

POST-FIRE RESTORATION OF PLANT COMMUNITIES WITH *PAEONIA TENUIFOLIA* IN THE KHVALYNSKY NATIONAL PARK (RUSSIA)

Guzyaliya F. Suleymanova^{1,2,*}, Vladimir A. Boldyrev^{2,**}, Victor A. Savinov¹

¹*Khvalynsky National Park, Russia*

*e-mail: suleymanovagf@mail.ru

²*Saratov State University, Russia*

**e-mail: boldyrev52@bk.ru

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The paper considers indicators of the dynamics of plant communities with *Paeonia tenuifolia* before and after fire impact. Studies were conducted in the Khvalynsky National Park (forest-steppe zone of Russia) in 2008–2018. The authors conducted a complex study in burned and unburned plant communities. An assessment of the effects of fire impact and the development of a post-fire action plan were considered in the Protected Area. The plant community *Paeonia tenuifolia* + *Calamagrostis epigejos* + *Adonis vernalis* – *Potentilla volgarica* burned down in 2009. The plant community *Paeonia tenuifolia* + *Stipa pennata* + *Adonis vernalis* – *Anemone sylvestris* was unburned. To characterise plant communities with *Paeonia tenuifolia* and its coenopopulations, we used standard geobotanical description methods. Sixty seven vascular plant species were part of the post-fire phytocoenosis. Of them, 14 species are included in the Red Data Book of the Saratov region. Changes in the post-fire plant community have occurred in the following order: 1) *Paeonia tenuifolia* + *Calamagrostis epigejos* + *Adonis vernalis* – *Stipa pennata* (in 2008) → 2) *Paeonia tenuifolia* + *Elymus repens* + *Stipa pennata* + *Adonis vernalis* + *Thalictrum simplex* (in 2010) → 3) *Paeonia tenuifolia* – *Stipa pennata* – *Calamagrostis epigejos* + *Festuca valesiaca* + *Phleum pratense* + *Poa bulbosa* + *Prunus tenella* (in 2011) → 4) *Paeonia tenuifolia* + *Adonis vernalis* + *Stipa pennata* (in 2015, 2017, 2018). After the fire influence on a plant community, the following changes took place: 1) annuals and ruderal plant species appeared and increased their abundance; 2) the ratio of dominant species has changed. In 2012–2018, the phytocenotic role of *Calamagrostis epigejos* decreased, while the coverage and abundance of *Stipa pennata* increased at the same period. The abundance dynamics of *Paeonia tenuifolia* decreased in 2010, while in 2015–2018, its value gradually increased. The species richness of the post-pyrogenetic plant community varied from 20 species in the first post-fire year to 38 species in the last study year. In the first post-fire year, the families Poaceae (six species), Leguminosae plants (three species), Rosaceae plants (three species) occupied the leading positions. During the post-pyrogenetic succession, the dominant position of the listed families was not changing. Species of Compositae, Poaceae, Ranunculaceae families prevailed in the unburned plant community. Steppe plants dominated in the post-fire plant community: *Stipa pennata*, *Adonis vernalis*, and *Paeonia tenuifolia*. The leading ecologic-coenotic groups were steppe plants (70%), meadow plants (16%), forest plants (5%), and ruderal plants (9%). Weed-steppe plants were indicators of habitat disturbance by human activities. Among weed-steppe plants, there were *Arenaria serpyllifolia*, *Viola rupestris*, *Erysimum canescens*, *Verbascum lychnitis*. Gradient analysis of environmental conditions showed that the highest value of the vitality index (IVC = 1.15) corresponds to the best conditions for the growth and survival of the *Paeonia tenuifolia* population in the post-fire community. In the control site, the vitality index (IVC = 0.85) corresponded to unfavourable conditions for plant development. We studied the age spectra of the natural *Paeonia tenuifolia* populations in the burned and unburned communities. We showed that both populations were normal, complete, and young. The fire-damaged populations were younger than the populations in the unburned communities. We suggest the need of comprehensive monitoring studies to properly assess the fire effects and subsequent management actions for the vegetation restoration after fire influence.

Key words: age spectrum, forest-steppe zone, plant community, plant population, Protected Area, pyrogenic succession, rare species, *Stipa pennata*

Introduction

The factors of negative impact on ecosystems in Protected Areas (PAs) are well known. These are wildfires (Batista et al., 2018; Brooke et al., 2018), logging (Remis & Jost Robinson, 2012; Slaght & Surmach, 2016), pollution (Kataev, 2017; Rodríguez-Jorquera et al., 2017), mining (Ferreira et al., 2014; Armendáriz-Villegas et al., 2015), road network development and construction (Garriga et al., 2012; Slaght & Surmach, 2016). The pyrogenic effect is long-term and has had an adverse effect on

biological diversity for decades. It changes the composition and ratio of the areas of natural complexes (Lukyanova & Lukyanov, 2004; Perevoznikova et al., 2007). It also affects the abundance of many plant and animal species (Kuleshova & Korotkov, 2010; Goud, 2017). Fires are often catastrophic phenomena. They cause the death of plant and animal populations, ecosystems as a whole (Stepanitskiy & Shestakov, 2005; Pereira et al., 2016; Batista et al., 2018). Fires pose especially a serious threat to rare and protected (i.e. included in Red Data Books)

plant species, the number of which is usually small (Bystrushkin, 2018). For a long time, Russian programmes of environmental monitoring included the studies of the natural ecosystem dynamics and their separate components associated with wildfires in PAs. In particular, they focused on the populations of Red Data Book species. And this topic has not lost its relevance until the present days (Isaeva, 2000; Malysheva & Malakhovsky, 2000; Kuleshova & Korotkov, 2010; Ilyina, 2011; Maslennikov & Maslennikova, 2011). The fire-caused change of the ecosystem is a pyrogenic succession (Komarova, 1980, 2009; Rozanov, 1999; Berezina & Afanasyeva, 2009). There are numerous studies focusing on the processes of pyrogenic succession of plant communities at different stages (Morozov, 1912; Curry & Fons, 1940; Korchagin, 1954; Belov, 1973; Rodin, 1981; Komarova, 1991, 1999, 2011; Agee, 1993; Isaeva, 2000; Popov, 2000; Oparin & Oparina, 2003; Ishutin, 2004; Golubtsova, 2012; Dusaeva, 2017). There is a lack of published data on this issue. According to some authors (e.g., Smelyanskiy et al., 2015), a fire in the steppe ecosystems does not lead to pyrogenic succession, but only changes the coenotic activity. It also causes pyrogenic fluctuations of the plant community including the projective cover of some species. There is especially little information about the attitude to the fire impact on population status of certain plant species.

The flora of the Saratov region consists of 1741 species of vascular plants (Elenevskiy et al., 2008). Of them, 285 species are listed in the Red Data Book of Saratov region (2006), including 42 species included in the Red Data Book of the Russian Federation (2008). Plant communities, which include Red Data Book species, are unique, sometimes one of a kind. *Paeonia tenuifolia* L. is one of the rare and protected species. This is a tuberiferous short-rhizome herbaceous perennial plant, optional calciphile, and a representative of Mediterranean steppe vegetation (Red Data Book of Saratov region, 2006). It is included in the Red Data Book of Saratov region (2006) with category 2 (V) – vulnerable, and listed in the Red Data Book of the Russian Federation (2008) with category 2B – declining in number. The species is also listed in the Appendix 1 of the Bern convention (Belousova et al., 2008). *Paeonia tenuifolia* has a discontinuous distribution area (Nosova, 1973). In the southeast of European Russia, its natural range is limited by the River Volga. In the south, its range borders with the North Caucasus and the Crimean peninsula. In the west, the distribution area is interrupted,

and *Paeonia tenuifolia* can be found in Ukraine and Central Europe (Romania, Bulgaria), in the southwest of Eurasia, in Asia Minor and Iran. The peculiarities of the ecological-phytocenotic organisation and the island character of the range indicate its relictness.

Along the southern limits of the forest-steppe on the right bank of the River Volga, the species inhabits open areas, pine (*Pinus sylvestris* L.) forests on the limestone outputs, chalky-covered sods on slopes with a northern exposure (Nosova, 1973). In the Saratov region, *Paeonia tenuifolia* is distributed in some districts located on the right bank of the River Volga: Atkarsky district, Balashovsky district, Volsky district, Kalininsky district, Krasnogarmeysky district, Khvalynsky district, Saratovsky district. The most significant localities of this Red Data Book species are known on the Volsky-Khvalynsky ridge (Red Data Book of Saratov region, 2006; Elenevskiy et al., 2008). *Paeonia tenuifolia* grows in *Stipa pennatae* – *Festucosa valesiaca* – *Herbosa* plant communities, steppe meadows, forest edges, shrub communities and on the sides of valleys, and on sandy steppes and hills (Red Data Book of Saratov region, 2006).

One of the necessary measures for the *Paeonia tenuifolia* protection is the study of its population status, implemented through the monitoring programme of plant communities in the Khvalynsky National Park. Since 2007, in the Khvalynskiy district, the studies of the status of *Paeonia tenuifolia* populations have been carried out (Suleymanova, 2010).

The aim of this current study was to identify the post-fire restoration patterns of plant communities with *Paeonia tenuifolia*. The following tasks were to be solved: 1) to characterise the natural plant communities after fire impact; 2) to analyse the plant community dynamics in 2008–2018; 3) to investigate the morphological traits of *Paeonia tenuifolia* individuals, floristic and coenotic composition of the plant community, age structure of the *Paeonia tenuifolia* population; 4) to estimate the conservation significance of the studied fire-damaged communities in comparison to the similar unburned plant community.

Material and Methods

Field studies have been carried out in 2008–2018. In order to characterise plant communities with *Paeonia tenuifolia* and its coenopopulations (Fig. 1), we used standard methods of geobotanical description (Tarasov, 1981; Matveev, 2006; Mirkin & Naumova, 2012).

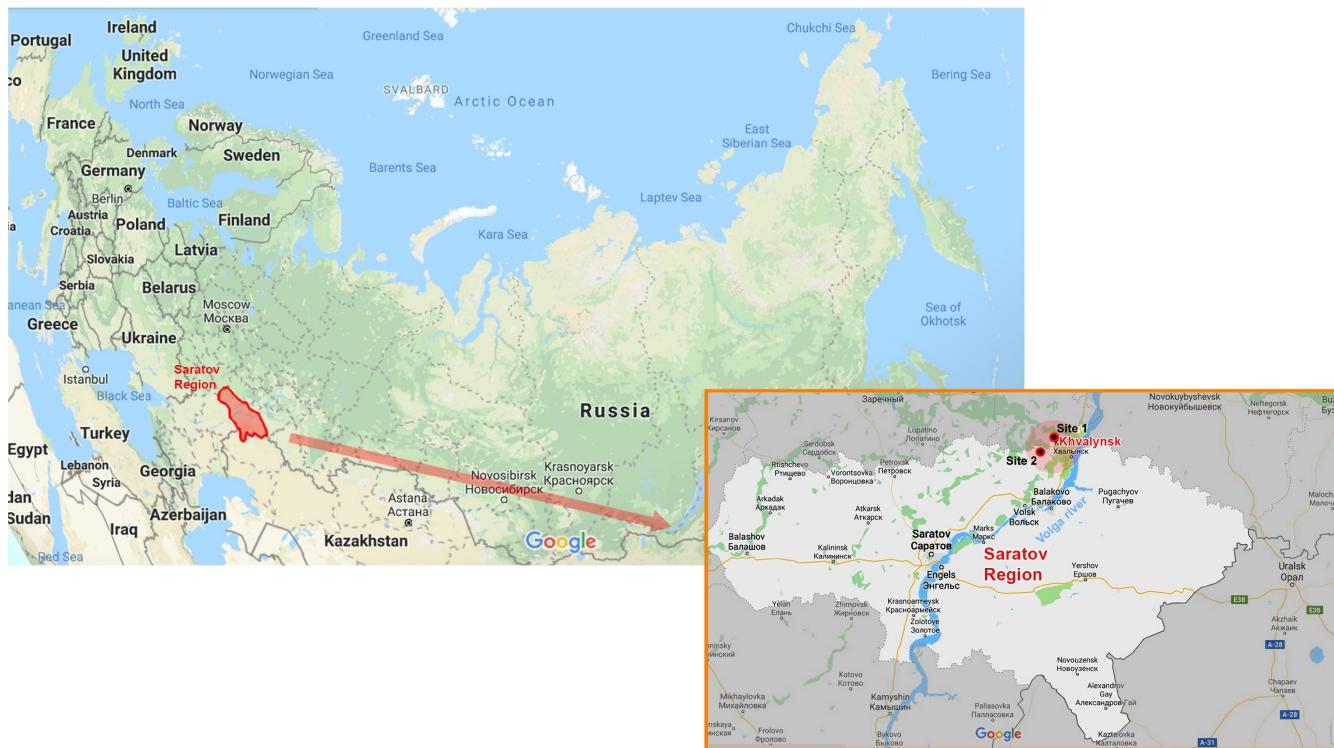


Fig. 1. Location of study sites in the Khvalynsky National Park, Saratov region, Russia. Site 1 – the post-fire plant community *Paeonia tenuifolia* + *Calamagrostis epigejos* + *Adonis vernalis* – *Potentilla volgarica* on the southern slope of mountain Pi-che-Panda in the vicinity of the village Staraya Lebezhayka, Khvalynsky district. Site 2 – unburned plant community *Paeonia tenuifolia* + *Stipa pennata* + *Adonis vernalis* – *Anemone sylvestris*, Sosnovo-Mazinskoe forestry.

The Khvalynsky National Park is located in the northern part of the Saratov region in Khvalynsky district at the border of the Middle Volga region and Lower Volga region. It occupies the remnant massif of Khvalynskye hills of the Volga Upland and part of the River Tereshka Valley in the vicinity of the town of Khvalynsk (Makarov, 2008). In accordance with the botanical-geographical division, the region under the study belongs to the Central Russian (Upper Don) subprovince of the Eastern European forest-steppe province of the Euro-Asian steppe region. Zonal vegetation types are deciduous forests and meadow steppes (Tarasov, 1977). Forests are confined to the highlands, on the plains yielding to the meadow steppes. The National Park area is 260.37 km². It is covered mainly by forests. The buffer zone of the National Park «Khvalynsky» is 1148.0 km².

There are both true steppes and meadow steppes in the buffer zone of the Khvalynsky National Park. The steppe component dominates (60%) in the forest-steppes of the Khvalynsky National Park. Forests and meadow steppes extend from the northeast to the southwest of the Protected Area. In meadow steppes, zonal plant communities are phytocoenoses with domination of *Stipa pennata* L., *Stipa capillata* L. These plant communities are *Stipeta pennatae* – *Bromopsisosa riparia* – *Pluriherbosa*, *Stipeta capillatae* – *Festucosa valesiaca* – *Herbosa*, and *Stipeta*

pennatae – *Festucosa valesiaca* – *Herbosa*. They form the narrow belts, which are almost always located directly near the forest areas, occupying dry ecotopes along slopes on chernozems. Sometimes they are distributed along small areas in the lower parts of the slopes. Meadow steppes have a rich species composition (60–70 species). These plant communities have a complex horizontal and vertical structure. Shrubs play a significant role in some of these plant communities. However, they usually do not form a layer. The main coenose-forming species are *Stipa pennata* and *Stipa capillata* and rhizomatous cereals (*Bromopsis riparius* Rehmann, *Poa angustifolia* L.). There are the following steppe cereals: *Festuca valesiaca* Schleich. ex Gaudin, *Koeleria pyramidata* P. Beauv., *Phleum phleoides* (L.) H. Carst., but their role is not high in formation of plant communities. The meadow-steppe herbaceous species (*Fragaria viridis* Weston, *Securigera varia* (L.) Lassen, *Galium verum* L., *Salvia nemorosa* L.) are widely represented (Malysheva & Malakhovsky, 2008).

The climate of the Khvalynsky National Park is continental. The summer is warm and dry. The winter is moderately cold and snowless. Daily, seasonal and annual fluctuations in the temperature of air and soil are typical for the weather conditions. The average annual temperature ranges from 5.2°C to 7.9°C. The average January isotherm is -13°C. The average

July temperature is +20.5°C. The relative humidity is 70%, the average annual precipitation is 425–450 mm (Anikin, 2013). To study pyrogenic changes, the following plant communities were selected:

1) *Paeonia tenuifolia* + *Calamagrostis epigejos* (L.) Roth + *Adonis vernalis* L., with *Potentilla volgarica* Juz. microgroups occupied the middle and lower parts of the southern slope of the mountain Piche-Panda in the vicinity of the village Staraya Lebezhayka, Khvalynsky district (52.65478 N, 47.86317 E), 185 m a.s.l. The total projective cover was 70%. The projective cover of *Paeonia tenuifolia* was 40%. The species number in the plant community was 67. The phytocoenosis was polydominant. The following co-dominants were found: *Stipa pennata*, *Paeonia tenuifolia*, *Adonis vernalis*. The soil is sod-calcareous.

On 8 May 2009, 3 km west of the village Staraya Lebezhayka (Khvalynsky district of the Saratov region), a fire broke out in the forest. The cause of the ignition was an unextinguished picnic campfire. A crown fire lasted for several hours and spread over an area of 0.5 km². It reached the height of about 20 m. The wildfire was also caused by steady dry weather conditions for almost two weeks, as the last precipitation (1.3 mm) before the fire dates back to 22 April. The average daily air temperature on 7 May was +16.7°C. The maximum value reached +22.7°C. The wind was 6–12 m/s. It also contributed to the fire spread. The consequences of the fire impact were catastrophic. The forest on the west of the mountain Piche-Panda (Volskoe forestry) was burned down. The fire spread to the east was stopped by the field road and the guard service of the Khvalynsky National Park. A botanical description of the burned steppe area was made a week later. Since 2008, a permanent study plot has been located on this site to monitor the status of the plant community with *Paeonia tenuifolia*. Therefore, we had an opportunity to compare its status before and after fire influence.

2) Unburned plant community *Paeonia tenuifolia* + *Stipa pennata* + *Adonis vernalis* – *Anemone sylvestris* L. is located on a site 300 m from the forest of the Sosnovo-Mazinskoe forestry (52.32602 N, 47.92722 E). The fire break was located from the north of the plant community. The total projective cover was 80%, including up to 30% projective cover of *Paeonia tenuifolia*. The plant community consisted of 69 species. This plant community is polydominant with the following co-dominants: *Stipa pennata*, *Paeonia tenuifolia*, *Adonis vernalis*, *Anemone sylvestris*. The soil is sod-carbonate. The unburned plant community was located under similar physical-geographical conditions with the unburned one. Therefore, we used

these data for its comparison with the burned plant community vegetation.

We studied the plant communities according to the standard methodics (Yaroshenko, 1969; Voronov, 1973; Mirkin & Rosenberg, 1983; Mirkin & Naumova, 2012). We estimated the species participation in each plant community by indicating the percentage of projective cover (Tarasov, 1981). To estimate the frequency of occurrence/coverage of a species, we used the scale of Drude (1890). The symbols are as follows: soc (socialis) – dominant species, frequency of occurrence/coverage exceeds 90%; cop₃ (copiosus) – abundant species, frequency of occurrence/coverage is up to 80%; cop₂ – species is represented by numerous individuals, frequency of occurrence/coverage is up to 20%; cop₁ – frequency of occurrence/coverage is up to 4%; sp (sparsus) – frequency of occurrence/coverage about 0.8%; sol (solitarus) – scanty individuals, frequency of occurrence/coverage not exceeds 0.16%; un (unicum) – single individual.

We defined phenophases and phenological events (Haggerty & Mazer, 2008) using the BBCH-scale (Zadoks et al., 1974; Meier, 2001; Meier et al., 2009; Polikarpova & Makarova, 2016). This system is used in Europe for a uniform coding of phenologically similar plant growth. For each *Paeonia tenuifolia* individual, we determined the following morphological parameters: plant height, corolla diametre, number of leaves, leaf length.

We determined the following coenotic groups according to Belgard (1950), and Albitskaya (1960): stepants (steppe plants), sylvants (forest plants), paludants (marsh plants), pratants (meadow plants), ruderants (wasteland plants), stepants-ruderants (weed-steppe plants), silvants-ruderants (weedy forest plants), pratants-ruderants (weedy meadow plants).

To estimate the demographic characteristics of *Paeonia tenuifolia* in a population, we defined the follow indices: recovery index – I_{recovery} (Glotov, 1998), replacement index – I_{replacement}, age index – I_{age} (Δ) (Uranov, 1975), efficiency index – I_{efficiency} (ω) (Zhivotovsky, 2001), index of species plasticity – ISP (IVC_{max} / IVC_{min}) (Ishbirdin & Ishmuratova, 2004).

To assess the species similarity of the studied phytocoenoses, we used the Jaccard similarity index (Jaccard, 1901). For protected species (i.e. listed in the Red Data Book of Saratov region (2006)), we calculated the value of conservation significance R according to Bednova (2004). We visually determined the ontogenetic status of *Paeonia tenuifolia* individuals by determining the following age classes based on morphometric traits: juvenile (j), immature (im), virginile (v), generative (g₀, g₁, g₂,

g₃) and post-generative senile (s), and subsenile (ss) age classes (Rabotnov, 1983; Mozgovaya et al., 2007; Serikova et al., 2013).

The statistical analysis has been processed by conventional methods using Statistica 6.0 software. We used Maevskiy (2014) for identifying plants. Scientific names of the plant species are given according to The Plant List (2019).

Results and Discussion

During the fire on 8 May 2009, dry grass, dead ground cover and aboveground parts of shrubs got

burnt. It seemed that the fire caused irreparable damage to the plant community. On 15 May 2009, we found that an aspect was black with bright-green large dots represented by vegetative and flowering plants on the study plots. These were mainly represented by short-rooted perennials *Thalictrum simplex* L., *Vincetoxicum hirundinaria* Medik., *Potentilla incana* P. Gaertn., B. Mey. & Scherb., and *Potentilla volgarica*. The floristic composition of the plant community *Paeonia tenuifolia* + *Calamagrostis epigejos* + *Adonis vernalis* before the fire impact is demonstrated in Table 1.

Table 1. The floristic composition and characteristics of the plant community *Paeonia tenuifolia* + *Calamagrostis epigejos* + *Adonis vernalis* – *Stipa pennata* before the fire impact (15.05.2008), Khvalynsky National Park, Saratov region, Russia

Species	Abundance	Cover, %	Height, cm	Growth stage	
				BBCH code	Phenological event title
Shrubs					
<i>Prunus tenella</i> Batsch.	sol	< 1	20–25	12–13	3–5 leaves unfolded
<i>Cerasus fruticosa</i> (Pall.) Woronow.	un	< 1	20–30	12–13	3–5 leaves unfolded
Semishrubs					
<i>Alyssum lenense</i> Adams.	sol	< 1	5–10	65	Full flowering
<i>Onosma simplicissima</i> L.	sol	1	20–25	12–13	3–5 leaves unfolded
Perennial herbs					
<i>Astragalus buchtormensis</i> Pall.	sol	< 1	18–10	65	Full flowering
<i>Adonis vernalis</i> L.	sp	3	20–25	86 / 10b	First ripe fruits
<i>Achillea setacea</i> Waldst. & Kit.	un	< 1	5–10	12–13	3–5 leaves unfolded
<i>Securigera varia</i> (L.) Lassen	un	< 1	10–15	12	3 leaves unfolded
<i>Calamagrostis epigejos</i> (L.) Roth.	cop ₁	5–15	15–20	12	3 leaves unfolded
<i>Carex praecox</i> Schreb.	sol	< 1	5–10	12–13	3–5 leaves unfolded
<i>Psephellus marschallianus</i> (Spreng.) K. Koch	un	+	5–10	60/13	First flower open, 5 leaves unfolded
<i>Eremogone longifolia</i> (M. Bieb.) Fenzl.	sol	< 1	31	69–71	End of flowering, witerly ripe
<i>Euphorbia esula</i> subsp. <i>tommasiniana</i> (Bertol.) Kuzmanov	sol	< 1	15	12–13	3–5 leaves unfolded
<i>Galium octonarium</i> (Klokov) Pobed.	sol	< 1	15–20	12	3 leaves unfolded
<i>Potentilla volgarica</i> Juz.	sol	< 1	10–30	65	Full flowering
<i>Plantago urvillei</i> Opiz	sol	< 1	5	11	Leaf unfolded
<i>Paeonia tenuifolia</i> L.	cop ₃	25–50	5–25 / 20–40	81–86	First ripe fruits
<i>Polygala nicaeensis</i> subsp. <i>mediterranea</i> Chodat	un	< 1	15–20	12–13	3–5 leaves unfolded
<i>Salvia tesquicola</i> Klok. & Pobed.	sol	< 1	5–10	12–13	3–5 leaves unfolded
<i>Salvia nutans</i> L.	sol	< 1	5–10	12	3–5 leaves unfolded
<i>Seseli libanotis</i> (L.) W. D. J. Koch.	un	< 1	5–10	12	3–5 leaves unfolded
<i>Stipa pennata</i> L.	sol	5	30–55	65	Full flowering
<i>Taraxacum campylodes</i> G. E. Haglund.	sol	< 1	5–10	11	Leaf unfolded
<i>Thalictrum simplex</i> L.	sol	< 1	25	11	Leaf unfolded
<i>Vincetoxicum hirundinaria</i> Medik.	sol	< 1	25–30	12–13	3–5 leaves unfolded
<i>Veronica spicata</i> subsp. <i>incana</i> (L.) Walters	un	< 1	15	11	Leaf unfolded
Biennials					
<i>Erysimum aureum</i> M. Bieb.	sol	< 1	10–25	12–13	3–5 leaves unfolded
<i>Verbascum lychnitis</i> L.	sol	< 1	5–10	11	Leaf unfolded

Table 1 shows that the species richness of the plant community was 26–28 species before the fire impact. The species density was not exceeding 7–12 species (Fig. 2A). *Paeonia tenuifolia* was the most abundant species. Its projective cover was 40–50%. *Calamagrostis epigejos* made an aspect with a projective cover of 15–20%. The remaining species had a low abundance and projective cover (Table 1). The general aspect was bright-green. We determined three layers in the plant community (Fig. 2B).

The first layer was 40–60 cm in height, consisting mainly of the generative shoots of *Paeonia tenuifolia* (30–40 cm) and *Stipa pennata* (50–60 cm). The projective cover was about 50%. The second layer (20–30 cm in height) was the most productive and viable. It was represented by a large species number of different life forms. Of them, there were shrubs *Prunus tenella* Batsch, *Cerasus fruticosa* Pall.; semishrubs: *Onosma simplicissima* L., *Alyssum lenense* Adams; perennials: *Adonis vernalis*, *Potentilla volgarica*, *Thalictrum simplex*, *Vincetoxicum hirundinaria*. There were no annual plants. The projective cover was about 30%. The third layer was 5–10 cm in height. It was represented mainly by leaf rosettes of perennial herbs (*Plantago urvillei* Opiz, *Salvia tesquicola* Klok. & Pobed., *Salvia nutans* L., *Seseli libanotis* (L.) W.D.J. Koch, *Taraxacum campyloides* G.E. Haglund). The projective cover was 15–20%.

In 2009, single vegetative shoots of *Potentilla volgarica*, *Thalictrum simplex*, *Vincetoxicum hirundinaria*, and flowering shoots of *Potentilla*

incana were found on this study site seven days after the fire impact. The projective cover was 3%. The aspect was black with bright-green spots of vegetating herbs.

One year later, the plant community had recovered. However, the weather conditions in 2010 were extreme for the steppe and forest vegetation (Chub, 2011; Lewis et al., 2011a,b; Report, 2011; Solovyov et al., 2011; Polyakova & Melankholin, 2013). Table 2 provides a description of the burnt site one year after the fire.

The plant community showed a greenish aspect with strawy hue and burgundy spots of *Paeonia tenuifolia*. In general, the flora of the plant community consisted of 20 species. There were no annual plants, despite the fact that the fire impact stimulated their germination, and the substrate was updated (Malysheva & Malakhovsky, 2008). The floristic composition decreased quantitatively and changed qualitatively. The shrubs (e.g. *Prunus tenella*) and semishrubs (e.g. *Onosma simplicissima*) recovered. At the same time, the Volga-Don endemic *Asperula tephrocarpa* Czern. ex Popov & Chrshan. appeared. We found that rhizomatous plants, bulbous plants and seeds of annual plants are fire-resistant, with a density of 7–8 species per 1 m². The dominant *Paeonia tenuifolia* and co-dominant *Elymus repens* (L.) Gould had a maximum projective cover. Other plant species have low values of both abundance and projective cover. The newly formed vegetative cover was fairly uniform. The vertical structure of the plant community was on an initial development stage. The total projective cover was 60%.

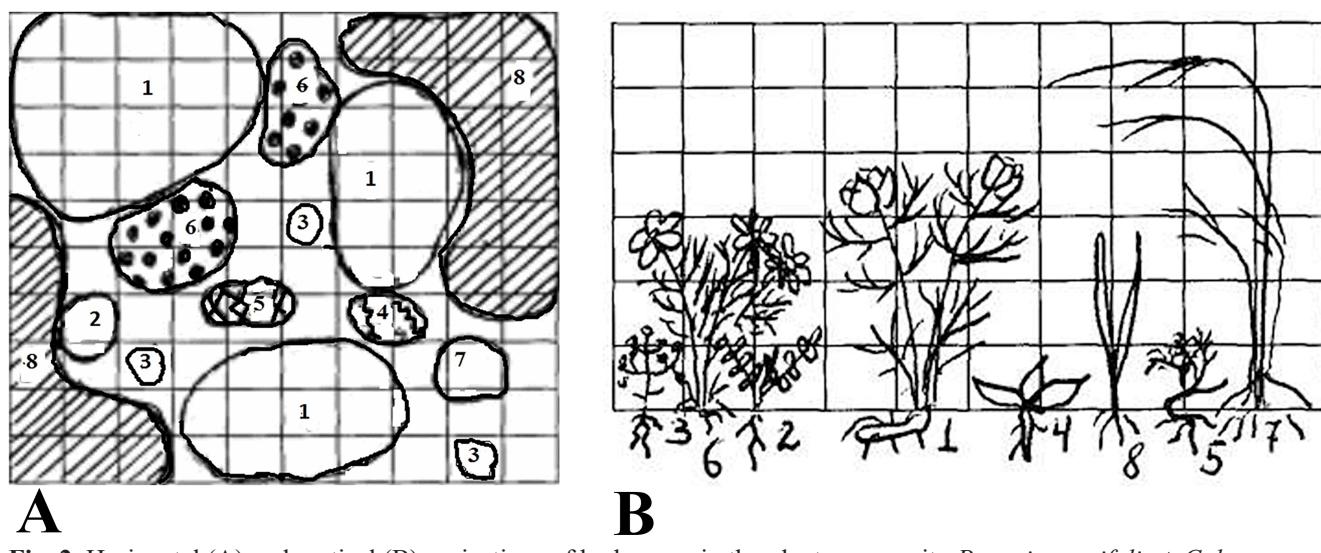


Fig. 2. Horizontal (A) and vertical (B) projections of herb cover in the plant community *Paeonia tenuifolia* + *Calamagrostis epigejos* + *Adonis vernalis* before the fire impact (15.05.2008) in the Khvalynsky National Park, Saratov region, Russia (area: 1 m²). Designations: 1 – *Paeonia tenuifolia*, 2 – *Astragalus buchtormensis*, 3 – *Erysimum aureum*, 4 – *Verbascum lychnitis*, 5 – *Onosma simplicissima*, 6 – *Adonis vernalis*, 7 – *Stipa pennata*, 8 – *Calamagrostis epigejos*.

Table 2. Floristic composition and characteristics of the plant community *Paeonia tenuifolia* + *Elymus repens* + *Stipa pennata* + *Adonis vernalis* + *Thalictrum simplex* investigated one year after the fire impact (12.05.2010), Khvalynsky National Park, Saratov region, Russia

Species	Abundance	Cover, %	Height, cm	Growth stage	
				BBCH code	Phenological event title
Shrubs					
<i>Prunus tenella</i> Batsch.	sol	< 1	15	12–13	3–5 leaves unfolded
Semishrubs					
<i>Onosma simplicissima</i> L.	sol	< 1	20	12–13	3–5 leaves unfolded
<i>Asperula tephrocarpa</i> Czern. ex Ledeb.	un	< 1	8	12–13	3–5 leaves unfolded
Perennial herbs					
<i>Adonis vernalis</i> L.	sp-gr	2	20	81 / 10a	First ripe fruits
<i>Astragalus buchtormensis</i> Pall.	un	< 1	10–20	65	Full flowering
<i>Psephellus marschallianus</i> (Spreng.) K. Koch	un	< 1	8	60, 13	First flower open, 5 leaves unfolded
<i>Securigera varia</i> (L.) Lassen	sol	1	10	12	3 leaves unfolded
<i>Carex praecox</i> Schreb.	sol	< 1	20	12–13	3–5 leaves unfolded
<i>Elymus repens</i> (L.) Gould	cop ₃	30	20	11	Leaf unfolded
<i>Gagea bulbifera</i> (Pall.) Salisb.	un	< 1	10–15	81–86	First ripe fruits
<i>Galium tinctorium</i> L.	un	< 1	20	11	Leaf unfolded
<i>Galium verum</i> L.	un	< 1	10–15	60	First flower open, 5 leaves unfolded
<i>Paeonia tenuifolia</i> L.	cop ₃	35	10–25 / 20–50	65, 19	Full flowering / 9 or more leaves unfolded
<i>Potentilla incana</i> P. Gaerth., B. Mey. & Scherb.	un	< 1	10	65	Full flowering
<i>Potentilla volgarica</i> Juz.	sol	< 1	15–25	65	Full flowering
<i>Salvia nutans</i> L.	sol	1	10	51, 15–16	First flower buds visible / 6 or more leaves unfolded
<i>Stipa pennata</i> L.	cop ₁	10	20–60	65	Full flowering
<i>Thalictrum simplex</i> L.	sol	2	30	51, 15–16	First flower buds visible / 6 or more leaves unfolded
<i>Vincetoxicum hirundinaria</i> Medik.	sol	< 1	25–35	51, 19	First flower buds visible / 9 or more leaves unfolded
Biennials					
<i>Verbascum lychnitis</i> L.	sol	< 1	15	10	Leaf unfolded

Thus, the first post-fire restoration stage was manifested by the change of the 2008 plant community *Paeonia tenuifolia* + *Calamagrostis epigejos* + *Adonis vernalis* – *Stipa pennata* into the 2010 plant community *Paeonia tenuifolia* + *Elymus repens* + *Stipa pennata* + *Adonis vernalis* + *Thalictrum simplex*. However, this phytocoenosis was not richer in species richness and had all the features contributing to the formation of a more productive plant community. However, further 2011 observations demonstrated a start of changes in this phytocoenosis. So, in 2011 the species composition of the fire-damaged plant community increased to 31 species (Table 3).

The aspect was straw hue-greenish with burgundy spots. It was formed by dead cereals (straw colour) and *Paeonia tenuifolia* (green colour with burgundy spots). According to life-form classification, there were one shrub (*Prunus tenella*), two semishrubs (*Onosma simplicissima*,

Asperula tephrocarpa), and 24 perennial species. The cereals were represented by various values of a projective cover. For example, the projective cover of *Phleum pratense* L., *Poa bulbosa* L., and *Festuca valesiaca* was 10–15%, while the projective cover of *Stipa pennata*, and *Calamagrostis epigejos* was 30–40%. Annual plants appeared (*Draba nemorosa* L., *Androsace maxima* L., *Alyssum linifolium* Stephan ex Willd.). In this plant community, the density was 8–13 species per 1 m² (Fig. 3).

We found a high projective cover for the dominant *Calamagrostis epigejos*. The impact of both fire and drought caused the elimination of the biennial *Erysimum aureum* M. Bieb., and the perennials *Veronica spicata* subsp. *incana* (L.) Walters, *Salvia tesquicola*, *Plantago urvillei*, *Seseli libanotis*, *Polygala nicaeensis* subsp. *mediterranea* Chodat, *Psephellus marschallianus* (Spreng.) K. Koch, and *Alyssum lenense*.

Table 3. Floristic composition and characteristics of the plant community *Paeonia tenuifolia* – *Stipa pennata* – *Calamagrostis epigejos* + *Festuca valesiaca* + *Phleum pratense* + *Poa bulbosa* + *Prunus tenella* investigated two years after the fire impact (20.05.2011), Khvalynsky National Park, Saratov region, Russia

Species	Abundance	Cover, %	Height, cm	Growth stage	
				BBCH code	Phenological event title
Shrubs					
<i>Prunus tenella</i> Batsch.	sol	5	20	12–13	3–5 leaves unfolded
Semishrubs					
<i>Onosma simplicissima</i> L.	sol	5	20	12–13	3–5 leaves unfolded
<i>Asperula tephrocarpa</i> Czern. ex. Popov & Chrshan.	un	+	10	12–13	3–5 leaves unfolded
Perennial herbs					
<i>Adonis vernalis</i> L.	sol	3	30	19	All leaves unfolded
<i>Astragalus buchtormensis</i> Pall.	sol	< 1	15	65	Full flowering
<i>Achillea setacea</i> Waldst. & Kit.	sol	< 1	10	12–13	3–5 leaves unfolded
<i>Calamagrostis epigejos</i> (L.) Roch.	cop ₃	35–40	20	12	3 leaves unfolded
<i>Carex praecox</i> Schreb.	sol	< 1	20	12–13	3–5 leaves unfolded
<i>Eremogone longifolia</i> (M. Bieb.) Fenzl.	sol	< 1	31	69, 81–86	End of flowering, First ripe fruits
<i>Euphorbia esula</i> subsp. <i>tommasiniana</i> (Bertol.) Kuzmanov	sol	< 1	15	19	All leaves unfolded
<i>Gagea bulbifera</i> (Pall.) Salisb.	un	+	11	69, 81–86	End of flowering, First ripe fruits
<i>Globularia punctata</i> Lapeyr.	sol	< 1	10	12–13	3–5 leaves unfolded
<i>Gypsophila altissima</i> L.	un	+	10	12–13	3–5 leaves unfolded
<i>Festuca valesiaca</i> Schleich. ex. Gaudin	cop ₁	10–15	28–29	69, 81–86	End of flowering, First ripe fruits
<i>Hedysarum grandiflorum</i> Pall.	sol	5	10	19	All leaves unfolded
<i>Origanum vulgare</i> L.	sol	< 1	10–15	12–13	3–5 leaves unfolded
<i>Phleum pratense</i> L.	cop ₁	10–15	24	12	3 leaves unfolded
<i>Poa bulbosa</i> L.	cop ₁	10–15	15–26	69, 81–86	End of flowering, First ripe fruits
<i>Potentilla volgarica</i> Juz.	sol	< 1	30	51/19	Fist flower bud visible, all leaves unfolded
<i>Potentilla incana</i> P. Gaerth., B. Mey. & Scherb.	sol	< 1	15	12–13	3–5 leaves unfolded
<i>Paeonia tenuifolia</i> L.	cop ₃	35	10–30, 25–55	69, 81–86	End of flowering, First ripe fruits
<i>Salvia nutans</i> L.	sol	1	15	12–13	3–5 leaves unfolded
<i>Securigera varia</i> (L.) Lassen	sol	< 1	15	12–13	3–5 leaves unfolded
<i>Stipa pennata</i> L.	cop ₃	30	30–60	65	Full flowering
<i>Taraxacum campyloides</i> G. E. Haglund	sol	< 1	10–15	12–13	3–5 leaves unfolded
<i>Thalictrum simplex</i> L.	sol	< 1	30		3–5 leaves unfolded
<i>Vincetoxicum hirundinaria</i> Medic.	sol	< 1	30	51/19	Fist flower bud visible, all leaves unfolded
Biennials					
<i>Verbascum lychnitis</i> L.	sol	< 1	15	12–13	3–5 leaves unfolded
Annuals					
<i>Draba nemorosa</i> L.	un	+	25	69, 81–86	End of flowering, First ripe fruits
<i>Androsace maxima</i> L.	sol	< 1	15	19	All leaves unfolded
<i>Alyssum linifolium</i> Stephan ex. Willd.	un	+	20	65	Full flowering

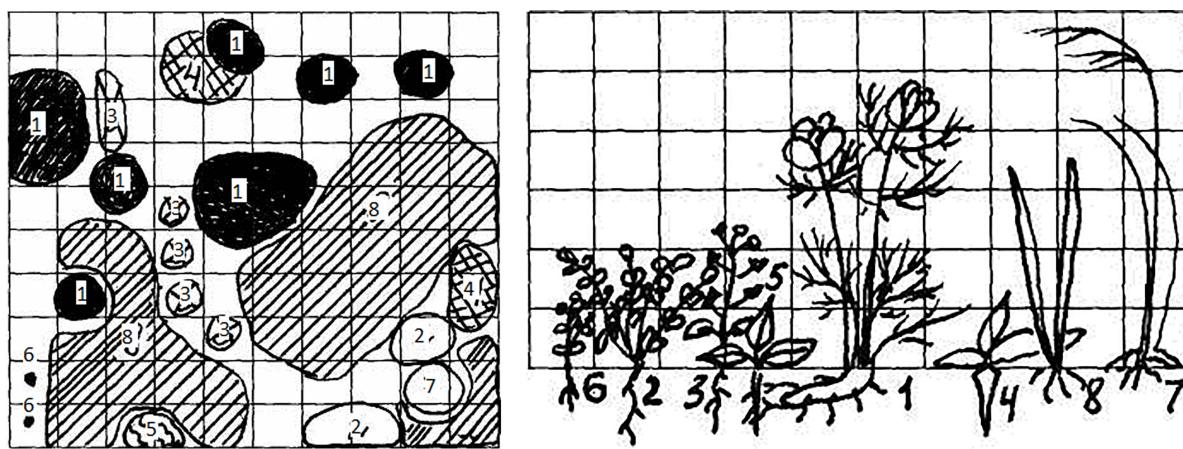


Fig. 3. Horizontal (A) and vertical (B) projections of herb cover in the plant community *Paeonia tenuifolia* – *Stipa pennata* – *Calamagrostis epigejos* + *Festuca valesiaca* + *Phleum pratense* + *Poa bulbosa* + *Prunus tenella* at the burned site two years after the fire impact (20.05.2011), Khvalynsky National Park, Saratov region, Russia (area: 1 m²). Designations: 1 – *Paeonia tenuifolia*, 2 – *Astragalus buchtormensis*, 3 – *Draba nemorosa*, 4 – *Verbascum lychnitis*, 5 – *Salvia nutans*, 6 – *Androsace maxima*, 7 – *Stipa pennata*, 8 – *Calamagrostis epigejos*.

The monocarpic herbaceous *Seseli libanotis* has polycyclic monopodally growing shoots with vertical rhizomes. Due to the peculiarities of its life cycle, this species has a cyclical participation in the composition of plant communities (Rabotnov, 1972; Knapp, 1974). Perhaps, a fire destroyed a few virginile *Seseli libanotis* individuals, which would be consequently turn into a generative stage and produce seeds. So, the cycle of the *Seseli libanotis* development ended on the study site in 2011. Outside the study plot, *Polygala nicaeensis* subsp. *mediterranea*, *Psephellus marschallianus*, *Alyssum lenense* were found. Therefore, they are likely to recover on this study site. A sharp decrease in the competition caused by the fire impact, was contributing to an appearance of R-strategy plants (Grime, 1979) in the burnt area. They are the little competitive vegetatively mobile perennials (e.g. *Euphorbia esula* subsp. *tommasiniana* (Bertol.) Kuzmanov), annuals and biennials (e.g. *Draba nemorosa*, *Androsace maxima*, *Alyssum linifolium* Stephan ex. Willd., *Verbascum lychnitis* L.), as well as weeds, like *Vincetoxicum hirundinaria* and *Taraxacum campylodes*. The presence of R-strategy species indicated a habitat disturbance and possible subsequent changes in structure of the plant community toward reducing the number of R-strategy plants, and ratio of the main phytocoenosis components (Rabotnov, 1972). We also noted the appearance of the following perennials: *Phleum pratense*, *Poa bulbosa*, *Festuca valesiaca*, *Eremogone longifolia* (M. Bieb.) Fenzl, *Potentilla incana*, and *Origanum vulgare* L.. Layers were well distinguishable (Fig. 3B). The first layer consisted of *Stipa pennata* (60 cm in height), vegetative shoots of *Calamagrostis epigejos*, generative shoots of *Paeonia tenuifolia* (30–50 cm in height). The second layer was formed by *Paeonia tenuifolia* vegetative shoots and perennial herbs in both vegetation and flowering stages. The third layer consisted of leaf rosettes of perennials and ephemeral annuals. The total projective cover was 65–70%.

The competition strongly limited the participation of some species in the plant community. The fire-caused competition reduction affected the increase of a coenose-forming role of *Calamagrostis epigejos* in the plant community. Table 4 shows the 2008–2018 plant community dynamics with indication of the species composition and their projective cover.

Over the study years, we found 67 plant species. In 2015, the total projective cover was 70%. The projective cover of *Paeonia tenuifolia* was 35%, while a value of this indicator for *Adonis*

vernalis was 8%. The general aspect was whitish-green with blooming spots of *Paeonia tenuifolia*. This plant community was named as *Paeonia tenuifolia* + *Adonis vernalis* + *Stipa pennata* (*Herbosae* – *Stipa pennatae*). In 2017, the total projective cover was 70%, whereas the projective cover of *Paeonia tenuifolia* was 37%. In 2018, the total projective cover of the plant community was 80%, including 35% of projective cover of *Paeonia tenuifolia*. The general aspect was green with a white mosaic of flowering *Vincetoxicum hirundinaria*. The species composition was the richest in 2017 with 38 plants. In 2018, the number of species in the plant community was 33.

Thus the fire was not so catastrophic, as we expected earlier. Moreover, it had rather positive consequences for the steppe vegetation. The fire impact caused the change from *Paeonia tenuifolia* + *Calamagrostis epigejos* + *Adonis vernalis* – *Stipa pennata* in 2008 to *Paeonia tenuifolia* + *Elymus repens* + *Stipa pennata* + *Adonis vernalis* + *Thalictrum simplex* in 2010. Then the plant community transformed into and the *Paeonia tenuifolia* – *Stipa pennata* – *Calamagrostis epigejos* + *Festuca valesiaca* + *Phleum pratense* + *Poa bulbosa* + *Prunus tenella* in 2011. The phytocoenotic role of *Calamagrostis epigejos* started decreasing from 2012 to 2018. In contrary, the projective coverage of *Stipa pennata* increased twice. Although the projective coverage of *Paeonia tenuifolia* decreased directly after the 2010 fire impact, in 2015–2018 both the projective cover and abundance of *Paeonia tenuifolia* increased. Thus, the *Paeonia tenuifolia* restoration was characterised by an increase in projective cover, abundance and vitality.

Xerophytic and mesoxerophytic plant species of different life forms turned out to be resistant to fire impact. Among them, there are *Prunus tenella*, *Onosma simplicissima*, *Adonis vernalis*, *Astragalus buchtormensis* Pall., *Calamagrostis epigejos*, *Potentilla volgarica*, *Paeonia tenuifolia*, *Stipa pennata*, *Securigera varia*, *Thalictrum simplex*, *Vincetoxicum hirundinaria*, and *Verbascum lychnitis*. These species have been present in the plant community both before and after the fire impact for ten years. These species are called pyrophytes.

Some species participated in the plant community structure from time to time, being present at certain years and being absent in other years. Among them, there are the xeromesophytic hemicryptophytes *Psephellus marschallianus*, *Eremogone longifolia*, and *Galium octonarium* (Klokov) Pobed.

Table 4. Changes of the projective coverage in the plant community *Paeonia tenuifolia* + *Calamagrostis epigejos* + *Adonis vernalis* – *Potentilla volgarica* during study years (2008–2018) in the Khvalynsky National Park, Saratov region, Russia

Species	Projective cover of species per study year, %						
	2008	2009	2010	2011	2015	2017	2018
Shrubs							
<i>Prunus tenella</i> Batsch.	< 1	—	< 1	5	3	—	< 1
<i>Cerasus fruticosa</i> (Pall.) Woronow.	< 1	—	—	—	—	—	—
Semi-shrubs							
<i>Alyssum tortuosum</i> Willd.	—	—	—	—	< 1	< 1	< 1
<i>Alyssum lenense</i> Adams.	< 1	—	—	—	< 1	—	—
<i>Onosma simplicissima</i> L.	1	—	< 1	5	< 1	1	< 1
<i>Asperula tephrocarpa</i> Czern. ex. Popov & Chrshan.	—	—	< 1	+	—	< 1	< 1
Perennials							
<i>Asparagus officinalis</i> L.	—	—	—	—	—	< 1	—
<i>Adonis vernalis</i> L.	3	—	2	3	8	8	1
<i>Astragalus buchtormensis</i> Pall.	< 1	—	< 1	< 1	1	0.9	< 1
<i>Astragalus testiculatus</i> Pall.	—	—	—	—	—	0.9	—
<i>Arenaria serpyllifolia</i> L.	—	—	—	—	—	—	< 1
<i>Achillea setacea</i> Waldst. & Kit.	< 1	—	—	< 1	—	< 1	—
<i>Bromus inermis</i> Leyss	—	—	—	—	—	—	1
<i>Calamagrostis epigejos</i> (L.) Roth.	5–15	—	—	35–40	—	< 1	1
<i>Carex praecox</i> Schreb.	< 1	—	< 1	< 1	< 1	0.3	—
<i>Psephellus marschallianus</i> (Spreng.) K. Koch	+	—	< 1	—	< 1	—	< 1
<i>Elymus repens</i> (L.) Gould	—	—	30	—	—	—	—
<i>Eremogone longifolia</i> (M. Bieb.) Fenzl	< 1	—	—	< 1	—	+	—
<i>Euphorbia esula</i> subsp. <i>tommasiniana</i> (Bertol.) Kuzmanov	< 1	—	—	< 1	—	—	—
<i>Euphorbia glareosa</i> Pall. ex M. Bieb.	—	—	—	—	—	—	< 1
<i>Gagea bulbifera</i> (Pall.) Salisb.	—	—	< 1	+	—	0.9	< 1
<i>Galium tinctorium</i> L.	—	—	< 1	—	< 1	—	< 1
<i>Galium octonarium</i> (Klokov) Pobed.	< 1	—	—	—	—	0.4	< 1
<i>Galium verum</i> L.	—	—	< 1	—	—	—	—
<i>Globularia punctata</i> Lapeyr.	—	—	—	< 1	—	< 1	< 1
<i>Gypsophila altissima</i> L.	—	—	—	+	< 1	—	—
<i>Gypsophila volgensis</i> Krasnova	—	—	—	—	—	< 1	< 1
<i>Festuca valesiaca</i> Schleich. ex Gaudin	—	—	—	10–15	—	1	< 1
<i>Filipendula vulgaris</i> Moench	—	—	—	—	—	< 1	< 1
<i>Hedysarum grandiflorum</i> Pall.	—	—	—	5	—	< 1	< 1
<i>Koeleria pyramidalis</i> P. Beauv.	—	—	—	—	—	—	—
<i>Medicago lupulina</i> L.	—	—	—	—	< 1	—	—
<i>Nonea pulla</i> (L.) DC.	—	—	—	—	—	—	< 1
<i>Origanum vulgare</i> L.	—	—	—	< 1	—	< 1	—
<i>Oxytropis pillosa</i> (L.) DC.	—	—	—	—	< 1	—	—
<i>Phleum pratense</i> L.	—	—	—	10–15	< 1	—	< 1
<i>Plantago urvillei</i> Opiz.	< 1	—	—	—	—	—	—
<i>Poa bulbosa</i> L.	—	—	—	10–15	—	—	—
<i>Potentilla volgarica</i> Juz.	< 1	—	< 1	< 1	—	< 1	< 1
<i>Potentilla incana</i> P. Gaertn., B. Mey. & Scherb.	—	+	< 1	< 1	—	< 1	—
<i>Potentilla recta</i> L.	—	—	—	—	—	< 1	< 1
<i>Polygala nicaeensis</i> subsp. <i>mediterranea</i> Chodat.	< 1	—	—	—	—	—	—
<i>Polygala sibirica</i> L.	—	—	—	—	—	< 1	—
<i>Paeonia tenuifolia</i> L.	25–50	—	35	35	35	37.3	40
<i>Salvia nutans</i> L.	< 1	—	—	1	1	0.9	2
<i>Salvia nemorosa</i> L.	< 1	—	—	—	—	—	—
<i>Seseli libanotis</i> (L.) W.D.J. Koch	< 1	—	—	—	—	—	—
<i>Securigera varia</i> (L.) Lassen	< 1	—	< 1	< 1	—	< 1	< 1
<i>Stipa pennata</i> L.	5	—	—	30	2.4	1.3	2
<i>Stachys recta</i> L.	—	—	—	—	—	< 1	1
<i>Taraxacum campyloides</i> G. F. Haglund.	< 1	—	—	< 1	—	< 1	—
<i>Thalictrum simplex</i> L.	< 1	+	—	< 1	—	< 1	< 1
<i>Trinia multicaulis</i> (Poir.) Schischk.	—	—	—	—	—	1	—
<i>Vincetoxicum hirundinaria</i> Medik.	< 1	+	< 1	< 1	—	< 1	< 1
<i>Veronica austriaca</i> L.	—	—	—	—	< 1	—	< 1
<i>Veronica spicata</i> subsp. <i>incana</i> (L.) Walters	< 1	—	—	—	—	—	—
<i>Veronica verna</i> L.	—	—	—	—	—	< 1	—
<i>Viola rupestris</i> F.W. Schmidt.	—	—	—	—	< 1	—	1
Biennials							
<i>Erysimum aureum</i> M. Bieb.	< 1	—	—	—	—	—	—
<i>Erysimum canescens</i> Roth.	—	—	—	—	—	< 1	—
<i>Verbascum lychnitis</i> L.	< 1	—	< 1	< 1	—	< 1	< 1
<i>Verbascum orientale</i> (L.) All.	—	—	—	—	—	< 1	—
Annuals							
<i>Draba nemorosa</i> L.	—	—	—	+	—	< 1	—
<i>Androsace maxima</i> L.	—	—	—	< 1	—	< 1	—
<i>Alyssum linifolium</i> Stephan ex. Willd.	—	—	—	+	—	—	—
Total	28	4	20	31	18	38	33

Some species were eliminated from the plant community after the impact of the fire and drought. These are perennials (*Salvia nemorosa*, *Polygala nicaeensis* subsp. *mediterranea*, *Plantago urvillei*, *Seseli libanotis*, *Veronica spicata* subsp. *incana*), and the shrub *Cerasus fruticosa*. Most of them were meso-xerophytic and xero-mesophytic hemicryptophytes.

The analysis of the coenotic groups showed the predominance of steppe plants (stepants) (60.85%) in the studied post-fire plant community. Among them, *Stipa pennata*, *Adonis vernalis*, *Paeonia tenuifolia*, *Onosma simplicissima*, and *Galium verum* had the highest projective cover. The meadow plants (pratants) were represented by 17.60% of the species in the plant community. Among them, there are cereals (*Calamagrostis epigejos*, *Bromus inermis* Leyss., *Phleum pratense*), herbaceous perennials (*Securigera varia*, *Thalictrum simplex*, *Filipendula vulgaris* Moench, *Asparagus officinalis* L.). The presence of forest species (sylvants) (6.21%) was to be expected, as the plant community was located near the forest massif. The forest species were represented by the shrub *Prunus tenella*, the herbs *Erysimum aureum*, *Origanum vulgare*, and *Gagea bulbifera* (Pall.) Salisb.

In their study of steppe plant communities with *Hedysarum grandiflorum* Pall. in the Volga Upland region, Lavrentiev & Boldyrev (2016) indicated the following species groups ratio: 64.05% of stepants (steppe plants), 7.84% of pratants (meadow plants), 9.15% of sylvants (forest plants), 18.96%

of ruderants (ruderal plants), ruderants-stepants, ruderant-pratants, rudrants-sylvants. *Hedysarum grandiflorum* inhabited a chalky substrate, where disturbance factors were more pronounced and more complex than under intact conditions. These factors were wind and water erosion, soil freezing in winter due to the absence of dry grass remnants, possible soil salinisation.

The presence of ruderal species (16.80%) (*Vincetoxicum hirundinaria*, *Viola rupestris* F.W. Schmidt, *Arenaria serpyllifolia* L., and *Nonea pulla* (L.) DC.) in the studied plant community with *Paeonia tenuifolia* indicated a certain level of habitat disturbance. The latter resulted of the fire impact and its consequences, moderate grazing, and natural factors (water and wind erosion). The effect of these factors is reduced due to an increase in the general projective cover of the vegetation, soil fertilisation with ash elements, and the general mesophytisation of the *Paeonia tenuifolia* habitat.

In 2018, we found 14 more species new for the plant community: *Alyssum tortuosum* Willd., *Asparagus officinalis*, *Euphorbia glareosa* Pall. ex M. Bieb., *Gypsophila volgensis* Krasnova, *Festuca valesiaca*, *Hedysarum grandiflorum*, *Filipendula vulgaris*, *Nonea pulla*, *Stachys recta* L., *Potentilla incana*, *Trinia multicaulis* (Poir.) Schischk., *Veronica austriaca* L., *Viola rupestris*, and *Verbascum orientale* (L.) All. Although the floristic composition of the studied phytocoenosis had changed, the ratio of coenotic groups remains the same as it was in 2008, i.e. before the fire impact (Table 5).

Table 5. The species number of each coenotic group in the studied plant communities in the Khvalynsky National Park (Saratov region, Russia) in 2008–2018

Coenotic groups	Number of plant species per study year													
	2008		2009		2010		2011		2015		2017			
	number of species	% of total number of plant species	number of species	% of total number of plant species	number of species	% of total number of plant species	number of species	% of total number of plant species	number of species	% of total number of plant species	number of species	% of total number of plant species		
Stepants	16	57	2	50	13	65	18	58	13	72	25	66	19	58
Pratants	4	15	1	25	3	15	4	13	3	17	5	13	7	21
Sylvants	2	7	0	0	2	10	3	10	1	5.5	2	5	2	6
Ruderants	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Stepants-ruderants	2	7	0	0	1	5	3	10	0	0	4	11	3	9
Pratants-ruderants	3	11	0	0	0	0	2	7	0	0	1	2.5	0	0
Sylvants-ruderants	1	3	1	25	1	5	1	3	1	5.5	1	2.5	2	6
Total	28	100	4	100	20	100	31	100	18	100	38	100	33	100

Semi-shrubs, tap-root perennials, short-root perennials, and long-root perennials determined the structure of the post-fire plant community for a number of years. Before the fire impact (i.e. in 2008), short-root perennials had a leading position (29.63%) in the plant community. They retained this position for a number of post-fire years: 25% in 2010, 26% in 2011, 35.14% in 2017, 36.36% in 2018. In 2015, tap-root perennials occupied a dominant position in the studied plant community with 33% of the total species number. In other years, they occupied the second position: 22% in 2008, 15% in 2010, 13% in 2011, 16% in 2017, 21% in 2018. Before the fire impact, the long-root perennials occupied the third position (11.11%). Subsequently, they demonstrated a resistance to pyrogenic effects, and an ability to quickly occupy the vacant space after the fire impact. In the 2010–2011 growing season, these plants, similarly to short-root and tap-root perennials, had a leading position in the plant community: 25% in 2010, 13% in 2011, 11% in 2015, 11% in 2017, 9% in 2018. Our results are in accordance with published data. For example, Marenina & Maslennikov (2014) demonstrated that in the Arsk forest-steppe (north of Ulyanovsk region, Russia), tap-root perennials (25.4%), long-root perennials (19.8%), and short-root perennials (10.8%) dominated in the post-fire plant communities. The same authors also noted a fire-caused increase in the proportion of root-sucker perennials (14.5%) and biennials (8.4%) in the ratio of life forms in the plant community.

The analysis of the morphometric traits of the *Paeonia tenuifolia* population before and after the fire impact showed, that the least variability of the trait is typical for the height of its generative shoots. The highest values of flowering shoot height were recorded in 2018 (47.13 cm). This is 36% more than in 2010. The smallest height of generative shoots was associated with unfavourable weather conditions of the spring and summer in 2017 (Svorotkin, 2017). In general, the height of the vegetative and generative shoots of *Paeonia tenuifolia* remained at a constant level for a number of post-fire years (Fig. 4). Extremely low and high values of these parameters depend on meteorological factors.

The development of an action plan for fires in Protected Areas should be based on the results of the assessment of biological diversity and comprehensive studies over succession on the burnt areas in compare with undisturbed habitats. For comparison, we chose similar plant community with *Paeonia tenuifolia*, not fire-disturbed in the southwestern part of the Khvalynsky National Park (Sosnovo-Mazovskoe forestry).

In the unburnt plant community, the height of generative shoots (36.47 cm) was slightly lower than in the post-fire plant community (47.13 cm). The probable reasons for this were the weakening of competition between plants caused by the fire impact and the soil fertilisation with ash elements. In contrary, in the unburnt plant community, the average plant height and the height of vegetative shoots were 3 cm larger than in the post-fire plant community (Table 6).

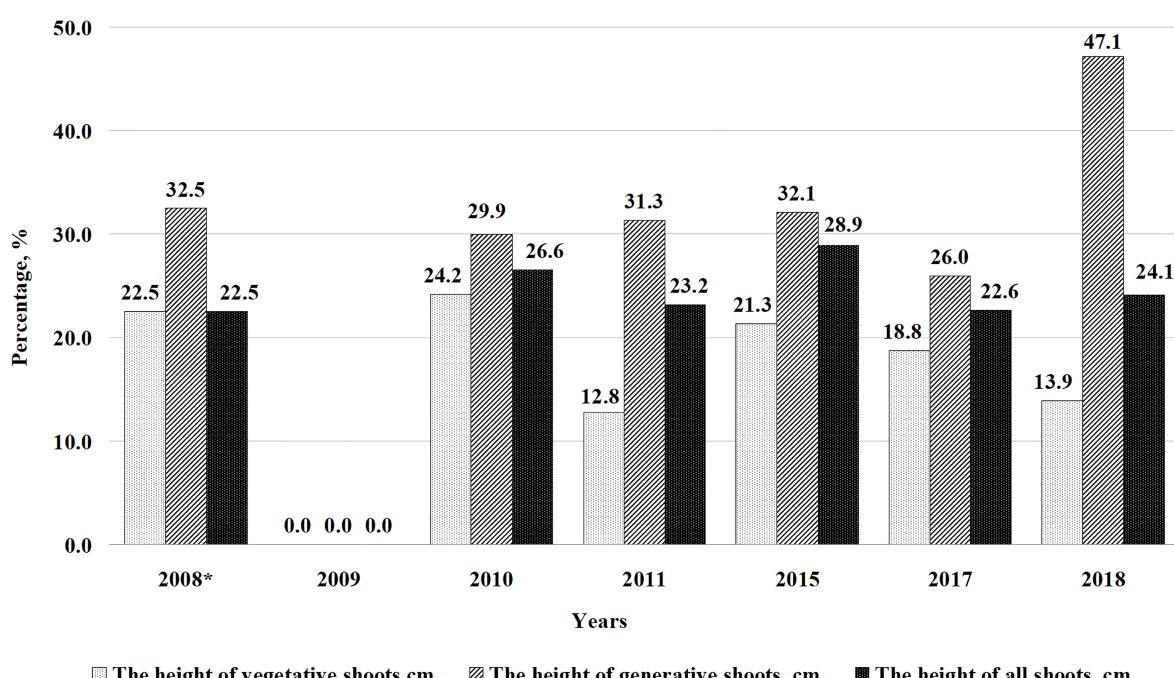


Fig. 4. The average height of *Paeonia tenuifolia* shoots in the fire-damaged plant community in the Khvalynsky National Park, Mountain Piche-Panda, 2008–2018.

Table 6. Average values of morphometric traits of *Paeonia tenuifolia* individuals in Khvalynsky National Park, quarter 86 of the Sosnovo-Mazovskoe forestry (17.05.2018)

Trait	N	M ± m	Limits	
			min	max
Average height of the shoots, cm	140	25.94 ± 12.06	5	51
Height of vegetative shoots, cm	78	16.75 ± 7.35	5	46
Height of generative shoots, cm	62	36.47 ± 6.56	19	51
Number of leaves per vegetative shoot	61	4.69 ± 3.57	1	14
Diameter of a bud, cm	30	1.53 ± 0.55	0.2	2.6
Diameter of a flower, cm	26	4.53 ± 1.74	1.6	8.8

It is caused by a large number of pre-generative *Paeonia tenuifolia* individuals, the height of which reached 11–17 cm. Individuals of juvenile, immature, and virginile age classes have vegetative shoots. In the post-fire plant community, the fire-stratified seeds of *Paeonia tenuifolia* germinated well. In subsequent years, we observed a large number of *Paeonia tenuifolia* juveniles (first year individuals) with an average height of 4.5 cm. The determination of age structure for the *Paeonia tenuifolia* population is of great importance, as it allows to a better understanding of the mechanisms of post-fire succession. The distribution of individuals along age groups and the completeness of population age structure contribute to the species sustainability in the plant community, since each group has its own specific relationship with the habitat (Bespalova & Popova, 1972). In addition, normal type populations are recognised as highly resistant (Rabotnov, 1983). If a plant population is incomplete or constist of individuals of the same age, its resistance to unfavourable conditions decreases. There are three types of age classes of a population: growing population, stationary population, declining population (Zlobin, 1989). Maslennikov & Maslennikova (2011) noted that the natural *Paeonia tenuifolia* population is characterised as complete, stationary. At the same time, young individuals predominate as most of them will eliminate before reaching flowering and fruiting stages. Ilyina (2011) found that the pyrogenic effect changes the age structure of a threatened species population by shifting age class percentage towards old (senile) individuals. As a result, the initially mature normal populations could be gradually changed into populations of aging (regressive) type. And it thus can contribute to plant population extinction. However, based on comparison of the unburnt and post-fire *Paeonia tenuifolia* population in the study area, we showed that young pre-generative individuals dominated (67% of the total number

of individuals) in the age spectrum of the post-fire populations (Table 7).

We found *Paeonia tenuifolia* seedlings in the study plots in April. In the second decade of May, the plants passed into a juvenile age class. Within group of generative plants, middle-age generative (g_2) individuals prevailed (13% of total number of individuals) in the post-fire plant community. Subsenile (6%) and senile (2%) individuals were also represented in the populations. In the age spectrum of the unburnt *Paeonia tenuifolia* population, generative individuals predominated (43%). Among them, generative individuals (g_2) dominated (63%). The post-generative age classes were represented by a small number of individuals in the unburnt *Paeonia tenuifolia* population (Fig. 5).

Since the studies were carried out on sites with a different disturbance degree, we used recovery and replacement indices to compare the populations' status. In the post-fire plant community, the $I_{recovery}$ of *Paeonia tenuifolia* population was $I_r = 2.70$. It indicates that this population is stable, and the pre-generative individuals are able to replace generative individuals. In the unburnt plant community, the $I_{recovery}$ was lower (1.25). It indicates a less stability of this *Paeonia tenuifolia* population, as a large number of pre-generative individuals are being eliminated and thus cannot sufficiently replace generative individuals. Based on the age index (Δ) of Uranov (1975) and the efficiency index (ω) of Zhivotovsky (2001), the post-fire population of *Paeonia tenuifolia* was estimated as younger ($\omega = 0.36$) than the *P. tenuifolia* population in the unburnt site ($\omega = 0.54$). According to the classification of normal type populations (Zhivotovsky, 2001), both populations were recognised as young full-membered populations. The post-fire plant community contained remarkably more juvenile and virginile individuals, than the population on the unburnt site. Both the recovery and replacement rates were higher in the burnt site than in the unburnt area.

Table 7. Age structure of the *Paeonia tenuifolia* population in steppe plant communities of Khvalynsky National Park in 2018

Plant community	Number of individuals per age class									Total	Demographics data					
	p	j	im	v	g_0	g_1	g_2	g_3	ss	s	I_{recovery}	$I_{\text{replacement}}$	Δ	ω	IVC	
Post-fire plant community	0	199	28	81	4	50	60	0	22	11	461	2.70	2.01	0.26	0.36	1.15
Unburned plant community	0	14	39	25	3	40	90	0	1	1	142	1.26	1.22	0.29	0.54	0.85

Note: p – seedlings, j – juvenile, im – immature, v – virginile, g_0 , g_1 , g_2 , g_3 – generative, s – senile, ss – subsenile.

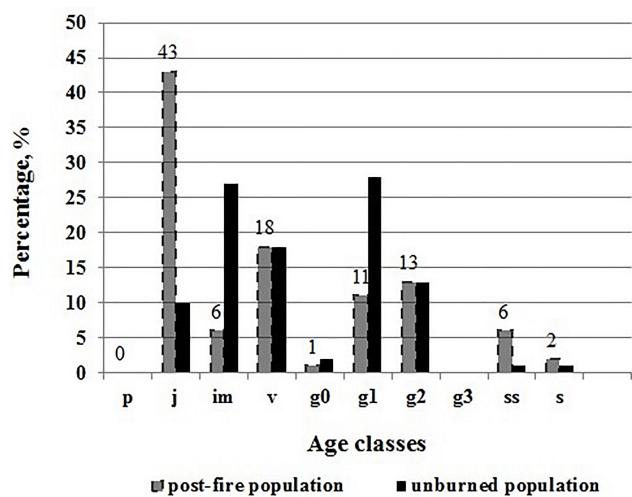


Fig. 5. Age structure of the *Paeonia tenuifolia* population in both post-fire and unburned plant communities in Khvalynsky National Park in 2018. Designations: p – seedlings, j – juvenile, im – immature, v – virginile, g_0 , g_1 , g_2 , g_3 – generative, s – senile, ss – subsenile.

The gradient analysis of environmental conditions showed that the *Paeonia tenuifolia* population in the fire-damaged plant community was characterised by the highest value of the vitality index ($IVC = 1.15$). It corresponded to the best conditions for population development. On the unburnt site, the vitality index (IVC) of the *Paeonia tenuifolia* population was 0.85. It indicated the unfavourable conditions for survival and development of this population. The index of species plasticity ($ISP = 1.35$) reflected a resistance of *Paeonia tenuifolia* to unfavourable conditions, in particular, to the fire effects. This is a low value in comparison with ISP values calculated for some other herbaceous plant species. For instance, the ISP of *Tulipa gesneriana* L. was 1.9 (Kashin et al., 2016, 2017). The ISP for *Iva xanthiifolia* Nutt. (as *Cyclachaena xanthiifolia* (Nutt.) Fresen.) was 4.95, and the ISP for *Atriplex tatarica* L. was 6.28 (Ishbirdin & Ishmuratova, 2004). The ISP value of *Paeonia tenuifolia* was within the limits of earlier obtained ISP values for perennial herbaceous plants (Ishbirdin & Ishmuratova, 2004). More specifically, its values are close to the ones calculated for *Cephalanthera rubra* (L.) Rich. with

$ISP = 1.31$ (Ishbirdin et al., 2005), and *Allium denudatum* F.Delaroche (as *Allium albidum* Fisch. et Bieb.) with $ISP = 1.38$ (Tkazaplisheva & Shkhagapsoev, 2008). This ISP value suggests that *Paeonia tenuifolia* is characterised by narrow limits of ecological preferences.

We considered the number of reproductive shoots on the study sites as an objective indicator of the status of Red Data Book plant populations (Table 8).

The positive effects of a fire impact were manifested by the higher number of *Paeonia tenuifolia* shoots in the post-fire plant community in comparison to the unburnt site. This is probably caused by the substrate renewal, improvement of lighting conditions, soil fertilisation with ash elements, and the reduced competition from other plant species.

In the studied plant communities, we identified 113 vascular plant species from 34 families. In post-fire plant community, the following plant families were the richest in species: Poaceae (13.43%), Leguminosae (11.94%), Rosaceae (8.95%), and Brassicaceae (8.95%). In the unburnt plant community, we found another ratio of the leading plant families in term of species number: Compositae (18%), Poaceae (11.76%), and Ranunculaceae (8.69%). The families Alliaceae, Asclepiadaceae, Asparagaceae, Dipsacaceae, Iridaceae, Geraniaceae, Globulariaceae, Liliaceae, Limoniaceae, Malvaceae, Onagraceae, Paeoniaceae, and Primulaceae were each represented by one plant species (Table 9).

Table 8. The number of shoots of Red Data Book plant species in both burnt and unburnt plant communities with *Paeonia tenuifolia* in Khvalynsky National Park in 2015

Shoots	Number of shoots	
	Burned site	Unburned site
<i>Paeonia tenuifolia</i>		
Vegetative, $M \pm m$	23.60 ± 13.43	10.25 ± 3.30
Generative, $M \pm m$	16.50 ± 11.95	8.00 ± 3.74
<i>Adonis vernalis</i>		
Vegetative, $M \pm m$	10.30 ± 12.54	7.50 ± 5.00
Generative, $M \pm m$	5.40 ± 5.73	3.50 ± 2.51

Note: M – average value, m – standard deviation of the average value.

Table 9. The ratio of the plant families richest by species on the study sites in the Khvalynsky National Park in 2009–2018

Family	Post-fire plant community		Family	Unburnt plant community	
	number of species	% of total species number		number of species	% of total species number
Poaceae	9	13.43	Compositae	12	18.00
Leguminosae	8	11.94	Poaceae	8	11.76
Rosaceae	6	8.95	Ranunculaceae	6	8.69
Brassicaceae	6	8.95	Rosaceae	5	7.35
Plantaginaceae	5	7.46	Leguminosae	4	5.88
Lamiaceae	4	5.98	Lamiaceae	4	5.88
Caryophyllaceae	4	5.98	Plantaginaceae	3	4.41
Rubiaceae	4	5.98	Rubiaceae	2	2.94
Compositae	3	4.48	Brassicaceae	2	2.94
Scrophulariaceae	2	3.00	Scrophulariaceae	2	2.94
Ranunculaceae	2	3.00	Caryophyllaceae	1	1.47
Others families	17	20.85	Others families	19	27.74
Total	67	100	Total	68	100

In the Arsk forest-steppe (central part of the Volga Upland), Marenina & Maslennikova (2014) obtained another ratio of plant families in the post-fire plant community: Compositae (16.6%), Poaceae (13.8%), Leguminosae (13.8%), Rosaceae (11.8%), Rubiaceae (5.5%), Apiaceae (5.5%), Lamiaceae (2.7%). A similar ratio was obtained in a result of study on the secondary succession dynamics in the fallow lands in the south of the Amur region (Nizkiy, 2014). Smelyanskiy et al. (2015) noted that the fire impact enhances bacterial and symbiotic nitrogen fixation in the soil, realised by Fabaceae plants. According to these authors, species of the families Poaceae (five species disappeared after fire), Rosaceae (three species), Rubiaceae (three species) were unstable to the fire factor under conditions of the South Ural steppes. On the contrary, the plant species number increased in the families Leguminosae (three species appeared after fire), Euphorbiaceae (two species), and Caryophyllaceae (two species) after the fire impact in Ural steppes (Smelyanskiy et al., 2015). Our results showed that in the Khvalynsky National Park, the most unstable plants were assigned to the following families: Compositae (two species disappeared after fire), and Apiaceae (one species). After the fire impact, the species number increased in the families Poaceae (three species appeared after fire), Rubiaceae (two species appeared after fire), Rosaceae (one species appeared after fire) and Leguminosae (one species appeared after fire).

The fire impact, spatial remoteness of both plant communities, closeness of the forest mas-

sif affected floristic composition of both studied phytocoenoses with *Paeonia tenuifolia*. As a result, the post-fire and unburnt plant communities differed in floristic composition based on the Jaccard similarity index equaled of 28.3%. Of the total of 113 obtained species, 21 taxa were observed on both sites (e.g., *Paeonia tenuifolia*, *Stipa pennata*, *Calamagrostis epigejos*, *Carex praecox* Schreb., *Elymus repens*, *Filipendula vulgaris*, *Hedysarum grandiflorum*, *Onosma simplicissima*, *Salvia nutans*, *Securigera varia*, *Thalyctrum simplex*, *Verbascum lychnitis*, *Vincetoxicum hirundinaria*).

In the studied plant communities, we recorded the plant species (e.g., *Anemone sylvestris*, *Adonis vernalis*, *Alyssum lenense*, *Asperula tephrocarpa*) listed in the Red Data Book of Saratov region (2006). *Globularia punctata* Lapeyr., *Hedysarum grandiflorum*, *Potentilla volgarica*, *Paeonia tenuifolia*, *Stipa pennata* were listed in the Red Data Book of the Russian Federation (2008). In the studied plant communities, we additionally found species (*Ajuga chamaepitys* subsp. *laevigata* (Boiss.) P.H. Davis, *Onosma simplicissima*, *Salvia nutans*) included in the additional list of the Red Data Book of Saratov region (2006), of which populations need special attention. The dominant and edificator of the plant communities *Paeonia tenuifolia* is included on the list of protected species of the European flora (Belousova et al., 2008). We found that the unburnt plant community had the highest value of the coefficient of conservation significance ($K = 67.20$) (Table 10).

Table 10. The presence of Red Data Book plant species in plant communities with *Paeonia tenuifolia* in the Khvalynsky National Park (2009–2018)

№	Species	Presence / absence (+ / –) of plant species	
		Post-fire community	Unburned community
1	* <i>Alyssum lenense</i> Willd.	+	–
2	* <i>Alyssum tortuosum</i> Adams.	+	–
3	* <i>Asperula tephrocarpa tephrocarpa</i> Czern. ex. Popov & Chrshan.	+	–
4	*** <i>Ajuga chamaepitys</i> subsp. <i>laevigata</i> (Boiss.) P.H.Davis	–	+
5	* <i>Astragalus cornutus</i> (Pall.) Kuntze	+	–
6	* <i>Adonis vernalis</i> L.	+	+
7	* <i>Anemone sylvestris</i> L.	–	+
10	** <i>Globularia punctata</i> Lapeyr.	–	+
11	* <i>Gypsophila volgensis</i> Krasnova	+	–
12	** <i>Hedysarum grandiflorum</i> Pall.	+	+
13	** <i>Iris pumila</i> L.	–	+
14	* <i>Linum ucranicum</i> (Griseb. ex Planch.) Czern.	–	+
15	*** <i>Onosma simplicissima</i> L.	+	+
16	** <i>Potentilla volgarica</i> Juz.	+	–
17	** <i>Paeonia tenuifolia</i> L.	+	+
18	* <i>Polygala sibirica</i> L.	+	+
19	** <i>Anemone pratensis</i> L.	–	+
20	*** <i>Salvia nutans</i> L.	+	–
21	** <i>Stipa pennata</i> L.	+	+
22	* <i>Thymus cimicinus</i> Blume ex Ledeb.	+	–
The coefficient of conservation significance		48.94	67.20

Note: * – species listed in the Red Data Book of Saratov region (2006); ** – species listed in the Red Data Book of the Russian Federation (2008); *** – species listed in Appendix 3 of the Red Data Book of Saratov region «Annotated list of taxa and plant populations, which require special attention to conditions of their natural environment» (Red Data Book of Saratov region, 2006).

It is well known that fires reduce the biodiversity of plant communities, and destroy the habitats of rare and threatened species (Ilyina, 2011; Bystrushkin, 2018). The fire impact caused remarkable damage to the populations of seven species of protected plants included in the Red Data Book of Saratov region (2006), three of which are listed in the Red Data Book of the Russian Federation (2008). The species represented by small populations with both small projective cover and abundance were in the most threatening situation. These plants are *Alyssum lenense*, *Onosma simplicissima*, *Potentilla volgarica*, *Salvia nutans*, and *Stipa pennata*. During the long-term monitoring, we found that four native plants of the studied plant community (*Paeonia tenuifolia*, *Adonis vernalis*, *Potentilla volgarica*, *Onosma simplicissima*) were pyrophytes. The semi-shrub *Alyssum lenense* disappeared from the plant community. The cereal *Stipa pennata* and tap-root perennial *Salvia nutans* recovered and strengthened their positions in the phytocoenosis structure as co-dominants. During the post-fire succession, we found six Red Data Book species (*Alyssum tortuosum*, *Asperula tephrocarpa*, *Globularia punctata*, *Gypsophila volgensis*, *Hedysarum grandiflorum*, and *Polygala sibirica* L.) in the floristic composition of the studied plant community. Since the study site was at the edge of the burnt area at the time of a fire, most of the Red Data Book plants penetrated into the plant community from the surrounding unburnt vegetation. The perennial *Paeonia tenuifolia* turned out to be resistant to the fire impact. And the plant community with *Paeonia tenuifolia* had recovered ten years after the fire impact.

Conclusions

The species richness of the post-fire plant community varied from 20 species in the first post-fire year to 38 species in the last study year. In the first post-fire year, the families of Poaceae (six species), Leguminosae (three species), Rosaceae (three species) occupied the leading position. The dominant position of the listed families remained during the pyrogenic succession of the plant community. In the unburnt plant community, other families (Compositae, Poaceae, Ranunculaceae) were richest in number of species.

After the fire impact, the plant community changed in the following order: 1) *Paeonia tenuifolia* + *Calamagrostis epigejos* + *Adonis vernalis* – *Stipa pennata* (in 2008) → 2) *Paeonia tenuifolia*

+ *Elymus repens* + *Stipa pennata* + *Adonis vernalis* + *Thalictrum simplex* (in 2010) → 3) *Paeonia tenuifolia* – *Stipa pennata* – *Calamagrostis epigejos* + *Festuca valesiaca* + *Phleum pratense* + *Poa bulbosa* + *Prunus tenella* (in 2011) → 4) *Paeonia tenuifolia* + *Adonis vernalis* + *Stipa pennata* (in 2015, 2017, 2018). Over the study years the ratio of dominant species had changed, and the phytocoenotic role of *Stipa pennata* had increased.

In the post-fire community steppe species dominated. In general, the full ecological-coenotical spectrum was represented by steppe plants (stepants) (70%), meadow plants (pratants) (16%), forest plants (sylvants) (5%), and ruderal plants (ruderants) (9%). At the same time, the ratio of coenotic groups remained the same before and after the fire impact. The only change was manifested in the appearance of new species in the studied phytocoenosis, most of which were steppe plants. During the post-fire succession, annuals and ruderals appeared and increased in abundance. This characterised an intermediate stage of pyrogenic transformation of the plant community with *Paeonia tenuifolia*.

The *Paeonia tenuifolia* populations in both the post-fire and unburned plant communities were normal, full-membered and young. Expectedfully, the age structure of post-fire *Paeonia tenuifolia* population was younger than its population in the unburnt plant community.

In the fire-damaged plant community, both the regeneration and growth processes of vegetative and generative shoots were more intense than in the unburnt plant community. This was caused by the substrate renewal and the decrease in species competition in the post-fire plant community.

Species saturation and stabilisation in species richness have become remarkable signs of a final restoration stage of the plant community affected by a fire.

Phytocoenoses with *Paeonia tenuifolia* are valuable botanical sites. In this area, they had grown for a long-time and were greatly adapted to local conditions under the influence of different factors. The presence of other Red Data Book species increases the conservation significance of the plant communities. The fire impact caused significant damage to the populations of Red Data Book plants in the post-fire community. Nevertheless, peculiarly, abiotic conditions contributed to the increased vitality of the *Paeonia tenuifolia* population and the restoration of the plant community after the fire impact.

The buffer zone of the Khvalynsky National Park contains mainly areas of meadow steppes with populations of *Paeonia tenuifolia* and other Red Data Book plant species. Therefore, it is necessary to include these areas with populations of protected plant species into the main area of the Khvalynsky National Park to ensure a reliable protection of intact habitats and populations of threatened species. To properly assess the fire effects on nature and its components and to subsequently create the correct recommendations for the ecosystem restoration, additional studies are needed.

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ОСОБЕННОСТИ ВОССТАНОВЛЕНИЯ ФИТОЦЕНОЗОВ С УЧАСТИЕМ *PAEONIA TENUIFOLIA* ПОСЛЕ ПОЖАРА НА ТЕРРИТОРИИ НАЦИОНАЛЬНОГО ПАРКА «ХВАЛЫНСКИЙ» (РОССИЯ)

Г. Ф. Сулейманова^{1,2,*}, В. А. Болдырев^{2,}, В. А. Савинов¹**

¹*Национальный парк «Хвалынский», Россия*

**e-mail: suleymanovag@mail.ru*

²*Саратовский национальный исследовательский государственный университет им. Н.Г. Чернышевского, Россия*

***e-mail: boldyrev52@bk.ru*

В статье рассматриваются показатели динамики растительного сообщества с *Paeonia tenuifolia* до и после воздействия пожара. Исследования проводились в Хвалынском национальном парке (лесостепная зона России) в 2008–2018 гг. Авторы проводили комплексное исследование в горелых и ненарушенных пожаром растительных сообществах. Для особо охраняемых природных территорий были рассмотрены оценка воздействия пожара и разработка плана действий после пожара. Растительное сообщество *Paeonia tenuifolia* + *Calamagrostis epigejos* + *Adonis vernalis* – *Potentilla volgarica* подверглось воздействию пожара в 2009 г. Растительное сообщество *Paeonia tenuifolia* + *Stipa pennata* + *Adonis vernalis* – *Anemone sylvestris* не было нарушено. Для характеристики растительных сообществ с *Paeonia tenuifolia* и его цепнопопуляций мы использовали стандартные методы геоботанического описания. Шестьдесят семь видов сосудистых растений входило в состав послепожарного фитоценоза. Из них 14 видов были занесены в Красную книгу Саратовской области. Преобразования в составе пост-пирогенного растительного сообщества происходили в следующей последовательности: 1) *Paeonia tenuifolia* + *Calamagrostis epigejos* + *Adonis vernalis* – *Stipa pennata* (в 2008 г.) → 2) *Paeonia tenuifolia* + *Elymus repens* + *Stipa pennata* + *Adonis vernalis* + *Thalictrum simplex* (в 2010 г.) → 3) *Paeonia tenuifolia* – *Stipa pennata* – *Calamagrostis epigejos* + *Festuca valesiaca* + *Phleum pratense* + *Poa bulbosa* + *Prunus tenella* (в 2011 г.) → 4) *Paeonia tenuifolia* + *Adonis vernalis* + *Stipa pennata* (в 2015, 2017, 2018 гг.). После воздействия огня на растительное сообщество в нем произошли следующие изменения: 1) появились и увеличили обилие малолетники иrudеральные виды; 2) изменилось соотношение доминирующих видов. С 2012 по 2018 гг. фитоценотическая роль *Calamagrostis epigeios* уменьшалась. Напротив, проективное покрытие и обилие *Stipa pennata* увеличилось в этот период. Динамика обилия *Paeonia tenuifolia* характеризовалась уменьшением в 2010 г. (сразу после пожара) и постепенным увеличением в 2015–2018 гг. Видовое богатство пост-пирогенного сообщества менялось от 20 видов в первый год после пожара до 38 видов в последний год исследования. В первый год пирогенной сукцессии лидирующее положение по числу видов занимали семейства Poaceae (шесть видов), Leguminosae (три вида), Rosaceae (три вида). Виды растений семейств Compositae, Poaceae, Ranunculaceae преобладали в ненарушенном растительном сообществе. Степные виды доминировали в послепожарном растительном сообществе. Это *Stipa pennata*, *Adonis vernalis*, *Paeonia tenuifolia*. Основные эколого-ценотические группы были представлены степными (70%), луговыми (16%), лесными (5%) и сорными (9%) видами растений. Наличие сорно-степных видов растений стало показателем нарушенности местообитаний вследствие антропогенной деятельности. Среди сорно-степных видов зафиксированы *Arenaria serpyllifolia*, *Viola rupestris*, *Erysimum canescens*, *Verbascum lychnitis*. Градиентный анализ экологических условий показал, что наибольшее значение индекса виталитета ($IVC = 1.15$) соответствует наилучшим условиям для роста и выживания в популяции *Paeonia tenuifolia* в послепожарном сообществе. На контролльном участке показатель виталитета ($IVC = 0.85$) соответствует худшим условиям для развития растений. Мы изучили возрастной спектр природных популяций *Paeonia tenuifolia* в послепожарном и ненарушенном сообществах. Мы показали, что обе популяции нормальные, полночленные, молодые. Послепожарная популяция была моложе, чем популяция в ненарушенном пожаром сообществе. Комплексные мониторинговые исследования должны быть продолжены для правильной оценки последствий пожара и последующих действий по управлению восстановлением растительности после воздействия пожара.

Ключевые слова: *Stipa pennata*, возрастной спектр, лесостепная зона, особо охраняемая природная территория, пирогенная сукцессия, популяция растений, растительное сообщество, редкий вид