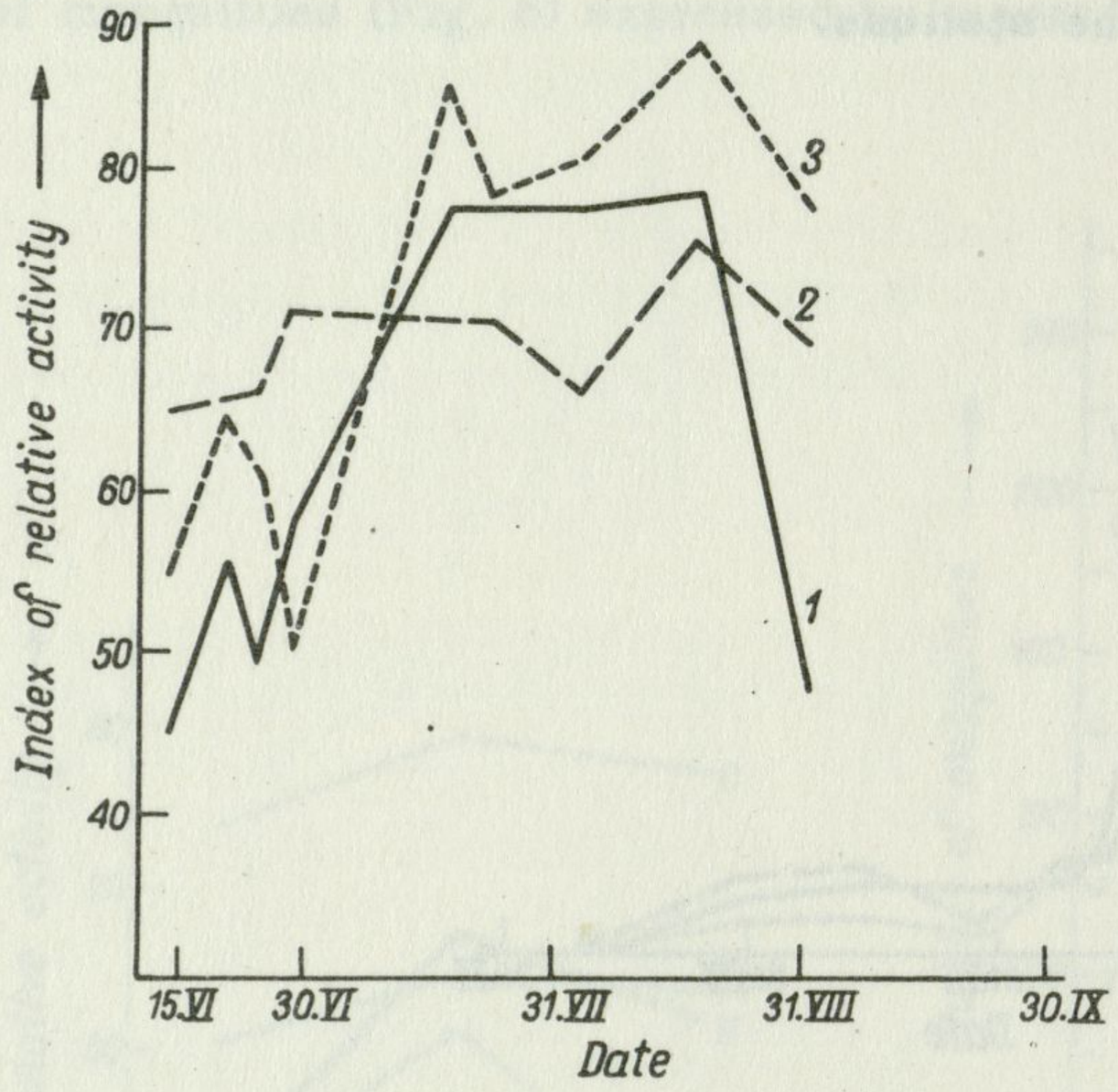

Fig. 10. Seasonal changes in the relative activity of mosquitoes
Explanations as in Fig. 7

Seasonal changes in the fauna of inactive mosquitoes mainly consisted in an increase in the numbers in the first half of the summer of *Ae. maculatus* and the clumping of *Ae. cinereus* in the wet habitat (station *1*), and then in a sudden drop in the number of mosquitoes in the middle of July. In spite of these changes the pattern of the spacial distribution, in different periods of the season, of all inactive mosquitoes and the three most numerous species corresponded with the pattern presented for the whole season (Fig. 5).

In the course of seasonal changes in the activity of mosquitoes (Fig. 10) we can single out a period of a relatively low activity of mosquitoes (until June 28); then there follows a period of an increase in the activity of mosquitoes at stations *1* and *3*, while there is no change in the ecotone (from June 28 to August 17). After this period there follows a drop in the activity of mosquitoes at all stations. In the period of the peak number of mosquitoes in the area (until the middle of July) the mosquito fauna was most active at the ecotone, while in the period when there occurs a drop in their numbers mosquitoes are most active in typical habitats. At the end of the season the activity of mosquitoes decreased in all the habitats.

SPIDERS OF THE ECOTONE AND NEIGHBOURING HABITATS

Simultaneously with our investigation on mosquitoes a quantitative study of herb layer spiders in the same area were carried out. The aim of the investigation was to find out what kind of communities are formed by spiders there and to estimate the effect of the ecotone habitat.

Methods

Spiders were captured with the entomological sweep-net, and the method applied was a suitable one in the area for estimates of quantitative relations between spider species occurring on plants of the herb layer. It should be stressed and reiterated here that the sweep-net captures only in a selective way (Łuczak 1958); species characterized by small size, and spreading their webs or staying low on plants, and big species which live on large webs spread between trees are captured in an irregular way or not at all. Such species will be excluded from our considerations (mainly *Micryphantidae* and *Argiopidae* – adult individuals of *Araneus* sp.).

Quantitative samples were taken on the following days: June 21, July 5, July 19, August 4, August 17, September 1, September 17 in two habitats divided each into eight investigated belts (*I–VIII*) parallel to each other (Fig. 1); each was 6 metres wide and about 150 metres long. Belts *I–IV* were chosen in the alder forest (*Carici elongatae-Alnetum*). Belt *I* was situated in the depth of the habitat and consequently it was the farthest one from the edge of the oak-pine forest (*Pino-Quercetum*) on the dune. Belts *II* and *III* were nearer to this edge, and belt *IV* was adjoining to the path separating the foot of the dune and the oak-pine forest growing on the slope from the marsh habitat. Belts *V–VIII* were chosen in the oak-pine forest. They ran from the foot of the dune (belt *V* just behind the path separating the two plants communities) up the hill on the slope (belts *VI* and *VII*); belt *VIII* was marked out on the dune in the proximity of the top. Belts *IV* and *V* were treated as the most ecotone habitat for spiders. In each of the belts a sample was taken consisting of 100 strokes with the sweep-net (material was gathered in four series – each one containing 25 strokes in order not to destroy spiders falling into the sweep-net). Materials obtained with the help of the method described give an idea of the species of spiders occurring on herbaceous plants, quantitative relations between these spiders, and changes in numbers of more numerous species of spiders occurring on plants during the season from June 21 to September 17 in the three habitats chosen.

Results of the investigation

In all 2,174 individuals belonging to 58 species and 13 families were captured. Five spider species were recorded as most numerous, and their individuals made up the following percentage of the entire spider fauna captured in the habitats investigated:

1. *Meta segmentata* (Clerck) 23%
2. *Linyphia triangularis* (Clerck) 17%
3. *Pachygnatha listeri* Sund. 14%
4. *Theridion ovatum* (Clerck) 7.5%
5. *Bathyphantes nigrinus* (Westr.) 5.0%.

Spiders of the alder forest (*Carici elongatae-Alnetum*)

Disregarding here species represented by single individuals, the following spider species were recorded as occurring on plants in the herb layer of the alder forest: *Meta segmentata*, *Tetragnatha montana* Sim., *Pachygnatha clercki* Sund., *Pachygnatha listeri* Sund., *Linyphia triangularis*, *Linyphia clathrata* Sund., *Floronia bucculenta* (Clerck), *Bathyphantes nigrinus*, *Gongylidium rufipes* (Sund.), *Theridion tepidariorum simulans* Thor., *Theridion ovatum*, *Episinus truncatus* Latr., *Micrommata virescens* (Clerck), *Xysticus ulmi* (Hahn), *Clubiona lutescens* Westr., *Dolomedes fimbriatus* (Clerck), very young individuals of *Araneus cornutus* Clerck and *Araneus cucurbitinus* Clerck, young individuals from the genus *Clubiona* belonging to the species *Clubiona lutescens* Westr., *Clubiona phragmitis* C.L. Koch, or *Clubiona germanica* (Thor.) (two adult individuals from the last two species were recorded), and a lot of young individuals from the family *Linyphiidae* belonging to different species.

Percentage participation of individuals of spiders from the dominating species in the belts of the environment chosen (all the individuals of the given species capture = 100%)

Tab. II

Species	Belts							
	I	*II*	*III*	*IV*	*V*	*VI*	*VII*	*VIII*
Meta segmentata	11.7	15.1	17.5	15.3	12.1	8.7	7.9	11.7
Tetragnatha montana	32.2	30.5	23.7	11.9	–	–	1.7	–
Pachygnatha listeri	18.4	23.5	24.5	20.1	10.7	2.8	–	–
Linyphia triangularis	3.3	11.2	9.8	31.3	12.5	12.0	4.6	15.3
Bathyphantes nigrinus	14.6	39.8	1.9	41.8	1.9	–	–	–
Theridion ovatum	3.6	10.3	7.8	17.0	16.4	21.8	10.9	12.2
Philodromus rufus	–	–	4.1	9.6	24.7	19.2	20.5	21.9
Clubiona lutescens	30.0	37.5	10.0	5.0	7.5	–	7.5	2.5
Dolomedes fimbriatus	14.3	23.2	16.1	8.9	10.7	12.5	10.7	3.6

Only in the alder forest the species *T. montana*, *P. clercki*, and *G. rufipes* were captured. They are characteristic species for this type of habitat. *T. montana* occurs most abundantly in belts *I–III*, typically marshy ones, and consequently more damp and with higher plants (Tab. II). *P. clercki* (adult in-

dividuals) occurs in too small a number of individuals for the analysis of distribution along the belts, although it seems that their distribution is more regular in all the four belts chosen in the alder forest than the distribution of *T. montana*. *G. rufipes* was also captured in small numbers of individuals occurring mainly in belts *I–III*.

The general relative abundance of spiders constantly increased in the course of the season from the lowest level in June to the highest one in September (Tab. III). This is a phenomenon well known from numerous arachnological works (among others Łuczak 1959). In August and in September higher numbers of spiders were recorded in the alder forest than in the oak-pine forest (Tab. III). What strikes in the structure of spider communities is a considerable quantitative preponderance of web spiders on herbaceous plants; their individuals make up 68% of all the individuals captured.

Number of species and abundance of spiders in the alder forest and in the oak-pine forest in different periods of the season

Tab. III

Date	Number of species		Number of individuals		
	alder forest	oak-pine forest	alder forest	oak-pine forest	Σ
21 VI	17	14	104	71	175
5 VII	18	22	106	124	230
19 VII	14	19	169	155	324
4 VIII	14	17	173	107	280
17 VIII	14	9	271	120	391
1 IX	14	23	238	152	390
17 IX	21	22	292	92	384
Total	34	33	1,353	821	2,174

As it usually happens in the case of investigation on animal communities it was concluded that the general abundance depends on the number of dominating species. To dominating web species belong in the alder forest *M. segmentata* and *L. triangularis*, while to subdominants – *T. montana*, *T. ovatum*, *B. nigrinus* and as far as wandering species are concerned *P. listeri* and *C. lutescens*. As it is evident from the above the dominating species (except *T. montana*) in the alder forest do not coincide with species characteristic for this habitat; this phenomenon has been well known to ecologists investigating animal communities for a long time. Dominating species belong to more eurytopic species.

M. segmentata is considerably more numerous in the alder forest than in the oak-pine forest and its participation in the spider community is more significant there, while the same applies to *L. triangularis* only in belt *IV* (Tab. II). The peak number of both these species occurs in different belts (*M. segmentata* in belt *III*), and in different periods of the season (Fig. 11

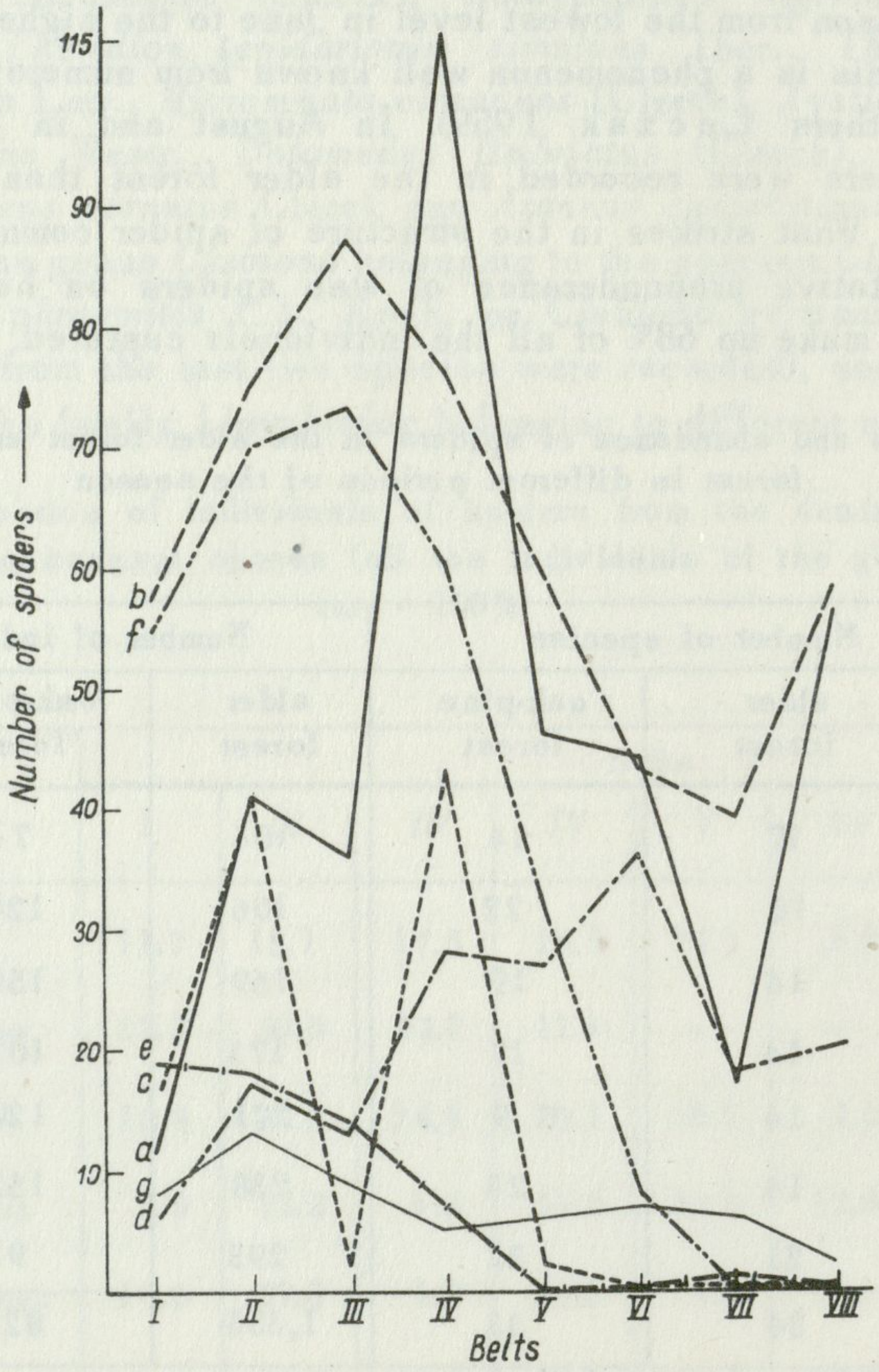

Fig. 11. Space distribution of dominant web spiders in different belts of the alder forest and oak-pine forest

a – Linyphia triangularis, b – Meta segmentata, c – Bathyphantes nigrinus, d – Theridion ovatum, e – Tetragnatha montana, f – Pachygnatha listeri, g – Dolomedes fimbriatus

and 12). In the course of the growth of individuals from these species, they become bigger and spread their webs in higher parts of the herb layer, and consequently they are more numerous in the sweep-net. This is another proof of the selectivity of the method which is suitable for an estimate of the relative abundance of species distributed higher on plants of the herb layer and

not just above the ground. The intensity of their occurrence on higher levels happens in the case of *M. segmentata* in August, and in the case of *L. triangularis* in July in both plant communities investigated. Individuals of *T. ovatum*

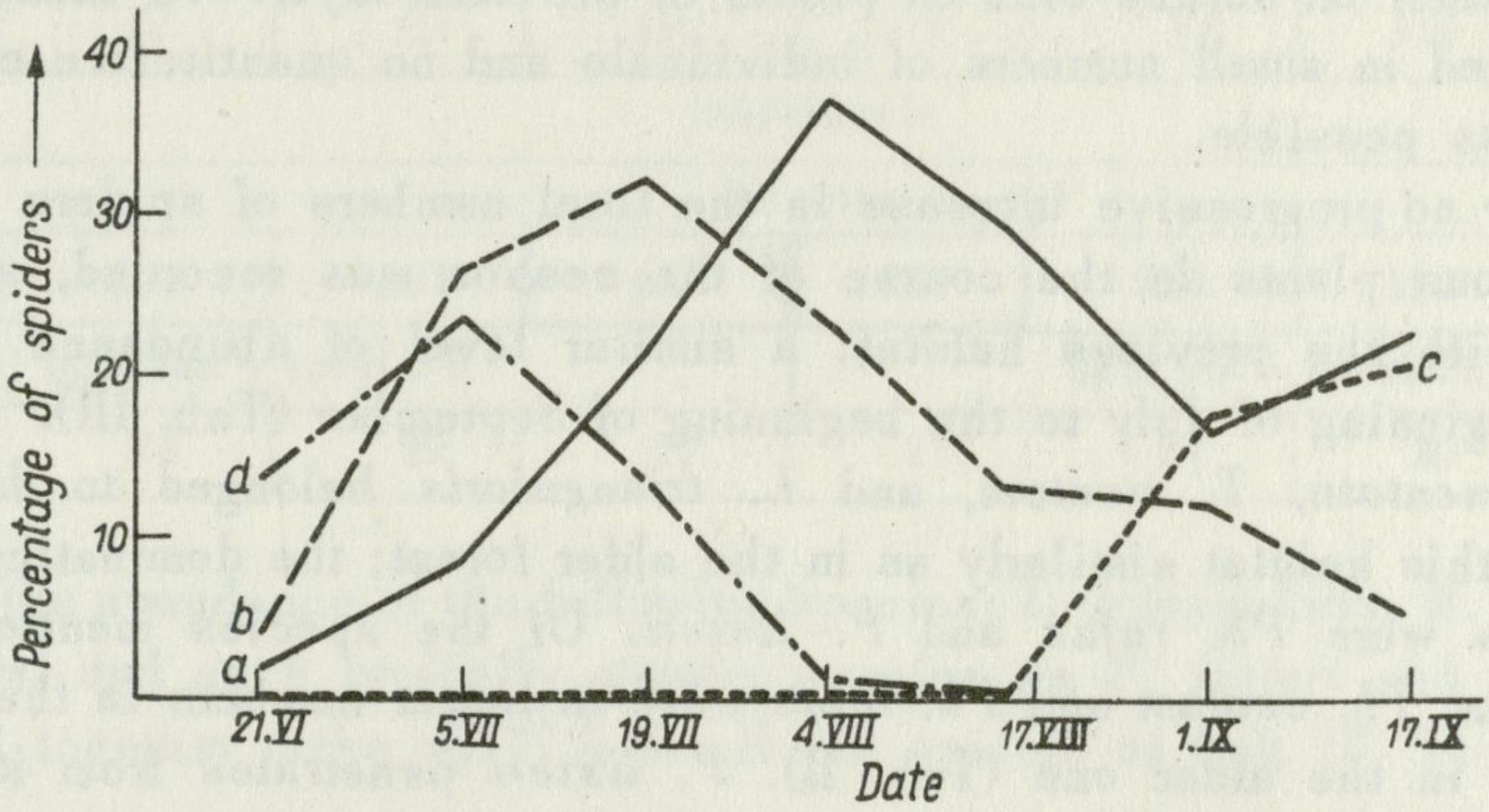

Fig. 12. Changes in the domination of web spiders in the alder forest
a – Linyphia triangularis, b – Meta segmentata, c – Bathyphantes nigrinus, d – Theridion ovatum

are more numerous in the oak-pine forest and their participation in the spider community is more significant there (Tab. II), while the period of its peak number lasts from the second half of June to the middle of July. *B. nigrinus* clearly and decidedly dominates only in September, while *T. montana* (adult individuals) in June and July. Within the community of web spiders occurring on plants of herb layer a tendency was observed to a domination change in the season and to the occurrence of the highest numbers of various species in different periods of the season (Fig. 12).

Spiders of the oak-pine forest (*Pino-Quercetum*)

The oak-pine forest on the dune has not such luxuriant growth of the herb layer as the habitat discussed above, and because of that it has a less numerous community of spiders occurring on herb layer plants. The number of spiders captured in the samples makes up 60% of their numbers in the alder forest. The following species occur here (except those species from which only single individuals were captured): *Araneus cucurbitinus, Zilla diodia* (Walck.), *Araneus sturmi* (Hahn), *Mangora acalypha* (Walck.), *Meta segmentata, Pachygnatha listeri, Linyphia triangularis, Linyphia clathrata, Theridion ovatum, Theridion bimaculatum* (L.), *Episinus truncatus, Dictyna* sp., *Micrommata virescens, Xysticus ulmi, Philodromus rufus* Walck., *Oxyptila brevipes* (Hahn), *Evarcha falcata* (Clerck), *Clubiona lutescens, Anyphaena accentuata* (Walck.), *Dolomedes fimbriatus.*

Of all the species mentioned in both the habitats (i.e. more abundant) – 11 belong to species occurring in both the habitats. Only in the oak-pine forest individuals from *Dictyna* sp., *A. sturmi*, *T. bimaculatum*, *E. falcata*, and *A. accentuata* were captured. The last species mentioned is a species occurring rather on shrubs than on plants of the herb layer. All these species were captured in small numbers of individuals and no quantitative ecological analysis was possible.

However no progressive increase in the total numbers of spiders occurring on herbaceous plants in the course of the season was recorded, as it was the case with the previous habitat; a similar level of abundance prevailed from the beginning of July to the beginning of September (Tab. III).

M. segmentata, *T. ovatum*, and *L. triangularis* belonged to dominating species in this habitat similarly as in the alder forest; the dominating wandering species were *Ph. rufus* and *P. listeri*. Of the species mentioned only subdominants *Th. ovatum* and *Ph. rufus* were in larger numbers in the oak-pine forest than in the alder one (Tab. II). *P. listeri* penetrates from its typical habitat, i.e. the alder forest into belts *V* and *VI* in the oak-pine forest (Tab. II).

No seasonal changes in the domination of separate species can be discerned in the spider community. This habitat is not so suitable for spiders as the alder forest in view of the patchy distribution of plants of the herb layer and because of that a less characteristic and less numerous community of spiders is formed. 76% of them are individuals from web species.

Spiders of the ecotone

Attempting to describe the relations between spider species in the ecotone, that is, in the case of our investigation of spiders, two belts – *IV* within the alder forest and *V* within the oak-pine forest – neighbouring each other and divided by a path, we have to stress first of all that it forms an area affected by both the spider communities. Conditions prevailing in the ecotone, different from conditions existing in typical habitats, render the habitat accessible only for some species, but from the other side it can be better for certain species than even typical habitats. It can be supposed that it is a habitat tolerated by a lot of species from typical habitats to which the surplus of the populations of these species can emigrate.

In the ecotone investigated there can be observed the phenomenon of the occurrence of a not smaller number of species than in the alder and oak-pine forest, and a higher total number of spiders as compared with typical habitats (Tab. IV); belt *IV* (from the side of the alder forest) is much more abundantly habitated by spiders than belt *V* (from the side of the oak-pine forest) (Tab. IV).

The higher number of spiders in the ecotone in belt *IV* (Fig. 13) is the

Total abundance of spiders in the belts chosen

Tab. IV

Alder forest				Oak-pine forest			
belts							
I	*II*	*III*	*IV*	*V*	*VI*	*VII*	*VIII*
individuals							
			ecotone				
248	354	331	419	267	204	150	201
species – total 34				species – total 33			
21	24	29	27	27	21	30	23

result of the abundance of the following species: *L. triangularis*, *M. segmentata*, *T. ovatum*, and such typically marshy species as *P. listeri* and *B. nigrinus*, which all together make up 77% of all the spiders of belt *IV*. In the ecotone

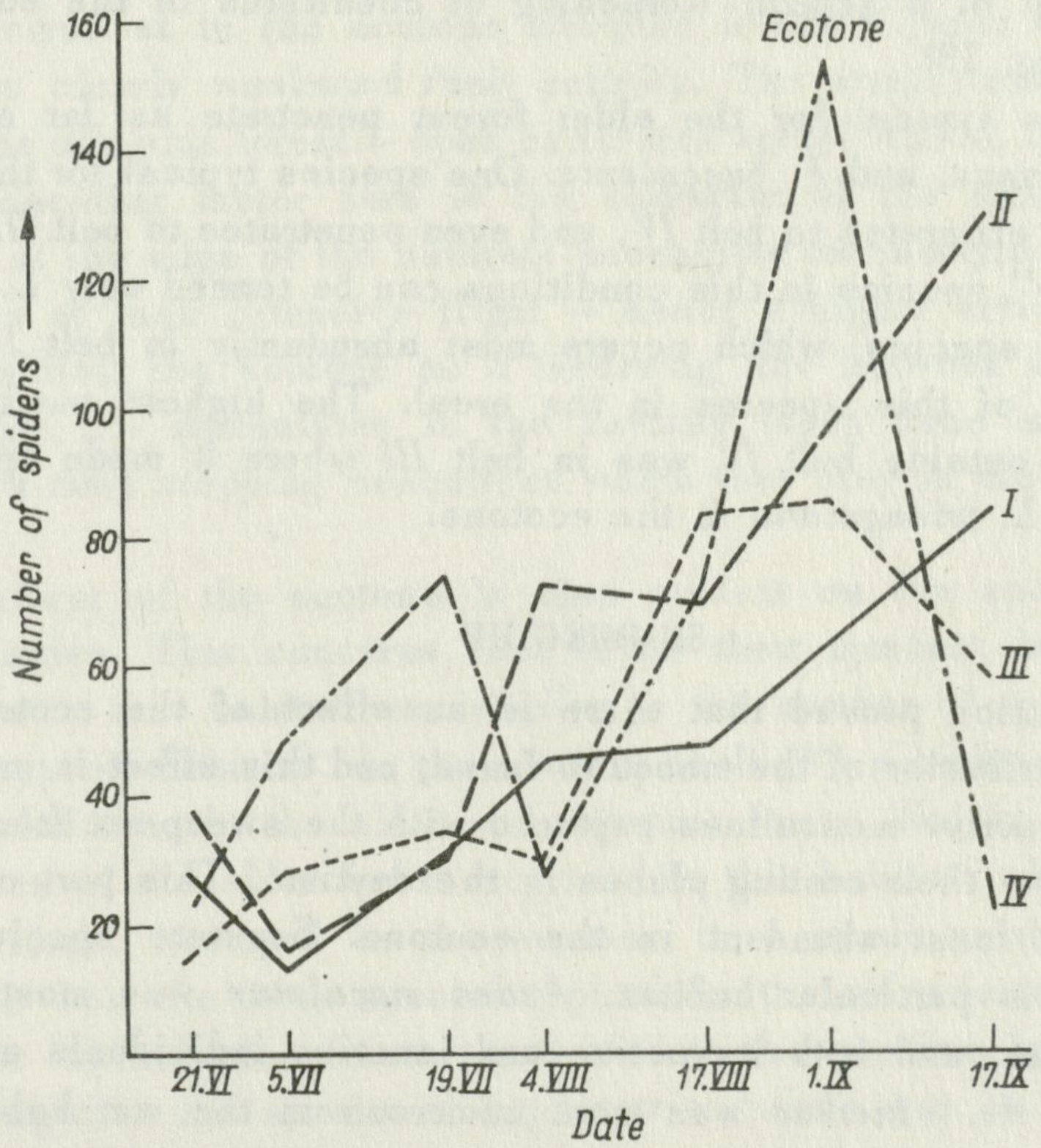

Fig. 13. The course of changes in the total number of spiders in belts of the alder forest (belts *I*, *II*, *III*), and in the ecotone (belt *IV*)

from the side of the oak-pine forest (belt *V*) the higher number of spiders is the result of the presence of numerous individuals of *L. triangularis*, *M. segmen-*

tata, and the expansive marshy species *P. listeri*; they make up all together 62% of the individuals of this belt.

The course of changes in numbers of spiders in the four belts of the alder forest investigated (Fig. 13) besides indicating a gradual increase in the number od spiders occurring on plants in the period from June to September, also indicates differences in numbers of spiders in separate belts of the habitat – a gradual increase in the numbers of spiders from the center of the habitat (belt *I*) to the ecotone (belt *IV*).

An interesting phenomenon is also the fact that in the period of the first half of September there is a change in the quantitative relations of spiders in the ecotone as compared with the central part of the habitat in the alder forest. In both the belts of the central part (belts *I* and *II*) there occurs in this period an increase in numbers of spiders, while in the ecotone belt (belt *IV*) a considerable drop in the numbers, which can also be observed with a much weakened intensity in belt *III* adjoining the ecotone zone. It seems that the fact that spiders emigrate from the ecotone to the depth of the alder forest may be the result of a general worsening of conditions in the edge habitat in this period (Fig. 13).

Three species typical for the alder forest penetrate as far as belt *V*: *P. listeri*, *B. nigrinus*, and *F. bucculenta*. One species typical for the oak-pine forest, *Ph. rufus*, emigrates to belt *IV*, and even penetrates to belt *III* (Tab. II).

The "ecotone" species in this conditions can be termed only *L. triangularis*, an eurytopic species, which occurs most abundantly in belt *IV* (31% of the total number of this species in the area). The highest number of that species recorded outside belt *IV* was in belt *III* where it made up only 50% of the number of *L. triangularis* in the ecotone.

SUMMING UP

The investigation proved that there is an effect of the ecotone habitat on the space distribution of the mosquito fauna, and this effect is more evident in the case of inactive mosquitoes captured with the sweep-net from the herb layer and shrubs – their resting places in the daytime. This part of the mosquito fauna was least abundant in the ecotone. Separate species reacted differently to this particular habitat. *Aedes maculatus* was most numerous in typical habitats, and both its active and inactive individuals avoided the ecotone habitat. *Ae. cinereus* was most numerous in the wet habitat of the alder forest, and much less numerous in the remaining two habitats, while the inactive individuals of this species most clearly avoided the ecotone. On the other hand *Ae. punctor* can be treated as a species preferring dry and ecotone habitats. The individuals of this species were most numerous in this type of habitats, while the active ones were particularly abundant in the ecotone. Inactive individuals of *Ae. punctor* avoided even the ecotone habitat adjoining

directly to the wet station *I*. The investigations carried out previously in other areas of Kampinos Forest showed that this species, together with *Ae. vexans*, is a dominating species of the ecotone habitat occurring between the oak-pine forest and open dune areas (Dąbrowska-Prot 1959, 1961, 1962). A similar position was recorded in the ecotone oak-pine forest – open cultivated areas, where investigations were carried out simultaneously with the investigation forming the basis of the present paper. Within this area *Ae. vexans* occurred exclusively in the ecotone, and *Ae. punctor* increased considerably its abundance in the ecotone in comparison with the depth of oak-pine forest.

The differences in the reaction of separate species to the ecotone habitat discussed above remained in the course of the entire season in spite of changes in the total number of mosquitoes in the area, and in their numbers in the habitats investigated.

It is interesting that the ecotone habitat investigated was characterized by a greater activity of mosquitoes; similarly each of the three most numerous species was more active in this habitat. This does not correspond with the results arrived at in the ecotone oak-pine forest – open dune areas, where mosquitoes clearly weakened their activity. The same result was obtained in the ecotone oak-pine forest – open cultivated areas. And so it can be concluded that the deciding factor here is the character of the ecotone. The ecotone occurring at the edge of the habitats accessible for mosquitoes in the daytime is an area of their intensive flight – hence a higher activity of mosquitoes in this habitat; the ecotone as a bordering line between a forest and areas inaccessible for mosquitoes in the daytime (open dune areas or cultivated areas) is a zone stopping mosquitoes where they stay in the daytime in resting places.

The effect of the ecotone is also evident on the space distribution of spider species. This concerns first of all their numbers because the number of species in this habitat was similar to the number of species occurring in both the typical habitats. In the ecotone (belt *IV*) a higher number of spiders was recorded than in the alder and oak-pine forest. Mainly eurytopic species, and species of the alder forest occurred in this habitat; while species of the oak-pine forest occurred in the ecotone in a small number of individuals. Individuals from the three species typical for the alder forest and one species typical for the oak-pine forest penetrated to the ecotone. In the conditions of our investigation the species *Linyphia triangularis* was an ecotone species – it occurred most abundantly in this habitat.

An increase in number of spiders was recorded from June to the beginning of September in the entire habitat of the alder forest, and in the ecotone from the side of the alder forest. However separate belts in these habitats differed in the course of the entire season in the level of the abundance of spiders. The number of spiders increased gradually from the smallest one in the center

of the alder forest to the highest one in the ecotone. In the first half of September there followed a change in the quantitative relations of spiders; there occurred a decrease in the number of spiders in the ecotone and a simultaneous increase in the center of the alder forest.

In the alder forest spiders are a group of predators occurring very abundantly (they are particularly numerous in the ecotone habitat at the edge of the alder forest) and because of that they can play in this habitat an important role as predators on mosquitoes. There are no direct data as far as this problem is concerned beside the fact of many spiders preying on mosquitoes, and we can stress the importance of spiders only on the basis of the phenomenon of the co-occurrence of mosquitoes and spiders in the habitat, and from seasonal changes in numbers of both the groups of animals.

The period of the peak number of mosquitoes and then their decrease in this habitat coincided with the period of an increase in numbers of the three dominating web spiders occurring on plants: *Meta segmentata*, *Linyphia triangularis*, and *Theridion ovatum* (Fig. 14). There are comments in the arachnolo-

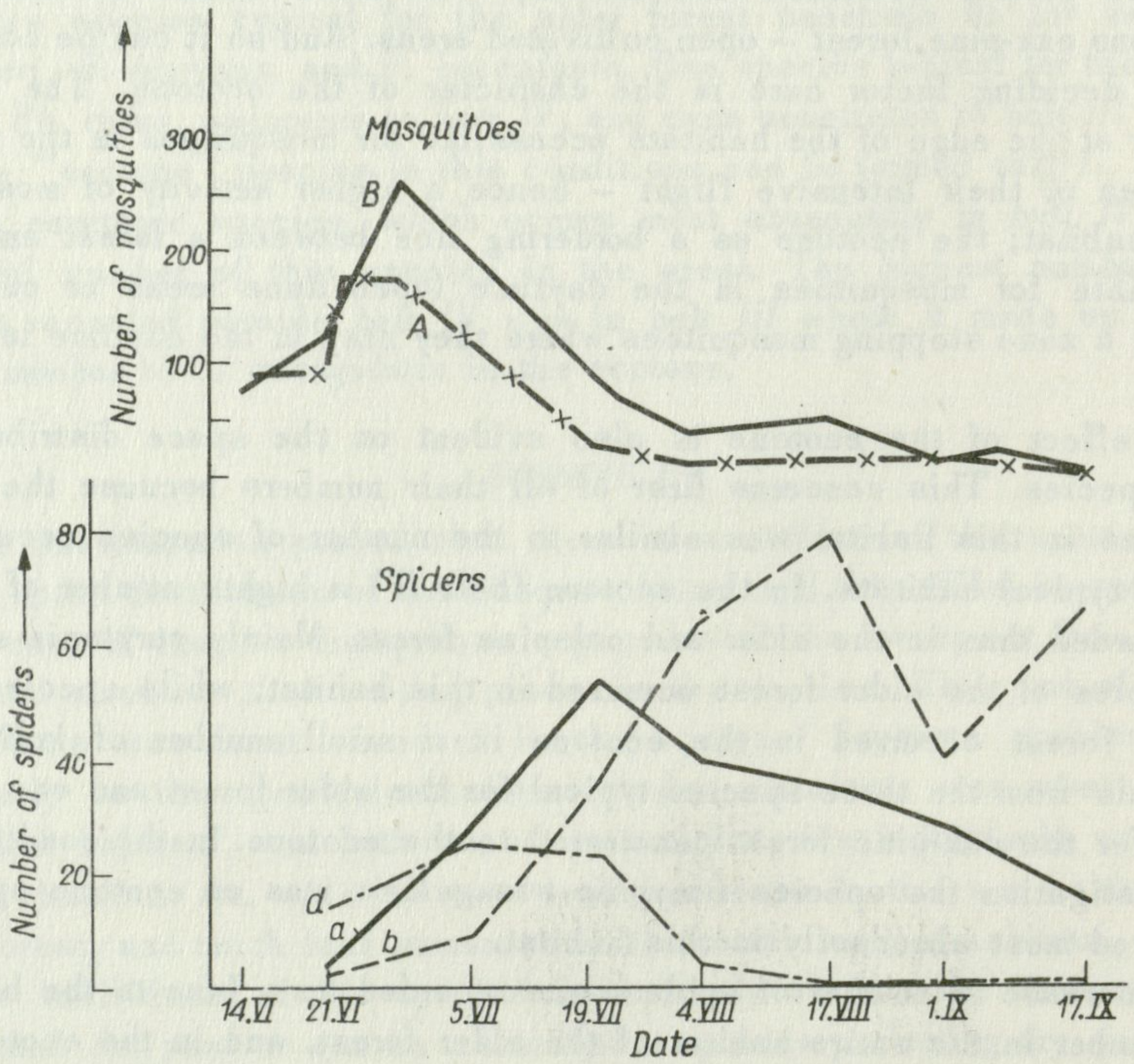

Fig. 14. Seasonal changes in the number of mosquitoes and the three species of web spiders in the alder forest

a – *Linyphia triangularis*, *b* – *Meta segmentata*, *d* – *Theridion ovatum*, *A* – inactive mosquitoes, *B* – active mosquitoes

gical literature on the subject of two of these species – *M. segmentata* and *L. triangularis* – as preying on *Nematocera*. The observations of Laird (1947) on captures of mosquitoes by *M. segmentata* are also known. Besides in the series of field experiments on spider predation of mosquitoes, carried out in the area, it was recorded that *L. triangularis*, and also *Th. ovatum* in a certain period, were effective predators on mosquitoes (Łuczak, Dąbrowska-Prot 1966).

It was also recorded (Dąbrowska-Prot, Łuczak, Tarwid in press) that the pressure of *L. triangularis* on mosquitoes increased in the course of the growth of mosquito activity. The present investigation showed that mosquitoes are most active in the ecotone and dry habitats (Fig. 6). As it is known *L. triangularis* also occurs very abundantly in such habitats. And we can conclude that this species is partly responsible for the reduction of the number of mosquitoes.

Changes in numbers of mosquitoes in the course of the season (Figs. 7 and 8), indicating a sudden drop in their numbers in the middle of July may suggest that there occurred drastic factors. They were certainly not factors connected with the weather. This was certainly not caused by the emigration of mosquitoes from the area and crowding in other habitats, because no such phenomenon was recorded within the considerable area of the investigation. The correlation existing between the decrease in numbers of mosquitoes and the increase in numbers of spiders may suggest that spiders are one of the important factors affecting the drop in numbers of mosquitoes in the middle of the summer.

This paper is the first contribution in the series of investigations on ecotone spiders and mosquitoes.

We desire to express our thanks to Dr. Zdzisława Wójcik for her floristic analysis of the habitats.

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PAJĄKI I KOMARY EKOTONU LASU OLSZOWEGO (*CARICI ELONGATAE-ALNETUM*) I BORU MIESZANEGO (*PINO-QUERCETUM*)

Streszczenie

Badania prowadzone były w lesie olszowym, borze mieszanym i na styku obu biocenoz w ekotonie. Celem pracy była analiza zgrupowań pająków i komarów występujących w wyróżnionych środowiskach. Badania wykazały, że istnieje wpływ ekotonu na rozkład przestrzenny komarów i pająków. W przypadku komarów wpływ ten był szczególnie wyraźny w stosunku do komarów nieaktywnych, wychwytywanych czerpakiem z runa i krzewów: miejsc ich dziennych schronień. Fauna komarów była w ekotonie znacznie mniej liczna niż w środowiskach sąsiadujących. Poszczególne gatunki komarów unikały ekotonu. Tylko *Aedes punctor* występował tam liczniej niż w wilgotnym lesie olszowym, dlatego można traktować go jako gatunek środowisk suchych i ekotonowych. Sposób reagowania poszczególnych gatunków komarów na środowisko ekotonowe nie ulegał zmianie w ciągu sezonu, mimo zmian ich liczebności w badanych środowiskach i postępującego spadku ogólnej liczebności komarów w całym terenie.

W okresie dużej liczebności komarów w terenie (pierwsza połowa lata) charakteryzowały się one największą aktywnością względną w ekotonie. Poziom tej aktywności nie ulegał zmianie w tym środowisku w ciągu całego sezonu, podczas gdy w pozostałych dwóch wzrastał w drugiej połowie lata powyżej poziomu aktywności względnej komarów w ekotonie.

W strukturze zgrupowań pająków poszczególnych środowisk występowały różnice liczebności i składu gatunkowego, natomiast liczba gatunków w badanych środowiskach

była podobna. W ekotonie stwierdzono większą liczebność pająków niż w lesie olszowym i borze mieszanym; występowały tam głównie gatunki eurytopowe i gatunki lasu olszowego. W warunkach naszych badań gatunkiem typowo ekotonowym była *Linyphia triangularis* (Clerck), najliczniejsza w tym środowisku. Ogólna liczebność pająków wzrastała od czerwca do połowy września; w ciągu tego okresu największą ogólną liczebność osiągnęły one w środowisku ekotonowym.

W połowie września nastąpiła zmiana w stosunkach ilościowych pająków. Na skutek pogorszenia się warunków w ekotonie zmniejszyła się liczebność zasiedlających go pająków, zwiększając się równocześnie w głębi lasu olszowego. Pająki opuszczały na jesieni środowisko brzeżne przenosząc się w głąb środowiska typowego.

Na podstawie korelacji w przebiegu zmian liczebności pająków i komarów w badanym lesie olszowym i w ekotonie, wysuwa się przypuszczenie, że pająki w tych środowiskach mają duże znaczenie w redukcji liczebności komarów.

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