Acta Scientiarum
http://periodicos.uem.br/ojs
ISSN on-line: 1807-8672
Doi: 10.4025/actascianimsci.v46i1.68717

ANIMAL PRODUCTION

A study into the current state of Saiga tatarica L. populations with the use of retrospective data

Talgat Begilov[1*], Yuriy Grachev[2] and Birlikbay Eszhanov[1]

[1]Department of Biodiversity and Bioresources, Al-Farabi Kazakh National University, Almaty, Kazakhstan. [2]Institute of Zoology, Committee of Sciences, Ministry of Science and Higher Education of the Republic of Kazakhstan, Almaty, Kazakhstan. *Author for correspondence. E-mail: begilov_talgat@rambler.ru

ABSTRACT. The saiga antelope (Saiga tatarica tatarica L., 1766, S) is a prominent ungulate mammal species inhabiting Central Asia. Over the latter half of the 20th century, saiga populations, including the Volga-Ural (Kazakhstan) population, experienced a continuous decline. However, there was a resurgence in their numbers in the 1980s. This study aims to assess the present status of saiga populations, particularly the Volga-Ural (V-U) population, by analyzing existing retrospective data. Our findings reveal that during the 21st century, the saiga population has increased in two key regions: the Volga-Ural and Betpak-Dala (B) populations. Notably, the Northern-Western Population (NWP) habitat saw a drastic 50-fold decline in population, while other populations decreased by 2.0-5.0 times. Despite this decline, the NWP habitat exhibited higher juvenile saiga yields compared to other regions. The resurgence of saiga populations has been significantly influenced by the support of the Government of Kazakhstan, along with the effective efforts of international wildlife conservation organizations and local community engagement.

Keywords: Saiga tatarica; population; habitat; Volga-Ural population; Pre-Caspian population; population decline.

Received on June 28, 2023.
Accepted on October 2, 2023.

Introduction

Over the past five centuries, human activity has led to the extinction of 869 mammal species (Meldebekov, 2010a; Ventsova & Safonov, 2021). More than 80% of terrestrial ecosystems have lost large mammals weighing over 20 kg (Meldebekov, 2010a; Safonov, Ermakov, Danilova, & Yakimenko, 2021). Several centuries ago, migrating ungulates inhabited the territory of Kazakhstan within pastoral ecosystems. However, many of them were either eradicated or saw their populations diminish due to agricultural activities, habitat fragmentation, construction projects, including linear infrastructure, and persecution (Frank, McNaughton, & Tracy, 1998; Kholodova et al., 2006; Morrison, Sechrest, Dinerstein, Wilcove, & Lamoreux, 2007; Harris, Thirgood, Hopcraft, Cromsigt, & Berger, 2009).

Kazakhstan's steppe ecosystems cover more than 120 million hectares and constitute unique habitats for flora and fauna, including numerous species of steppe fauna that are currently on the brink of extinction (Eastwood, Lazkov, & Newton, 2009; Meldebekov, 2010b). These steppes are home to approximately 2,000 species of higher plants, with about 30 of them being endemic and forming distinct communities (Eastwood et al., 2009). Furthermore, globally endangered species of fauna inhabiting steppe biotopes can be found within Kazakhstan's steppes (Eastwood et al., 2009; Ussenbekov et al., 2022). Nine out of twenty-four endangered mammal species are found here (Bliznyuk, 2009; Zhirnov, 1982).

The primary threat to steppe populations in Kazakhstan stems from the degradation of steppe biocenoses, where large ungulates graze and thrive (Eastwood et al., 2009). Alongside hunting, this has led to the near-extinction of the saiga population (Gabunshchyna, 2010; Phillipson & Milner-Gulland, 2023). Presently, steppe ecosystems, including those within Kazakhstan, are exceptionally vulnerable, with a limited representation among Protected Natural Areas (PNAs) (Grachev & Bekenov, 2006; Ukrainskiy, Ukrainskiy, & Pereladova, 2019). In western Kazakhstan, there exists a system of natural territory protection comprising three State Nature Reserves of Republican Significance and seven regional protected areas, covering a total area of 189 thousand hectares, which corresponds to 1% of the region's total area (Fadeev & Sludsky, 1982; Vlasova, Ventsova, Vostroilov, Safonov, & Golubtsov, 2020).

The saiga population has been adversely affected by human activities (Zhirnov, 1982; Grachev & Bekenov, 2006; Grachev, Meldebekov, & Bekenov, 2009; Karimova & Lushchekina, 2018). In the mid-1950s, the population numbered around 800,000 individuals (Bannikov, Zhirnov, Lebedeva, & Fandeev, 1961). However, due to hunting and other human interventions, the saiga population declined to 145-165 thousand by the end of the 1980s (Bogun, 2019). Following the dissolution of the USSR, uncontrolled poaching escalated, and many governmental institutions, including environmental ones, ceased functioning (Milner-Gulland, 2003; Rzabayev, Assanbayev, Rzabayev, Bazargaliyev, & Rzabayev, 2022). These developments led to a sharp reduction in the saiga population, with some populations numbering only 16-19 thousand individuals in 2006 (Karimova, Lushchekina, Neronov, Pyurvenova, & Arylov, 2020). In 2015, the saiga population further decreased to 3-4 thousand individuals (Grachev & Bekenov, 2006). Some researchers consider this decline to be one of the most significant reductions in mammal populations worldwide (Frank et al., 1998; Morrison et al., 2007).

The history of species is marked by extremes. In the early eighteenth century, the S's range extended over a vast territory from Ukraine (the Carpathians and their foothills) to China (Xinjiang) (Milner-Gulland, 2003; Milner-Gulland et al., 2020). Nevertheless, mass hunting, industrialization, and agricultural expansion nearly drove this species to extinction at the beginning of the 20th century. At that time, only around 1,000 individuals remained, and they were confined to remote areas of the NWP and the Turan Lowland (Milner-Gulland et al., 2020). However, thanks to a complete hunting ban and high reproductive rates, the species slowly began to recover (Sokolov & Zhirnov, 1998).

By the mid-20th century, the saiga had successfully colonized desert and steppe territories suitable for permanent habitation, forming four populations with limited interconnectivity: NWP, V-U, Ustyurt (Us), and B. Estimates indicate that by the end of the 1980s, the saiga population reached 1.2 million individuals (UNEP, 2010). During this time, numerous saigaherds coexisted with cattle on pastures (Migushin & Gorskikh, 2017). In the 1990s, there was a rising demand for saiga horns in Eastern countries, leading to a surge in poaching throughout the species' habitat range. Today, illegal poaching poses a significant threat to the S, pushing it to the brink of extinction (Baydavletov et al., 2018).

In the early 21st century, the population in NWP faced a critical situation. Approximately 19,000 individuals were recorded in the NWP, with about 28,000 in habitats located within Kazakhstan's borders (Gabunshchyna, 2010; Ukrainskiy et al., 2019). The Government of Kazakhstan implemented effective measures to protect antelopes, conducted scientific research, and engaged in environmental and educational activities aimed at local residents. As a result, the situation for Kazakhstan's saiga populations improved significantly, leading to an increase in their numbers (Convention on the Conservation of Migratory Species of Wild Animals [CMS], 2023). By spring 2015, the population had grown to 243,000 individuals (Karimova & Lushchekina, 2018).

In NWP, however, the saiga population continued to decline, dwindling to a mere 3-4 thousand individuals by 2015 (Nurushev & Baytanayev, 2018). In recent years, there has been a slight increase in the population in this habitat, with approximately 7,000 individuals in 2020 (Nurushev & Baytanayev, 2018). Studies have revealed high fertility rates among the same population in NWP. Nonetheless, due to an extremely low number of adult males and population decline, this fertility has proven to be ineffective. Nevertheless, some improvements have been observed in the sex and age structure of the population (Ukrainskiy & Ukrainskiy, 2017). In Kazakhstan, there are three distinct saiga populations: B, Us, and V-U. Studies conducted between 1986 and 1993 found no direct connections between these populations, although each population displayed a high level of interbreeding. The distance between subpopulations of the V-U region ranges from 250 to 350 km latitudinally (Fadeev & Sludsky, 1982; Gabunshchyna, 2010; Migushin & Gorskikh, 2017).

Throughout the history of the saiga populations, mass killings have occurred at various times, resulting in the deaths of hundreds of thousands of animals. In the first decade of the 21st century alone, the total number of all three groups of populations decreased by a factor of 45, plummeting from 980,000 individuals in 1993 to 20,000 in 2003 (Gabunshchyna, 2010). Although protective measures, including hunting bans extended until 2023, have improved the situation, instances of poaching and outbreaks of pasteurellosis are still reported. In May-June 2014, an epizootic of pasteurellosis led to the death of 130,000 to 200,000 individuals (IUCN, 2008; Convention on the Conservation of Migratory Species of Wild Animals [CMS], 2023). Currently, the saiga population stands at approximately 325,000 animals (Grachev & Bekenov, 2006).

The high fertility of the saiga species allows for rapid recovery and resurgence from the brink of extinction. Most females become fertile at 7-8 months of age, even before reaching full maturity. Many females are capable of producing two cubs as early as 1.5 years of age, accounting for up to 80% of all breeding animals

(Salikhov, 2006). However, female fertility can vary depending on various factors, primarily climatic ones (Baydavletov et al., 2018). For instance, following the harsh winter of 1952-53 with low temperatures, the NWP saiga population declined from 180,000 to 100,000 individuals, but it rebounded to previous levels within a year (Karimova et al., 2020).

When examining the causes of the mass deaths among the saiga population in V-U, various hypotheses have been proposed, including the poisoning of anthropogenic origin, toxic plants, as well as infectious and non-infectious diseases (Ukrainskiy et al., 2019; Sokolov & Zhirnov, 1998). Notably, the deceased antelopes were predominantly females. There is no consensus on the reasons behind the fluctuations in the saiga populations in V-U and other habitats. The factors driving these changes remain incompletely understood (Kholodova et al., 2006; Karimova & Lushchekina, 2018; Nurushev & Baytanayev, 2018). This knowledge gap underscores the significance of our study. This paper presents data on the mass deaths of saiga within major epizootics in the V-U and B populations. Using the saiga population in the V-U interfluve and B (Kazakhstan) as a case study, which numbered 218,000 individuals in 2022, our study aims to investigate the biological parameters influencing the characteristics of these four saiga populations (IUCN, 2008; Glázer, 2017; Robinson, 2018). We seek to identify the differences that have enabled the saiga populations within the V-U interfluve and B (Kazakhstan) to recover from population declines and begin increasing in number. To achieve this, we have undertaken the following objectives: a) comparing population spatial distributions; b) analyzing ethological features; c) studying population composition characteristics based on the sex and age of animals, as well as their reproductive indicators. These indicators have been examined across four well-documented saiga populations.

Materials and methods

Searching and analyzing literary data

To conduct this study, we conducted a search and analysis of literary data related to the population size and status of the saiga antelope (Saiga tatarica). The data for analysis were obtained from various scientific sources, including scientific articles, reports, and publications available in various databases.

The fundamental actions we conducted:

Literature Search: We searched scientific literature using multiple academic databases, including but not limited to Scopus, Web of Science, and Google Scholar. Keywords and phrases related to the saiga antelope and its population were employed in the search, such as ‘Saiga tatarica population’, ‘Saiga tatarica abundance’, ‘Saiga tatarica conservation’, and ‘Saiga tatarica poaching’.

Article selection

We selected scientific articles and publications containing information on saiga population size, the influence of abiotic and biotic factors, anti-poaching efforts, and other related data. During the article selection process, we focused on the relevance and currency of the data. All articles selected by us are included in the reference list.

Data analysis

The obtained data were analyzed, taking into account temporal changes in the Saiga population and the factors influencing its status. We conducted a comparative analysis of data from various sources and drew generalized conclusions about the dynamics of the saiga population and its condition. For some data analyses, such as comparing population parameters and conditions at different periods, we employed statistical methods, including means, standard deviations, and tests for significant differences. These methods were applied when the data were publicly available or provided by the authors of the studies upon request.

Integration of results

The obtained results were integrated into the discussion to provide a deeper understanding of the current status of the saiga and the factors influencing its population. It is important to note that our study is based on the analysis of data obtained by other researchers and includes the meta-analysis of data provided in scientific literature. This approach enables to synthesis of existing knowledge about the saiga and its populations, as well as identifying trends and issues related to its conservation.

Study area

Our study focused on saiga populations within the steppe ecosystems of Kazakhstan, including the NWP (Northern-Western Population), V-U (Volga-Ural Population), Ustyurt (Us), and B (Betpak Dala Population). These populations were selected due to their significance in the saiga's distribution range. To provide a visual reference, please consult Figure 1 for the geographical distribution of these populations.

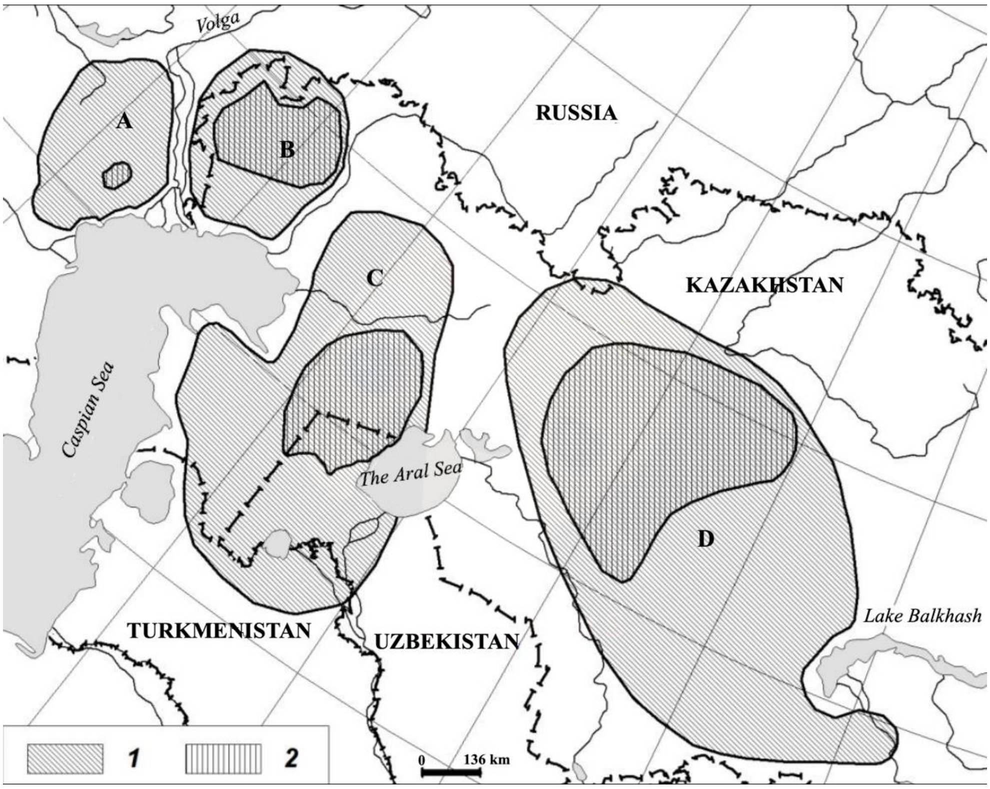

Figure 1. The distribution and main populations of Saiga. 1 – during the increase in livestock until 1997, 2 – after a decrease (since 1998). A – NWP (north-western Prikaspiy), B – Volga-Ural (V-U), C – Usturt (Us), D – Betpak-Dala (B). Note: The abbreviations: A – NWP, B – V-U, C – Us population, D – B.

Betpak-Dala (B): The saiga population in the Betpak-Dala region is located in the southern part of Kazakhstan. This region is characterized by a significant impact of anthropogenic factors such as industrial development and livestock farming.

Ustyurt: Ustyurt is a plateau and coastal region extending across the south of Kazakhstan and Turkmenistan. This region is also inhabited by a population of saigas.

Volga-Ural (V-U): The saiga population in the Volga-Ural region covers territories in the southern part of Russia and the northern part of Kazakhstan. This region is characterized by diverse natural conditions and occupies an extensive territory.

Northwest Caspian (NWP): The saiga population in the Northwest Caspian region is located within Kazakhstan and in close proximity to the Caspian Sea. This region is also subject to various factors, including climatic and anthropogenic changes.

Data collection

Our comprehensive study spanned a broad timeframe, ranging from 1987 to 2022, encompassing both historical and recent data. This extensive dataset allowed for a thorough analysis of saiga populations. Data collection methods, used by colleagues were specifically tailored to address key biological parameters impacting saiga populations.

Visual Monitoring: The field researchers conducted systematic visual monitoring of saiga populations. Equipped with optical instruments such as binoculars and spotting scopes, trained observers collected data on saiga behavior, habitat use, and interactions with conspecifics. Observations were conducted regularly during saiga's active periods, primarily from July to August, as this period corresponded to critical reproductive and behavioral phases.

Reproductive Assessments: Fertility and infertility rates among female saigas by different authors were determined through reproductive assessments. Researchers closely monitored pregnant and lactating females, recording birth events and assessing calf survival. These data were vital for understanding saiga reproductive success.

Sex Ratio Analysis: To gain insights into population demographics, the sex ratio of saiga calves was analyzed. The proportion of male-to-female calves was calculated to assess potential variations over time.

Population Composition: The composition of saiga populations, categorized by gender and age, was meticulously recorded. This categorization allowed for a detailed examination of population structure and potential shifts in age-class distributions.

Statistical analysis

Collected data underwent rigorous statistical analysis to identify trends, correlations, and variations. Our research aimed to address specific questions concerning saiga population dynamics, reproductive success, and ethological behavior. The statistical tests employed included but were not limited to:

Correlation Analysis: To assess potential relationships between variables such as environmental factors and reproductive success.

Regression Analysis: To model population trends and predict future population dynamics.

T-Tests and ANOVA: To compare means and variations within saiga populations.

Chi-Square Tests: To analyze the significance of sex ratio variations.

Ethological Analysis: Ethological data were analyzed using specialized software to identify behavioral patterns and trends.

Integration of historical data

Historical data from previous studies conducted between 1987 and 1996 were integrated into our analysis to provide a broader temporal perspective. This inclusion allowed for a more comprehensive understanding of saiga population dynamics.

Data validation

To ensure data accuracy, validation procedures were implemented. These included cross-checking observational data, assessing inter-observer reliability, and conducting periodic quality control assessments. In summary, our study employed a multidisciplinary approach that combined visual monitoring, reproductive assessments, sex ratio analysis, and population composition analysis with rigorous statistical methodologies. This comprehensive methodology aimed to address the objectives outlined in the introduction, contributing valuable insights to saiga conservation efforts.

Results

Population indicators

Table 1 provides insights into significant instances of saiga population declines caused by natural catastrophic events over the past seven decades.

Notably, there have been no reported instances of mass saiga extinctions in the Ural population since the 1950s. In the NWP population, such events have been observed over the past six decades. Additionally, population B has faced external pressures, leading to multiple reductions in its numbers, but due to its high fertility, the saiga population was able to rebound within 2-4 years following significant declines (refer to Figure 2).

Population declines typically occur in tandem with deteriorating habitat conditions and demographic shifts. These processes often result in decreased genetic diversity. In response to these challenges, Kazakhstan and Russia initiated hunting and poaching bans in the early 2000s, which are still in effect today.

Despite tightened hunting regulations, isolated instances of poaching persist. Nevertheless, Kazakhstan has experienced relatively effective anti-poaching measures (see Table 2), leading to population increases in the V-U and B populations in recent years, even in the face of epidemics like pasteurellosis between 2010 and 2015 (see Table 1).

Table 1. The influence of abiotic and biotic factors (droughts, black ice, flooding, mass poisoning, epizootics of diseases, predator attacks) on the number of Saigas (UNEP, 2010; Milner-Gulland et al., 2020; Convention on the Conservation of Migratory Species of Wild Animals [CMS], 2023; Milner-Gulland, 2003; Phillipson & Milner-Gulland, 2023).

Year	Itching[1]		Foot and mouth disease (FMD)		Pasteurellosis	
	NWP	Kazakh populations[2]	NWP	Kazakh populations	NWP	Kazakh populations
1951	+[3]	+	no data	no data	no data	no data
1952	no data[4]	+	no data	no data	no data	no data
1953	no data	+	no data	no data	no data	no data
1955	15 no data	no data	no data	no data	no data	no data
1956	no data	no data	no data	+	no data	no data
1957	+	no data	no data	+	no data	no data
1958	no data	no data	4 no data	no data	no data	no data
1959	no data	no data	+	+	no data	no data
1968	no data	no data	no data	5 no data (B)	no data	no data
1969	+	no data	no data	no data	no data	no data
1972	no data	no data	no data	+	no data	no data
1973	+	4 no data (B)	+	no data	no data	no data
1974	no data	+ (V-U)	no data	no data	no data	no data
1975	no data	no data	no data	+	no data	no data
1977	no data	+ (B)	no data	no data	no data	no data
1978	no data	1no data (B)	+	no data	no data	no data
1982	no data	no data	no data	no data	нет no data	7 no data -1 no data (B)
1985	no data	+ (B)	no data	no data	no data	1no data (V-U)
1986	+	+ (B)	no data	no data	no data	no data
1988	+	no data	no data	no data	no data	no data
1989	no data	45 (B)	no data	no data	no data	27 no data (B)
1995	no data	12 no data (B)	no data	no data	no data	no data
1998	no data	35 (B)	no data	no data	no data	no data
2010	+	no data	no data	no data	no data	no data
2011	+	no data	no data	no data	no data	119 (V-U)
2012	no data	no data	no data	no data	no data	no data.4 (V-U)
2013	no data	no data	no data	no data	no data	1 (B)
2014	no data	no data	no data	no data	no data	1.5 (B)
2016	no data	no data	no data	no data	no data	21 no data (B)

Notes: [1]the data for December of the previous year plus for January, February, and March of the following; [2]the data array of the Kazakh saiga populations are indicated (B, V-U); [3]there is no available data on the causes of the reduction; [4]there is data on the extinction, but there was no mass extinction. The figures are in thousands.

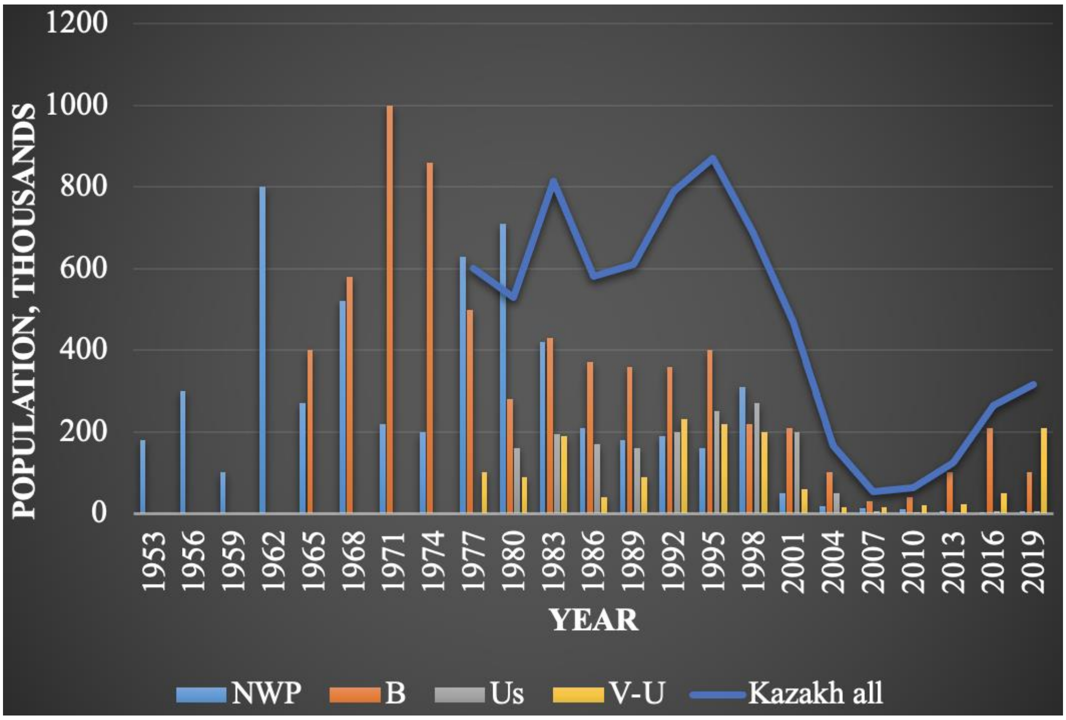

Figure 2. Population indicators in different habitats of Saiga.

Table 2. The recorded indicators of saiga poaching cases from 2009 to 2022 (Milner-Gulland, 2003; Milner-Gulland & Kühl, 2006; IUCN, 2008; UNEP, 2010; Glázer, 2017; Robinson, 2018; Milner-Gulland et al., 2020; Convention on the Conservation of Migratory Species of Wild Animals [CMS], 2023).

Indicators	Year													
	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
The number of cases	13	13	16	39	33	47	58	80	28	51	59	44	27	35
The number of confiscated horns	58	128	130	1823	96	5488	424	1175	2139	1420	1175	329	734	2501

Population structure indicators

The most pronounced changes have occurred in the NWP habitat. Over the latter half of the 20th century, the range of the NWP population has substantially diminished, and saiga has lost its seasonal migratory patterns. Conversely, changes in the Kazakh population have been less significant. Currently, both the V-U and B populations of saiga are gradually expanding their territorial range in conjunction with increasing population sizes (see Table 3).

Table 3. The indicators of the habitat areas and length of migration ways for 4 populations (Milner-Gulland, 2003; Milner-Gulland & Kühl, 2006; IUCN, 2008; UNEP, 2010; Glázer, 2017; Robinson, 2018; Milner-Gulland et al., 2020; Phillipson & Milner-Gulland, 2023; Convention on the Conservation of Migratory Species of Wild Animals [CMS], 2023).

Population	Maximum population		Minimum population	
	Area, km^2 and years	The length of migration ways, km	Area, km^2 and years	The length of migration ways, km
NWP	110-130 (1957-1961)	430	3-4 (2011-2022)	No
V-U	139 (1973-1994)	480	58 (2001-2006)	160-210
Us	436 (1973-1994)	1150	88 (2011-2022)	410-510
B	759 (1973-1994)	810	227 (2001-2006)	410-610

Ecological Population Indicators

In the NWP, during periods of peak saiga populations from 2015 to 2021, there was a prevalence of large and medium-sized herds, constituting approximately 65% of the total number, while small herds comprised roughly 35%. However, during periods of lower saiga populations, small herds increased to 57%, medium-sized herds to 30%, and large herds decreased to 13%. This shift may be attributed to concentrated monitoring efforts within the Chornye Zemli Nature Reserve, a distinct ecological region where herds are frequently observed and recorded multiple times. This can skew the assessment towards larger herds. In Kazakhstan, the assessment covered a larger and more diverse area, making repeated observations of the same herds less likely.

Fertility indicators impacting population structure

For the analysis of saiga population conditions before and during their decline, two-time intervals (1987-1996 and 2005-2010) were examined. The data available for analysis was deemed sufficient. In the 1987-1996 period, the NWP population exhibited a slightly higher proportion of mature males (15.9 ± 5.5%) compared to the Kazakh populations (14.0 ± 6.5%). However, these differences were statistically insignificant (U (9.27) = 81.3, p = 0.45). Notably, some males were captured and removed from populations during these years, which could have led to changes in population structure, particularly the sex and age ratios ofsaigain Kazakh populations. The reduced proportion of males in the B population (10.9 ± 5.3%) may be attributed to selective hunting and winter food scarcity, leading to famines and saiga losses in 1985, 1986, and 1989. Although the NWP population had a higher proportion of young females (10.8 ± 5.1%) compared to the Kazakh populations (9.3 ± 5.9%), these differences were not statistically significant. The percentage of males among saiga cubs was slightly lower in the NWP than in the Kazakh populations (48.9 ± 1.7% and 52.2 ± 2.9%, respectively). During this period, the survival rate of young animals in the first four months was higher in the NWP (38.2 ± 15.9%) compared to other populations (52.4 ± 3.0% in V-U, 52.1 ± 10.4% in B, and 66.3 ± 10.9% in Us).

In the 2005-2010 period, nearly all essential reproductive indicators declined across all saiga populations, with statistically significant decreases observed in Kazakh populations. Total fertility indicators for females in the NWP declined to 0.79 ± 0.36 (U (5.3) = 4.0, p = 0.13), while in Kazakhstan, they decreased to 0.86 ± 0.30 (U (15.9) = 0.6, p = 0.01). The ratio of one female to saiga declined to 0.82 ± 0.19 in the NWP (U (9.7) = 21.9, p = 0.93) and to 0.44 ± 0.22 in Kazakhstan (U (22.9) = 39.0, p = 0.05). The proportion of adult males also declined to 11.3 ± 1.6% in the NWP (U (9.8) = 10.5, p = 0.10) and to 8.6 ± 2.7% in Kazakhstan (U (22.2) = 83.3, p = 0.02). The US population exhibited the poorest indicators, with the proportion of adult males at 4.6 ± 1.5% and total fertility of females at 0.51 ± 0.03.

Surprisingly, the condition of the saiga population in the NWP during 2005-2010 was slightly better in terms of certain indicators, such as the number of cubs and the proportion of mature males, compared to the Kazakh populations. Nevertheless, these differences did not reach statistical significance. Given that population indicators were comparable in the early 2000s, the marked differences in current population sizes may be attributed to external factors. Previous studies have suggested that the insufficient number of adult males in the NWP population was the primary driver behind saiga population declines.

In the NWP, the reduction of suitable habitats for the isolated saiga population contributed to its extinction and population decline. This habitat loss played a critical role in these processes. In the Republic of Kalmykia, the primary habitat for the NMPsaigapopulation, agricultural land covers 85.0% of the territory, with 78.0% designated as pastures. The pasture load here amounts to 57.9 individuals per square kilometre, with sheep and goats being the main competitors for resources at 47.8 individuals per square kilometre. In Kazakhstan, although the number of cattle per unit area of pastures is also high at 73.5 individuals per square kilometre, the vast saiga habitat areas enable them to locate food sources and migrate away from unfavourable habitats.

Despite the lower proportion of males in the V-U and B populations, which remained consistently low at 13.0 ± 3.1% and 9.6 ± 1.9%, respectively, during 2005-2010 and 12.1-14.5% in V-U and 5.5-9.4% in B, significant population increases were observed in 2017. This growth can be attributed not only to high saiga fertility but also to human intervention. However, the transborder US population continues to face significant challenges, resulting in a minimal population size due to poaching and the obstruction of migration routes.

Discussion

The influence of abiotic and biotic factors

Throughout the study period (Figure 2), the population of saiga experienced significant fluctuations. For instance, in the North-Western Province (NWP) during the 1950s, the saiga population reached its peak with an estimated 610-810 thousand individuals. In the 1970s, Kazakhstan witnessed the largest herds, with approximately 1.1 million individuals (Bogun, 2019) (Figure 2).

Over the past decade, from 2012 to 2022, the population of saiga in the West Kazakhstan region has surged from around 12 thousand to 801 thousand individuals. However, local farmers have reported adverse impacts of this population growth on hayfields and pastures. Meanwhile, the Ural population of saiga has consistently remained below 295 thousand individuals throughout the research period.

Climatic conditions, such as harsh winters with low temperatures, winter food scarcity due to snow crust formation, and vegetation loss resulting from elevated temperatures during the growing season, have been identified as key factors influencing population dynamics. Additionally, various biotic factors, including diseases, parasites, and predators, have played roles in population fluctuations. Anthropogenic influences, such as hunting, poaching, habitat reduction, fragmentation, decreased grazing opportunities on pastures, and physical barriers like canals and fences, have also significantly contributed to these dynamics.

Our data analysis allows us to assert that abiotic and biotic factors have a significant impact on the abundance and condition of saiga populations. Specifically, climatic conditions such as droughts and extreme temperatures can lead to mass poisonings and starvation, resulting in a decrease in saiga numbers. Epizootics of diseases and predator attacks also play a role in population regulation. Understanding these factors is of paramount importance in developing management strategies for saigas and their habitats.

Combatting poaching and conservation of populations

Our findings confirm that combating poaching has a positive impact on the saiga population. With stricter measures to combat poaching in Russia and Kazakhstan, we have observed an increase in the numbers of certain populations. This suggests that effective conservation measures can contribute to the preservation of the saiga.

Changes in environmental indicators and genetic diversity

The analysis of changes in saiga ecological indicators allows identifying potential threats to this species. Deterioration of habitat conditions and changes in demographic structure can lead to a reduction in genetic diversity, increasing the vulnerability of populations to various threats. Preserving diversity within intrapopulation groups and populations remains a crucial task for the long-term survival of the saiga.

Analysis of numerical data

Our data indicates that the saiga population can fluctuate over decades. These fluctuations may be associated with various factors, including climatic anomalies, disease epizootics, and changes in food availability. It is important to note that some saiga populations demonstrate a high capacity for population recovery following significant declines, underscoring their potential for survival provided effective conservation and management measures are in place.

Prospects for future research

For a deeper understanding of saiga populations' dynamics and their ecology, further research is required. The use of modern monitoring methods, genetic studies, and data analysis can provide additional insights into the factors influencing this species. It is also important to conduct more detailed research in the areas of habitat management and anti-poaching efforts.

The conservation of saiga remains a relevant task in terms of preserving the biodiversity of the steppe zone. Our research provides essential data for the development of strategies to conserve this unique species. We hope that our findings will be utilized to strengthen conservation efforts for saiga and its habitat, ensuring its place in the natural world.

As a species, saiga has developed an adapted strategy for survival in difficult conditions, such as climate change and biotic factors. This strategy includes mobility, gregariousness, high fertility, polygamy, and other features (Filippova, 2018). Loss of genetic diversity can negatively affect the ability of animals to adapt to environmental changes (Khanyari et al., 2022; Kashinina, Lushchekina, Sorokin, Tarasyan, & Kholodova, 2023). Recent studies have shown that the saiga population in NWP had a lower level of genetic diversity than other populations that were often exposed to adverse factors (Liu et al., 2019; Rey-Iglesia et al., 2022).

For a long time, hunting was legal on the territory of the former USSR. It did not harm populations when hunters followed the rules of shooting animals. However, in some cases, for example, in Kazakhstan in 1976-1978, excessive capturing of animals took place. It led to a reduction in the number of saiga by 2-3 times. In subsequent years, the capturing rates decreased, making it possible to restore the population of animals to the level of 1975. At the end of the 20th century, the collapse of the economy began in the post-Soviet republics. This process caused an increase in poaching, which, in turn, was a reason for the decline in saiga populations (Milner-Gulland & Kühl, 2006). A shortage of mature male animals was especially noticeable since they were valuable in traditional Chinese medicine (Abaturov, Dzhapova, Kazmin, Ajusheva, & Dzhapova, 2019). During the period from 1952 to 1991, in NWP, there were 2.0 million S. In Kazakhstan, their population amounted to 5.4 million for the period from 1956 to 1994 (Du et al., 2020).

Studies show that the capturing of up to 20% of the saiga population does not seriously harm their existence (Syrym et al., 2019). However, poaching is becoming a serious problem for cross-border saiga populations, for instance, the US population, declined to 1,500 individuals in 2016 due to poaching (Naumova, Zharova, Chistova, & Luschekina, 2020). On the territory of the Republic of Kalmykia, there were only 28 cases of illegal hunting for S, but the illegal trade in horns continues (Ukrainskiy et al., 2019).

In addition, changes in the number of saiga also affect the size of their habitat (Nurushev, Nurusheva, & Baibagyssov, 2020). Saiga form herds and clusters, ensuring safety from predator attacks and rapid movement in search of food (Wang & Jin, 2019). However, the number of animals in a herd depends on the total population (Rduch & Sliwa, 2019; Maikanov et al., 2020). Thus, at a high population level, small herds accounted for 30, medium – 35, and large – 35% (Rey-Iglesia et al., 2022), while at a low population level, small herds accounted for 80.0-100.0 of meetings, medium – 0-15, large – 0-5.0% (Du et al., 2020).

According to some studies, the number of saiga in clusters at calving sites decreased in proportion to the entire population. In the second half and the end of the 20th century, the number of saiga was tens and hundreds of thousands of individuals, whereas in 2004-2008 the number of animals in Kazakhstan decreased to 2-6 thousand. It was noted that in 2014-2016, the number of saigas in NWP also decreased (Karimova & Lushchekina, 2018; Yespembetov et al., 2019).

For the revival of saiga in Kazakhstan, the government has adopted legislative acts. The state allocates significant and stable funding, contributes to the creation of new specially protected areas in saiga habitats, and strengthens conservation measures. The letter implies the organization of special mobile groups for the protection of saiga and other animal species that require protection. In addition, international funds and organizations take in the restoration of the population. They carry out various events to raise awareness among the population. The events include lectures on saiga biology and actions aimed at nature conservation with the help of eco-activists. The developed and distributed posters and printed materials, as well as films and videos, also give positive results (Fereidouni et al., 2019; Roberts, Mun, & Milner-Gulland, 2022).

Conclusion

S, a species of antelope, has developed evolutionary strategies, such as early reproduction, high female fertility, polygamy, gregariousness, and migration. These features allowed them to survive in changing environmental conditions. However, they have not been able to adapt to human influences that include poaching, hunting, and agricultural development. As a result, the number of saigas decreased from 1.1 million individuals to 40-50 thousand, and the area of their habitat decreased by 50 times for the NWP population and by 2.5-5.0 times for Kazakh populations. The NWP population has settled, and migrations have become smaller and less massive. In the 2000s, the biological parameters of saiga were comparable. However, in the NWP population, the proportion of mature males and the number of cubs per 1 female were higher than in Kazakh populations.

The effective organization of saiga protection requires support from the state, foreign funds, and educational work with the population. This approach has proven results: the growth of populations B and V-U became constant. Nevertheless, there has been the loss of habitats, especially those of the NWP territory. In this case, it is almost impossible to restore the saiga population to the level of the end of the 20^{th} century, i.e. up to 1.1 million individuals. Currently, the preservation of the saiga in the NWP and the increase in their population indicators depend on the measures taken at different levels.

During the period when the number of saiga populations was low, the number of herds of different sizes that could be found throughout the year decreased. Herds with no more than 50 animals decreased in 50.0-100.0% of cases. At the beginning of the first decade of the 21st century, the main characteristics of the four saiga populations were comparable to each other. However, in the NWP population, there was a greater number of mature males and young animals per 1 female in summer than in the Kazakh populations (11.7 ± 2.0% and 0.85 ± 0.21 against 8.9 ± 3.5% and 0.51 ± 0.39, respectively).

The growth of populations in B and V-U became possible due to effective protection organized by government agencies and international foundations, as well as educational work among the population. These measures significantly reduced the level of poaching. The example of populations B and V-U shows that saiga can increase the number in a short period with effective protection. The saiga population (*Saiga tatarica tatarica*) living in the steppes west of the Ural River in the West Kazakhstan region has grown from about 12,000 individuals to about 801,000 individuals within ten years, from 2012 to 2022. As a result of the rapid population growth, agricultural producers have begun to complain about the negative consequences for their hayfields and pastures from visits by large groups of saigas. At the same time, during the entire observation period, the number of the Ural population did not exceed 295 thousand individuals. It should be noted that the preservation and restoration of the saiga population in NWP currently require numerous measures at different levels. These measures include the organization of full-fledged protection and comprehensive monitoring, the prevention of habitat fragmentation, the improvement of habitat forage, and the creation of new protected habitats in the territory of the most suitable biotopes.

References

Abaturov, B. D., Dzhapova, R. R., Kazmin, V. D., Ajusheva, E. C., & Dzhapova, V. V. (2019). Comparative features of the nutrition of the Przewalski horse *Equus przewalskii*, the camel *Camelus bactrianus*, and the saiga Saiga tatarica on an isolated steppe pasture. *Biology Bulletin, 46*, 594-607. DOI: https://doi.org/10.1134/S1062359019060037

Bannikov, A. G., Zhirnov, L. V., Lebedeva, L. S., & Fandeev, A. A. (1961). *Biology of saiga*. Moscow, RU: Publishing House of Agricultural Literature, Magazines and Posters.

Baydavletov, E. R., Grachev, A. A., Kantarbayev, S. S., Saparbayev, S. K., Baydavletov, R. Z., Bekmanov, N. M., & Grachev, Y. A. (2018). Saiga monitoring in Kazakhstan in 2017. *Saiga News, 23,* 19-23.

Bliznyuk, A. I. (2009). *The Kalmyk saiga population*. Elista, RU: Jangar.

Bogun, S. A. (2019). State of the saiga population in the Chernye Zemli reserve: problems and prospects for its conservation. *Collection of Research Papers of the Khvalynsky National Park, 11*, 7-14.

Convention on the Conservation of Migratory Species of Wild Animals [CMS]. (2023). *Experts' recommendations for Saiga conservation and management in Kazakhstan, taking into account insights gained on the field visit to Western Kazakhstan*. Retrieved from https://bitily.me/zbFPb

Du, X., Liu, X., Mawolo, J. B., Wang, H., Mi, X., Dong, J., ... Wen, Y. (2020). Determination of haematological and biochemical parameters of Calf Saiga antelope (*Saiga tatarica*) living in the Gansu Endangered Animals Research Center. *Veterinary Medicine and Science, 6*(3), 591-599. DOI: https://doi.org/10.1002/vms3.236

Eastwood, A., Lazkov, G., & Newton, A. C. (2009). *The red list of trees of central Asia*. Cambridge, CA: Fauna and Flora International.

Fadeev, V. A., & Sludsky, A. A. (1982). The saiga antelope in Kazakhstan. Ecology, economic importance. *Almaty Science, 160*, 1-10.

Fereidouni, S., Freimanis, G. L., Orynbayev, M., Ribeca, P., Flannery, J., King, D. P., ... Kock, R. (2019). Mass die-off of saiga antelopes, Kazakhstan, 2015. *Emerging Infectious Diseases, 25*(6), 1169-1176. DOI: https://doi.org/10.3201/eid2506.180990

Filippova, A. (2018). *Report on the analysis of the illegal market for saiga derivatives in Russian Federation*. Moscow, RU: IFAW.

Frank, D. A., McNaughton, S. J., & Tracy, B. F. (1998). The ecology of the earth's grazing ecosystems: profound functional similarities exist between the Serengeti and Yellowstone. *BioScience, 48*(7), 513-521. DOI: https://doi.org/10.2307/1313313

Gabunshchyna, E. B. (2010). The features of agriculture development in the Republic of Kalmykia during the transition period. *Bulletin of the Kalmyk Institute for Humanitarian Research RAS, 2,* 90-95.

Glázer, G. (2017). *An overview of the saiga antelope (Saiga tatarica) in captivity in Europe and the United States*. Retrieved from https://www.saigaresourcecentre.com/sites/default/files/2020-06/an_overview_of_the_saiga_antelope_in_captivity_in_europe_and_the_us_glazer_2.pdf

Grachev, Y. A., & Bekenov, A. B. (2006). The state of populations and prospects for the conservation of the saiga in Kazakhstan. *Steppe Bulletin, 21-22,* 15-17.

Grachev, Y. A., Meldebekov, A. M., & Bekenov, A. B. (2009). Abundance, structure and reproduction of saiga populations in Kazakhstan. *Steppe Bulletin, 27,* 47-50.

Harris, G., Thirgood, S., Hopcraft, J. G. C., Cromsigt, J. P. G. M., & Berger, J. (2009). Global decline in aggregated migrations of large terrestrial mammals. *Endangered Species Research, 7*(1), 55-76. DOI: https://doi.org/10.3354/esr00173

IUCN. (2008). *The IUCN red list of threatened species*. Retrieved from http://www.iucnredlist.org

Karimova, T. Y., & Lushchekina, A. A. (2018). Features of the spatial distribution and ethological structure of the saiga population on the territory of the Stepnoi Reserve (Astrakhan region). *Ecosystems: Ecology and Dynamics, 2*(1), 73-91.

Karimova, T. Y., Lushchekina, A. A., Neronov, V. M., Pyurvenova, N. Y., & Arylov, Y. N. (2020). Biological features of the Northwest Pre-Caspian saiga population at different sizes. *Arid Ecosystems*, *10*, 298-304. DOI: https://doi.org/10.1134/S2079096120040113

Kashinina, N. V., Lushchekina, A. A., Sorokin, P. A., Tarasyan, K. K., & Kholodova, M. V. (2023). The modern state of the European saiga population (*Saiga tatarica tatarica*): mtDNA, DRB3 MHC gene, and microsatellite diversity. *Integrative Zoology, 18*(4), 661-676. DOI: https://doi.org/10.1111/1749-4877.12704

Khanyari, M., Milner-Gulland, E. J., Oyanedel, R., Vineer, H. R., Singh, N. J., Robinson, S., ... Morgan, E. R. (2022). Investigating parasite dynamics of migratory ungulates for sustaining healthy populations: application to critically-endangered saiga antelopes *Saiga tatarica*. *Biological Conservation*, *266*, 109465. DOI: https://doi.org/10.1016/j.biocon.2022.109465

Kholodova, M. V., Milner-Gulland, E. J., Easton, A. J., Amgalan, L., Arylov, I. A., Bekenov, A., ... Ryder, O. (2006). Mitochondrial DNA variation and population structure of the critically endangered saiga antelope *Saiga tatarica*. *Oryx, 40*(1), 103-107. DOI: https://doi.org/10.1017/S0030605306000135

Liu, X., Mawolo, J. B., Du, X., Zhou, Y., Wang, H., Liu, F., ... Marela, H. A. (2019). Investigation of biochemical and physiological parameters of the newborn Saiga antelope (*Saiga tatarica*) in Gansu Province, China. *Plos One, 15*(3), e0230095. DOI: https://doi.org/10.1371/journal.pone.0224822

Maikanov, B. S., Auteleyeva, L. T., Ismagulova, G. T., Wiśniewski J., BeŁkot, Z., Anusz, K. (2020). Quality and safety of fish products in the Shuchinsk-Burabay Resort Zone. *Medycyna Weterynaryjna, 76*(10), 585–588. DOI: https://doi.org/10.21521/mw.6462

Meldebekov, A. M. (2010a). *Red book of the Republic of Kazakhstan. Volume. 1. Animals. Part 1. Vertebrates* (4th ed.). Moscow, RU: DPS.

Meldebekov, A. M. (2010b). *Red book of the Republic of Kazakhstan. Volume. 1. Animals. Part 2. Invertebrates* (4th ed.). Moscow, RU: DPS.

Migushin, A. A., & Gorskikh, V. G. (2017). The state of the saiga population in Kazakhstan. In A. A. Migushin, & V. G. Gorskikh (Eds.)*, Problems of biology, animal science, and biotechnology: The collection of the scientific and practical conference of the Scientific Society of Students and postgraduates of the Faculty of Biology and Technology of Novosibirsk State Agrarian University* (p. 42-45). Novosibirsk, RU: Novosibirsk State Agrarian University.

Milner-Gulland, E. J. (2003). Using Saiga antelope conservation to improve rural livelihoods. *CMS Bulletin*, *17*, 16-17.

Milner-Gulland, E. J., & Kühl, A. (2006). Desperately seeking saiga. *BBC Wildlife*. Retrieved from https://www.saigaresourcecentre.com/sites/default/files/migrated/media/9696/saiga_bbc_wildlife__2006_.pdf

Milner-Gulland, E. J., Hughes, P., Bykova, E., Buuveibaatar, B., Chimeddorj, B., Karimova, T. Y., … Zuther, S. (2020). *The sustainable use of Saiga Antelopes: perspectives and prospects. Report to the Bundesamt für Naturschutz and the Convention on the Conservation of Migratory Species of Wild Animals.* CMS. Retrieved from https://www.saigaresourcecentre.com/sites/default/files/2022-07/unep-cms_saiga_mos4_outcome2_sustainable-use-saiga-antelopes_e_.pdf

Morrison, J. C., Sechrest, W., Dinerstein, E., Wilcove, D. S., & Lamoreux, J. F. (2007). Persistence of large mammal faunas as indicators of global human impacts. *Journal of Mammalogy, 88*(6), 1363-1380. DOI: https://doi.org/10.1644/06-MAMM-A-124R2.1

Naumova, E. I., Zharova, G. K., Chistova, T. Y., & Luschekina, A. A. (2020). Transformation of food lignocellulose compounds in the digestive tract of *Saigatatarica*: functional and comparative aspects. *Biology Bulletin, 47*, 283-290. DOI: https://doi.org/10.1134/S1062359020030061

Nurushev, M. Z., & Baytanayev, O. A. (2018). Problems and methods of rescue of the saiga (*Saiga tatarica L.*) in Kazakhstan. *Bulletin of the Orenburg Scientific Center of the Ural Branch of the Russian Academy of Sciences, 1*, 1-21. DOI: https://doi.org/10.24411/2304-9081-2018-11005

Nurushev, M., Nurusheva, A., & Baibagyssov, A. (2020). The role of climate change in the dynamics of the kazakhstan population of Saiga (*Saiga Tatarica* L.). *Global Journal of Ecology, 5*(1), 146-153. DOI: https://doi.org/10.17352/gje.000034

Phillipson, A., & Milner-Gulland, E. J. (2023). *Darwin project 18-015. Addressing the illegal trade in the critically endangered ustyurt saiga. USAID SCAPES ustyurt landscape conservation initiative project. Socio-economic research component.* Cambridge, CA: Fauna & Flora International.

Rduch, V., & Sliwa, A. (2019). Saiga-Antilopen (*Saiga tatarica*): aus den Steppen Asien über den Kölner Zoo ins Museum Koenig nach Bonn. *Koenigiana, 13*(1), 13-30.

Rey-Iglesia, A., Hjort, J., Silva, T. L., Buuveibaatar, B., Dalannast, M., Ulziisaikhan, T., … Campos, P. F. (2022). Genetic diversity of the endangered Mongolian saiga antelope *Saiga tatarica mongolica* (Artiodactyla: Bovidae) provides insights into conservation. *Biological Journal of the Linnean Society, 137*(1), 100-111. DOI: https://doi.org/10.1093/biolinnean/blac074

Roberts, D. L., Mun, K., & Milner-Gulland, E. J. (2022). A systematic survey of online trade: Trade in Saiga antelope horn on Russian-language websites. *Oryx, 56*(3), 352-359. DOI: https://doi.org/10.1017/S0030605320001313

Robinson, S. (2018). *Summaries of Russian documentation of mass mortality events in saiga during the 1970s and 1980s*. Retrieved from https://bitily.me/xkxVw

Rzabayev, T. S., Assanbayev, T. S., Rzabayev, S., Bazargaliyev, A., & Rzabayev, K. S. (2022). Linebreeding as a system of stock breeding to improve the productive qualities of horses of the Kushum breed. *Reproduction in Domestic Animals, 57*(12), 1584-1592. DOI: https://doi.org/10.1111/rda.14235

Safonov, V., Ermakov, V., Danilova, V., & Yakimenko, V. (2021). Relationship between blood superoxide dismutase activity and zinc, copper, glutathione and metallothioneines concentrations in calves. *Biomath, 10*(2), 2111247. DOI: https://doi.org/10.11145/j.biomath.2021.11.247

Salikhov, T. K. (2006). The current state of the Ural saiga population on the territory of the projected State Natural Reserve «Bokeyorda» of the West Kazakhstan region. *Hydrometeorol Ecology, 4,* 147-156.

Sokolov, V. E., & Zhirnov, L. V. (1998). *The Saiga: phylogeny, systematics, ecology, conservation and use*. Moscow, RU: House of the Russian Agricultural Academy.

Syrym, N. S., Yespembetov, B. A., Sarmykova, M. K., Konbayeva, G. M., Koshemetov, Z. K., Akmatova, E. K., … & Siyabekov, S. T. (2019). Reasons behind the epidemiological situation of brucellosis in the Republic of Kazakhstan. *Acta Tropica, 191,* 98–107. https://doi.org/10.1016/j.actatropica.2018.12.028

Ukrainskiy, V. V., & Ukrainskiy, E. V. (2017). Some data obtained during the monitoring of the Betpak-Dala saiga population before the mass death in 2015. In V. V. Ukrainskiy, & E. V. Ukrainskiy (Eds.)*, Biological diversity of the Asian steppes. Materials of the III International Scientific Conference* (p. 127-132). Kostanay, KZ: Kostanay State Pedagogical University.

Ukrainskiy, V. V., Ukrainskiy, E. V., & Pereladova, O. B. (2019). Saiga monitoring methodology to support species conservation: an example of the Betpak-Dala population. *The Steppe Bulletin, 51-52,* 58-63.

UNEP. (2010). *Progress towards the fulfilment of the CMS medium term international work programme for the saiga antelope (for the period 2007-2011). A document prepared for the CMS Secretariat by UNEP (2010).* Ulaanbaatar, MN: CMS.

Ussenbekov, Y., Bagdat, A., Bimenova, Z., Orynkhanov, K., Sobiech, P., Samardžija, M., … Dobos, A. (2022). Identification of monomorphic and polymorphic genes associated with recessive fertility defects in Holstein cows reared in Kazakhstan. *Veterinarski Arhiv, 92*(1), 27-35. DOI: https://doi.org/10.24099/vet.arhiv.1390

Ventsova, I., & Safonov, V. (2021). Biochemical criteria for the development mechanisms of various reproduction disorders in dairy cows. *Biodiversitas Journal of Biological Diversity, 22*(11), 4997-5002. DOI: https://doi.org/10.13057/biodiv/d221135

Vlasova, I., Ventsova, I., Vostroilov, A., Safonov, V., & Golubtsov, A. (2020). Beef productivity of limousine cattle at stable keeping. *American Journal of Animal and Veterinary Sciences, 15*(4), 266-274. DOI: https://doi.org/10.3844/ajavsp.2020.266.274

Wang, S., & Jin, K. (2019). Global population status and conservation strategy of Saiga tatarica. *World Forestry Research, 32*(6), 49-53. DOI: https://doi.org/10.13348/j.cnki.sjlyyj.2019.0051.y

Yespembetov, B. A., Syrym, N. S., Zinina, N. N., Sarmykova, M. K., Konbayeva, G. M., Basybekov, S. Z., … Siyabekov, S. T. (2019). Phenotypic and genotypic characteristics of Brucella isolates from the Republic of Kazakhstan. *Tropical Animal Health and Production, 51*(8), 2361–2370. DOI: https://doi.org/10.1007/s11250-019-01941-y

Zhirnov, L. V. (1982). *Brought back to life: ecology, conservation and use of saigas*. Moscow, RU: Timber Industry.