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A comparative analysis of the structure of *Neuropteroidea* communities of tree canopies in linden-oak-hornbeam forests, light oak forests, mixed coniferous forests and pine forests

Abstract. The following paper is based on studies carried out from 1976 to 1987 on *Neuropteroidea* of tree canopies in 4 types of forest characteristic of lowland and upland areas in Poland: the subcontinental variety of the linden-oak-hornbeam forest (*Tilio-Carpinetum*), light oak forest (*Potentillo albae-Quercetum*), mixed coniferous forest (*Querco roboris-Pinetum*) and pine forest (*Peucedano-Pinetum* and *Leucobryo-Pinetum*; the *Dicranio-Pinion* alliance). The following parameters were analysed and compared: species composition, abundance, structure as well as ecological and zoogeographical diversification of the neuropteran communities. Materials, totalling 10,280 imagines of 45 species of neuropterans, were collected in mature stands from various tree species: oaks, lindens, hornbeams, elms, pines and larches.

Key words: fauna, Poland, *Neuropteroidea*, community structure, forests.

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INTRODUCTION

Advances in ecology and the transformation of natural habitats have resulted in a need to investigate biological diversity and faunal organization and, consequently, to study animal communities in their actual biocoenoses. In the case of *Neuropteroidea*, particularly their forest communities, the knowledge is still scarce. Papers describing quantitative relations of the *Neuropteroidea* of a given area or habitat are not numerous, be it by Polish (BERNDT 1984, CZECHOWSKA 1985, 1986, 1990, 1994, DOBOSZ 1993) or foreign authors (RESSL 1971a, b, 1974, GEPP 1973).

Determination of the structure of neuropteran communities in Polish forests has been possible owing to zoocoenological studies carried out until quite recently by the Institute of Zoology of the Polish Academy of Sciences in various types of natural forests (linden-oak-hornbeam, light oak, mixed coniferous and pine forests) as well as their transformed counterparts subject to economic exploitation or human settlement. The above-mentioned forest associations are the potential natural vegetation of large areas of Polish lowlands and uplands. In Poland, some of these associations probably reach their optimum habitat conditions. This group includes above all the mixed pine-oak forest (*Querco roboris-Pinetum*) occurring in Poland in its most typical form (without an admixture of spruce, fir or beech), the pine forest (*Peucedano-Pinetum*) in its Sarmatian variety and the subcontinental linden-oak-hornbeam forest (*Tilio-Carpinetum*) (MATUSZKIEWICZ 1987).

At present only a small part of Polish forests have a natural or near-natural appearance[1]. The development of agriculture and silviculture has affected original forest acreage and influenced the species composition and age structure of the stands. The total area of forests growing on fertile soils, that is mainly linden-oak-hornbeam forests, but also mixed coniferous forests and light oak forests, has shrunk, while the area occupied by pine forests has expanded. Almost 2/3 of the total forest area in Poland are now occupied by coniferous forests, with the pine (*Pinus silvestris*) as the dominant tree species accounting for nearly 70% of the areas. The prevailing age classes of the forest stand are I through IV, with stands representing class V (81–100 years old) and older accounting for only 16% (GUS 1994).

The results of the zoocoenological studies of neuropterans have been partially published (CZECHOWSKA 1985, 1990, 1994). This paper brings together data from the many years of studies showing the diversification of *Neuropteroidea* of tree canopies in forest areas typical of Poland. The main aims are to describe and compare the communities specific to natural linden-oak-hornbeam forests, light oak forests, mixed coniferous forests and pine forests in terms of species composition, structure, seasonal community dynamics and ecological and zoogeographical diversification.

An ecological classification of the neuropterans was based on a paper by ASPÖCK et al. (1980) and the author's own investigations. The criteria for a zoogeographical classification come from a paper by CZECHOWSKI and MIKOŁAJCZYK (1981).

AREAS OF STUDY

The results discussed herein have been gathered from four linden-oak-hornbeam forests, three light oak forests, three mixed coniferous forests and six pine forests. All the forests were composed of mature stands whose composition was generally typical of the respective association types, and covered large areas of compact forest that had allowed for specific microclimates to develop. The study sites lay far away from agrocenoses. The linden-oak-hornbeam, light oak and mixed coniferous forests studied were

[1]After KORNAŚ (1977), as natural is regarded a forest, which - in terms of the species composition of the vegetation - is similar to a considerable extent to a typical climax community that forms spontaneously in a particular climate and habitat.

situated in the Mazovian Lowland, while the pine forests were located in the Mazovian Lowland, the Podlasie region, the Pomeranian Lakeland, the Cuiavia–Wielkopolska Lowland and Roztocze.

Within the geographical range of a forest association, geographical varieties develop that supersede one another. This typological diversification of plant associations is attributable to continental or regional geographical factors as well as local habitat conditions, mostly soil fertility and humidity. The joint effect of these factors (now also including economic exploitation) turns almost every plot in the forest into a specific spatial combination of plant species and a unique habitat for animals. Due to this fact, detailed geobotanical analyses of the areas of study were carried out to facilitate zoocoenological investigations (KOTOWSKA and NOWAKOWSKI 1989, MATUSZKIEWICZ et al. 1993). They should be regarded as complementary to the descriptions presented below.

Phytosociological characteristics of the forest types under study

Subcontinental linden-oak-hornbeam forests (*Tilio-Carpinetum*)

General description

A multi-species deciduous forest whose main species are hornbeam (*Carpinus betulus*), two species of oak (*Quercus robur* and *Q. sessilis*) and linden (*Tilia cordata*). There may be admixtures of maple (*Acer pseudoplatanus, A. platanoides*), elm (especially *Ulmus laevis*), spruce (*Picea abies*), fir (*Abies alba*) and, in poorer and drier habitats, of pine (*Pinus silvestris*). The forest has a multi-layer structure with canopies formed of oaks and lindens (and possibly spruces) towering above canopies of hornbeam trees. Due to forest floor shadiness the understorey is usually not dense, though it does show qualitative diversification, being composed of the undergrowth of trees and numerous bushes, particularly *Corylus avellana, Evonymus verrucosa, E. europaea, Lonicera xylosteum* and *Cornus sanguinea*. The ground cover is usually uniform, not tall, covering 60–80% of the area and abundant in species. Characteristic species include *Carex pilosa, Galium schultesii, Ranunculus cassubicus* and *Isopyrum thalictroides*. In Poland, this association is found east of the lower Vistula, the upper Noteć and a line extending from the town of Konin through Krotoszyn to Wrocław; there are numerous regional and habitat-specific varieties (SZAFER et al. 1977, MATUSZKIEWICZ 1981).

Study sites

1. "Dębina" reserve. Strict reserve, 51.2 ha in area, near the village of Klembów, south-east of Warsaw. The study plot extended over 6.8 ha in division 16. It was a bi-level stand, made up of 150-year-old oak trees and 130–150-year-old hornbeam trees. Canopy density 90%.

2. "Cyganka" reserve. Strict reserve in Puszcza Kampinoska near the village of Truskaw with low linden-oak-hornbeam forest and swampy alder carr as the prevailing habitats. The study plot occupied 1.8 ha in division 1721. The stand was composed of oak and hornbeam with an admixture of pine, birch and linden; canopy density 90%.

3. "Modrzewina" reserve. Strict reserve, 286.6 ha at the village of Mała Wieś near Belsk, formed in order to preserve a solitary *Larix polonica* larch site in Mazovia. The study plot occupied 1.2 ha in division 152. A multistorey forest stand with an upper layer composed of canopies of oak (*Quercus sessilis*), larch and some pines, and a lower one consisting of canopies of hornbeams and some 100-year-old oaks; canopy density 60–80%.

4. Radziejowice forest district. A 250 ha forest near the lokality of Mszczonów. The study plot was situated in the south-eastern part of a low and high linden-oak-hornbeam complex, about 250 m away from the rivulet Pisia-Gągolina. The stand was composed of 75-year-old oaks (*Quercus robur*) and 40- to 50-year old hornbeams and lindens with an admixture of birch and pine; canopy density 80%.

Light oak forest (*Potentillo albae-Quercetum*)

General description

An association with predominant oak (usually *Quercus sesilis*, with *Q. robur* abundant only in north-eastern Poland) and pine as a constant natural admixture. Canopy density usually about 60–70%. These forests grow on moderately fertile and relatively dry soils abundant in calcium. The understorey is well-developed and includes, among others, *Berberis vulgaris*, *Crategus monogyna*, *C. oxycantha*, *Pirus communis*, *Prunus spinosa*, *Rhamnus catharctica* and *Sorbus aucuparia*. Has the richest ground cover of all forest association types, characterized by the presence of species slighly calciphilous, but heat- and light-loving. The most important of these are *Vicia cassubica*, *Ranunculus polyanthemos*, *Pulmonana angustifolia* and *Potentilla alba*. In Poland, the light oak forest reaches the northernmost limit of its range. It is found mainly in subprovinces of Central Polish Lowlands, Podlasie-Belarussian Uplands and the Southern-Baltic Lakeland. Plots of light oak forest are often surrounded by pine and mixed coniferous stands, less commonly by linden-oak-hornbeam forests (Szafer et al. 1977, Matuszkiewicz 1981).

Study sites

1. King Jan III Sobieski reserve. A partial reserve within the city limits of Warsaw (Marysin Wawerski, Praga South district); a 113.5 ha conservation area. The study plot was 7.4 ha in division 7, made up mainly of 130-year-old oaks (*Quercus robur*) and lindens.

2. B. Hryniewiecki reserve. A 24.73 ha partial reserve in Podkowa Leśna near Warsaw, formed in order to protect surviving oak woods. The study plot

was over 9 ha in division 349b. The stand was made up of 165-year-old oaks with an approximately 20% addition of pine; canopy density 40%.

3. Radziejowice forest district. A 250 ha forest near the town of Mszczonów. The 25.3 ha study plot was situated in division 110a. The stand was composed of 75- to 80-year-old trees, mainly oaks (*Quercus robur*) with an admixture of hornbeam, linden and pine; canopy density 70–80%.

Continental mixed coniferous forest (*Querco roboris-Pinetum*)

General description

A syntaxon that is a more exact equivalent of the *Pino-Quercetum* association. The dominant species include oak (*Quercus robur* or *Q. sessilis*) and pine (*Pinus silvestris*). There may be admixtures of birch (*Betula verrucosa*), aspen (*Populus tremula*) and linden (*Tilia cordata*). The forest allows quite a lot of light to penetrate, with canopy density reaching about 70% in older stands. The shrub layer is quite luxuriant, consisting, among others, of *Corylus avellana*, *Frangula alnus*, *Sorbus aucuparia*, *Viburnum opulus* and *Crategus sp.*. In the ground cover the dominant is most frequently *Vaccinium myrtillus* or, quite often, *Pteridium aquilinum*, with *Majanthemum bifolium*, *Convallaria majalis*, *Veronica officinalis*, *Solidago virgaurea* and *Entodon schreberi* also being fairly constant elements. In Poland mixed pine-oak forests are found in the lowlands, in the subcontinental area, generally beech- and spruceless (SZAFER et al. 1977, MATUSZKIEWICZ 1981).

Study sites

1. Łomna I. A coniferous forest plot, 2.5 ha in area, in division 21 of the district of Laski in Puszcza Kampinoska. The stand is 65 to 75 years old and composed of oak (*Quercus robur*), with an admixture of birch and pine. In its centre are 40-year-old pines growing as solitary trees and in clusters. Adjoining on one side was a pine forest stand, and on the other, a 35-year-old alder swamp.

2. Łomna II. A plot 7 ha in area in division 38b of the Laski forest district. 80- to 90-year-old stand of pine, oak and birch. Understorey composed of 20- to 30-year-old oaks and isolated hornbeams.

3. Kaliszki reserve. A plot 15 ha in area in division 24c. Mixed coniferous forest with areas of alder swamp in land hollows. Stand composed of 120- to 140-year-old pine trees. Understorey with 20- to 30-year-old oaks and pines.

Pine forests of the *Dicranio-Pinion* alliance

General description

A typical association of poor sandy soils with a low underground water level. Pine (*Pinus silvestris*) is the stand-forming species while verrucose birch (*Betula verrucosa*), rowan (*Sorbus aucuparia*), oak (*Quercus robur*), sometimes beech (*Fagus silvatica*), spruce (*Picea excelsa*) and fir (*Abies alaba*) are accompanying elements. Within the range of the pine forest, two geographical varieties superseding each other can be identified: the suboceanic pine forest and the subcontinental pine forest.

The suboceanic pine forest (*Leucobryo-Pinetum*) is commonly found in and occupies large areas in western, central, southern and parts of eastern Poland. The subcontinental pine forest (*Peucedano-Pinetum*), also widely distributed, is seen east of the River Bug and the lower Vistula, crossing this line where the climate is markedly subcontinental (Toruń and Płock basins, Kutno Plain, Polesie). It differs from the other variety in having a richer flora that includes species with a continental geographical range, usually slightly xerothermal perennials (Szafer et al. 1977, Matuszkiewicz 1981).

Study sites

Subcontinental pine forests (*Peucedano-Pinetum*)

1. Puszcza Białowieska. Vast forest complex, 58,000 ha in area (on Polish territory) in the Northern Podlasie Lowland region. Linden-oak-hornbeam forests are dominant and pine forests occupy 4.6% of the area (Zaręba 1986). The study plots (Hajnówka forest inspectorate, divisions 607b, 668a and 538b) represented the subboreal variety of the association, characterized by a constant presence of spruce. Stand composed mostly of about 150-year-old pines with a small admixture of spruce; sporadic *Betula verrucosa* and *Quercus robur* in the understorey and undergrowth.

2. Puszcza Biała. Coniferous forest complex, about 60,000 ha in area in the North Mazovian Lowland region. Pine (*Pinus silvestris*) is the dominant species. The mature stands are largely natural, the younger ones are mostly plantings; stands are pure pine or there is a small admixture of birch, oak or aspen. The study plots (Ostrów Mazowiecka forest inspectorate, divisions 34f, 62g and 38b) represented the Sarmatian variety of the association, characterized by the presence of *Juniperus communis* in the understorey; the stands are 97 to 132 years old.

3. Puszcza Kampinoska. 35,721 ha in area in the Mazovian Lowland near Warsaw. Terrain considerably varied in terms of topography and habitat. The forest under study occupied 26 ha in the north-western part of Puszcza Kampinoska near the village of Łomna (Laski forest district, divisions 21 and 8); 70- to 80-year-old stand, composed mostly of pine with a small addition of birch and oak; understorey consisted of *Juniperus communis*, *Quercus robur* and *Picea excelsa*.

Suboceanic pine forests (*Leucobryo-Pinetum*)

1. Bory Tucholskie. A forest complex about 120,000 ha in area, in the Southern Pomeranian Lakeland region. Coniferous forest sites, growing usually on poor sandy soils, make up 98% of the complex. The prevailing association type is pine forest, often a transitory form between a *Leucobryo-Pinetum* and a *Peucedano-Pinetum* forest (Szafer et al. 1977). The study plots

(Osie forest district, division 306b, 340c, 346a) composed almost entirely of pine with a minor admixture of birch.

2. Babimost. Pine forests on former agricultural land, near the lokality of Babimost in the Cuiavia-Wielkopolska Lowland. Stand composed entirely of pine, approximately 100 years old. Ground cover and bush layers have not yet developed association-specific flora.

3. Roztocze. A forest complex, 6832 ha in area, in Middle Roztocze (Roztocze National Park). *Leucobryo-Pinetum* forests occupy nearly 18% of the area. A region-specific feature is the presence of fir, spruce and beech in the understorey, and sometimes also in the stand. The study plots were situated in the Zwierzyniec forest inspectorate in divisions 38, 178 and 198.

TIME OF STUDY, METHODS AND MATERIAL

The material used for analysis was obtained during catches carried out in 1976 and 1987. The insects were caught using yellow plastic bowls, 18 cm in diameter, filled with a water solution of ethylene glycol and some detergent. The bowls were hung high in tree canopies and remained there from April until the end of October. They were emptied at regular intervals, every 10 or 14 days. The method, introduced by Moericke for the sampling of aphids, was used in the zoocoenological studies organized by the Institute of Zoology PAS for collecting all insect taxa inhabiting tree canopies (Bańkowska and Garbarczyk 1981, Sawoniewicz 1996). Years of studies have shown this method to yield the most complete sampling material as far as this forest layer is concerned.

The traps were hung on trees belonging to a variety of species: oaks, lindens and hornbeams, sometimes also elms or larches in the linden-oak-hornbeam forests; oaks, lindens and (where possible) pines in the oak forests; oaks, birches and pines in the mixed coniferous forests; and pines in the pine forests. Nine traps were hung in each linden-oak-hornbeam, oak and mixed coniferous forest (3 traps per tree), and 15 traps were placed in each pine forest (1 per tree). The total yield was 10,280 specimens of *Neuropteroidea*, with 43% of these collected in pine forests, 34% in linden-oak-hornbeam forests, 14% in mixed coniferous forests and 9% in oak forests.

The abundance of individual species and entire communities was expressed as an index corresponding to the number of individuals caught in one trap over 100 days. The multiplication factor of 100 was applied so that the values of the index would be high enough to be easily handled in computations.

An analysis of the structures of dominance of the communities made it possible to distinguish four categories of species: eudominants (>15.0%), dominants (15.0–5.1%), subdominants (5.0–1.1%) and accessory species (≤1.0%).

Qualitative similarity (species composition similarity) between communities was calculated according to SÖRENSEN's formula (*So*) (SÖRENSEN 1948):

$$So = \frac{2c}{a+b} 100\%$$

where: *a* – the number of species in the 1st community; *b* – the number of species in the 2nd community; *c* – the number of species common to both communities.

The similarity of dominance structures of communities was obtained using Morisita's formula (*Mo*) modified by HORN (1966):

$$Mo = \frac{2\sum_{I=1}^{n} x_i y_i}{\sum_{a=1}^{n} x_a^2 + \sum_{a=1}^{n} y_a^2}$$

where: x_i and y_i – the percentage contributions of species common to both communities; x_a and y_a – the percentage contributions of individual species in each of the communities compared.

Species characteristic of individual communities were found using a quantitative constancy formula (*W*):

$$W = \frac{a}{b} 100\%$$

where: *a* – the abundance of a given species in a given habitat; *b* – the sum of community abundance figures from all habitats studied.

The characteristic species threshold was set at $W \geq 51\%$.

Biocoenotic diversity of communities was assessed using Shannon and Weaver's index of actual species diversity (*H'*):

$$H' = -\sum_{i=1}^{S} \frac{n_i}{N} \log \frac{n_i}{N}$$

where: n_i – the abundance of the ith species; *N* – the total abundance of the community.

This index sorts faunal structure both in terms of species richness and evenness of resources distribution among individual species (TROJAN 1992). Potential species diversity of communities (H_{max}), which also marks the limit of the *H'* index, is equal to *logS**.

Pielou's index (*J*):

$$J = \frac{H'}{\log S*} 100\%$$

was applied to determine the degree of realization of potential diversity by individual communities (*S** is the potential number of species in a community determined using the negative binomial distribution).

SPECIES COMPOSITION AND COMMUNITY STRUCTURE

Linden-oak-hornbeam forests (*Tilio-Carpinetum*)

28 species of *Neuropteroidea*, including 3 species of *Raphidioptera* and 25 species of *Neuroptera* s. str., were found in the linden-oak-hornbeam forests under study (Table I). Individual communities were composed of 10 to 21 species, and qualitative similarity ranged from 58% to 72% (Fig. 1). The species with the highest constancy of occurrence, found in all the linden-oak-hornbeam forests studied, were as follows: *Hemerobius humulinus*, *H. micans*, *Nineta flava*, *N. vittata*, *Chrysotropia ciliata*, *Chrysopa pallens*, *Mallada prasina* and *Chrysoperla carnea*. Together, they accounted for 62–80% of species forming individual communities.

The poorest community inhabited a remarkably shady linden-oak-hornbeam forest composed only of deciduous trees situated in Dębina Reserve. Communities made up of a greater number of species were found in forests with less dense stands and an admixture of coniferous trees. A greater number of thermophilous species of *Neuropteroidea* were identified there and the presence of pine and larch was propitious to species with specialized eating habits, feeding on phytophages living only on these trees. The richest community inhabited the Radziejowice site, which was characterized by a high proportion of the tall linden-oak-hornbeam forest with an admixture of pine.

The abundance of *Neuropteroidea* varied quite widely (17.65–66.65), the abundance index being related to habitat conditions in a given plot of forest. The lowest abundance was recorded for the community in the low linden-oak-hornbeam forest of Cyganka, and in the community of the shady common linden-oak-hornbeam forest of Dębina the figure was only a little higher. An approximately twice as high abundance index was obtained for the community of a common linden-oak-hornbeam forest with an admixture of larch (Modrzewina), while a figure three times as high as the lowest abundance was recorded in the plot with a high proportion of high linden-oak-hornbeam forest (Radziejowice).

In the entire material collected in the linden-oak-hornbeam forests, there were three eudominants, namely, *Chrysotropia ciliata* (28.5%), *Chrysoperla carnea* (24.7%) and *Nineta flava* (19.8%); one dominant – *Mallada prasina* (14.6%), and the subdominant species group consisted of *Hemerobius humulinus*, *Chrysopa pallens*, *Nineta vittata* and *Cunctochrysa albolineata*. The other 20 species, accounting for 3.5% of the total number of specimens, were classed as accessory elements. The most abundant of these were *Raphidia notata*, *Coniopteryx tineiformis*, *Hemerobius micans*, *Sympherobius klapaleki* and *Mallada ventralis*.

A characteristic feature of the structures of dominance of individual communities was a marked numerical prevalence of 3–4 species that accounted for about 90% of individual community abundance. At the same

Table I. Abundance (n –index) and proportion (%) of particular species of *Neuropteroidea* in the linden-oak-hornbeam forests (*Tilio-Carpinetum*) (+ – n<0.01))

	Plots	Dębina res.		Cyganka res		Modrzewina res.		Radziejowice		Mean	
No	Species	*n*	%	*n*	%	*n*	%	*n*	%	*n*	%
1	*Raphidia notata* FABR.	-	-	0.02	0.1	0.44	1.0	0.17	0.2	0.16	0.4
2	*Raphidia major* BURM.	-	-	-	-	0.14	0.3	-	-	0.04	0.1
3	*Raphidia xanthostigma* SCHUMM.	-	-	0.02	0.1	-	-	-	-	+	+
4	*Coniopteryx tineiformis* CURT.	-	-	-	-	0.09	0.2	0.45	0.7	0.14	0.4
5	*Coniopteryx borealis* TJED.	-	-	-	-	-	-	0.08	0.1	0.02	0.1
6	*Coniopteryx parthenia* (NAV. et MARC.)	-	-	-	-	-	-	0.09	0.1	0.02	0.1
7	*Coniopteryx haematica* MCLACHL.	-	-	-	-	-	-	0.19	0.3	0.05	0.1
8	*Semidalis aleyrodiformis* (STEPH.)	-	-	-	-	-	-	0.08	0.1	0.02	0.1
9	*Conwentzia psociformis* CURT.	-	-	-	-	0.22	0.5	-	-	0.05	0.1
10	*Drepanopteryx phalaenoides* (L.)	-	-	-	-	0.05	0.1	0.09	0.1	0.04	0.1
11	*Wesmaelius concinnus* (STEPH.)	-	-	-	-	0.05	0.1	0.09	0.1	0.04	0.1
12	*Wesmaelius quadrifasciatus* (REUT.)	-	-	-	-	0.30	0.7	-	-	0.08	0.2
13	*Wesmaelius nervosus* (FABR.)	-	-	0.06	0.3	-	-	0.11	0.2	0.04	0.1
14	*Hemerobius humulinus* L.	0.80	3.6	1.43	8.1	1.00	2.3	0.91	1.4	1.04	2.8
15	*Hemerobius atrifrons* MCLACHL.	-	-	-	-	0.29	0.7	-	-	0.07	0.2
16	*Hemerobius micans* OLIV.	0.21	1.0	0.11	0.6	0.24	0.6	0.08	0.1	0.16	0.4
17	*Hemerobius marginatus* STEPH.	-	-	0.02	0.1	-	-	-	-	+	+
18	*Sympherobius klapaleki* ZEL.	0.10	0.5	0.02	0.1	-	-	0.50	0.8	0.16	0.4
19	*Nineta flava* (SCOP.)	5.60	25.5	3.89	22.0	18.45	42.8	1.65	2.5	7.40	19.8
20	*Nineta vittata* (WESM.)	0.38	1.7	0.13	0.7	1.90	4.4	0.91	1.4	0.83	2.2
21	*Nineta inpunctata* (REUT.)	-	-	0.05	0.3	-	-	0.09	0.1	0.04	0.1
22	*Chrysotropia ciliata* (WESM.)	8.89	40.5	6.49	36.8	11.60	26.9	15.56	23.3	10.64	28.5
23	*Chrysopa perla* (L.)	0.05	0.2	-	-	-	-	-	-	0.02	0.1
24	*Chrysopa pallens* (RAMB.)	0.32	1.5	0.07	0.4	2.85	6.6	0.25	0.4	0.87	2.3
25	*Mallada prasina* (BURM.)	0.58	2.6	1.06	6.0	0.79	1.8	19.39	29.1	5.46	14.6
26	*Mallada ventralis* (CURT.)	-	-	0.12	0.7	0.14	0.3	0.39	0.6	0.16	0.4
27	*Chrysoperla carnea* (STEPH.)	5.01	22.9	4.16	23.7	4.60	10.7	23.17	34.8	9.24	24.7
28	*Cunctochrysa albolineata* (KILL.)	-	-	-	-	-	-	2.40	3.6	0.60	1.6
	Total	21.94	100.0	17.65	100.0	43.15	100.0	66.65	100.0	37.39	100.0
	Number of species	10		15		17		21		28	

time, dominance structure similarity was generally very high (Fig. 2). The highest similarity indices (*Mo*=0.84–0.98) were obtained for the communities found in the typical linden-oak-hornbeam forests and the low linden-oak-hornbeam forest, the latter with *Chrysotropia ciliata*, *Nineta flava* and *Chrysoperla carnea* as dominants. Dominance structure similarity was lower when obtained these communities were compared to that in the high linden-oak-hornbeam forest (Radziejowice). The main structural difference was the absence of the mesohygrophilous and shade-loving *Nineta flava* from the dominant group in the latter type of forest, where it was replaced by *Mallada prasina*, also hygrophilous but light-loving.

		Linden-oak-hornbeam forests				Light oak forests			Mixed coniferous forests			Pine forests					
		Dębina	Cyganka	Modrzewina	Radziejowice	Sobieski	Hryniewiecki	Radziejowice	Łomna I	Łomna II	Kaliszki	Puszcza Białowieska	Puszcza Biała	Puszcza Kampinoska	Bory Tucholskie	Babimost	Roztocze
Linden-oak-hornbeam forests	Dębina		72	60	58	72	55	70	48	53	40	33	37	29	28	50	45
	Cyganka			63	72	65	62	62	58	69	46	51	50	41	41	48	44
	Modrzewina				68	73	63	57	65	54	49	43	41	39	44	39	47
	Radziejowice					65	67	62	59	57	52	54	53	40	50	51	52
Light oak forests	Sobieski						67	62	62	50	50	44	42	40	40	47	38
	Hryniewiecki							55	70	70	70	60	60	54	57	65	64
	Radziejowice								55	67	47	53	52	33	41	50	45
Mixwd coniferous forests	Łomna I									70	70	65	65	65	67	70	59
	Łomna II										70	85	81	59	72	71	68
	Kaliszki											70	76	71	72	71	62
Pine forests	Puszcza Białowieska												89	61	84	65	65
	Puszcza Biała													71	78	69	68
	Puszcza Kampinoska														67	69	63
	Bory Tucholskie															71	65
	Babimost																72
	Roztocze																

<20 | 21-40 | 41-60 | 61-80 | 81-100%

Fig. 1. Qualitative similarity between communities of *Neuropteroidea* from the particular forests studied

Linden-oak-hornbeam forests are moist forests, but the degree of moisture varies with underground water level and stand density. In this habitat, neuropteran communities were composed of species with diverse moisture and temperature preferences, owing to which the communities could easily adapt to the conditions prevailing in a given forest.

Among the dominant species, *Chrysotropia ciliata* has the strictest moisture preferences, while *Mallada prasina* is the most flexible in this respect, and the preferences of *Nineta flava* can be described as intermediate. Numerical prevalence of one of these species over the others served as a criterion for distinguishing three moisture-related varieties of the structure of dominance of the communities. The three varieties are as follows:

		Linden-oak-hornbeam forests				Light oak forests			Mixed coniferous forests			Pine forests					
		Dębina	Cyganka	Modrzewina	Radziejowice	Sobieski	Hryniewiecki	Radziejowice	Łomna I	Łomna II	Kaliszki	Puszcza Białowieska	Puszcza Biała	Puszcza Kampinoska	Bory Tucholskie	Babimost	Roztocze
Linden-oak-hornbeam forests	Dębina		0.98	0.89	0.69	0.63	0.70	0.61	0.17	0.19	0.10	0.04	0.05	0.08	0.02	0.05	0.07
	Cyganka			0.84	0.73	0.58	0.74	0.67	0.25	0.27	0.32	0.07	0.07	0.11	0.04	0.05	0.09
	Modrzewina				0.43	0.88	0.64	0.49	0.10	0.12	0.18	0.04	0.04	0.06	0.03	0.02	0.05
	Radziejowice					0.19	0.86	0.83	0.71	0.71	0.74	0.27	0.16	0.17	0.13	0.08	0.21
Light oak forests	Sobieski						0.47	0.59	0.04	0.04	0.06	0.01	0.02	0.07	0.01	0.01	0.02
	Hryniewiecki							0.69	0.69	0.66	0.77	0.33	0.23	0.26	0.23	0.07	0.23
	Radziejowice								0.43	0.76	0.41	0.12	0.11	0.14	0.06	0.10	0.14
Mixwd coniferous forests	Łomna I									0.99	0.91	0.42	0.21	0.22	0.21	0.13	0.32
	Łomna II										0.93	0.43	0.21	0.21	0.21	0.08	0.28
	Kaliszki											0.49	0.28	0.26	0.31	0.16	0.38
Pine forests	Puszcza Białowieska												0.80	0.59	0.79	0.12	0.18
	Puszcza Biała													0.78	0.95	0.23	0.31
	Puszcza Kampinoska														0.86	0.28	0.43
	Bory Tucholskie															0.13	0.27
	Babimost																0.89
	Roztocze																

<0.20 0.21-0.40 0.41-0.60 0.61-0.80 0.81-1.00

Fig. 2. Dominance structure similarity between communities of *Neuropteroidea* from the particular forests studied.

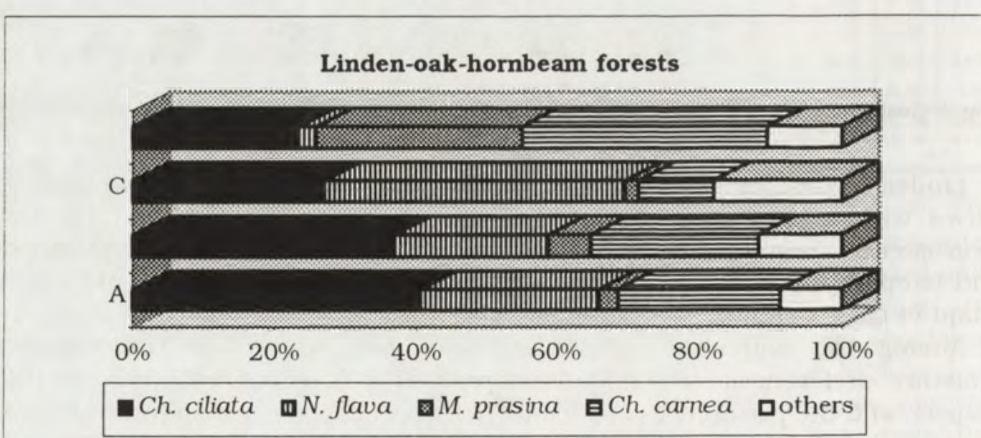

Fig. 3. Proportions of the most important species of *Neuropteroidea* communities in the linden-oak-hornbeam forests: A - Dębina, B - Cyganka, C - Modrzewina, D - Radziejowice.

– variant I: a prevalence of *Chrysotropia ciliata*, found in low linden-oak-hornbeam forest and extremely shady common linden-oak-hornbeam forest (Dębina, Cyganka);

– variant II: a high proportion of *Nineta flava*, seen typically in slightly light-penetrated common linden-oak-hornbeam forest (Modrzewina);

– variant III: a particularly high proportion of *Mallada prasina*, specific to high linden-oak-hornbeam forest with an admixture of pine (Radziejowice).

A feature common to all communities in the linden-oak-hornbeam forests under study was the presence of the hygrophilous *Chrysotropia ciliata* in the eudominant group. However, the contribution of this species would fall with decreasing moisture level in the habitat (Fig. 3).

Table II. Values of the various structural parameters calculated for *Neuropteroidea* communities in the particular types of forests: S - number of species, n - abundance index, H' - Shannon and Weaver's actual species diversity index, H - potential value of this index, J - percentage ratio of H'/H:

	S	n	H'	H	J
Linden-oak-hornbeam forests					
Dębina res.	10	21.94	2.15	3.32	65
Cyganka res.	15	17.65	2.33	3.91	60
Modrzewina res.	17	43.15	2.42	4.09	59
Radziejowice	21	66.65	2.34	4.39	53
In general	28	37.38	2.70	4.81	56
Light oak forests					
Radziejowice	10	12.23	2.33	3.32	70
King Sobieski res.	16	16.13	1.93	4.00	48
B. Hryniewiecki res.	23	15.68	3.13	4.52	69
In general	26	14.69	2.91	4.70	62
Mixed coniferous forests					
Kaliszki res.	20	17.69	2.97	4.32	69
Lomna I	20	35.18	2.26	4.32	52
Lomna II	23	69.40	2.00	4.52	44
In general	31	40.76	2.25	4.95	46
Pine forests					
Puszcza Kampinoska	14	28.25	3.07	3.81	81
Babimost	15	13.68	2.19	3.91	56
Puszcza Biała	17	8.38	3.23	4.17	77
Bory Tucholskie	19	10.10	3.06	4.39	70
Puszcza Białowieska	20	12.33	2.87	4.52	63
Roztocze	21	13.99	3.21	4.39	73
In general	31	14.47	3.58	4.95	72

Communities inhabiting individual linden-oak-hornbeam forests differed in the number of species and abundance, but had similar general species diversity indices (H'=2.15–2.42; Table II). The value of Shannon and Weaver's index is most influenced by the dominant species in a community (TROJAN 1992). The fairly similar values of species diversity obtained for *Neuropteroidea* communities in individual forests were due to the fact that the communities were formed according to the same structural model, with 3–4 species much more abundant than the others. The values of actual species diversity (H') equalled 53–65% of the respective values of the index of potential diversity (*H*). The two indices were most similar for the community of the common linden-oak-hornbeam forest (Dębina), while the largest discrepancy between them was noted for the community of the high linden-oak-hornbeam forest in Radziejowice (Table II).

Assessment of the constancy of individual species in the habitat showed that in the dominant group (>1%), the following species were characteristic of the linden-oak-hornbeam forest: *Chrysotropia ciliata* (*W* = 80%), *Nineta flava* (60%) and *Cunctochrysa albolineata* (53%). The group of accompanying elements was composed of: *Chrysoperla carnea* (*W* = 47%), *Nineta vittata* (38%), *Chrysopa pallens* (36%), *Hemerobius humulinus* (33%) and *Mallada prasina* (17%).

Light oak forests (*Potentillo albae-Quercetum*)

A total of 26 species of *Neuropteroidea* were found in this habitat, including 4 species of *Raphidioptera* and 22 species of *Neuroptera* s. str. (Table III).

Table III. Abundance (*n* - index) and proportions (%) of particular species of *Neuropteroidea* in light oak forests (*Potentillo albae-Quercetum*)

No	Plots / Species	King Sobieski res.		B. Hryniewiecki res.		Radziejowice		Mean	
		n	%	*n*	%	*n*	%	*n*	%
1	*Raphidia flavipes* STEIN.	–	–	0.02	0.1	–	–	0.01	0.1
2	*Raphidia notata* FABR.	0.11	0.7	0.19	1.2	-	–	0.10	0.7
3	*Raphidia major* BURM.	0.04	0.2	–	–	–	–	0.01	0.1
4	*Raphidia xanthostigma* SCHUMM.	–	–	0.02	0.1	–	–	0.01	0.1
5	*Coniopteryx parthenia* (NAV. ET MARC.)	–		0.02	0.1	–	–	0.01	0.1
6	*Coniopteryx haematica* MCLACHL.	–	–	0.02	0.1	–	–	0.01	0.1
7	*Semidalis aleyrodiformis* (STEPH.)	0.06	0.4	0.36	2.3	-	-	0.14	1.0
8	*Conwentzia psociformis* CURT.	0.06	0.4	0.36	2.3	-	-	0.14	1.0
9	*Drepanopteryx phalaenoides* (L.)	–	-	0.02	0.1	-	-	0.01	0.1
10	*Wesmaelius concinnus* (STEPH.)	0.06	0.4	0.58	3.7	-	-	0.21	1.4
11	*Wesmaelius nervosus* (FABR.)	0.02	0.1	–	–	0.08	0.7	0.03	0.2
12	*Hemerobius humulinus* L.	1.55	9.6	0.26	1.7	0.54	4.4	0.78	5.3
13	*Hemerobius stigma* STEPH.	-	-	0.07	0.5	-	-	0.02	0.1
14	*Hemerobius nitidulus* FABR.	-	-	0.05	0.3	-	-	0.02	0.1
15	*Hemerobius micans* OLIV.	0.23	1.4	0.03	0.2	-	-	0.09	0.6
16	*Sympherobius pygmaeus* (RAMB.)	0.06	0.4	-	-	-	-	0.02	0.1
17	*Sympherobius klapaleki* ZEL.	0.15	0.9	0.27	1.7	-	-	0.14	1.0
18	*Nineta flava* (SCOP.)	10.31	63.9	2.57	16.4	1.45	11.9	4.78	32.5
19	*Nineta vittata* (WESM.)	0.41	2.5	0.41	2.6	1.30	10.6	0.71	4.8
20	*Chrysotropia ciliata* (WESM.)	1.85	11.5	2.49	15.9	1.22	10.0	1.85	12.6
21	*Chrysopa pallens* (RAMB.)	0.08	0.5	0.09	0.6	0.08	0.7	0.08	0.5
22	*Mallada flavifrons* (BRAU.)	-	-	0.06	0.4	-	-	0.02	0.1
23	*Mallada prasina* (BURM.)	0.03	0.2	4.17	26.6	1.22	10.0	1.81	12.3
24	*Mallada ventralis* (CURT.)	-	-	0.44	2.8	0.15	1.2	0.20	1.3
25	*Chrysoperla carnea* (STEPH.)	1.11	6.9	2.91	18.6	6.04	49.3	3.35	22.8
26	*Cunctochrysa albolineata* (KILL.)	-	-	0.27	1.7	0.15	1.2	0.14	1.0
	Total	16.13	100.0	15.68	100.0	12.23	100.0	14.69	100.0
	Number of species	16		23		10		26	

The number of species caught in individual forests ranged from 10 to 23, with species composition similarity equalling 55–67% (Fig. 1). The following common species: *Hemerobius humulinus*, *Nineta flava*, *N. vittata*, *Chrysotropia ciliata*, *Chrysopa pallens*, *Mallada prasina* and *Chrysoperla carnea*, made up 30–70% of the species content of a community. The rich species content of neuropterans observed in light oak forests was due both to diversification of the spatial structure of the forest stand as well as to the species composition of the stand. The greatest number of species was found in the light oak forest of B. Hryniewiecki Reserve, which differed from the others with the habitat being more patchy (plots of considerably thinned stand with a high proportion of pine growing alongside shadier areas with a well-developed undergrowth).

The average abundance of lacewings in light oak forests was 14.69, and the figures obtained for individual communities were not much different (Table III). In the material as a whole, the group of eudominants was composed of *Nineta flava* (32.5%) and *Chrysoperla carnea* (22.8%); the class of dominants was formed by *Chrysotropia ciliata*, *Mallada prasina* and *Hemerobius humulinus*, and the subdominant group consisted of *Nineta vittata*, *Wesmaelius concinnus* and *Mallada ventralis*. 18 species, accounting for 7.0% of the total material, were classed as the accessory element. The most abundant of these were *Semidalis aleyrodiformis*, *Conwentzia psociformis*, *Sympherobius klapaleki* and *Cunctochrysa albolineata*. The relatively low abundance of neuropterans in light oak forests was basically due to a nearly sixfold decrease in the abundance of *Ch. ciliata* in comparison to linden-oak-hornbeam forests, and a similar, though not so marked, fall in the abundance of *N. flava*, indicating that the two species, though both belonged to the dominant group in light oak forests, found more favourable living conditions in linden-oak-hornbeam forests.

Individual communities differed in the composition of the dominant group and the proportions of particular species as was reflected by the wide range of the values of the *Mo* index (0.47– 0.69) (Fig. 2). The greatest similarities were found in the two light oak forests which had an admixture of pine (B. Hryniewiecki Reserve and the Radziejowice forest). Both communities showed a high proportion of *Mallada prasina*. A visibly distinct structure, with *Nineta flava* as the only dominant, was revealed in the community inhabiting the King Jan III Sobieski Reserve light oak forest, situated in an oak-linden stand (Table III).

The differences in the proportions of *Mallada prasina* and *Nineta flava*, of which the former finds optimum habitat conditions in mixed stands of oak and pine, while the latter thrives in homogeneous deciduous stands, make it possible to distinguish the following two variants of the structure of dominance of *Neuropteroidea* communities in light oak forests:

– variant I: a strong dominance of *Nineta flava*, peculiar to purely deciduous forests (King Jan III Sobieski Reserve);

– variant II: the proportion of *Nineta flava* considerably reduced for the sake of *Mallada prasina*, typically occurs in light oak forests with an admixture of pine (B. Hryniewiecki Reserve) (Fig. 4).

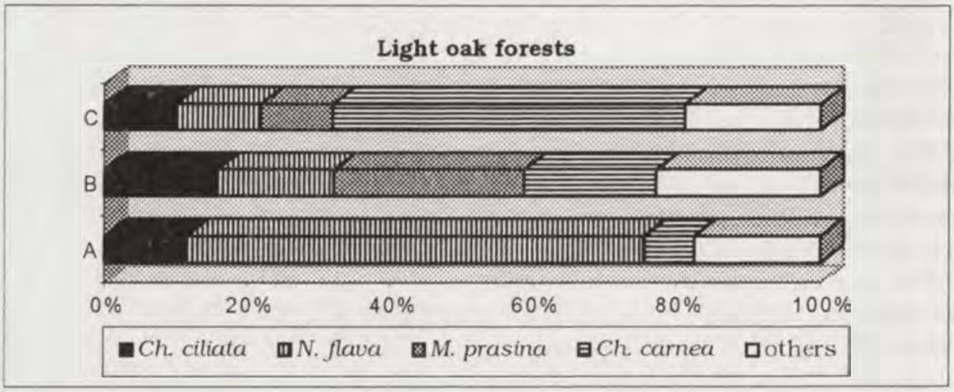

Fig. 4. Proportions of the most important species of *Neuropteroidea* communities in the light oak forests: A - Sobieski, B - Hryniewiecki, C - Radziejowice.

The third community, from the Radziejowice forest (with a smaller admixture of pine), had a structure similar to variant II, but with a rather unexpectedly high proportion of *Chrysoperla carnea*, whose larvae develop mostly in the herb layer.

The neuropteran communities in the light oak forests studied were similar in abundance, but differed in terms of species diversity and dominance structure. General species diversity in these communities was more diversified than in the communities inhabiting linden-oak-hornbeam forests, with *H'* index values ranging between 1.93–3.13 and accounting for 48–70% of the respective potential diversity indices (*H*) (Table II). The lowest diversity figures were obtained for the community inhabiting the purely deciduous forest, where *Nineta flava* made up most of the community.

A constancy analysis embracing the species found in light oak forests did not reveal any elements characteristic of this habitat in the group of dominant species of *Neuropteroidea*.

Mixed forests (*Querco roboris-Pinetum*)

The 31 species found in this habitat included 4 species of *Raphidioptera* and 27 species of *Planipennia* (Table IV). Communities from individual forests numbered 20–23 species and had a qualitative similarity of 70% (Fig. 1). The following species were common to all the forests: *Raphidia notata*, *R. xanthostigma*, *Coniopteryx parthenia*, *Hemerobius humulinus*, *H. stigma*, *H. nitidulus*, *Nineta vittata*, *Chrysotropia ciliata*, *Chrysopa pallens*, *Mallada prasina*, *Chrysoperla carnea* and *Cunctochrysa albolineata*. Together, they accounted for 52–60% of the species content of individual communities.

The index of abundance of individual communities ranged from 17.69 to 69.40 (Table IV). In the whole material, the eudominant group was composed of *Mallada prasina* (58.9%) and *Chrysoperla carnea* (16.2%); the class of dominants contained only *Coniopteryx parthenia* (4.9%); and the subdominant group was composed of *Raphidia notata*, *Chrysopa pallens*, *Hemerobius humulinus*, *Chrysotropia ciliata*, *Nineta vittata*, *Hemerobius stigma* and *Mallada ventralis*. The accessory element included 21 species, accounting for 5.6% of the material, with *Hemerobius nitidulus*, *Raphidia xanthostigma* and *Wesmaelius concinnus* being the most numerous.

Table IV. Abundance (*n* - index) and proportions (%) of particular species of *Neuropteroidea* in mixed coniferous forests (*Querco roboris-Pinetum*)

No	Species / Plots	Lomna I		Lomna II		Kaliszki res.		Mean	
		n	%	*n*	%	*n*	%	*n*	%
1	*Raphidia ophiopsis ophiopsis* L.	-	-	0.07	0.2	0.07	0.4	0.05	0.1
2	*Raphidia notata* FABR.	2.52	3.6	0.50	1.4	1.24	7.0	1.42	3.5
3	*Raphidia xanthostigma* SCHUMM.	0.62	0.9	0.25	0.7	0.19	1.1	0.35	0.9
4	*Inocellia crassicornis* (SCHUMM.)	-	-	0.06	0.2	-	-	0.02	0.1
5	*Aleuropteryx loewii* KLAP.	-	-	-	-	0.13	0.7	0.04	0.1
6	*Coniopteryx parthenia* (NAV. et MARC.)	4.30	6.2	0.76	2.2	0.97	5.5	2.01	4.9
7	*Parasemidalis fuscipennis* REUT.	0.27	0.4	-	-	-	-	0.09	0.2
8	*Semidalis aleyrodiformis* (STEPH.)	-	-	-	-	0.18	1.0	0.06	0.1
9	*Conwentzia psociformis* (CURT.)	0.12	0.2	-	-	-	-	0.04	0.1
10	*Conwentzia pineticola* END.	0.40	0.6	-	-	0.07	0.4	0.16	0.4
11	*Drepanopteryx phalaenoides* (L.)	0.12	0.2	-	-	0.06	0.3	0.06	0.1
12	*Wesmaelius concinnus* (STEPH.)	0.62	0.9	-	-	0.20	1.1	0.27	0.7
13	*Wesmaelius nervosus* (FABR.)	-	-	0.25	0.7	-	-	0.08	0.2
14	*Wesmaelius mortoni* (MCLACHL.)	-	-	0.07	0.2	0.06	0.3	0.04	0.1
15	*Hemerobius humulinus* L.	0.88	1.3	1.66	4.7	0.37	2.1	0.97	2.4
16	*Hemerobius stigma* STEPH.	0.42	0.6	0.52	1.5	0.59	3.4	0.51	1.3
17	*Hemerobius pini* STEPH.	0.13	0.2	-	-	-	-	0.04	0.1
18	*Hemerobius nitidulus* FABR.	0.40	0.6	0.52	1.5	0.26	1.5	0.39	1.0
19	*Hemerobius micans* OLIV.	0.12	0.2	0.19	0.5	-	-	0.10	0.2
20	*Sympherobius pygmaeus* (RAMB.)	0.12	0.2	-	-	-	-	0.04	0.1
21	*Sympherobius elegans* (STEPH.)	-	-	-	-	0.07	0.4	0.02	0.1
22	*Sympherobius fuscescens* (WALL.)	-	-	0.19	0.5	-	-	0.06	0.1
23	*Nineta flava* (SCOP.)	0.23	0.3	0.06	0.2	-	-	0.10	0.3
24	*Nineta vittata* (WESM.)	0.23	0.3	0.40	4.0	0.25	1.4	0.63	1.6
25	*Chrysotropia ciliata* (WESM.)	0.12	0.2	0.98	2.8	1.10	6.2	0.73	1.8
26	*Chrysopa dorsalis* BURM.	0.12	0.2	-	-	-	-	0.04	0.1
27	*Chrysopa pallens* (RAMB.)	0.62	0.9	0.88	2.5	1.94	11.0	1.15	2.8
28	*Mallada prasina* (BURM.)	43.12	62.0	21.23	60.4	7.65	43.3	24.00	58.9
29	*Mallada ventralis* (CURT.)	0.95	1.4	0.43	1.2	-	-	0.46	1.1
30	*Chrysoperla carnea* (STEPH.)	12.85	18.4	5.04	14.3	1.90	10.7	6.60	16.2
31	*Cunctochrysa albolineata* (KILL.)	0.12	0.2	0.12	0.3	0.39	2.2	0.21	0.5
	Total	69.40	100.0	35.18	100.0	17.69	100.0	40.74	100.0
	Number of species	23		20		20		31	

The structure of dominance of all the communities studied in the mixed coniferous forests were very similar, with *Mo* ranging from 0.91 to 0.99, which was due to a high proportion of Mallada prasina (Table IV, Figs 2 and 5).

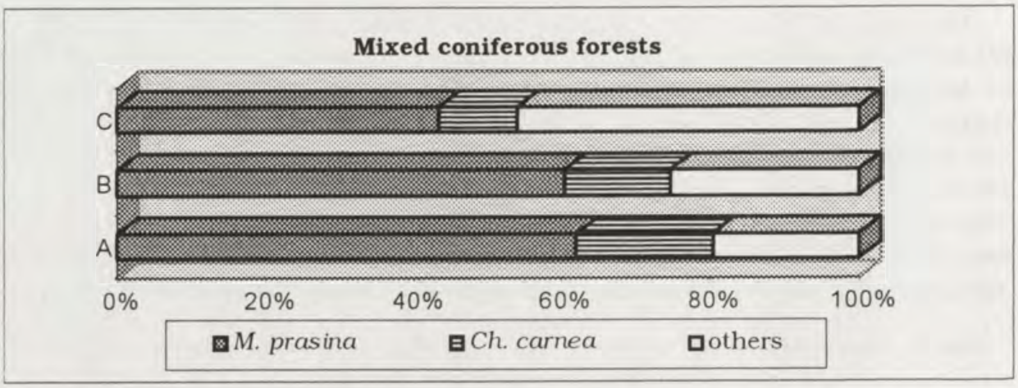

Fig. 5. Proportions of the most important species of *Neuropteroidea* communities in the mixed coniferous forests: A -Łomna I, B - Łomna II, C - Kaliszki.

Table V. Abundance (*n* - index) and proportions (%) of particular species of *Neuropteroidea* on various tree species in linden-oak-hornbeam forests (*Tilio-Carpinetum*)

No	Species / Tree species	Quercus sp.		Tilia cordata		Carpinus betulus		Ulmus sp.		Larix polonica	
		n	%	*n*	%	*n*	%	*n*	%	*n*	%
1	Raphidia notata Fabr.	0.13	0.2	0.03	0.1	-	-	-	-	1.30	4.2
2	Raphidia major Burm.	-	-	-	-	-	-	-	-	0.40	1.3
3	Raphidia xanthostigma Schumm.	-	-	0.03	0.1	-	-	-	-	-	-
4	Coniopteryx tineiformis Curt.	0.06	0.1	0.34	1.2	0.08	0.3	-	-	-	-
5	Coniopteryx borealis Tjed.	-	-	-	-	0.06	0.2	-	-	-	-
6	Coniopteryx parthenia (Nav. et Marc.)	-	-	0.09	0.3	-	-	-	-	-	-
7	Coniopteryx haematica McLachl.	0.14	0.3	-	-	-	-	-	-	-	-
8	Semidalis aleyrodiformis (Steph.)	-	-	0.08	0.3	-	-	-	-	-	-
9	Conventzia psociformis Curt.	0.16	0.3	-	-	-	-	-	-	-	-
10	Drepanopteryx phalaenoides (L.)	-	-	0.09	0.3	0.04	0.2	-	-	-	-
11	Wesmaelius concinnus (Steph.)	0.07	0.1	-	-	-	-	-	-	0.15	0.5
12	Wesmaelius quadrifasciatus (Reut.)	-	-	-	-	0.11	0.4	-	-	0.45	1.5
13	Wesmaelius nervosus (Fabr.)	-	-	0.11	0.4	-	-	0.25	1.2	-	-
14	Hemerobius humulinus L.	0.75	1.4	1.10	3.9	1.12	4.1	2.38	11.3	0.70	2.3
15	Hemerobius atrifrons McLachl.	-	-	-	-	-	-	-	-	0.85	2.7
16	Hemerobius micans Oliv.	0.02	0.1	0.15	0.5	0.28	1.0	0.18	0.9	0.15	0.5
17	Hemerobius marginatus Steph.	-	-	-	-	-	-	0.08	0.4	-	-
18	Sympherobius klapaleki Zel.	0.08	0.2	0.21	0.7	0.21	0.8	-	-	-	-
19	Nineta flava (Scop.)	10.77	19.6	2.24	8.0	6.40	23.3	5.48	25.8	11.85	38.1
20	Nineta vittata (Wesm.)	1.34	2.4	0.43	1.5	0.46	1.7	-	-	1.60	5.2
21	Nineta inpunctata (Reut.)	-	-	0.09	0.3	0.05	0.2	-	-	-	-
22	Chrysotropia ciliata (Wesm.)	13.14	23.9	11.61	41.3	9.22	33.6	6.15	29.1	3.70	11.8
23	Chrysopa perla (L.)	-	-	-	-	0.04	0.2	-	-	-	-
24	Chrysopa pallens (Burm.)	1.10	2.0	0.26	1.1	0.21	0.8	0.15	0.7	4.40	14.2
25	Mallada prasina (Burm.)	13.38	24.3	1.91	6.8	1.33	4.9	0.50	2.4	1.45	4.7
26	Mallada ventralis (Curt.)	0.44	0.8	-	-	0.02	0.1	0.18	0.9	-	-
27	Chrysoperla carnea (Steph.)	13.03	23.7	8.50	30.2	6.89	25.2	5.78	27.3	4.05	13.0
28	Cunctochrysa albolineata (Kill.)	0.34	0.6	0.83	3.0	0.83	3.0	-	-	-	-
	Total	54.95	100.0	28.10	100.0	27.35	100.0	21.13	100.0	31.05	100.0
	Number of species	16		18		17		10		13	

Table VI. Mean abundance (*n* - index) and proportions (%) of particular species of *Neuropteroidea* on various tree species in light oak forests (*Potentillo albae-Quercetum*)

No	Tree species / Species	*Quercus sp.*		*Tilia cordata*		*Carpinus betulus*		*Pinus silvestris*	
		n	%	*n*	%	*n*	%	*n*	%
1	*Raphidia flavipes* STEIN.	-	-	-	-	-	-	0.11	1.0
2	*Raphidia notata* FABR.	0.14	1.0	0.03	0.2	-	-	0.67	6.0
3	*Raphidia major* BURM.	-	-	0.03	0.2	-	-	-	-
4	*Raphidia xanthostigma* SCHUMM.	0.02	0.1	-	-	-	-	0.11	1.0
5	*Coniopteryx parthenia* (NAV. et MARC.)	-	-	-	-	0.04	0.4	-	-
6	*Coniopteryx haematica* MCLACHL.	-	-	-	-	-	-	0.11	1.0
7	*Semidalis aleyrodiformis* (STEPH.)	0.05	0.3	0.27	1.4	0.30	3.4	-	-
8	*Conwentzia psociformis* CURT.	0.30	2.0	0.07	0.4	-	-	-	-
9	*Drepanopteryx phalaenoides* (L.)	-	-	-	-	0.04	0.4	-	-
10	*Wesmaelius concinnus* (STEPH.)	0.07	0.5	-	-	-	-	2.90	26.1
11	*Wesmaelius nervosus* (FABR.)	-	-	0.03	0.2	0.08	0.9	-	-
12	*Hemerobius humulinus* L.	0.24	1.6	1.24	6.3	0.93	10.4	0.11	1.0
13	*Hemerobius stigma* STEPH.	-	-	-	-	-	-	-	-
14	*Hemerobius nitidulus* FABR.	-	-	-	-	-	-	0.37	3.3
15	*Hemerobius micans* OLIV.	-	-	0.14	0.7	0.14	1.6	0.30	2.7
16	*Sympherobius pygmaeus* (RAMB.)	-	-	0.06	0.4	-	-	-	-
17	*Sympherobius klapaleki* ZEL.	0.25	1.7	0.12	0.6	0.05	0.6	-	-
18	*Nineta flava* (SCOP.)	3.93	26.7	8.06	41.0	2.09	23.4	0.82	7.4
19	*Nineta vittata* (WESM.)	0.72	4.9	1.09	5.4	0.25	2.8	0.41	3.7
20	*Chrysotropia ciliata* (WESM.)	1.54	10.5	2.85	14.4	1.93	21.6	0.45	4.1
21	*Chrysopa pallens* (RAMB.)	0.17	1.2	0.03	0.2	-	-	0.30	2.7
22	*Mallada flavifrons* (BRAU.)	0.05	0.3	-	-	-	-	-	-
23	*Mallada prasina* (BURM.)	3.19	21.7	0.84	4.3	0.72	8.1	3.31	29.9
24	*Mallada ventralis* (CURT.)	0.34	2.3	0.15	0.8	0.05	0.6	-	-
25	*Chrysoperla carnea* (STEPH.)	3.56	24.3	4.49	22.7	2.25	25.2	0.67	6.0
26	*Cunctochrysa albolineata* (KILL.)	0.13	0.9	0.15	0.8	0.05	0.6	0.45	4.1
	Total	14.70	100.0	19.65	100.0	8.92	100.0	11.09	100.0
	Number of species	16		17		14		15	

The abundance of this species in individual coniferous forests, markedly influencing the total abundance of the communities, varied widely (Table IV). In an oak-dominated forest (Łomna I) *M. prasina* was nearly 6 times as abundant as in a forest formed predominantly of pine (Kaliszki) and 2 times as high as in a forest with similar proportions of pine and oak (Łomna II). The dependence of the size of the population of *M. prasina* on the proportion of oak in the stand stems from its marked trophic preference for oak. The proportions of *M. prasina* among neuropterans collected from oak trees were usually higher than on other tree species (Tabels V–VIII).

Though similar in quality and structure, the communities of neuropterans in the mixed coniferous forests under study were considerably distinct in abundance as well as species diversity. *Mallada prasina* was the species whose abundance influenced most strongly the overall abundance of communities and the distribution of the species' proportions. The most equal distribution of proportions of individual species was recorded for the community with the smallest percentage contribution of *Mallada prasina*.

Species diversity (*H'*) varied between 2.00 and 2.97 (Table II) and reached 44–69% of potential diversity (*H*). The lowest index of diversity was recorded for the community from the oak-dominated coniferous forest (Łomna I), where *M. prasina* was also most abundant and had its greatest share in a community.

Table VII. Mean abundance (*n* - index) and proportions (%) of particular species of *Neuropteroidea* on various tree species in mixed coniferous forests (*Querco roboris-Pinetum*)

No	Species / Tree species	*Quercus sp.*		*Betula verrucosa*		*Pinus silvestris*	
		n	%	*n*	%	*n*	%
1	*Raphidia ophiopsis ophiopsis* L.	-	-	-	-	0.13	0.5
2	*Raphidia notata* FABR.	1.20	1.7	0.25	1.0	2.81	11.3
3	*Raphidia xanthostigma* SCHUMM.	0.37	0.5	0.23	0.9	0.45	1.8
4	*Inocellia crassicornis* (SCHUMM.)	0.06	0.1	-	-	-	-
5	*Aleuropteryx loewii* KLAP.	-	-	-	-	0.13	0.5
6	*Coniopteryx parthenia* (NAV. et MARC.)	0.50	0.7	2.62	10.4	2.91	11.7
7	*Parasemidalis fuscipennis* REUT.	-	-	0.13	0.5	0.13	0.5
8	*Semidalis aleyrodiformis* (STEPH.)	0.18	0.2	-	-	-	-
9	*Conventzia psociformis* (CURT.)	0.12	0.2	-	-	-	-
10	*Conwentzia pineticola* END.	0.13	0.2	-	-	0.33	1.3
11	*Drepanopteryx phalaenoides* (L.)	0.12	0.2	0.06	0.2	-	-
12	*Wesmaelius concinnus* (STEPH.)	-	-	-	-	0.81	3.2
13	*Wesmaelius nervosus* (FABR.)	-	-	0.25	1.0	-	-
14	*Wesmaelius mortoni* (MCLACHL.)	-	-	0.06	0.2	0.07	0.3
15	*Hemerobius humulinus* L.	0.92	1.3	1.92	7.6	0.07	0.3
16	*Hemerobius stigma* STEPH.	0.12	0.2	-	-	1.40	5.6
17	*Hemerobius pini* STEPH.	-	-	0.13	0.5	-	-
18	*Hemerobius nitidulus* FABR.	0.06	0.1	0.26	1.0	0.86	3.5
19	*Hemerobius micans* OLIV.	-	-	0.30	1.2	-	-
20	*Sympherobius pygmaeus* (RAMB.)	-	-	0.12	0.5	-	-
21	*Sympherobius elegans* (STEPH.)	-	-	-	-	0.07	0.3
22	*Sympherobius fuscescens* (WALL.)	0.06	0.1	0.06	0.2	0.07	0.3
23	*Nineta flava* (SCOP.)	0.18	0.2	0.12	0.5	-	-
24	*Nineta vittata* (WESM.)	1.39	1.9	0.37	1.5	0.13	0.5
25	*Chrysotropia ciliata* (WESM.)	1.45	2.0	0.68	2.8	0.07	0.3
26	*Chrysopa dorsalis* BURM.	-	-	-	-	0.12	0.5
27	*Chrysopa pallens* (RAMB.)	1.04	1.4	0.25	1.0	2.16	8.8
28	*Mallada prasina* (BURM.)	53.45	74.1	10.58	41.9	7.96	32.0
29	*Mallada ventralis* (CURT.)	1.20	1.7	-	-	0.18	0.7
30	*Chrysoperla carnea* (STEPH.)	9.34	12.9	6.78	26.9	3.68	14.8
31	*Cunctochrysa albolineata* (KILL.)	0.24	0.3	0.06	0.2	0.33	1.3
	Total	72.13	100.0	25.23	100.0	24.87	100.0
	Number of species	20		20		22	

Of the dominant species, *Mallada prasina* (W=74%), *Raphidia notata* (65%) and *Mallada ventralis* (52%) were revealed to be characteristic of this habitat, while *Chrysopa pallens* (W = 47%), *Coniopteryx parthenia* (42%), *Chrysoperla carnea* (34%), *Hemerobius humulinus* (30%), *Hemerobius stigma* (29%) and *Niteta vittata* (29%) were identified as accompanying species.

Table VIII. Abundance (n – index) and proportions (%) of particular species of *Neuropteroidea* in the pine forests (*Peucedano-Pinetum* and *Leucobryo-Pinetum*) on pine (*Pinus silvestris*) (+ – n<0.01)

No	Species / Plots	Puszcza Białowieska		Puszcza Biała		Puszcza Kampinoska		Bory Tucholskie		Babimost		Roztoczański National Park		Mean	
		n	%	*n*	%	*n*	%	*n*	%	*n*	%	*n*	%	*n*	%
1	*Raphidia ophiopsis ophiopsis* L.	0.06	0.5	0.11	1.3	1.90	6.7	0.19	1.9	–	–	0.10	0.7	0.39	2.7
2	*Raphidia flavipes* STEIN	–	–	–	–	–	–	–	–	–	–	0.62	4.4	0.10	0.7
3	*Raphidia notata* FABR.	0.38	3.1	1.01	12.1	0.80	2.8	0.41	4.1	–	–	0.42	3.0	0.50	3.5
4	*Raphidia xanthostigma* SCHUMM.	4.98	40.4	1.97	23.5	4.85	17.2	2.38	23.6	0.27	2.0	–	–	2.41	16.7
5	*Inocellia crassicornis* (SCHUMM.)	0.06	0.5	0.24	2.9	–	–	0.04	0.4	0.10	0.7	0.67	4.8	0.19	1.3
6	*Aleuropteryx loewii* KLAP.	–	–	–	–	0.40	1.4	–	–	0.03	0.2	–	–	0.07	0.5
7	*Coniopteryx parthenia* NAV. et MARC.	0.02	0.2	0.28	3.3	2.90	10.3	0.18	1.8	7.77	56.8	5.45	39.0	2.77	19.1
8	*Parasemidalis fuscipennis* (REUT.)	–	–	–	–	0.40	1.4	0.02	0.2	1.30	9.5	0.47	3.3	0.37	2.6
9	*Conwentzia pineticola* END.	–	–	0.07	0.8	0.40	1.4	–	–	–	–	0.05	0.4	0.09	0.6
10	*Drepanopteryx phalaenoides* (L.)	–	–	–	–	–	–	0.02	0.2	–	–	–	–	+	+
11	*Wesmaelius concinnus* (STEPH.)	1.06	8.6	1.59	19.0	9.45	33.5	2.69	26.6	0.24	1.8	0.88	6.3	2.65	18.3
12	*Wesmaelius nervosus* (FABR.)	0.06	0.5	0.03	0.4	–	–	0.02	0.2	–	–	–	–	0.02	0.1
13	*Wesmaelius mortoni* (MCLACHLN.)	0.02	0.2	–	–	–	–	0.02	0.2	–	–	–	–	0.01	0.1
14	*Hemerobius humulinus* L.	0.08	0.6	0.12	1.4	2.00	7.1	0.09	0.9	0.10	0.7	0.05	0.4	0.41	2.8
15	*Hemerobius stigma* STEPH.	1.04	8.4	1.36	16.2	0.35	1.2	1.56	15.4	2.23	16.3	0.78	5.6	1.22	8.4
16	*Hemerobius pini* STEPH.	0.15	1.2	–	–	–	–	0.04	0.4	–	–	–	–	0.03	0.2
17	*Hemerobius fenestratus* TJED.	0.02	0.2	–	–	–	–	–	–	–	–	0.05	0.4	0.01	0.1
18	*Hemerobius atrifrons* MCLACHL.	–	–	–	–	–	–	0.02	0.2	–	–	–	–	+	+
19	*Hemerobius nitidulus* FABR.	0.16	1.3	0.25	3.0	1.20	4.2	0.58	5.7	0.37	2.7	1.35	9.6	0.65	4.5
20	*Hemerobius micans* OLIV.	–	–	–	–	–	–	–	–	0.07	0.5	0.05	0.4	0.02	0.1
21	*Sympherobius fuscescens* (WALL.)	0.06	0.5	0.07	0.8	–	–	–	–	–	–	–	–	0.02	0.1
22	*Nothochrysa capitata* (FABR.)	–	–	–	–	–	–	–	–	–	–	0.21	1.5	0.04	0.3
23	*Nineta flava* (SCOP.)	–	–	–	–	0.40	1.4	–	–	–	–	–	–	0.07	0.5
24	*Nineta vittata* (WESM.)	0.18	1.5	0.05	0.6	–	–	–	–	–	–	–	–	0.04	0.3
25	*Chrysotropia ciliata* (WESM.)	–	–	–	–	–	–	–	–	0.03	0.2	0.10	0.7	0.02	0.2
26	*Chrysopa perla* (L.)	–	–	–	–	–	–	–	–	–	–	0.05	0.4	0.01	0.1
27	*Chrysopa pallens* (RAMB.)	0.73	5.9	0.35	4.2	–	–	0.47	4.7	0.10	0.7	0.42	3.0	0.35	2.4
28	*Mallada prasina* (BURM.)	2.48	20.1	0.59	7.0	2.05	7.3	0.84	8.3	0.10	0.7	1.45	10.3	1.25	8.6
29	*Mallada ventralis* (CURT.)	0.26	2.1	–	–	–	–	–	–	–	–	0.10	0.7	0.06	0.4
30	*Chrysoperla carnea* (STEPH.)	0.16	1.3	0.25	3.0	1.15	4.1	0.10	1.0	0.83	6.1	0.62	4.4	0.52	3.6
31	*Cunctochrysa albolineata* (KILL.)	0.37	3.0	0.04	0.5	–	–	0.43	4.3	0.14	1.0	0.10	0.7	0.18	1.2
	Total	12.33	100.0	8.38	100.0	28.25	100.0	10.10	100.0	13.68	100.0	13.99	100.0	14.47	100.0
	Number of species	20		17		14		19		15		21		31	

Pine forests (*Peucedano-Pinetum* and *Leucobryo-Pinetum*)

31 species of *Neuropteroidea* were recorded from these forests, including 5 *Raphidioptera* and 26 *Planipennia* species. The number of species in individual forests varied from 14 to 21 (Table VIII), and qualitative similarity ranged from 61 to 89% (Fig. 1).

The average abundance of *Neuropteroidea* in the pine forests equalled 14.47, with the abundance of most communities either similar or only slightly lower than this value. The only exception was the *Neuropteroidea* community of Puszcza Kampinoska, with an abundance twice as high as the average (Table VIII).

In the whole material, the class of eudominants consisted of *Coniopteryx parthenia* (19.1%), *Wesmaelius concinnus* (18.3%) and *Raphidia xanthostigma* (16.7%). The class of dominants was formed by *Mallada prasina* and *Hemerobius stigma*, while the group of subdominants comprised *Hemerobius nitidulus*, *Chrysoperla carnea*, *Raphidia notata*, *Hemerobius humulinus*, *Parasemidalis fuscipennis*, *Raphidia ophiopsis*, *Chrysopa pallens*, *Innocelia crassicornis* and *Cunctochrysa albolineata*. The above species were also those with the highest constancy of occurrence: except *Parasemidalis fuscipennis*, recorded only from 4 areas, the others were found in 5 to 6 of the forests under study (Table VIII). The accessory element was represented by 17 species (4.3% of the material), the most abundant of which were *Raphidia flavipes* and *Conwentzia pineticola*.

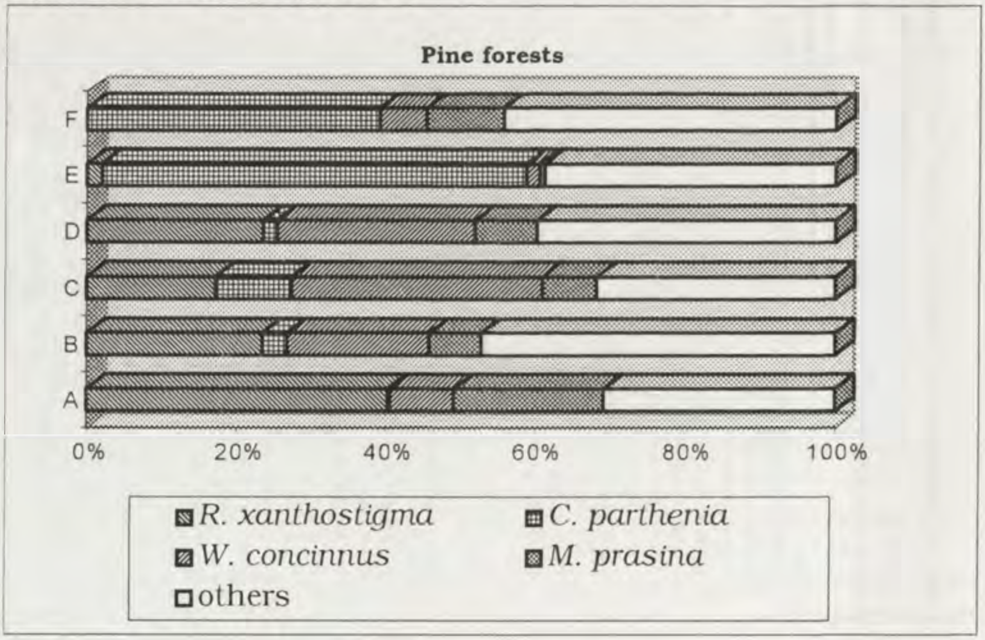

Fig. 6. Proportions of the most important species of *Neuropteroidea* communities in the pine forests: A - Puszcza Białowieska, B - Puszcza Biała, C - Puszcza Kampinoska, D - Bory Tucholskie, E - Babimost, F - Roztocze.

Unlike communities from the habitats discussed earlier, where eudominant positions were occupied by species of the family *Chrysopidae*, it was *Raphidiidae*, *Coniopterygidae* and *Hemerobiidae* that prevailed in the pine forests. Another characteristic feature of the communities of *Neuropteroidea* in these forests was differences in the shares of representatives of the three families. These were mostly due to fluctuations in the numbers of *Raphidia xanthostigma*, *Wesmaelius concinnus* and *Coniopteryx parthenia* (Fig. 6).

The communities of *Neuropteroidea* from the four pine forests (Puszcza Białowieska, Puszcza Biała, Puszcza Kampinoska, Bory Tucholskie) situated in northern Poland were characterized by higher contributions of *Raphidiidae* and *Hemerobiidae* than *Coniopterygidae*. The dominant species there were *Raphidia xanthostigma* and *Wesmaelius concinnus*, and locally also *Raphidia notata*, *R. ophiopsis* and *Hemerobius stigma* (Table VIII). The values of the index of structural similarity (*Mo*) ranged from 0.59 to 0.95. The highest structural similarity was recorded for the communities of Puszcza Biała and Bory Tucholskie (Fig. 2).

A different picture was observed with the structures of dominance of *Neuropteroidea* communities in the pine forests of south-eastern and south-western Poland (Roztocze, Babimost). There, the most abundant species was *Coniopteryx parthenia*, while the proportions of species of the families *Raphidiidae* and *Hemerobiidae* were considerably limited (Table VIII, Fig. 6). The index of structural similarity of these communities equalled 0.89.

Thus, *Neuropteroidea* communities from the pine forests under study were shown to belong to one of two variants of the structure of dominance. The similarity between the two variants ranged from 0.12 to 0.43, with the lowest values recorded for the Puszcza Białowieska community, dominated by *Raphidia xanthostigma* and the Babimost forest community, characterized by an exceptionally high proportion of *Coniopteryx parthenia* (Fig. 2, Fig. 6).

Higher proportions of *Raphidiidae* and *Hemerobiidae* in comparison with *Coniopterygidae* were seen in *Peucedano-Pinetum* forests (Puszcza Białowieska, Puszcza Biała, Puszcza Kampinoska) and in Bory Tucholskie, situated on the border between the geographical ranges of the *Peucedano-Pinetum* and the *Leucobryo-Pinetum* varieties. On the other hand, on sites representing the typical *Leucobryo-Pinetum* association (Babimost, Roztocze), the dominant form was *Coniopteryx parthenia*.

Although there were differences in abundance and the number of species between individual communities, these were not high, considering the situation of the study sites in different regions of Poland. The general species diversity of the communities was also similar, *H'* ranging from 2.87 to 3.23, with the exception of the Babimost forest *Neuropteroidea* community, where *H'* equalled 2.19. The actual species diversity of individual communities accounted for 56–81% of the potential diversity (*H*), the two parameters being particularly close in communities from Puszcza Kampinoska, Puszcza Biała, Roztocze and Bory Tucholskie (Table II).

The species most closely associated with pine forests and showing very high indices of constancy were: *Innocelia crassicornis* (W = 91%), *Raphidia ophiopsis* (89%), *R. xanthostigma* (87%), *Wesmaelius concinnus* (84%) and *Parasemidalis fuscipennis* (80%). Somewhat smaller constancy values were calculated for *Hemerobius stigma* (W=70%), *H. nitidulus* (61%) and *Coniopteryx parthenia* (58%).

ANALYSIS OF SIMILARITY BETWEEN THE COMMUNITIES FROM THE STUDY FORESTS

The number of *Neuropteroidea* species recorded in the various types of forest investigated varied between 26 and 31 (Table IX). Qualitative similarity of the neuropterofanuas of these habitats ranged from 56% to 84% (Table X). The most similar species compositions were seen between the pine forest and the mixed coniferous forest, which had as many as 26 species in common. The least similar neuropterofaunas to each other had the pine forest and the linden-oak-hornbeam forest, where only 17 common species were found to be common.

The following species were common to all the four types of forest: *Raphidia notata*, *R. xanthostigma*, *Coniopteryx parthenia*, *Drepanopteryx phalaenoides*, *Wesmaelius concinnus*, *W. nervosus*, *Hemerobius humulinus*, *H. micans*, *Nineta flava*, *N. vittata*, *Chrysotropia ciliata*, *Chrysopa pallens*, *Mallada prasina*, *M. ventralis*, *Chrysoperla carnea* and *Cunctochrysa albolineata*. The occurrence of those species accounted for a generally high qualitative similarity between the *Neuropteroidea* communities of the forest habitats investigated (mean SÖRENSEN index of 69%).

The above species can be divided into three groups with respect to the position occupied in the dominance structure . The first group consisted of extremely abundant species, functioning as eudominants in at least one type of forest: *Raphidia xanthostigma*, *Coniopteryx parthenia*, *Wesmaelius concinnus*, *Nineta flava*, *Chrysotropia ciliata*, *Mallada prasina* and *Chrysoperla carnea*. It was mostly owing to marked differences in the proportions of these species that the communities of *Neuropteroidea* had considerably diversified structures. The second group was composed of moderately abundant forms, usually classed as subdominants, more rarely as dominants: *Raphidia notata*, *Hemerobius humulinus*, *Nineta vittata*, *Chrysopa pallens* and *Cunctochrysa albolineata*. The third group was formed by three species occurring in small numbers in all the habitats: *Hemerobius micans*, *Wesmaelius nervosus* and *Mallada ventralis*.

Figure 2 presents the values of the *Mo* index, showing the similarity of the structures of dominance of pairs of communities. The least similar in structure were the communities from the pine forest on the one hand and the linden-oak-hornbeam forest (in its low and common varieties) as well as the pineless light oak forest on the other. The respective values of the *Mo* index ranged between 0.01 and 0.11, which was due to the fact that the dominant species in deciduous forests (*Nineta flava*, *Chrysotropia ciliata*)

Table IX. Mean abundance (*n* - index) and proportions (%) of particular species of *Neuropteroidea* in the types of forests studied (+ - n<0.01)

No	Forest types / Species	Linden-oak-horbeam forest		Light oak forest		Mixed coniferous forest		Pine forest	
		n	%	*n*	%	*n*	%	*n*	%
1	*Raphidia ophiopsis ophiopsis* L.	-	-	-	-	0.05	0.1	0.39	2.7
2	*Raphidia flavipes* STEIN	-	-	0.01	0.1	-	-	0.10	0.7
3	*Raphidia notata* FABR.	0.16	0.4	0.10	0.7	1.42	3.5	0.50	3.5
4	*Raphidia major* BURM.	0.04	0.1	0.01	0.1	-	-	-	-
5	*Raphidia xanthostigma* SCHUMM.	+	+	0.01	0.1	0.35	0.9	2.41	16.7
6	*Inocellia crassicornis* (SCHUMM.)	-	-	-	-	0.02	0.1	0.19	1.3
7	*Aleuropteryx loewii* KLAP.	-	-	-	-	0.04	0.1	0.07	0.5
8	*Coniopteryx tineiformis* CURT.	0.14	0.4	-	-	-	-	-	-
9	*Coniopteryx borealis* TJED.	0.02	0.1	-	-	-	-	-	-
10	*Coniopteryx parthenia* (NAV. et MARC.)	0.02	0.1	0.01	0.1	2.01	4.9	2.77	19.1
11	*Coniopteryx haematica* MCLACHL.	0.05	0.1	0.01	0.1	-	-	-	-
12	*Parasemidalis fuscipennis* (REUT.)	-	-	-	-	0.09	0.2	0.37	2.6
13	*Semidalis aleyrodiformis* (STEPH.)	0.02	0.1	0.14	1.0	0.06	0.1	-	-
14	*Conwentzia psociformis* (CURT.)	0.05	0.1	0.14	1.0	0.04	0.1	-	-
15	*Conwentzia pineticola* END.	-	-	-	-	0.16	0.4	0.09	0.6
16	*Drepanopteryx phalaenoides* L.	0.04	0.1	0.01	0.1	0.06	0.1	+	+
17	*Wesmaelius concinnus* STEPH.	0.04	0.1	0.21	1.4	0.27	0.7	2.65	18.3
18	*Wesmaelius quadrifasciatus* (REUT.)	0.08	0.2	-	-	-	-	-	-
19	*Wesmaelius nervosus* (FABR.)	0.04	0.1	0.03	0.2	0.08	0.2	0.02	0.1
20	*Wesmaelius mortoni* (MCLACHL.)	-	-	-	-	0.04	0.1	0.01	0.1
21	*Hemerobius humulinus* L.	1.04	2.8	0.78	5.3	0.97	2.4	0.41	2.8
22	*Hemerobius stigma* STEPH.	-	-	0.02	0.1	0.51	1.3	1.22	8.4
23	*Hemerobius pini* STEPH.	-	-	-	-	0.04	0.1	0.03	0.2
24	*Hemerobius fenestratus* TJED.	-	-	-	-	-	-	0.01	0.1
25	*Hemerobius atrifrons* MCLACHL.	0.07	0.2	-	-	-	-	+	+
26	*Hemerobius nitidulus* FABR.	-	-	0.02	0.1	0.39	1.0	0.65	4.5
27	*Hemerobius micans* OLIV.	0.16	0.4	0.09	0.6	0.10	0.2	0.02	0.1
28	*Hemerobius marginatus* STEPH.	+	+	-	-	-	-	-	-
29	*Sympherobius pygmaeus* (RAMB.)	-	-	0.02	0.1	0.04	0.1	-	-
30	*Sympherobius elegans* (STEPH.)	-	-	-	-	0.02	0.1	-	-
31	*Sympherobius fuscescens* (WALL.)	-	-	-	-	0.06	0.1	0.02	0.1
32	*Sympherobius klapaleki* ZEL.	0.16	0.4	0.14	1.0	-	-	-	-
33	*Nothochrysa capitata* (FABR.)	-	-	-	-	-	-	0.04	0.3
34	*Nineta flava* (SCOP.)	7.40	19.8	4.78	32.5	0.10	0.2	0.07	0.5
35	*Nineta vittata* (WESM.)	0.83	2.2	0.71	4.8	0.63	1.6	0.04	0.3
36	*Nineta inpunctata* (REUT.)	0.04	0.1	-	-	-	-	-	-
37	*Chrysotropia ciliata* (WESM.)	10.64	28.5	1.85	12.6	0.73	1.8	0.02	0.2
38	*Chrysopa perla* (L.)	0.02	0.1	-	-	-	-	0.01	0.1
39	*Chrysopa dorsalis* BURM.	-	-	-	-	0.04	0.1	-	-
40	*Chrysopa pallens* (RAMB.)	0.87	2.3	0.08	0.5	1.15	2.8	0.35	2.4
41	*Mallada flavifrons* (BRAU.)	-	-	0.02	0.1	-	-	-	-
42	*Mallada prasina* (BURM.)	5.46	14.6	1.81	12.3	24.00	58.9	1.25	8.6
43	*Mallada ventralis* (CURT.)	0.16	0.4	0.20	1.3	0.46	1.1	0.06	0.4
44	*Chrysoperla carnea* (STEPH.)	9.24	24.7	3.35	22.8	6.60	16.2	0.52	3.6
45	*Cunctochrysa albolineata* (KILL.)	0.60	1.6	0.14	1.0	0.21	0.5	0.18	1.2
	Total	37.39	100.0	14.69	100.0	40.74	100.0	14.47	100.0

were reduced to the role of merely accessory elements in pine forests. A similar role reversal was noted in deciduous forests in the case of dominants from the pine forests (*Raphidia xanthostigma*, *Coniopteryx parthenia*, *Wesmaelius concinnus*, *Hemerobius stigma*).

Table X. Similarity of species composition (*So*) and mean dominance structures (*Mo*) between communities of *Neuropteroidea* from the particular types of forests

	Linden-oak-hornbeam forest	Light oak forest	Mixed coniferous forest	Pine forest	
Linden-oak-hornbeam forest		78	61	56	So
Light oak forest	0.89		74	63	
Mixed coniferous forest	0.45	0.40		80	
Pine forest	0.15	0.17	0.29		
Mo					

A unique structure was also found in the communities from the mixed coniferous forests, both when compared with the pine forest *Neuropteroidea* communities and with the communities from the low and typical linden-oak-hornbeam forests, with *Mo* index values ranging from 0.08 to 0.49 (Fig. 2). In the mixed coniferous forests, low abundances and percentage shares were obtained for species dominant in the deciduous forests as well as those dominant in the pine forests (Table IX).

The mixed coniferous forest *Neuropteroidea* communities, on the other hand, differed from the communities of the other forests owing to an extremely high proportion of *Mallada prasina*. The species being a light- and warmth-loving one and showing a preference for the oak aphid, it was not often seen in cool linden-oak-hornbeam forests or warm pine forests. It had slightly higher shares in the communities inhabiting the high linden-oak-hornbeam forest with an admixture of pine at Radziejowice, the light oak forests with an admixture of pine in B. Hryniewiecki Reserve and Radziejowice and the pine forest with an admixture of oak in Puszcza Białowieska. As a result, the dominance structures of of the mixed coniferous forest *Neuropteroidea* communities were quite similar to the structures of the communities from these forests (Fig. 2).

Generally, the communities of *Neuropteroidea* from the light oak forests were most closely related structurally to the communities from the linden-oak-hornbeam forests (Fig. 2). What made them different was a lower proportion of the hygrophilous *Chrysotropia ciliata* in the light oak forests and a slightly lower proportion of the mesohygrophilous *Nineta flava* there (Table IX).

A comparison of averaged structures of dominance of the communities from the forests under investigation revealed the lowest similarity of the neuropterofaunas of the pine forest and the other types of forest. Medium values of the *Mo* index were obtained when the neuropterofauna of the mixed coniferous forest was compared to the fauna from the linden-oak-hornbeam forest and the light oak forest. The greatest structural similarity was seen in the case of the neuropterofaunas of the linden-oak-hornbeam forest and the light oak forest (Table X, Fig.7).

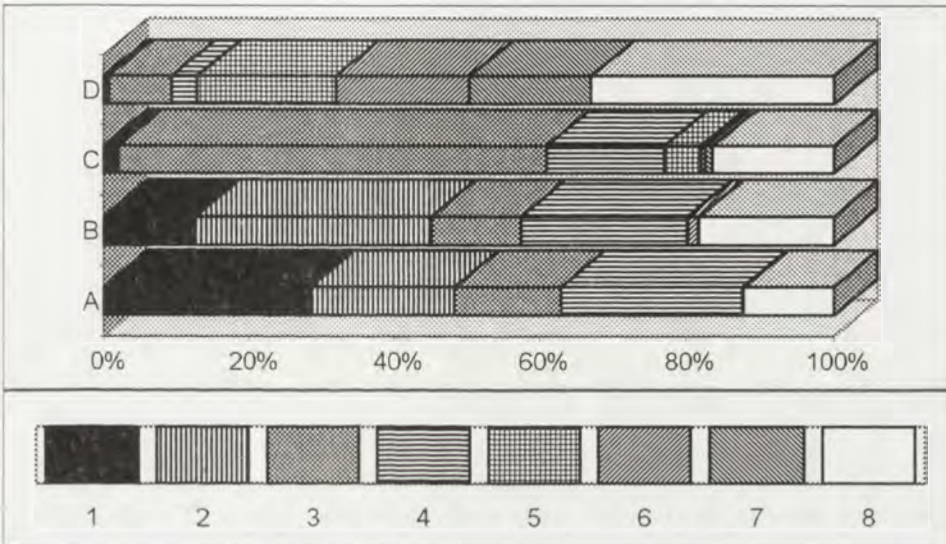

Fig. 7. Mean proportions of the most important species of *Neuropteroidea* communities from the patricular types of forests:
A - linden-oak-hornbeam forest, B - light oak forest, C - mixed coniferous forest, D - pine forest;
1 – Chrysotropia ciliata, 2 – Nineta flava, 3 – Mallada prasina, 4 – Chrysoperla carnea, 5 – Coniopteryx parthenia, 6 – Wesmaelius concinnus, 7 – Raphidia xanthostigma, 8 – others;

In the linden-oak-hornbeam, light oak and mixed coniferous forests, *Chrysopidae* were the most abundant group of neuropterans, constituting from 83% to 94% of the study material from these habitats (Table XI). A different pattern of numerical relations was observed in the *Neuropteroidea* communities of the pine forests, where *Chrysopidae* made up less than 18% of the sampling material, much less than representatives of the families *Raphidiidae*, *Coniopterygiidae* and *Hemerobiidae*. The average proportions of the representatives of each of the latter three families were quite similar in the pine forest, though one or another could prevail locally (Table VIII).

The distinctive structure of the neuropterofauna in the pine forest observed when the communities were compared to the communities from the other three types of forest was also reflected in the values of the species diversity index. Potential species diversity values (*H*), obtained by averaging data from all sites representing the same type of forest, ranged from 4.70 to

4.95, while the values of the index of actual species diversity (H') equalled 2.25 for the mixed coniferous forest, 2.70 for the linden-oak-hornbeam forest, 2.91 for the light oak forest and 3.58 for the pine forest. Thus, in the pine forest the actual species diversity of *Neuropteroidea* was the highest and the most similar to the potential value (72% of H). In the other types of forest, actual species diversity was equal to 46–62% of the respective potential diversity values (Table II).

Table XI. Contributions of the particular families of *Neuropteroidea* to the species composition and mean community abundance in the various types of forests (S - number of species, n - abundance index)

Forest types	Linden-oak-hornbeam forest				Light oak forest				Mixed coniferous forest				Pine forest			
Taxonomic groups	*S*	%	*n*	%	*S*	%	*n*	%	*S*	%	*n*	%	*S*	%	*n*	%
Raphidioptera																
Raphidiidae	3	10.7	0.20	0.5	4	15.4	0.13	1.0	3	9.7	1.82	4.5	4	12.9	3.40	23.6
Inocelliidae	-	-	-	-	-	-	-	-	1	3.2	0.02	0.1	1	3.2	0.19	1.3
Planipennia																
Coniopterygidae	6	21.4	0.30	0.9	4	15.4	0.30	2.2	6	19.4	2.40	5.8	4	12.9	3.30	22.8
Hemerobiidae	9	32.1	1.64	4.4	9	34.6	1.32	8.9	12	38.7	2.58	6.4	12	38.7	5.04	34.7
Chrysopidae	10	35.7	35.25	94.2	9	34.6	12.94	88.0	9	29.0	33.92	83.2	10	32.3	2.54	17.6
Total	28	100.0	37.39	100.0	26	100.0	14.69	100.0	31	100.0	40.74	100.0	31	100.0	14.47	100.0

PHENOLOGY AND SEASONAL DYNAMICS

The time of appearance, the length of occurrence span and the number of generations vary widely among lacewings, resulting in marked seasonal variations in species composition and community abundance. In the forests studied, the imagines of *Raphidioptera* could be seen from May until mid-July. *Raphidia xanthostigma* was caught earliest in the year and was followed by the appearance of *R. notata*, *R. ophiopsis*, *Inocellia crassicornis* and, lastly, *R. flavipes*. Species of the family *Chrysopidae* were mainly found in summer, most of them beginning to appear in June and disappearing in August. These neuropterans usually breed one generation per season, a second, less abundant, generation appearing only sporadically and under particularly favourable conditions. The only exception is *Chrysoperla carnea*, which regularly breeds two generations every year.

Species belonging to the families *Coniopterygidae* and *Hemerobiidae* appear usually in May and typically have more than one generation in one season, the number of generation depending actually on the weather and abundance of food. The genus *Wesmaelius* is an exception with a one-generation-per-year lifestyle and imagines appearing as late as June. In a number of low-abundance species, it is difficult to determine the number of generations. In the case of some relatively abundant species, e.g. *Hemerobius humulinus*, *H. stigma* or *H. nitidulus*, two generations could generally be seen in the forests under study.

A comparison of the number of species cought in each month shows that in linden-oak-hornbeam forests, light oak forests and mixed coniferous forest, *Neuropteroidea* were richest in species in June (before an abundance peak), while in the pine forest, the highest number species could be seen in July (the end of the abundance peak) (Fig. 8). It was in these months that rare and not numerous species would appear.

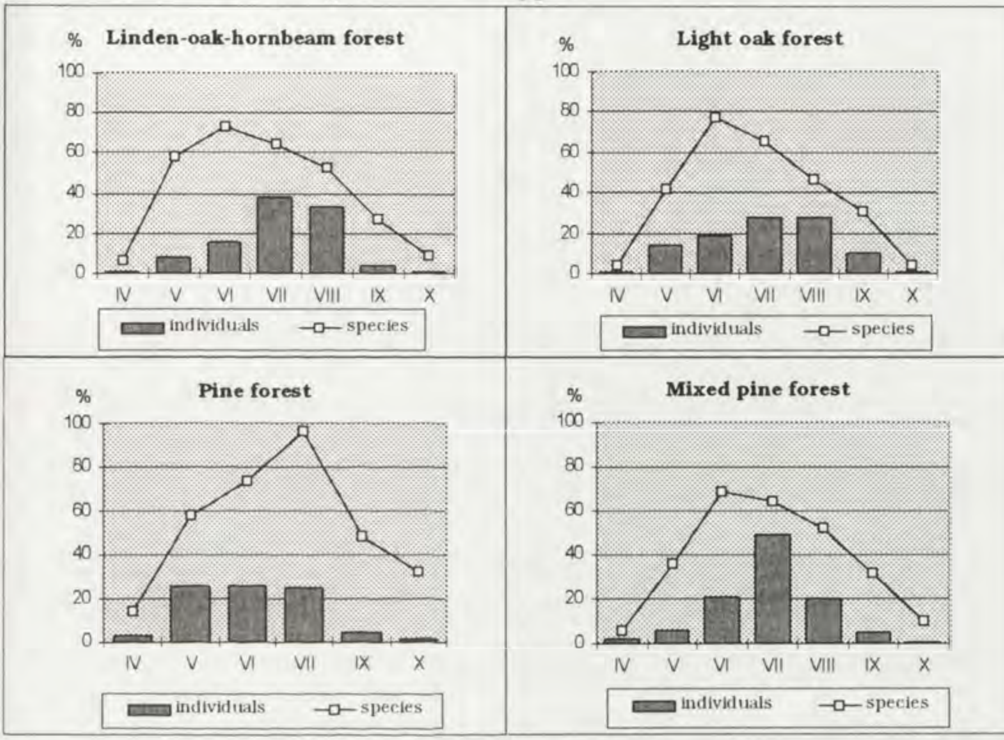

Fig. 8. Seasonal changes in the nubers of species and individuals of Neuropteroidea (percentage of the total material collected in the types of forests studied

The dynamics of seasonal changes of abundance in *Neuropteroidea* communities of the forests studied depended predominantly on the most abundant species in a given habitat. In the linden-oak-hornbeam forests, light oak forests and mixed coniferous forests, *Chrysopidae* were the dominant group in terms of abundance, with *Chrysotropia ciliata*, *Nineta flava* and *Mallada prasina* being the most abundant species. The seasonal dynamics of *Neuropteroidea* in the linden-oak-hornbeam forests and mixed coniferous forests was characterised by low abundance in spring (April–May), a surge in June and a peak in July (Figs 8 and 9). A similar abundance curve, if slightly less steep, could be plotted for the communities in the light oak forests. Owing to a relatively high proportion of species of the family *Hemerobiidae*, a surge in community abundance could be seen there as early as May, and the summer peak continued throughout July and August (Figs 8 and 9).

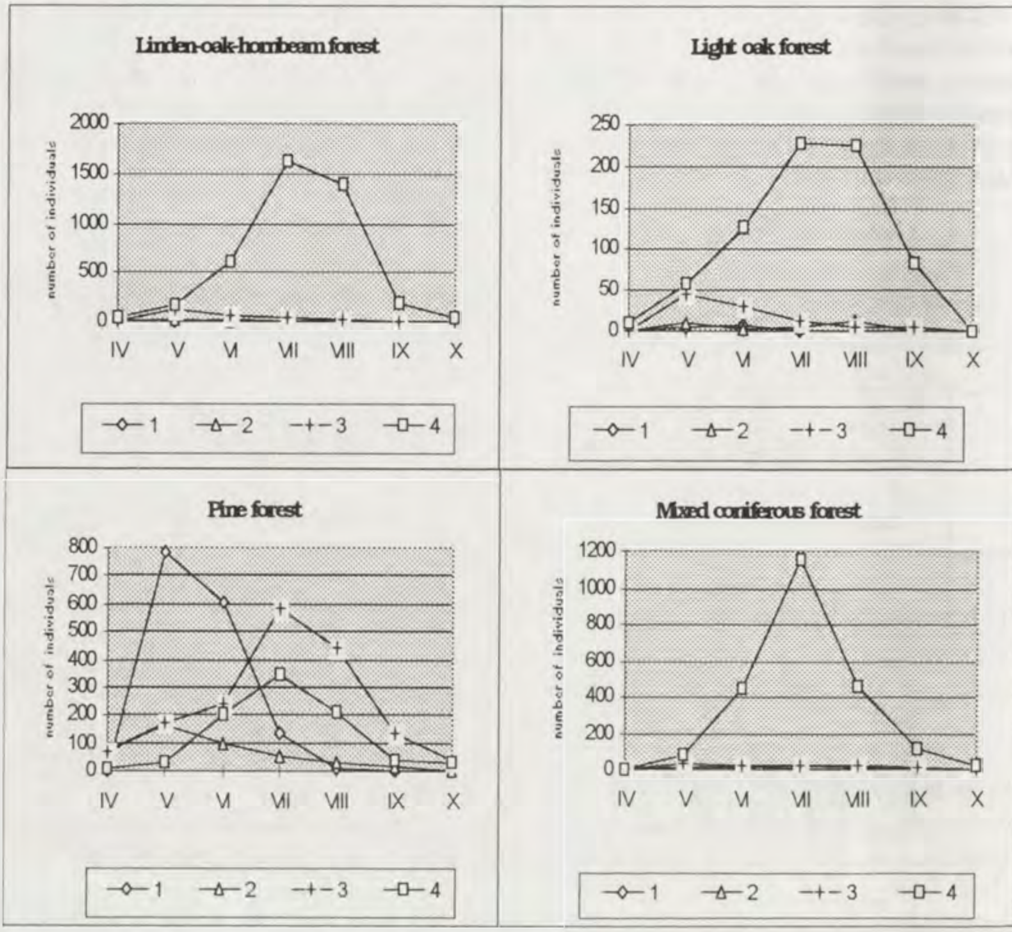

Fig. 9. Seasonal changes in the number of individuals representing particular families of *Neuropteroidea* caught in the types of forest studied: 1 – *Raphidiidae*, 2 – *Coniopterygidae*, 3 – *Hemerobiidae*, 4 – *Chrysopidae*;

A different picture of seasonal changes in abundance was observed in the case of *Neuropteroidea* communities from the pine forests. Following a surge in May, community abundance remained high in June and July to decrease gradually thereafter (Figs 8 and 9). Such a pattern of abundance dynamics was due to high proportions of species of the families *Raphidiidae*, *Coniopterygiidae* and *Hemerobiidae*. In spring (May and the first half of June), the most important species in those communities were *Raphidia xanthostigma*, *R. notata* and the first generations of *Coniopteryx parthenia*, *Hemerobius stigma* and *H. nitidulus*. In summer the most abundant species were *Wesmaelius concinnus*, *Hemerobius stigma* (the second generation) and *Mallada prasina*.

FEEDING AND HABITAT REQUIREMENTS

The relationship of individual species of *Neuropteroidea* with the habitat was determined by recognizing their feeding, thermal and moisture requirements. The species recorded from the forests studied can basically be classified into 4 groups of species feeding on phytophages of 1) deciduous trees and shrubs, 2) coniferous trees and shrubs, 3) coniferous and deciduous trees and shrubs, 4) coniferous and deciduous trees and shrubs and herbaceous plants.

The group of neuropterans preying on deciduous trees and shrubs consisted of 17 species (Table XII), accounting for half of the species registered in linden-oak-hornbeam forests and light oak forests, and nearly 55–54% of the mean number of individuals in these habitats (Table XIII). In the mixed coniferous forests these forms accounted for nearly a third of the total number of species recorded there, but only 4.9% of the number of individuals, a percentage 11 times lower than in the linden-oak-hornbeam forests and light oak forests. In the pine forests the share of forms feeding on the phytophages of deciduous trees and shrubs was 19.4% of the number of species and only 2.3% of mean community abundance (Table XIII).

The group of neuropterans feeding on phytophages of coniferous trees and shrubs numbered 19 species (Table XII). These contributed the most to the neuropterofauna of the pine forests, where they accounted for nearly 55% of the total number of species. In terms of mean community abundance their share was 76.2%. In the mixed forests the species belonging to this group accounted for 45% of the number of species and only 10% of mean community abundance. In the linden-oak-hornbeam forests and light oak forests they accounted for about 20% of the total number of species and had an insignificant share in the communities as far as abundance was concerned (0.6% in linden-oak-hornbeam forests, 1.9% in light oak forests) (Table XIII).

The group of *Neuropteroidea* feeding on phytophages of deciduous and coniferous trees and shrubs comprised 7 species (Table XII). With the exception of *Nineta inpunctata*, recorded only from the linden-oak-hornbeam forests with an admixture of pine, the other species were found in all types of forest studied and accounted for 19–25% of the species registered there. In terms of community abundance, their contribution was highest in the mixed coniferous forests (68,9%). In the other forests they made up 18–21% of mean community abundance (Table XIII).

The most flexible group in terms of feeding habits, preying on phytophages of trees, shrubs and herbaceous plants, consisted only of 2 species: *Chrysoperla carnea* and *Chrysopa perla*. The other was occasionally seen only in the linden-oak-hornbeam forests. *Ch. carnea* was found in all the types of forests studied, but its proportions in communities varied markedly: from 25% in the linden-oak-hornbeam forests to less than 4% of mean community abundance in the pine forests (Table XIII).

Table XII. Zoogeographical and ecological characterization of *Neuropteroidea* species; the zoogeographical elements:C - Cosmopolitan, H - Holarctic, P - Palaearctic, ES - Euro-Siberian, E –European,SM - Submediterranean; types of vegetation: C - coniferous trees, D - deciduous trees, H - herbaceous plants; thermal requirements: T - thermophilous, C - cold-loving, N - non-specified; moisture requirements: X - xerophilous, M - mesohygrophilous, H - hygrophilous

No	Species	Elements	Ecologica		
		Zoogeographical	Types of vegetation	Thermal requirements	Moisture requirements
1	*Raphidia ophiopsis ophiopsis* L.	Euro-Siberian	C	T	X
2	*Raphidia flavipes* STEIN	Submediterranean	C	T	X
3	*Raphidia notata* FABR.	European	CD	T	M
4	*Raphidia major* BURM.	Submediterranean	D	T	M
5	*Raphidia xanthostigma* SCHUMM.	Euro-Siberian	C	T	X
6	*Inocellia crassicornis* (SCHUMM.)	Euro-Siberian	C	T	X
7	*Aleuropteryx loewii* KLAP.	Submediterranean	C	T	M
8	*Coniopteryx tineiformis* CURT.	Holarctic	D	N	M
9	*Coniopteryx borealis* TJED.	Submediterranean	D	T	M
10	*Coniopteryx parthenia* (NAV.et MARC.)	Euro-Siberian	C	N	M
11	*Coniopteryx haematica* MCLACHL.	Submediterranean	D	T	M
12	*Parasemidalis fuscipennis* (REUT.)	Holarctic	C	T	X
13	*Semidalis aleyrodiformis* (STEPH.)	Palaearctic	D	T	M
14	*Conwentzia psociformis* (CURT.)	Holarctic	D	T	M
15	*Conwentzia pineticola* END.	Holarctic	C	T	M
16	*Drepanopteryx phalaenoides* L.	Euro-Siberian	D	T	M
17	*Wesmaelius concinnus* STEPH.	Euro-Siberian	C	T	X
18	*Wesmaelius quadrifasciatus* (REUT.)	Euro-Siberian	C	C	H
19	*Wesmaelius nervosus* (FABR.)	Euro-Siberian	DC	N	M
20	*Wesmaelius mortoni* (MCLACHL.)	Euro-Siberian	C	T	X
21	*Hemerobius humulinus* L.	Holarctic	DC	N	M
22	*Hemerobius stigma* STEPH.	Holarctic	C	T	X
23	*Hemerobius pini* STEPH.	Euro-Siberian	C	C	H
24	*Hemerobius fenestratus* TJED.	Euro-Siberian	C	N	M
25	*Hemerobius atrifrons* MCLACHL.	Euro-Siberian	C	C	H
26	*Hemerobius nitidulus* FABR.	Euro-Siberian	C	T	X
27	*Hemerobius micans* OLIV.	Euro-Siberian	D	N	M
28	*Hemerobius marginatus* STEPH.	Euro-Siberian	D	N	H
29	*Sympherobius pygmaeus* (RAMB.)	Submediterranean	D	T	M
30	*Sympherobius elegans* (STEPH.)	Submediterranean	D	T	M
31	*Sympherobius fuscescens* (WALL.)	Euro-Siberian	C	T	X
32	*Sympherobius klapaleki* ZEL.	Submediterranean	D	T	M
33	*Nothochrysa capitata* (FABR.)	Submediterranean	C	T	X
34	*Nineta flava* (SCOP.)	Euro-Siberian	D	N	M
35	*Nineta vittata* (WESM.)	Euro-Siberian	D	N	M
36	*Nineta inpunctata* (REUT.)	European	DC	T	M
37	*Chrysotropia ciliata* (WESM.)	Euro-Siberian	D	C	H
38	*Chrysopa perla* (L.)	Euro-Siberian	HDC	N	M
39	*Chrysopa dorsalis* BURM.	Submediterranean	C	T	X
40	*Chrysopa pallens* (RAMB.)	Palaearctic	DC	T	M
41	*Mallada flavirons* (BRAU.)	Submediterranean	D	T	M
42	*Mallada prasina* (BURM.)	Palaearctic	DC	T	M
43	*Mallada ventralis* (CURT.)	European	DC	N	M
44	*Chrysoperla carnea* (STEPH.)	Cosmopolitan	HDC	N	M
45	*Cunctochrysa albolineata* (KILL.)	Euro-Siberian	D	N	M

Among the species feeding on phytophages of both coniferous and deciduous trees, *Raphidia notata* and *Chrysopa pallens* were more abundant on coniferous trees (larches and pines), while *Hemerobius humulinus*, *Wesmaelius nervosus*, *Mallada ventralis* and *M. prasina* occurred more numerously on deciduous trees, the latter two being particularly abundant on oaks.

With respect to their moisture requirements, the *Neuropteroidea* were classified into hygrophilous, mesohygrophilous and xerophilous elements (Table XII). The hygrophilous element was represented by 5 species, with only *Chrysotropia ciliata* occurring in abundance. It reached its highest proportions in communities in the linden-oak-hornbeam forests (28.9% on average), and in the light oak forests (12.6% on average). In the mixed coniferous forests its mean percentage contribution did not exceed 2% and in the pine forests it was found occasionally (Tables IX and XIII).

Table XIII. Mean contributions of the particular ecological elements for *Neuropteroidea* communities in the studied types of forests (*S* - number of species, *n* - abundance index)

Forest types / Ecological elements	Linden-oak-hornbeam forest			Light oak forest			Mixed coniferous forest			Pine forest		
	S	*n*	%	*S*	*n*	%	*S*	*n*	%	*S*	*n*	%
Species asociated with:												
deciduous trees	14	20.15	53.9	13	8.06	54.9	10	1.99	4.9	6	0.33	2.3
coniferous trees	5	0.21	0.6	6	0.28	1.9	14	4.07	10.0	17	11.02	76.2
deciduous and coniferous trees	7	7.78	20.8	6	3.00	20.4	6	28.08	68.9	6	2.59	17.9
trees and herbs	2	9.25	24.7	1	3.35	22.8	1	6.60	16.2	2	0.53	3.6
Hygrophilous species	4	10.80	28.9	1	1.85	12.6	2	0.77	1.9	3	0.05	0.4
Mesohygrophilous species	22	26.55	71.0	21	12.38	84.3	19	38.15	93.6	16	6.36	44.0
Xerophilous species	2	0.04	0.1	4	0.46	3.1	10	1.82	4.5	12	8.06	55.6
Thermophilous species	11	6.76	18.1	15	2.74	18.7	20	28.81	70.7	17	9.81	67.8
Others	17	30.63	81.9	11	11.95	81.3	11	11.93	29.3	14	4.66	32.2

The xerothermal species group included 12 species. In the pine forest communities, this group numbered 12 species and accounted for nearly 56% of individuals; in the mixed forests, despite an only slightly smaller number of species (10), the community share of its individuals was only 4.5%. In the linden-oak-hornbeam forests and the light oak forests these forms contributed insignificantly to community abundance (Tab XIII).

The remaining 28 species were mesohygrophilous forms. They formed the core of the communities in the linden-oak-hornbeam forests, light oak forests and mixed coniferous forests. They had a low abundance in the pine forests (Tabel XIII). The most abundant species in this group were *Nineta flava* and *Mallada prasina*.

Of the 45 species of neuropterans recorded from tree canopies in the forests under study, 28 (62%) are thermophilous forms (Table XII). The greatest number of thermophilous species were found in the mixed coniferous forests (20) and the pine forests (17), with their respective mean community shares equalling 71% and 68% (Tabel XIII).

In the linden-oak-hornbeam forests, the largest number of thermophilous species occurred in the high linden-oak-hornbeam forest, and the smallest, in the low variety. On the whole, 11 thermophilous species were noted to occur in this habitat and their share in mean community abundance approximated 18%). In the light oak forest 15 thermophilous species were found, their total share being still not much higher (Tabel XIII).

Generally, it can be said that the prevailing forms in the *Neuropteroidea* communities of the linden-oak-hornbeam forests were meso- and hygrophilous and had moderate or insignificant thermal requirements. The light oak forest communities had a higher proportion of mesohygrophilous forms and fewer hygrophilous ones, in comparison to the previous type of forest, as well as a slightly higher proportion of thermo- and xerophilous forms. In the mixed coniferous forest, mesohygrophilous and thermophilous forms occurred in abundance, while xero- and thermophilous forms prevailed in the pine forests.

ZOOGEOGRAPHICAL ANALYSIS

The *Neuropteroidea* recorded from the study forests belonged to 6 zoogeographical elements: cosmopolitan, Holarctic, Palaearctic, Euro-Siberian, European and Submediterranean (Table XII). In communities in the various types of forest, the core of the community was formed by Euro-Siberian elements, accounting for 39 to 58% of the total number of species (Table XIV). The most abundant representatives of this zoogeographical element were *Nineta flava*, *Chrysotropia ciliata*, *Raphidia xanthostigma* and *Wesmaelius concinnus*, the first two of which dominated in linden-oak-hornbeam forests and light oak forests, while the other two prevailed in pine forests. In the above three types of habitat, the Euro-Siberian elements accounted for 46–53% of mean community abundance. The picture changed in the mixed coniferous forest, where despite a large number of Euro-Siberian species their abundance accounted for only 7.7% of mean community abundance. The prevailing group in this association was the Palaearctic element, represented by nearly 67% of the total number of individuals. The most abundant Palaearctic species there were *Mallada prasina* and *Coniopteryx parthenia*.

In respect of the number of individuals, the Palaearctic element was in the second place (after the Euro-Siberian one) in *Neuropteroidea* of the pine forest (30.2%). Its shares in the linden-oak-hornbeam forest and light oak forest communities were also fairly significant (from 14% to17%) (Table XIV).

Of the 6 Holarctic species, the number found in a given type of forest ranged from 3 (linden-oak-hornbeam forests and light oak forest) to 5 in mixed coniferous forests. Their abundance was 3.3% (linden-oak-hornbeam forest) to 14.4% (pine forest) of total community abundance (Table XIV). The most important species of this group were *Hemerobius humulinus* and *H. stigma*, the latter, due to its ecological bond with the coniferous biome, occurred abundantly only in the pine forests.

Table XIV. Zoogeographical composition of the *Neuropteroidea* communities in the types of forests studied

Forest types	Linden-oak-hornbeam forest				Light oak forest				Mixed coniferous forest				Pine forest			
Zoogeographical elements	*S*	%	*n*	%	*S*	%	*n*	%	*S*	%	*n*	%	*S*	%	*n*	%
Cosmopolitan	1	3,6	9,24	24,7	1	3,8	3,35	22,8	1	3,2	6,60	16,2	1	3,2	0,52	3,6
Holarctic	3	10,7	1,23	3,3	3	11,5	0,94	6,4	5	16,1	1,77	4,3	4	12,9	2,09	14,4
Palaearctic	4	14,3	6,37	17,0	4	15,4	2,04	13,9	4	12,9	27,22	66,9	3	9,7	4,37	30,2
Euro-Siberian	13	46,4	19,92	53,3	10	38,5	7,85	53,4	15	48,4	3,13	7,7	18	58,0	6,72	46,4
European	3	10,7	0,36	1,0	2	7,7	0,30	2,1	2	6,5	1,88	4,6	2	6,5	0,56	3,9
Submediterranean	4	14,3	0,27	0,7	6	23,1	0,21	1,4	4	12,9	0,14	0,3	3	4,7	0,21	1,5

The shares of the European element in terms of the number of species were similar in every type of forest studied, while its abundance shares were much higher in coniferous than deciduous forests. The most abundant of the European species, *Raphidia notata* and *Mallada ventralis*, reached their ecological optimums in the mixed coniferous forest.

Chrysoperla carnea was the only representative of the cosmopolitan element. It showed a distinctive preference for deciduous trees, being only sporadically caught in the canopies of pine trees. Its mean proportion in the linden-oak-hornbeam forest was 24.7%, but it fell to only 3.6% in the pine forests.

The Submediterranean element, despite accounting for nearly a fourth of all the species recorded in the study forest, was numerically insignificant. Most species belonging to this group were found in the light oak forests, with *Sympherobius klapaleki*, an inhabitant of light oak forests and thinned linden-oak-hornbeam forests, being the most abundant.

SUMMARY

A total of 45 species of *Neuropteroidea* were caught in the tree canopies of the study forests, which equals about 50% of Polish neuropterans. The core of the neuropterofauna was formed by Euro-Siberian species (44% of species), almost 60% of which represented the family *Hemerobiidae*, 25% belonged to *Chrysopidae* and 15% to *Raphidioptera*. The Submediterranean element was also numerous, grouping nearly 25% of the species recorded, which, however, did not usually occur in abundance in the forests under investigation.

Linden-oak-hornbeam forests (*Tilio-Carpinetum*), pine forests (*Peucedano-Pinetum*) as well as mixed coniferous forests (*Querco roboris-Pinetum*) are widespread in subcontinental areas in Central as well as in Eastern Europe. The study plots situated in these habitats, and those situated in light oak forests, were located in central and north-eastern Poland, in the subcontinental climate zone. The percentage of the Euro-Siberian element among neuropterans inhabiting forests situated in this climatic zone is probably higher than in the mutually superseding forest associations

situated within the Atlantic climate zone, as indicated by the results obtained in the pine forests (*Leucobryo-Pinetum*) in Babimost (western Poland) and Roztocze (eastern Poland), where the Euro-Siberian species were less abundant, while the Palaearctic species occurred in greater numbers. A higher proportion of certain Mediterranean species (such as *Raphidia flavipes*) could also be seen there.

The neuropterofaunas of the study forests turned out to be remarkably similar, in terms of both species richness and species composition. Out of the average number of 30 species found in each habitat, there were 16 common species, and mean species composition similarity was 89%. Such a high faunal similarity was mainly due to the extensive occurrence of species exhibiting marked ecological resilience, capable of surviving in different types of forest. It was also brought about by spontaneous exchanges of species between the habitats. Such exchanges were possible owing to the fact that these types of forest are among the most widespread in the Polish lowland and often lie adjacent to one another. Still, as some of the common species reach their ecological optimums in one of the study forest types and are less abundant or sporadically found in the others, individual communities displayed different structures of dominance. Visibly distinct dominance structures were seen in the communities of linden-oak-hornbeam forests, mixed coniferous forests and pine forests. *Chrysotropia ciliata* and *Nineta flava* were characteristic dominant species in the linden-oak-hornbeam forest; *Mallada prasina* in the mixed coniferous forest and *Raphidia xanthostigma*, *Coniopteryx parthenia* and *Wesmaelius concinnus*. The above-mentioned species occupied eudominant positions in the structures of abundance of their communities and were remarkably constant ($W > 50\%$) in their habitats. No such species were identified in the light oak forest, which was probably attributable to the fact that this plant alliance occurs locally in Poland, outside the dense area of the syntaxon (Medwecka-Kornaś 1977). This results in light oak forest plots, usually small in area, being inhabited by insects penetrating from the neighbouring habitats. Generally, the light oak forest community of *Neuropteroidea* was similar to the community from the linden-oak-hornbeam forest.

The results of the studies make it possible to discern three main types of dominance structure of *Neuropteroidea* communities, specific to: 1) the deciduous forest, 2) the mixed oak-pine forest, 3) the pine forest. Variants of the type-specific dominance structure, related to local variations in habitat conditions – could be seen in *Neuropteroidea* communities from the plots of linden-oak-hornbeam forest, light oak forest and mixed coniferous forest. In pine forests, with their two variations (subcontinental and suboceanic), two variants of the dominance structure can be distinguished which are probably related to regional variations in the occurrence of certain species.

Trophic relations between species of *Neuropteroidea* and their phytophagous prey presented themselves as associations with particular types of vegetation. Dietary preferences of individual species, combined with their abiotic requirements and phenology, provide good grounds for differentiating two groups of *Neuropteroidea*: one associated with coniferous tree species and one preferring deciduous trees. The species belonging to each of these groups differ in ecological resilience, owing to which the qualitative and quantitative structure of a given community can be shaped by the conditions prevailing in a given phytocoenosis.

In most parts of Europe, linden-oak-hornbeam forests are climax associations. They grow in a wide range of habitats differing in the type of soil, soil fertility and water relations, and are spatially and ecologically linked with almost every type of natural forest association found in the Central European Lowlands, including light oak forests and mixed coniferous forests. In terms of flora and habitat, the mixed coniferous forest is related to the thermophilous oak forest and the poorer varieties of the linden-oak-hornbeam forest on the one hand, and to the pine forest on the other (MATUSZKIEWICZ 1981). Thus, the types of forest studied form a continuity of habitats along a gradient of habitat conditions. This helped to compare the structures of *Neuropteroidea* communities and describe changes in these communities related to the species composition of the stand and the forest's microclimate. In the two trophic groups distinguished, the changes were as follows: in the linden-oak-hornbeam forest and the light oak forest, the greatest number of species and individuals represented neuropterans developing only on deciduous trees, shade- and moisture-loving. In the mixed coniferous forest, both the hygrophilous and xerophilous elements were less abundant, while the prevailing forms were mesohygrophilous and thermophilous and associated mainly with deciduous tree species. In the pine forest, on the other hand, the majority of species and individuals represented xerophilous forms feeding on the entomofauna of coniferous trees.

As far as habitat requirements are concerned, the mixed coniferous forest differs considerably both from the linden-oak-hornbeam forest and the pine forest. It is either not penetrated at all or inhabited by very small numbers of the species dominant in linden-oak-hornbeam forests (*Chrysotropia ciliata* and *Nineta flava*) or those dominant in pine forests (*Raphidia xanthostigma* and *Wesmaelius concinnus*). The above are Euro-Siberian forms with a small abiotic tolerance scope. In the mixed coniferous forest, the dominant species of *Neuropteroidea* was the Palaearctic *Mallada prasina*. It found optimum ecological conditions in this habitat, but would also penetrate into linden-oak-hornbeam forests and light oak forests with an admixture of pine. For *Neuropteroidea*, the mixed coniferous forest is a transitory habitat, a link between linden-oak-hornbeam forests and pine forests. The mixed coniferous forests under study were inhabited by species typical of the two formations mentioned above, but they had their own "leader" species peculiar to this type of forest, whose ecological characteristics placed it in between the species dominant in the deciduous forests and the pine forest.

The indices *H'* and *J* (Table II) show the degree of structural uniformity in *Neuropteroidea* communities, and can be indirectly applied to the whole aphidophagous link in the phytocoenoses investigated. A comparison of the mean values of these indices shows that the most stable community was that of the pine forest, the deciduous communities (light oak forest and linden-oak-hornbeam forest) had a medium stability level while the mixed coniferous forest *Neuropteroidea* community was the least stable. The difference in structural parameters between the pine forest communities of neuropterans on the one hand and the deciduous *Neuropteroidea* communities on the other stems from the existence of two trophic groups and the different principles according to which they function.

In the group feeding on phytophages of deciduous trees, the main role was played by species of the family *Chrysopidae*, whose imagines feed on the honey-dew of aphids. The species would appear at nearly the same time but were differentiated spatially due to differences in moisture and temperature tolerance. The most hygrophilous species, *Chrysotropia ciliata*, was dominant only in the remarkably shady and moist plots of the linden-oak-hornbeam forest. In slightly thinned forests its position in a community was taken over by *Nineta flava*. In forests and woods with a scattered tree stand, *Nineta flava* was superseded by *Mallada prasina*.

Species feeding on the fauna of coniferous trees presented a different pattern. Pine forests are a homogeneous habitat in terms of the species composition of the stand and microclimatic conditions; they were inhabited mostly by neuropterans preferring the entomofauna of pine trees as their prey. The niches of the species belonging to this association type overlap to a considerable extent. As a result there is strong competition between them which considerably affects the positions of species in the dominance structure. Species of the families *Coniopterygidae*, *Hemerobiidae* and *Raphidiidae*, dominant in the pine forest, differ in the size of their imagines, which, like the larvae, are predators. Therefore, whenever there was a shortage of food, smaller neuropterans were likely to be eliminated by bigger ones. Thus, the position of a species in the structure of dominance depended to some extent on the size of the body.

A greater diversity means longer trophic chains and more instances of co-existence (competition, parasitism, predation, etc) as well as more potential for the zoocoenosis being regulated by negative feedback that reduces oscillations and consequently strengthens the stability of the system (ODUM 1982). These relationships were also confirmed by the results of this study. Greater oscillations in abundance and less stable communities were seen in linden-oak-hornbeam forests in comparison to pine forests (especially the *Peucedano-Pinetum* variety). In linden-oak-hornbeam forests, elimination of imagines through feeding competition between species was impossible. In larvae the phenomenon occurred on a small scale. In pine forests such elimination was observed in both development stages.

In this paper, the description of the forest neuropterofauna was narrowed down to the neuropterans of tree canopies, the least-known layer so far. Among the few papers on numerical relations between neuropteran species, there is a paper by BERNDT (1984) discussing the neuropterofauna of the Bory Tucholskie forest complex. In her work, the author used other methods to collect their materials and limited the catches to the understorey and the lover parts of tree canopies. Therefore, it is difficult to compare or interpret her results.

The picture of the structure of the neuropterofauna of a mixed coniferous forest in Bory Tucholskie provided by BERNDT differs from the description presented in this paper by virtue of a complete absence of *Mallada prasina* and a very high proportion of *Hemerobius micans*, the second most abundant species after *Chrysoperla carnea*.

Neuropterans developing on trees interact also with the fauna of shrubs, but individual species may have different preferences in this respect as well, as indicated by the dissimilar data mentioned above. In order to elucidate these inconsistencies completely, special studies over vertical distribution of neuropterans in forests must be carried out.

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STRESZCZENIE

[Tytuł: Analiza porównawcza struktury zgrupowań siatkoskrzydłych (*Neuropteroidea*) koron drzew w grądach, świetlistych dąbrowach, borach mieszanych i borach świeżych]

Praca jest syntezą badań prowadzonych w latach 1976–1987 nad *Neuropteroidea* koron drzew czterech typów lasów charakterystycznych dla niżowo-wyżynnej części Polski: grądów subkontynentalnych (*Tilio-Carpinetum*), świetlistych dąbrów (*Potentillo albae-Quercetum*), borów mieszanych (*Querco roboris-Pinetum*) i borów sosnowych świeżych (*Peucedano-Pinetum* i *Leucobryo-Pinetum*; związek *Dicrano-Pinion*). Wszystkie badane grądy (4 stanowiska), dąbrowy (3 stanowiska) i bory mieszane (3 stanowiska) znajdowały się na Nizinie Mazowieckiej, natomiast bory świeże (6 stanowisk) były rozmieszczone na Nizinie Mazowieckiej, Podlasiu, Pojezierzu Pomorskim, Nizinie Wielkopolsko-Kujawskiej i Roztoczu. Odłowy prowadzono w drzewostanach dojrzałych lub dojrzewających przy użyciu żółtych misek. Zebrany materiał liczy 10.280 imagines 45 gatunków.

W pracy omówiono i porównano skład gatunkowy, struktury dominacyjne, przebieg dynamiki sezonowej oraz ekologiczny i zoogeograficzny profil zgrupowań siatkoskrzydłych.

Neuropterofauny badanych zbiorowisk leśnych okazały się w dużym stopniu podobne do siebie pod względem składów gatunkowych. Wśród około 30 (26–31) gatunków wykazanych w lasach poszczególnych typów aż 16 było

wspólnych (Tab. IX), a średnie podobieństwo jakościowe (wg wzoru Sörensena) zawierało się w granicach 56–84% (Tab. X). Zgrupowania siatkoskrzydłych z lasów poszczególnych typów różniły się natomiast między sobą strukturami dominacyjnymi. Wskaźnik podobieństwa struktur dominacyjnych (wg wzoru Morisity) siatkoskrzydłych z lasów poszczególnych typów wahał się w zakresie 0,15–0,89 (Tab. X). Wyraźnie odrębne struktury dominacyjne, miały *Neuropteroidea* grądu, boru mieszanego i boru sosnowego świeżego (Fig. 7). W grądzie gatunkami dominującymi były *Chrysotropia ciliata* i *Nineta flava*, w borze mieszanym – *Mallada prasina*, a w borze świeżym – *Raphidia xanthostigma*, *Coniopteryx parthenia* i *Wesmaelius concinnus*. Wymienione gatunki odznaczały się także dużą wiernością (*W*>50%) w stosunku do danego środowiska. Struktura dominacyjna siatkoskrzydłych świetlistej dąbrowy w ogólnym zarysie była podobna do struktury zgrupowania z lasu grądowego (Tab. IX, Fig. 7).

Uzyskane wyniki pozwoliły na wyróżnienie trzech głównych typów struktur dominacyjnych zgrupowań siatkoskrzydłych, właściwych dla: 1) lasu liściastego, 2) boru mieszanego i 3) boru sosnowego świeżego. Różne warianty struktury dominacyjnej w ramach danego typu, uwarunkowane lokalną zmiennością warunków siedliskowych, prezentowały zgrupowania z badanych płatów grądu, świetlistej dąbrowy i boru mieszanego (Fig. 3–5) W przypadku borów świeżych, reprezentowanych przez dwie odmiany – suboceaniczną i subkontynentalną – stwierdzone dwa warianty struktury, były związane prawdopodobnie z regionalnym zróżnicowaniem występowania niektórych gatunków. Wyższe udziały *Raphidiidae* i *Hemerobiidae* niż *Coniopterygidae* miały zgrupowania w borach *Peucedano-Pinetum* (Puszcza Białowieska, Puszcza Biała i Puszcza Kampinoska oraz w Borach Tucholskich leżących na styku zasięgu *Leucobryo-* i *Peucedano-Pinetum*. W obiektach położonych w obrębie areału typowego zespołu *Leucobryo-Pinetum* (Babimost, Roztoczański PN) przeważał *Coniopteryx parthenia* (Fig. 6)

Badane lasy (grądy, świetliste dąbrowy, bory mieszane, bory świeże) tworzyły ciąg środowisk w gradiencie zmieniających się warunków siedliskowych. Pozwoliło to na porównanie profilu ekologicznego zgrupowań siatkoskrzydłych i określenie zmian w nim zachodzących, zależnie od składu gatunkowego drzewostanu i warunków mikroklimatycznych danego środowiska. W grądzie i w świetlistej dąbrowie gatunkowo i liczebnie przeważały siatkoskrzydłe odbywające rozwój wyłącznie na drzewach liściastych, a pod względem wymagań abiotycznych cienio- i wilgociolubne. W borze mieszanym wyraźną przewagę zyskały natomiast formy mezohigrofilne i ciepłolubne, związane głównie z drzewami liściastymi. Z kolei w borze świeżym gatunkowo i liczebnie przeważały siatkoskrzydłe związane pokarmowo z entomofauną drzew iglastych i sucholubne pod względem wymagań siedliskowych (Tab. XIII). W zespole związanym pokarmowo z fitofagami drzew liściastych główną rolę odgrywały sieciarki z rodziny *Chrysopidae*. Natomiast w zespole związanym troficznie z fitofagami drzew iglastych dominantami były gatunki z rodzin *Coniopterygidae*, *Hemerobiidae* i *Raphidiidae*.

Analiza zoogeograficzna neuropterofauny wykazała, że w lasach poszczególnych typów trzonem zgrupowań były gatunki eurosyberyjskie, stanowiące od 38 do 58% całkowitych składów gatunkowych (Tab. XIV). Element ten dominował również ilościowo w grądach, świetlistych dąbrowach oraz borach świeżych stanowiąc od 46 do 53% średniej liczebności zgrupowań. Do najliczebniej reprezentowanych gatunków należały *Chrysotropia ciliata*, *Nineta flava*, *Raphidia xanthostigma* i *Wesmaelius concinnus*. Inaczej przedstawiały się te relacje w borze mieszanym. Mimo dużej liczby gatunków eurosyberyjskich, ich udział w średniej liczebności zgrupowań wynosił zaledwie 7,7%. Ilościowo przeważały siatkoskrzydłe o zasięgu palearktycznym wśród których największą liczebnością odznaczały się *Mallada prasina* i *Coniopteryx parthenia*. Element palearktyczny zajmował drugie pod względem liczebności miejsce (po eurosyberyjskim) wśród *Neuropteroidea* boru świeżego (30,2%) miał też dość znaczny udział (w granicach 14–17%) w zgrupowaniach z grądu i świetlistej dąbrowy.

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