TO THE BRYOPHYTE FLORA OF COMMUNITIES OF STEPPE AND STEPPE SCRUBS IN THE BASHKIR CIS-URALS (THE SOUTHERN URALS REGION)

К БРИОФЛОРЕ СООБЩЕСТВ СТЕПНЫХ КУСТАРНИКОВ И СТЕПЕЙ БАШКИРСКОГО ПРЕДУРАЛЬЯ (ЮЖНО-УРАЛЬСКИЙ РЕГИОН)

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Abstract

57 bryophyte species (3 liverworts and 54 mosses) are revealed within communities of steppe scrubs and steppes in the Bashkir Cis-Urals (the Republic of Bashkortostan). The list of species annotated with occurrences in the steppe shrublands, meadow steppes, genuine dry steppes and stony (petrophytic) steppes is provided. Results of the ecological analysis of bryophyte flora are discussed.

KEYWORDS: mosses, hepatics, steppe, Ural Mts., rare species

INTRODUCTION

Steppes have a high economical and conservational value around the world and are recognized as vulnerable ecosystems dramatically degraded due to the human impact during the last centuries (Smelansky & Tishkov, 2012; Hurka et al., 2019). Steppes of the Bashkir Cis-Urals are no exception. The agricultural development of the territory is very high. The overgrazing, recreation and other adverse environmental impacts led to fragmentation of steppe communities which remained mostly in habitats unsuitable for plowing (Yamalov et al., 2012).

Despite this, the steppe vegetation of the Bashkir Cis-Urals is characterized by high diversity. It depends on several regional factors: complex topography, numerous sandstone and lime outcrops, and unique geographic position between Europe and Asia. According to a European system of floristic classification of vegetation (Mucina et al., 2016), the steppe shrublands of the Bashkir Cis-Urals belong to the alliance Prunion fruticosae Tx. 1952 (the order Prunetalia spinosae Tx.1952, the class Crataego-Prunetea Tx. 1962), whereas grass communities are included in the orders Brachypodietalia pinnati Korneck 1974, Helictotricho-Stipetalia Toman 1969 and Tanacetoto achillefolii-Stipetalia lessingianae Lysenko et Mucina in Mucina et al. 2016 of the class Festuco-Brometea Br.-Bl. et Tx. ex Soy 1947, which combines genuine bunchgrass and forbs-bunchgrass steppes, meadow steppes, stony (petrophytic) steppes, as well as different types of human-modified steppe communities.

The earliest information on the bryophyte species found in steppes of the Bashkir Cis-Urals dates to the first half of the 20th century (Podpera, 1921; Bachurina, 1946). Later, some species were reported in the framework of syntaxonomical investigations conducted in several nature protected areas (Mirkin, 2010; Melentyev & Martynenko, 2014; Mirkin & Martynenko, 2018). Nevertheless, bryophyte flora in the steppe communities of the Bashkir Cis-Urals was still relatively unexplored.

The present study is aimed to record and analyze data on the bryophyte composition in different types of steppe scrub and steppe communities in the Bashkir Cis-Urals.

MATERIALS AND METHODS

The study was conducted in the forest-steppe zone of the Bashkir Cis-Urals. It is the south-eastern part of the East European Plain bordering the western foothills of the Southern Urals. According to zonation of Eurasian steppe (Lavrenko, 1970), the study area is located within East European forest-steppe and Transvolga-Kazakhstan steppe provinces of the Black Sea-Kazakhstan subregion. The terrain of the study area is a gently sloping and hilly plain with an average elevation of about 200–300 m a.s.l. The climate is continental with short warm summers and long and moderately cold winters. The average temperature ranges from +2.5 to +3.5°C, while the sum of effective temperatures during the growing period varies from 1900 to 2350°C. The average annual precipitation is 450–500 mm, while Selyaninov’s geothermal coefficient is 0.8–1.4 (Yaparov, 2005).
Fig. 1. Collecting localities.

1. Davlekanovskiy district, 1.7 km N from Kidryachevo Village. 54.34458°N, 54.46802°E. Alt 307 m.
2. Buzdyakskiy district, 2.5 km S from Kanly-Turkeevo village. 54.35433°N, 54.45663°E. Alt 307 m.
3. Davlekanovskiy district, 2.5 km SE from Chapaevo village. 54.32253°N, 54.52072°E. Alt 210 m.
4. Davlekanovskiy district, 1.8 km NE from Burangulovo village. 54.30866°N, 54.53380°E. Alt 250 m.
5. Davlekanovskiy district, vicinity of the southern shore of Aslykul’ Lake. 0.5 km W from Yangi-Turmush village. 54.29416°N, 54.58008°E. Alt 258 m.
6. Davlekanovskiy district, 4 km W from Alga village. 54.28047°N, 54.56258°E. Alt 341 m.
7. Davlekanovskiy district, 2 km E from Burangulovo village. 54.29158°N, 54.54111°E. Alt 333 m.
8. Davlekanovskiy district, vicinity of Sokolovka village. 54.20371°N, 55.13887°E. Alt 120 m. (Bachurina, 1946).
9. Davlekanovskiy district, 1 km E from Dyurtyulen village. Yaryshtau Mt. 54.14985°N, 55.09035°E. Alt 240 m.
10. Alsheevskiy district, 3 km SE from Churaev village. Susaktau hill. 53.98671°N, 55.04979°E. Alt 265 m.
11. Miyakinskiy district, Vicinity of Miyakitamak village. 53.77556°N, 54.75306°E. Alt 150 m.
12. Aurgazinskiy district, 2.5 km E from Turumbe village. 54.01793°N, 55.57447°E. Alt 230 m.
13. Bishbulyakskiy district, 2.5 km E from Muradymovo village. 53.73675°N, 53.93802°E. Alt 250 m.
14. Gafuriyaskiy district, 4.5 km NE from Tabynskoye village. Voskresenka Mt. 54.00333°N, 56.45122°E. Alt 202 m.
15. Sterlitamakskiy district, 2 km N from Belskoye village. Yuraktu Mt. 53.47161°N, 56.09919°E. Alt 130 m.
16. Ishimbayskiy district, 3 km NE from Urman-Bishkadak village. Tratau Mt. 53.55516°N, 56.10150°E. Alt 372 m.
17. Sterlitamakskiy district, vicinity of Vasilyevka village. 53.47749°N, 55.93300°E. Alt 150 m. (Bachurina, 1946).
18. Sterlitamakskiy district, vicinity of Ayubevo village. 53.43625°N, 55.79115°E. Alt 140 m. (Bachurina, 1946).
19. Sterlitamakskiy district, vicinity of Murdashevo village. 53.38934°N, 55.79873°E. Alt 170 m. (Bachurina, 1946).
20. Ishimbayskiy district, 3 km NE from Sargaevo village. Iliskyntash Mt. 53.71197°N, 56.64138°E. Alt 380 m.
21. Ishimbayskiy district, 7 km E from Gumerovo village. 53.57160°N, 56.66503°E. Alt 600 m.
22. Meleuzovskiy district, 1.5 km NE from Zirikovo village. 53.01855°N, 56.40083°E. Alt 390 m.
23. Kugarchinskiy district, 4.5 NE from Nizhnebikkuzino village. 52.96723°N, 56.57630°E. Alt 420 m.
24. Kugarchinskiy district, 5 km NE from Bogdashkino village. 52.63348°N, 56.93153°E. Alt 510 m.
25. Kugarchinskiy district, 5 km E from Kugarchi settlement. 52.43123°N, 56.67502°E. Alt 467 m.
26. Duvanskiy district, Northern vicinity of Varoslavka village. Gladkaya Mt. 55.86929°N, 57.94363°E. Alt 340 m.
27. Duvanskiy district, 3.5 km SE from Elantube village. 55.61203°N, 57.89372°E. Alt 270 m.
28. Salavatskiy district, 1 km E from Iltaevo village. Kantuntau Mt. 55.26328°N, 58.16812°E. Alt 370 m.
29. Belokatayskiy district, 3.5 km S from Maygaza village. 55.57607°N, 58.8731°E. Alt 350 m.
The present publication is based on the identification of bryophytes collected in 2006–2020 within steppe communities located in fourteen districts of the Republic of Bashkortostan, including the territories that are key objects of the projected Geopark “Toratau” nominated for inclusion in the UNESCO Global Geoparks Network.

Most of the specimens were collected from different habitat niches, i. e. soil, rock substrates, decaying wood, barks of shrubs, etc. within 100 m² sample plots of geobotanical relevés. In total, bryophyte diversity was recorded for 134 geobotanical relevés, including 42 sample plots located in meadow steppes, 24 – in true dry steppes, 57 – in petrophytic variants of both meadow and dry steppes, and 11 – in steppe scrub communities. The species which could be easily recognized were recorded in the field, while the other specimens were collected for identifying in the laboratory. Some specimens were collected during floristic observations, and their labels were provided with short description of habitats. Also, literature sources were considered.

In total, about 500 specimens of bryophytes were studied. The species were identified with the microscopes Olympus CX31 and Al’tami SPM0880 using the traditional anatomical-morphological method. Specimens are kept in the Herbarium of the Ufa Institute of Biology of Ufa Research Centre of RAS (UFA). The nomenclature of species follows “An annotated checklist of bryophytes of Europe, Macaronesia and Cyprus” (Hodgetts et al., 2020).

The data on bryophyte diversity within steppes and steppe shrublands of the study area are provided for localities listed in Fig. 1.

RESULTS

The study was conducted within different vegetation types. Steppe scrub communities dominated by Caragana frutex L., K. Koch, Spiraea crenata L., Spiraea hypericifolia L., Prunus tenella Batsch (syn. Amygdalus nana L.), Prunus fruticosa Pall. (Fig. 2 A) occur in the small hollows and on the slopes of different steepness and exposures across all study area. These communities present the order Prunetalia spinosae, and their bryophyte composition was investigated in localities 14-16, 20, 21 (Fig. 1).

The meadow steppes of the order Brachypodietalia pinnati usually occur in relatively small and not so extremely dry sites on gentle slopes (< 20°) or near foot of northern slopes (Fig. 2 C). The floristic composition of these communities includes Stipa pulcherrima K. Koch, Stipa pennata L., Adonis vernalis L., Campanula sibirica L., Galium verum L., Veronica spicata L., Thalictrum minus L., Trifolium montanum L., Fragaria viridis Weston (Fig. 2 B) These steppes were explored in localities 1-8, 11-19, 21-29 (Fig. 1).

Genuine (true) dry steppes with Helictotrichon desertorum (Less.) Pilg., Festuca valesiaca Schleich. ex Gaudin, Carex supina Willd. ex Wahlenb., Euphorbia caesia Kar. & Kir. (Fig. 2 C) belong to the order Helicototricho-Stipetalia and usually cover dry plain surfaces and gentle southern and east-southern slopes of hills. These communities were studied in localities 1-7, 9, 10, 14-16 (Fig. 1).

The petrophytic variants of meadow and genuine dry steppes (Fig. 2 D, E) occupy steep southern and eastern slopes (>30–40°) with stony soils and different bedrock types including chalks, gypsum, limestones and sandstones (localities 2–6, 9, 10, 13–16, 20–23, 26, 27). The projective cover of stones within these habitats may reach up to 80 %. Such typical for dry steppe species as Stipa lessingiana Trin. & Rupr., Kochia prostrata (L.) Schrad., Stipa sarepta Beck and petrophytes (Hedysarum razoumovianum DC, Artemisia salsoloides Willd., and Oroystachys spinosa (L.) Sweet) usually grow there.

Semi-arid steppe communities of the order Tanacetio achilleifolii-Stipetalia lessingianae are rare in the study area, and their bryophyte diversity was not investigated.

The list of species annotated with occurrences in the different community types is provided (Table 1).

The bryophyte flora of investigated steppes and steppe shrublands includes 57 species (3 liverworts and 54 mosses). To determine the differences between bryophyte compositions of studied communities, an ecological analysis was conducted. The proportions of taxa with different life strategies, life forms, ecological groups associated with different habitat and vegetation types, as well as in relation to water regime and light are presented as a share (in percentage terms) of the total number of species recorded in each type of community (Table 2). The assessment of ecological groups was based on expert knowledge of the habitat preferences of each species in the Southern Urals region.

DISCUSSION

The diversity of bryophytes in steppes of the study area (57 species) is lower than bryophyte richness in steppes of the Central Russian Upland (80 species) (Popova, 2019), but similar with data on similar vegetation described in other regions of Russia, i.e. the Republic of Altay (47 species) (Pisarenko & Korolyuk, 2003), the Bashkir Trans-Urals (42 species) (Aznabayeva & Baisheva, 2017), south-western shore of Baikal Lake (62 species) (Prelovskaya, 2012). In the more restricted areas, i.e. Orenburg State Nature Reserve, the number of bryophytes growing in steppe communities was even lower (24 moss species) (Afonina et al., 2006).

The number of bryophytes revealed in different types of communities is from 16 to 35 species, being the richest, as expected, in the petrophyte steppes (Table 1). In the Urals, these communities have a high level of floristic and phytocoenotic diversity (Korolyuk et al., 2018).

In studied communities, the bryophytes were found mainly on rocks or soil. 22 species are terrestrial (e.g.
Fig. 2. Vegetation of steppe shrublands and steppes in the Bashkir Cise-Urals (photos of Baisheva). A: steppe scrub communities, habitat of *Dicranum dispersum* on the top of Ilsyntash Mt.; B: meadow steppe; C: true dry steppe; D, E: stony steppes; F: habitat of *Grimmia plagiopodia* and *Jaffueliobryum latifolium* near the southern shore of Aslykul’ Lake.

Pterygoneurum ovatum, *P. subsessile*, *Weissia brachycarpa*), 26 species are saxicolous and grow on rock outcrops and boulders (*e.g.* *Grimmia spp.*, *Schistidium spp.*, *Syntrichia intermedia*), and 9 species were found on both substrates (*e.g.* *Abietinella abietina*, *Brachythecium albicans*, *Syntrichia ruralis*). Obligate epilithic species have the larger representation in stony steppes and steppe scrub communities (45–50 % of total species number within vegetation type) (Table 2).

Human and animal disturbances are common and typical for steppe ecosystems, particularly grazing and fire (Smelansky & Tishkov, 2012). The effect of grazing and recreation is more evident in terrestrial bryophyte communities, whereas saxicolous communities are rarely affected by these disturbance factors (McIntosh, 1986). To reflect the response of bryophyte composition towards different environmental conditions, we used the system of bryophyte life strategies including the seven main categories distinguished at present (*e.g.*, annual shuttle species, colonists, fugitives, geophytes, perennial shuttle species, perennial stayers, short-lived shuttle species) (Kürschner & Frey, 2012).
Table 1. Bryophyte composition of steppe scrub and steppe communities in the Bashkir Cis-Urals (Republic of Bashkortostan).

| Community types                     | I   | II  | III | IV  | LS   | Localities |
|--------------------------------------|-----|-----|-----|-----|------|------------|
| Liverworts                           |     |     |     |     |      |            |
| Lophocolea minor                     | Rar |     |     |     | PSs,as| 15         |
| Mannia fragrans                      | Rar |     |     |     | PaS  | 15, 22     |
| Porella platyphylla                  |     |     |     |     | PeS  | 15         |
| Mosses                               |     |     |     |     |      |            |
| Abietinella abietina                 | Com | Com | Sp  |     | PSm  |            |
| Aloina rigida                        |     |     |     |     |      |            |
| Barbula anguiculata                  |     |     |     |     |      |            |
| Brachytheciustrum velutinum          | Rar |     |     |     | PSs  | 14         |
| Brachythecium albicans               |     |     |     |     |      |            |
| Brachythecium campestre              |     |     |     |     |      |            |
| Brachythecium capillaceum            |     |     |     |     |      |            |
| Brachythecium glareosum              |     |     |     |     |      |            |
| Brachythecium laetum                 |     |     |     |     |      |            |
| Bryoerythrophyllum recurvirostrum    | Rar |     |     |     |      | 15         |
| Bryum argenteum                      |     |     |     |     |      |            |
| Buckia vaucheri                      |     |     |     |     |      |            |
| Campsiadelphus chrysophyllus         | Rar | Sp  |     |     | PSs  |            |
| Ceratodon purpureus                  |     |     |     |     |      |            |
| Didymodon rigidulus                 |     |     |     |     |      |            |
| Dicranum dispersum                   |     |     |     |     |      |            |
| Encalypta ciliata                    | Rar |     |     |     |      | 5          |
| Encalypta raphotecarpa                |     |     |     |     |      |            |
| Encalypta vulgaris                   |     |     |     |     |      |            |
| Euryhynchiastrum pulchellum          |     |     |     |     |      |            |
| Flexitrichum flexicaule              | Sp  |     |     |     | PSm  |            |
| Grimmia anodon                       |     |     |     |     |      |            |
| Grimmia plagiopodia                  |     |     |     |     |      |            |
| Grimmia teretinervis                 |     |     |     |     |      |            |
| Homomallium incurvatum               |     |     |     |     |      |            |
| Hypnum cupressiforme                 |     |     |     |     |      |            |
| Jaffueliobryum lattifolium           |     |     |     |     |      |            |
| Orthotrichum anomalum                |     |     |     |     |      |            |
| Pleuridium subulatum                 |     |     |     |     |      |            |
| Polytrichum juniperinum              |     |     |     |     |      |            |
| Pseudaumblysium subtile              | Rar |     |     |     |      | 15         |
| Pseudoleskeaella catenulata          | Sp  | Sp  |     |     | PSm  |            |
| Pseudoleskeaella nervosa             | Sp  |     |     |     |      |            |
| Pseudoleskeaella tectorum            |     |     |     |     |      |            |
| Pterygoneurum kozlovi                | Rar |     |     |     |      | 5          |
| Pterygoneurum ovatum                 |     |     |     |     |      |            |
| Pterygoneurum sub sessile            |     |     |     |     |      |            |
| Schistidium apocarpum                |     |     |     |     |      |            |
| Schistidium submuticum               | Sp  |     |     |     |      |            |
| Sciuro-hypnum reflexum               |     |     |     |     |      |            |
| Syntrichia caninervis                |     |     |     |     |      |            |
| Syntrichia montana                   |     |     |     |     |      |            |
| Syntrichia ruralis                   |     |     |     |     |      |            |
| Tortella tortuosa                    |     |     |     |     |      |            |
| Tortula acaulon                      |     |     |     |     |      |            |
| Tortula muralis                      |     |     |     |     |      |            |
| Weissia brachycarpa                  |     |     |     |     |      |            |
| Weissia longifolia                   |     |     |     |     |      |            |
| Total number of species              | 16  | 20  | 23  | 35  |      |            |

Explanations: Community types: I = steppe scrub communities; II = meadow steppes; III = genuine dry steppes; IV = stony steppes. The indices in columns are occurrence calculated for each species per community type according to the following scale: Rar = rare (1-3 localities), Sp = sporadic (4-15 localities); Com = common (>15 localities). LS – life strategy: AnS = annual shuttle species, PaS = short-lived shuttle species, PeS = perennial shuttle species, Cs = colonists with sexual reproduction, Cas = colonists with high asexual reproductive effort, Cpa = pauciennial colonists, PSm = perennial stayers with moderate or rare reproductive effort, PSs = perennial stayers with sexual reproduction, PSs,as = perennial stayers with sexual and asexual reproduction. Localities according to Fig. 1 are indicated for species with rare occurrences within studied communities.
In bryophytes, tolerance and avoidance of environmental stress are two main alternative possibilities to survive within a plant community (Kürschner & Frey, 2012). The dominance of bryophytes within some unproductive habitats of low biomass (for instance, bogs or rock outcrops) is related not any exceptional ability to monopolize resource capture in competition with neighbours; rather they have assumed dominance slowly through the capacity to retain and protect captured resources (Grime et al., 1990).

The species with such types of strategies as annual shuttles (AnS), fugitives (F) and geophytes (G) follow an avoidance strategy, while other species seem to be following tolerance strategy (Kürschner & Frey, 2012). The species with strategies fugitives and geophytes were absent in studied communities. Shuttle species have large spores (>25 μm in diameter) and are typical for unstable habitats with the disturbed ground (During 1979; Kürschner & Frey, 2012).
ron spp.) is significant only in genuine dry steppes, subject to grazing (26%). Perennial shuttle species (e.g. Encalypta vulgaris, Tortula protobryoides) are not numerous. In total, the proportion of species with shuttle strategy varies from 17 to 26 %, being lowest in petrophyte steppes and communities of steppe scrubs (Table 2).

Colonists are mainly pioneer species able to colonize a new substrate. They dominate sites during primary successional stages and also can often be seen as an indicator of disturbance (Kürschner & Frey, 2012). The proportion of colonists is highest in genuine dry steppes (30 %) and petrophyte steppes (34 %). This strategy includes both terrestrial (Aloina rigida, Bryum argenteum, Ceratodon purpureus, Pterigoniwnum crenberrimum, Jaffueliobryum latifolium) and saxicolous (Bryoerythrophyllum recurvirostrum, Grimmia anodon, Schistidium submucitum) bryophytes (Tables 1, 2).

Species with perennial stayers strategy (Brachythecium laetum, Buckia vaucheri, Dicranum dispersum, Eurhynchiastrum pulchellum, Pseudolekueiella catenulata, Syntrichia ruralis, Tortella tortuosa) have a significant presence in all communities. Their proportion is maximal in meadow steppes and steppe scrub communities (60-62 %), and minimal in genuine dry steppes (43 %) (Table 2). These species are most frequent in long-lasting habitats under more or less constant environmental conditions, but also can tolerate environmental stress (Kürschner & Frey, 2012).

The range of life-forms of revealed bryophytes is not wide. The proportion of acrocarpous bryophytes with life-forms of cushions (mostly saxicolous species – Orthotrichum anomalum, Schistidium spp., Grimmia spp.) and turfs (terrestrial species Aloina rigida, Ceratodon purpureus, Bryum argenteum, Encalypta spp., Pterigoniwnum crenberrimum) ranges from 49 to 69 %, being highest in genuine dry steppes and lowest in steppe scrub communities. Mat-forming species (e.g. Brachythecium spp., Pseudolekueiella spp., Homomallium incrustum) are also prominent (21-37 %) (Table 2). Species with life-forms of felt (e.g. Abietinella abietina, Campyliadelphus chrysophyllus) and thalloid mat (Mannia fragrans) are not numerous.

Among groups of species associated with different habitat and vegetation types, proportion of petrophytic bryophytes (Grimmia spp., Schistidium spp., Flexitrichum flexicaule) is quite high and varies from 26 % (in genuine dry steppes) to 40 % (in petrophyte and meadow steppes) of the total number of species recorded in each vegetation type. The share of steppe (Abietinella abietina, Brachythecium glareosum, Pterigoniwnum spp.) and forest-steppe (Brachythecium albicans, Dicranum dispersum, Pleuridium subulatum) species is highest in genuine dry steppes (52 %) and communities of steppe scrubs (50 %), whereas the part of forest species (Brachythecium capillaceum, Pseudaombylystegium brittle, Pseudolekueiella nervosa) is more or less significant only in steppe scrublands (18 %) and petrophyte steppes (11 %). Eurytopic species (Bryum argenteum, Barbula unguiculata, Ceratodon purpureus, Pspychostomum imbricaturn) were revealed only in steppes (Table 2). Heterogeneity of bryophyte composition, which includes species associated with different habitat and vegetation types, may be explained by fragmentation and the small area size of investigated communities, that are surrounded by agricultural lands and forests in study area.

As expected, the range of ecological groups in relation to light and water regime shows the high proportion of xerophytes and heliophytes among bryophytes of almost all studied communities. The share of indifferent to water regime species (Rhutidium rugosum, Ceratodon purpureus) is considerable only in meadow (20 %) and petrophytic (17 %) steppes (Table 2).

Several species, which are rare for Europe and the Southern Urals, are associated with investigated communities. Mannia fragrans (VU), Dicranum dispersum (EN), Grimmia plagiopodia (VU), Grimmia teretinervis (NT), and Pterigoniwnum koslowii (CR) are listed in the European Red List of Mosses, Liverworts and Hornworts (Hodgetts et al., 2019). Brachythecium laetum is included into Red Data Book of the Republic of Bashkortostan (Mirkin, 2011). Jaffueliobryium latifolium is known from only one locality in Europe (Ellis et al., 2019). It grows on the stony sites with steppe vegetation together with Grimmia plagiopodia (Fig. 2 F). The population size of these species was not investigated but it seems to be not large. Usually, the number of mature individuals per subpopulation do not exceed 25-50 (considered as 1 m²), except recently found subpopulation of Dicranum dispersum (locality 20, Fig. 2 A), which cover is about 250 m². In the Republic of Bashkortostan, all these species are probably relic, and their habitats need protection.

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