Population organization of rare species of the genus *Jurinea* as an indicator of conservation of steppe ecosystems of the Volga Region (Russian Federation)

V N Ilyina¹, T E Zenkina²,³, A E Mitroshenkova⁴, O V Kozlovskaya⁴ and V A Sagalaev²

¹ Samara State University of Social Sciences and Education, 26, Antonov-Ovseenko St., Samara, 443090, Russia
² Volgograd State University, Institute of Natural Sciences, 100, Universitetsky Ave, Volgograd, 400062, Russia
³ Volgogradnefteproekt, 85A, Lesogorskaya str., Volgograd, 400048, Russia
⁴ Samara State Technical University, 244, Molodogvardeyskaya St., Samara, 443100, Russia

E-mail: 5iva@mail.ru

Abstract. The article presents the results of the study of the population structure of rare species of the genus *Jurinea* (*Jurinea polyclonos* (L.) DC. s. l. (incl. *Ju. tenuiloba* Bunge), *J. ewersmannii* Bunge, *J. ledebourii* Bunge and *J. multiflora* (L.) B. Fedtsch.) in the steppe Volga region (European part of the Russian Federation). The species is characterized by rarity and its population characteristics change under the influence of anthropogenic factors. The works were carried out in 2000-2021 using population-ontogenetic methods. The species has insufficient potential for self-regeneration of their natural populations. Demographic indices (Replacement index, Recovery index, Aging index) are low. Ontogenetic spectra of populations are similar in their parameters, the predominant group of individuals are mature generative. Anthropogenic pressure leads to a decrease in the number of individuals, their density, low reproductive activity, and gradual aging of populations.

1. Introduction
The population structure of rare and vulnerable plant species is one of the main parameters demanded in determining the state of a particular species in nature and the conservation of plant cover as a whole. Not only the number of individuals but also the ontogenetic and spatial structure as well as the dynamics of demographic and spatial parameters of natural populations allow us to evaluate the stability and lability of plant cover and, consequently, to reveal the condition of ecosystems, including those in specially protected areas. Currently, rare species are used as indicators for searching and identifying the condition of specially protected natural areas (SPNAs) as well as for determining the effectiveness of conservation measures in SPNAs [2;3;6;10-11].

Steppe ecosystems of the Volga region (including those in the Samara, Saratov, Orenburg, and Volgograd oblasts) have undergone significant changes in recent decades due to plowing, the impact of grazing, fires, and recreation. This trend is observed throughout the steppe zone, as noted by various researchers [1;11]. The fact of the decrease of the species, cenotic and landscape diversity first of all as
a result of anthropogenic influence on steppe natural complexes was repeatedly pointed out by researchers. The region is subjected to a high anthropogenic load. Steppe areas have undergone transformation during plowing, cattle grazing, recreation, fires, alienation of the territory for settlements and infrastructure. Only a small part of the former volume of steppe ecosystems has been preserved and they need to be monitored and protected, especially in the intensively developed regions.

Representatives of the genus *Jurinea* (*Asteraceae*) are among the rare and vulnerable species in steppe natural complexes. In spite of wide enough areal of many species, population-ontogenetic study of representatives of genus *Jurinea* is carried out seldom enough. The bioecology of these representatives, including the ability to apomixis, which increases their anthropotolerance, is somewhat better studied [4;5]. It is believed that apomictic species are more prone to adaptation in an urbanized environment than obligate sexual species. Thus, representatives of the genus *Jurinea* can be considered sufficiently resistant to anthropogenic impact, and their disappearance in one or another geographical location can be regarded as a result of the increased anthropogenic pressure.

In the Volga Region, the study of the population structure of rare species of the genus *Jurinea* has not been carried out before. For the first time we revealed the peculiarities of spatial and ontogenetic structure of cenopopulations of four representatives. In general, the presented work is important for the development of effective ways to assess the state of vegetation and planning of conservation measures, the maintenance of Red Books, as well as makes a theoretical contribution to biology and ecology, revealing the issues of structural and functional organization of populations and their assemblages (plant communities).

The aim of the work is to determine the main parameters of the population structure of rare and vulnerable representatives of the genus *Jurinea* in the steppes of the Volga region (Russian Federation).

The article presents data on the results of the study of the spatial and ontogenetic structure of the cenopopulation of four representatives of the steppe flora of the Volga region – *Jurinea polyclonos* (L.) DC. s. l. (incl. *Ju. tenuiloba* Bunge), *J. ewersmannii* Bunge, *J. ledebourii* Bunge and *J. multiflora* (L.) B. Fedtsch. in steppe ecosystems of the Volga Region.

2. Materials and methods

We studied ontogenesis and population characteristics in four representatives of the steppe flora of the Volga region – *Jurinea polyclonos* (L.) DC. s. l. (incl. *Ju. tenuiloba* Bunge), *J. ewersmannii* Bunge, *J. ledebourii* Bunge, and *J. multiflora* (L.) B. Fedtsch. On the whole, the range of species is quite wide, but in a number of subjects of the Russian Federation species are considered rare or vulnerable. Some species are also protected outside of Russia. *J. ewersmannii* in the territory of Russia is included in the Red Books of Voronezh and Samara oblasts, Stavropol Krai and the Republic of Tatarstan. The species grows in southern Europe and Western Siberia, is confined to steppe habitats, and is recorded on sandy and loamy soils.

*J. ledebourii* on the territory of Russia is included in the Red Books of Volgograd, Moscow, Nizhni Novgorod, Samara, Tambov, Chelyabinsk oblasts, and Chuvash Republic; outside Russia – in the Republic of Bulgaria. Eastern European species. It grows most often on stony (limestone) steppe slopes.

*J. multiflora* on the territory of Russia is included in the Red Books of Belgorod, Voronezh, and Tyumen oblasts and the Republic of Khakassia; previously, it was included in the list of protected species in Samara oblast (in 2017, it was included in the monitoring list). Outside Russia, it is protected in Ukraine (Poltava oblast). The range covers Eastern Europe, the Caucasus, Western and Eastern Siberia, China, Central Asia. The representative usually grows in steppe and meadow-steppe cenoses.

*J. polyclonos* in Russia is included in the Red Books of Voronezh, Saratov, and Tambov oblasts. The species grows in the southern steppe and semi-desert zones on sandy soils and chalky slopes (sandy and petrophytic steppes).
The area of our study covers the Volgograd, Samara, northern part of the Saratov, and western part of the Orenburg oblasts. The key plots, where the test sites for the study of species and their phytocenotic environment were established, are located in the Volga River basin. The territory is located in the forest-steppe, steppe, and semi-desert zones, which determines the diversity of steppe communities. The works were carried out in 2000-2021. Five J. polyclonos, 20 J. ewersmannii, 60 J. ledebourii, and 35 J. multiflora cenopopulations were surveyed.

Field studies of cenopopulations of representatives of the genus Jurinea were conducted according to the basic recommendations, criteria, and methodological approaches of the population-ontogenetic direction [8;9;12;14]. Populations in natural conditions were searched by route methods. They were surveyed at permanent and temporary sites, the size of which was determined by the area of cenopopulations, the number and density of individuals included in it, and the actual boundaries of the phytocenosis. A cenopopulation is understood as a part of the species population within a single phytocenosis. Sample plots from 1 to 25 m² were laid on stationary plots. Due to seed reproduction of species, a single individual was taken as a counting unit. The ontogenetic and spatial structure of populations was revealed without removing individuals from the communities. Maintaining the integrity of the population under study is an important aspect of the work in order to preserve biodiversity and identify the dynamics of cenopopulations and vegetation cover. During the cameral period, the ontogenetic states of the recorded individuals were clarified, ontogenetic spectra of the populations were compiled, and the main demographic parameters were calculated. These data served as the basis for determining the type of some populations of model species using L.A. Zhivotovsky’s "delta-omega" criterion [13]. The study of cenopopulations determined the number of individuals and the average density. In order to identify the ecological and phytocenotic conditions of species habitats, geobotanical descriptions were carried out.

3. Results

Tables 1 and 2 present the main results obtained during the study of the population organization of J. ewersmannii, J. ledebourii, J. multiflora, and J. polyclonos in the Volga Region. The main indices of the demographic and spatial structure of these species have been established. The paper gives the indices averaged for the given part of the range, but individual cenopopulations may differ from the averaged values by their characteristics.

| Representative       | Prevailing group of individuals, % | Main type of the ontogenetic spectrum | Average area of cenopopulations, m² | Average density of individuals |
|----------------------|------------------------------------|---------------------------------------|------------------------------------|--------------------------------|
| J. ewersmannii       | Mature generative, 45.6             | Incomplete                            | 10 m²                              | 2.3                            |
| J. ledebourii        | Mature generative, 32.4             | Complete                              | 50 m²                              | 5.3                            |
| J. multiflora        | Mature generative, 24.4             | Incomplete                            | 15 m²                              | 2.7                            |
| J. polyclonos        | Mature generative, 52.5             | Incomplete                            | 25 m²                              | 1.6                            |

The revealed ontogenetic spectra of cenopopulations are the most diverse in J. ledebourii (with a sufficiently high number of individuals, they are always complete, mainly with a maximum on mature generative individuals and a high proportion of virgin and juvenile individuals, in some cases, virgin plants prevail in cenopopulations); the dynamics of ontogenetic structure is fluctuating (at a low level of anthropogenic load). For J. ewersmannii and J. multiflora, the main trend in the ontogenetic spectra is gradual accumulation of old generative individuals, dominance or subdominance of mature generative individuals, low proportion of pregenerative plants, weak fluctuating changes or gradual aging of cenopopulations, incomplete ontogenetic spectrum (with the absence of individuals at the initial stages of ontogenesis); at the same time, anthropogenic impact, soil erosion, and increased competition on the part of turfgrasses cause a decrease in the number of populations in the study sites. The peculiarity of J. polyclonos cenopopulations is the predominance of young and mature generative
instars and the absence of pregenerative plants. Seed germination and seedling survival are probably difficult due to arid habitat conditions on sandy outcrops. In addition, the study area is under the influence of intensive anthropogenic pressure (cattle grazing, recreational load), which led to the thinning of cenopopulations and incompleteness of their ontogenetic spectra.

### Table 2. Demographic indicators of the populations of the studied species (compiled by the authors).

| Representative | Replacement index (Irep) | Recovery index (Irec) | Aging index (lag) | Age index (Δ) | Efficiency index (ω) | Prevailing type of population |
|----------------|--------------------------|-----------------------|------------------|---------------|----------------------|-------------------------------|
| *J. ewersmannii* | 0.22                     | 0.24                  | 0.05             | 0.46          | 0.75                 | Mature                        |
| *J. ledebourii*  | 0.62                     | 0.64                  | 0.07             | 0.48          | 0.74                 | Mature                        |
| *J. multiflora*  | 0.38                     | 0.40                  | 0.04             | 0.41          | 0.69                 | Transitional                  |
| *J. polyclonos*  | 0                        | 0                     | 1                | 0.39          | 0.9                  | Mature                        |

Spatial organization is similar in all species: at high abundance and density of individuals, distribution in space is group or practically uniform, at low abundance – random or group (presence of small clusters of daughter plants near the parent individual).

The studies of ontogenesis of these species indicate the duration of reaching the generative phase (from 3 to 7 years), the existence in the generative period (from 2 to 10 years) and the rapid die-off of senile plants (1-2 years). Total complete ontogeny of *J. ewersmannii* can exceed 10 years, *J. ledebourii* – 12 years, *J. multiflora* – 9 years, *J. polyclonos* – 10 years.

### 4. Discussion

The diversity of cenopopulations according to the ontogenetic spectrum reflects the efficiency of adaptation of specific species to habitat conditions and co-existence with other species. Completeness and fluctuational changes testify to the most complete use of environmental resources by representatives and their more stable position in the composition of phytocenoses. The identification of definitive cenopopulations of rare plant species, characterized by stability and at the same time by the lability of population parameters, allows us to predict the existence and conservation of plant species in phytocenoses and, consequently, the state of protected areas (or unprotected areas). The structural and functional organization of populations determines the duration of the species' existence in a place of growth.

The revealed population characteristics of four representatives of the genus *Jurinea* show that species have significant similarity of basic ontogenetic spectra. Due to the duration of life form accumulation and formation of generative individuals, the main group is mature generative.

The basic type of cenopopulations is mature (according to the delta-omega criterion), in *J. multiflora* – transient (in this species, specific populations are 40% transient, 35% mature, 15% young, 6% ripe, and 4% young). High level of anthropogenic load causes low values of demographic indices (Replacement index, Recovery index, Aging index). Somewhat higher demographic indices are characteristic of the population of *J. ledebourii*, this species being the most widespread of those studied in the Volga Region. Demographic indices (Replacement index, Recovery index) of *J. polyclonos* cenopopulations have zero values due to the absence of pregenerative plants in them, primarily due to a high level of anthropogenic pressure. In the same species, the Aging index of populations is 1.0 due to the same features of the ontogenetic structure (incompleteness of the ontogenetic spectrum).

In addition, the small proportion of pregenerative individuals in some years of the study may be due to the different ratio of fertile and sterile baskets, which is characteristic of different species of the genus *Jurinea*, for example observed in *Jurinea roegneri* [15]. The presence in populations of a large number of young generative and old generative individuals implies a general decrease in reproductive activity at the population level. Thus, the data on the ontogenetic spectra of specific populations is important for determining the ability of a population to self-regenerate, so it can be considered an indicative sign of the efficiency of seed reproduction.
Seed performance and germination (under natural conditions) are essential for population regeneration. However, the data on these indicators still need to be clarified for the studied species, but it is known that the ground germination of *J. centauroides* seeds is 6.5% [7].

The average density of individuals in populations of species of the genus *Jurinea* indicates their low competitive ability in phytocenoses, weak adaptive capacity of individuals during soil erosion, trampling or destruction of vegetation cover.

Thus, the probable resistance of species to anthropogenic impact is still insufficient in the conditions of the highly developed region of the Volga region for effective self-maintenance and self-renewal of the population as a whole. Only in some locations, the populations have high abundance and density, a full ontogenetic spectrum, and significant reproductive activity.

5. Conclusion
The conducted study of biology, ecology and structural features of *J. ewersmannii*, *J. ledebourii*, *J. multiflora* and *J. polyclonos* populations in the Volga region confirm the need for their protection due to a decrease in the number of individuals, a reduction in the number of suitable habitats and anthropogenic transformation of natural-territorial complexes. With an increase in anthropogenic pressure and subsequent changes in environmental conditions, populations gradually lose their positions in phytocenoses.

The main indicators of the spatial and ontogenetic structure of cenopopulations were revealed. Common features are the fluctuational type of population dynamics and ontogenetic structure of *J. ewersmannii*, *J. ledebourii*, *J. multiflora*, *J. polyclonos*, low indices of demographic characters, weak ability to self-regeneration and self-maintenance of populations (except for populations of *J. ledebourii*). In general, the condition of *J. ledebourii* and *J. multiflora* should be considered satisfactory, *J. ewersmannii* and *J. polyclonos* – threatened. However, some cenopopulations of species are in a critical condition in conditions of high anthropogenic pressure.

The presence of *J. ewersmannii*, *J. ledebourii*, *J. multiflora* and *J. polyclonos* in the Volga steppes and the general state of populations, which can be determined taking into account the spatial and ontogenetic characteristics of species, can serve as an indicator sign of ecosystem state.

Acknowledgments
The study was funded by the state assignments of the Samara State University of Social Sciences and Education, Samara State Technical University and the Volgograd State University.

References
[1] Dusaeva G Kh, Kalmykova O G and Dusaeva N V 2019 Fire influence on dynamics of above-ground phytomass in steppe plant communities in the Burtinskaya steppe (Orenburg State Nature Reserve, Russia). *Nature Conservation Research* 4(1) 78–92
[2] Ibatulina Y V 2018 Ecological and demographic structure of cenopopulations as an indicator of the state of vegetation of chalk outcrops. *Vestnik VSU. Series Chemistry, Biology, Pharmacy* 2 135-142
[3] Ilyina V N 2021 Efficiency of protection of populations of *Astragalus cornutus* Pall. on the specially protected natural territories of regional importance in Samara oblast. *Samarskaya Luka: Problems of Regional and Global Ecology* 30(2) 53-58
[4] Kochanova I and Kashin A 2007 Main parameters of seed reproduction system in population of some Asteraceae species in connection with their antropotolerance. *Problems of Botany of South Siberia and Mongolia. VI International Scientific and Practical Conference* 6 156-158
[5] Kashin A S and Demochko Y A 2003 Seed productivity in apomictic and sexual populations of some species of Asteraceae. *Botanical Journal* 88(8) 42-56
[6] Kazakova M V 2017 Indication potential of plant species of universal importance (on the example of the Ob basin). *Vestnik (Herald) of Tver State University. Ser.: Biology and ecology* 2 287-295
[7] Nazarenko A S 2009 Features of the development of *Jurinea centauroides* Klokov at the early stages of ontogenesis. *Industrial Botany* **9** 84-89
[8] Notov A A and Zhukova L A 2019 The concept of ontogenesis polyvariance and modern evolutionary morphology. *Biology Bulletin* **46(1)** 47-55
[9] Osmanova G O and Zhivotovsky L A 2020 Ontogenetic spectrum as an indicator of the state of plant populations. *Proceedings of the Russian Academy of Sciences. Biological Series* **2** 144-152
[10] Ostapko V M and Ibatulina Y V 2008 *Structure of cenopopulations of steppe species in the southeast of Ukraine* (Donetsk: Weber) 268
[11] Prikhodko S A, Ibatulina Y V and Ostapko V M 2013 *Ecological-demographic structure of natural and introdution cenopopulations as an indicator of the state of steppe phytocenoses* (Donetsk) 309
[12] Smirnova O V, Palenova M M and Komarov A S 2002 Ontogeny of different life forms of plant and specific features of age and spatial structure of their populations. *Russian Journal of Developmental Biology* **33** 1-10
[13] Zhivotovsky L A 2001 Ontogenetic states, effective density and classification of plant populations. *Russian Journal of Ecology* **1** 3-7
[14] Zhukova L A 2001 Diversity of ontogenic pathways in plant populations. *Russian Journal of Ecology* **32(30)** 151-158
[15] Vakhrusheva L P and Vasilieva V S 2014 Signs of age states and age structure of the cenopopulations of *Jurinea roegneri* K.Koch (Jurinea sordida Stev.) in the phytocenoses of the Foothill Crimea. *Notes of V.I. Vernadsky Tavrida National University Biology, Chemistry Series* **27(66)(5)** 19-28