Status of local populations of protected species *Psephellus marschallianus* (Asteraceae) in the Stavropol region

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Abstract. *Psephellus marschallianus* is distributed in the steppe zone of Eastern Europe, in the North Caucasus only in the Stavropol region. This species has a narrow ecological affinity and can disappear when overgrown with stony substrates. Therefore, the work aimed at studying the state of local populations of *P. marschallianus* is of scientific interest and is relevant. Field studies were conducted according to the methods recommended for the study of rare species. Geobotanical descriptions are made according to generally accepted methods. The area, number and density of individuals were determined, and the ontogenetic structure was studied, which allowed us to characterize the state and prospects for the development of *Psephellus marschallianus* populations. For the first time, the state of the species was assessed according to the criteria of the International Union for Conservation of Nature (IUCN). The condition and structure of 5 local populations of *Psephellus marschallianus* (ASTERACEAE), a protected species in the Stavropol Krai, has been studied. The area of the local populations, number and density of individuals are determined, the ontogenetic structure, allowing to characterize a condition and the prospects of development of populations of *Psephellus marschallianus* is studied. For the first time, an assessment of the condition of the species according to the criteria of the International Union for Conservation of Nature (IUCN) is given.

1. Introduction

Stavropol region is located in the South of European Russia in the Central part of the North Caucasus, which is a complex topography and a variety of soil and climatic conditions, a gradual change of landscapes from semi-desert to the East, to the steppes and meadow steppes in the center and in the West to deciduous forests and Alpine meadows in the South. According to A.L. Ivanov, the flora of the Stavropol region includes 2252 species of vascular plants, many of which are endemic, very rare within their ranges [1].

The second edition of the Red Book of the Stavropol Territory includes 317 protected species of vascular plants. In the Red Book of the Stavropol region, *P. marschallianus* is listed under the name *Psephellus annae* Galushko, assigned to the status category 2 (V) – a vulnerable species that is declining in number as a result of changing living conditions and habitat destruction [2].

*P. marschallianus* is distributed in the steppe zone of Eastern Europe, in the North Caucasus only in the Stavropol region [3]. This species lives on stony steppe slopes, has a narrow ecological means, occupies an unstable position in the vegetation cover and can disappear when overgrown with stony substrates [2].
2. Objects and Methods of research
The aim of the research is to study the state of local populations of *Psephellus marschallianus* in the Stavropol region. The object of the study is the protected species *Psephellus marschallianus*.

The material was collected by the authors during field research in May-September 2018–2019 in the Stavropol region (figure 1, table 1).

![Figure 1. Location scheme of *Psephellus marschallianus* populations in the Stavropol region.](image)

The study of cenopopulations (CP) was carried out according to the methods recommended for the study of rare species [4]. Geobotanical descriptions were carried out according to generally accepted methods [5]. At test sites measuring 10 × 10 m, all species of vascular plants, moss, and lichens, were taken into account. Their projective coating was evaluated as a percentage (%), a restriction of *P. marschallianus* by various types of vegetation, the influence of natural and anthropogenic factors was detected. Location coordinates are determined using the GPS satellite navigator (in the WGS-84 system).

The age state and density in the cenopopulations were determined according to the scheme of T.A. Rabotnov [6] and A.A. Uranov [7]. In the ontogenesis of the species, we distinguished the following age states: v – virgine (young vegetative), given the rarity of the species, the populations were studied without excavating plants and did not separate juvenile, immature individuals; g1 – young generative individuals are characterized by the presence of a small number (1–4) generative shoots; g2 – mature generative individuals with 5–10 generative shoots; g3 – aging generative individuals; ss – sub-senile (old) individuals have a partially destroyed caudex with 1–2 dead heads, there is a division into particles; s – senile individual (dying plants). For the counting unit in the pregenerative and generative periods, an individual was taken, and in the postgenerative period – a particle.

Phytocenoses are named in accordance with the work of D.S. Dzybov [8]. The names of the species are given according to the summary of S.K. Cherepanov [9].
**Table 1.** Characteristic of populations *Psephellus marschallianus* (Spreng.) K. Koch in the Stavropol region.

| №  | Location                                                                 | Phytocoenosis                                      | Area m² | Number of species | Date       | Projective covering of % | Density individual P. marschal lianus on 1 square meter |
|----|--------------------------------------------------------------------------|---------------------------------------------------|---------|-------------------|------------|--------------------------|----------------------------------------------------------|
| 1  | 45.011944°N, 41.805556°E Shpakovsky district, Stavropol region, nature monument "Landscapes of the high-altitude zone of the Stavropol mountain", rocky slope with limestone outcrops, steepness of 30°, 611 m | Rich-multiplicity grass-cereal forest-steppe       | 400     | 250               | 01.05.18   | 53                       | 7                                                        | 0.6                                                      |
| 2  | 44.556111°N, 42.603889°E Andropovsky district, 3 km South of the village of Sultan, natural monument "Mount Bryk", sandy-rocky slope of the western exposure, steepness of 60°, 637 m | Meadow steppe with thickets of shrubs              | 20808   | 381               | 08.06.18   | 64                       | 6                                                        | 0.02                                                     |
| 3  | 45.0725°N, 41.817778°E Shpakovsky district, 15 km west of Stavropol, Vishnevaya Polyana nature reserve, steppe slope with sandstone outcrops, 647 m | Worm wood-cereal steppe                           | 300     | 150               | 02.07.18   | 55                       | 20                                                      | 0.5                                                      |
| 4  | 44.752222°N, 42.805°E Alexandrovsky district, 5 km away, sandy-rocky slope, steepness of 30°, 592 m | Turf-grass steppe                                 | 1225    | 880               | 21.05.19   | 75                       | 13                                                      | 0.7                                                      |
| 5  | 44.860278°N, 41.905278°E Shpakovsky district, 45 km. South of Stavropol, Nedremanny mountain, slope of the northern exposure, steepness of 40°, 639 m | Meadow steppe in the forest-steppe zone            | 600     | 410               | 29.06.19   | 55                       | 6                                                       | 0.7                                                      |
3. Results and Discussion

*Psephellus marschalliana* (Spreng.) K. Koch (Asteraceae) – herbaceous perennial with rod root system. The stems are semi-recumbent up to 10 cm long. The leaves are located in the basal rosette and on the stems, gray-greenish above, bottom white felt. The flowers are pink-purple, the margins are larger, funnel-shaped, the inner ones are tubular (figure 2).

![Figure 2. *Psephellus marschallianus* (Spreng.) K. Koch.](image)

The baskets are raised, sitting singly at the ends of the shoots. The wrappers are ovoid 10–15 mm long, 8–14 mm wide. Achenes are brown up to 5 mm long. The caudex is underground, mostly multi-headed, its length is 1-3 cm, its thickness is up to 1 cm. Reproduction is seed-based. Hemicryptophyte. Blooms in May-July [10].

The state of *P. marschallianus* in 5 coenopopulations (CP) was studied (figure 1, table 2).

**Table 2.** Summary list of plant species of phytocenoses involving *Psephellus marschallianus*.

| (a) Species                              | Woody and shrubby plants | Projective covering (%) | The number of cenopopulations |
|-----------------------------------------|---------------------------|-------------------------|-------------------------------|
|                                         |                           |                        | 1 2 3 4 5                     |
| **Woody and shrubby plants**            |                           | 3 20                   |                              |
| *Amygdalus nana* L.                    |                           | 20                     |                              |
| *Chamaecytisus ruthenicus* Klask.      |                           | 1                      |                              |
| *Crataegus pentagyna* Waldst. & Kit. ex Willd. |                           | 7                      |                              |
| *Ligustrum vulgare* L.                 |                           | 1                      |                              |
| *Genista patula* M. Bieb.              |                           | 5 15                   | 2                             |
| *Rhamnus pallasii* Fisch.              |                           | 4 10                   | 2                             |
| *R. pimpinellifolia* L.                |                           | 5                      | 1                             |
| **Herbaceous plants**                  |                           | 5 1 3                  |                              |
| *Achillea nobilis* L.                  |                           | 5                      | 3                             |
| *A. micrantha* Willd.                  |                           |                        |                              |
| *A. millefolium* L.                    |                           | 3                      | +                             |
| *A. setacea* Waldst. & Kit.            |                           |                        |                              |
| *Acinos arvensis* (Lam.) Dandy         |                           | 2 7 4                  | 2                             |
| *Allium albidum* Fisch. ex M. Bieb.    |                           | 2                      | 1                             |
| *A. globosum* Bieb.                    |                           | +                      | 2                             |
| *A. fuscoviolaceum* Fomin.             |                           |                        |                              |
| *Alyssum alyssoides* (L.) L.           |                           | +                      | 3                             |
| *A. calycinum* L.                      |                           | +                      | 2                             |
| *A. tortuosum* Waldst. & Kit. ex Willd.|                           | 2 5 5                  | 2                             |
| Species | Projective covering (%) | The number of cenopopulations |
|---------|-------------------------|-------------------------------|
|         |                        | 1   | 2   | 3   | 4   | 5   |
| Agrimonia eupatoria L. | + | 1 | 3 | + |
| Agropyron pectinatum (M.Bieb.) P. Beauv. | | 5 | 3 |
| Arenaria serpyllifolia L. | + | 5 | 2 |
| Artemisia absinthium L. | 3 |
| A. austriaca Jacq. | 5 | 30 | 5 | 2 |
| A. campestris L. | 7 |
| A. scoparia Waldst. & Kit | 5 |
| Aster bessarabicus Bernh. ex Rchb. | 3 |
| Astragalus austriacus Jacq. | 4 |
| A. bungeanus Boiss. | 2 | 1 |
| A. calycinus Bieb. | |
| A. demetrii Kharadze | 7 |
| A. pseudophyllus Boriss. | + | 4 |
| Bilacunaria microcarpa (M. Bieb.) Pimenov & V.N. Tikhom. | |
| Bothriochloa ischaemum (L.) Keng | |
| Brachypodium rupestre (Host) Roem. & Schult. | + | 10 |
| Bromus japonicus Thumb. | 7 |
| B. riparia (Rehmann) Holub | |
| Bupleurum rotundifolium L. | + |
| Calophaca wolgarica (L. fil.) Fisch.ex DC. | 5 |
| Capsella bursa-pastoris (L.) Medikus | |
| Carex humilis Leyss. | 4 | 4 | 5 | 30 |
| Centaurea diffusa Lam. | 5 | 3 | 5 | 2 |
| C. orientalis L. | 3 | 4 | + | + |
| Cirsium arvense L. | + | + |
| Coronilla varia L. | 10 |
| Crinitaria villosa (L.) Grossh. | |
| Dianthus pallidiflorus Ser. | + | + | 1 |
| D. pseudomeria M. Bieb. | 5 |
| Dictamnus albus L. | 7 | + |
| Dracocephalum austriacum L. | 3 |
| Echinops sphaerocephalus L. | + |
| Echium russicum J.F. Gmel. | + | + |
| E. vulgare L. | + | + | + |
| Elytrigia repens (L.) Nevski | |
| Euphorbia glareosa Pall. ex M.Bieb. | 1 | 1 | 1 | 5 |
| E. iberica Boiss. | 2 | 3 | 2 | 5 | 5 |
| E. sequieriana Neck. | 5 | 2 |
| E. stepposa Zoz ex Prokh. | 5 | 4 |
| Erodium stevenii M.Bieb. | + | 2 |
| Eryngium campestre L. | + | + |
| Euphrasia pectinata Ten. | 2 |
| Filipendula vulgaris Moench | 2 | 5 |
| Festuca rapoica Heuff. | 10 | 15 | 30 | |
| F. saxatilis Schur | 2 |
| F. valesiaca Schleich. ex Gaudin | 12 | 3 | 10 | 8 |
| Fragaria viridis Weston. | + | + | 1 |
| Galatella dracunculoides (Lam) Nees | 2 | + |
| G. villosa (L.) Rehbs. f. | 2 |
| Galium ruthenicum Willd. | + | 3 | 2 |
| G. verum L. | + | 1 |
| Geranium sanguineum L. | 5 | 1 | 5 |
| Globularia punctata Lapeyr | + |
| Glycyrrhiza glabra L. | + |
| Gypsophila globulosa Pall. ex Adams | 10 | + | 5 | 1 |
| G. paniculata L. | 4 |
| Species                                      | Projective covering (%) | The number of cenopopulations |
|---------------------------------------------|-------------------------|------------------------------|
| Hedysarum biebersteinii Zertova             | 1                       | +                            |
| Helichrysum arenarium (L.) Moench           | 1                       |                              |
| Helictotrichon pubescens (Huds.) Pilg.     | 1                       |                              |
| Hieracium umbellatum L.                    |                         |                              |
| Hypericum perforatum L.                    | 2                       | +                            |
| Inula britannica L.                        | +                       | 1                            |
| Iris aphylla L.                            |                         |                              |
| J. furcata M. Bieb.                        | 1                       | +                            |
| L. norra M. Bieb.                          | +                       |                              |
| L. pumila L.                               | 1                       | +                            |
| L. taurica Lodd.                            | 2                       |                              |
| Jurinea arachnoidea Bunge                   |                         | 1                            |
| J. ewetsmannii Bunge                       |                        |                              |
| Koeleria cristata L. Pers                  |                         | 4                            |
| L. tauricum Willd.                         | +                       | 45                           |
| Lotus caucasicus Kuprian. ex Juz.           | +                       |                              |
| Medicago lupulina L.                       |                         | 3                            |
| M. romanica Prodan.                        |                         | 4                            |
| Melica transsilvanica Schur.               |                         |                              |
| Melandrium album (Mill.) Garcke            |                         |                              |
| Mascari muscarini Medikus                  | +                       |                              |
| Myosotis arvensis (L.) Hill                |                         |                              |
| Onobrychis vassilczekoi Grosh.             |                         | 5                            |
| Orchis picta Loisel.                       |                        |                              |
| Origianum vulgar L.                        | 3                       | 1                            |
| Peucedanum tauricum M. Bieb.               | 1                       |                              |
| Phleum phleoides (L.) H. Karst.            | +                       | 5                            |
| P. pratense L.                             | 2                       |                              |
| Phlomis pangens Willd.                     | +                       |                              |
| Phlomoides tuberosa (L.) Moench            | +                       |                              |
| Plantago lanceolata L.                     | 4                       | +                            |
| Poa angustifolia L.                        |                         | 40                           |
| P. bulbosa L.                              |                         | 7                            |
| P. pratensis L.                            |                         | 5                            |
| Polygala comosa Schkuhr.                   |                         |                              |
| Potentilla adenophylla Boiss. & Hohen.     |                         | 5                            |
| P. argentea L.                             | +                       | 5                            |
| P. recta L.                                |                         |                              |
| Poterium polyganum Waldst. & Kit.          |                         |                              |
| Primula macrocalix Bunge                   |                         |                              |
| Psephellus marschallianus (Spreng.) K. Koch|                         |                              |
| P. deablatus (Willd.) K. Koch              |                         | 13                           |
| Pyrethrum corymbosum (L.) Scop.            | +                       | 6                            |
| Reseda lutea L.                            |                         |                              |
| Rhinanthus minor L.                        |                         |                              |
| Rumex confertus Willd.                     |                         | 2                            |
| Salvia nutans L.                           |                         | 3                            |
| S. tescucola Klokov & Pobed.               |                         | 3                            |
| S. verticillata L.                         |                         | 2                            |
| Scabiosa ochroleuca L.                     | +                       |                              |
| S. isetensis L.                            |                         |                              |
| Scorzonera stricta Hormem.                 |                         |                               |
| Securigera varia (L.) Lassen               | +                       |                              |
| Sutrum caucasicum (Grosh.) Boriss.         |                         | 2                            |
| Senecio vernalis Waldst. & Kit.            |                         |                               |
| Serratula radiata (Waldst. & Kit.) M. Bieb |                         | 1                            |
| Seseli libanotis (L.) W.D.J. Koch          |                         | 1                            |
| S. transcaucasicas Schischk.               |                         | 1                            |
The studied phytocenoses contain 8 species of woody and shrubby plants and 165 species of herbaceous plants (table 2).

From the analysis of the data in table 2, it can be seen that the following species have a high abundance index in communities with *P. marschallianus*: *Stipa pulcherrima* K. Koch, *Festuca rupicola* Heuff., *Bromopsis riparia* (Rehmann) Holub, *Medicago romanica* Prodan., *Gypsophila globulosa* Pall. ex Adams, *Teucrium chamaedrys* L., *Dactylis glomerata* L. We found that the total projective cover (OPC) of the herbage in the studied phytocenoses varies from 35% to 85% (it depends on the degree of stony soil, the outcrops of the parent rock to the surface).

The highest projective coverage of *P. marschallianus* is recorded in CP 3 and is 20%, the lowest in CP 2 and CP 5–6%. During the research, it was revealed that CP 2, located in the meadow steppe, has the largest number of plant species (104), and CP 3,4 located in the sod-grass steppe, were characterized by a smaller number of species (45–49).

CP 1. Meadow steppe (*Stipa pennata* + *Festuca valesiaca* + *Geranium sanguineum* + *Teucrium chamaedrys*). The projective coverage of lichens is 30%, the stony nature of the substrate is 40%. 250 individuals of *P. marschallianus* were found in the following ontogenetic states: v: g1: g2: g3: ss = 130:40:30:16:34 = 52:16:12:6:4; 13.6%. The age spectrum is left-sided with a predominance of young vegetative individuals. A trail passes through the surveyed area, where vacationers walk and ride quad
bikes, as a result of which the plants are trampled. Individuals of P. The *P. marschallianus* are in satisfactory condition.

CP 2. Meadow steppe with thickets of shrubs (*Amygdalus nana* + *Rhamnus pallasii* + *Stipa pulcherrima* + *Festuca ripicola*). The soil is low-power chernozem, stony—30%. 381 individuals found: *v*:g;g;g;ss:s = 66:96:94:65:40:20= 17.3:25.2:24.6:17.1:10.5:5.2 %. In the spectrum, the maximum falls on young and mature generative individuals. The population is located on the territory of the natural monument "Mount Bryk", where it is forbidden to light fires, graze cattle, collecting plants for bouquets, the condition of *P. marschallianus* is good.

CP 3. Stony Steppe (*Artemisia austriaca* + *Festuca ripicola* + *Stipa pulcherrima*) on saline chernozem, stony—40%. Dead cover (steppe felt) 25 %. The CP has 150 individuals: g;g;g;ss:s = 30:45:60:15 = 20:30:40:10%. Age spectrum with a peak in mature and aging generative plants. We assumed that the absence of young vegetative individuals is due to the fact that there was a thick layer of dead cover on the soil surface, which negatively affects the germination of seeds. The population is mature and has a low capacity for self-maintenance by seed [11]. The condition of the species *P. marschallianus* is satisfactory.

CP 4. Sod-cereal steppe (*Koeleria cristata* + *Bothriochloa ischaemum* + *Stipa pulcherrima* + *Thymus marschallianus*) on carbonate chernozems, dead cover—15%. 880 individuals of *P. marschallianus* were found: *v*:g;g;g;ss:s = 300:150:100:50 = 39.8:17:14:8:11:4:11:4:5.6%. The age spectrum is dominated by young vegetative individuals. The individuals are in good condition, perhaps because the population is located in a remote place with a dissected terrain (gullies, hills), it is not subject to anthropogenic influence.

CP 5. Meadow steppe in the forest-steppe zone (*Carex humilis* + *Phleum phleoides* + *Stipa trichoides* + *Teucrium chamaedrys* + *Thymus marschallianus*). The soil is low-power carbonate chernozem, stony—25%. 410 generative individuals were found: g;g;ss:s = 164:102:82:62 = 40:25:20:15%. The age spectrum is represented only by generative individuals, there are no young plants in the population. The plant population is mature. Most of the territory is subject to grazing, individuals are in a depressed state.

Studies have shown that all CP of *P. marschallianus* are characterized by a low density of individuals (from 0.02 to 0.7 individuals on 1 m²). The highest density (0.7 plants on 1 m²) is recorded in SP 4 (Oak Grove village) and CP 5 (m. Nedremanny), the lowest density (0.02 plants on 1 m²) in CP 2 (natural monument "Mount Bryk"). In all CP, the individuals were placed in the space contiguously, the plants were located at a distance of 1 to 2–3 m from each other. In sparse areas, the distance to neighboring individuals reached 10–14 m, which is due to environmental conditions (soil, aggregate composition, area of stony substrate), anthropogenic and biogenic factors (pasture overload).

In CP 3, 5, there were no young individuals, no renewal processes were observed. During the research, we noticed plants in a dried state, due to the prevailing unfavorable climatic and natural conditions (too dry summer, lack of rain, steppe fires).

The most optimal conditions for the development of *P. marschallianus* in CP 2, 4 they have a more stable state, since they are located in hard-to-reach places with dissected terrain (mountain slope, gullies, hills), where there is no anthropogenic load. In CP 5, grazing remains the main factor negatively affecting the condition of *P. marschallianus*.

Based on our data, criteria B, C and D can be applied [12, 13]. The studied species corresponds to the provisions of the subcriteria B1 (the distribution area is less than 20,000 km²), B2 - the habitat area is less than 2000 km²; in the presence of two conditions: the range is highly fragmented - "a" and a decrease in the quality of the habitat is established - "b (iii)"; based on criterion C, based on observations, it was found that the number of sexually mature individuals in each local population is less than 1000, we add (C2 (i)); Final classification of the species in category VU - vulnerable according to the following criteria: (B1B2av (iii)); (C2 (a, i));
4. Conclusion
All the studied CP of *P. marschallianus* (with the exception of CP 2, 4) are subject to anthropogenic impact – grazing, trampling and destruction by fires, as a result of which their condition worsens. Measures are needed to regulate and reduce recreational loads and livestock grazing. In CP 3, 5 individuals of *P. marschallianus* were in a depressed state, it is necessary to continue monitoring observations.

In the analysis of ontogenetic spectra CP *P. marschallianus* found that left-sided spectrum have CP 1,4, centered – CP 2,5.

For the first time, the state of the species was assessed according to the criteria of the International Union for Conservation of Nature (IUCN) [14], *P. marschallianus* was found to correspond to category VU - vulnerable by criteria (B1B2av (iii)); (C2(a, i)).

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