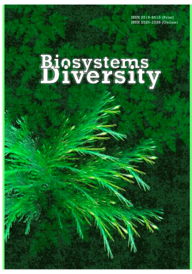

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Structure of litter macrofauna communities in poplar plantations in an urban ecosystem in Ukraine

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The litter macrofauna of 8 plantations of *Populus italica* (Du Roi) Moench, *P. deltoides* Marsh. and *P. alba* L. was studied in the city of Dnipro. The invertebrates were taken by manual sifting of litter from experimental plots of 8 m^2. The total number of litter macrofauna in the poplar plantations varied from 8 to 187 specimen/m^2, on average 53 specimen/m^2. The greatest variety of species was obtained from a white poplar plantation with common hop and an elm-poplar plantation with bare soil and *Amorpha fruticosa* L. bushes (15 and 9 species correspondingly). The maximum readings on the Shannon–Weaver diversity index come from the abovementioned areas (3.2 and 2.9 bits respectively). The highest number of zoophages (40%) was obtained from the white poplar plantation with common hop. There was great consistency in the species composition across the plots, with the same 60 species (more than 50% of the total number of species of litter macrofauna recorded in the study) being found in 7 out of the 8 study plots. The share of species rare for any given ecosystem exceeded 10% in only 2 out of the 8 plantations studied. The dominant group in the size structure of the litter macrofauna of the poplar plantations (44–96%) was invertebrates of 4–7 mm length. In 5 out of 8 poplar plantations no species over 15 mm in length were found. This indicates the degraded size structures of the litter macrofauna communities. In taxonomic structure the dominant groups were Formicidae, Pulmonata, Porcellionidae, Lygaeidae, Julidae, Silphidae, Araneae, Carabidae, Staphylinidae. The results obtained indicate the low variety and degradation of the trophic and size structure of the litter macrofauna of these urban poplar plantations, which are subject to lack of moisture.

Keywords: forest ecosystems; biological diversity; litter invertebrates; dominance structure; trophic structure; size structure

Introduction

Variability in the share of species and their ecological groups in community structures is most obvious in ecosystems under heavy anthropogenic pressure (Pearce and Venier, 2006; Spitzer et al., 2008). Many regions of Central and Eastern Ukraine are located in a zone of ecological impoverishment. A large part of this territory is affected by the intensive influence of agriculture, coal mining and the metallurgical industry (Faly and Brygadyrenko, 2014; Kul'bachko et al., 2015). Plantation forests and shelterbelts form a major part of South Ukraine's forest vegetation. In urban environments they are subject to heavy technogenic pressure (Moroz et al., 2011; Brygadyrenko and Ivanyshin, 2014). The dominant tree species in forest belts of the steppe zone are planted *Robinia pseudoacacia* L. and *Fraxinus excelsior* L. In urban landscapes, apart from the abovementioned species, plantations of *Populus pyramidalis* Borkh., *P. alba* L., *P. tremula* L. are widespread (Brygadyrenko, 2014, 2015c).

Earlier, we studied litter invertebrate communities in forest plantations of Ukraine's steppe zone, the peculiarities of the size, trophic and taxonomical structures of their communities (Brygadyrenko, 2015a, 2015b, 2016a). The distribution of an animal population within the litter horizon is regulated by many factors. The most significant are a mixture of phytocenosis, humidity, soil texture and litter capacity (Brygadyrenko, 2015a, 2015b, 2015c, 2016b). In urban forest plantations, a specific community composition develops which is very different from those of natural forest ecosystems (Moroz et al., 2011). In general, the species composition of urban landscapes is impoverished, being formed from ubiquitous species that are not specialized in their feeding and habitat requirements (Faly and Brygadyrenko, 2014). Many litter invertebrates react to even insignificant negative changes in their habitat by decreasing in number (Cameron and Leather, 2012). In this connection, the question arises of using dominant groups of invertebrates in zoological diagnostics of transformation processes in urbanized ecosystems in Ukraine's steppe zone (Moroz et al., 2011). Detailed studies of the basic characteristics of litter invertebrates allow the most vulnerable species of invertebrates in need of protection to be identified. Complex analysis of the litter macrofauna of urban landscapes is represented in the literature covering soil-zoology (Slipinski et al., 2012). Often the authors restrict themselves to counting the species present or the total number of invertebrates. However, apart from abundance it is also important to analyse the share taken by separate trophic, size and taxonomic groups (Oxbrough et al., 2005; Brygadyrenko, 2014).

The objective of this article is to provide a description of the structure of litter invertebrate communities in poplar plantations in a large city, based on the example of Dnipropetrovsk.

Materials and methods

Collection was carried out in August of 2013 in the city of Dnipro (Central Ukraine). In the studied types of artificial plantations the dominant species were *Populus italica* (Du Roi) Moench, *P. deltoides* Marsh. and *P. alba* L. (Table 1). The age of the plantations was about 60–65 years. For the count of invertebrates the method of manual sifting of litter was used. On each of the 8 study plots the sampling of invertebrates was made from 8 subplots, each 1 x 1 m. The selected plots varied in litter volume, number of plant species and density of the herbaceous layer, percentage of cover of each tree and shrub species at the juvenile and immature stages of development. Before collecting the macrofauna, a description of the vegetation cover was made with measurements (%) for the cover of every species of herbaceous plant, bush and tree. For collecting the invertebrates from each 1 m^2 plot, we collected litter, put it through a soil sieve (60 x 60 cm, mesh diameter – 2 cm) and sifted it onto a polyethylene sheet. After sifting, the coarse and fine fragments of plant remains were examined for invertebrates. For the assessment of the diversity of the litter macrofauna we used the most well-known indexes Shannon–Weaver (Shannon and Weaver, 1949; Pielou, 1977). The statistical analysis of the results was performed through a set of Statistica 8.0 programmes (StatSoft Inc., USA), on the diagrams is shown the median, 25% and 75% quartiles, minimum and maximum values.

Table 1
Brief characteristics of the studied poplar plantations

No	Type of plantation	Moisture conditions	Density of tree crown layer, %	Density of bush, liana and sapling layer, %	Density of herbaceous layer, %
1	Sycamore poplar plantation with Virginia creeper	mesohygrophilous	95 (*Populus italica* (Du Roi) Moench – 70, *Ulmus carpinifolia* Rupp. ex G. Suckow – 15, *Acer platanoides* L. – 10)	95 (*Parthenocissus quinquefolia* Planch.)	0
2	Acacia-poplar plantation with small balsam	xeromesophilous	55 (*Populus italica* (Du Roi) Moench – 45, *Robinia pseudoacacia* L. – 10)	5 (*Swida sanguinea* (L.) Opiz. – 5)	80 (*Impatiens parviflora* L. – 80, *Chelidonium majus* L. – 3)
3	Poplar plantation with various ruderal plants	mesohygrophilous	75 (*Populus italica* (Du Roi) Moench – 75)	0	30 (*Elytrigia repens* L. – 10, *Ambrosia artemisiifolia* L. – 8, *Ballota nigra* L. – 5, *Geum urbanum* L. – 5, *Solidago virgaurea* L. – 3)
4	Poplar plantation with bare soil	mesoxerophilous	65 (*Populus deltoides* Marsh. – 65)	65 (*Sambucus nigra* L. – 45, *Morus nigra* L. – 20)	0
5	Sycamore-poplar plantation with bare soil	mesophilous	90 (*Populus italica* (Du Roi) Moench – 75, *Acer negundo* L. – 10, *Acer tataricum* L. – 8)	0	0
6	Poplar-willow plantation with common hop	mesohygrophilous	70 (*Populus alba* L. – 65, *Salix alba* L. – 8)	90 (*Humulus lupulus* L. – 90)	5 (*Equisetum arvense* L. – 5)
7	White poplar with Virginia creeper and common hop	hygromesophilous	95 (*Populus alba* L. – 95)	35 (*Parthenocissus quinquefolia* Planch. – 15, *Humulus lupulus* L. – 15, *Swida sanguinea* (L.) Opiz. – 5)	7 (*Geum urbanum* L. – 5, *Torilis japonica* (Houtt.) – 2)
8	Elm-poplar plantation with desert false indigo, bare soil	mesophilous	95 (*Populus italica* (Du Roi) Moench – 85, *Ulmus carpinifolia* Rupp. ex G. Suckow – 10)	2 (*Amorpha fruticosa* L. – 2)	0

Results

The total number of litter macrofauna in the poplar plantations varied within a wide range. The dominance of one or two species of invertebrates in particular forest plots can account for extremely high numbers of invertebrates (187 specimen/m^2), more than three times the average value for the studied plantation types (53 specimen/m^2) (Fig. 1*a*). The study plots varied ($F = 12.47$, $P = 4.3*10^{-7}$) widely in the number of species they supported. The greatest variety of species was collected from the plantations of white poplar with common hop and elm and poplar plantations with *Amorpha fruticosa* L. and bare soil (15 and 9 species correspondingly) (Fig. 1*b*). The Shannon–Weaver diversity index includes the number of species on a study plot, hence its value reaches its maximum for the abovementioned plots (3.2 and 2.9 bits respectively). The Pielou index shows the range of species uniformity according to their number, assesses the absence of dominant species in communities and reaches a high level (0.55–0.99 bits) (Fig. 1*c*, *d*) in all the studied forest types.

The trophic structure of the litter macrofauna of poplar plantations is distinguished by the irregular distribution of the main functional groups. The percentage of phytophages in the total number of invertebrates in the study plots varied significantly (0–70%). The greatest share of phytophages in the litter macrofauna was seen in forest ecosystems with a well developed shrub and herbaceous layer, on plots of mesohygrophilous moisture type. A rapid decrease in the number of phytophages was registered on the plots with a thinned-out herbaceous layer (or where herbaceous plants were absent) and in types of plantations with xeromesophilous moisture conditions (0–13%) (Fig. 2*a*).

Variation in numbers of zoophages in different poplar plantations was not manifested (Fig. 2*c*). The dominant families (a family was considered to be dominant if it comprised 5% or more of the total number of litter invertebrates at a site) were Lycosidae, Carabidae, Staphylinidae. The greatest number (40%) of total predator invertebrates was registered in the white poplar plantation with common hop. The distribution of Staphylinidae individuals across the study plots was irregular. In the studied types of artificial forests a decrease in species variety within this family was observed and a relatively low number of individuals (1–6 specimen/m^2). The greatest number of Staphylinidae species was registered in the litter horizon of forest plots with a developed shrub layer, characterized by mesophilous, mesohygrophilous and hygromesophilous moisture conditions, which is partly caused by the hygrophilous character of these insects and their need for shade. The dominants in the litter of the poplar plantations were *Xantholinus linearis* (Olivier, 1795), *Falagria sulcatula* (Gravenhorst, 1806), *Rugilus similis* Erichson, 1840, *Cryptobium fracticorne* (Paykull, 1800), *Drusilla canaliculata* (Fabricius, 1787), *Medon apicalis* (Kraatz, 1857). In the drier poplar plantations *Staphylinus caesareus* Cederhjelm, 1798, *Tachyporus hypnorum* (Fabricius, 1775), *Astenus immaculatus* Stephens, 1832 were registered (Table 2).

The number of ground beetles was higher in mesophilous poplar plantations (0.5–7.0 specimen/m^2). *Asaphidion flavipes* (Linnaeus, 1761), *Bembidion lampros* (Herbst, 1784), *Harpalus rufipes* (De Geer, 1774) and *Microlestes minutulus* (Goeze, 1777) were recorded in almost all the studied poplar plantations. In drier plantations these species were supplemented by steppe, mesophilous forest and ubiquitist, species: *Notiophilus laticollis* Chaudoir, 1850, *Poecilus versicolor* (Sturm, 1824), *Pterostichus ovoideus* (Sturm, 1824), *Calathus fuscipes* (Goeze, 1777), *Amara similata* (Gyllenhal, 1810), *Harpalus tardus* (Panzer, 1797), *H. ampicollis* Menetries, 1848, *Licinus depressus* (Paykull, 1790), *Badister bullatus* (Schrank, 1798) and *Syntomus truncatellus* (Linnaeus, 1761). In the moist conditions of white poplar plantations, hygrophilous species of Carabidae were present: *Clivina fossor* (Linnaeus, 1758), *Pterostichus anthracinus* (Illiger, 1798), *Agonum lugens* (Duftschmid, 1812), *Oxypselaphus obscurum* (Herbst, 1784), *Stenolophus teutonus* (Schrank, 1781) and *S. proximus* Dejean, 1829. All these species of ground beetle are characteristic of the region under research. Specialized and rare species of ground beetle were not found in the forest plantations studied.

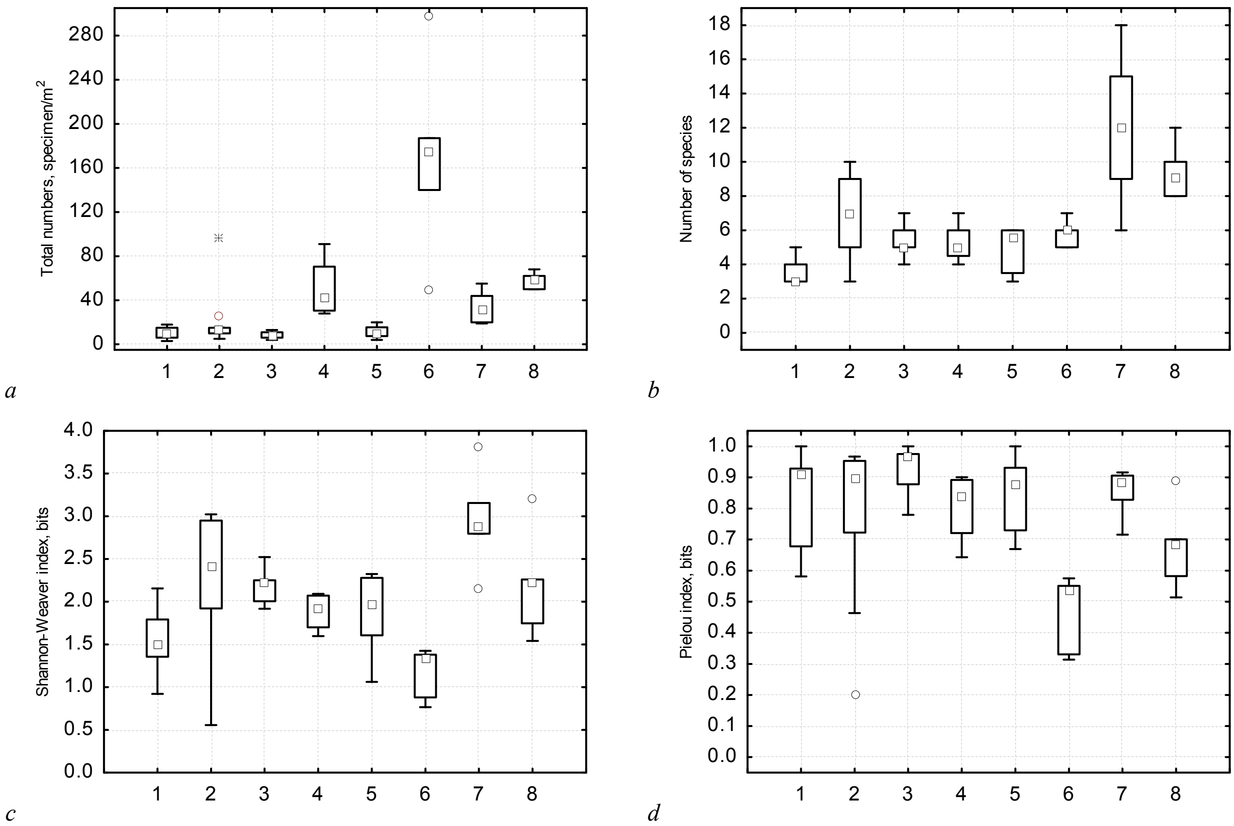

Fig. 1. Basic characteristics of litter macrofauna of poplar plantations: *a* – total numbers (specimen/m^2), *b* – number of species, *c* – Shannon–Weaver index (bits), *d* – Pielou index (bits); abscissia – sample plot (see Table 1), ordinate – value of the characteristic; on this and Fig. 2–5 the small squares shown the median, the large rectangles show the 25% and 75% quartiles, the vertical lines show 95% of the variation, the stars and circles show the outliers

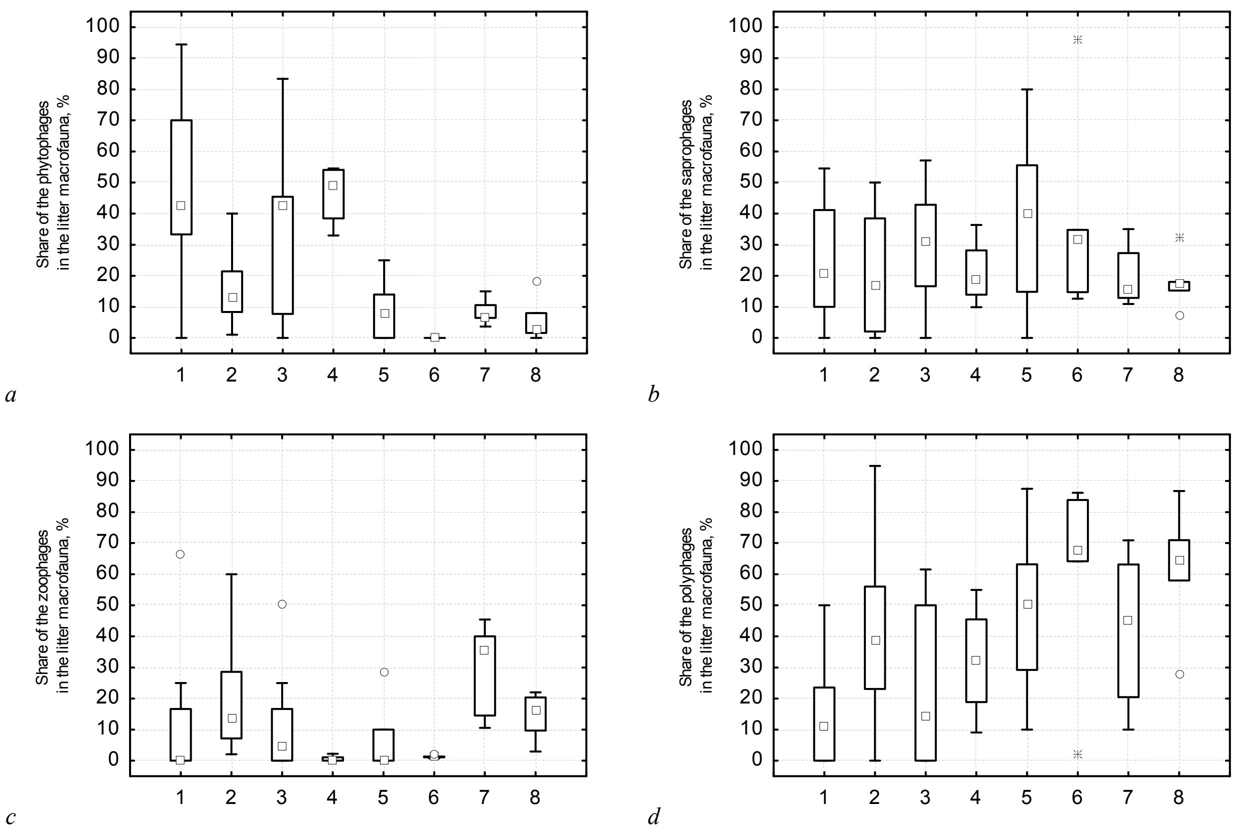

Fig. 2. Trophic structure (by abundance) of the litter macrofauna of poplar plantations: *a* – phytophages, *b* – saprophages, *c* – zoophages, *d* – polyphages; abscissia – sample plot (see Table 1), ordinate – share of the trophic group in the litter macrofauna (%)

Table 2
Taxonomic composition of the species found on the study plots in relation to distribution across the 64 subplots, trophic and size groups

Order	Family	Species	Frequency, % subplots where species was found	Size group, average body length in mm	Trophic group, according to commonest category of food consumed
1	2	3	4	5	6
Lumbricomorpha	Lumbricidae	*Dendrobaena sp.*	1.6	> 20	s
Lumbricomorpha	Lumbricidae	*Octolasion sp.*	4.7	> 20	s
Isopoda	Armadillidiidae	*Armadillidium vulgare* (Latreille, 1804)	1.6	4–7	s
Isopoda	Porcellionidae	*Porcellio laevis* Latreille, 1804	14.1	4–7	s
Isopoda	Porcellionidae	*P. scaber* Latreille, 1804	57.8	4–7	s
Diplopoda	Polydesmidae	*Turanodesmus dmitriewi* (Timopheev, 1897)	3.1	16–19	s
Geophilomorpha	Geophilidae	*Arctogeophilus sp.*	6.3	16–19	z
Lithobiomorpha	Lithobiidae	*Lithobius forficatus* (Linnaeus, 1758)	9.4	12–15	z
Collembola	Entomobriidae	*Entomobrya sp.*	12.5	< 4	s
Hemiptera	Lygaeidae	*Trapezonotus sp.*	9.4	4–7	z
Hemiptera	Lygaeidae	*Scolopostethus sp.*	18.8	4–7	z
Hemiptera	Miridae	Miridae sp.	1.6	4–7	p
Hemiptera	Nabidae	Nabidae sp. 1	6.3	4–7	p
Hemiptera	Nabidae	Nabidae sp. 2	1.6	4–7	p
Hemiptera	Nabidae	*Nabis ferus* (Linnaeus 1758)	3.1	4–7	p
Hemiptera	Pirrhocoridae	*Pyrrhocoris apterus* (Linnaeus, 1758)	20.3	8–11	p
Hemiptera	Lygaeidae	Lygaeidae sp. 1	6.3	8–11	z
Hemiptera	Lygaeidae	Lygaeidae sp. 2	1.6	4–7	z
Hymenoptera	Formicidae	*Dolichoderus quadripunctatus* (Linnaeus, 1771)	6.3	4–7	p
Hymenoptera	Formicidae	*Formica cinerea* Mayr, 1853	12.5	4–7	p
Hymenoptera	Formicidae	*F. glauca* Ruzsky, 1896	18.8	4–7	p
Hymenoptera	Formicidae	*F. pratensis* Retzius, 1783	6.3	4–7	p
Hymenoptera	Formicidae	*Lasius alienus* (Foerster, 1850)	1.6	< 4	p
Hymenoptera	Formicidae	*L. flavus* (Fabricius, 1782)	3.1	< 4	p
Hymenoptera	Formicidae	*L. niger* (Linnaeus, 1758)	1.6	< 4	p
Hymenoptera	Formicidae	*L. platythorax* Seifert, 1991	59.4	< 4	p
Hymenoptera	Formicidae	*Myrmica ruginodis* Nylander, 1846	6.3	4–7	p
Hymenoptera	Formicidae	*M. scabrinodis* Nylander, 1846	28.1	4–7	p
Hymenoptera	Formicidae	*Ponera coarctata* (Latreille, 1802)	1.6	< 4	p
Hymenoptera	Formicidae	*Tetramorium caespitum* (Linnaeus, 1758)	3.1	< 4	p
Neuroptera	Chrysopidae	*Chrysoperla carnea* (Stephens, 1836)	1.6	8–11	z
Neuroptera	Hemerobiidae	Hemerobiidae sp.	1.6	4–7	z
Diptera	Stratiomyidae	Stratiomyidae sp., larvae	1.6	4–7	s
Diptera	Sarcophagidae	Sarcophagidae sp.	1.6	12–15	s
Diptera	Tipulidae	Tipulidae sp.	3.1	12–15	s
Coleoptera	Carabidae	*Asaphidion flavipes* (Linnaeus, 1761)	1.6	< 4	z
Coleoptera	Carabidae	*Badister bullatus* (Schrank, 1798)	1.6	4–7	z
Coleoptera	Carabidae	*Bembidion lampros* (Herbst, 1784)	4.7	< 4	z
Coleoptera	Carabidae	*Curtonotus aulicus* (Panzer, 1796)	3.1	12–15	ph
Coleoptera	Carabidae	*Harpalus rufipes* (De Geer, 1774)	3.1	12–15	p
Coleoptera	Carabidae	*Microlestes minutulus* (Goeze, 1777)	10.9	< 4	z
Coleoptera	Carabidae	*Syntomus truncatellus* (Linnaeus, 1761)	6.3	< 4	z
Coleoptera	Staphylinidae	*Astenus immaculatus* Stephens, 1832	3.1	< 4	z
Coleoptera	Staphylinidae	*Atheta sp.*	3.1	< 4	z
Coleoptera	Staphylinidae	*Cryptobium fracticorne* (Paykull, 1800)	1.6	4–7	z
Coleoptera	Staphylinidae	*Drusilla canaliculata* (Fabricius, 1787)	1.6	4–7	z
Coleoptera	Staphylinidae	*Falagria sulcatula* (Gravenhorst, 1806)	1.6	< 4	z
Coleoptera	Staphylinidae	*Lathrobium sp.*	1.6	8–11	z
Coleoptera	Staphylinidae	*Medon apicalis* (Kraatz, 1857)	1.6	< 4	z
Coleoptera	Staphylinidae	*Rugilus similis* Erichson, 1840	1.6	4–7	z
Coleoptera	Staphylinidae	*Staphylinus caesareus* Cederhjelm, 1798	4.7	16–19	z
Coleoptera	Staphylinidae	*Xantholinus linearis* (Olivier, 1795)	4.7	8–11	z
Coleoptera	Staphylinidae	*Tachyporus hypnorum* (Fabricius, 1775)	10.9	4–7	z
Coleoptera	Coccinellidae	*Coccinella septempunctata* Linnaeus, 1758	3.1	< 4	z
Coleoptera	Coccinellidae	*Propylea quatuordecimpunctata* (Linnaeus, 1758)	1.6	4–7	z
Coleoptera	Curculionidae	Curculionidae sp.	1.6	4–7	ph
Coleoptera	Curculionidae	*Otiorhynchus raucus* (Fabricius, 1777)	1.6	4–7	ph
Coleoptera	Cantharidae	Cantharidae sp., larvae	3.1	4–7	z
Coleoptera	Cerambycidae	Cerambycidae sp., larvae	1.6	8–11	ph
Lepidoptera	Noctuidae	Noctuidae sp. 1	1.6	> 20	ph
Raphidioptera	Raphidiidae	*Dichrostigma flavipes* (Stein, 1863), larvae	6.3	8–11	z
Dermaptera	Forficulidae	*Forficula auricularia* Linnaeus, 1758	3.1	16–19	p
Araneae	Araneidae	*Cercidia prominens* (Westring, 1851)	1.6	4–7	z
Araneae	Clubionidae	Clubionidae sp., juv.	4.7	< 4	z
Araneae	Dictynidae	*Robertus arundineti* (O. Pickard-Cambridge, 1871)	1.6	< 4	z
Araneae	Dysderidae	*Dysderidae sp.*, juv.	1.6	< 4	z
Araneae	Gnaphosidae	Gnaphosidae sp., juv.	3.1	< 4	z
Araneae	Linyphiidae	*Maso sundevalli* (Westring, 1851)	1.6	< 4	z
Araneae	Linyphiidae	*Neriene clathrata* (Sundevall, 1830)	1.6	< 4	z
Araneae	Linyphiidae	*Tenuiphantes flavipes* (Blackwall, 1854)	1.6	< 4	z
Araneae	Linyphiidae	Linyphiidae sp., juv.	1.6	< 4	z

1	2	3	4	5	6
Araneae	Lycosidae	Lycosidae sp., juv.	4.7	< 4	z
Araneae	Philodromidae	*Thanatus sp.*, juv.	1.6	< 4	z
Araneae	Tetragnathinae	*Tetragnatha sp.*, juv.	3.1	< 4	z
Araneae	Theridiidae	*Parasteatoda tepidariorum* (C. L. Koch, 1841)	1.6	4–7	z
Araneae	Theridiidae	*Theridiidae sp.*, juv.	1.6	< 4	z
Araneae	Thomisidae	Thomisidae sp., juv	3.1	< 4	z
Araneae	Titanoecidae	Titanoecidae sp., juv.	1.6	< 4	z
Pulmonata	Arionidae	*Arion subfuscus* (Draparnaud, 1805)	12.5	> 20	ph
Pulmonata	Cochlicopidae	*Cochlicopa lubrica* (O. F. Muller, 1774)	20.3	4–7	ph
Pulmonata	Cochlicopidae	*C. lubricella* (Rossmassler, 1834)	12.5	4–7	ph
Pulmonata	Gastrodontidae	*Zonitoides nitidus* (O. F. Muller, 1774)	25.0	4–7	ph
Pulmonata	Oxychilidae	*Aegopinella minor* (Stabile, 1864)	4.7	4–7	ph
Pulmonata	Succineidae	*Succinea putris* (Linnaeus, 1758)	1.6	16–19	ph
Pulmonata	Succineidae	*Succinella oblonga* (Draparnaud, 1801)	18.8	4–7	ph

Notes: trophic groups of the litter macrofauna: ph – phytophages, z – zoophages, p – polyphages, s – saprophages.

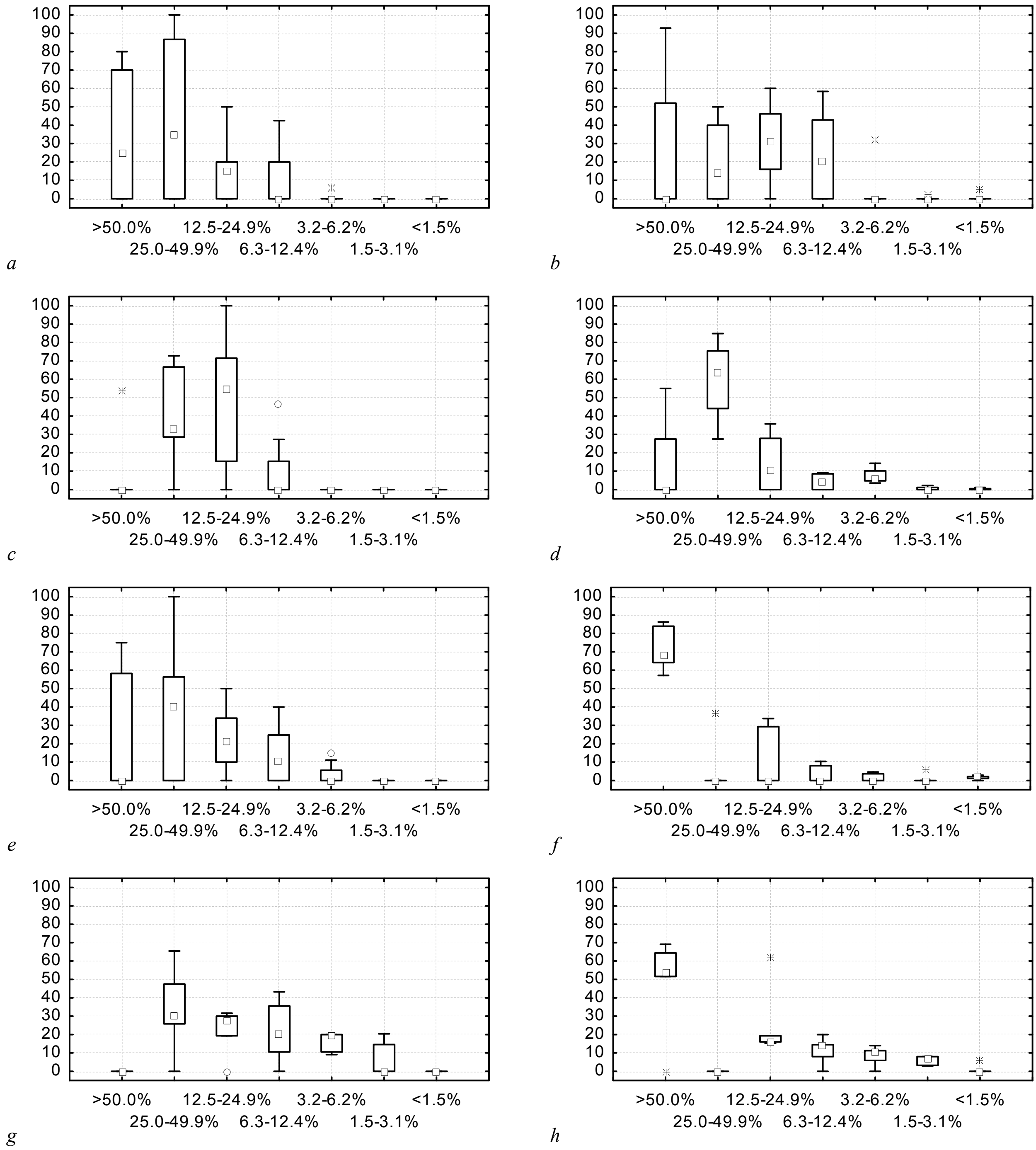

Fig. 3. Dominance structure of the litter macrofauna of poplar plantations: *a* – *h* – sample plot 1–8 (see Table 1); abscissa – share of the species in the community (%), ordinate – numerical dominance of given group of species (%)

The distribution of Araneae by habitat was also observed to have an irregular character. In xeromesophilous and mesophilous poplar plantations litter spiders were uncommon (0–1 specimen/m^2), the main species being *Parasteatoda tepidariorum* (C. L. Koch, 1841) and *Tenuiphantes flavipes* (Blackwell, 1854). Possibly this is connected to the limited food base provided by plantations in xeromesophilous and mesophilous moisture conditions, the sparseness of the vegetation and the highly irregular moisture regime (Polchaninova and Prokopenko, 2013). The species diversity of spiders was greatest in hygomesophilous and mesophilous plantations of *Populus alba* L. The most numerous were juveniles of the following groups: Lycosidae, Gnaphosidae (5–7 specimens/m^2), Dysderidae, Linyphiidae, Clubionidae and Thomisidae (1–2 specimen/m^2).

In the litter horizon of forest plantations of the steppe zone saprophages and polyphages form the numerically dominant groups. The abundance of saprophages (Fig. 2) fluctuated insignificantly (from 19–66%; F = 1.19, P = 0.21) depending on the type of poplar plantation. The median number of saprophages reached its maximum in moist (mesophilous and mesohygophilous) plots with a thick litter layer. The most numerous representatives were Isopoda (*Porcellio scaber* Latreille, 1804 – 5–18 specimen/m^2), Pulmonata (*Succinea putris* (Linnaeus, 1758), *Succinella oblonga* (Draparnaud, 1801), *Cochlicopa lubrica* (O. F. Muller, 1774), *C. lubricella* (Rossmassler, 1834), *Aegopinella minor* (Stabile, 1864) and *Zonitoides nitidus* (O. F. Muller, 1774)).

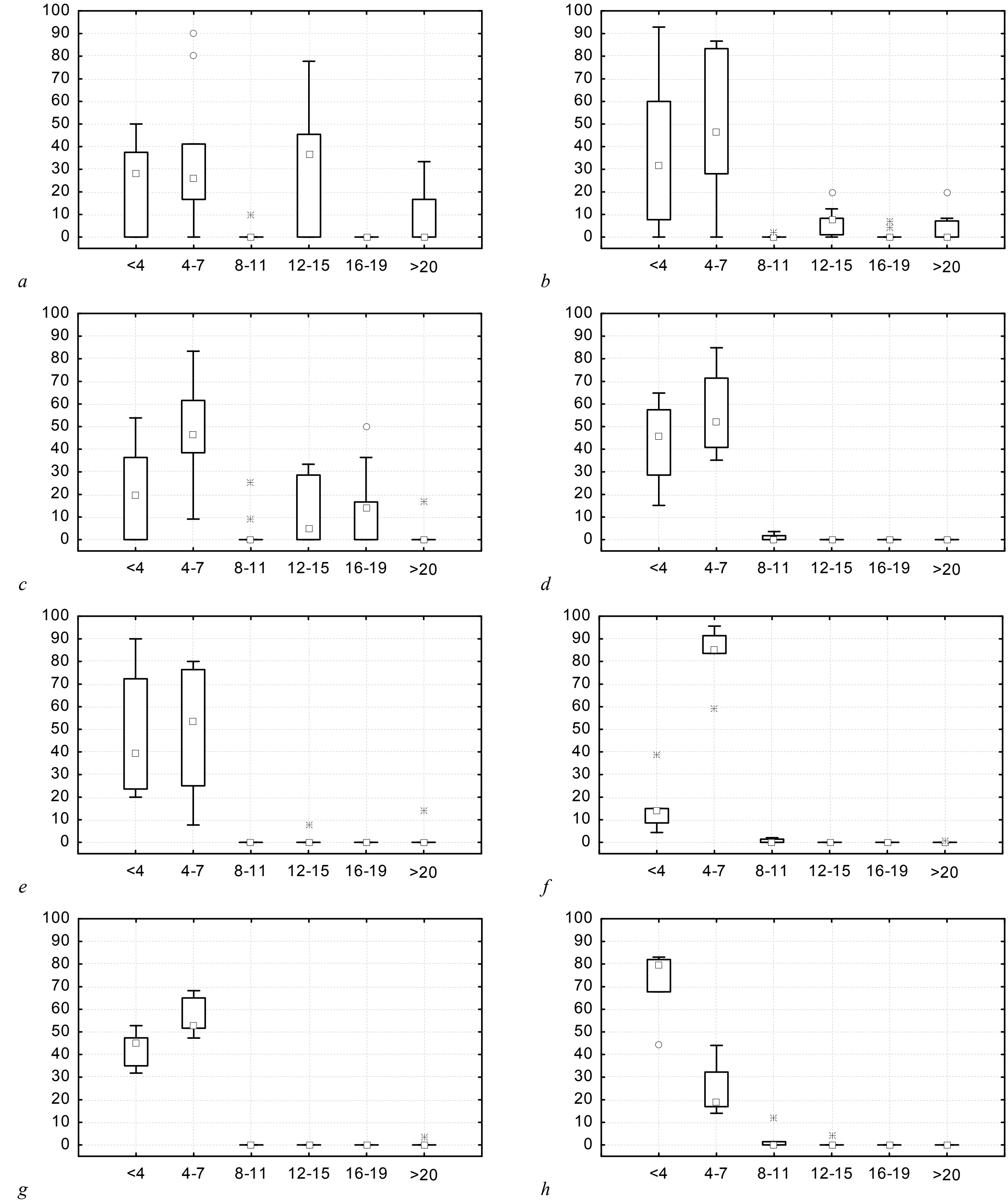

Fig. 4. Size strucure of litter macrofauna in poplar plantations: *a* – *h* – sample plot 1–8 (see Table 1); abscissa – individuals' body length (mm), ordinate – share of individuals with given size group in the community (%)

The polyphage group was represented mainly by ant species: *Formica glauca* Ruzsky, 1896, *F. cinerea* Mayr, 1853, *F. pratensis* Retzius, 1783, *Lasius niger* (Linnaeus, 1758), *L. platythorax* Seifert, 1991, *L. alienus* (Forster, 1850), *L. flavus* (Fabricius, 1782), and more rarely by *Myrmica scabrinodis* Nylander, 1846, *M. ruginodis* Nylander, 1846, *Tetramorium caespitum* (Linnaeus, 1758) and *Dolichoderus quadripunctatus* (Linnaeus, 1771). Overall, polyphages were numerous on all the study plots, their abundance varying from 24% to 85% of the total numbers of invertebrates. Their maximum numbers were noted in floodplain plantations of *Populus alba* L. in hygromesophilous and mesophilous conditions.

The dominance structure (Fig. 3) characterizes the resistance of ecosystems to external influences. The presence of a group of species which composed over 50% of the total number of the litter macrofauna in 7 of the 8 studied poplar plantations (with the exception of the white poplar plantation with Virginia creeper (*Parthenenocissus quinquefolia* (L.) Planch.) and common hop (*Humulus lupulus* L.) (Fig. 3*g*) indicates the unbalanced taxonomic structure of the communities. Species of average relative abundance (6.3–24.9%) provide a varied stream of energy to an ecosystem, they can promote a change in the functional regime of litter macrofauna, and, under certain conditions, can become dominant. In half the researched poplar plantations species of average abundance (for a given ecosystem) accounted for about half the species collected (Fig. 3*b*, *c*, *e*, *g*), while in the remaining ecosystems the percentage was very low. The share of species which are rare for a particular ecosystem (with a relative abundance of less than 6.2%), with the exception of two moister ecosystems (Fig. 3*g*, *h*) did not exceed 10%, which indicates a lack of potential resources for renewal of the dominance structure of species in case of change in the conditions of an urban ecosystem.

The size structure of an invertebrate community reflects the completeness of use by the litter fauna of the trophic resources of an ecosystem. A community which contains all size groups can be considered to be more saturated with species and life forms, its ecological niches are more varied (narrow, specialized and diversified), and so such an ecosystem can be considered more stable in relation to external influences. The urban poplar plantations investigated are distinguished by the simplified size structure of the litter macrofauna (Fig. 4). The dominant groups in most of the study plots were invertebrates 4–7 mm long (the position of the peak in the diagrams fluctuates between 44% and 96%). An analogical percentage of domination for this size group has been observed for other types of forest plantation in the steppe zone. The abundance (expressed as a percentage) of the smallest size group of litter invertebrates, under 4 mm, reaches 93% on some plots (acacia-poplar plantations with small balsam (*Impatiens parviflora* DC.)). The high abundance of this size group is an indicator of a relatively stable temperature and moisture regime over the course of a season.

In the types of poplar plantations researched a significant violation of the norms for the size structure of the macrofauna was observed, with reduction in the number of size groups. In the poplar-willow bed with common hops (Fig. 4*f*) the share of the size group of less than 4 mm was only 16%, while species belonging to the size groups of 8–11, 12–15, 16–19 and over 20 mm in body length were entirely absent. The size group 4–7 mm dominated (96%) on account of the high numbers of the ant species *Myrmica scabrinodis* Nylander, 1846 and *Lasius platythorax* Seifert, 1991. An analogical percentage ratio of size groups was observed for the majority of the forest plots researched. The absence of species with body length exceeding 8 mm (Fig. 4*d*, *e*, *g*, *h*) indicates an unstable ecosystem and damage to the most important trophic chain. For different types of poplar plantation (Fig. 4*a*) the size structure of the litter macrofauna shows a double peak (invertebrates of two size groups dominate with considerably lesser numbers for the size groups inbetween). Additional peaks in the size structure could be seen as indicators of disturbance to an ecosystem.

Analysis of the taxonomic structure of the litter macrofauna (Fig. 5) shows that Formicidae dominate in all types of poplar plantation. The most clear case of dominant status of ants (150 specimen/m^2) was observed in plots with mesohygrophilous and mesophilous moisture regimes, under which conditions the numbers of other types of invertebrates did not exceed 35 specimen/m^2 (Fig. 5*f*, *h*). The second most dominant group, numerous on almost all study plots was Geophilia. The moisture conditions in the studied poplar plantations, the light regime and the food resources were optimal for land molluscs. In some types of plantation (Fig. 5*b*, *e*, *f*) Porcellionidae shared an equal place with molluscs in the dominance structure, which is characteristic of artificial forests of the steppe zone. In the studied poplar plantations, which grow in steppe ecosystems with insignificant moisture of the soil and litter horizons (an ecosystem which takes up half the territory of Ukraine), higher numbers of Lygaeidae were observed (up to 7 specimen/m^2) (Fig. 5*d*). Saprophages (Julidae, Silphidae) and zoophages (Araneae, Carabidae, Staphylinidae), which are numerous in both natural and plantation forests of the steppe zone, were either entirely absent from the taxonomic structure or were present in low numbers (1–6 specimen/m^2) in the studied poplar plantations.

Discussion

The total number of litter macrofauna for poplar plantations does not significantly differ from similar indicators in natural bottomland forests and ravine broadleaved forests of Ukraine's steppe zone (Brygadyrenko, 2014, 2015c). The variations in the data for the different study plots means that this group cannot be used to conduct a univocal system of habitat indicators for poplar plantations (Ferguson and Berube, 2004; Pearce and Venier, 2006; Malaque et al., 2008; Schuldt et al., 2008).

The abundance of any particular macrofauna group is determined primarily by the trophic connections within a litter horizon community. The trophic connections with the food resources of the soil layer, herbaceous layer, tree and shrub layers increases in those plots where the depth of the litter does not exceed 10–20 mm, and therefore cannot maintain optimal conditions for the macrofauna during the period of summer drought. The number of mesophilous invertebrate species (the inhabitants of litter, as opposed to the inhabitants of soil and plant stand which occasionally appear on the soil surface) is significantly lower in poplar plantations without a developed litter layer. In mesohygrophilous poplar plantations a thicker litter layer (30–40 mm) supports a constant moisture regime and hence a richer and more stable macrofauna.

One of the mechanisms of stability in natural ecosystems is the distribution of the various species which inhabit it into ecological niches, which often overlap. The richness of an ecological niche within an ecosystem depends, first of all, upon the microclimatic conditions that develop within the biotope. The more mosaic-like and varied the spatial structure of a forest plantation, the more species can establish their ecological niches there (Brockerhoff et al., 2008; Oxbrough et al., 2012).

In general, the litter macrofauna of poplar plantations is a diffusive, undetermined system. It is difficult to attribute its dynamics to change in any particular single factor (soil texture, soil moisture, the litter capacity, density of tree, shrub and herbaceous layers). Interactions within the system are more significant for litter macrofauna than external factors (Butterfield and Malvido, 1992; Reynolds et al., 2003; Spitzer et al., 2008; Taboada et al., 2010; Brygadyrenko, 2014).

The most important group of litter macrofauna (which also significantly affects both the soil and crown horizons of ecosystems) is the Formicidae family (Slipinski et al., 2012). Ants alter plant cover both at the level of horizontal distribution of plant remains in the litter, which regulates the tempo and possibilities for seed growth, and at the level of redistribution of seeds of flowering plants (Dlussky, 2001; O'Grady et al., 2013). Apart from exerting an influence on the vegetation, ants also affect the litter macrofauna directly (Sobek et al., 2009). In artificial forests of Ukraine's steppe zone phytophages inhabit mostly the herbaceous, shrub and tree layers.

They inhabit litter only at certain stages of ontogenesis or in extreme weather conditions. On average, phytophages make up 3–14% of the litter invertebrate fauna for different types of poplar plantations. These are mostly steppe or habitat generalist species of the Chrysomelidae, Cicadellidae, Scutellaridae and other families (Moroz et al., 2011; Brygadyrenko, 2014, 2015a). With an increase in the number of phytophages, the number of individuals that fall from the tree crowns and bushes onto the ground increases, providing food for litter polyphage-predators (Carabidae, Staphylinidae, Lycosidae, Thomisidae, Tabanidae larvae and others). Certain species of crown and trunk dwelling pests of poplars (Noctuidae, Tortricidae, Cossidae and others) migrate into the soil during the period of pupation, providing an additional food base for zoophages.

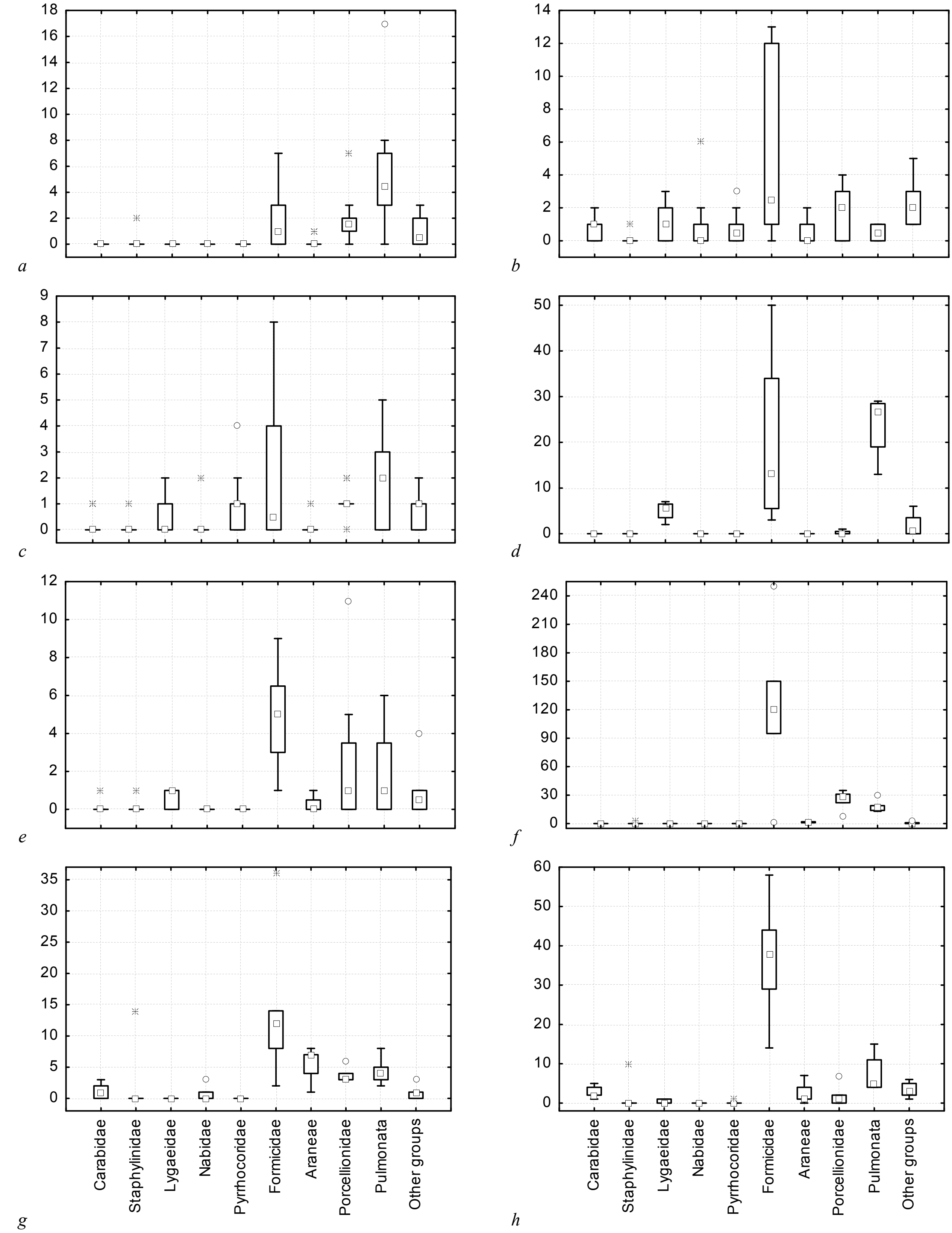

Fig. 5. Taxonomic structure of litter macrofauna of poplar plantations: *a* – *h* – sample plots 1–8 (see Table 1); abscissa – dominant taxonomic group, ordinate – abundance (specimen/m^2)

It is highly likely, though this has not yet been proved for our region, that similar types of artificial poplar plantations outside cities will have a less impoverished and more variable compound of litter invertebrate species. We are not aiming here to assess the impact of urbanization upon the studied communities. However, in so far as urban conditions affect certain groups of litter invertebrates, it seems that under the influence of urbanization the structure of these communities is bound to be altered (Cmoluch, 1972; Kubicka, 1981; Czechowski, 1982; Crouau et al., 2002; Christian and Szeptycki, 2004; Halaj et al., 2008).

Conclusion

The species variety and complexity of litter macrofauna communities of poplar plantations can in general be characterized as impoverished and simplified compared to invertebrate communities in the plantations of most other trees. The total number of litter macrofauna of poplar plantations varies within a wide range (8–187 specimen/m^2, on average 53 specimen/m^2). The widest variety of species was recorded in the white poplar plantation with common hop and in the elm and poplar plantation with *Amorpha fruticosa* L. and bare soil (15 and 9 species correspondingly). The Shannon–Weaver index of biological diversity reached its maximum for the abovementioned plots, at 3.2 and 2.9 bits respecttively. The largest number of zoophages (40%) was registered in the white poplar plantation with common hop. In 7 out of the 8 studied poplar plantations the same group of species comprising just over 50% of the total number of litter macrofauna species recorded in the study was found, which indicates an unbalanced dominance structure of the community. Only in 2 out of the 8 ecosystems did the share of species rare for a given ecosystem exceed 10%, which indicates an absence of potential resources for renewal of the species compound in case of change in the conditions of existence in an urban ecosystem. In the size structure of poplar plantations invertebrates of 4–7 mm length dominated (44–96%). In 5 out of the 8 poplar plantations species with a body length of over 15 mm were not registered, which indicates a degradation of the size structure of the communities. In the taxonomic structure of litter macrofauna the dominant group in all types of poplar plantation was Formicidae. The subdominants were Pulmonata, Porcellionidae, Lygaeidae, Julidae, Silphidae, Araneae, Carabidae, Staphylinidae.

The data obtained can be used for evaluation of the condition of poplar plantations and for increasing their ecological resilience in urban areas of the steppe zone, where they are subject to insufficient moisture.

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