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RESEARCH PAPER

Sparganion hyperborei – new alliance in water-bodies of the Arctic and mountainous regions of Eurasia

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ABSTRACT

New associations of aquatic vegetation of the Arctic and mountain regions outside the Arctic, *Sparganietum hyperborei* **ass. nov.** with two variants (*S. h. inops* и *S. h. typica*) and ass. *Warnstorfio exannulatae–Sparganietum hyperborei* **ass. nov.**, are described. Associations assigned to the new alliance *Sparganion hyperborei* **all. nov.** in the class *Littorelletea uniflorae* Br.-Bl. et Tx. ex Westhoff et al. 1946.

Keywords: reservoir vegetation, Arctic, Braun-Blanquet approach, *Littorelletea uniflorae*, *Sparganium hyperboreum*

РЕЗЮМЕ

Тетерюк Б.Ю., Лавриненко О.В., Киприянова Л.М. *Sparganion hyperborei* – новый союз в водоёмах Арктики и горных районов Евразии. Описаны новые ассоциации водной и прибрежно-водной растительности водоёмов Арктики и горных районов вне Арктики: *Sparganietum hyperborei* **ass. nov.** с двумя вариантами (*S. h. inops* и *S. h. typica*) и *Warnstorfio exannulatae–Sparganietum hyperborei* **ass. nov.** Ассоциации отнесены к новому союзу *Sparganion hyperborei* **all. nov.** в классе *Littorelletea uniflorae* Br.-Bl. et Tx. ex Westhoff et al. 1946.

Ключевые слова: растительность водоёмов, Арктика, подход Браун-Бланке, *Littorelletea uniflorae*, *Sparganium hyperboreum*

New relevé data obtained in the study on vegetation of water bodies and streams of the East European and Taimyr tundras, mountainous regions of the Altai, Circumpolar and Polar Urals shaded a light on new peculiarities of syntaxonic structure of the aquatic vegetation (Lavrinenko & Lavrinenko 2018, Chepinoga & Kipriyanova 2020, Lavrinenko & D'yachkova 2021).

After analysis of the accumulated geobotanical material (about 12 500 relevés), we identified a group of relevés with *Sparganium hyperboreum* Laest. ex Beurl. as a community forming species. This is a circumpolar hypoarctic species distributed in the arctic-subarctic and north alpine regions of the Holarctic.

Sparganium hyperboreum is a herbaceous polycarpic long-rooted perennial species of the family Typhaceae with anisotropic mid-rosette shoots and floating leaves. It grows along the shores and on the drying shallow waters of tundra lakes, sometimes occurs in the shallow waters of lowland slow-flowing rivers and streams.

Sparganium hyperboreum usually forms plant communities throughout its distribution range. On the basis of collected material and the analysis of syntaxonic literature (Korotkov et al. 1991, Gogoleva et al. 2017, Matveyeva & Lavrinenko 2021), we have identified new syntaxa of aquatic macrophytes not previously described.

MATERIAL AND METHODS

Study area

Geobotanical studies were conducted in six sites (Fig. 1).

1. Pechora River delta and adjacent tundra localities (islands Lovetskii and Kashin, Cape Bolvanskii Nos) (Nenets Autonomous Area, Russia). According to the botanical and geographical zonation (Aleksandrova et al. 1989), these areas are located in the subarctic floodplain and in the ecotone between the subzones of south tundra and typical tundra. The climate is marine arctic. The mean annual temperature in the 21st century is –2.6°C, the annual precipitation is 450 mm (Malkova et al. 2018).

2. The south-eastern part of the Bolshezemelskaya tundra (Nenets Autonomous Area, Russia). The study area is located in the subzone of south tundra. The Bolshezemelskaya tundra is a hilly accumulative plain with numerous lakes, rivers and streams (Makeyev 2005). Mean annual temperature is −4.9°C. Annual precipitation is 420 mm (Gulinova 1986).

3. The Polar Urals (Komi Republic, Russia). The study area is located in the subzone of south tundra. The landforms are of different geomorphology. Mid-mountain groups of subalpine type dominate in relief (Gladkova 1977). The climate is cold subarctic (Alisov 1956). Mean

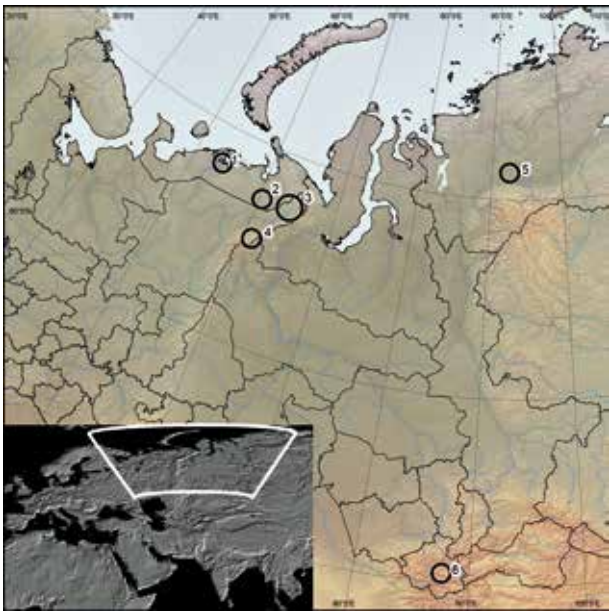


Figure 1 Study sites: 1 – Pechora River delta and adjacent tundra localities; 2 – The south-eastern part of the Bolshezemelskaya tundra; 3–The Polar Ural; 4 – The Subpolar Ural; 5 – The Dudypta River basin, Taimyr Peninsula; 6 – The Mountain Altai

annual temperature ranges from −7 to −6ºC. Annual precipitation is 900–1000 mm (Bratsev & Bratsev 1997).

4. The Subpolar Urals (Komi Republic, Russia). We surveyed vegetation of the north taiga area (Aleksandrova et al. 1989). The landforms are of mid-mountain type (Gladkova 1977). The climate is atlantic-arctic (Alisov 1956). Mean annual temperature is −5 ºC. Annual precipitation is 800–900 mm (Bratsev & Bratsev 1997).

5. The Dudypta River basin, Taimyr Peninsula (Taimyrskii Dolgano-Nenetskii district, Krasnoyarsk Territory, Russia). At the latitude 71°13'N, flat south tundra areas cover the central part of the Taimyr Peninsula. The landforms are mainly denudation landscapes with a dense network of river valleys. The climate is sharply continental. Mean annual temperature is −12ºC. Annual precipitation is 350 mm (Alisov 1956).

6. The Mountain Altai (Ulagan District, Republic of Altai, Russia). The study area in the Mountain Altai morphologically is a plateau, deeply dissected by river erosion. The climate is sharply continental with mean annual temperature –3.7ºC and annual precipitation 271 mm. Larch forests are common in this study area (Kuminova 1960). The studied water-bodies are located in the mid (1925 m a.s.l.) and high (2150 m a.s.l.) mountain areas with mountain forest and mountain tundra vegetation.

Sampling and measurements

We made 32 relevés of plant communities dominated by *Sparganium hyperboreum*. The relevés were made during summer seasons of 2010–2021.

The material was collected and analyzed according to the Braun-Blanquet's phytosociological approach (Westhoff & van der Maarel 1973) in view of the methodical recommendations for the study of the aquatic vegetation (Katanskaya 1981).

The size of relevés varied from 10 to 100 m^2. Small plant communities (but not less than 10 m^2) were described within their natural limits. The cover of each species in a plant community was assessed by the old Braun-Blanquet's scale (Becking 1957): "r" – extremely rare; "+" – rare with low cover; "1" – cover up to 5 %; "2" – 5–25 %; "3" – 25–50 %; "4" – 50–75 %; "5" – 75–100 %. The table contains median values of the species abundance. The species constancy is given in frequency categories from I to V: I – 0–20 %, II – 21–40 %, III – 41–60 %, IV – 61–80 %, V – 81–100 %.

The geobotanical data were processed using the integrated botanical information system IBIS 7.2 (Zverev 2007) and Juice 7.1 (Tichý 2002).

The names of vascular plant taxa are given in accordance with Cherepanov (1995), and the names of mosses – with Ignatov et al. (2006). New syntaxonomic units are named according to the 'International Code of Phytosociological Nomenclature. 4th edition' (ICPN) (Theurillat et al. 2021). The nomenclature of higher vegetation units corresponds to 'Vegetation of Europe…' (Mucina et al. 2016).

The chemical analysis of water samples was performed at the Institute of Biology, Komi SC UB RAS (Syktyvkar) and in the Institute for Water and Environmental Problems SB RAS (Barnaul).

RESULTS

Characteristics of syntaxa

The relevés with *Sparganium hyperboreum* are well separated into two blocks with different floristic and ecological features. So, we can classify them as two syntaxonomic units of association rank (Table 1).

***Sparganietum hyperborei* Teteryuk, Lavrinenko et Kipriyanova ass. nov. (Table 1, relevés 1–25; Figs 2A–C) –** the northern bur-reed communities with submerged hydrophytes

Synonyms: *Sparganium hyperboreum*–typ (Påhlsson 1994) (ICPN Art. 3c); *Sparganietum hyperborei subpurum* (Neshataeva et al. 2017) (ICPN Arts. 3d, 3i).

Diagnostic species: *Sparganium hyperboreum* (dom.).

Holotypus: Table 1: relevé 22 (author's number – T11-251), Komi Republic, the Vorkuta District, outskirts of Vorkuta town, river Vorkuta, stretch, shore-line shallow water, 67°31'54.9"N 64°01'58.0"E, 10.08.2011, author – B.Yu. Teteryuk.

Composition. The association comprises 25 mainly hydrophilous species, including 4 moss species and 2 species of *Chara* algae. About 60 % of the species composition are fully submerged plants.

The association includes species-poor communities. The only dominant species is *Sparganium hyperboreum* (median abundance value – 4). The species number ranges from 1 to 5, and, in very rare cases, there may be more species (rel. 24). The floristic composition of the association is not stable. Only 1 of 25 species has the constancy II. It is *Hippuris vulgaris*, growing in a wide range of the ecological conditions. Other species of the association cenoflora have the constancy I.

According to the floristic features there are two variants of the association. Variant *typica* (rel. 15–25; Fig. 2C) contains

Table 1. Associations *Sparganietum hyperborei* **ass. nov.** and *Warnstorfio exannulatae–Sparganietum hyperborei* **ass. nov.**

Association	***Sparganietum hyperborei* (1)**																										***Warnstorfio exannulatae–Sparganietum hyperborei* (2)**							Constancy and abundance			
Variant	***inops* (1a)**															***typica* (1b)**																					
Relevé area, m²	25	16	25	10	25	25	10	10	10	10	10	100	32	25	12	10	16	20	10	10	10	10	25	10	10	10	10	10	10	10	10					
Water depth, cm	70	10	70	30	50	15	100	40	50	50	50	30	90	120	160	40	0	25	40	50	50	60	20	0	50	90	40	100	60	40	80	60				
Bottom	sa	sa	c-p	c-p	p	p	sa	s	c	c-si	c	si	s-si	si	sa	si	c	si	si	si	c	sa-si	c-si	si	si	c	p	p	p	p	p	p	p				
Cover, total, %	50	50	40	40	70	60	60	60	60	60	80	80	80	80	55	40	80	70	80	60	80	90	95	60	90	60	90	40	70	50	60	70				
Herbs	50	50	40	40	70	60	60	60	60	60	80	80	80	80	55	40	80	70	80	60	80	90	95	60	90	15	10	40	70	50	60	35				
Mosses	0	0	0	0	0	+	0	0	+	0	0	0	+	0	0	0	+	0	0	0	0	0	0	+	0	60	90	10	15	10	10	50				
Number of taxa	1	1	2	2	1	3	1	1	2	2	2	4	3	1	5	3	5	3	2	4	3	5	4	8	4	3	2	2	4	4	5	3				
Relevé number author's	L31-20	L40-20	T10-169	T11-138	Ta67-21	Kash1-20	T11-254	T10-186	T12-271	T10-214	BN9-20	20-29	20-32	DP20-20	21-91	T10-222	BN17-20	L48-20	T04-274	T10-224	T11-253	T11-251	BN20-20	BN13-20	T15-Ha32	T10-203	T15-Ya14	T10-054l	T15-Ha27	T11-101	T11-102	T10-199				
table	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22*	23	24	25	26	27	28	29*	30	31	32	1a	1b	1	2
Diagnostic species of the *Sparganietum hyperborei* and the *Warnstorfio exannulatae–Sparganietum hyperborei*																																				
Sparganium hyperboreum	3	3	3	3	4	4	4	4	4	4	4	5	5	5	4	3	4	4	5	3	4	5	4	3	4	2	2	3	4	3	3	3	V[4]	V[4]	V[4]	V[3]
Diagnostic species of the variant *S. h. typica*																																				
Myriophyllum sibiricum	·	·	·	·	·	·	·	·	·	·	·	·	·	·	+	1	2	2	5	·	·	·	·	·	·	·	·	·	·	·	·	·	·	III[2]	I[2]	·
Potamogeton alpinus	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	1	2	2	·	·	·	·	·	·	·	·	·	·	·	II[2]	I[2]	·
Myriophyllum verticillatum	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	2	2	·	·	·	·	·	·	·	·	·	I[2]	I[2]	·
Potamogeton berchtoldii	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	+	2	·	·	·	·	·	·	·	·	I[1]	I[1]	·
Diagnostic species of the *Warnstorfio exannulatae–Sparganietum hyperborei*																																				
Warnstorfia exannulata	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	+	·	4	5	2	2	2	2	3	·	I[+]	I[+]	V[3]
Constant species of syntaxa																																				
Hippuris vulgaris	·	·	·	·	·	·	·	·	·	·	1	+	·	·	·	·	+	2	·	2	·	·	r	·	1	1	·	·	+	2	2	2	I[1]	III[1]	II[1]	IV[2]
iagnostic species of the class *Potamogetonetea*																																				
Callitriche palustris	·	·	·	·	·	·	·	·	·	+	·	·	·	·	·	·	·	·	·	·	+	+	·	·	·	·	·	·	·	·	+	·	I[+]	I[+]	I[+]	I[+]
Potamogeton perfoliatus	·	·	·	+	·	·	·	·	·	·	·	·	·	·	+	·	·	·	·	·	·	·	·	+	·	·	·	·	·	·	·	·	I[+]	I[+]	I[+]	·
Batrachium mongolicum	·	·	·	·	·	·	·	·	·	·	+	+	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	I[+]	·	I[+]	·
B. trichophyllum s. l.	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	1	·	·	·	r	·	·	·	·	·	·	·	·	·	I[+]	I[+]	·
Other species																																				
Lemna trisulca	·	·	2	·	·	·	·	·	·	·	·	·	·	·	·	·	+	·	·	·	·	·	·	1	·	·	·	·	·	·	·	·	I[2]	I[1]	I[1]	·
Utricularia vulgaris	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	1	1	·	·	·	·	II[1]

Note. Taxa found in 1 relevé with an abundance of + (others are indicated in brackets): *Batrachium confervoides* 16, *Calliergon giganteum* 17, *C. megalophyllum* 24, *Carex aquatilis* 25, *Chara* sp. 15 (2), *C. vulgaris* 22, *Equisetum fluviatile* 22 (2), *Potamogeton friesii* 29, *P. praelongus* 15, *P. sibiricus* 23, *Sparganium emersum* f. *fluitans* 12, *Sphagnum platyphyllum* 6, *S. riparium* 9, *Warnstorfia trichophylla* 6.

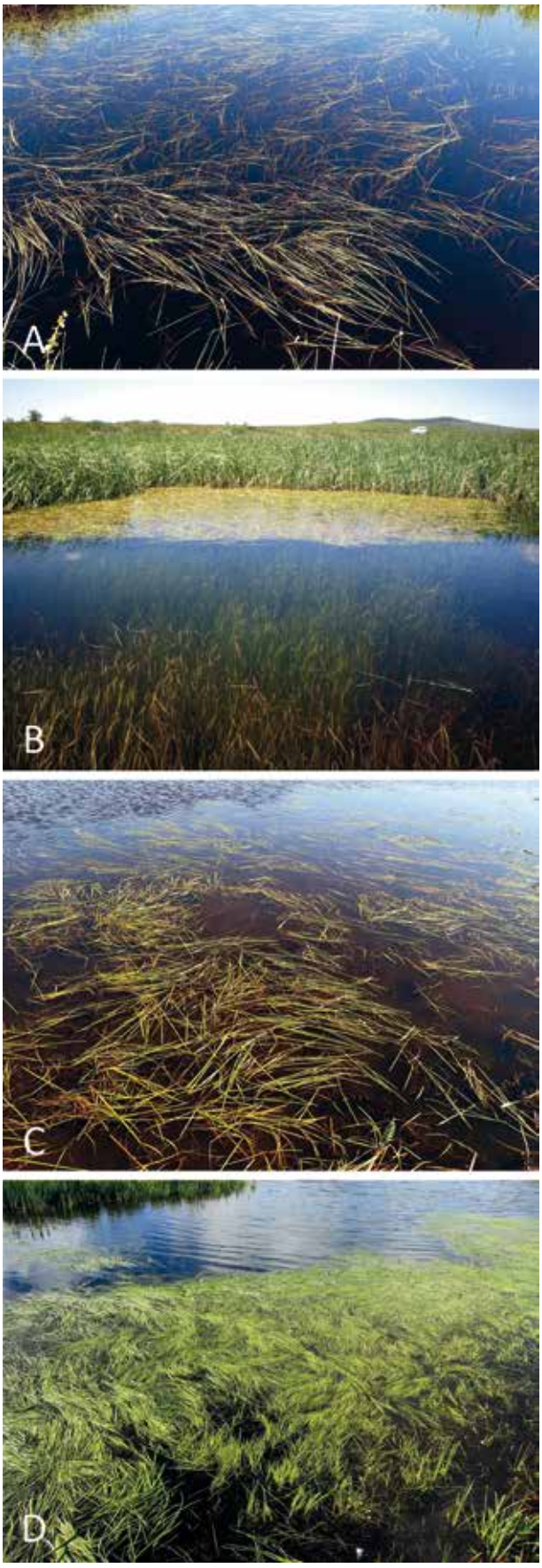
Location of communities (GPS coordinates WGS 84, N, E), date and authors of relevés:

Nenets Autonomous Area: author – O.V. Lavrinenko (Fig. 1, site 1): 1 – Pechora Bay, Lovetskii Island, nameless tundra lake, 05.08.2020, 68°21'24.0"N 53°57'42.1"E; **2** – ibid, nameless tundra lake, shallow water along the edge of the lake, 68°19'28.2"N 53°54'12.4"E, 10.08.2020; **18** – ibid, nameless tundra lake, 68°21'12.8"N 53°58'33.4"E, 13.08.2020; **6** –Korovinskaya Bay, Kashin Island, nameless tundra lake, shallow water along the edge, 68°14'48.4"N 53°52'55.7"E, 07.08.2020; **11** – right bank of the river Pechora at the mouth, Bolvanskii Nos Cape, nameless tundra lake, nearshore shallow water, 68°17'01.5"N 54°30'20.7"E, 27.07.2020; **17** – ibid, dry lake behind the nearshore pebble shaft, 68°16'15.9"N 54°26'02.2"E, 28.07.2020; **23** – ibid, dried up lake, 68°16'08.0"N 54°25'50.9", 28.07.2020; **24** – ibid, nameless tundra lake, nearshore shallow water, 68°16'18.4"N 54°26'17.9"E, 28.07.2020; **14** – lower course in the delta of the river Pechora, dead-end channel flowing into Kozlyukov Shar, 68°13'50.2"N 53°48'04.0"E, 08.08.2020; **author – B.Yu. Teteryuk (Fig. 1, site 2): 25** – the valley of the lake Variato, thermokarst lake, swampy shallow water, 67°38'44.0"N 60°27'42.1"E, 26.06.2015; **27** – ibid, 67°40'12.7"N 60°27'19.9"E, 25.06.2015; **29** – ibid, vicinity of the shift camp Khasyrei, thermokarst subsidence near the roadway, swampy shallow water, 67°39'00.3"N 60°31'04.2"E, 26.06.2015; **Komi Republic: author – B.Yu. Teteryuk (Fig. 1, site 3): 3** – Vorkuta district, lake Bolshoi Kharbei, nearshore shallow water, 67°31'54.4"N 62°54'15.5"E, 05.08.2010; **7** – ibid, outskirts of the Vorkuta town, river Vorkuta, slow flow, 67°29'36.6"N 64°03'00.4"E, 10.08.2011; **8** – ibid, valley of the lake Bolshoi Kharbei, thermokarst lake, open shallow water, 67°35'07.2"N 62°57'29.3"E 06.08.2010; **21** – ibid, river Vorkuta, stretch, shore-line shallow water, 67°31'05.9"N 64°01'41.2"N, 10.08.2011; **22** – ibid, 67°31'54.9"N E64°01'58.0"E, 10.08.2011; **10** – Vorkuta district, thermokarst lake in the valley of the river Niya-yu, open shallow water, 67°26'22.3"N 65°05'37.4"E, 13.08.2010; **16** – ibid, swampy shallow water, 67°26'41.6"N 65°06'09.5"E, 14.08.2010; **20** – ibid, 67°27'09.4"N 65°04'31.9"E, 14.08.2010; **26** – ibid, 67°27'30.4"N 65°03'49.7"E, 13.08.2010.; **32** – ibid, thermokarst lake, open shallow water, 67°26'52.2"N 65°06'28.6"E, 06.08.2010; **19** – Vorkuta district, vicinity of the village Sovetskii, roadside ditch, overgrowing shallow water, 67°29'41.5"N 64°12'11.4E, 04.08.2004; **author – B.Yu. Teteryuk (Fig. 1, site 4): 4** – Inta district, National Park "Yugyd-Va", mountain-valley lake Vodety, shallow peaty water, 65°25'41.2"N 60°49'01.7"E, 31.07.2011; **9** – ibid, vicinity of the base "Zhelannoe", mountain-valley lake, swampy shallow water, 67°13'14.0"N 60°17'46.2"E, 27.07. 2012; **30** – ibid, mountain-valley swampy lake Maloe Tavrotaty, open shallow water, 65°29'28.8"N 60°38'09.9"E, 26.07.2011; **31** – ibid, 65°29'25.9"N 60°38'12.2"E, 26.07.2011; **28** – Inta district, "Lemvinskii" reserve, mountain-valley lake, nearshore shallow water, 65°23'52.6"N 61°07'57.2"E, 31.07.2010**; Krasnoyarsk Territory: author – O.V. Lavrinenko (Fig. 1, site 5): 5** – Taimyrskii Dolgano-Nenetskii district of the, Taimyr Peninsula, river Dudypta at the confluence of the river Bataika (5 km downstream Ust-Avam village), a small lake in the tundra-marsh complex, 02.08.2021, 71°13'31.9"N 92°38'50.4"E; **Republic of Altai: author – L.M. Kipriyanova (Fig. 1, site 6): 12** – Ulaganskii district, small waterbody No. 1 in the Chibitka river system, 50°27'19.5"N 87°39'39.4"E, 2150 m a.s.l. (alpine belt, tundra), 18.07.2020; **13** – ibid, small waterbody No. 2 of the Chibitka river system, 50°27'14.7"N 87°39'48.7"E, 2150 m a.s.l. (alpine belt, tundra), 18.07.2020; **15** – ibid, lake Igistukel, nearshore shallow water, 50°30'54.5"N 87°40'33.2"N, 1925 m a.s.l. m. (forest belt), 24.08.2021.

* – nomenclatural types (**holotypus**): ass. ***Sparganietum hyperborei*** – relevé 22 (author's number – T11-251), Komi Republic, Vorkuta district, outskirts of Vorkuta town, river Vorkuta, stretch, shore-line shallow water, 67°31'54.9"N 64°01'58.0"E, 10.08.2011, author – Teteryuk B.Yu; ass. ***Warnstorfio exannulatae–Sparganietum hyperborei*** – relevé 29 (author's number – T15-Xa27), Nenets Autonomous Area, vicinity of the shift camp Khasyrei, thermokarst subsidence near the roadway, swampy shallow water, 67°39'00.3"N, 60°31'04.2"E, 26.06.2015, author – Teteruk B.Yu.

Dark grey shading indicates the absence of diagnostic species of the ***Sparganietum hyperborei*** association in the depleted variant.

Abbreviations. Substrate: c – clay, si – silt, s – stones, sa – sand, p – peat, s-si – stones with silt deposits, c-si – clay with silt, c-p – clay with peat deposits, sa-si – sand with silt.



communities with well-represented submerged rooted hydrophytes, forming the diagnostic group of the variant: *Myriophyllum sibiricum*, *M. verticillatum*, *Potamogeton alpinus* and *P. berchtoldii*. The species number in the communities ranges from 2 to 8, total species number in the variant – 20. Variant *inops* (rel. 1–14; Fig. 2A–B) has a poor species composition (1–4 species per community, total species number in the variant – 10) and has no diagnostic species of the var. *typica*.

Structure. The diversity of the spatial structure of the association's communities is determined by their species composition. For instance, in the communities of var. *inops* there is only 1 vertical layer formed by plants with leaves floating on the surface of the water. Its cover is 40–80 %. This layer is formed by a single association species – *Sparganium hyperboreum*.

The communities of the var. *typica* have two vertical layers. While the total cover is 40–95 %, the portion of the first layer, formed by *Sparganium hyperboreum*, is 30–90 %. Rooting hydrophytes form the second vertical layer of submerged plants (*Myriophyllum sibiricum*, *M. verticillatum*, *Potamogeton alpinus*, *P. perfoliatus* etc.) with the cover 20–80 %.

Hippuris vulgaris is in the first layer. When the water level is stable, this subterranean-stolon polycarpic species is slightly elevated above the water surface. When the water level drops, it lodges on the water surface and behaves similarly to the shoots of *Sparganium hyperboreum*. Both species form anisotropic shoots, when the ecotope is completely and permanently dry.

Helophytes (*Equisetum fluviatile* and *Carex aquatilis*), growing in several plant communities of the association, do not form a separate layer. Their cover is less than 5 %.

The shape of the communities of all subordinated syntaxa of the association depends on the size and flow pattern of the water-bodies. At coastal shallow waters of large tundra lakes, the communities usually have a broad ribbon shape, following the contours of the water areas embedded in the shoreline. These are often broadly contoured thickets in wind-sheltered lake lagoons and river channels. The community size varies from several square meters to hectares (the Lakes Variato and Bolshoi Kharbei in the Bolshezemelskaya tundra).

Ecology. Plant communities of both variants usually occur at the shallow sheltered areas of water bodies with stagnant or low flowing water. The grounds are different, often mineral (clay, sand), with silt deposits. The plants from this association can grow on stony substrates with sufficient accumulation of silt sediments.

By chemical compositions, the water the communities prefer is mainly calcium-hydrocarbonate (less frequently calcium chloride and sodium-hydrocarbonate). In the Bolshezemelskaya tundra, its mineralization is 0.68–1.50 mg/l, in the Altai – 10.0–30.0 mg/l.

The optimal depths of the communities of all subsyntaxa are 40–60 cm, with a maximum depth of 160 cm. The phytocenoses can exist for a short time in dried-out habitats (rel. 17 and 24).

Distribution. Communities of this association were reported from the East European and Central Siberian sectors of the Arctic and Altai Mountains. In the European North, its distribution range covers plain inland tundra and mountain areas of the sub-Polar and Polar Urals.

Figure 2 Community of: A – *Sparganietum hyperborei* var. *inops* on Taimyr Peninsula; Table 1, rel. 5 (Ta67-21); photo by O.V. Lavrinenko); B – *Sparganietum hyperborei* var. *inops* in Republic of Altai; Table 1, rel. 13 (20-32), photo by L.M. Kipriyanova; C – *Sparganietum hyperborei* var. *typica* with *Myriophyllum verticillatum* on Bolvanskiy Nos Cape, Bolshezemelskaya tundra; Table 1, rel. 23 (BN20-20); photo by O.V. Lavrinenko; D – *Warnstorfio exannulatae–Sparganietum hyperborei* on Kolguev Island; photo by O.V. Lavrinenko

Communities of *Sparganium hyperboreum* are found in lakes and thermokarst depressions of Iceland and Scandinavia (Påhlsson 1994, Dierßen 1996), on the Islands Kolguev, Dolgii and Vaigach (Lavrinenko et al. 2016), and in lakes of Kamchatka (Neshataev et al. 2017).

The distribution range of *Sparganium hyperboreum* (Sekretareva 2004; Panarctic Flora [website]) suggests that it is one of the most common associations in water-bodies of the Arctic and Holarctic mountain-tundra belt.

***Warnstorfio exannulatae–Sparganietum hyperborei* Teteryuk, Lavrinenko et Kipriyanova ass. nov. (Table, rel. 26–32; Fig. 2D)** – the northern bur-reed communities with hypnum mosses (*Warnstorfia exannulata*)

Diagnostic species: *Warnstorfia exannulata* (dom., codom.) and *Sparganium hyperboreum* (dom., codom.).

Holotypus: Table 1, relevé 29 (author's number – T15-Xa27), Nenets Autonomous Area, vicinity of the shift camp Khasyrei, thermokarst subsidence near the roadway, swampy shallow water, 67°39'00.3"N 60°31'04.2"E, 26.06.2015, B.Yu. Teteryuk.

Composition. The association unites plant communities with *Sparganium hyperboreum* and the hydrophilic moss *Warnstorfia exannulata*. Phytocenoses are species-poor (2–5 species), total number of species in the association is 6. *Hippuris vulgaris* is the most constant species. In the taiga zone, *Utricularia vulgaris* occurs in communities (rel. 30–31).

Structure. Plant communities of the association have a 2-layer structure and the total cover 40–90 %. The first layer (cover 10–70 %) is mostly formed by *Sparganium hyperboreum*. Sometimes, *Hippuris vulgaris* is abundant. The second submerged plant layer with cover 10–60 % (up to 90 %) is formed by *Warnstorfia exannulata*. The communities usually occupy the entire space of water body in thermokarst subsidences, small thermokarst and floodplain lakes.

Ecology. The communities of this association are found in sheltered ecotopes of small shallow oligo- and oligo-mesotrophic water-bodies and swampy lakes predominantly with peat substrates. They appear to be the final stage of autogenic succession of communities of the ass. *Sparganietum hyperborei* accompanied by *Warnstorfia exannulata*.

Distribution. The association is recorded from the East European sector of the Arctic (the Bolshezemelskaya tundra and mountain areas of the Subpolar and Polar Urals). Probbaly, such communities occur also in the water-bodies of the Arctic and in the mountain-tundras in the Holarctic throughout the shared range of *Sparganium hyperboreum* and *Warnstorfia exannulata*.

DISCUSSION

Higher units of the aquatic vegetation

The communities of the associations described are formed in periodically drying coastal shallow waters of nutrient-poor water pools between high and low water lines on the organo-mineral to mineral substrates.

Such communities belong to the class *Littorelletea uniflorae* Br.-Bl. et Tx. ex Westhoff et al. 1946 and the order *Littorelletalia uniflorae* Koch ex Tx. 1937 (Tüxen 1937, Braun-Blanquet 1949, Oberdoffer 1957, Dierßen 1996, Pingitore et al. 2013, Mucina et al. 2016).

The syntaxonic structure of the *Littorelletea uniflorae* is very complex and houses vegetation of oligotrophic glacial lakes and shallow mesotrophic waters of dystrophic peaty water pools (Pietsch 1995, Mucina et al. 2016).

According to the up-to-date compedium 'Vegetation of Europe' (Mucina et al. 2016), the class *Littorelletea uniflorae* comprises one order that includes eight alliances.

The communities of the class *Littorelletea uniflorae* dominated by species of the genus *Sparganium* (*S. minimi*, *S. angustifolium*) on organic to mineral substrates of nutrient-poor water pools belong to the alliance *Littorellion uniflorae* Koch ex Klika 1935 or the alliance *Sphagno–Utricularion* Müller et Görs 1960 (Tüxen 1937, Braun-Blanquet 1949, Oberdoffer 1957, Dierßen 1996, Chytrý et al. 2011). Sometimes, bur-reed communities of nutrient-poor water pools are placed into the class *Potamogetonetea* (Molenaar 1976, Chepinoga et al. 2013).

Multiple syntaxonomical decisions are known for species-poor aquatic communities worldwide.

In 1996, K. Dierßen described communities dominated by *Sparganium hyperboreum* with participation of *Utricularia* sp. from North Europe as *Sparganium hyperboreum* Gesellschaft. He included them into the alliance *Sphagno–Utricularion* T. Müller et Görs 1960 and the class *Littorelletea uniflorae*. According to the authors of the alliance T. Müller and S. Görs (1960), the alliance *Sphagno–Utricularion* unites vegetation dominated by *Utricularia minor* L. and *Utricularia intermedia* Hayne and by species of *Sphagnum* in oligotrophic and dystrophic peaty water pools. This definition of the alliance was thereafter described in the monograph by Mucina and co-authors (2016).

In the communities of the *Warnstorfio exannulatae–Sparganietum hyperborei* described in this study, the hypnum water moss *Warnstorfia exannulata* co-dominates. In 1998, Szańkowski described the ass. *Warnstorfietum exannulatae* Szańkowski 1998 n. n. [Art. 2b]. He included it into the alliance *Sphagno–Utricularion* (Matuszkiewicz 2008).

There are no *Utricularia minor* and *Utricularia intermedia* (diagnostic species (d. s.) of *Sphagno–Utricularion*) in the communities of associations described here. Peat-moss (*Sphagnum* spp. (also d. s. of *Sphagno–Utricularion*)) has a very low frequency and cover (Table 1). *Warnstorfia exannulata* tends to occur in more mesotrophic environmental conditions compared with the conditions of this alliance (Szańkowski & Kłosowski 2004) and is not a diagnostic species of *Sphagno–Utricularion*.

These peculiarities do not allow to include the *Sparganietum hyperborei* and *Warnstorfio exannulatae–Sparganietum hyperborei* into the alliance *Sphagno–Utricularion*.

According to L. Mucina with co-authors (2016), the alliance *Littorellion uniflorae* unites communities of low-growing amphibious plants in fluctuating shallow oligo-mesotrophic waters. The communities of the alliance are widely distributed in temperate and boreal zones of Eurasia.

The *Littorellion uniflorae* includes taxa characteristic apparently of the transitional zone between land and water, such as *Alopecurus aequalis*, *Eleocharis acicularis*, *Juncus bulbosus*, *Littorella uniflora*, *Ranunculus reptans* (Den Hartog & Segal 1964, de Molenaar 1976).

The absence of diagnostic species of the *Littorellion uniflorae* in the communities of the associations described in this study does not allow to consider the *Sparganietum hyperborei* and *Warnstorfio exannulatae–Sparganietum hyperborei* within the alliance *Littorellion uniflorae*.

Therefore, we propose a new alliance for two associations we have described.

***Sparganion hyperborei* Teteryuk, Lavrinenko et Kipriyanova all. nov.**

Name-giving taxon: *Sparganium hyperboreum* Laest. ex Beurl.

Holotypus: ass. *Sparganietum hyperborei* **ass. nov.** (Table 1, rel. 1–25).

Diagnostic taxa: *Sparganium hyperboreum*, *Sparganium angustifolium*, *Hippuris vulgaris*, *Warnstorfia exannulata*.

Vegetation is dominated by amphibious helophytic plants in shallow oligotrophic to oligo-mesotrophic, sometimes dystrophic waters, in shallow water of quiet bights along the shore of slowly flowing rivers; with a considerably fluctuating water level; between high and low water lines; on sandy, clay, stony, dygyttja, amorphous peaty substrates; mineral substrates commonly covered by thin dygyttja layer; in boreal to low-arctic areas and mountain-tundra belt of the Holarctic.

Other previously described associations may also be included into this alliance.

So, in 1976 J.G. de Molenaar described communities dominated by *Sparganium angustifolium* in the Angmagssalik District, Southeast Greenland (P. 31–34; Table I, rel. 3–5 on P. 34). He affiliated these communities to the ass. *Callitricho–Sparganietum angustifolii* Br.-Bl. 1919 (de Molenaar 1976). The floristic composition (besides *Sparganium angustifolium*), physiognomy and habitat of these communities are very similar to those we have described. We think that these communities can be characterized as an autonomous association such as *Warnstorfio exannulatae–Sparganietum angustifolii* ass. prov. We also suggest to include the association *Lemno trisulcae–Sparganietum graminei* Chepinoga, Bergmeier, Rosbakh et Fleckenstein 2013 into the alliance *Sparganion hyperborei*.

Syntaxonomic position of new syntaxa

Class *Littorelletea uniflorae* Br.-Bl. et Tx. ex Westhoff et al. 1946

Order *Littorelletalia uniflorae* Koch ex Tx. 1937

Alliance *Sparganion hyperborei* Teteryuk, Lavrinenko et Kipriyanova **all. nov. hoc loco**

Association *Sparganietum hyperborei* Teteryuk, Lavrinenko et Kipriyanova **ass. nov. hoc loco**
Variant *inops*
Variant *typica*

Association *Warnstorfio exannulatae–Sparganietum hyperborei* Teteryuk, Lavrinenko et Kipriyanova **ass. nov. hoc loco**

CONCLUSION

Communities of the circumpolar hypoarctic species *Sparganium hyperboreum* are among the most common and widespread in water bodies in the temperate Arctic and the mountain tundra belt of the Holarctic. However, until now, its communities have not been described in accordance to the Braun-Blanquet's approach. This paper fills this gap. Communities of the association *Sparganietum hyperborei* (monospecies thickets – var. *inops* or with the participation of other rooting macrophytes – var. *typica*) are formed in coastal water areas and shallow water bodies on mineral (clay, sand) grounds, with silt deposits. Communities of the *Warnstorfio exannulatae–Sparganietum hyperborei* occupy thermokarst lakes and small shallow oligo- and oligo-mesotrophic water-bodies predominantly with peaty substrates. The new alliance *Sparganion hyperborei* in the class *Littorelletea uniflorae* unites communities of amphibious helophytic plants in shallow oligotrophic to oligo-mesotrophic, sometimes dystrophic waters with fluctuating water level. As the geography of research expands, the list of diagnostic species of the alliance can be enriched.

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