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CURRENT STATE, GROWING CONDITIONS AND RESTORATION OF RAVINE PLANT COMMUNITIES IN THE LAKE ELTON BIOSPHERE RESERVE (VOLGOGRAD REGION)

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In this paper, we have summarized the available data on the habitats of the lost ravine forests of the Elton Region, the current state of their derivatives, the polydominant shrub communities, as well as the soil and vegetation conditions surrounding their growth. We have also examined the negative factors affecting these communities. It was discovered that significant altitudinal differences, along with a developed river and gully system provides a variety of natural conditions for the growth of ravine trees and shrubs communities in the lake depressions in general and at the northern shore of Lake Elton in particular. As expected, destruction of ravine forests leads to the disappearance of these communities. By now, the total area of polydominant shrub communities is extremely small and continues to decrease rapidly, while climate conditions of the last decades leave no room for hope that their natural seed regeneration and spatial distribution will intensify sometime soon. This problem becomes more urgent the more the area covered by polydominant communities decreases, the more the negative impact of grazing and frequent fires grows, and the longer the issue of their economic and ecological value and possibilities for their protection remain unresolved. Nevertheless, a vast number of habitats that are potentially suitable for the natural plantations of such type allows us to expect their successful restoration; while a vast number of habitats that are occupied by communities directly sourcing from ravine forests makes it possible to reintroduce them to the nature later.

We identified the most significant factors that determine the current state of the polydominant communities; e.g. issues with seed regeneration of cenosis-forming species, cattle grazing and wild fires. We found out that in the overwhelming majority of cases the groundwater level in the gullies of the Elton Lake Depression is high and has low salinity, which makes these gullies suitable for the formation of polydominant shrub communities. We also discovered that there is a certain potential for these communities to persist and develop; however, it is only true to their current habitats, since their seeds are unable to spread to other potentially suitable habitats.

With such a significant number of habitats potentially available for ravine trees and shrubs in most of the Elton gullies, we believe that there is a possibility to restore polydominant tree stands, and a positive prospect for experiments to re-establish lost ravine forests to the larger gullies where they were present before. We offer recommendations for the restoration of polydominant communities and the reintroduction of such lost species of ravine forests as poplar and willow.

Keyword: Caspian Depression, Volga-Ural Interfluve, Elton Lake, polydominant tree and shrub communities, systems of ravines and gullies, ravine forests, forest restoration.

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Assessment of the historical development, growing conditions and current state of natural communities of tree and shrub vegetation of the argillaceous semi-desert of the Volga-Ural Interfluve is necessary to preserve ecosystem and species diversity of this environment. This territory is unique due to its transboundary location, both geographical as it spreads through Europe and Asia, and zonal since it includes steppe and desert. In the 18th century, there were ravine forests with a specific and relatively rich fauna along small saline rivers and at the bottom of the gullies of lake depressions (Dinesman, 1960; Khodashova, 1960; Lindeman et al., 2005). As the economic development of this area intensified, these forests became extinct. All that reminds of them now are polydominant shrub communities formed by a few ravine species. The total area of these communities is frighteningly small and continues to decline rapidly. The difficulties of seed regeneration of their species, the negative impact of cattle grazing and frequent fires inevitably lead to their complete extinction as well (Bykov, Bukhareva, 2016).

As a result, a significant number of forest and dendrophilic animals, whose existence was determined by the ravine forests and communities, are leaving the region. In the second half of the 20th century, the establishment of artificial tree and shrub systems strengthened and helped some of those species return there (Bykov, 2006, 2010; Lindeman et al., 2005; Oparin, 2010; Bykov, Bukhareva, 2015). However, now, due to frequent forest fires and lack of overall maintenance, the area of artificial communities is decreasing, with the number of forest and dendrophilic animals decreasing along with it (Bykov et al., 2006; Bykov, Bukhareva, 2017, 2018). All of that makes us search for new ways to preserve and restore the still-existing polydominant communities, and to re-establish the lost ravine forests, raising an urgent need for a specific methodology for artificial restoration of polydominant groups and ravine communities that would take into account their growing conditions and their current state.

In this paper, we have summarized the available and mostly published data on the habitats of the lost ravine forests of the Elton Region, the current state of their derivative polydominant shrub communities, as well as the soil and vegetation conditions surrounding their growth. We have also examined the negative factors affecting these communities.

Materials and Methods

Our research was carried out at the Dzhanybek Research Station of the Institute of Forest Science of the Russian Academy of Sciences, Volgograd Oblast, Pallasovsky District. We collected all required materials in the Elton Nature Park established around Elton, the largest salt lake in Europe. In 2019, this park and its adjacent territories were officially proclaimed a UNESCO “Lake Elton” biosphere reserve (Fig. 1).

A drainless argillaceous plain with almost zero surface runoff extends there across Russia and Kazakhstan, in the northwestern part of the Caspian Depression. Most of it is raised up to 25-30 m above sea level, occupied by steppe and desert communities. This drainless plain has complex soil and vegetation covers, with surface saline groundwater (Rode, Polsky, 1961). However, within its territory, between +16 and -16 m above sea level, there are several closed basins of saline lakes Elton, Bulukhta, Botkul and Aralsor where the short saline rivers run into. In turn, numerous gullies of various sizes and ages run into these rivers and lakes.

The local climate is characterized by sharp atmospheric aridity and lack of water (Doskach, 1979). It is important to note that for the most part changes in the frequency of dry years were the only kind of climate changes in the region from the second half of the 18th century to the middle of the 20th century (Dinesman, 1960). Starting from the first quarter of the 19th century, there was a long dry period with cold winters, which lasted until 1970-1980s, only briefly interrupted (Dinesman, 1960; Sotneva, 2004). These cold winters resulted in deeply frozen soils, while melt water in the lake depressions ran into rivers through ravines and gullies and directly

down the slopes. L.G. Dinesman described (1960) catastrophic consequences of those years, such as rockslides, landslides, and deaths of animals. Since the last quarter of the 20th century, the average annual temperature began to rise and precipitation increased significantly, which humidified the territory, because the main volume of melt water was absorbed directly on the spot. In general, climate humidization throughout the entire region has become a trend in recent decades (Sazhin, 1993; Oparin, 2007; Sapanov, Sizemskaya, 2015).

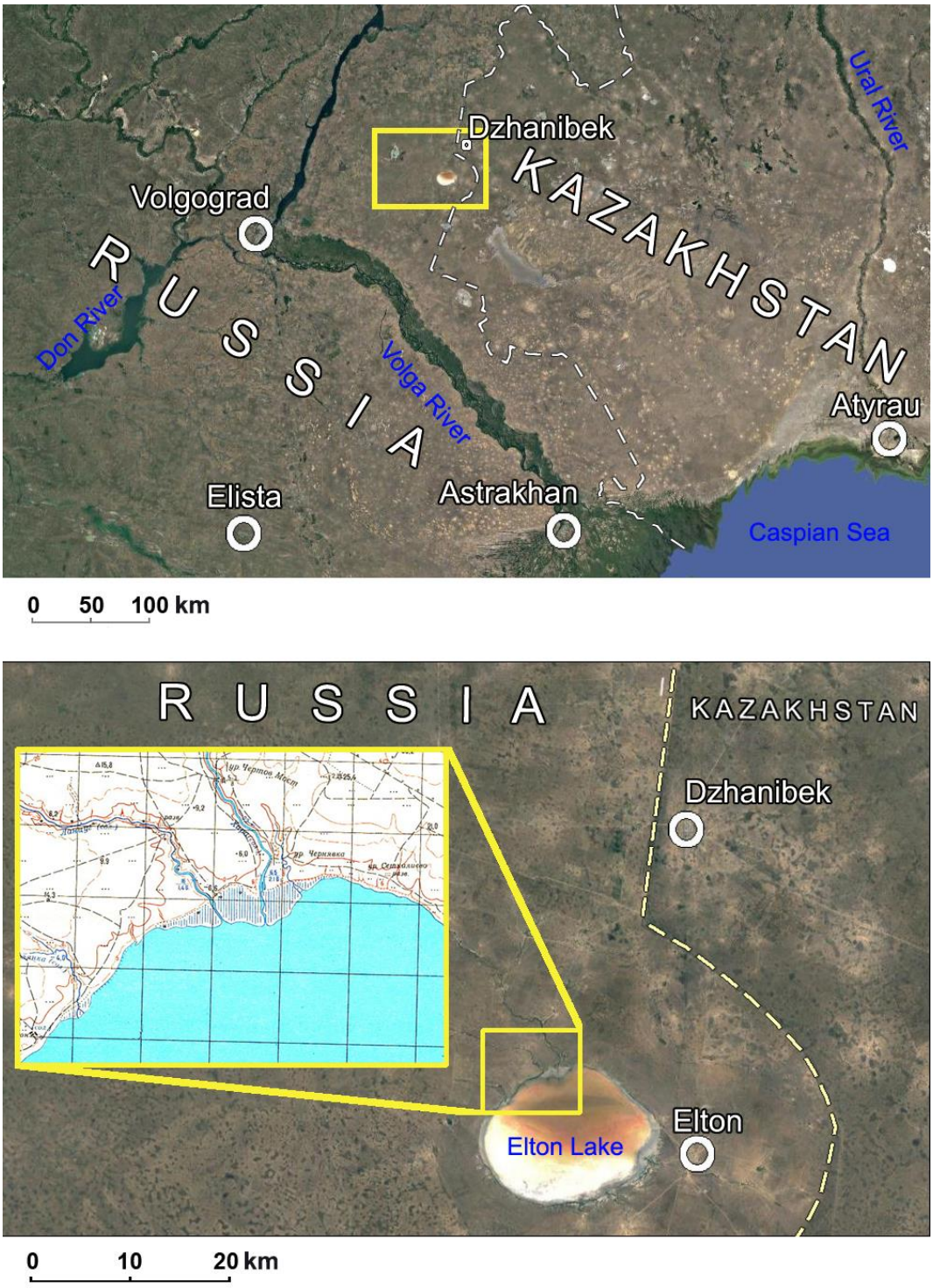

Fig. 1. Study area.

L.G. Dinesman studied (1958, 1960) the history of species composition, nature and growing conditions both of the preserved and lost ravine communities in the region since the late 1940s. After analyzing numerous archives, publications and conducting direct observations, he identified the main species that used to form the lost forests, and revealed that the main reason for their extinction was human activities such as logging, cattle grazing and man-made fires rather than climate change. Additionally, L.G. Dinesman described those polydominant shrub communities that came after the ravine trees and shrubs that had survived under anthropogenic pressure. Using the available data, he was able to compile a quite complete list of birds and mammals that inhabited the lost forests before their destruction (Dinesman, 1960). Therefore, it became possible to assess the catastrophic losses of the regional fauna over the past 1.5-2 centuries (Khodashova, 1960; Lindeman et al., 2006).

Since the 1950s, this kind of studies was continued by staff from the Institute of Forest Science of the USSR Academy of Sciences, as well as some researches from other facilities of the Russian Academy of Sciences. They conducted soil, geological and botanical, zoological studies in the vicinity of lakes Elton and Bulukhta (Russia), as well as Aralsor, the lower reaches of the Gorkaya River and Priurdinsky Khaki (i.e. drainless ponds) (Kazakhstan). Over that period, information was obtained on the history of economic activity in the area in general and individual natural boundaries in particular for the last 50-100 years. Additionally, a lot was learned on the nature, condition, growth and regeneration of natural ravine polydominant communities. Attention was especially paid to post-fire recovery of such communities and the impact of livestock grazing.

Since the 1980s, a detailed study of the northern shore of Lake Elton began, including the lower reaches of such small saline rivers as Chernaya, Khara, Lantsug and Solyanka and the gullies running into them (Fig. 1). The first and second floodplain terraces were well-defined and visible on the interfluve plain, where an accession of all areas with polydominant shrub communities was conducted twice (1982-1986 and 2013-2014) on an area of ~110 km^2. Coordinates of polydominant bio-groups and single specimens of blackthorn, buckthorns, honeysuckles, spindle and apple trees were marked using Garmin GPS, while their geobotanical descriptions, species composition, trunk and crown diameter, height were carried out according to the widely accepted methods, on route (Field Geobotany, 1964).

Since the early 1980s, annual monitoring of cattle grazing intensity and its impact has been conducted in the “Biological Gully”, the largest mesophilic ravine-gully community, and in 3 smaller gullies. Additionally, restoration of polydominant communities that were affected by the 2002 and 2018 fires was monitored.

Subfossil shells of *Chondrula tridens* (O.F.Müller, 1774) mark the locations of lost ravine forests (Dinesman, 1960). L.G. Dinesman (1960) discovered that this mollusk was distributed in the Volga-Ural interfluve inside the broad-leaved forests. “Today ... living individuals of this species can be found only in the Saltovsky Forest on the oxbow banks of the Yeruslan, overgrown with oak. ... This species protects itself from drying out by plugging its shell with a film of mucus. ... The mucus is squeezed out ... by so-called ‘teeth’ on the inner edge of the opening of the ... shell” (Dinesman, 1960, p. 59). The individuals found in arid regions tend to have bigger teeth, the size of which is estimated using a special index (Matyokin, 1951). The index values for *C. tridens* shells collected in the Northern Elton Region are the same with the living shells from the Saltovsky Forest, which indicates that in the past, the habitat conditions at the sites of subfossil shells findings were similar to the present-day conditions in the Saltovky oak forests (Dinesman, 1960).

We carried out a theodolite profiles survey in 3 gullies with developed ravine communities, starting at their mouth and ending in their upper parts which are occupied by herbaceous vegetation. We made 4-10 boreholes along their bottoms, and determined the groundwater level and its salt composition in spring, summer and fall for a few years. Additionally, we made 1-2 boreholes in 5 more afforested and unforested gullies to determine groundwater level.

Based on the analysis of the obtained materials, we compiled a schematic map of the areas suitable for restoration of both polydominant shrub communities and lost ravine forests (Fig. 2, Table 1), and indicated the main factors preventing such restoration.

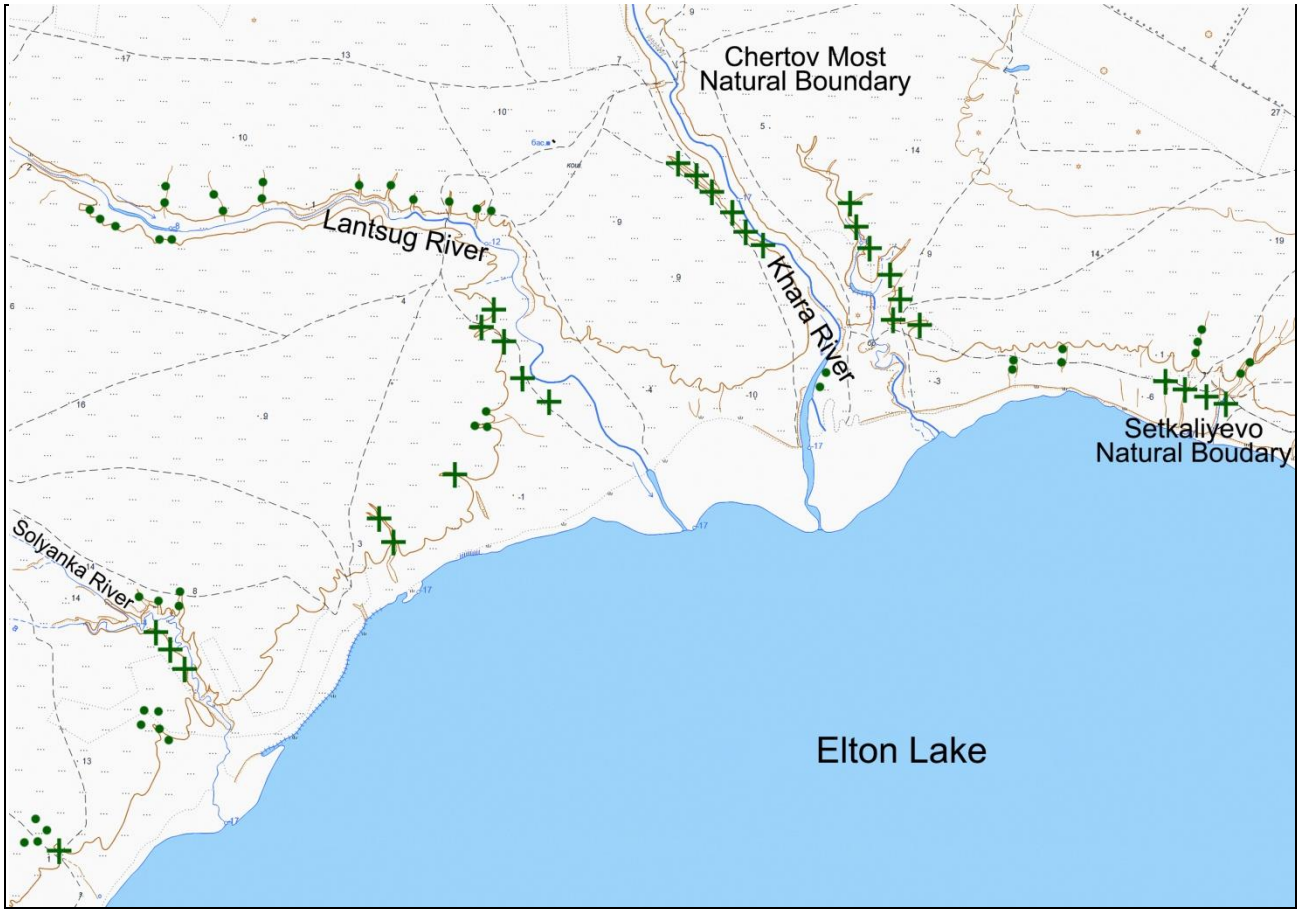

Fig. 2. Areas of the Northern Elton Region that are suitable for restoration of the polydominant shrubs (●) and trees (+) communities.

Table1. Geographic coordinates of habitats in the Northern Elton Region suitable for restoration of polydominant shrub communities and tree plantations.

Polydominant shrub communities		**Tree plantations**	
Coordinates	**Site**	**Coordinates**	**Site**
N 49° 12′ 38.0″, E 46° 43′ 34.2″	Gullies of the “Setkaliyevo” Natural Boundary	N 49° 12′ 28.7″, E 46° 43′ 07.1″	Shore of Lake Elton near the “Setkaliyevo” Natural Boundary
N 19° 12′ 45.0″, E 46° 43′ 00.2″		N 49° 13′ 06.4″, E 46° 40′ 23.2″	Gullies of the left bank of the Chernaya River
N 49° 12′ 47.1″, E 46° 41′ 36.1″	Gullies that run into Lake Elton, east of the Chernaya River	N 49° 13′ 03.9″, E 46° 40′ 25.6″	
N 49° 12′ 47.8″, E 46° 41′ 23.0″		N 49° 12′ 57.0″, E 46° 40′ 31.3″	

Continuation of Table1.

Polydominant shrub communities		Tree plantations	
Coordinates	**Site**	**Coordinates**	**Site**
N 49° 12′ 52.7″, E 46° 40′ 00.6″	Gullies of the left bank of the Khara River	N 49° 13′ 08.3″, E 46° 40′ 21.3″	
N 49° 12′ 52.0″, E 46° 40′ 00.0″		N 49° 13′ 04.6″, E 46° 40′ 20.9″	Slope of the right bank of the valley of the Chernaya River
N 49°14′ 08.3″, E 46° 33′ 41.4″	Gullies of the right bank of the Lantsug River	N 49° 13′ 43.6″, E 46° 39′ 05.2″	“Biological Gully”
N 49 °13′ 51.1″, E 46° 33′ 41.4″		N 49° 13′ 29.1″, E 46° 39′ 28.9″	Right bank of the lower reaches of the Khara River
N 49° 13′ 59.1″, E 46° 33′ 53.5″	Network of gullies on the left bank of the Lantsug River	N 49° 13′ 04.0″, E 46° 37′ 33.8″	Left bank of the Lantsug River
N 49° 13′ 56.8″, E 46° 33′ 58.2″		N 49° 12′ 48.7″, E 46° 37′ 43.7″	
N 49° 13′ 51.9″, E 46° 34′ 10.8″		N 49° 11′ 47.7″, E 46° 36′ 46.6″	Gully of the “Presnyi Ruchey”
N 49° 13′ 45.5″, E 46° 34′ 35.6″		N 49° 11′ 38.3″, E 46° 36′ 32.0″	Gully that runs into Lake Elton east of the Lantsug River
N 49° 13′ 39.0″, E 46° 34′ 45.7″		N 49° 11′ 34.6″, E 46° 35′ 00.6″	Right bank of the Solyanka River
N 49° 03′ 38.4″, E 46° 34′ 55.0″		N 49° 09′ 44.9″, E 46° 33′ 32.0″	Lower reaches of the gully in the “Kordon” Natural Boundary
N 49° 13′ 34.7″, E 46° 35′ 02.5″		-	-
N 49° 13′ 36.6″, E 46° 35′ 29.1″		-	-
N 49° 13′ 39.1″, E 46° 35′ 46.1″		-	-
N 49° 12′ 19.9″, E 46° 38′ 27.6″	Unnamed gully west of the Lantsug River	-	-
N 49° 11′ 40.1″, E 46° 35′ 00.3″	Gullies on the left bank of the Solyanka River	-	-
N 49° 10′ 14.9″, E 46° 34′ 35.7″	Gully of the “Opaly Redut” Natural Boundary	-	-
N 49° 09′ 45.6″, E 46° 33′ 30.1″	Gully of the “Kordon” Natural Boundary (“Yablonevaya”)	-	-

Results and Discussion

Ravine forests and conditions of formation of polydominant shrub communities. For lake depressions in general and for the northern shore of Lake Elton in particular, significant elevation

differences, as well as developed river and gully systems determine a conditions variety for the growth of ravine tree and shrub communities.

Naturally, the lost ravine forests tended to river valleys, but we can determine their former biotopic position only by indirect signs. No doubt, their destruction entailed the disappearance of any dependent habitats, hence the freshly formed cliffs and continuous destruction of the many coastal slopes in the lower reaches of the rivers. Redistribution of surface precipitation provokes erosion and rapid growth of ravine-gully network of local drainless basins. Periodic seasonal movement of solid runoff to the focus of erosion includes hill-wash and washout that reach considerably deep, depriving soils from carbonates and easily soluble salts. Soil-forming rocks acquire properties that, unlike zonal soils, include good porosity, water permeability and high water capacity. At the same time, as salts are washed away, soils change their vegetation, shifting from predominantly halophytic species to those less resistant to salts.

Ravine forests of the Elton Region were formed with white willow (*Salix alba*)[1], black poplar (*Populus nigra*), silver poplar (*P. alba*), common aspen (*P. tremula*), apple tree (*Malus praecox*), European buckthorn (*Rhamnus cathartica*) and blackthorn (*Prunus spinosa*). It is possible that there were also such species as Tatarian maple (*Acer tataricum*) and Russian olive (*Elaeagnus oxycarpa*), but there's no evidence to support it (Dinesman, 1960). These were sparse low-quality tree stands of different age, with a shrub layer of such trees as buckthorns and blackthorn that usually grow into bushes with multiply trunks: Tatarian honeysuckle (*Lonicera tatarica*), cinnamon rose (*Rosa cinnamomea*) and, possibly, warted spindleberry (*Euonymus verrucosus*). Old willows and poplars with cracks and hollows in their trunks were present as well, which provided nests and shelters for a number of animals that are currently absent there, e.g. cavity-nesting ducks (Dinesman 1960).

The destruction of ravine forests began after the development of the Elton salt fields. For example, vegetation cover was quickly gone within several kilometers around the settlement of Stary Elton which was founded in the middle of the 18th century on the southern shore of Elton Lake, the center of the salt industry (Dinesman, 1960). The northern shore with all its forests and interfluve pastures, deep gullies that provide shelter for cattle in bad weather, reed thickets suitable for cattle to hide in during winter, as well as a huge estuary in the northwest, is subjected to intensive economic development; in this case, such complex terrain makes it easier to control the territory. A redoubt with several cannons was built in the 18th century to protect the grazing cattle from nomads; the land was crossed by numerous roads and trails. Numerous foundations (Rus. “bazishcha”) are still being found near the rivers, large gullies and the coastal zone; they are the remains of residential and farming buildings, dams, wells and small temporary water reservoirs. Built in 19th century, there was a water mill on the Khara River, which functioned until the early 1920s. Judging by these finds, blacksmiths worked in the Elton Region, and simple pottery was produced.

The aforementioned activities initially led to destruction of forests. Old hollow trunks were used for firewood, tall trees and pole timber was used for construction. The condition of tree and shrub communities was affected by fires, while cattle ate and trampled the seedlings. Tall trees, such as poplars, aspens, willows and, possibly, other species disappeared from their natural habitats. The only trees to survive were buckthorns, the underground shoots of which produce numerous aboveground shoots, and blackthorns, the numerous renewal buds of which provide mass shoot regeneration stemming from the horizontal rhizomes (Bykov et al., 2013). These trees, which can easily form bushes, maintains a perennial relationship with their vegetative shoots, which, in turn, form new vegetative shoots, thus, developing a dense clump with a radius of several meters around the mother plant.

[1] Latin names of plants are given according to S.K. Cherepanov (1995).

In the late 1940s-1950s, L.G. Dinesman (1960) studied these peculiar polydominant shrub communities that emerged on the basis of the above-mentioned species: they are thickets of buckthorn and blackthorn, Tatarian honeysuckle (*Lonicera tatarica*), warted spindleberry (that can be found only in the "Biological Gully", geographical coordinates of the center of plant community: N 49° 13′ 43.6″, E 46° 39′ 05.2″), cinnamon rose and dwarf Russian almond (*Amygdalus nana*). Single apple trees found in such communities do not form a separate layer.[2]

The most significant factors determining the current state of the polydominant communities are impeded seed regeneration of cenosis-forming species, cattle grazing and fires (Dinesman, 1960; Bykov et al., 2013). The last mass seed regeneration of ravine species was observed after the exceptionally humid year of 1952, by the time of which poplars, aspens and willows had already been cut down. In 1953, that was also quite wet, numerous shoots of blackthorn, buckthorn and apple tree appeared in some places (Dinesman, 1960). Since then, despite the fact that seeds of these species are widely spread by birds, badgers and water streams, their mass renewal has never been noted (Bykov, 2010); single seedlings of buckthorn, blackthorn, apple trees and honeysuckle began to appear only since the mid-2000s.

L.G. Dinesman (1960) emphasized that climate change was not the reason for ravine forests disappearance; instead, the major factor was a direct negative anthropogenic impact, such as tree logging, fires and cattle grazing. The latter two affect polydominant communities even today.

Grazing of large and small cattle, horses and camels was intensive, often excessive, throughout the entire Elton Region until the middle of the 20th century. In some of the largest gullies, drinking wells were made to provide water for animals. During that period, polydominant communities were represented by individual bushes and clumps only, while the denser ones grew in the gullies with much steeper slopes which hindered access of animals.

Since the 1940s, the number of livestock grazing in the Northern Elton Region has declined sharply; from the 1970s to the early 1990s, there were no shepherd farms between the Chernaya and Solyanka rivers. It was a place to harvest hay and make summer camps to graze a limited number of sheep. After mass seed regeneration in 1952, polydominant communities emerged and established in a number of new habitats, primarily, in shallow and narrow gullies. The already existing communities grew denser and significantly expanded by the early 1990s (Bykov et al., 2021).

It is known that fires do not have such a catastrophic effect on herbaceous vegetation in steppes and semi-deserts (Tishkov, 2003; Mordkovich et al., 1997), however, they have a fundamentally different effect on trees and shrubs of natural or anthropogenic origin. Fire resistance of dense patches of polydominant thickets is quite high. Density of their trunks does not give a chance for development of grass cover or the inflow of organic matter carried by wind and water, which makes it difficult for fire to spread outside the patch. In addition, they have dense litter of relatively large fragments of trunks and branches due to the rapid recycling of fine debris thanks to the high nitrogen content in buckthorn leaves (Archibold et al., 1997; Wyckooff et al., 2005). Such litter may start smoking on the leeward side, but will suffocate deeper in the thickets, while only the bases of a few thin trunks may get scorched and wither in a year or two. Fire shortly affects only the lower part of the gully that is overgrown with reeds; then, the above-ground parts of buckthorns, blackthorns and spireas die, but remain in the tree stand for several years after that. A very strong wind, however, along the channel of the gully can spread the fire up on the branches and trunks and cause a total burnout of litter down to its mineral layer, as it happened in 2018 in the "Biological Gully".

Individual bushes, small clumps, and narrow belts of shrubs in the shallow gullies are more affected. However, their branches and trunks are covered by fire for such a short time that their

[2] Aside from the Elton Region, large areas of such communities can be found in the Aralsor Lake Depression in Western Kazakhstan (Dinesman, 1960; Bykov, Bukhareva, 2016).

leaves only dry out, but the entire above-ground part of affected area usually withers in 1-3 years. And even then, the burnt community recovers fairly quickly as the regrowth of vegetative shoots begins in the first fall after the fire (Bykov et al., 2013), reaching 1.8 m after that, while the most of their non-woody parts freezes off during the following winter. In addition, while rising above the snow, these shoots are nibbled away by hares, rodents and cattle, so by spring the height of buckthorn, blackthorn and honeysuckle is only about 30-50 cm, growing by the same 30-50 cm per year in the following years. Apple trees are the only ones that lose their shoots in the second or third year.

Referring to what we talked about above, we would like to emphasize once again that dense plant communities can exist only in the absence of grazing of cattle and horses. Grazing, and even more so intensive grazing, severely reduces their fire resistance and the rate of shoot regrowth.

Several shepherd settlements have been founded in the Northern Elton Region since the early 1990s. Cows and horses willingly visited the thickets, breaking branches, eating fresh shoots, trampling new trails and paths, and barring places of their rest. The most severe results were observed in places where they sheltered in winter: by spring, all herbaceous vegetation on the bottom of the gully and its slopes was completely destroyed, turf was broken and soil was eroded by melt water. There were trails leading through the shrubs, degraded into actual ditches in some areas, while branches along them were either chewed off or broken. Weeds entered through the gaps and spread quickly, and wind-borne tumbleweeds and manure accumulated there as well. In areas previously affected by fires, these processes develop with doubled intensity. In addition, grazing animals actively trample and eat regrowing shoots, sharply reducing the density of thickets. As grazing continues, massifs of shrubs break up into clumps, and, if grazing intensifies, they proceed to break up into individual bushes. As a result, the fire resistance of such communities decreases catastrophically: fire penetrates them and covers the entire patch quickly. Large amount of combustible material leads to charring of litter and burning of trunks bases, with some bushes getting burnt to the ground. As a result, the buds on the underground parts of shoots are severely damaged and post-fire recovery of some areas takes decades, with soil erosion developing in some cases and the habitat becoming unsuitable for trees and shrubs (Bykov et al., 2013).

We do not have any information on old large fires in Elton Region, but we can say for sure that there have been none in the study area since the beginning of the 20th century and up until the early 2000s. The fire of 2002 covered almost the entire north of the region and affected many areas of polydominant stands. However, in “Biological Gully”, only its right slope burned, and the main tree stand on its bottom, slightly affected by the cows, remained intact. In the following decades, the intensity of grazing in the area only grew, increasing the fragmentation of phytocenosis. In the fire of 2018, unfortunately, the “Biological Gully” burned completely.

State of polydominant communities in 1982-1984. Livestock grazing was minimal in the Northern Elton Region from the 1980s through the early 1990s. Areas of polydominant shrub communities, ranging in size from 100 to 3,500 m^2, persisted in 2 river valley and 18 gullies (43% of the total number of gullies deeper than 4 m). Their total area, with the exclusion of individual clumps, reached 15,000 m^2 (Bykov, Bukhareva, 2016).

We have already mentioned that the habitats of the lost ravine forests are mostly destroyed in the river valleys. In the valley of the Chernaya River, the smallest area of about 100 m^2 was preserved for a long time only in a huge river bend, 150 m from the riverbed, under a steep slope of the right bank, which has not been eroded by the river for a while (geographical coordinates: N 49° 12′ 58.1″, E 46° 40′ 13.8″).

Another significant area (600 m along the channel; 5,000 m^2 in total) of polydominant stands was preserved under a cliff of the right bank in the lower reaches of the Khara River (geographical coordinates: N 49° 12′ 52.7″, E 46° 40′ 00.6″). Prior to the fire of 2002 in these two habitats, the bases diameter of the individual old buckthorns exceeded 34 cm, with a few of them exceeding 40

cm (Photo 1), their height reaching 5 m, and density almost reaching 1. This site on the Khara River was different from other polydominant shrubs of the Northern Elton Region due to noticeably large, evenly scattered apple trees (at least 12 ind.) up to 8 m high. Technically speaking, this was the only area of natural polydominant communities of the region with a relatively distinct tree layer.

Photo 1. Trunk base (d = 44 cm) of the European buckthorn (*Rhamnus cathartica*) in the valley of the Chernaya River.

Numerous subfossil shells of *Chondrula tridens* were found in the vicinity of these sites, exclusively in the upper third of the coastal slopes, proving that these communities are derived from lost ravine forests.

In the lower third of the gullies, as deep as 4 to 12 m, polydominant communities are formed around narrow rain channels with bare edges, where rare seedlings of ravine species are most often observed, primarily of buckthorn which cannot compete with grass (Knight et al., 2007). Once settled on the slopes of the rain channels, these species gradually spread along the bottom and sometimes move to the lower part of the slopes (Bykov et al., 2013a). The gully mouths are occupied by meadow forb-cereal communities and common reed (*Phragmites australis*). In the middle and upper parts of the gullies, above the polydominant communities, clumps of almond and spirea can form, with grass communities, primarily couch grass (*Elytrigia repens*), in the upper reaches.

On some gentle slopes of deep river valleys, there are small areas of polydominant communities at the short, shallow and, apparently, young washouts the channels of which do not run into the interfluve plains. This is where small polydominant phytocenoses grow, confined exclusively to the second river (floodplain) terraces. There can also be found single old bushes of buckthorn (base d = 32-34 cm), however, with no apple trees or *Chondrula tridens* shells. We believe that such patches have formed on the sites of destroyed valley habitats of ravine forests, and their degradation

and area decrease are still ongoing. Since the beginning of 2020, under the strongest grazing pressure (Photo 2, 3) most of these tree stands have been almost destroyed.

The age and history of formation divides polydominant communities of gullies into two groups: those growing in ancient large gullies of at least 6 m depth, and those growing in shallow gullies 4 to 6 m deep.

Photo 2. Former vegetation cover, now entirely destroyed by overgrazing on the left bank of the Chernaya River.

Photo 3. Overgrazing consequences on the left bank of the Chernaya River.

In the studied area of the Northern Elton Region, we found 5 large gullies, with subfossil shells of *Chondrula tridens* discovered in all of them (Photo 4). From the 1980s, individual apple trees thicker than 30 cm in diameters and as high as 7-8 m, buckthorns (base d > 34 cm), and honeysuckles (base d > 18 cm) persisted in these gullies. Until the early 1990s, the average height of thickets was not less than 6 m, and density was reaching 1 in four of these gullies: "Biological Gully", unnamed gully to the west of the Lantzug River (geographical coordinates: N49° 12′ 19.9″, E46° 38′ 27.6″), gully of the "Presnyi Ruchey" natural boundary (N49° 11′ 47.7″, E46° 36′ 46.6″) and gully of the "Kordon" natural boundary (N49° 09′ 45.6″, E46° 33′ 30.1″). However, in the fifth gully (west of the Solyanka River, N49° 10′ 31.5″, E46° 34′ 53.5″), the polydominant community was destroyed by the early 1980s due to the unknown changes in the hydrological regime, when salinization became so severe that washouts at the bottom of the gully became overgrown with marsh samphire (*Salicornia europaea*). Fortunately, in the 1980s, single large clumps of buckthorn, as well as a dry apple tree were still present there, on both slopes. Around the gully mouth, basically on the shores of the lake itself, there were huge bushes of buckthorn as well.

Obviously, these thickets were formed long before 1952 and already existed, in one form or another, at the beginning of the 20th century. They have also derived from the lost ravine forests, and this is indirectly confirmed by black poplar and aspen, the last representatives of the natural Elton communities, that were cut down by the early 1930s in the "Biological Gully" (Dinesman, 1960).

Photo 4. Subfossil shells of *Chondrula tridens* in the valley of the Chernaya River.

Polydominant thickets of shallow gullies are of the same age. The diameter of the bases of both living and dead buckthorns rarely exceeds 10 cm, with an average height of 3 m. It is clear that these communities appeared in 1952. However, subfossil shells of *Chondrula tridens* are absent in

the area. Interestingly enough, dense monodominant communities of *Rhamnus cathartica* were formed in some of these gullies, known only for the USA, where this plant was introduced from Europe. The presence of such communities in the natural range of buckthorns is usually questioned (Knight et al., 2007).

Condition of polydominant communities in 2013-2023. Twelve years after the fire of 2002, the total area of polydominant thickets did not exceed 9,000 m^2, meaning that it decreased by 40% since the 1980s. The reason for this was a fire destructing some habitats, but mainly, a heavy grazing reducing almost every area of the shrubs. Burned clearings where the cow trails turned into wide gaps, up to 5 m between trunk bases, and overgrew with grass. By 2014, the height of regrowing buckthorns reached 2.2 m, with crown diameter up to 1.5 m (Bykov, Bukhareva, 2016).

By 2023, despite another major fire in 2018, polydominant shrub communities persisted in 3 of the 5 major gullies: “Biological Gully”, Lantzug river gully, and the “Kordon” gully. In the “Presnyi Ruchey” gully they were preserved until mid-2010, now completely destroyed by cattle. In the Solyanka river gully, at the bottom of which salinization started, this community disappeared.

Polydominant thickets in the valleys of the Chernaya and Khara rivers were severely damaged by the fire in 2002, but, fortunately, spared by the fire in 2018 as it had never reached them. A section on the Chernaya River was burnt completely in 2002, but managed to partially recover by 2014, however, in 2018, a cow trail crossed the area coming from a steep slope and left a hollow about 1 m deep. As a result, by 2023 these thickets had completely withered away (Photo 5).

Photo 5. Dried-out polydominant community in the valley of the Chernaya River.

The fire of 2002 has split a single massif of polydominant thickets in the Khara River valley into five patches. By 2014, the density of regenerating cenoses was 0.7-0.8, the average height reached 2.2 m, and the total area of preserved plots was 2,670 m^2.

It should be noted that by 2023, one of the two surviving habitats of derived polydominant communities in the valley of the Chernaya River was completely destroyed due to a significant increase in the number of cattle and constantly grazing horses. Three patches on the second terrace of the valley were virtually destroyed as well.

Soil and vegetation conditions of growing polydominant communities in the gullies of the Northern Elton Region. In an argillaceous semi-desert, the limiting factor for the existence of trees and shrubs is the availability of fresh groundwater. Soil cover of erosional elements of the relief, where polydominant communities develop, is very different from zonal soils. It is represented by synlithogenic soils, i.e. light humus, water-accumulative stratozems, formed mostly on mineral substrate, and partially on buried sedimentary soils of poorly developed soil. Soils transported by water along the bottom of the gully form differently sorted sediments of various depths (Bykov et al., 2020).

Dynamic development of soils with mineral substrate, associated with constant deposition and redeposition, is confined mainly to the area of active growth of the top and the middle part of the gully. Formation of its lower part occurs under the prevailing synlithogenic soil formation, with newly arriving solid runoff from higher parts of the gully getting actively introduced into the local soil-forming material. The following overgrowth leads to the formation of layered soils with morphologically weak genetic horizons.

The degree of development of trees and shrubs in such habitats is determined by moisture inflow, which, in turn, depends on the catchment area size, exposure, presence of annual stable snow cover, formed when snow is blown from the adjacent territory, and, most importantly, availability of fresh and slightly saline groundwaters. From bottom to top, their depth increases from 0.9-1.2 m at the mouths to more than 4.5 m in the direction of upper reaches, while mineralization decreases from 5.94-8.46 to 2.89-4.28 g/l (Kolesnikov et al., 2018, 2019; Bykov et al., 2020).

Since the groundwater level rises from the most elevated are to the lowest one, while salinity changes the other way around, the spread of thickets along the lower part of the gully is limited by the increasing sodium chloride salinization of surface groundwater, and, consequently, by its unavailability in the upper part (Kolesnikov et al., 2018, 2019).

In the gullies with homogeneous lithologic composition of soil strata, ground is soaked by melt water down to 120-230 cm and is practically non-salinized. In a few of those gullies where the strata is lithologically heterogeneous, there is sometimes no permanent connection between root systems and groundwater, which makes plants dependent on the amount of water accumulated during snowmelt. However, in the absence of negative anthropogenic impacts, those areas merge when buckthorn and blackthorn shoots penetrate since they have access to groundwater through the root systems of their mother plants. We discovered this phenomenon in one of the gullies on the left bank of the Lantsug River, where the dense thickets were formed by 3 groups of old buckthorns, with a low blackthorn between them (Bykov et al., 2013; Kolesnikov et al., 2018, 2019).

We have shown that, despite the diversity of soil-hydrological conditions in different gullies, in the vast majority of cases there is a high groundwater level and low salinity and, therefore, such habitats are suitable for the formation of polydominant shrub communities. In fact, in each gully that reaches 4 m of depth at its mouth, there is an area stretching from fifteen to several hundred meters and suitable for the growth of such communities. This indicates that polydominant communities still retain considerable potential for preservation and development, but only in those areas where they are present at the moment, since they are unable to spread to new, potentially suitable habitats by seed.

Issues with artificial restoration of polydominant communities. A significant number of biotopes potentially available for the ravine trees and shrubs indicates that there is a possibility of restoration of polydominant communities in most of the gullies of the Elton Region. Due to the fact

that moisture reserves depend on the size of the catchment area, it is obvious that restoration of tree stands of lost ravine forests are more promising in larger gullies.

It is known that various artificial hollows, such as quarries, trenches, empty canals and emptied ponds, can overgrow with self-seeding anemic and zoochoric trees and shrubs, primarily, with poplars and Russian olives. This process is fueled by a decent supply of melt water that can even flood such hollows during spring. Additionally, it requires a bunch of closely growing seedlings of the corresponding species (Sizemskaya et al., 2020).

In the Elton Region, tree species of the lost ravine forests are present in artificial plantations around ponds that are directly connected to the Elton Lake Depression. However, seedlings of poplar and willow do not spread along gullies and river valleys, and are very rare along pond banks. The vegetative shoots of these species are not numerous and usually wither away after reaching 1-1.5 m of height (Photo 6), only occasionally forming small groups of silver poplar that shoot from roots and reach 3-5 m of height. Seed regeneration, however, requires extremely wet soils, usually, areas that get flooded periodically by melt waters. In hot climate of the Elton region, by the early July the upper soil layers dry up down to 1.3-1.5 m which is the depth that usually marks beginning of wilting, because this level of humidity causes capillary rupture in plants (Table 2). In the first 3 months of their life, root systems of self-sown ravine species are only 10-15 cm long (Trees and Shrubs of the USSR, 1951) and do not have time to reach the capillary fringe. Meanwhile, soil profiles of the gullies do not get soaked through every year. Additionally, natural seed regeneration of willows and poplars mostly occurs in exposed areas (i.e. alluvial sediments), because their seedlings are very light-demanding and cannot survive in shade and competition with herbaceous vegetation (Trees and shrubs of the USSR, 1951).

Photo 6. White poplar tubers at the upper reaches of the Khara River near the Phinogenov Pond.

Our experiments on the reintroduction of lost ravine species in two gullies of the upper Lantsug River outside the nature park have shown that this is the key factor. For example, more than 30% of rooted cuttings of poplar and willow (50 of each) planted in late March 2022 had vegetated until

the end of June, but then withered in mid-July. The following excavations revealed that their root systems had no time to reach the capillary fringe. Thus, in the lowest points of gullies, where the fringe rose only to 70 cm even in spring seasons of 1952-1953 (the most wet years), but dropped down to 140-160 cm by mid-summer (Dinesman, 1960), which is also confirmed by Table 2.

Table 2. Soil moisture in the Elton gullies during spring-summer.

Depth, cm	Soil moisture, %			
	Under the tree and shrub community ("Biological Gully")		Gullies without any woods	
	Thorough soaking (May 2013)	No thorough soaking (May 2021)	"Ternovaya" (July 2021)	"Chernaya Rechka" (July 2021)
10	27.5	26.2	*11.2*	*13.4*
20	26.8	22.5	*11.4*	*12.2*
30	21.1	20.9	*10.9*	*14.7*
40	19.0	20.0	*11.0*	*12.4*
50	20.5	21.0	*11.3*	*13.8*
60	20.9	19.7	*12.9*	*12.9*
70	18.4	18.5	*12.8*	*13.0*
80	18.2	16.5	*12.4*	*13.6*
90	17.6	*13.6**	*13.1*	*14.4*
100	17.9	*12.8*	*12.9*	*14.1*
110	17.4	*12.5*	*13.3*	*14.8*
120	18.9	*11.5*	*13.9*	*14.5*
130	19.1	*15.2*	*15.3*	*14.7*
140	17.8	19.4	17.7	*14.3*
150	21.1	19.9	19.0	*14.2*
160	20.7	20.2	20.5	17.4
170	22.1	18.3	22.0	17.5
180	22.0	19.2	24.5	17.9
190	21.9	19.5	27.8	18.6
200	22.1	21.2	29.5	19.1
210	22.6	20.2	30.2	17.8
220	21.8	20.6	29.6	19.1
230	22.5	23.1	32.1	17.7
240	21.6	25.0	30.7	16.4
250	22.7	26.1		16.9
260	25.5			18.6
270	21.4			18.9
280	24.1			20.4
290	22.8			20.5
300	23.2			24.4

Note to Table 2: * – italic marks moisture values for the dried-up layers.

Naturally, the capillary fringe drops much lower during dry years. At the request of L.G. Dinesman (1960), S.D. Erpert and S.N. Karandina, researchers from the Dzhanybeksky Station, dissected and sketched root systems of several ravine species in “Biological Gully”, the largest one in the Elton Region. They showed that these systems were mixed, containing of both lateral and tap roots; in this case, lateral roots provide plants with moisture only from March to June, while tap roots start functioning from July. Therefore, the root systems of the artificial plantations in medium-humid and dry years should reach deeper than 150 cm by July, which requires seedlings with a sufficiently developed and closed root system to be planted in the fall, so that the plant could have time to utilize both spring and summer moisture in the upper soil layers.

It should be taken into account that any species of trees and shrubs planted in the gullies will be soon destroyed by grazing cattle. Moreover, grazing horses find shelter down there in bad weather, entirely breaking the ground cover by spring and stripping the trunks and branches up to 2 m (Photo 7).

Photo 7. Tree and shrub community destroyed by the cattle in the gully on the left bank of the Chernaya River.

We believe that in the near future it is necessary to carry experiments on recreation of polydominant shrub communities and reintroduction of the lost ravine species, such as poplars and willows. For this purpose, a fenced and irrigated nursery must be built in Elton Village. In our opinion, at first, it will be enough to have seedlings of black and white poplars, aspen, willow, apple tree, buckthorn and blackthorn, 50 of each.

At least two young gullies with no shrubs and one large gully suitable for reintroduction of lost species should be used for planting of buckthorn, blackthorn and honeysuckle thickets. As a test site, it could be wise to find two young gullies that run into the lake east of the Chernaya River and into a large gully in the “Presnyi Ruchey” natural boundary. The most important factor for this experiment is complete isolation of the test sites from cattle and presence of a firebreak.

This experiment requires 2 to 3-year-old saplings of appropriate tree species with a developed closed root system. They should be planted in the fall, taking into account the weather, then watered periodically, and monitored. Based on the results of the monitoring, a schedule of seedling regrowth should be compiled that would include records of the budding, beginning and end of vegetation, as well as any signs of weathering or physical damage.

Conclusions

Ravine forests, which used to grow in lake depressions and along the valleys of drainless rivers of the Northern Caspian Region, are now completely destroyed, and their habitats are lost for the most part. However, a number of tree and shrub species of these forests formed specific polydominant shrub communities. At present, few patches of these communities, 1 in a river valley and 3 in large gullies, are directly derived from the lost forests, while the rest are the result of mass seed regeneration of 1952-1953.

The polydominant communities are adapted to the deadly impact of fires due to their high density and the ability to quickly recover through a vegetative regrowth. Unfortunately, a cattle grazing decreases their density and leads to accumulation of flammable organic matter underneath them, which, in turn, reduces their fire resistance. As a result, over the last 50 years the total area of polydominant shrub communities has decreased more than twice and continues to wane.

At present, their total area is alarmingly small and can no longer provide refuge for forest and dendrophilic animals. Based on the long-term analysis of the dynamics of the vertebrates' composition and population in the region, we can predict a sharp decline in their number to the point when they might leave the region for good. This includes such breeding birds as the eastern imperial eagle, long-legged buzzard, long-eared owl and Eurasian pendulines, whose place would be taken by synanthropic species, the presence of which negatively affects such zonal birds as the little bustard, lesser kestrel, Eurasian stone-curlew and larks (Bykov, Bukhareva, 2015).

The climate conditions of recent decades leave no room for hope that their natural seed regeneration and spatial distribution will improve in the nearest future. At the same time, a large number of habitats in the region, potentially suitable for the natural polydominant shrub communities, as well as habitats occupied by communities directly derived from ravine forests, allow us to expect a success restoration and reintroduction of these communities. The ever-increasing reduction of their area, as well as unsolved issues of their protection from fires and grazing makes this problem extremely urgent.

Additionally, we must emphasize the need to develop measures for the conservation of natural complexes of the gullies. The "Biological Gully" shows that flora of large gullies has more than 200 species of vascular plants from 44 families (about 30% of species or 80% of families from their total number in the region), including ~14 species from various Red Data Books. The gullies ecosystems preserve almost 40 species that are wild relatives of cultivated plants, which are part of genetic plant resources and should be preserved as a national natural heritage (Nukhimovskaya et al., 2022). Gullies are dynamically evolving systems, but these days they are subjected to extreme zoogenic pressure due to unregulated cattle grazing. We have already mentioned trampling and severe damage of vegetation cover. Aside from that, animals create numerous trails down the slopes, which quickly turn into small ravines, the depth of which can reach 4-6 m in 5-10 years (Photo 8). Erosion of slopes provokes screes and landslides, which disturbs the established systems of both surface runoff and groundwater.

Creation of the Elton Nature Park and the Lake Elton Biosphere Reserve should change the nature of anthropogenic and economic pressure on this territory, providing the prerequisites for its regulation. The park administration is doing its best to preserve local flora, fauna and natural ecosystems, however, their possibilities are rather limited.

Photo 8. Consequences of cattle grazing with a destroyed polydominant shrub community in the valley of the Chernaya River.

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СОВРЕМЕННОЕ СОСТОЯНИЕ, УСЛОВИЯ ПРОИЗРАСТАНИЯ И ПУТИ ВОССТАНОВЛЕНИЯ БАЙРАЧНЫХ СООБЩЕСТВ В БИОСФЕРНОМ РЕЗЕРВАТЕ «ОЗЕРО ЭЛЬТОН» (ВОЛГОГРАДСКАЯ ОБЛАСТЬ)

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В статье обобщен имеющийся материал о местообитаниях утраченных байрачных лесов Приэльтонья, современном состоянии производных от них полидоминантных кустарниковых сообществ, почвенно-растительных условиях их произрастания и рассматриваются факторы, негативно влияющие на эти насаждения. Показано, что для озерных депрессий вообще, а для северного побережья оз. Эльтон в особенности, значительные перепады высот, развитая речная и балочная системы обуславливают многообразие вариантов условий произрастания древесно-кустарниковых сообществ байрачного типа. Уничтожение байрачных лесов влечет за собой исчезновение соответствующих местообитаний. Отмечается, что к настоящему времени суммарная площадь полидоминантных кустарниковых сообществ исчезающе мала и быстро сокращается, в то время как климатическая обстановка последних десятилетий не позволяет рассчитывать на интенсификацию процессов их естественного семенного возобновления и пространственного распространения. Все убыстряющиеся сокращение площади, занятой полидоминантными кустарниковыми сообществами, негативное воздействие на них выпаса скота и часто повторяющихся пожаров, ведущее к их полному исчезновению, неясность с

вопросом их хозяйственной и экологической ценности и возможностями охраны именно сейчас дела.т эту проблему крайне актуальной. Тем не менее, наличие в регионе значительного числа местообитаний, потенциально пригодных для существования естественных насаждений этого типа, а также местообитаний, занятых сообществами, непосредственно производными от байрачных лесов, позволяет рассчитывать на успех восстановления первых и реинтродукцию вторых. Выявлены наиболее значимые факторы, определяющие современное состояние рассматриваемых полидоминантных сообществ, такие как затрудненность семенного возобновления ценозообразующих пород, выпас скота и пожары. Показано, что в подавляющем большинстве случаев в балках Эльтонской озерной депрессии имеет место высокий уровень залегания грунтовых вод с низкой минерализацией, следовательно, данные местообитания пригодны для формирования полидоминантных кустарниковых сообществ. Отмечен значительный потенциал сохранения и развития этих сообществ, но только в местах своего нынешнего присутствия, поскольку в настоящее время в новые, потенциально пригодные для них биотопы, семенным путем они распространиться не могут.

В связи с наличием значительного числа биотопов, потенциально доступных для произрастания деревьев и кустарников байрачной группы в большинстве балок Приэльтонья отмечена принципиальная возможность восстановления полидоминантных кустарниковых насаждений, перспективность экспериментов по восстановлению древостоев утраченных байрачных лесов, некогда существовавших в крупных балках и необходимость их проведения. Приведены рекомендации по воссозданию полидоминантных кустарниковых сообществ и реинтродукции утраченных байрачных пород: тополей и ветлы.

Ключевые слова: Прикаспийская низменность, Волго-Уральское междуречье, оз. Эльтон, полидоминантные древесно-кустарниковые сообщества, овражно-балочные системы, байрачные леса, восстановление.

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