Shrub steppe communities in the Samara Volga Region

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Abstract. Shrubs are an important component of steppe vegetation. Vegetation groups dominated by or including typical steppe shrubs form so-called "shrub steppes". The ecological-phytocenotic and floristic characteristics of the communities of shrub steppes of the Samara Volga Region are given. The analysis includes data from 41 geobotanical relevés made in 2013–2018. Typical communities for the region under study are formations Amygdalus nana, Caragana frutex, Cerasus fruticosa, Chamaecytisus ruthenicus, Spiraea crenata, S. hypericifolia and S. litwinowii. The highest species diversity of vascular plants was registered in phytocenoses dominated by Caragana frutex and Cerasus fruticosa, growing on fairly rich soils with medium-steppe moisture and weak influence of grazing. In these phytocenoses, on average, up to 20 species are recorded on the registration site. The results of DCA-ordination of steppe shrub communities of the Samara Volga Region are presented. It was revealed that communities with the participation of typical steppe shrubs Amygdalus nana, Spiraea crenata, Cerasus fruticosa develop more moistened ecotopes with rather rich soils compared to the other studied phytocenoses. In the studied phytocenoses, 35 rare species included in the Red Books of the Russian Federation and Samara Oblast were found. Their greatest number was recorded in phytocenoses dominated by Caragana frutex, Cerasus fruticosa and Amygdalus nana. Further study of shrub steppes in the region will reveal their syntaxonomic status and will form a comprehensive view of these communities for their effective conservation.

1. Introduction
Shrubs are an important component of steppe vegetation. Some shrub species are characteristic only for the steppe biome and are not found outside of it. Vegetation groups dominated by or including typical steppe shrubs form so-called "shrub steppes" [1, 2]. Shrub steppe communities are considered as an intermediate link between steppe phytocenoses and shrub thickets [3–5]. In thickets, shrubs form a continuous tier (in terms of the closure of their crowns) with a higher projective cover compared to the herbaceous tier.

The species diversity of shrubs that make up the communities is monotonous. The predominant shrub species in the steppe communities of the Trans-Volga-Zaural Region are Amygdalus nana L.,
Caragana frutex (L.) K. Koch, Spiraea crenata L., S. hypericifolia L. и Chamaecytisus rhenicus (Fisch. ex Wol.) Klášek. [5]. In Samara Oblast, the communities of Cerasus fruticosa Pall. and Spiraea litwinowii Dobrocz. are added to them. These species can occur together with each other. In the steppe communities of the Samara Volga Region with the participation of shrubs, herbaceous plant species dominate, such as Stipa capillata L., S. lessingiana Trin. et Rupr., S. pennata L., Medicago romanica Prodan, Falcaria vulgaris Bernh., Bromopsis inermis (Leyss.) Holub, Viola ambigua Waldst. et Kit., Echinops meyeri Iljín, E. tataricus Knjaz., Poa angustifolia L., Artemisia austriaca Jacq., A. campestris L., A. marshallianus Spreng., Filipendula vulgaris Moench, Veronica incana L., Scabiosa ochroleuca L., Salvia stepposa Des.-Shost., S. nutans L., Gypsophila paniculata L., Allium lineare L., Galatella villosa (L.) Rechb. f., Centaurea ruthenica Lam., Hedysarum razoumovianum Helm et Fisch. ex DC., Festuca valesiaca Schleich. ex Gaudin s.str., Thymus marshallianus Willd., Gypsophila altissima L. s.l., Galium rhenicum Willd., Asparagus officinalis L., Allium strictum Schrad. Although in general the species composition of steppe shrub communities is not rich in floristic composition, their species diversity determines the differences in vegetation cover [6].

Shrub steppes are usually confined to areas with hilly relief, occupying slope habitats and growing along depressions and ravines [5]. Such locations occur on chernozem soils and on poor soils, including stony substrates [7]. In the past, they occupied larger areas, but now their areal has shrunk. Shrub steppes were preserved only on forms of relief inconvenient for arable development, as well as in protected areas [2, 8]. This paper describes and analyzes the main ecological factors in the organization of shrub steppe communities found in Samara Oblast.

2. Materials and Methods

The Samara Volga Region is located in the southeast of European Russia in the middle course of the Volga River between 51°47' and 54°41' N and 47°55' and 52°35' E. The study area is characterized by two types of steppes [2]:

- meadow steppes are the least dry and the most mesophytic steppe grasslands that typically form the grassland component of the forest-steppe landscape, i.e. intermingle with tree and bush groves even on plain watersheds;
- genuine forbs-bunchgrass steppes. These are dominated by xero-mesophytic graminoids (Stipa zalesskii, S. tirs, S. pulcherrima, Helictotrichon desertorum are characteristic), and have a significant proportion of xero-mesophytic and even mesophytic forbs.

The study used 41 geobotanical relevés. The authors of the relevés are S.A. Senator (2018), V.M. Vasjukov and A.E. Mitroshenkov (2013–2014). Geobotanical relevés were performed according to standard methods on sites of 100 m2 or within the actual contour of plant communities. Geographic coordinates were set for each relevé using a Garmin device. The results of the field surveys were entered into a database on the TURBOVEG software platform [9]. Herbaric specimens are stored at the Institute of Ecology of Volga River Basin RAS (PVB). Latin names of vascular plant species are standardized mainly according to the International Plant Names Index [10].

The data were processed using JUICE software packages [11]. Cluster analysis was performed using PC-ORD 5.0. Euclidean distance was chosen as a measure of distance between objects, and objects were grouped using the "flexible betta" method \( \beta > 0.25 \) [12]. The ecological assessment of the communities was carried out using the scales of L.G. Ramensky [13], calculated using the IBIS software using the "weighted averaging" method [14]. Interpretation of ordination axes was performed using the correlation coefficient between indicator indices and description coordinates [15]. Diagnostic species were determined by calculating the phi coefficient [16, 17].

The value of the phi coefficient above which a taxon was considered diagnostic was taken to be 0.5. In addition to diagnostic species, the category of constant species was established, whose occurrence in the communities was 80% or more. Species whose occurrence in clusters was 50% or more were considered dominant. DCA-coordinated geobotanical relevés were performed using the "Ordijuice" module of the R-package built into the JUICE software, with a down-weighting of rare species [18].
3. Results and Discussion
The total array of geobotanical relevés was subjected to cluster analysis. The maximum value of clarity of classification is achieved when the sample of relevés is divided into 4 groups (figure 1). Below we present their characteristics.

![Figure 1](image-url) Changes in the classification clarity index with an increase in the number of clusters.

Cluster 1 includes 7 sites dominated by *Caragana frutex* (table 1). Floristically not rich, on average 8 species are registered at the site. Total projective coverage varies from 40 to 80%.

**Table 1.** Abbreviated synoptic table of shrub steppe communities of the Samara Volga Region.

| Cluster   | 1 | 2 | 3 | 4 |
|-----------|---|---|---|---|
| Number of relevés | 7 | 9 | 15 | 10 |
| Average value of indicators of ecological scales |  |  |  |  |
| L.G. Ramensky |  |  |  |  |
| soil moistening | 43 | 45 | 47 | 44 |
| wealth-salinity | 14 | 13 | 12 | 14 |
| pasture degradation | 3.5 | 3.7 | 3.3 | 3.4 |
| Average number of species per site | 8 | 20 | 7 | 11 |

*Caragana frutex*  
* Cerasus fruticosa  
* Amygdalus nana  
* Spiraea crenata  
* Chamaecytisus ruthenicus  
* Potentilla hamifusa D.F.K. Schltdl.  
* Artemisia austriaca  
* Salvia nutans  
* Gypsophila paniculata  
* Artemisia campestris  
* Allium lineare  
* Tulipa biebersteiniana Schult.f.
| Species | Information |
|---------|-------------|
| *Hieracium virosum* |  |
| *Allium strictum* |  |
| *Taraxacum serotinum* |  |
| *Salvia tesquicola* |  |
| *Hedysarum* |  |
| *Euphorbia seguierana* |  |
| *Centaurea* |  |
| *Agrimonia asiatica* |  |
| *Salvia verticillata* |  |
| *Phlomis* |  |
| *Artemisia absinthium* |  |
| *Verbascum lychnitis* |  |
| *Euphorbia virgata* |  |
| *Stachys recta* |  |
| *Onosma* |  |
| *Centaurea apiculata* |  |
| *Galium tinctorium* |  |
| *Convolvulus arvensis* L. |  |
| *Stipa pulcherrima* |  |
| *Galium rathenium* |  |
| *Asparagus officinalis* |  |
| *Bromopsis riparia* (Rehmann) Holub |  |
| *Scorzonera stricta* Hornem. |  |
| *Veronica incana* |  |
| *Vincetoxicum stepposum* (Pobed.) Á. et D. Löve |  |
| *Galatella villosa* |  |
| *Centaurea apiculata* Ledeb. |  |
| *Centaurea sumensis* Kalen. |  |
| *Cichorium intybus* L. |  |
| *Allium rotundum* L. |  |
| *Centaurea pseudomaculosa* Dobrocz. |  |
| *Achillea millefolium* L. |  |
| *Galium tinctorium* L. |  |
| *Centaurea apiculata* Ledeb. |  |
| *Centaurea sumensis* Kalen. |  |
| *Onosma volgensis* Dobrocz. |  |
| *Stachys recta* L. |  |
| *Euphorbia virgata* Waldst. et Kit. |  |
| *Verbascum lychnitis* L. |  |
| *Artemisia absinthium* L. |  |
| *Phlomis pungens* Willd. |  |
| *Salvia verticillata* L. |  |
| *Agrimonia asiatica* Juz. |  |
| *Centaurea carbonata* Klokov |  |
| *Euphorbia seguierana* Neck. |  |
| *Hedysarum razoumovianum* |  |
| *Salvia tesquicola* Klokov et Pobed. |  |
| *Taraxacum serotinum* (Waldst. et Kit.) Poir. |  |
| *Allium strictum* |  |
| *Hieracium virosum* Pall. |  |
(e)

Potentilla incana G. Gaertn., B. Mey. et Scherb. . 22+1 30*
Artemisia latifolia Ledeb. . 11+ 30*
Adonanthe volgensis (Steven ex DC.) Chrtek & Slaviková . . 7+ 30*
Astragalus testiculatus Pall. . . 7+ 30*
Hedysarum grandiflorum Pall. . . 33+1-2 20*
Koeleria cristata (L.) Pers. . . 13+1 40*
Thalictrum minus L. . 33+1 33+1-2 10*
Melamphyrum argyrocomum Fisch. ex Steud. . 33+1 33+1
Fragaria viridis Weston . 33+1 33+1 10*
Camelina macrocarpa Andrz. ex DC. . 33+1 20+
Pentanema hirtum (L.) D. Gut. Larr., Santos-Vicente, Anderb., E. Rico et M.M. Mart. Ort. . 33+1 7+ 30*
Campanula sibirica L. . 33+1-2 30*
Galatella angustissima (Tausch) Novopokr. 14+ 11+ 30*
Oxytropis pilosa (L.) DC. . 22+1 47+1
Nonea rossica Steven . 22+1 33+1 20*
Carduus acanthoides L. . 43+ 43+
Vincetoxicum mugodsharicum Pobed. . 29+ 29+
Galatella villosula . 29+2 29+
Festuca rupicola Heuff . 29+ 29+
Clausia aprica (Stephan ex Willd.) Korn.-Trotzky . 33+1 33+1
Adonanthe vernalis Spach . 33+1-1 33+1
Knautia arvensis (L.) Coult. . 33+1 33+1
Carex pediformis C.A. Mey. . 33+1 33+1
Draba lutea Gilib. . 33+1 33+1
Veronica prostrata L. . 33+1-2 33+1
Eremogone biebersteinii (Schltdl.) Holub . 33+1 33+1
 Arenaria viscida Haller f. ex Loisel. . 33+1-2 33+1-2
Ceratocarpus arenarius L. . . 33+1 33+1
Coronilla varia L. . . 33+1 33+1
Serratula lycopifolia (Vill.) A. Kern. . . 33+1 33+1
Campanula glomerata L. . . 27+1 33+1
Scorzonera austriaca Will.d. . . . 30*
Scabiosa isetensis L. . . . 30+1 30+1
Silene chlorantha . . . . 30*
Thalictrum simplex L. . . . 30+1 30+1
Centaurea diffusa Lam. . . . . 30*
Eremogone koriniana (Fisch. ex Fenzl) Ikonn. . . . . 30*

Note. Species persistence is given in %, in the upper index – abundance of plants in points of projective coverage (“+” – less than 1%, “1” – 1–5%, “2” – 6–10%, “3” – 11–25%, “4” – 26–50%, “5” – 55% and more). The rates of occurrence of diagnostic species are marked in gray. Taxa whose occurrence does not exceed 25% in any of the clusters are not given. Clusters: 1 – with dominance of Caragana frutex, 2 – with dominance of Caragana frutex and Cerasus fruticosa, 3 – with participation of steppe shrubs, 4 – with dominance of Amygdalus nana.

There are no diagnostic species.

Constant species: Caragana frutex, Stipa capillata, Medicago romanica, Falcaria vulgaris.
Dominant species: Caragana frutex, Stipa capillata, Medicago romanica, Falcaria vulgaris, Bromopsis inermis, Viola ambigua, Echinops tataricus, Poa angustifolia, Artemisia marschalliana, Stipa lessingiana.
Rare species (listed in the Red Book of Samara Oblast [19], * – in the Red Book of the Russian Federation [20]): *Astragalus zingeri* Korsh., *Hedysarum razoumovianum*, *Stipa pulcherrima* K. Koch*.

Habitat assessment according to L.G. Ramensky's assessment scales: medium-steppe moisture, rich soils, low impact of grazing.

Cluster 2 includes 9 sites dominated by *Caragana frutex* and *Cerasus fruticosa*. The average number of species is 20. ROD varies from 40–100%.

Diagnostic species: *Potentilla humifusa*.

There are no constant species.

Dominant species: *Caragana frutex, Cerasus fruticosa, Potentilla humifusa, Echinops tataricus, Stipa pennata, Filipendula vulgaris, Veronica incana, Vincetoxicum stepposum*.

Rare species: *Adonanthe vernalis, Alyssum lenense* Adams, *Astragalus zingeri*, *Cephalanthera rubra* (L.) Rich.*, *Cerastium zhiguliense* Saksonov, *Clausia aprica, Cotoneaster laxiflorus* J. Jacq. ex Lindl., *Crataegus volgensis* Pojark., *Euphorbia zhiguliensis* Prokh.*, *Gypsophila jupezczukii* Ikonn., *Iris pumila* L.*, *Koeleria sclerophylla* P.A. Smirn.*, *Stipa dasyphylla* (Lindem.) Trautv.*, *S. pennata*, *Thymus zheguliensis* Klokov et Des.-Shost.

Habitat assessment according to L.G. Ramensky's assessment scales: medium-steppe moisture, rather rich soils, weak influence of grazing.

Cluster 3 includes 15 sites with participation of steppe shrubs *Amygdalus nana, Spiraea crenata, Cerasus fruticosa*. On average, 7 species per site are recorded. Projective coverage varies from 40 to 100%.

Diagnostic species: *Artemisia austriaca, A. campestris, Salvia nutans, Gypsophila paniculata, Allium lineare, Tulipa biebersteiniana, Verbascum marschallianum*.

Constant species: *Artemisia austriaca, Stipa capillata, Salvia nutans*.

Dominant species: *Amygdalus nana, Spiraea crenata, Stipa capillata, Medicago romanica, Falcaria vulgaris, Echinops tataricus, Scabiosa ochroleuca, Artemisia austriaca, A. campestris, Salvia nutans, Gypsophila paniculata, Allium lineare, Galatella villosa, Centaurea ruthenica, Hedysarum razoumovianum*.

Rare species: *Adonanthe wolgensis, Astragalus zingeri*, *Ephedra distachya* L., *Hedysarum grandiflorum*, *H. razoumovianum*, *Helianthemum nummularium* Guss., *Iris pumila*, *Tulipa biebersteiniana*.

Habitat assessment according to L.G. Ramensky's assessment scales: medium-steppe moisture, rather rich soils, weak influence of grazing.

Cluster 4 dominated by *Amygdalus nana* includes 10 sites. The average number of species per site is 11. Total projective coverage is 85-95%.

Diagnostic species: *Festuca valesiaca, Echinops meyeri, Thymus marshallianus, Gypsophila altissima* s.l.

Constant species: *Festuca valesiaca, Galiumruthenicum*.

Dominant species: *Amygdalus nana, Festuca valesiaca, Thymus marshallianus, Echinops meyeri, Gypsophila altissima* s.l., *Medicago romanica, Stipa capillata, S. pennata, Galium ruthenicum, Asparagus officinalis, Salvia stepposa, Allium strictum, Artemisia austriaca*.

Rare species: *Adonanthe wolgensis, Alyssum lenense, Artemisia salsooides* Willd., *Astragalus helmii* Fisch. ex DC., *A. henningii* (Steven) Boriss, *A. macropus* Bunge, *A. sulcatus* L., *A. wolgensis* Bunge, *A. zingeri*, *Cotoneaster laxiflorus, Crambe tataria* Sebeók, *Ephedra distachya, Eremogone koriniana, Globularia punctata* Lapeyr.*, *Hedysarum grandiflorum*, *H. razoumovianum*, *Iris pumila*, *Jurinea ewersmannii* Bunge, *Oxytropis floribunda* DC., *Polygala sibirica* L., *Scabiosa isetensis, Stipa pennata*, *S. pulcherrima*.

Habitat assessment according to L.G. Ramensky's assessment scales: medium-steppe moisture, rich soils, weak influence of grazing.
Visualization of the projections of phytocenosis relevés in the plane of two DCA-coordination axes shows that axis 1 accounts for 43% of the total variability, along it a negative reliable correlation of community positions with indicators of the L.G. Ramensky soil richness-salinity scale was established (figure 2, table 2). Axis 2 accounts for 27% of the total variability, along it a reliable correlation with the indicators of soil moisture.

![Figure 2. DCA-ordination of steppe shrub communities of the Samara Volga Region. Eigen values of the axes: axis 1 – 0.43, axis 2 – 0.27. The lines connect the outermost external points of the geobotanical relevés. 1 – cluster with Caragana frutex dominance, 2 – cluster with Caragana frutex and Cerasus fruticosa dominance, 3 – cluster with steppe shrubs participation, 4 – cluster with Amygdalus nana dominance.](image)

As a result, in the Samara Volga Region communities with typical steppe shrubs Amygdalus nana, Spiraea crenata, Cerasus fruticosa (cluster 3) develops more moistened ecotopes with rather rich soils compared to the other studied phytocenoses in which Caragana frutex, Cerasus fruticosa and Amygdalus nana dominate. Due to the small number of geobotanical relevés, syntaxonomic analysis is not given in the article.

| Indicators | Humidification | Soil richness-salinity |
|------------|----------------|------------------------|
| Axis 1     | 0.20*          | -0.46                  |
| Axis 2     | -0.33          | 0.28*                  |

Note. Asterisks denote unreliable values of correlation coefficients at a significance level of 0.05.

The highest species diversity of vascular plants is characteristic of phytocenoses growing on fairly rich soils with medium-steppe moisture and weak grazing influence (cluster 2).

In the studied phytocenoses, 35 (12% of the total number of registered species) rare species included in the Red Books of the Russian Federation [19] and Samara Oblast [20] were found. The greatest number of them was noted in clusters 2 (phytocenoses dominated by Caragana frutex and Cerasus fruticosa) and 4 (phytocenoses dominated by Amygdalus nana).

Shrub steppe communities in the vegetation cover of the Middle Volga Region are very monotonous. At the same time, the reduction of their area due to the direct destruction of occupied habitats, fragmented distribution and uneven representation in the currently existing network of specially protected natural areas actualizes the necessity of their protection [21]. Further study of shrub steppes in the region will reveal their syntaxonomic status and form a comprehensive view of these communities for their effective conservation.

Acknowledgements
We thank O.G. Kalmykova and N.O. Kin of the Landscape Ecology Department of the Institute of Steppe, Ural Branch of the Russian Academy of Sciences for discussion of the manuscript and L.V. Sidiyakina of the Laboratory of Phytodiversity Problems of the Institute of Ecology of Volga River Basin RAS (PVB) for participation in the field research. The study was performed within the state
assignment No. 0111-2019-0001 of the Tsitsin Main Botanical Garden of the Russian Academy of Sciences.

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