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Article

Ephemeral riparian flora of the Bolonsky Nature Reserve (Khabarovsk Krai)

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Abstract. The ephemeral floodplain riparian vegetation of the margins of the Simmi River (Amur River basin) is studied. It includes communities dominated by *Lindernia procumbens*. The taxonomic composition of the ephemeral floodplain riparian vegetation includes 33 species of vascular plants from 27 genera and 15 families. As in other low-water riparian floras of Amur, the families Cyperaceae, Asteraceae and Scrophulariaceae were the most diverse. The studied flora is characterized by a high proportion of obligate riparian marginal species (48.5%), about half of which have an East Asian range. It was found that obligate species have a higher occurrence and abundance than facultative ones. Ruderal and synanthropic species are absent in the ephemeral floodplain riparian flora of the reserve.

Keywords: floodplain ephemeral vegetation, coenopopulation, Amur basin

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Научная статья

Флора меженных отмелей заповедника «Болоньский» (Хабаровский край)

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Аннотация. Исследован пойменный эфемеретум отмелей р. Симми (бассейн р. Амур), представленный сообществами с доминированием *Lindernia procumbens*. Таксономический состав эфемеретума включает 33 вида сосудистых растений из 27 родов и 15 семейств. Как и в других амурских отмельных флорах, наибольшим разнообразием отличались семейства Cyperaceae, Asteraceae и Scrophulariaceae. Изученная отмельная флора характеризовалась высокой долей облигатных отмельных видов (48.5%), около половины которых имеют восточно-азиатский ареал. Установлено, что облигатные виды имеют более высокую встречаемость и обилие, чем факультативные. Рудеральные и синантропные виды в составе отмельной флоры заповедника отсутствуют.

Ключевые слова: отмельная флора, пойменный эфемеретум, ценопопуляция, бассейн Амура

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Introduction

Low-water-exposed riparian habitats are characterized by prominent fluctuations in the hydrological regime during one season: from multi-month flooding to prolonged drying. These fluctuations prevent the stable settlement of both typical aquatic perennials, which do not survive prolonged drying, and typical waterside plants, which die during prolonged flooding. Here, a specific riparian flora develops and short-lived communities, referred to as the "ephemeral floodplain vegetation," are formed (Mirkin and Solomeshch, 1990; Taran, 1995).

The Amur floodplain communities are distinguished not only by endemism, but also by the pronounced ephemeral nature of their species (Kryukova, 2005: Voroshilov, 1968). The life cycle of these species is associated with short-term low-water periods between summer monsoon floods, while in years of extreme flooding of the Amur River, the ephemeral floodplain flora is absent.

The most complete data are contained in the reports on the flora of the Russian Far East and Lower Amur region (Kharkevich, 1985–1996; Kryukova, 2005; Voroshilov, 1968, etc.), as well as in the few publications on the flora of the Amur floodplains (Kasatkina, 2013; Nechaev and Gapeka, 1970; Tsyrenova, 2022; Tsyrenova and Kasatkina, 2013, etc.). We have carried out special studies of the ephemeral floodplain communities in specially protected areas of the Amur River basin for the first time. The state and dynamics of this vegetation can serve as a sensitive bioindicator of natural and anthropogenic changes in the floodplain environment.

The results of more than 20 years of research show that the flora of the Bolonsky Reserve includes 311 species of vascular plants from 216 genera and 88 families (Antonova, 2013; Antonova and Malykhina, 2005, etc.), of which 49 species form the ephemeral floodplain flora. Over the past 10 years, high water levels, the absence of low-water exposed riparian habitat, and the inaccessibility of the territory have prevented the study of floodplain flora associations in the reserve.

The purpose of this study is to identify and analyze the structure of the flora and vegetation of the near-channel low-water exposed riparian habitat of the middle reaches of the Simmi River.

Material and methods

We studied areas of the coastal strip in the middle reaches of the Simmi River in the vicinity of the Vakhtar cordon, located on the southern border of the reserve (Fig. 1).

The Bolonsky Nature Reserve is located in the north-eastern part of the Middle Amur Lowland (N 49.742–49.402° E 135.521–136.372°) within the Amur and Nanai municipal districts of Khabarovsk Krai. Its territory belongs to the Lake Bolon basin and covers mainly the lower part of the Simmi River basin, as well as part of the coast of the lake itself. This is the lowest part of the plain with prevailing absolute heights of 22–26 m (the average elevation is no more than 3 m). The nature of the relief is largely determined by the accumulative activity of the Amur River, connected to the lake by a channel. The territory is characterized by a combination of low floodplains, flattened spaces, ancient and modern coastal hills (“relks”); 80% of the area is occupied by swamps and marshy meadows. The multi-branch low wet swampy floodplain occupies 23.8% of the total area of the reserve. Willow-grass associations, grass meadows of low wet and swampy floodplain mainly on peaty and sod-gley soils dominate here (Ostroukhov et al., 2020).

The hydrological regime of the lower reaches of the river and the coastal zone of Lake Bolon is closely related to the regime of the Amur River, which forms surge and backwater fluctuations in water level. However, in the middle reaches of the Simmi River, fluctuations of water level are determined by

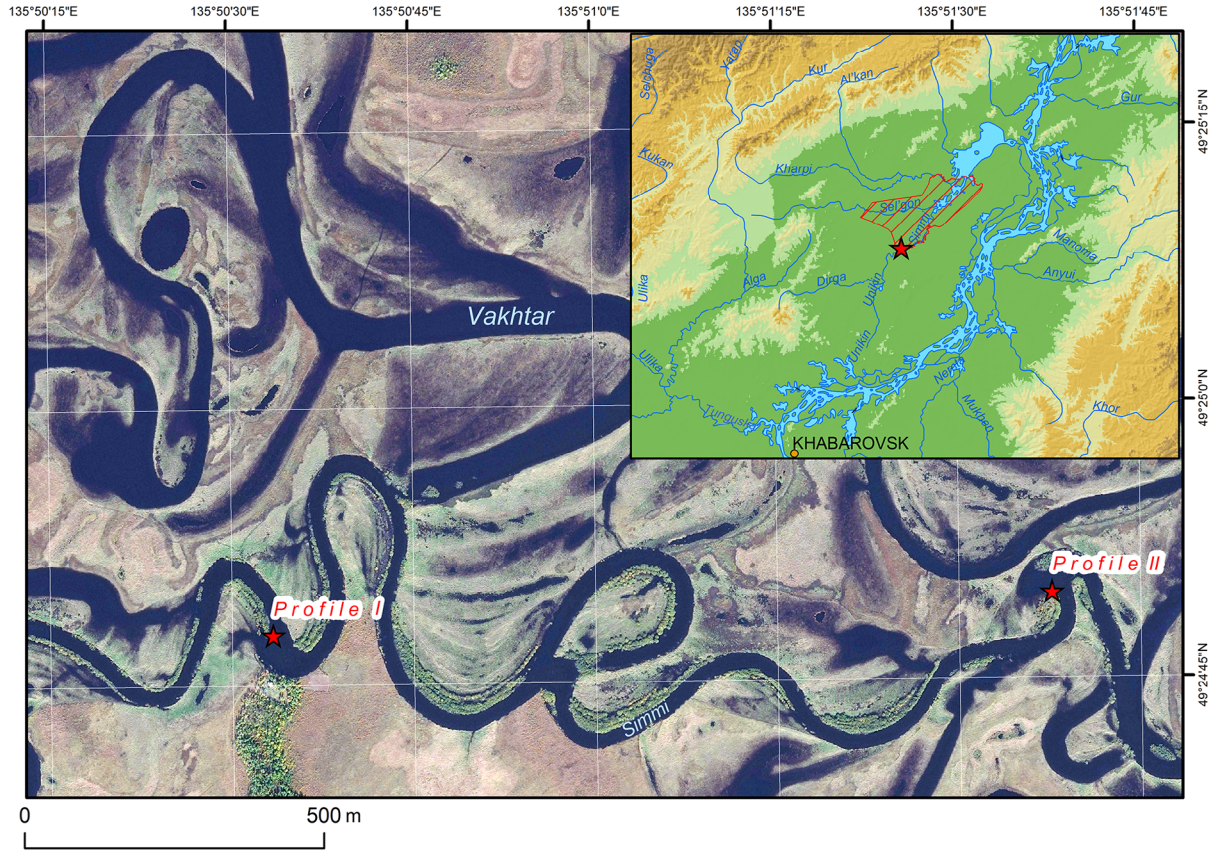

Fig. 1. Geographical location of the research area.

inflow from the catchment surface: spring snowmelt and spring-early summer thawing of marshland. In the second half of summer, short-term floods associated with the passage of summer-autumn monsoon cyclones through the territory are often observed. In some years (2013, 2018, 2019, 2020), catastrophic floods were observed in the basin of the middle and lower reaches of the Amur River, and despite a significant distance from the riverbed, the territory was completely flooded due to low absolute elevations. However, no regular hydrological observations are carried out in the river basin, therefore we characterize its hydrological regime based on the general patterns of its formation and analysis of Earth remote sensing data. Consequently, the average long-term course of water levels can be characterized as follows: pronounced spring-early summer flood (late April – early June), gentle extended decline in water levels determined by gradual thawing of marshland (June – mid-July), summer-autumn low water, interrupted by the passage of rain floods (August – mid-October), long winter low water season (November–March).

Field studies were carried out in August 2023, descriptions of communities were made on two profiles within natural stands of riparian vegetation on survey plots with an area of 1 m^2.

Profile I (N 49°24'47.584" E 135°50'33.358") is traced on the right bank of the Simmi River on a spit adjacent to the lower end of a pronounced coastal ridge. The length of the profile from the water's edge to the main bank was 35 m, the difference in height from the water's edge to the upper point was 130 cm, observations are taken from seven survey plots. The characteristics of the course of water levels in April–August 2023 were carried out on the basis of the phenological observation diary of the Vakhtar cordon.

Profile II (N 49°24'49,627"N E135°51'37,687") 22 m long from the water's edge to the ledge of the riverbank ridge (elevation difference 121 cm) is located on the left bank of the Simmi River on a spit adjacent to the lower end of a pronounced coastal hill. The observations were taken from six survey sites on it.

Due to the small size of floodplain ephemeral sites, the description of their communities is quite difficult. A profile with 6–7 survey plots is quite satisfactory in terms of both the speed of description and the representation accuracy of floodplain ephemeral communities.

The projective participation of species was taken into account by continuous recounting of individuals of each species (Figs. 2, 3). Then the count data were converted into percentages and into abundance points according to the Braun-Blanquet scale (r – rare, less than 1% – +, up to 5% – 1 point, 6–25% – 2 points, 25–50% – 3 points, 51–75% – 4 points, 76–100% – 5 points) (Braun-Blanquet, 1964). The frequency of occurrence of a species was calculated as a percentage as the ratio of the number of descriptions in which the species was found to the total number of descriptions. Based on these data, the constancy of the species was determined on a 5-point scale (I – occurrence of the species in descriptions from 1 to 20%, II – 21–40%, III – 41–60%, IV – 61–80%, V – 81–100%) (Braun-Blanquet, 1964). Based on the constancy (occurrence) and abundance (projective cover), an assessment of the phytocoenotic activity of riparian species was made (Bulokhov, 2005).

Plant species were identified according to “Vascular Plants of the Soviet Far East” (Kharkevich, 1985–2006), “Flora of the Russian Far East” (Kozhevnikov and Probatova, 2006) and refined according to Plants of the World Online[1].

Results and discussion

The species composition and structure of the flora of the near-channel low-water exposed riparian habitat of the Simmi River have been identified, which includes 33 species of vascular plants belonging to 27 genera and 15 families.: *Alisma orientale* (Sam.) Juz., *Sagittaria trifolia* L., *Artemisia mongolica* (Fisch. ex Bess.) Nakai, *Bidens maximowicziana* Oett., *Centipeda minima* (L.) A. Br. et Asch., *Gnaphalium tranzschelii* Kirp., *Rorippa palustris* (L.) Bess., *Callitriche palustris* L., *Ceratophyllum demersum* L., *Carex bohemica* Schreb., *Cyperus orthostachyus* Franch. et Savat., *C. limosus* Maxim., *C. nipponicus* Franch. et Savat., *Eleocharis ovata* (Roth) Roem. et Schult., *E. ussuriensis* Zinserl., *Fimbristylis dipsacea* (Rottb.) C.B. Clarke (= *F. verrucifera* (Maxim.) Makino), *F. velata* R. Br., *Schoenoplectiella komarovii* (Roshev.) J. Jung et H.K. Choi (= *Scirpus komarovii* Roshev.), *Juncus bufonius* L., *J. virens* Buschenau, *Nymphoides peltata (*S.G. Gmel.) O. Kuntze, *Echinochloa caudata* Roshev., *Glyceria triflora* (Korsh.) Kom., *Persicaria lapathifolia* (L.) Delarbre (= *P. lapathifolia* (L.) S.F. Gray), *Rumex maritimus* L., *Monochoria korsakowii* Regel et Maack, *Salix nipponica* Franch. et Savat., *S. schwerinii* E. Wolf, *Gratiola japonica* Miq., *Limosella aquatica* L., *Lindernia procumbens* (Krock.) Borb., *Trapella sinensis* Oliv., *Trapa japonica* Fler. The greatest taxonomic diversity is represented in the family Cyperaceae: nine species (27.3% of the entire riparian flora) from five genera. The family Asteraceae is represented by four species, Scrophulariaceae by three species, and the remaining families include 1–2 species.

Fig. 2. Survey plot.

Рис. 3. Complete count of individual plants.

[1] Plants of the World Online. Web page. URL: https://powo.science.kew.org/ (accessed: 08.02.2024).

Specific features of the studied flora include a high proportion of shoreline plants and the absence of ruderal and synanthropic species. According to A.P. Nechaev and Z.I. Gapeka (1970), 114 plant species of 56 genera and 21 families are found in the riparian zone of the Amur River from Khabarovsk to Nikolaevsk, a distance of about 1000 km. All species are divided by these authors into two groups: obligate (49 species, or 42.9%) and facultative (65 species, or 57.1%) ephemerals. Obligate ephemerals inhabit the lowest strip of the bank, located between the levels of the most frequent floods and low waters. These ecotopes are characterized by intense illumination and constantly changing humidity. Facultative ephemerals are also found in other habitats, in addition to the low-water zone, and are represented by two groups: coastal and ruderal plants.

For the vicinity of Khabarovsk, 108 species of riparian flora are listed, of which the riverbank species proper, confined to coastal alluvial substrates and forming the so-called “core” of the riverbank flora, make up 22.2% (24 species) (Tsyrenova and Kasatkina, 2013). According to these authors, ruderal species predominate in the riparian zone in the vicinity of Khabarovsk, easily colonizing disturbed habitats, including riparian margins.

As a result of our research, 16 obligate (48.5%) and 17 facultative (51.5%) species were listed in the riparian flora of the Simmi riverbanks. Thus, the proportion of true riparian species in the studied riparian ecotopes of the reserve significantly exceeds that in the vicinity of populated areas and is not inferior to this ratio in the riparian flora of the entire Lower Amur. As in other Amur riparian floras (Kryukova, 2005; Nechaev and Gapeka, 1970; Tsyrenova, 2022), the families Cyperaceae and Scrophulariaceae dominate taxonomically. The absence of ruderal species in the studied flora is explained by the protected status of the territory. At the same time, near populated areas, their proportion is more than a third of the species composition of the riparian flora of the Amur River (Tsyrenova, 2022).

Geographical analysis showed that the obligate fraction of the riparian flora of the Simmi River is dominated by East Asian species (43.8%), which is a much higher fraction than in the studied Amurian riparian floras (Tsyrenova and Kasatkina, 2013). The remaining species have a wider range – circumpolar (31.3%), tropical (18.8%) and Eurasian-Mediterranean multizonal (6.3%). Only the species *Lindernia procumbens* belongs to the last group.

For the first time in the Bolonsky Reserve, we have assessed the abundance and constancy of species of the riparian flora (Table 1).

It was found that obligate riparian species have a higher occurrence and abundance than facultative species. Four species have the highest constancy in the studied areas of the Simmi River: *Lindernia procumbens*, *Fimbristylis dipsacea*, *F. velata* and *Rorippa palustris*. At the same time, *L. procumbens* has a high abundance throughout the profile. Most of the facultative species have a constancy of I^+, are found in one or two areas along the profile, singly or with a projective cover of less than 5%. There are no species with a high degree of constancy (IV–V) among the facultative species, which once again confirms the high specificity of riparian ecotopes and the adaptive specialization of low-water ephemerals (Fig. 4).

The riparian vegetation of the Simmi River in the vicinity of the Vakhtar Cordon is classified using the Braun-Blanquet method as belonging to the class Isoëto-Nanojuncetea Br.-Bl. et Tx. 1943 (Deil, 2005; Pietsch, 1973). This class includes short-lived communities of alluvial ephemerals that inhabit the floodplains of large rivers in Northern Eurasia. The studied riparian vegetation is of an ephemeral floodplain kind, formed exclusively by densely closed monodominant communities of *Lindernia procumbens*. Similar ephemeral meadows of *Lindernia* are described for the islands in the Ob River bed (Altai Krai) as rare plant communities in need of protection, included in the Green Book of Siberia (Taran, 1996).

In the Bolonsky Reserve, *Lindernia* meadows stretch along the river in a strip 5–30 m wide. Closer to the native bank, tall-grass communities of *Echinochloa caudata, Persicaria lapathifolia,* and *Bidens maximowicziana* are formed, but even here in the lower tier the projective cover of *Lindernia* is no less than 50% (Figs. 5, 6).

The following ecological-cenotic groups of species are distinguished in the composition of the riparian communities of the studied territory: riparian (48.5%), coastal-aquatic (39.4%), aquatic (12.1%), meadow (3.0%).

Data on the density of coenopopulations of 16 species of obligate low-water ephemerals of the banks of the Simmi River are reflected in Table 2.

Table 1. Constancy and abundance indices of riparian species on the water edge–baseline profile. Obligate species are shown in bold. Species activity: base of degree – species constancy, degree index – abundance according to the Braun-Blanquet scale.

	Profile I							Profile II						
Description no.	1	2	3	4	5	6	7	1	2	3	4	5	6	Species activity
Number of species	3	9	11	12	12	15	13	3	11	15	15	12	12	
Distance from the water's edge (m)	3	5	10	12	15	26	32	3	7	10	14	16	19	
Alisma orientale		+												I^{+}
Sagittaria trifolia		+												I^{+}
Artemisia mongolica							+							I^{+}
Bidens maximowicziana							2				+	+		II^{+-2}
Centipeda minima			+		+	+	1			+	1	+	+	IV^{+-1}
Gnaphalium tranzschelii			+	+			+			+	+			II^{+}
Rorippa palustris	r	+	+		1	+	2	+	+	1	+	2	+	V^{r-2}
Callitriche palustris			+						+					I^{+}
Ceratophyllum demersum	r													I^{+}
Carex bohemica					+							+	+	II^{+}
Cyperus orthostachyus				+							+			I^{+}
Cyperus limosus				+		+				+	+		+	II^{+}
Cyperus nipponicus			+	+	+	+			+	+	3	+	+	IV^{+-3}
Eleocharis ovata					+	+			+		+	+	+	III^{+}
Eleocharis ussuriensis				+			+							I^{+}
Fimbristylis dipsacea		+	1	1	1	1	1		+	1	+	2	1	V^{+-2}

	Profile I							Profile II						
Description no.	1	2	3	4	5	6	7	1	2	3	4	5	6	Species activity
Number of species	3	9	11	12	12	15	13	3	11	15	15	12	12	
Distance from the water's edge (m)	3	5	10	12	15	26	32	3	7	10	14	16	19	
Fimbristylis velata		+	+	1	1	1	+		+	+	+	+	1	V^{+-1}
Schoenoplectiella komarovii			+	+						+				II^{+}
Juncus bufonius			+											I^{+}
Juncus virens			+	+		+					+			II^{+}
Nymphoides peltata		r												I^{+}
Echinochloa caudata					+	2	2			+	+	+	1	III^{+-2}
Glyceria triflora				+		+	+		+					II^{+}
Persicaria lapathifolia					+	2	4			+	3	5	5	III^{+-5}
Rumex maritimus						r								I^{+}
Monochoria korsakowii		r												I^{+}
Salix nipponica					1	2	3			2	4	4	3	III^{1-4}
Salix schwerinii						1	1			+	1	1	2	III^{+-2}
Gratiola japonica				+	+				+	+				II^{+}
Limosella aquatica		+				+				+				I^{+}
Lindernia procumbens	3	3	3	3	3	4	1	2	4	5	5	5	1	V^{1-5}
Trapella sinensis									+	+				I^{+}
Trapa japonica									r					I^{+}

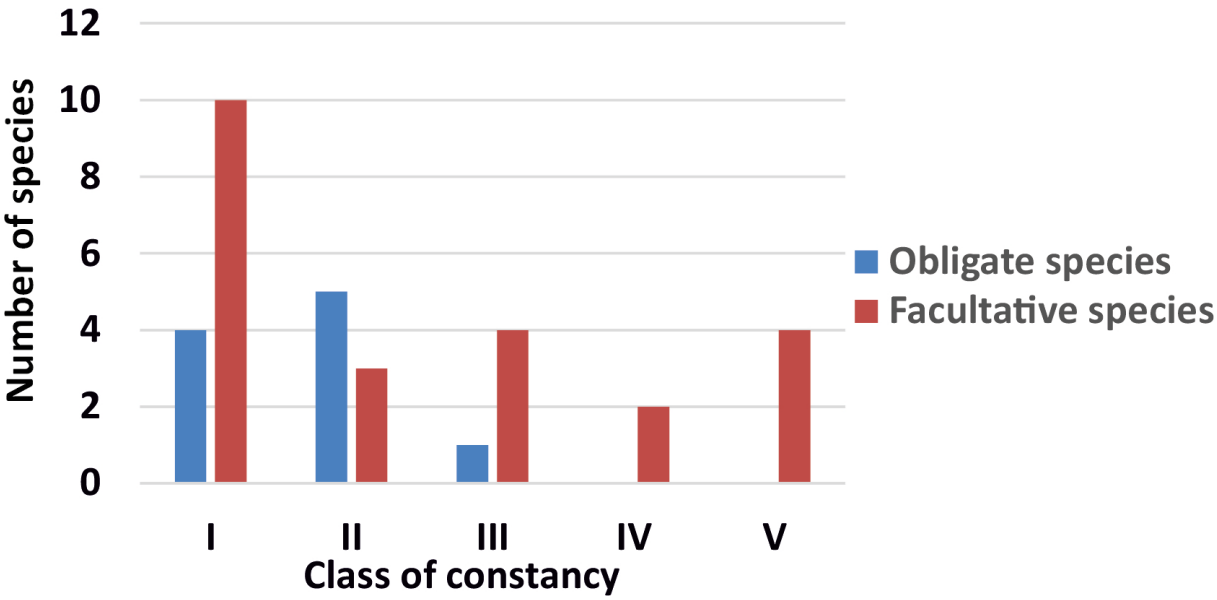

Fig. 4. Constancy of obligate and facultative riparian species of the Bolonsky Nature Reserve.

Fig. 5. *Lindernia procumbens*.

Fig. 6. *Lindernia* community of the Simmi riparian habitat.

Table 2. Population density of obligate low-water ephemerals on the profiles of the riparian habitats of the Simmi River (specimens/m^2).

	Profile I							Profile II						
Description no.	1	2	3	4	5	6	7	1	2	3	4	5	6	Average
Distance from the water's edge (m)	3	5	10	12	15	26	32	3	7	10	14	16	19	
Centipeda minima			1		1	2	45			7	5	4	3	5.2
Gnaphalium tranzschelii			2	1			2			3	2			0.8
Rorippa palustris		4	5		12	1	9		12	25	10	13	4	7.3
Callitriche palustris									12					0.9
Cyperus limosum			1	5						1			1	0.6
Cyperus nipponicus					1	1			7	9	44	31	9	8.0
Eleocharis ovata					2		3		4		2	2	2	1.2
Eleocharis ussuriensis				1										0.08
Fimbristylis dipsacea		13	34	17	6	7	2			1	12	7	11	8.5
Fimbristylis velata		3	14	14	4	7	3			20	2		2	5.3
Schoenoplectiella komarovii			1											0.08
Juncus bufonius		1												0.2
Juncus virens						1					1			0.2
Gratiola japonica									1	1				0.2
Limosella aquatica		2				2				1				0.4
Lindernia procumbens	68	82	78	79	88	178	39	82	238	619	571	308	45	199.7

Profile I shows a clear correlation between the drop in the water level in the river, the formation of new sections of exposed riparian habitat, and the density of the *Lindernia* coenopopulation (Fig. 7). On the fresh riparian habitats that began to be exposed at the end of June (survey plots nos. 5–1), the density of the coenopopulation is half or a third of that on the riparian habitats that formed at the end of April (survey plot no. 6).

The correlation is less pronounced at survey plot no. 7, the furthest from the water's edge (32 m): the lowest density of *Lindernia* is observed here (39 specimens/m^2). This plot is a washout between the native bank and a sandbank formed when the water level in the river drops, so this plot was later not covered by water. Seeds of the main species of coastal meadow communities (*Echinochloa caudata*, *Persicaria lapathifolia*) brought by water also settled here, and willow seeds (*Salix nipponica*, *S. schwerinii*) germinated in May. Compared to other sections of the profile, where stagnant moisture persisted for a long time, the groundwater level dropped faster at survey plot no. 7, so the seeds were able to germinate, and form closed tall-grass communities. *Lindernia procumbens* seeds germinate poorly in low light conditions and do not germinate at all in the dark. In addition, the rapid drop in groundwater levels led to the drying out of the surface layer, which also inhibited the germination of *Lindernia*.

Similar data were obtained on profile II (Fig. 8). At the end of April, a riparian habitat was exposed on survey plot No. 6, and favorable conditions appeared for germination, not only of riparian species, but also dominants of coastal aquatic cenoses, for which the absence of stagnant moisture on the surface of the riparian habitat is important. As on plot No. 7 of profile I, dense tall-grass communities of *Echinochloa*, *Persicaria*, and willows formed here. In addition, the drying of the surface layer of silt inhibited the germination of *Lindernia*, so its density here is low (45 specimens/m^2). On survey plots nos. 5–3, the water level in the Simmi River decreased gradually over 50 days (12.05–28.06), and favorable conditions for the development of riparian ephemerals remained, many of which are capable of germinating and vegetating under a thin layer of water. At these survey plots, the density of *Lindernia* reaches its maximum values: from 308 to 619 specimens/m^2. With a further decrease in the water level at the beginning of July, riparian habitats were exposed at survey plots no. 2 and 1; by mid-August, the density of *Lindernia* there was 238 and 82 specimens/m^2, respectively.

In all the profile survey plots, in mid-August, all *Lindernia* plants were at the flowering and fruiting stage.

Conclusions

For the first time, the floodplain ephemeral flora has been studied in one of the specially protected areas of the Amur River basin. It was found that in 2023, the riparian vegetation of the Simmi River was represented exclusively by densely closed monodominant communities formed by the Eurasian-Mediterranean multizonal species *Lindernia procumbens*. The taxonomic composition of the ephemeral flora included 33 species of vascular plants belonging to 27 genera and 15 families. As in other Amurian riparian floras, the greatest diversity was represented in the families Cyperaceae, Asteraceae and Scrophulariaceae. Specific features of the studied flora were a high proportion of obligate riparian species (48.5%), about half of which have an East Asian range, as well as the absence of ruderal and synanthropic species in its composition.

Data on the density of coenopopulations of 16 species of low-water obligate ephemerals depending on the water level are presented for the first time. An assessment of the abundance and constancy of the flora species of the riparian habitats, on a profile from the water's edge to the main bank, is made. It is established that obligate riparian species have a higher occurrence and abundance than facultative species. The species *Lindernia procumbens*, *Fimbristylis dipsacea*, *F. velata* and *Rorippa palustris* have the highest constancy on the studied sections of the Simmi riverbank.

The obtained data on the state of the ephemeral floodplain flora of the Simmi River in the Bolonsky Nature Reserve can be used to assess natural and anthropogenic changes in the floodplain environment of the Amur River.

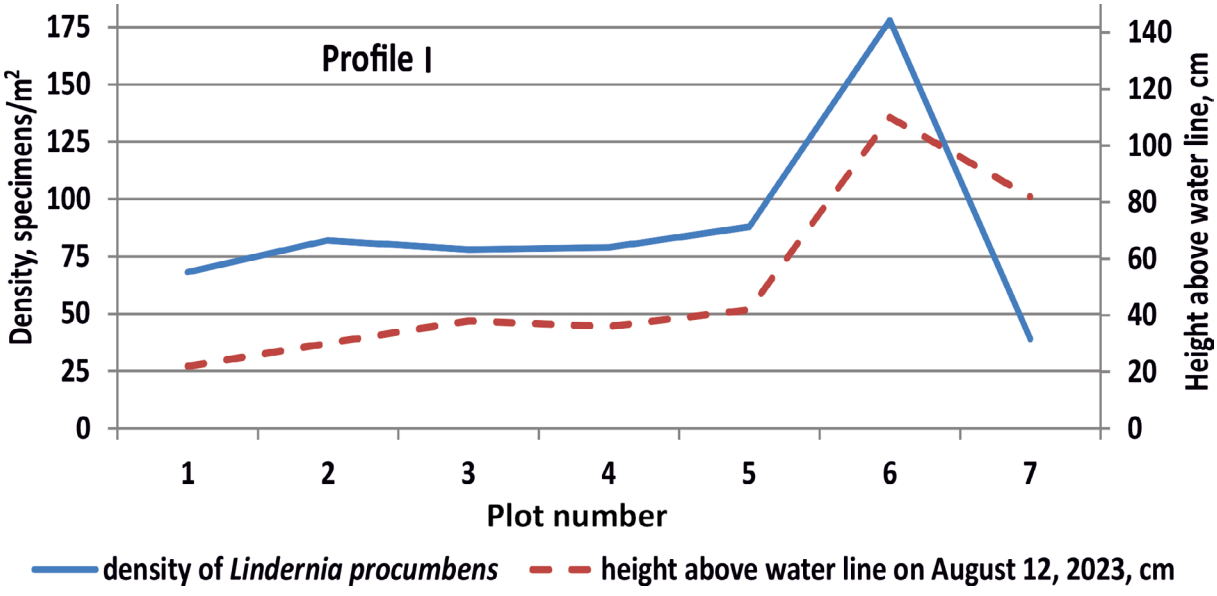

Fig. 7. Density of *Lindernia procumbens* on the survey plots of profile I.

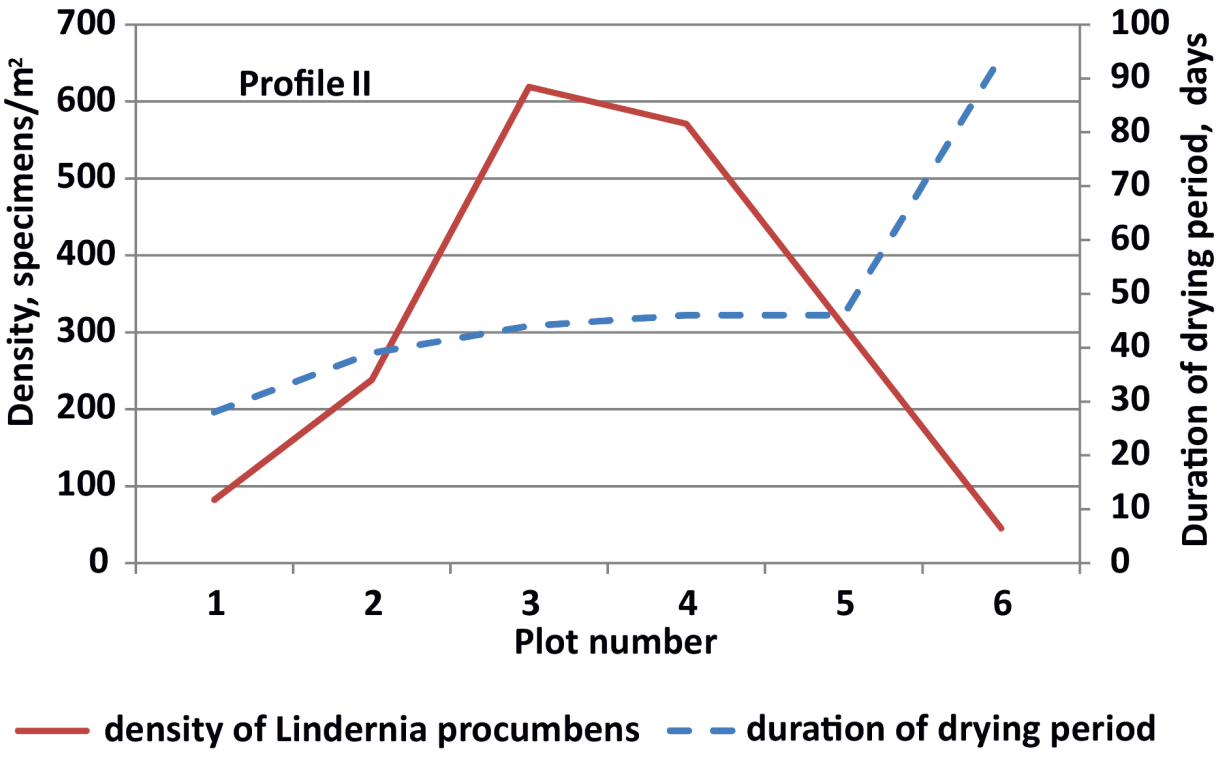

Fig. 8. Density of *Lindernia procumbens* on the survey plots of profile II.

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