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Classification of the floodplain meadows of the Seym and the Dnieper river valleys in the north-eastern part of Ukraine

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Abstract

The present study concerns the floristic-sociological classification of the floodplain meadow vegetation of the Seym and the Dnieper rivers (within the eastern part of Polissya of Ukraine). The relevé matrix was clustered using the DRSA (Distance-Ranked Sorting Algorithm) method, and the Ochai fidelity index was applied for species sorting and allocating the differentiating species. Species composition of the syntaxa has been evaluated using the phytoindication method and an assessment of shares of species of different classes of vegetation (phytosociological spectrum). These variables were used for phytocoenological characterization and to fit with the NMDS ordination axes using the multiple regression approach. We identified 8 associations of psammophytic, mesic and temporarily wet meadows which were assigned to 3 alliances and 3 orders of the *Molinio-Arrhenatheretea* class. Syntaxa were characterized using a unified scheme: habitat type according to EUNIS classification, ecological and synmorphological traits, distribution, and anthropogenic transformation. Comparative floristic tables were constructed taking into account the synoptic columns of the studied associations and western syntaxa including the holotypes. Four associations have been introduced, such as *Galio molluginis-Festucetum pratensis* ass. nova in the alliance *Arrhenatherion*, and *Veronici longifoliae-Iridetum sibirici* ass. nova, *Poo trivialis-Alopecuretum arundinaceae* ass. nova, *Dactylorhizo incarnati-Caricetum nigrae* ass. nova in all. *Deschampsion cespitosae*.

Keywords Floodplain · Meadow vegetation · *Molinio-Arrhenatheretea* class · Syntaxonomy · Ukraine

Introduction

Floristic-sociological classification of meadow vegetation in Ukraine is still incomplete. Before the 1980s, meadow vegetation was studied using the dominant (floristic-physiognomic) classification approach (Shelyag-Sosonko and Balashov 1967; Afanasyev 1975, 1976), making comparisons with the European schemes impossible. In the 1980s–1990s, vegetation began to be studied using the Braun-Blanquet floristic-sociological approach, which started the process of consolidation of the schemes used in describing Ukrainian vegetation with those applied in most of Europe (Sipaylova et al. 1985, 1987; Shelyag-Sosonko et al. 1986, 1987). The bulk of publications describing new associations from the territory of Ukraine were published in small regional periodicals or deposited in the VINITI Database RAS (All-Russian Institute for Scientific and Technical Information of the Russian Academy of Sciences). The situation began to improve recently due to the creation of national databases on meadow vegetation, such as the Ukrainian Grassland Database, (GIVD ID EU-UA-001). After monograph by A. Kuzemko (Kuzemko 2009a), a general scheme of classification of the *Molinio-Arrhenatheretea* class was formed. This became an important milestone. However, data from many territories remain insufficient, particularly in the north-eastern part of Ukraine.

Nevertheless, issues exist that are not only related to territory coverage but come from the fact that phytosociology in ex-USSR countries inherited much from the former dominant

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vegetation classification approach. Many associations reported for Ukraine raise questions. This applies primarily to such broad associations as *Festucetum pratensis* Soó 1938 (Shelyag-Sosonko et al. 1987; Bajrak 1998; Kuzemko 1999; Fitsailo 2003; Gomlya 2005; Galchenko 2006; Kuzemko and Kozyr 2011; Vashenyak and Didukh 2011), *Alopecuretum pratensis* (Regel 1925) Steffen 1931 (Bajrak 1998; Kuzemko 1999; Fitsailo 2003; Galchenko 2006; Tertishnyy and Yakubenko 2013), *Deschampsietum caespitosae* Horvatić 1930 (Shelyag-Sosonko et al. 1987; Bajrak 1998; Kuzemko 1999; Gomlya 2005; Kuzemko and Kozyr 2011; Vashenyak and Didukh 2011; Tertishnyy and Yakubenko 2013). These associations were described in the western regions and based on a different pool of Central European flora. They represent most likely heterogeneous complexes in Ukraine and modern research is needed in order to establish their more accurate floristic and geographical differentiation. Considering the relatively small region of our study, we will touch on this issue only partially, on the example of some associations.

Current study is aimed at inventorying the coenotic diversity of meadow vegetation from northeastern region of Ukrainian Polissya. Floristic-sociological classification will be applied as a well-grounded and conventional approach, and methods of ordination and phytoindication as reliable techniques for determining environmental drivers in differentiation of vegetation. In this study, we will involve the relevé data from the floodplains of two rivers, the Dnieper and the Seym, which have different hydrological regimes and the structure of alluvial sediments on floodplain surface. Data collected from these two parts of the study region will be used in the classification of vegetation together as a joint phytocoenotic dataset, in order to reveal whether the mentioned specificities of two river valleys are significant with respect to floristic differentiation of vegetation and determine the selective distribution of the syntaxa in the floodplain of only one of these rivers.

Materials and methods

The study area comprises two parts located in the floodplains of the Seym and the Dnieper rivers (Fig. 1). The main part of the study area is in the Chernihiv Polissya lowland, and the second smaller one is in the Kyiv Polissya region (Marinich et al. 1982). We chose two quite distant locations aiming to reveal the distribution and coenotic diversity of meadow vegetation in floodplains of rivers with different hydrological regimes. The Dnieper has an ancient and wide floodplain with sandy soils prevailing, while floodplains of Polissya rivers, including the Seym, are young, relief-monotonous and with heavier soils covering the surface.

The climate of this territory is humid continental with warm summer, or *Dfb* according to the Köppen climate classification (Kottek et al. 2006), with the annual temperature averaging +6.5 °C. The annual precipitation is 613 mm, with the wettest month of July (81 mm) and the driest February (34 mm). In the landscape of the region the moraine terrace complexes with sod-podzolic soils prevail. The area is mainly covered with oak-pine forests in the past, but currently they are largely destroyed and occupy much smaller areas. The plain relief is rugged by river valleys. The main ones are the Dnieper and the Desna with their smaller tributaries. In floodplains peat-marsh and sod-meadow soils are found, which is caused by relatively cold and humid climate. Meadow vegetation is widespread in floodplains and is represented by various types of meadows from temporarily wet meadows on mineral and peaty soils to sandy steppic meadows on elevated parts of the floodplain relief.

Vegetation classification was done based on a dataset of 709 relevés of meadow vegetation collected for the period from 2005 to 2014. Vegetation was sampled using 100 m^2 plots. Species abundances were recorded using the Braun-Blanquet cover-abundance scale. The species taxonomy is in accordance with the checklist of Ukrainian flora (Mosyakin and Fedoronchuk 1999) with minor corrections (Table S1) according to ThePlantList resource (http://www.theplantlist.org). Field data have been maintained using the Turboveg software (Hennekens and Schaminée 2001).

The automatic classification of relevé matrix was conducted in order to delineate clusters of relevés, i.e. phytocoenones. For cluster analysis of relevé matrix, the DRSA algorithm was applied (Goncharenko 2015), which has two distinctive features. First, it is based on a matrix of ranked distances and k-nearest neighbors approach (Cover and Hart 1967) for agglomeration procedure. Second, it is a method of noise clustering. At the end of agglomeration procedure, a noise cluster is usually produced, in which transitional relevés (outliers) are allocated. The size of noise cluster depends on the data and grows in the case of hardly separated groups. After the classification of relevés, differential species were determined using the fidelity concept (Bruelheide 2000; Chytrý et al. 2002). The species-to-cluster fidelities were calculated using the Ochiai index (De Cáceres et al. 2008; Cáceres and Legendre 2009), and its value of 40 % was chosen for differential species. As a result, we identified and characterized 10 syntaxa. For syntaxonomic interpretation, we relied on literary sources from different regions (Chytrý and Tichý 2003; Hegedüšová Vantarová and Škodová 2014; Matuszkiewicz 2007; Jarolimek et al. 2008; Solomakha 2008; Kuzemko 2009a; Borhidi et al. 2012; Yamalov et al. 2012; Kącki et al. 2013; Mucina et al. 2016).

Fig. 1 Study region (two rectangles)

Proportions of species of different classes of vegetation are an important criterion for understanding the syntaxonomic relations and phytocoenotic structure of each syntaxon. If diagnostic species are rare or absent, a unique "character" combination of species of two or more classes plays the same differential role (Goncharenko et al. 2013). In general, the phytosociological spectrum is defined as the proportions of diagnostic species associated with different vegetation units at the same level of hierarchy (classes in most cases). Some authors prefer using orders instead of classes (Yamalov and Bayanov 2010), which depends on the objectives of the study. In diagnostic species classification among classes of vegetation we relied on a reputable All-European survey by Mucina et al. (2016). The method of phytosociological spectrum has some in common with the Cocktail approach (Bruelheide 2000), but the former is limited to calculating proportions of species, as the latter concerns formal definitions (formulas) of vegetation units.

The hierarchical cluster analysis was performed based on the distance matrix calculated for synoptic columns. The similarities between the species lists of syntaxa were calculated using the Ochiai index and the distance matrix was derived after the square root transformation: $d = \sqrt{(1 - s)}$, where s indicates similarity coefficients (Gower and Legendre 1986). Calculations were performed using the *hclust* function of R software (https://www.r-project.org). In order to identify gradients in the species composition we carried out the NMDS ordination. Phytoindicational data (supplementary variables) were added to understand the nature of axes of ordination in terms of environmental factors. For eight variables we chose the Didukh's ecological scales for the Ukrainian flora (Didukh 2011). In order to assess anthropogenic load we used the naturalness scale of A. Borhidi (1995). Calculations of ordination and multiple regression a posteriori with the axes of ordination were performed using the *metaMDS* and *envfit* functions (Oksanen et al. 2018).

Results and discussion

Based on the relevé data analyzed, we identified 3 orders, 3 alliances, 8 associations, and 5 variants within the *Molinio-Arrhenatheretea* class. The combined synoptic table with species constancy and fidelity values is provided in Table 1, and the full relevé matrix is placed in Table S2. The numbers in the syntaxonomic scheme correspond to the numbers also used in the tables and figures hereinafter in the text.

Table 1 Combined synoptic table with constancy and fidelity (in superscript) of species. Values greater than 40 % are marked in bold

Syntaxon ID	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
Number of relevés	**23**	**17**	**10**	**20**	**53**	**20**	**22**	**25**	**8**	**56**
D.s. *Eryngio-Bromopsietum inermis* var. *Oenothera rubricaulis*										
Sedum acre	**61**^{76}				2^{2}					
Oenothera rubricaulis	**61**^{74}	6^{7}								
Bromus inermis	**78**^{71}	18^{16}			4^{4}		14^{13}			2^{2}
Eryngium planum	**52**^{68}	6^{8}								
Calamagrostis epigejos	**74**^{65}	24^{21}					23^{21}			
Dianthus borbasii	**35**^{42}		10^{12}	15^{18}	2^{2}					
D.s. *Koelerio delavignei-Agrostietum vinealis* var. *Asparagus officinalis*										
Asparagus officinalis	9^{8}	**100**^{89}	10^{9}		2^{2}					
Trifolium montanum	4^{4}	**71**^{66}		10^{9}	6^{6}		14^{13}			
D.s. *Koelerio delavignei-Agrostietum vinealis* var. *Ranunculus polyanthemos*										
Ranunculus polyanthemos		6^{6}	**100**^{92}				9^{8}			
Trifolium ambiguum			**100**^{87}	15^{13}	4^{3}					2^{2}
Cichorium intybus			**40**^{53}		6^{8}					2^{3}
Glechoma hederacea			**40**^{41}	10^{11}	13^{13}	5^{5}		16^{16}		2^{2}
D.s. ass. *Koelerio delavignei-Agrostietum vinealis*										
Filipendula vulgaris		**71**^{44}	**70**^{44}	**45**^{28}	4^{3}		**45**^{28}			2^{1}
Koeleria delavignei	13^{8}	**71**^{45}	**100**^{63}	30^{19}			5^{3}	4^{3}		5^{3}
Agrostis vinealis	9^{6}	**47**^{33}	**100**^{71}	10^{7}	8^{6}					2^{1}
Carex praecox		**53**^{44}	**60**^{51}	5^{4}	2^{2}		14^{12}			
D.s. ass. *Galio molluginis-Festucetum pratensis*										
Gladiolus tenuis			10^{9}	**95**^{84}		5^{4}		4^{4}		7^{6}
Leucanthemum vulgare			10^{9}	**80**^{75}	2^{2}		9^{8}			
Galium mollugo			10^{9}	**70**^{65}	2^{2}	5^{5}		4^{4}	12^{11}	2^{2}
D.s. ass. *Medicago lupulinae-Phleetum pratensis*										
Medicago lupulina				10^{11}	**66**^{67}	5^{5}	5^{5}			
Trifolium repens			10^{8}	15^{12}	**79**^{64}	10^{8}		4^{3}	12^{11}	
Festuca rubra	4^{3}	29^{25}			**62**^{53}	15^{13}	5^{4}	4^{3}		2^{2}
D.s. ass. *Dactylorhizo incarnati-Caricetum nigrae*										
Dactylorhiza incarnata					2^{2}	**90**^{93}				
Carex nigra						**75**^{82}		4^{4}		2^{2}
Equisetum palustre						**55**^{74}				
Eleocharis uniglumis						**30**^{55}				
D.s. ass. *Veronici longifoliae-Iridetum sibirici*										
Iris sibirica		6^{6}					**95**^{91}			5^{5}
Veronica longifolia		18^{15}	10^{8}				**91**^{76}			20^{17}
Filipendula ulmaria					6^{6}	5^{5}	**64**^{66}	4^{4}		12^{12}
Lythrum virgatum						5^{7}	**41**^{61}			
Lysimachia vulgaris						20^{23}	**50**^{57}			5^{6}
Inula salicina		12^{16}					**41**^{55}			
D.s. ass. *Poo trivialis-Alopecuretum arundinaceae*										
Alopecurus arundinaceus					9^{8}	5^{4}		**92**^{81}		9^{8}
Stellaria palustris					2^{2}	10^{11}		**64**^{72}		
Poa trivialis			10^{11}		4^{4}	20^{21}		**56**^{57}		
Carex leporina		6^{8}					5^{6}	**44**^{55}		2^{3}
D.s. *Poo palustris-Alopecuretum pratensis* var. *Agrostis stolonifera*										
Persicaria lapathifolia									**88**^{92}	2^{2}
Triglochin palustris									**75**^{87}	

Table 1 (continued)

Syntaxon ID Number of relevés	**1** **23**	**2** **17**	**3** **10**	**4** **20**	**5** **53**	**6** **20**	**7** **22**	**8** **25**	**9** **8**	**10** **56**
Anacamptis palustris					2^{2}	5^{6}			**75^{83}**	
Agrostis stolonifera						**40^{34}**		4^{3}	**88^{75}**	2^{2}
D.s. *Poo palustris-Alopecuretum pratensis* var. *Scutellaria galericulata*										
Galium uliginosum						30^{27}	9^{8}	4^{4}		**79^{71}**
Scutellaria galericulata					2^{2}	5^{5}		8^{8}	12^{12}	**68^{67}**
D.s. ass. *Poo palustris-Alopecuretum pratensis*										
Alopecurus pratensis		6^{4}	10^{6}				**82^{51}**		**75^{46}**	**84^{51}**
Poa palustris						30^{22}	5^{4}	8^{6}	**75^{54}**	**68^{49}**
Allium angulosum				10^{7}	4^{3}		5^{4}	16^{12}	**50^{36}**	**91^{66}**
Eleocharis palustris						10^{9}		8^{7}	38^{33}	**71^{62}**
Galium palustre					2^{2}	15^{14}		8^{8}	**62^{61}**	20^{19}
D.s. ord. *Galietalia veri*										
Galium verum	**70^{41}**	**94^{53}**	**40^{23}**	15^{9}	4^{2}	5^{3}	**59^{33}**			2^{1}
Potentilla argentea	**52^{35}**	**59^{39}**	20^{13}	**40^{27}**	21^{14}		5^{3}			
Poa angustifolia	**70^{48}**	**65^{45}**	**50^{34}**	5^{3}	9^{6}					
Dianthus deltoides	22^{22}	35^{36}	10^{11}	15^{15}	4^{4}			4^{4}		
Festuca valesiaca	**43^{49}**	18^{21}	10^{11}							
D.s. ord. *Arrhenatheretalia elatioris*										
Plantago lanceolata	35^{19}	35^{19}	**70^{39}**	**95^{53}**	32^{18}	10^{6}	14^{8}			
Lotus corniculatus	4^{2}	12^{7}	**50^{28}**	**80^{45}**	**74^{41}**	10^{6}	32^{18}		12^{7}	7^{4}
Trifolium pratense		24^{15}	30^{19}	**85^{53}**	**47^{29}**	10^{6}	32^{21}	4^{2}		
Centaurea jacea		18^{12}	**60^{38}**	**90^{58}**	2^{1}		**55^{35}**			
Stellaria graminea	17^{11}	6^{4}	30^{21}	**60^{41}**	**62^{42}**		5^{3}	4^{3}		5^{3}
Rhinanthus serotinus	9^{6}	35^{24}	10^{7}	**55^{38}**	26^{18}	5^{3}	**50^{35}**			
Agrostis capillaris	4^{4}		10^{9}	5^{5}	**49^{45}**		23^{21}	12^{11}		
Euphorbia virgultosa	26^{24}	6^{6}	30^{28}	15^{14}	2^{2}	5^{5}	18^{17}			5^{5}
Dactylis glomerata	13^{14}	12^{13}		20^{22}	8^{9}		18^{21}			
D.s. ord. *Molinietalia caeruleae*										
Potentilla anserina					23^{14}	**90^{55}**	5^{3}	**44^{27}**	**62^{38}**	25^{15}
Lysimachia nummularia					25^{17}	**40^{27}**	5^{3}	24^{16}	**88^{59}**	29^{19}
Deschampsia caespitosa			10^{7}		13^{9}	**55^{39}**		16^{11}	**88^{62}**	4^{3}
Silene flos-cuculi			20^{15}	35^{26}	11^{8}	15^{11}	5^{4}	32^{24}	12^{9}	20^{15}
Carex vulpina					2^{2}	**40^{31}**		**60^{47}**	12^{9}	**45^{35}**
Potentilla reptans			10^{8}		25^{21}	5^{4}	5^{4}	**64^{54}**		12^{11}
Juncus gerardii					8^{7}			28^{25}	**50^{45}**	30^{27}
Beckmannia eruciformis						5^{5}		20^{21}	38^{38}	32^{32}
Ranunculus repens						**45^{53}**	9^{11}	12^{14}		2^{2}
D.s. cl. *Molinio-Arrhenatheretea*										
Phleum pratense	26^{11}	**53^{23}**	**90^{39}**	**80^{35}**	**68^{31}**	20^{9}	**73^{32}**	20^{9}	25^{11}	20^{9}
Achillea millefolium	39^{17}	**65^{29}**	**60^{27}**	**85^{38}**	**66^{29}**	**40^{18}**	36^{16}	20^{9}	38^{17}	7^{3}
Festuca pratensis	9^{4}	29^{14}	**70^{33}**	**90^{42}**	**68^{32}**	**40^{19}**	**55^{26}**	20^{9}		29^{14}
Ranunculus acris				**65^{33}**	28^{14}	**55^{28}**	23^{12}	**44^{22}**	**75^{38}**	**68^{34}**
Elymus repens	17^{9}	18^{9}	**80^{41}**	20^{11}	**58^{31}**	15^{8}	9^{5}	**44^{23}**	25^{13}	**43^{22}**
Rumex thyrsiflorus	**48^{26}**	**88^{48}**	**50^{27}**	30^{16}	19^{11}		**41^{22}**	20^{11}		4^{2}
Poa pratensis	4^{2}	6^{3}	20^{11}	**45^{25}**	38^{21}	**40^{22}**	**64^{35}**	**40^{22}**	25^{14}	12^{7}
Thalictrum lucidum		12^{7}	**80^{49}**	**40^{24}**	11^{7}	5^{3}	**41^{25}**	12^{7}		**50^{31}**
Vicia cracca	9^{5}	35^{21}	20^{12}	25^{15}	4^{2}	25^{15}	**55^{34}**	8^{5}	12^{7}	**59^{36}**
Galium boreale	4^{3}	**59^{38}**	**70^{45}**	20^{13}			**73^{47}**			

Table 1 (continued)

Syntaxon ID Number of relevés	**1** **23**	**2** **17**	**3** **10**	**4** **20**	**5** **53**	**6** **20**	**7** **22**	**8** **25**	**9** **8**	**10** **56**
Taraxacum officinale			20^{16}	10^{8}	$\mathbf{45^{36}}$	10^{8}	5^{4}	36^{29}		9^{7}
Prunella vulgaris			20^{17}	5^{4}	$\mathbf{45^{38}}$	20^{17}	5^{4}	12^{11}		9^{8}
Carex hirta				15^{13}	9^{8}	$\mathbf{85^{75}}$	5^{4}			
D.s. cl. *Koelerio-Corynephoretea*										
Veronica spicata	35^{39}	$\mathbf{41^{46}}$								
Rumex acetosella	35^{43}	24^{31}								
Artemisia campestris	39^{54}	12^{17}								
Sedum ruprechtii	30^{42}	18^{25}								
Trifolium aureum	17^{29}	12^{21}			4^{7}					
Koeleria glauca	22^{46}									
Artemisia austriaca	17^{36}									
D.s. cl. *Artemisietea vulgaris*										
Rumex confertus	13^{6}	12^{5}	$\mathbf{60^{27}}$	$\mathbf{85^{38}}$	$\mathbf{49^{22}}$	15^{7}	18^{8}	$\mathbf{76^{34}}$	38^{17}	$\mathbf{80^{36}}$
Erigeron annuus	$\mathbf{48^{27}}$	$\mathbf{65^{37}}$	30^{17}	30^{17}	32^{18}		$\mathbf{59^{33}}$	16^{9}		2^{1}
Cirsium arvense			20^{12}	15^{9}	$\mathbf{45^{27}}$	20^{12}	32^{19}	$\mathbf{64^{38}}$	12^{7}	$\mathbf{41^{24}}$
Convolvulus arvensis	4^{4}		$\mathbf{60^{55}}$	5^{5}	8^{7}		14^{13}	4^{4}	12^{11}	
Equisetum arvense			20^{19}	10^{9}	8^{7}	30^{28}	23^{21}			7^{6}
Tanacetum vulgare	22^{29}	6^{8}					23^{31}			
Erigeron canadensis	26^{46}						5^{9}			
D.s. cl. *Phragmito-Magnocaricetea*										
Rorippa sylvestris			10^{11}		9^{10}			28^{31}	12^{13}	16^{18}
Lycopus europaeus					8^{10}	20^{25}	9^{11}	12^{15}		7^{9}
Symphytum officinale						5^{8}	5^{8}	4^{6}		23^{37}
Carex riparia								4^{7}	25^{45}	2^{4}
Alisma plantago-aquatica						5^{9}		8^{15}		16^{29}
Carex acuta									25^{51}	
Butomus umbellatus								8^{18}		11^{25}
Phragmites australis							5^{11}		12^{28}	2^{5}
Other species										
Aristolochia clematitis	17^{32}	6^{11}					5^{9}			
Berteroa incana	13^{25}				6^{12}	5^{10}				
Fragaria vesca		29^{42}			2^{3}		14^{21}			
Anthyllis macrocephala		18^{27}		15^{23}	2^{3}		5^{8}			
Jasione montana			10^{24}	5^{12}						
Agrimonia eupatoria			10^{25}	5^{12}						
Viola matutina			10^{32}							
Campanula patula				25^{42}			5^{8}			
Myosotis arvensis		6^{11}		20^{37}	2^{4}					
Briza media				20^{42}						
Plantago media		6^{7}		20^{23}	15^{17}	5^{6}	9^{10}	12^{14}		
Daucus carota	4^{8}			20^{38}						
Polygala vulgaris				20^{44}						
Vicia tetrasperma	4^{7}			10^{17}	4^{7}			4^{7}		4^{7}
Trifolium medium				15^{35}						
Anthoxanthum odoratum			10^{15}	15^{23}	6^{9}			4^{6}		
Veronica chamaedrys		6^{11}		10^{18}	2^{4}		9^{16}			
Achillea collina				5^{8}	25^{41}					
Carex pallescens			10^{11}	15^{15}	28^{28}		9^{9}		25^{25}	

Table 1 (continued)

Syntaxon ID Number of relevés	**1** **23**	**2** **17**	**3** **10**	**4** **20**	**5** **53**	**6** **20**	**7** **22**	**8** **25**	**9** **8**	**10** **56**
Trifolium fragiferum		6^{7}			26^{32}		9^{11}	4^{5}	12^{15}	2^{2}
Plantago major				5^{8}	15^{25}	5^{8}		4^{7}		2^{3}
Juncus compressus					2^{3}	25^{41}		4^{6}		4^{6}
Angelica sylvestris						25^{51}				
Juncus effusus						25^{51}				
Scirpus sylvaticus						20^{45}				
Myosoton aquaticum						15^{39}				
Mentha arvensis						10^{32}				
Cirsium palustre						10^{31}				
Ranunculus sceleratus						15^{39}				
Bidens tripartita						10^{24}				5^{12}
Blysmus compressus						10^{32}				
Achillea inundata						15^{39}				
Juncus inflexus						10^{32}				
Lathyrus pratensis		18^{24}		10^{13}			23^{31}			2^{3}
Valeriana officinalis						5^{8}	23^{37}			11^{18}
Gratiola officinalis	4^{6}	6^{8}					27^{37}			12^{17}
Rumex crispus						20^{29}	27^{39}			
Rubus caesius							18^{41}			
Melampyrum nemorosum		12^{22}					18^{33}			
Vicia sepium		6^{8}			2^{3}	10^{13}		20^{26}	12^{16}	4^{5}
Xanthium albinum					15^{21}	5^{7}		20^{27}		7^{10}
Cerastium holosteoides				5^{6}		5^{6}			38^{48}	11^{14}
Agrostis gigantea					2^{5}				12^{31}	
Tussilago farfara								4^{9}	12^{26}	4^{9}
Rorippa brachycarpa								8^{12}		30^{46}
Myosotis palustris										11^{32}
Althaea officinalis					2^{4}			12^{21}		16^{28}

Species with constancy not exceeding 10 % in any syntaxon:

Alopecurus geniculatus (10); *Amorpha fruticosa* (7); *Arctium lappa* (4); *Arrhenatherum elatius* (5, 8); *Artemisia absinthium* (1, 4, 5); *A. vulgaris* (5, 7, 8); *Barbarea stricta* (6); *Bromus hordeaceus* (1, 2, 4, 5); *B. tectorum* (5); *Calystegia sepium* (7); *Capsella bursa-pastoris* (5); *Carduus acanthoides* (4, 5, 8, 10); *Carex distans* (10); *C. otrubae* (6); *Carum carvi* (6); *Chenopodium album* (5); *Cicuta virosa* (6); *Cirsium setosum* (6); *Cynosurus cristatus* (4); *Echium vulgare* (4, 5); *Eryngium campestre* (1, 2, 5); *Euphorbia cyparissias* (2); *Galium aparine* (8, 10); *Genista tinctoria* (7); *Geranium palustre* (6); *Glyceria maxima* (10); *Humulus lupulus* (6); *Hypericum perforatum* (2, 4); *Inula britannica* (1, 6, 10); *Iris pseudacorus* (7, 8); *Juncus articulatus* (6); *J. atratus* (7); *Lamium purpureum* (7); *Leontodon autumnalis* (6); *Lolium perenne* (5, 8); *Lupinus polyphyllus* (1, 5); *Malva mauritiana* (7); *Melandrium album* (4, 5, 8); *Melilotus albus* (1); *Papaver rhoeas* (5); *Phleum phleoides* (2); *Pilosella officinarum* (2); *Poa annua* (5, 6); *P. bulbosa* (5); *Populus alba* (5); *P. nigra* (5); *Ptarmica salicifolia* (6); *Pyrus communis* (5, 7); *Raphanus raphanistrum* (4); *Rhinanthus aestivalis* (6); *Rh. vernalis* (6); *Rorippa palustris* (8); *R. prostrata* (6); *Salix caprea* (5); *Silene viscaria* (7); *Tragopogon dubius* (1); *Trifolium arvense* (2); *T. hybridum* (6, 7); *Tripleurospermum inodorum* (4, 5); *Ulmus laevis* (7); *Urtica dioica* (5, 6, 8, 10); *Verbascum lychnitis* (1, 5); *Veronica serpyllifolia* (6); *Vicia villosa* (7).

Syntaxonomic scheme of vegetation

***MOLINIO-ARRHENATHERETEA* Tx. 1937**

Galietalia veri Mirkin et Naumova 1986 (syn. *Poo-Agrostietalia vinealis* Shelyag-Sosonko et al. 1985)

Agrostion vinealis Sipaylova et al. 1985

Eryngio plani-Bromopsietum inermis Shevchyk et V. Solomakha 1996

1. *Eryngio-Bromopsietum inermis* var. *Oenothera rubricaulis*

Koelerio delavignei-Agrostietum vinealis (Sipaylova et al. 1985) Shelyag et al. 1987

2. *Koelerio-Agrostietum vinealis* var. *Asparagus officinalis*
3. *Koelerio-Agrostietum vinealis* var. *Ranunculus polyanthemos*

Arrhenatheretalia elatioris Tx. 1931

4. *Galio molluginis-Festucetum pratensis* ass. nova hoc loco
5. *Medicago lupulinae-Phleetum pratensis* Goncharenko 2003

Arrhenatherion elatioris Luquet 1926 (syn. *Festucion pratensis* Sipaylova, Mirk., Shelyag et V. Solomakha 1985)

Molinietalia caeruleae Koch 1926

Deschampsion cespitosae Horvatić 1930 (syn. *Cnidion venosi* Balátová-Tuláčková 1966, *Alopecurion pratensis* Passarge 1964)

6. *Dactylorhizo incarnati-Caricetum nigrae* ass. nova hoc loco
7. *Veronici longifoliae-Iridetum sibirici* ass. nova hoc loco
8. *Poo trivialis-Alopecuretum arundinaceae* ass. nova hoc loco

Poo palustris-Alopecuretum pratensis Shelyag, Sipaylova, Solomakha, Mirkin 1987

9. *Poo palustris-Alopecuretum pratensis* var. *Agrostis stolonifera*
10. *Poo palustris-Alopecuretum pratensis* var. *Scutellaria galericulata*

Cluster analysis of syntaxa

Figure 2 shows a tree diagram obtained from hierarchical cluster analysis of syntaxa, as explained in the Methods section.

Three groups (gray-painted areas) of appear based on species composition of synoptic columns. These groups correspond well to the division into three orders in the syntaxonomic scheme – *Galietalia veri* (A), *Arrhenatheretalia* (*B*), *Molinietalia* (C). Group A unites associations 1 and 2 of the alliance of psammophytic *Agrostion vinealis* meadows. The association *Koelerio delavignei-Agrostietum vinealis* has two variants (clusters 2 and 3) split between A and B groups. This is explained by the fact that cluster 2 unites communities mainly from the Dnieper floodplain, where extensive sandy sediments occupy more areas. Therefore, in addition to common species in clusters 2 and 3, which are parts of the same association, cluster 2 is similar to cluster 1, and the latter also unites psammophytic meadows. Group B incorporates two associations from the *Arrhenatherion* alliance (clusters 4 and 5). Group C unites meadows of the alliance *Deschampsion cespitosae* and is in compliance with the syntaxonomic scheme, except cluster 7. The latter unites meadows which are formed on unstable and fluctuating mode of soil moistening with the dry summer period, and featured by the co-occurrence of mesohygrophytes with relatively drought-tolerant species.

Ordination

Figure 3 shows the ordination plot with vectors of the supplementary phytoindicational variables and Table 2 summarizes the results of multiple regression of 9 supplementary (passive) variables using the *envfit* function which tests correlations

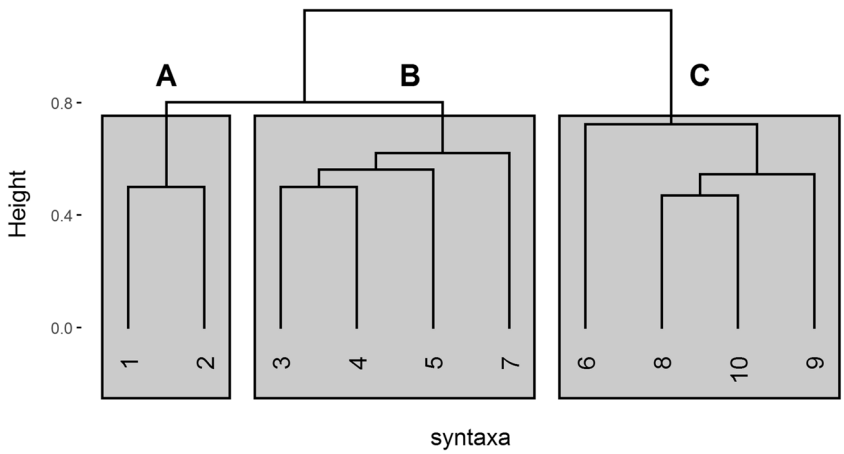

Fig. 2 Cluster analysis of the studied meadow syntaxa

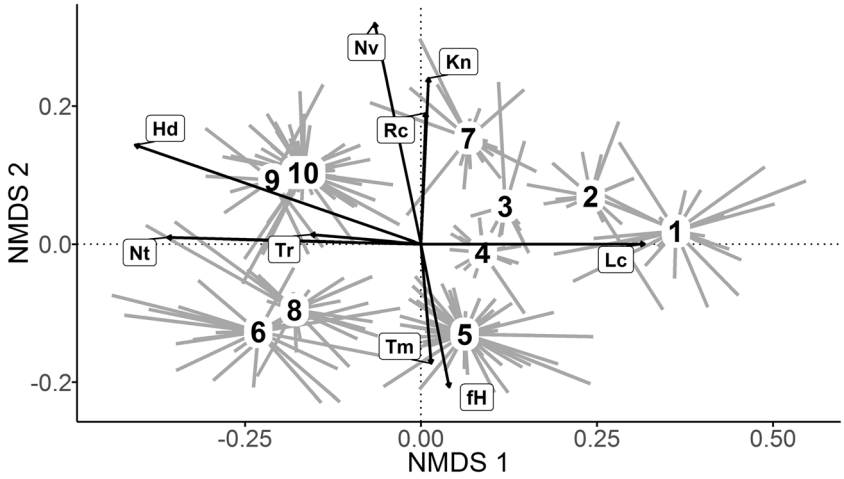

Fig. 3 Ordination diagram with vectors of supplementary phytoindicational variables Numbers indicate clusters. For codes of the phytoindicational variables see Table 2

between variables and ordination scores. Variables were ordered by the values of the coefficient of determination r^2.

As can be seen from Table 2, the first axis is most correlated with the factors *Hd* and *Nt*. Moreover, the moisture has the largest value of r^2, which is quite expectable, since it is moisture that determines most differentiation of meadows at a high syntaxonomic level of orders from the semi-dry *Galietealia veri* to temporarily wet *Molinietalia* meadows. The second axis is most associated with anthropogenic factors, since the *Nv* vector has the highest value in the NMDS2 column. Thus, edaphic (*Hd* and *Nt*) and anthropogenic (*Nv*) variables demonstrate the highest r^2 values. By contrast, soil reaction and salt regime appear to have a lower impact considering the differentiation of studied meadow syntaxa.

Phytosociological spectra of syntaxa

The phytosociological spectra of the 10 obtained syntaxa are summarized in Table 3**.** Only classes with a share of species greater than 0.01 (10 %) are presented in the table. The differences in percentages between the first and the second classes of the phytosociological spectrum were placed in the *"diff"* column. This indicator is a measure of how certain syntaxon has a transitional species composition.

As seen from Table 3, the diagnostic species of the seven classes of vegetation constitute the species composition of the studied syntaxa. The percentages of *Molinio-Arrhenathretea* species vary greatly – from 15.2 % to 100 % with a maximum for mesic meadows. The species of *Alnetea glutinosae* and *Trifolio-Geranietea* appear in only one syntaxon and play a role of differential species. From cluster 1 to 10, there is a quite expected tendency of a gradual decrease in the proportion of *Festuco-Brometea* species and an increase of *Phragmito-Magnocaricetea*. The species of the *Koelerio-Corynephoretea* class differentiate *Agrostion vinealis* alliance (clusters 1, 2). Synanthropic classes may indicate the intensity and the direction of anthropogenic transformation of meadows in the region. From Table 3, anthropogenic transformation is mainly manifested by the class of *Artemisietea vulgaris*, with the percentages varying from 14.9 % to 33.3 % and decreasing toward wet meadows.

Table 2 Results of multiple regression of 9 supplementary variables on the first two ordination axes

Variables	Plant indicator scale	NMDS1	NMDS2	r^2	r^2.ranked
Hd	moisture	−0.90	0.32	0.92	1
Nt	soil nitrogen value	−0.80	0.02	0.64	2
Nv	naturalness value	−0.15	0.71	0.53	3
Lc	light value	0.71	0.01	0.50	4
Kn	continentality value	0.02	0.53	0.28	5
fH	variability of moisture	0.09	−0.46	0.22	6
Rc	soil reaction	0.02	0.42	0.18	7
Tm	temperature value	0.03	−0.38	0.15	8
Tr	total salt regime	−0.35	0.03	0.12	9

Table 3 Shares of species of different classes of vegetation in the species composition of the studied syntaxa (phytosociological spectra) in percentages, %

syntaxon	*diff*, %	*MOL*	*FES*	*COR*	*ART*	*ALN*	*GER*	*PHR*
1	0.0	15.2	33.3	18.2	33.3	–	–	–
2	2.6	31.6	34.2	15.8	18.4	–	–	–
3	2.6	41.0	38.5	–	20.5	–	–	–
4	39.1	60.9	21.7	–	17.4	–	–	–
5	56.2	78.1	–	–	21.9	–	–	–
6	58.6	79.3	–	–	–	20.7	–	–
7	36.2	55.3	19.1	–	14.9	–	10.6	–
8	100.0	100.0	–	–	–	–	–	–
9	53.3	76.7	–	–	–	–	–	23.3
10	47.1	73.5	–	–	–	–	–	26.5

Abbreviations of vegetation classes according to Mucina et al. (2016)

Phytocoenological characterization

The phytocoenotic characteristics of syntaxa are based on the quantitative characteristics of species composition and qualitative characteristics of their habitats. Each syntaxon is described according to a unified scheme – habitat type according to the EUNIS classification, ecologic peculiarities and synmorphology features of communities, distribution, degree of anthropogenic transformation and syntaxonomic relations. Constant (const.) and differential (diff.) species are given for each association, as well as a list of related syntaxa. The term "related" does not mean that we regard the syntaxa as synonyms in the nomenclatural sense. This implies similarity in species composition and position in the syntaxonomic scheme. Related syntaxa lists were used to demonstrate close and remote syntaxonomic relations, as well as to suggest the potential range of syntaxa over a wider area than the region of research.

Some characteristics were derived from header data and species lists of relevés, aggregated taking into account belonging to certain syntaxa (Table 4). Following statistics were calculated:

- *N* – the total number of relevés in the cluster;
- *R* – the average number of species per relevé;
- *S* – the total number of species in joint species lists of syntaxa (after merging the same species in different layers);
- *min-max* – the range of minimum and maximum number of species in the relevés of the cluster;
- *cov.herbs* – the average total coverage of the herb layer in the relevés of the cluster;
- *S20%* – the ratio of the number of species with constancies higher than 20 % (II-V constancy classes) to *S*, the total number of species;
- *S40%* – the same, but with a more stringent threshold of constancy of 40 %. To a certain extent, both are indicators of the average similarity of relevés within clusters.

Table 4 Descriptive characteristics of the syntaxa

syntaxon	*N*	*R*	*S*	*min-max*	*cov.herbs*	*S20%*	*S40%*
1	23	13	56	11–20	60	43	20
2	17	17	65	10–26	79	38	23
3	10	20	55	11–31	70	62	40
4	20	20	74	14–34	66	43	24
5	53	16	106	10–24	57	25	14
6	20	16	93	10–24	80	32	15
7	22	19	88	13–27	92	36	22
8	25	13	74	9–21	58	32	16
9	8	15	39	11–19	67	62	33
10	56	14	84	8–27	72	29	15

To assess the degree of anthropogenic transformation, we relied on the results of the assessment by the method of phytosociological spectrum (Table 3), because this approach allows quantifying the proportion of species of classes of natural and synanthropic vegetation. The numbers next to each association in this article section correspond to the syntaxonomic scheme.

Alliance *Agrostion vinealis* Sipaylova et al. 1985

The *Agrostion vinealis* alliance unites psammophitic steppic floodplain meadows. It was described from the Left-Bank Polissya (Sipaylova et al. 1985).

Association *Eryngio plani-Bromopsietum inermis* Shevchyk et V. Solomakha 1996

Diff: *Artemisia campestris*, *Dianthus borbasii*, *Eryngium planum*, *O. rubricaulis*, *Oenothera biennis*, *Potentilla argentea*, *P. impolita*

Const.: *Bromus inermis*, *Calamagrostis epigejos*, *Festuca valesiaca*, *Galium verum*, *Poa angustifolia*

EUNIS: E1.9 – Open non-Mediterranean dry acid and neutral grassland, including inland dune grassland.

Holotypus. Shevchyk & Solomakha (1996).

Related syntaxa: *Festuco valesiacae-Poetum angustifoliae* Mirkin in Denisova et al. 1986, *Potentillo impolitae-Festucetum valesiacae* Goncharenko 2003, *Potentillo argenteae-Poetum angustifoliae* Solomakha 1996, *Scabioso ochroleucae-Poion angustifoliae* Bulokhov 1999, *Artemisio dniproicae-Sedetum sexangulari* Shevchyk et V. Solomakha in Shevchyk et al. 1996, *Diantho borbasii-Agrostietum syreistschikovii* Vicherek 1972, *Artemisio campestri-Diantheum borbasii* Yakushenko 2004.

Ecology. The association combines steppic meadows which develop in central parts of floodplains on sod sandy soils.

Synmorphology. Communities are characterized by a low or middle herbaceous layer (30 – 50 cm high), with the mean total cover 60 % and moderate species richness (Table 4). Drought-tolerant grasses, such as *Bromus inermis*, *Calamagrostis epigejos*, *Poa angustifolia* are the most frequent dominants, with *Festuca valesiaca* dominating under intensive grazing conditions.

Syntaxonomy. This association was originally placed in the alliance *Trifolion montani* Naumova 1986 (Shevchyk and Solomakha 1996). However, this alliance is much more eastern and described from continental regions of Russia, Republic of Tatarstan (Naumova 1986). We consider reasonable and suggest transferring this association to another, much more ecologically and geographically close alliance, *Agrostion vinealis*. The association is characterized by a

differential combination of diagnostic species of three classes of vegetation: *Koelerio-Corynephoretea*, *Molinio-Arrhenathretea*, and *Festuco-Brometea* (Tables 1, 3).

Distribution. The association develops on the floodplains of larger rivers from middle to low courses with the basic distribution in subcontinental regions of Eastern Europe in the Forest-Steppe zone. Communities of the association are common on Dnieper's islands in Kyiv (Hidropark, Zhukiv, Trukhaniv). This association is one of those that we found commonly in the floodplain of the Dnieper River and rarely in the Seym river valley. At the same time, the association is rather common for the Left-Bank Forest-Steppe, as judged by the distribution of similar vegetation units. Related associations are known from the floodplains of the Psel River (ass. *Potentillo impolitae-Festucetum valesiacae*, Goncharenko 2003), the Vorskla River (ass. *Potentillo argenteae-Poetum angustifoliae*, Solomakha 1981), and the Dnieper River (*Artemisio dniproicae-Sedetum sexangulari*, Shevchyk et al. 1996). There is considerably less data from the Right-Bank Ukraine, which might indicate indirectly that these communities are mainly distributed east of the Dnieper.

Anthropogenic transformation. Share of synanthropic species is rather high, with 33.3 % being from the *Artemisietea vulgaris* class (Table 3). The meadows are used mainly for pastures. Because of the low productivity of the herbaceous layer, the meadows are not suitable for hay mowing.

Association *Koelerio delavignei-Agrostietum vinealis* (Sipaylova et al. 1985) Shelyag et al. 1987

Diff.: *Agrostis vinealis*, *Asparagus officinalis*, *Cichorium intybus*, *Koeleria delavignei*, *Ranunculus polyanthemos*, *Trifolium montanum*

Const.: *Achillea millefolium*, *Carex praecox*, *Centaurea jacea*, *Convolvulus arvensis*, *Elymus repens*, *Festuca pratensis*, *Filipendula vulgaris*, *Galium verum*, *Lotus corniculatus*, *Phleum pratense*, *Plantago lanceolata*, *Poa angustifolia*, *Potentilla argentea*

EUNIS: E1.9 – Open non-Mediterranean dry acid and neutral grassland, including inland dune grassland.

Holotypus. Shelyag-Sosonko et al. (1987).

Related syntaxa: *Agrostietum vinealis-tenuis* Shelyag et al. 1981 ex Shelyag, Solomakha & Sipaylova 1985, *Festuco valesiacae-Agrostietum vinealis* Shelyag, Sipaylova, V. Solomakha et Mirk. in Shelyag et al. 1985, *Agrostio vinealis-Calamagrostietum epigeios* (Shelyag et al. 1981) Shelyag, V. Solomakha et Sipaylova 1985, *Festuco ovinae-Koelerietum delavignei* Bulokhov 1994.

Ecology. Psammophitic meadows which develop on elevated parts of the riverbed and the central part of the floodplain on sod sandy soils.

Synmorphology. Communities are mainly two-layered with the height of the first layer reaching 70 cm; contain 17 and 20 species per relevé in two variants of associations, accordingly (Table 4). Such grasses, as *Agrostis vinealis*, *Poa angustifolia*, *Calamagrostis epigejos* are usually dominating together with meadow-steppe herbs (*Filipendula vulgaris*, *Galium verum* etc.) (Table 1).

Syntaxonomy. The syntaxonomic position of the association is characterized by a high proximity to *Festuco-Brometea* and *Molinio-Arrhenathretea* classes (34.2 % and 31.6 %, Table 3). The *Asparagus officinalis* variant differs by a greater portion (15.8 %) of psammophilous species typical of the *Koelerio-Corynephoretea* class.

Subordinate vegetation units:

- *Koelerio delavignei-Agrostietum vinealis* var. *Asparagus officinalis*, mostly occur in the floodplains of the Dnieper River
- *Koelerio delavignei-Agrostietum vinealis* var. *Ranunculus polyanthemos*, more common on the Seim and other small rivers of the Left-Bank Polissya

Distribution. The distribution area covers the Left-Bank Polissya of Ukraine and likely the adjacent territories of Belarus and Russia. The association has been reported from the floodplains of many Left-Bank Dnieper tributaries and rivers of Polissya, such as the Desna, the Seym, the Sozh, the Sudost', the Ivotka (Sipaylova et al. 1985, 1987; Shelyag-Sosonko et al. 1987; Kuzemko 2009a, b).

Anthropogenic transformation. The meadows are used for pastures. In addition, there is a trend towards reduction of the areas of the communities dominated by *Agrostis vinealis* and their replacement with *Festuca valesiaca*-dominated communities, with the latter species being more resistant to grazing and anthropogenic drainage conditions.

Alliance *Arrhenatherion elatioris* Luquet 1926

The *Arrhenatherion elatioris* alliance unites mesic hay meadows on mineral-rich soils, widely distributed throughout Central Europe. In a close vicinity of the study region, in the floodplain of the Desna, on the Left-Bank Ukrainian Polissya, the *Festucion pratensis* alliance has also been reported (Sipaylova et al. 1985). But later this alliance was recognized as a synonym of *Arrhenatherion* in the European vegetation survey (Mucina et al. 2016). The reason for this was the fact that the new alliance was introduced using the Hungarian association *Festucetum pratensis* Soó 1938 from *Arrhenatherion* as a nomenclature type (art. 24, ICPN) (Kuzemko 2016). Surely, the choice of a distant Hungarian association as a nomenclature type for the eastern alliance is questionable. In 2011, an attempt was made to identify differences between these two alliances along the continentality gradient (Birzniece et al. 2011). Although the authors stated the fact of floristic differences, they did not propose to

consider these alliances separately in the nomenclatural sense. Nevertheless, *Festucion pratensis* is often mentioned in publications from many territories in Eastern Europe (also outside Ukraine), such as Belarus (Sapegin et al. 2009), western European Russia (Bulokhov 2001) and the Urals (Yamalov 2005). Since the description of the *Festucion pratensis* alliance was likely incorrect, here we include two more associations in the *Arrhenatherion* alliance in our syntaxonomic scheme.

Association *Galio molluginis-Festucetum pratensis* ass. nova hoc loco

Diff.: *Festuca pratensis*, *Galium mollugo*, *Gladiolus tenuis*, *Leucanthemum vulgare*
Const.: *Achillea millefolium*, *Centaurea jacea*, *Lotus corniculatus*, *Phleum pratense*, *Plantago lanceolata*, *Ranunculus acris*, *Stellaria graminea*, *Trifolium pratense*

EUNIS: E2.2 Low and medium altitude hay meadows.

Holotypus. Relevé 308 (Table S2), sampled by M.S. Kozyr, 22.06.2006, in the floodplain of the Seym, near the village of Osich, Bakhmach district, Chernihiv region, Ukraine. The total coverage of the herbaceous layer is 85 %. On the plot of 100 m^2 area, 34 species were registered: *Festuca pratensis* 4, *Anthyllis macrocephala* 3, *Achillea millefolium* 2, *Cynosurus cristatus* 2, *Trifolium pratense* 2, *Cirsium arvense* 1, *Daucus carota* 1, *Poa pratensis* 1, *Agrostis capillaris* +, *Anthoxanthum odoratum* +, *Carex hirta* +, *C. pallescens* +, *Centaurea jacea* +, *Dactylis glomerata* +, *Dianthus deltoides* +, *Echium vulgare* +, *Elymus repens* +, *Erigeron annuus* +, *Galium mollugo* +, *Gladiolus tenuis* +, *Leucanthemum vulgare* +, *Lotus corniculatus* +, *Myosotis arvensis* +, *Phleum pratense* +, *Plantago media* +, *Polygala vulgaris* +, *Potentilla argentea* +, *Ranunculus acris* +, *Rhinanthus serotinus* +, *Rumex confertus* +, *Silene flos-cuculi* +, *Stellaria graminea* +, *Thalictrum lucidum* +, *Tripleurospermum inodorum* + .

Related syntaxa: *Agrostio giganteae-Festucetum pratensis* Sipaylova et al. 1987, *Festucetum pratensis* sensu auct. ukrain. non Soó 1938, *Poetum pratensis* Stepanovič 1999, *Filipendulo vulgaris-Festucetum rubrae* Bulokhov 1990, *Caro carvi-Festucetum pratensis* Bulokhov 1990, *Festuco pratensis-Leucanthemetum vulgaris* Bulokhov 2014.

Ecology. Mesic *Festuca pratensis*-dominated meadows with other mesophytic herbs (*Lotus corniculatus*, *Trifolium pratense* etc.) on sod-gley soils. Communities develop in central and riverbed parts of floodplains on flat relief.

Synmorphology. One or two-layered communities, with the first layer 60 – 80 cm high. The total coverage varied from 60 to 95 %, averaging 66 %, and the average floristic richness was 20 species per relevé (Table 4).

Syntaxonomy. In Ukrainian publications, meadow communities with significant participation or dominance of *Anthoxanthum odoratum* and *Anthoxanthum odoratum* are often identified as an association of *Anthoxantho odorati-Agrostietum capillaris* Sillinger 1933 (Shelyag-Sosonko et al. 1987; Sipaylova and Shelyag-Sosonko 1996; Goncharenko 2000; Onyshchenko 2006; Kuzemko and Kozyr 2011; Vashenyak and Didukh 2011; Tertishnyy and Yakubenko 2013). In contrast, we assume this actually represents in Ukraine not one, but a large floristically heterogeneous complex, which has yet to be reliably studied and divided. As for the true association *Anthoxantho-Agrostietum capillaris* Sillinger 1933, it unites pastures in the submontane-montane belt of the Western Carpathians (Sillinger 1933). Therefore, communities in the flat part of the territory of Ukraine, and especially in the floodplains, are mistakenly ascribed to this association and most likely represent a different syntaxon. A comparative table of the association *Galio molluginis-Festucetum pratensis* and the association *Anthoxantho-Agrostietum capillaris* from the Low Tatras is given in Table S3.

Distribution. The geographic range of the association *Galio molluginis-Festucetum pratensis* appears to cover large areas in the forest and north forest-steppe parts of the Left-Bank Ukraine and the adjacent regions of Russia and Belarus. In the Forest-Steppe, the communities are not limited to river valleys, and rise to watershed uplands too.

Anthropogenic transformation. Under mowing-grazing conditions, the share of synanthropic species is up to 17.4 % (Table 3). In a few localities on the Seym, we found populations of *Gladiolus tenuis* which is in the Red Book of Ukraine. This Eastern-European species is also known from the floodplain of the Desna River (Lukash et al. 2007). The biotopes (Natura 2000: 6510. extensively managed hay meadows of the planar to submontane zones) are under protection in accordance with Directive 92/43/EEC.

Association *Medicago lupulinae-Phleetum pratensis* Goncharenko 2003

Diff.: *Festuca rubra*, *F. pratensis*, *Medicago lupulina*, *Phleum pratense*
Const.: *Achillea millefolium*, *Elymus repens*, *Lotus corniculatus*, *Stellaria graminea*, *Trifolium pratense*

EUNIS: E2.2 Low and medium altitude hay meadows.

Holotypus. Goncharenko (2003).

Related syntaxa: *Medicago lupulinae-Poetum angustifoliae* Bulokhov 1990, *Festuco pratensis-Deschampsietum caespitosae* Shelyag-Sosonko et al. 1985, *Deschampsio-Festucetum rubrae* Sapegin 1986, *Festucetum pratensis-regelianae* Kuzemko 2012.

Ecology. Eutrophic mesic meadows on sod-loamy soils in central parts of floodplains, on lower river terraces, also in gullies and ravines outside rivers valleys.

Synmorphology. Two-layered communities with the first layer being 60 – 80 cm high, and the total coverage averaging 57 %; the species richness is moderate, 16 species per relevé

(Table 4). The communities are dominated by *Festuca pratensis* and co-dominated by *Poa pratensis*, *Phleum pratense*, *Dactylis glomerata*, *Festuca rubra*.

Syntaxonomy. The association is central in the alliance with a high proportion of *Molinio-Arrhenathretea* species, 78.1 % (Table 3).

Distribution. The association was first described from the Left-Bank Forest-Steppe of Ukraine, Sumy district (Goncharenko 2003). Related syntaxa are also known from the Left-Bank Ukrainian Polissya (ass. *Festuco pratensis-Deschampsietum caespitosae*) and Belarus (ass. *Deschampsio-Festucetum rubrae*). More accurate range cannot be specified, since *Festuca pratensis*-dominated meadows were usually exaggerated and mixed under the name of broad association *Festucetum pratensis* Soó 1938 (Shelyag-Sosonko et al. 1987; Bajrak 1998; Fitsailo 2003; Gomlya 2005; Galchenko 2006; Kuzemko and Kozyr 2011; Vashenyak and Didukh 2011).

Anthropogenic transformation. Due to mowing-grazing conditions, the share of synanthropic species is high (21,9 %) with most of them characteristic of the *Artemisietea vulgaris* class (Table 3).

Alliance *Deschampsion cespitosae* Horvatić 1930

The alliance unites wet meadows on heavy soils on floodplains in the Forest and Forest-Steppe zones of (sub)continental Central and Eastern Europe (Mucina et al. 2016). The syntaxonomy of the *Deschampsion cespitosae* alliance is rather complicated. On the one hand, in recent publications the alliances *Cnidion dubii* Bal.-Tul. 1966, *Alopecurion pratensis* Passarge 1964, *Agrostion albae* Soó 1941 are synonymized to *Deschampsion cespitosae* Horvatić 1930 for priority reasons (Botta-Dukát et al. 2005; Černý and Šumberová 2007; Hegedüšová Vantarová and Škodová 2014; Mucina et al. 2016). On the other hand, many European phytosociologists consider the *Cnidion dubii* and *Alopecurion pratensis* alliances as separate in the narrow sense (Borysiak 1994; Matuszkiewicz 2007; Jarolimek et al. 2008; Kącki et al. 2013).

In our opinion, this debate cannot be resolved only on the basis of nomenclature. We believe that the separation of the *Cnidion dubii* and *Alopecurion pratensis* meadows is mainly based on seasonal variability of moisture regimens. *Cnidion*-meadows usually develop under greatly changing soil moisture with a wet flooding period in the spring and a dry phase in the summer. Flooding also significantly enriches soils with nutrients, and there are many eutrophic species. At the same time, humidity fluctuations lead to the intermixing of mesohygrophytes with relatively drought-tolerant species. Such dualism has been highlighted by other authors, too (e.g. Schneider-Binder 2014).

By contrast, the *Alopecurion pratensis* alliance is more typical among *Molinietalia* meadows and is developed under stable humidity conditions. Ecological and floristic differences between *Cnidion dubii* and *Alopecurion pratensis*, the two being considered as synonyms in Western European syntaxonomy, are increasing eastward with the increasing climate continentality. This is most clearly observed east of the Dnieper, as well as in the lower courses of its left-bank tributaries wherever favorable edaphotopes exist. Perhaps because of this, in Ukrainian syntaxonomy (Solomakha 2008), the *Deschampsion caespitosae* alliance is treated somewhat differently than in European publications and in some sense closer to *Potentillion anserinae* Tx. 1947 (Kuzemko 2016). Many east European phytocoenologists also support the *Alopecurion pratensis* alliance (Kuzemko 1999, 2009a; Bulokhov 2001; Grigoriev et al. 2002; Goncharenko 2003; Sapegin et al. 2009; Kuzemko and Kozyr 2011; Yamalov et al. 2012; Tertishnyy and Yakubenko 2013). In any case, this issue requires additional research over broader areas, but first of all in the eastern continental regions, since even European authors recognize these meadows as "summer-dry" (Botta-Dukát et al. 2005), "continental" (Černý and Šumberová 2007).

Association *Dactylorhizo incarnati-Caricetum nigrae* ass. nova hoc loco

Diff.: *Carex nigra*, *Dactylorhiza incarnata*, *Equisetum palustre*, *Juncus compressus*
Const.: *Achillea millefolium*, *Carex hirta*, *Cirsium arvense*, *Deschampsia caespitosa*, *Festuca pratensis*, *Lysimachia nummularia*, *Potentilla anserina*, *Prunella vulgaris*, *Ranunculus acris*

EUNIS: E3.4 – Wet eutrophic and mesotrophic grasslands and flood meadows of the boreal and nemoral zones, dominated by grasses [Poaceae], rushes [Juncus] spp. or club-rush [*Scirpus sylvaticus*].

Holotypus. Relevé 711 (Table S2), sampled by I.V. Goncharenko, 14.06.1999, in the central part of the floodplain of the Vyr river, near the village of Vyri, Bilopillya district, Sumy region, Ukraine (51.0615° N, 34.3828° E). The total coverage is 80 %. On the plot of 100 m^2 area, 24 species were registered: *Agrostis stolonifera* 2, *Beckmannia eruciformis* 1, *Carex hirta* 1, *C. nigra* 1, *C. vulpina* 1, *Dactylorhiza incarnata* 1, *Festuca pratensis* 1, *Galium uliginosum* 1, *Juncus compressus* 1, *Lysimachia nummularia* 1, *Poa pratensis* 1, *Potentilla anserina* 1, *P. reptans* 1, *Ranunculus acris* 1, *R. repens* 1, *Symphytum officinale* 1, *Trifolium hybridum* 1, *T. repens* 1, *Vicia cracca* 1, *Equisetum arvense* +, *Plantago lanceolata* +, *Poa palustris* +, *Rhinanthus aestivalis* +, *Silene flos-cuculi* + .

Related syntaxa: *Eleocharito palustris-Agrostietum stoloniferae* Denisova ex Taran 1995, *Agrostio stoloniferae-Equisetetum palustris* Bulokhov 1990 ex Bulokhov 2001, *Galio palustre-Agrostietum stoloniferae* Sipaylova, V. Sl. & Shelyag 1987, *Carici vulpinae-Juncetum effusi* Goncharenko 2003, *Junco gerardii-Agrostietum stoloniferae* Grigoriev et al. 2002.

Ecology. Wet mesotrophic pastures of the association occupy flat poor-drained depressions in floodplains, on gley, slightly acid soils.

Synmorphology. Middle-grown (40 – 60 cm high) communities, usually dominated by *Carex nigra* and *Deschampsia caespitosa*, with the total coverage averaging 80 % (Table 4). A notable feature is prevailing tussock grasses and low-grown sedges over rhizomatous species, which may indicate denser upper soil horizons, reduced drainage and worse soil aeration conditions on pastures.

Syntaxonomy. The association is diagnosed by a combination of species characteristic of the alliances *Deschampsion*, *Calthion* (*Angelica sylvestris*, *Carex nigra*, *Filipendula ulmaria*, *Juncus effusus*, *Scirpus sylvaticus*) and *Potentillion anserinae* (*Agrostis stolonifera*, *Potentilla anserina*, *Ranunculus repens*).

Distribution. The relevés were collected from the Chernihiv and Sumy districts. Similar associations are reported from a larger number of locations from adjacent territories of Ukraine, Belarus and Russia – *Agrostio stoloniferae-Equisetetum palustris* association from Bryansk region, Russia (Bulokhov 2001), *Galio palustre-Agrostietum stoloniferae* association from the floodplain of the Desna River, Ukraine (Sipaylova et al. 1987).

Anthropogenic transformation. Compared to other studied associations, the share of synanthropic species is low, with a small number of species typical of the *Plantaginetea majoris* class. The diagnostic species *Dactylorhiza incarnata* is included in the Red Book of Ukraine. This species is to some extent resistant to zoogenic factors such as moderate grazing pressure: we observed the populations of hundreds of individuals without a decrease in vitality on pastures. At the same time, *Dactylorhiza incarnata* and most other species of the association are stenotopic and threatened mainly because of the disappearance of favorable wet turfy habitats. Therefore, this association needs protection.

Association *Veronici longifoliae-Iridetum sibirici* ass. nova hoc loco

Diff.: *Alopecurus pratensis*, *Galium boreale*, *Gratiola officinalis*, *Inula salicina*, *Iris sibirica*, *Lathyrus pratensis*, *Lysimachia vulgaris*, *Lythrum virgatum*, *Veronica longifolia*
Const.: *Festuca pratensis*, *Phleum pratense*, *Poa pratensis*, *Vicia cracca*

EUNIS: E3.43 – Subcontinental riverine meadows.

Holotypus. Relevé 699 (Table S2), sampled by M.S. Kozyr, 14.06.2012, within the city of Kyiv, Ukraine, 50.5146° N, 30.5435° E, in a flat depression in the central part of the Muromets Island. On the plot of 100 m^2 area, 23 species were recorded: *Bromus inermis* 3, *Galium verum* 3, *Alopecurus pratensis* 2, *Festuca pratensis* 2, *Filipendula ulmaria* 2, *Galium boreale* 2, *Phleum pratense* 2, *Trifolium pratense* 2, *Artemisia vulgaris* 1, *Cirsium arvense* 1, *Gratiola officinalis* 1, *Inula salicina* 1, *Iris sibirica* 1, *Poa pratensis* 1, *Rumex crispus* 1, *Centaurea jacea* +, *Erigeron annuus* +, *Lathyrus pratensis* +, *Lysimachia vulgaris* +, *Lythrum virgatum* +, *Rhinanthus serotinus* +, *Tanacetum vulgare* +, *Veronica longifolia* + .

Related syntaxa: *Allio angulosi-Alopecuretum pratensis* Shevchyk et V. Solomakha 1996, *Eleocharito palustris-Elytrigetum repentis* Shevchyk et V. Solomakha 1996, *Agrostio caninae-Alopecuretum pratensis* Kuzemko 2012, *Gratiolo-Caricetum suzae* Balátová-Tuláčková 1966, *Scutellario hastifoliae-Veronicetum longifoliae* Walther 1955, *Pseudolysimachio longifoliae-Alopecuretum pratensis* Blažková 1993, *Cnidio dubii-Deschampsietum caespitosae Passarge* 1960, *Lathyro palustris-Gratioletum officinalis* Balátová-Tuláčková 1966.

Ecology. Tall-herb meadows on productive nutrient-rich sites on gley-loamy, slightly saline soils. The changing moisture regimen with a dry summer period leads to the intermixing of mesohygrophytes (*Filipendula ulmaria*, *Gratiola officinalis*, *Iris sibirica*, *Lysimachia vulgaris*, *Lythrum virgatum*, *Valeriana officinalis)* with drought-adapted species (*Agrostis capillaris*, *Filipendula vulgaris*, *Galium verum*). Soils are enriched with nutrients during the spring flooding phase. In Central-East Europe, communities of similar ecology occur generally along the lower courses of rivers on heavy clay-like soils (Balátová-Tuláckova 1969).

Synmorphology. The height of the first layer varied from 60 to 120 cm, with the total coverage ranging from 70 % to 100 % and averaging 92 % (Table 4). Due to moisture fluctuations, communities demonstrate the phenological changes, a very specific feature that is not typical of meadows, but of steppes.

Syntaxonomy. Our communities are much different from the association *Iridetum sibiricae* Philippi 1960 (Table S4). Comparing with the original source (Philippi 1960), only few species, for example *Iris sibirica* and *Filipendula ulmaria*, are common. Such species as *Galium verum*, *Gratiola officinalis*, *Inula salicina*, *Veronica longifolia* are differential for eastern association.

Distribution. The distribution area of the association most likely covers eastern regions of the forest and forest-steppe parts of Ukraine and the adjacent territories of Belarus and Russia. Everywhere communities are sporadic, in some territories they are found quite common, and in others – they completely disappear. We also noted a strict tendency of occurring only along large rivers and only in floodplain conditions. Communities are quite common on the Dnieper and very rare on the Seym (Kozyr et al. 2008). Some assumptions can also be made from the findings of *Iris sibirica*, which is a characteristic species of the association, in the floodplain of the nearby Desna River (Lukash et al. 2007).

Anthropogenic transformation. The association has a natural species composition, and the percentage of synanthropic species is not exceeded 14.9 % (Table 3). Most species of the association are specialists. The main threat is anthropogenic drainage of floodplains which lowers the groundwater level. *Iris sibirica* is included in the Red Book of Ukraine. The biotopes (Natura 2000: 6440 Alluvial meadows of river valleys of the *Cnidion dubii* alliance) are under protection in accordance with Directive 92/43/EEC.

Association *Poo trivialis-Alopecuretum arundinaceae* ass. nova hoc loco

Diff.: *Alopecurus arundinaceus*, *Carex leporina*, *Poa trivialis*, *Stellaria palustris*
Const.: *Carex vulpina*

EUNIS: E3.4 – Wet eutrophic and mesotrophic grasslands and flood meadows of the boreal and nemoral zones, dominated by grasses [Poaceae], rushes [Juncus] spp. or club-rush [*Scirpus sylvaticus*].

Holotypus. Relevé 125 (Table S2), sampled by M.S. Kozyr, 26.06.2005, in the central part of the floodplain of the Seym River, near the village of Chumakove, Buryn district, Sumy region, Ukraine (51.2328° N, 33.8955° E). The coverage of herbaceous layer is 60 %. On the plot of 100 m^2 area, 14 species were recorded: *Alopecurus arundinaceus* 4, *Potentilla anserina* 3, *Carex leporina* 1, *Poa trivialis* 1, *Ranunculus acris* 1, *Althaea officinalis* +, *Carex vulpina* +, *Deschampsia caespitosa* +, *Erigeron annuus* +, *Lysimachia nummularia* +, *Plantago major* +, *Rumex thyrsiflorus* +, *Silene flos-cuculi* +, *Stellaria palustris* + .

Related syntaxa: *Alopecuro pratensis-Beckmannietum eruciformis* Solomeshcz in Barabash et al. 1989, *Alopecuretum arundinaceae* Mirkin et al. 1985.

Ecology. *Alopecurus arundinaceus* meadows are usually considered to be slightly saline. In the studied region, and perhaps generally in more northern locales, the conditions are different. In the association, halophytes (*Beckmannia eruciformis*, *Juncus gerardii*) are very few and have low constancies. On the contrary, north boreo-temperate species (*Carex leporina*, *Poa trivialis*, *Stellaria palustris*), which do not grow on saline soils, are more numerous. So, these traits lead us to argue that this association should belong to the *Molinio-Arrhenatheretea* class, not *Festuco-Puccinellietea*.

Synmorphology. Two-layered communities dominated by grasses of rhizomatous or short-stoloniferous growth forms. The number of species averaged 13 per relevé and totaled 74 in 25 relevés (Table 4).

Syntaxonomy. In our previous publications, communities of this type were classified within the *Alopecuro pratensis-Beckmannietum eruciformis* and *Elytrigio repentis-Alopecuretum arundinaceus* associations, both from the *Festuco-Puccinellietea* class (Kuzemko and Kozyr 2011). But, as already noted, they are closer ecologically and floristically to the *Molinio-Arrhenatheretea* class in northern conditions, so we use a new name: *Poo trivialis-Alopecuretum arundinaceae*.

Distribution. Most of the relevés were collected from Sumy district, Ukraine. Such communities on the Dnieper floodplain, in the second part of the study region, are rare and atypical. Since similar associations with *Alopecurus arundinaceus* are usually reported from more southern regions and included in another class of saline vegetation, it is difficult to determine whether such communities are limited only to our region and where their southern border is. It is suggested that they are northern vicariants of the alliance *Agrostio stoloniferae-Beckmannion eruciformis* Mirkin in Barabash et al. 1989.

Anthropogenic transformation. In the species composition of the association, the share of synanthropic species is quite low, 23.3 %, and most of them have low constancies, therefore classes of anthropogenic vegetation were not shown in Table 3.

Association *Poo palustris-Alopecuretum pratensis* Shelyag, Sipaylova, Solomakha, Mirkin 1987

Diff.: *Allium angulosum*, *Alopecurus pratensis*, *Eleocharis palustris*, *Galium palustre*, *Poa palustris*
Const.: *Deschampsia caespitosa*, *Lysimachia nummularia*, *Potentilla anserina*, *Ranunculus acris*, *Vicia cracca*

EUNIS: E3.4 – Wet eutrophic and mesotrophic grasslands and flood meadows of the boreal and nemoral zones, dominated by grasses [Poaceae], rushes [Juncus] spp. or club-rush [*Scirpus sylvaticus*].

Holotypus. Shelyag-Sosonko et al. (1987).

Related syntaxa: *Deschampsio-Poetum palustre* Mirkin et Sapegin 1985, *Galio palustris-Agrostietum stoloniferae* Sipaylova, Solomakha, Shelyag-Sosonko 1987, *Carici vulpinae-Deschampsietum cespitosae* Mirkin ex Grigorjev et al. 2002, *Cerastio holosteoidis-Deschampsietum cespitosae* Grigorjev et al. 2002, all. *Poion palustris* Shelyag-Sosonko et al. 1985, *Poetum palustris* Resmerita et Ratiu 1974.

Ecology. Communities usually develop in lowered flat depressions in central and outer parts of floodplains, on gley-like loamy soils. Groundwater is at depths of 0.5–1 m (Shelyag-Sosonko et al. 1987).

Synmorphology. The communities are dominated by moisture-demanding grasses; *Poa palustris*, *Alopecurus pratensis*, and *Deschampsia caespitosa*. The height of the first layer varied from 60 cm to 120 cm.

Syntaxonomy. The association appears to be transitional between *Molinietalia* and *Magnocaricetalia* orders (the presence of *Carex acuta*, *Phragmites australis*, *Scutellaria galericulata*, *Symphytum officinale* corroborates this) with the proportions of species of *Molinio-Arrhenatheretea* and

Phragmito-Magnocaricetea classes vary between 73.5 – 76.7 % and 23.3 % – 26.5 % accordingly (Table 3).

Distribution. The association is widespread from the Forest zone and throughout the Forest-Steppe zone in the Left-Bank Ukraine. It has been reported from the Dnieper, the Desna, the Seym and other rivers of the Left-Bank Ukraine (Shelyag-Sosonko et al. 1987; Sipaylova and Shelyag-Sosonko 1996; Gomlya 2005; Kuzemko and Kozyr 2011; Tertishnyy and Yakubenko 2013); the Ros' River from the Right-Bank Ukraine (Kuzemko 1999); from the estuary of the Dnieper (Dubyna and Dzyuba 2007), from the adjacent regions of Russia and Belarus (Averinova and Semenishchenkov 2009; Sapegin et al. 2009; Bulokhov et al. 2013), and even from the Bashkiria region in Russia (Yamalov et al. 2012). In view of such widely ranging reports of this association from very distant regions, its distribution area might be overestimated and is likely narrower.

Anthropogenic transformation. Meadows of this association, just as the previous one, are moderately resistant under hay-mowing conditions, but quickly degrade under grazing pressure. The most likely explanation for this is that trampling promotes densification of the upper soil horizons and worsening of soil aeration while most of the rhizomatous grasses are sensitive to the latter factor.

Conclusions

In this study, we presented the results of the classification of meadow vegetation in the floodplains of two rivers, the Dnieper and the Seym, with a different structure of main alluvial sediments and the prevailing soil types in the floodplains, which affected vegetation.

In general, the coenotic diversity of studied floodplain meadow vegetation should be ascribed to 1 class, 3 orders, 3 alliances and at least 10 syntaxa of the association rank and subordinate units. Communities of psammophytic and steppic meadows are occupying more areas in the floodplain of the Dnieper, while in the floodplain of the Seym mesic meadows are prevailing. Wet meadows are equally characteristic for floodplains of both rivers and are concentrated in various depressions in the central parts and lowered outer parts of the floodplains.

Specificity and distinctive features of syntaxa is most clearly traced at the level of alliances. Associations from the *Agrostion vinealis* alliance and the *Veronici longifoliae-Iridetum sibirici* from the alliance *Deschampsion* tend to occur in the floodplain of the Dnieper. On the contrary, associations demanding stable soil wetness, such as *Dactylorhizo incarnati-Caricetum nigrae* and *Poo trivialis-Alopecuretum arundinaceae* cover larger areas on the Seym. It depends on the hydrological dynamics of the rivers which affect the abundance of particular physical habitats.

Despite the fact that the study region is northern and plain, the syntaxonomic interpretation of the syntaxa reported from this territory is not obvious. Knowledge of meadow vegetation in Ukraine, especially in the northeast region, remains incomplete. As the comparative tables showed, even considering that the *Molinio-Arrhenatheretea* class represents azonal and geographically nonspecific vegetation type, a more detailed investigation, taking into account the full species composition of syntaxa, evidences a significant number of differentiating species. Of course, the species composition of floodplain meadows does not differ too much in different natural zones and floristic provinces, but we have demonstrated on concrete examples that at least some eastern associations should not be considered identical to western ones.

Leading factors of differentiation of the studied meadow communities are moisture, nitrogen and anthropogenic factor. In synanthropic fraction, the *Artemisietea vulgaris* species are most numerous, and the proportion of which is a reliable indicator of the level of anthropogenic load. Under different management regimes, the proportion of synanthropic species ranged from 16.7 % to 40 %. Considering generally, meadow vegetation on the Seym has been preserved better and also contains rare and threatened species. In both parts of the study region, less natural and more degraded are meadows in the drier part of the moisture gradient.

The overall ecological regimens of floodplains have changed as well. Anthropogenic activity (disposal of biomasses, land amelioration, intensive grazing pressure) leads to instability and unpredictability in the abundance of particular physical factors which plant communities rely on. These processes, by affecting the plant communities, also require corresponding revisions in the syntaxonomy of the native vegetation.

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Compliance with ethical standards

Conflict of interest The authors declare that they have no conflict of interest.

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