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Perspective

Changing Asian Mountain Steppes Require Better Conservation for Endangered Argali Sheep

Terry V. Callaghan [1,2,*], Irina I. Volkova [3], Igor V. Volkov [3,4], Alexey O. Kuzhlekov [4], Denis I. Gulyaev [4,5] and Olga M. Shaduyko [3]

1 Western Bank, Alfred Denny Building, University of Sheffield, Sheffield S10 2TN, UK
2 36 Lenin Pr., Biological Institute, Tomsk State University (on Hold), Tomsk 634050, Russia
3 36 Lenin Pr., Tomsk State University, Tomsk 634050, Russia; volkovhome2016@gmail.com (I.I.V.); volkovhome@yandex.ru (I.V.V.); dolcezzamia@mail.ru (O.M.S.)
4 1 Sailugemskaya Street, Sailugemsky National Park, Kosh-Agach 649780, Russia; altaec_vip@mail.ru (A.O.K.); gulyayev94@mail.ru (D.I.G.)
5 1 Lenin Street, Gorno-Altaisk State University, Gorno-Altaisk 649000, Russia
* Correspondence: terry_callaghan@btinternet.com

Abstract: We present a rare insight into the biodiversity of a remote, mountainous area of central Asia and outline challenges to conserve the critically endangered keystone argali (Ovis *ammon ammon* L.), the largest subspecies of mountain sheep. Existing conservation is set in the context of competition with livestock grazing and disturbance by local pastoralists. We suggest how this pressure would increase as pastures become degraded by a future more arid climate. Focusing on the transboundary population, migrating between the Russian and Mongolian Altai over the Sailugem Ridge, we track historical population numbers. Due to increased protection, the argali's local population is currently growing. However, most argali populations live outside the protected areas where they are forced to compete for forage with livestock. Due to ever-increasing anthropogenic pressures, argali has almost reached the region's environmental capacity, so the number of local populations is decreasing. Consequently, even the current situation requires more areas of protection, and climate change will accelerate pasture degradation, thereby further increasing competition with livestock. We present various ways to predict the impacts of changes in climate, e.g., the "7 M's approach" and grazing pressure and then recommend additional conservation measures acceptable for the indigenous population of traditional pastoralists.

Keywords: biodiversity; argali; mobile pastoralism; seasonal protected areas; Altai; Sailugem; pasture degradation; climate change; "7 M's" approach

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1. Introduction

Loss of natural habitats and their fragmentation due to various forms of human activity are the main causes of biodiversity loss worldwide [1]. Super-imposed on this activity are both the direct (pasture productivity, forage quality, and phenology) and indirect (adaptive pastoralism) effects of climate change on the biodiversity of grazing animals [2]. In areas with traditional forms of economic activity such as pastoralism, populations of wild animals may be forced out of pastures even where regulations are in place to protect them. The hunting and trade of wild sheep are increasingly recognized globally as a major threat to their persistence [3], while at the same time, it has been recognised for more than 3 decades that global warming will result in structural and distributional changes in vegetation [4]. Therefore, farmers and pastoralists will need to adapt their land use [5,6]. These problems are key to the conservation of the largest of the rams, or giant sheep, the endangered argali (*Ovis ammon* L.) [7] (Figure 1).

Figure 1. Argali rams (*Ovis ammon*); Photo by A. Kuzhlekov, 2022.

O. ammon is classified into seven subspecies: *nigrimontana*, *hodsoni*, *jubata*, *darwini*, *ammon*, *polii*, and *karelin*. The argali subspecies *Ovis ammon ammon* L. (argali in the text) is the largest sheep on the planet, with a body length of 174–180 cm, a height at the withers of 114–125 cm, and a weight of up to 200 kg (Figure 1). It inhabits the Altai Mountains in Siberia (Russia) (Figure 2A) and neighbouring parts of Mongolia, China, and Kazakhstan. It was listed in the 2021 *Red Book of the Russian Federation* as "critically endangered (Category I, (CR A4ac)), hunting prohibited" [8], whereas in the IUCN report of 2020, it is listed as Near Threatened under criteria NT A2de [9]. We focus on the largest population in Russia that lives in the transboundary territory of the Sailugem Ridge of the Altai Mountains on the border of Russia and Mongolia (Figure 2B,C), and we accept the "local", Russian categorisation of its "Critically endangered" status. Because argali are threatened, are keystone species in their ecosystem, and are likely to experience population decline in the future, in this perspectives paper, we describe in more detail argali numbers, pressures on their populations, and current conservation measures. We present new, up-to-date information and field observations on sheep, vegetation, land use, and climate change in one remote area. Based on this information and the need for improved conservation, we put forward several proposals to improve argali protection in both short- and long-term time frames and recommend actions for research to underpin conservation aims.

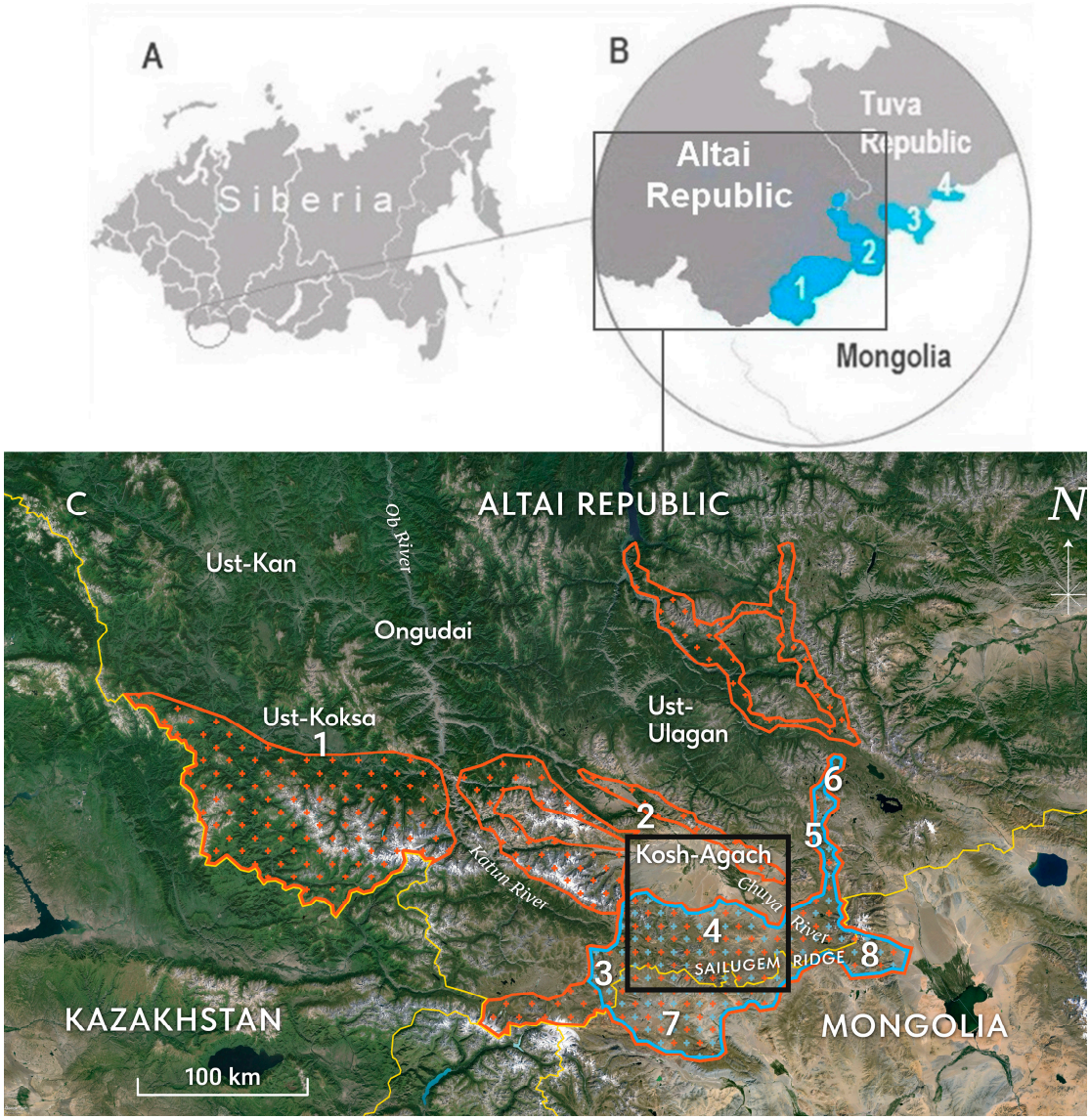

Figure 2. Distribution of argali subspecies *Ovis ammon ammon* L. (**A**)—study site location; (**B**)—transboundary population (blue): 1—Sailugem Ridge group, 2—Chikhachev Ridge group, 3—Mongun-Taiga Ridge group, 4—Tsagaan-Shibetu Ridge group; (**C**)—range of the argali in the Russian Altai in the 18th century (red outline and dots): 1—area from which the argali had disappeared by 1826, 2—area in which an argali skull with remains of skin was found in 1826, Blue outline and dots—current argali distribution: 3—western part of the Sailyugem argali population, 4—on the Sailugem Ridge, 5—on the Chikhachev Ridge, 6—in the Bogoyash River Valley, 7—on Mongolian part of Sailugem Ridge, 8—Mongolian part of the Mongug-Taiga Ridge group. The black square is the area detailed later in the text 7. Scheme 2B is developed from [8] and modified according to research by the co-authors. The modern range in Figure 2C is based on research by the co-authors. The historical range of argali is drawn from [10–12].

2. History of Argali in the Russian Altai

Scattered rock paintings—petroglyphs—depict scenes of people hunting sheep 2–3 thousand years ago, suggesting argali lived throughout the entire Altai-Sayan Mountain lands [10] (Figure 3). Even 200 years ago, the argali range covered the mountain–steppe belt and extended from the southwestern foothills of the Altai to the mountain ranges east of Lake Baykal (Figure 4). In the 18th century, when scientific study of the region began, the range of argali was decreasing and covered only the southeastern ridges of

the Russian Altai. According to Ledebour [11], by 1826, argali had disappeared from the Uymon Village area (Figure 2C, point 1). Also in 1826, the skull of an argali with huge horns and preserved remnants of the skin was discovered near the mouth of the Chagan River [11] (Figure 2C, point 2). Overall, argali sheep numbers have decreased over the past two hundred years and populations of all seven subspecies are declining [8]. The main period of the recent decline in the population was the last 30–40 years, when the number of argali decreased by about 1.5–2 times [13]. In 1988, their number in the Russian Altai hardly reached 150 individuals [14]. In 2021, argali was a "critically endangered" species and is a CITES-listed migratory species [15].

Figure 3. An ancient rock painting (petroglyph) of two argali, probably made before the Bronze Age. (Yenisei River valley, the Sayan Mountains). Retrieved from https://nplus1.ru/news/2022/10/22/rock-art. Accessed on 1 November 2022.

At present, the distribution of argali is limited to the mountain systems of the Mongolian Altai, the Khangai, and individual ranges in East Kazakhstan, the southeast Russian Altai, the southwest Russian Tuva, and western Mongolia (Figure 4).

The population dynamics of argali in their Russian range have fluctuated in the past 100 years [12,16,17]. The collapse of the USSR and the deep economic crisis at the end of the 20th century led to the depression of agriculture, resulting in the lack of competition for argali food resources from domestic animals. The number of argali therefore gradually increased. In 2010, an estimated 600–700 argali lived in Russia [13]. In 2019, their estimated number in transboundary (Russia–Mongolia) groups was 4795–4886. During 2019–2021, this population increased by about 22.5% [18] to 6189 individuals.

Following the earlier increase in argali due to the reduced intensity of agriculture, the number of argali in the Altai Republic in general and in the Kosh-Agach District (Figure 2C) in particular, has continued to increase due to local conservation measures. Also, according to the recent inventory data, the argali sheep population has been increasing within the Mongolian and Russian border zones thanks to the multifaceted conservation actions undertaken within the species distribution ranges [19]. In fact, Russia and Mongolia have committed to safeguarding their wildlife by vowing to maintain diverse, representative, and vulnerable ecosystems and biodiversity through national legislation. This legislation is within the framework of the implementation of the Convention on Biological Diversity (ratified by Mongolia in 1993 and by the Russian Federation in 1995) and the Convention

on International Trade in Endangered Species of Wild Fauna and Flora (CITES, ratified by Mongolia in 1996, by the Soviet Union in 1979, and by the Russian Federation in 1992) [15]. However, despite the international agreements and national protection, the Altai Mountain transboundary region is rapidly losing its wildlife, and argali are threatened due to many interconnected factors discussed in detail below [13,18–20].

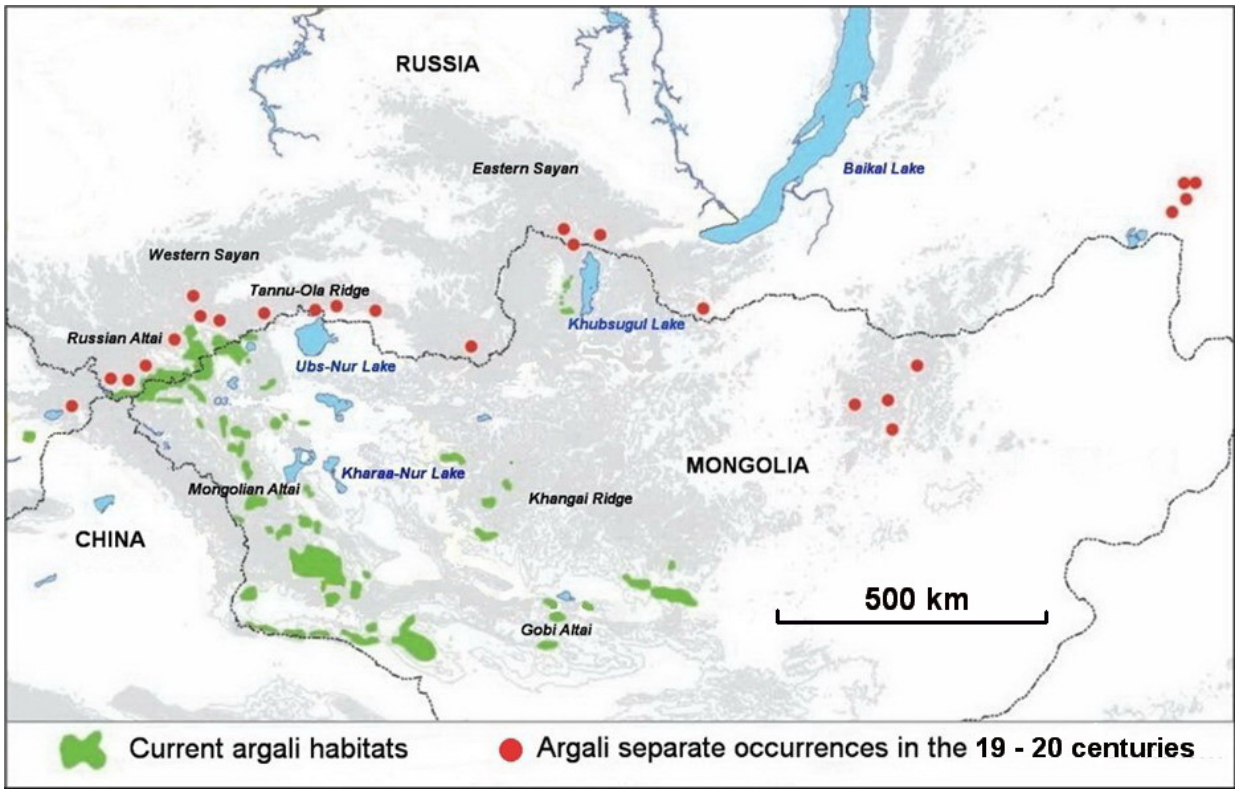

Figure 4. Current and former occurrences of argali (after [13], modified graphically by the authors).

While the conservation of argali is important for their intrinsic biodiversity value, i.e., as a carrier of the genome, they are also important and integral components of the mountain ecosystems (gamma diversity) where they occur. In a similar way as reindeer and small herbivores in the Arctic [21], argali likely limit the upward spread of invading species from lower in the mountains (alpha diversity) and preserve mountain steppe ecosystems in their natural state during climate change. Also, they are prey and an important food source for the globally threatened snow leopard [22], of which, according to WWF experts, there are about 70–90 individuals in the Russian part of the Altai-Sayan ecoregion [23]. If argali populations decline as expected, snow leopards are likely to seek the alternative prey of herded animals, with the result that local farmers and herders will be tempted to kill more snow leopards. Argali are also likely to be a food source for scavenging and predatory birds (for example, the golden eagle *Aquila chrysaetos* L., *Russian Red Book* species and sacred bird of the Altai People) and mammals of the upper alpine zone. An increase in the argali population contributes to a decrease in wolf attacks on livestock. So, after the rut, many wolf attacks on argali were recorded, while their attacks on livestock stopped [18].

3. Factors Affecting the Argali Population in Russia

3.1. Distribution

In total, four transboundary groups of argali can be identified in the Altai-Sayan ecoregion (Figure 2B, [8]):

- The group in the Sailugem Ridge. The argali habitat here is located on both sides of the Sailugem Ridge in the Altai Republic (Russia) and Mongolia. The largest

transboundary grouping of argali occurs here (Figure 2B, 1). In 2023, 2644 argali were recorded in Russian territory, and 2477 in Mongolian territory [24]

- The group in the Chikhachev Ridge, Russia (Figure 2B, 2). The habitat is located on the southern spurs of the Chulyshman Ridge (the territory of the Altai Reserve), Bogoyash River Valley, the Chikhachev Ridge (the Altai and Tuva Republics), and the Talduair Mountain group. The main habitats are the western macroslope of the Chikhachev Ridge and the Talduair Mountain group. The argali enter Mongolia and the most southern part of the Chikhachev Ridge only in especially snowy winters. The number of argali on the Chikhachev Ridge is decreasing dramatically (in 2017, there were 360 argali individuals, but in 2023 there were only 60) [24].
- The Mongun-Taiga group (Figure 2B, 3). The habitat of the argali here is located on the southern spurs of the Mongun-Taiga Mountain Ridge in Tuva and Mongolia. The main habitats are located in Mongolia at the following sites: Atsat khar and Khurmiin nuru, Nariin gol, Tsagan gol, and Mandakh Hills. Recently, argali have not ventured far into the territory of Tuva, but have kept to the areas near the Russian state border. In total, 1058 argali were registered in Mongun-Taiga in 2023 (136 were in Russia and 922 in Mongolia) [24].
- The group in the Tsagaan-Shibetu Ridge in the territory of Russia (Tuva) and Mongolia (Figure 2B, 4). Argali adhere only to the western macroslope of the Ridge. In recent years, only small groups or single individuals have been recorded. In total, 57 individuals were spotted in the territory of Tuva in 2023 [24].

3.2. Habitat and Carrying Capacity

The unprotected range of the argali in the Russian territory is mainly represented by plateaus with altitudes of 2400–2700 m above sea level with steppe tundra vegetation, which is a typical forage habitat for this species.

Our surveys of argali pastures on the Sailugem Ridge in the summers of 2022 and 2023 showed that the vegetation most disturbed by domestic livestock is located mainly in the river valleys and adjacent mountain slopes (Figure 5) and occupies a relatively small area. At the same time, pastures at higher elevations on the flat mountain tops, which occupy almost 80% of the area of the Sailugem Ridge, are in relatively good condition.

To assess the range of pasture productivity in relation to grazing pressure, five key study areas representing the most important vegetation types were studied in different parts of the Sailugem Ridge. These areas included argali locations with the presence of livestock varying from abundant to few, the latter in a protected area. The sites are confined to the Valleys of the Chagan-Burgazy, Kulun-Bazhi, Sarzhemata, Ulandryk (represented by two subsites because it was a particularly extensive area), and Tarkhata rivers. Measurement of the forage biomass in summer 2022 using standard techniques revealed that the steppes with dominant *Poa attenuata* Trin. (Figure 6), which is the most common vegetation on the plateaus of the Sailugem Ridge at altitudes of 2400–2600 msl, have a fairly high productivity of 1.02 t/ha dry matter per year. The productivity of some highland pastures at altitudes of 2700–2750 msl reached 1.75 t/ha. Calculations based on the amount of fodder required for argali (16 to 19 kg wet phytomass per day [25] and on the productivity of pastures (see above) showed that just 2.7% of the Sailugem Ridge territory is enough to produce the food base for argali. Although stocking rates are private and unavailable, our calculations suggest that, in general, livestock use the main pasture phytomass, and the argali population consumes a small part of it.

The habitats in the Mongolian territory are more attractive for the argali sheep. Mongolia has less snow and more accessible foraging in winter [26]. Although part of the population remains to winter in Russia in places where there is little snow, increasing human impact on reducing the range in the Russian territory forces almost all argali to migrate to Mongolia in winter. Unfortunately, we do not have the same up-to-date data on the state of the argali forage base in this part of Mongolia. However, according to Luschekina and Fedosenko (1994) [27], the large-scale privatization of domestic livestock in Mongolia,

which started in 1991, was accompanied by practically uncontrolled pasturing even in areas that were previously under state protection and intended exclusively for wild animals. This resulted in competitive displacement of argali to poorer quality habitats, and increased poaching of argali by herdsmen. Widespread degradation of argali habitats by domestic livestock is described by Reading et al. in 1997 [28] and implicitly only by Maroney in 2006 [29] and Wingard et al. in 2011 [30]. On the Mongolian part of the Sailugem Ridge, the situation has probably improved with the creation of the Siilkhem Nuuru National Park, but the pastures on the southern macroslope of this Ridge are less resilient to a warming climate because they are warmer and dryer than the north facing slopes on the Russian side. In addition, trophy hunting still takes place on the Mongolian part of the Sailugem Ridge [13,24].

Figure 5. Degraded vegetation in a valley on the Sailugem Ridge. Photo by I. Volkov, 2022.

3.3. Pressures from Indigenous Peoples' Land Use

The traditional way of life of the indigenous population has preserved the unique nature of the Altai-Sayan region in almost its original state. This way of life is based on a subtype of pastoralism—distance transhumant pastoralism (mobile pastoralism)—which is a traditional land use style of the indigenous people of the Altai both in Russia and Mongolia, involving the movement of herds between fixed locations—winter and summer pastures [31,32] (Figure 7). This way of life is based on the knowledge and skills of survival, which have been formed over many thousands of years.

Figure 6. The main pasture type on the plateaus of the Sailugem Ridge—the grassland is dominated by *Poa attenuata*. Photo by I. Volkov, 2022.

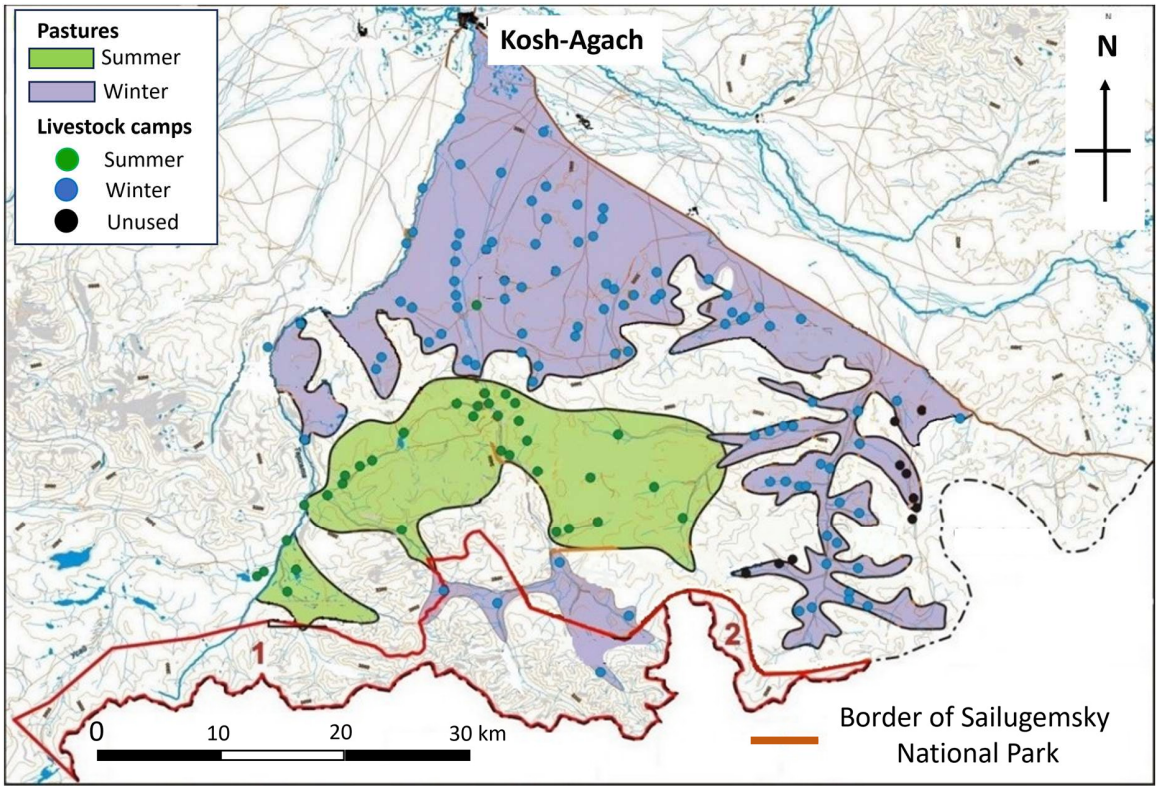

Figure 7. Sailugem Ridge and adjacent territory land use: summer and winter pastures of livestock and Sailugemsky National Park clusters (1—cluster "Sailugem", 2—cluster "Ulandryk", cluster 3 is not shown: it is about 90 km northwest of cluster 1 and is not on the Sailugem Ridge). Data for the camps include multiple years (after [33], modified by the authors).

The Altaians have always felt that they are part of nature and have never reduced the number of argali to a dangerously low level. In particular, among the Telengits, who are one of the tribes of the Altaians, living in the south and southeast of the Altai Republic, the argali is considered a sacred animal. These beliefs come from the ancient Pazyryk culture of the Altai Mountains which used horses in religious ceremonies disguised as deer and argali mountain sheep [34]. The Telengits have never hunted argali with the largest horns, considering such argali to be the "master of the mountain" [35], thus leaving the most important sires in the population. This is in complete contrast with trophy hunting of the largest rams available only to wealthy people: the price of a hunting tour in Mongolia is USD 42–48 thousand (for only one ram) [36]. Killing dominant rams splinters herds as young males spend a lot of energy competing for dominance and becoming easier prey for predators.

The cultural ideas of the Altaians are consistent with the ecosystem approach to the conservation of the natural environment, which is facilitated by the historical experience of the relationship between the indigenous peoples of Altai and nature. However, potential, new protected habitats of the argali are currently affected by remote pasture use by various types of livestock. A preliminary analysis (according to the authors' long-term visual observations) showed that the proximity of livestock does not directly interfere with argali, which often graze together with domestic animals. However, in contrast, overgrazing by domestic sheep, goats, and cows in some areas, as well as poaching, disturbance, and harassment of argali by herdsmen's dogs limit the use of non-protected areas by argali. Harassment by sheep dogs is especially important, given that in April, female argali have offspring that are vulnerable not only to predators, but also to sheep dogs [18,24]. Also, in the absence of regulation of pasture for animal husbandry, the displacement of the argali from traditional habitats by livestock farming may arise in the future.

3.4. Climate Change

Against this background of various threats to argali population numbers, future climate change is also expected to play additive and interactive roles. Direct impacts, such as increased temperatures on heat stress of the animals, are likely to be minor compared with reduced pasture productivity from increasing aridity and, therefore, greater competition for forage with livestock [37]. Although the impacts of changes in argali habitats due to climate change are not currently known [38], it is known that alpine habitats are particularly at risk as available land becomes limited with increasing elevation [39] and the ranges of alpine vegetation are changing [40]. Aridization of the climate in the argali habitats is expected but its likely harmful impacts are not included in the argali's conservation strategy [38]. At present, pasture degradation in the southern part of the Chuya Depression (the "Chuya Steppe", Figure 8), which is subject to strong economic activity, has led to significant desertification greater than elsewhere. The cryoarid ecosystems are now less productive [41]. This naturally leads to more intensive use by pastoralists of high mountain pastures in the range of the argali population that have better water supply.

The reconstruction of past vegetation changes is informative when forecasting the direction and intensity of aridization. These showed a significant xerophytization of the vegetation in the Sailugem Ridge passes during the Holocene climatic optimum (about 7 thousand years ago) [41,42]. During this time, the Chuya Depression was occupied by desert vegetation. The slopes of the depression, now a belt of steppe vegetation, were dominated by desert steppe, desert cushion, and plant communities of rough, hard grasses. On the top of the Sailugem Ridge, communities of cryophyte-steppe and alpine plants grew [43]. This altitudinal vegetation belt structure resembled the modern vegetation in the Gobi Altai. Bottom sediments of lakes in the Altai foothills [44] also indicated a warming of the climate in the Atlantic period of the Holocene about 7350–5030 years ago, which coincided with glacier degradation in the Aktru Valley [45].

Figure 8. View from the Sailugem Ridge to the Chuya Depression. Photo by I. Volkov, 2022.

The forecast of climate change compared with a baseline for 1990–1999 suggests that the average monthly temperatures in the Sailugem Ridge area will increase by 3–3.5 °C by 2030–2039, and by 6–6.55 °C by 2090–2099 [37]. At the same time, the currently observed cooling in the winter period is predicted to stop in the future [37]. As the climatic conditions of the growing season are the most important for the formation of vegetation, forage will probably soon be limited on the Sailugem Ridge. Based on our studies of vegetation differentiation by altitudinal zones and its exposure, we can estimate how the vegetation in the Chuya Depression and the main types of vegetation in the Sailyugem Ridge will change (Table 1, Figure 9).

Table 1. Assessment of expected possible vegetation changes compared to current vegetation in the Altai Mountains (Russian part, Siberia) due to an increase in temperature of 2 °C. Predominant vegetation types are illustrated in Figure 9. Main topography components are illustrated in Figure 10.

Topographic Location	Current Vegetation	Estimated Future Vegetation	Changes in Forage Value
Kosh-Agach Village vicinities in the Chuya Steppe (Figure 2C)	Fragmentary desert vegetation dominated by *Krascheninnikovia ceratoides (L)* and *Anabasis brevifolia* C.A.Mey., (Figure 9i,j) and other petrophytes and halophytes (Figure 9a)	Widespread desert vegetation dominated by *Krascheninnikovia ceratoides*	Reduced vegetation productivity and forage quality and quantity

Table 1. *Cont.*

Topographic Location	Current Vegetation	Estimated Future Vegetation	Changes in Forage Value
Chuya Depression (Figure 8)	Currently increasing areas of halophytic and petrophytic vegetation ([41]) Fragments of shrub deserts of the Central Asian type occur in the western part of the Depression	Reduction in desertified steppes, which will be restricted to the foothill aprons. A significant increase in petrophytic and halophytic communities, among which significant areas will be occupied by communities of desert plants	Reduced pasture productivity by 40 to 50% Reduced forage quality and quantity
Lower reaches of the valleys of Sailugem Ridge's main rivers (2–3% of the Ridge area)	Sparse vegetation with a high degree of anthropogenic disturbance. Halophytic communities with *Leymus* sp. predominate Communities dominated by *Artemisia santolinifolia* inhabit steep rocky slopes (Figure 9b)	Mass penetration of mountain desert communities, which will occupy the habitats with the highest soil salinity	Due to vegetation disturbance, its productivity will decrease slightly—by 10–20%—with a subsequent decrease in forage quality and quantity
Slopes of the lower reaches of the river valleys of the Sailugem Ridge in a belt of 2100–2300 m a.s.l. (about 4–5% of the Ridge area)	Dry steppes dominated by *Poa botryoides*, *Artemisia frigida*, and *Potentilla acaulis* (Figure 9c,f)	Gradual replacement of desertified steppe phytocoenoses by communities of wormwood (*Artemisia santolinifolia*) (Figure 9b)	Degree of productivity change is unclear, but it will reduce, with a decrease in forage quality and quantity
Plateaus at altitudes up to 2300–2700 m a.s.l.) occupying most of the northern territory of the Sailugem Mountain Ridge (about 60% of the Ridge pasture area)	Steppes dominated by *Poa attenuata* (Figure 6), many of them with significant degradation caused by anthropogenic influence (Figure 9f)	On the southern slopes, *P. attenuata* steppes will be replaced by steppes with *Agropyron cristatum* (Figure 9d) and *Koeleria cristata* On rocky slopes up to 2500–2600 m a.s.l., communities of spiny cushion plants (e.g., *Oxytropis tragacanthoides* (Figure 9e) will spread. Slopes of other exposures up to an altitude of 2500 m a.s.l. will be occupied by cold wormwood steppes with a predominance of *Artemisia frigida* (Figure 9f) At about 2800–2900 m a.s.l., where steppes with *Poa attenuata* will occur, the co-dominants will be *Saussurea schanginiana* and other xeromorphic species [46]	On southern slopes, pasture productivity will decrease by 50%. Overall reduction in productivity of 35–40%. Decrease in quality and quantity
	Sparse dryad-kobresia communities (*Dryas oxyodonta*, *Kobresia myosuroides*)	These communities will disappear	No forage
	Areas of *Kobresia* phytocoenoses	Remnants on the highest peaks and pre-summit slopes of northern exposure	Very limited forage, suitable just for argali males

With an increase in the average annual temperature by 4 degrees, low-productivity pastures will prevail on the plateaus of the Sailugem Ridge, and the belt of mountain steppes with fragments of high-mountain vegetation remaining only on the highest mountain peaks (at altitudes above 2700 msl). The overall productivity of pastures will be similar to one of the modern arid regions of Central Asia [46].

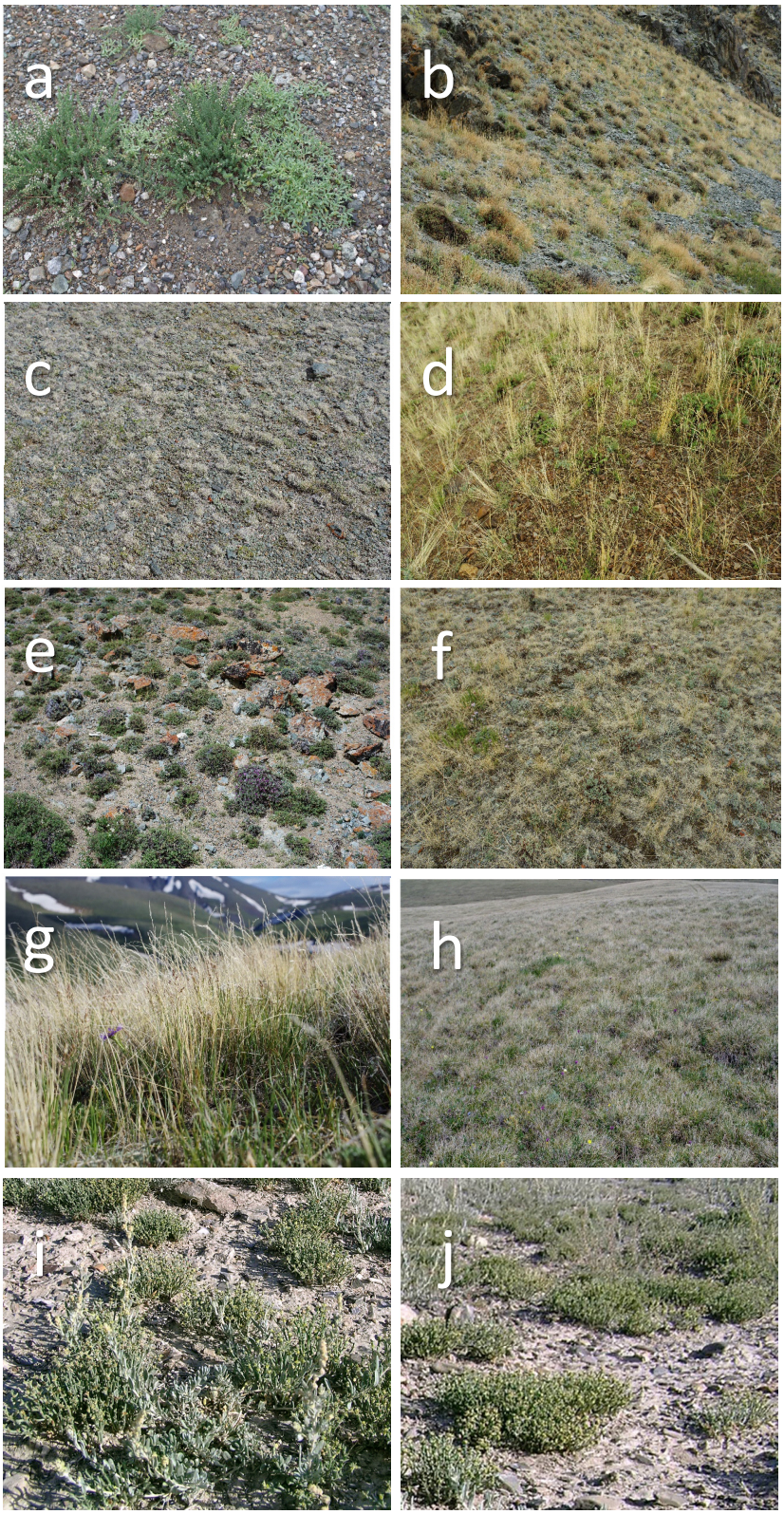

Figure 9. Vegetation in the Sailugem Ridge and Chuya Depression: petrophytic vegetation in the Chuya Depression (**a**), community of *Artemisia santolinifolia* on the talus slopes of the Chagan-Burgazy River Valley (**b**), dry steppes with Poa botryoides (**c**), steppe with a dominance of *Agropyron cristatum* (**d**), community of spiny cushion plants of *Oxytropis tragacanthoides* (**e**), steppe degradation with *Poa attenuata*, where this species is replaced by *Artemisia frigida* (**f**), steppe with a dominance of *Festuca lenensis* (**g**), community with a dominance of tussock *Festuca kryloviana* (**h**), community dominated by

Kraschenninnikovia ceratoides (L.) Gueldenst (**i**), community dominated by *Anabasis brevifolia* C.A.Mey (**j**). Photos by Igor Volkov.

Desertification and degradation of pastures will force herds of livestock to graze increasingly higher. The most likely consequence will be increased competition between domestic animals and argali for food resources. Therefore, in the future, climate change may be an even stronger factor in the degradation of pastures on the Sailugem Ridge than grazing with livestock.

Little is still known about how climate change will affect the vegetation in the western and highest part of Sailyugem Ridge bordering Mongolia with alpine landforms since this vegetation is affected by westerly winds that bring snow from much farther away [46] from the higher South Chuisky Ridge and the Ukok Plateau. Also, for the highest ridges, there is a barrier effect of interception of precipitation from the Atlantic cyclone. Currently, the west steppes are dominated by *Festuca lenensis* Drob. (Figure 9g). At higher altitudes, these steppes are dominated by *Festuca tschujensis* Reverd. and tussock communities dominated by *Festuca kryloviana* Reverd. (Figure 9h) species, which grow in much better moisture conditions and relatively low anthropogenic pressure.

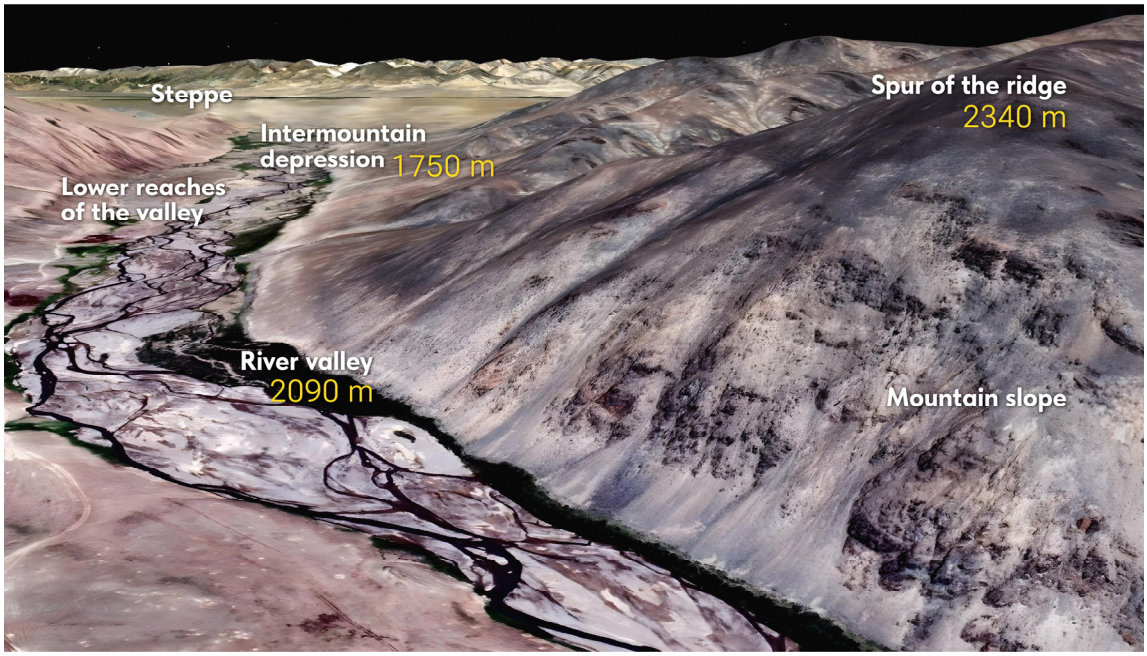

Figure 10. Main topography components of the study area (schematically developed from Google Earth, https://earth.google.com/web/, accessed 25 August 2024).

3.5. Risks during Migrations between Russia and Mongolia

Argali migrate between the Russian Federation and Mongolia. They spend their summers in Russia and move to Mongolia to over-winter, returning in springtime. This seasonal migration makes the argali population relatively vulnerable. The recent and current conservation of argali has led to a growth in their total population but any negative changes in either their territory in Mongolia or Russia may threaten argali survival, which is critically dependent on potential changes in the state of forage and conservation status in both states. The reasons for such changes can be both a change in nature management, a change in habitats associated with climate transformation, and a change in land use. Since winter pastures on the Russian side of the Sailugem Ridge, according to our estimates, have enough food and water supply, and they are underused by the argali, their population should be sustained by ensuring that a sufficiently large part remains in the territory of the Russian Federation in the winter. To do this, it would be necessary to eliminate the factors that led to the reduction in the argali range there [18,24].

4. Recent and Current Risks to Argali and Conservation

Currently, most of the transboundary group in Russia inhabits the Sailugem Ridge. This park was created in 2010 with adjacent protected areas. Initially, the park was created to protect and sustain populations of rare and endangered animals and plants listed in the *Red Book* (particularly the snow leopard and the Altai Mountain sheep—argali) in the Kosh-Agach District in the Russian part of the Sailugem Ridge. The boundaries of the protected areas in the Sailugemsky National Park are designed to preserve the territories of traditional pastoralism by the indigenous peoples of Altai adjacent to the national park (Figure 7). As a result, only about 5% of the argali are protected in summer in the National Park (oral report by the Director of the Sailugemsky National Park). The protected area consists of clusters of three sub-regions. Preserving argali is also aided by infrequent patrols by interdepartmental anti-poaching brigades [47]

Two of the three clusters of the national park are located on the border with Mongolia. To the south, the Sailugemsky National Park borders the Mongolian Siilkkhem Nuuru National Park, and together they have developed a program to monitor the transboundary group of argali [48]. Since 2014, specialists in the national park have been constantly monitoring the transboundary group of argali on the Sailugem Ridge by visual counting. Between 2014 and 2023, a significant increase in the number of argali occurred (Figure 11).

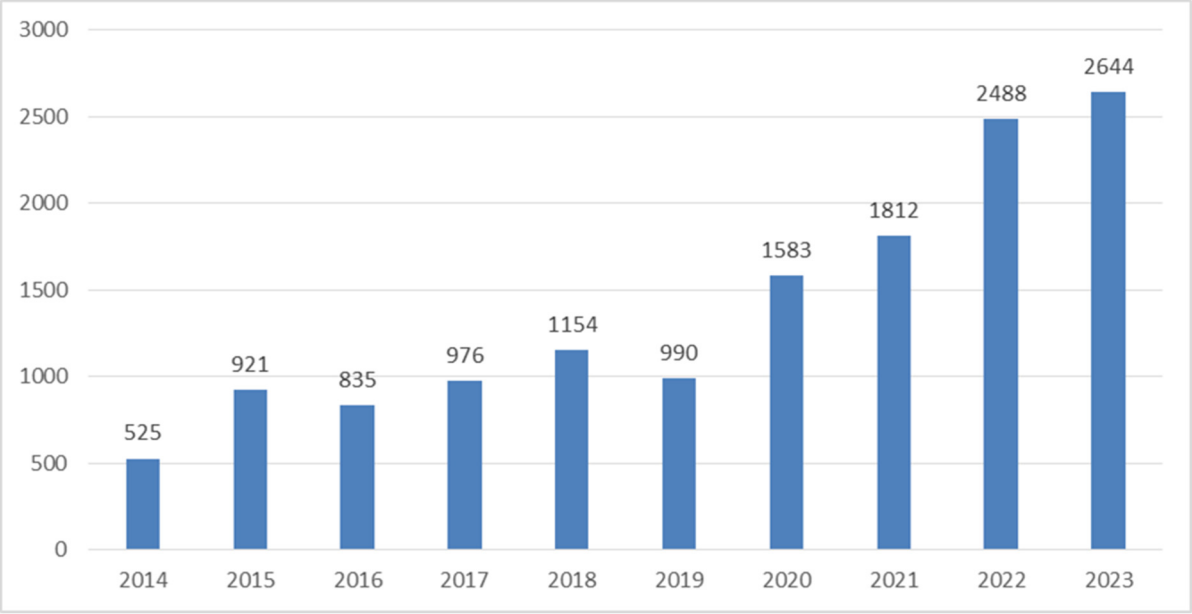

Figure 11. Dynamics of argali numbers in the Russian part of the Sailugem Ridge [18,24,49,50].

The significant increase in the argali population on the Sailugem Ridge [18,24], accompanied by a relatively small increase in its range (authors personal observation), is a local success because of effective protection. However, a decrease in the argali population has been recorded elsewhere. On the Chikhachev Ridge (Figure 2B, 2), there were 367 individuals in 2019 but only 163 in October 2021. This reduction resulted from poaching. Also, the number and range of the Mongun-Taiga Ridge argali group decreased (Figure 2B, 3) due to the construction of wires along the border across seasonal migration routes [18]. Thus, the main factor hindering the restoration of the former argali range in these areas is high anthropogenic pressure, which is not accompanied, as in the Sailugem Ridge, by effective measures to protect this species. Also, although argali sometimes appear on the adjacent mountain ridges outside of the main locations, they cannot gain a foothold there because of disturbance associated with livestock management. Despite the local success of conservation measures for argali populations on the Sailugem Ridge, further population increase will be limited by the capacity of the environment in the limited area of the Ridge.

Recent population increases should be viewed as a partial recovery to past, higher population levels and argali populations are expected to decline in the future without new conservation measures as available habitat decreases and poaching and disturbance increase. In the Russian part of the argali world range, argali have been protected from hunting since 1934 but there is a problem of illegal ram hunting, which has even been carried out by border guards, police, and customs officers [51]. There were cases of illegal hunting using a helicopter, which was highlighted publicly in 2009 in Chernaya Mountain (Figure 12) because of a helicopter crash and the death of some high-ranking officials [51]. Currently, poaching on such a scale is impossible, thanks to the presence of national park staff, wide publicity about their activities, and the help of the local population. The level of illegal hunting of argali by pastoralists and local hunters is less significant and is driven mostly by enhancing diets rather than hunting for trophies. However, there were several cases of illegal trophy hunting by visitors in which local residents took part as guides. In contrast, trophy hunting is a legal business in Mongolia [52] and an added pressure on argali. Though the Mongolian Law on Reinvestment of Natural Resource Use Fees requires that the government reinvest 50% of trophy hunting revenue in wildlife conservation, it has not been doing so [53].

Figure 12. Depression of the Chagan-Burgazy River and Chernaya Mountain (Sailugem Ridge), one of the main locations of argali. Photo by I. Volkov, 2022.

Additional factors threatening the conservation of argali in the Russian part of the range are the degradation of the forage base—pasture productivity declined by 5.4 to 11.1% between 1985 and 2010 [33]—and the gradual displacement of argali to sub-optimal, more marginal areas (less productive areas on steep, inaccessible slopes) when livestock (sheep, goats, cattle, camels, yaks) are moved by pastoralists to the argali habitat. Associated disturbance, poaching, and harassment by herding dogs lead to fragmentation of the argali range.

Our observations on the Sailugem Ridge in the summer of 2022 showed that a significant part of the argali population is concentrated in areas outside the National Park, on the

northern slope of Mount Chernaya (Figure 12), where relatively few livestock graze, and the condition of pastures is quite good. In contrast, a significant group of argali live in the eastern part of the Sailugem Range, in the territory of the Ulandryk River Valley, where pastures have a fairly high degree of degradation. The high mobility of argali probably allows them to find sufficient food even in areas with a high pasture load, and, if necessary, they quickly migrate to parts of the Ridge where pastures are better preserved. In summer, the argali can more efficiently use pastures on the tops of mountain ranges, compared to domestic livestock (except domestic yaks).

5. Likely Future Risks to Conservation

In the near future (10–15 years), more extensive changes are likely to occur on the warmer, drier southern macroslope of the Sailugem Ridge in Mongolia, which will probably increase the value of habitats for the conservation of argali on the northern macroslope within Russia [37]. However, climate change is likely to have multiple effects in addition to habitat limitation, such as increased risk of vector-borne diseases [54]. Also, climate change is likely to interact with land use through increased exploitation of upland pastures on the Russian side. Although the creation of protected areas in such places that are not optimal for nature conservation contributes to protecting wildlife in general, the protection of only a small part of the argali range in the Russian part of the Sailugem Ridge is an inadequate argali conservation strategy.

Conservation in a period of rapid climate change is difficult. "Classical" territory-based static conservation approaches are often limited in their ability to respond to rapid environmental change and have elicited a need to integrate spatially dynamic threats into conservation planning [55]. Dynamic area-based management represents a flexible conservation that is adaptive to ecosystem dynamics and climate changes [56]. Under this approach, areas are temporarily protected from anthropogenic pressures, and later released from formal protection when they are no longer needed. To date, this idea has gained the most traction in marine environments [57,58], but it is also applicable to terrestrial and freshwater environments [59,60]. Such strategies of conservation may be especially useful in fragmented habitats with a strong anthropogenic impact and for species with certain ecological traits such as migratory behaviours [61]. Argali is one such migratory species.

The combination of all the various pressures on argali populations does not allow us to be optimistic about their future on the Sailugem Ridge even if current strategies for their conservation are followed. Despite some recent population increases due to current local protection, the pressures are likely to increase faster than local protection achievements. Because past protectionist approaches to argali conservation in western Mongolia and the greater Altai-Sayan ecoregion have not achieved effective habitat conservation or anti-poaching enforcement, alternative management policies should be considered [62]. We therefore put forward several proposals to improve their protection in both short- and long-term time frames.

6. Proposals to Improve Argali Conservation under Current Conditions

The carrying capacity of the National Park will not be able to maintain the Russian argali population into the future. Therefore, its conservation depends on the conditions in the range in which most of the population is located and that does not have the status of a protected area. Also, protected areas are often not representative of a particular region in terms of gamma biodiversity. Protected areas are often biased to the upper belts of mountains and represent marginal habitats because they are of less economic value to humans. This bias reduces their value in terms of biodiversity conservation [1] and occurred in the allotment of territories for the Sailugem National Park (as well as for the Katunsky Biosphere Reserve about 95 km northeast of the first cluster in the Altai (Figure 7)) [63]. Superficially, the creation of the protected areas appears like a concession to the environmental community in the dispute between "economic managers" (i.e., decision-makers and takers) and "environmentalists" [64].

To conserve the argali, the management and researchers of the Sailugemsky National Park suggest the following:

- Optimize the network of protected areas and create a buffer zone for the Sailugemsky National Park on the Sailugem Ridge. In autumn 2021, almost all argali stayed outside the protected territory. It is advisable to create another buffer zone for the Altai Biosphere Reserve on the Chikhachev Ridge.
- Exert proper control on public hunting grounds for marals, wolves, boar, ducks, etc., which almost surround the Sailugemsky National Park.
- Develop and implement compensatory economic mechanisms for the local population in the habitats of argali. Local residents should feel the benefit of the presence of argali in their territory. Educational ecological tourism should be developed, where the argali are the main focus.
- Develop international cooperation for the creation of transboundary biosphere reserves in the habitats of the species to maximize conservation and obtain data on its status.
- Be aware and responsive to potentially harmful developments. Areas of bismuth and cobalt deposits (the Karakulskoye Field) are located about 80 km from the Kosh-Agach Village (Figure 2C), on the Talduair massif of the Chikhachev Ridge. The deposits are on the migration routes of argali and snow leopards, and in habitats of Red Book birds. Development should be kept under control and stopped in the future.
- Pay due attention, at the local level, to the veterinary care of livestock that have infestations and diseases that might be shared with wild ungulates.
- Breed argali in semi-free conditions for subsequent reintroduction into habitats where they are extinct. This measure must be implemented in a timely manner after the completion of all the above tasks; otherwise, there will simply be nowhere to release the animals.

7. Recommending Conservation Measures Responsive to Climate Change

7.1. Recommendations to Identify Climate Change Impacts on the Argali Range

The contribution of climate change to the process of pasture degradation in the Chuya Depression and surrounding mountains has not been studied. However, climate change is likely to be the most important driver of adaptive pastoralism impacts on the argali population rather than direct climate change impacts through heat stress, etc. The impact of climate change on pasture productivity and alpha biodiversity along a transect from the most arid Chuya Steppe to the crest of the Sailugem Ridge should be studied to understand the processes that will soon affect the strategy for the conservation of argali populations. The study should include the conservation of traditional ways of nature management by the indigenous peoples of Altai. Research should follow the "7 M's" approach developed by Callaghan et al. (2021) [65] in which monitoring identifies a change in real time, manipulation predicts responses to future environments, modelling extends the future time and geographical scales, and management aims to solve ecological and environmental challenges. The term "minorities" in the "7 M's" approach emphasises the important involvement of local and indigenous people in designing and implementing management plans and assessing success. Furthermore, a systems analysis approach is required with multiple participants working together to navigate the pathway from identifying the environmental problem to solving the issues.

To predict and determine how argali and livestock impact the vegetation under current and environmental change scenarios, we recommend the initiation of permanent plots, environmental manipulation experiments, the use of exclusion areas, and the deployment of wildlife cameras. Measurements should be made of plant species composition, environmental conditions, pasture productivity, and pasture degradation. Additional surveys should be conducted of other essential habitat services for the argali such as shelter, water supply, healing plants, etc. By identifying preferred food sources and impacts of the argali on vegetation, we will also identify how argali could potentially affect larger-scale plant

biodiversity by retarding the unwanted spread of lowland plants upwards in response to climate change [21].

The manipulation experiments would refine the rapid "space for time" estimates of vegetation change by applying experimental perturbations that are expected from climate projections from models. For example, aridization could be simulated by constructing rain shelters [66] and drainage channels. Passive heating devices could be installed to increase air temperature [67,68]. Results from the above research should be used to construct a predictive model of spatial and temporal changes in the productivity and species composition/nutrient composition ("quality") of pastures under various scenarios of climate dynamics related to the argali diet. This is particularly important as no dynamic vegetation models apparently exist at an appropriate scale for this area.

The study will underpin understanding of the consequences of increased anthropogenic impact on the range of the argali population. The rate of pasture degradation at lower altitudes, assuming the current livestock population belonging to indigenous people, will increase the grazing pressure by argali on highland pastures. Understanding this process will support the development of future conservation strategies to help sustain the gamma biodiversity of plants and grazing animals.

7.2. Recommendations for the "Temporal Protected Area" Approach to Argali Conservation

New, flexible approaches to nature conservation that include ecosystem dynamics are required to adapt to and mitigate climate change impacts. They are one of the Sustainable Development Goals [69].

The Sailugem National Park represents a network of three connected protected areas (clusters), two of which occupy the Sailugem Ridge, that allow genetic material, individuals, and species to be exchanged between parts of the total population area and can help maintain diversity and function within the entire network [70]. Integrating network-based and dynamic-area-based management approaches may further protect dynamic ecological processes [56]. We propose additional conservation measures as follows:

1. Include the territories of indigenous people's summer livestock pastures (green in Figure 7) that are parts of the argali winter range as new protected clusters formally associated with, but outside the current borders of, the Sailugemsky National Park. We suggest three more clusters to be created in unprotected areas. These clusters would have dual use as summer pastures for herders' livestock and winter pastures for argali. This recommendation clearly contradicts the opinion of the local authorities and the population of the Kosh-Agach District. As the number of livestock and the potential degradation of lower mountain pastures adjacent to the arid territories of the Chuya River Depression increase, they are, and will be, forced to graze ever more livestock in the territories adjacent to the National Park (Figure 7). The system of clusters is a typical structure for Russian nature protection [71].

2. Optimize nature management to reduce the disturbance factor (including the control of herding dogs) and exclude poaching. Even in the territory of existing clusters, there are livestock breeders' camps and cattle grazing. The conservation status allows the protection of argali while often grazing with livestock, but some people illegally hunt argali and snow leopards for valuable trophies.

Our field observations support the recommendation for reducing disturbance. Very often the areas with the highest concentrations of the argali population (for example, in the Sarzhematy River Valley) adjoin territories used as summer livestock pastures. Driving away the livestock and herding dogs from these pastures for the winter season (the period when competition between livestock and argali for food resources intensifies against a backdrop of a decrease in the nutritional value of pastures [30,72]) will "free up" this territory for safe argali winter grazing. However, implementation requires a management regime. The designation of temporal protected areas—seasonal (winter) clusters of the National Park, which we propose in point 1 above—will exclude factors

disturbing wintering argali. As an official part of the National Park, seasonal clusters would control any visits to this territory, and therefore control dogs and firearms.

Strengthening the protection of the potential territory of the seasonal clusters is possible within the framework of the current legislation, since argali, as a *Red Data Book* species, is subject to protection in territories with different nature use statuses.

Various national government agencies have also proposed the use of dynamic conservation areas as part of broader management plans for marine biodiversity [73], but without substantial implementation [56]. In Russia, there have been no applications for dynamic-based conservation management so far. Also, the UNEP/CMS International Single Species Action Plan for the Conservation of the Argali *Ovis ammon* [38] does not include dynamic conservation areas.

In future, habitat change associated with climate transformation may complicate the conservation of argali, particularly in Mongolia, partly because the Russian side of the Sailugem Ridge is a macroslope of northern exposure, which will preserve lush pastures longer than the arid climate conditions of the Mongolian side of the Ridge. Thus, the restoration of the argali range in Russia can neutralize this threat. The creation of winter-protected areas (=seasonal clusters of the National Park) on livestock summer grazing areas will increase the number of argali remaining in Russia during winter. Realising some of the potential habitats of argali in the Russian Federation is the most important action required for the conservation of this subspecies of mountain sheep.

7.3. Stakeholders' Consensus as Part of a Long-Term Argali Conservation Strategy

Conservation of the Russian argali population depends not only on the concerns of the environmental community and the official Russian environmental protection structures but also on the local population. We, therefore, recommend the organization of a stakeholder forum to develop a consensus for a long-term conservation strategy for the argali in which the indigenous people will play a decisive role. They are represented mainly by the small Indigenous Telengits population and the Altaian leadership of the Altai Republic and the Kosh-Agach District of the Altai Republic, in whose territory the largest part of the argali population in Russia is located. An important component of the conservation of the transboundary argali population is the coordination of actions with the management and staff of the Siilkhem Nuuru National Park in the Mongolian territory of the Sailugem Ridge. Cooperation between the indigenous people and scientists in education is important to combine "different ways of knowing" to preserve this species as part of a nature sacred to any Altaian. Indigenous knowledge has already been used successfully in understanding the conservation of the snow leopard in the WWF program "Snow Leopard Keepers" [74].

8. Conclusions

Our rare insights into current and likely future changes in biodiversity within a remote area of central Asia show complex interactions among indigenous land use for livestock grazing, climate change impacts on vegetation, and conservation of the critically endangered argali sheep. Despite the current local increase in the transboundary argali population on the Sailugem Ridge of the Russian and Mongolian Altai Mountains through better recent protection by national parks there, the future of the argali is insecure.

While current livestock grazing and associated disturbance already affect argali populations, climate change and particularly greater aridity, will change plant diversity and reduce forage quality for both argali and domestic livestock. This will lead to greater competition between land use practices and conservation goals.

To reconcile future improved argali protection and traditional land use by the local Altaian and Telengits Indigenous people, we propose working with local people to assess climate change impacts on vegetation diversity, production, and utilisation by herbivores using the "7 M's" approach [65]. The Sailugem Ridge is a northern outpost of the vast territory of the mountain–steppe zone of inland Asia where mobile pastoralism is the basis

of local livelihoods. Consequently, this research should be carried out in at least two more model arid mountain regions in central and south Asia.

We also propose improved protection of argali responding to the impacts of climate change. This includes options for both increasing protected areas and forming seasonal protected clusters. Three new seasonal clusters will diversify and protect the wintering grounds of the argali. This measure should not be an alternative to expanding the territories of the clusters of the Sailugemsky National Park or creating new "permanent" clusters but will allow for a more flexible conservation of the argali population on the Sailugem Ridge that will include the interests of the indigenous population. A legislative framework should be developed for the formation of a new type of protected area—the "seasonal clusters of the Sailugem National Park" —which will justify environmental protection measures and ensure their financing.

The experience of creating a new type of protected area can be used to optimize the protection of argali in other areas adjacent to the Sailugem National Park. In a wider context, our approach can be extended to reconcile the wider conservation of biodiversity and traditional land use styles of indigenous peoples of the vast arid areas and mountain–steppe landscapes of inner Asia during a changing climate.

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