ISSN 1995-4255, Contemporary Problems of Ecology, 2024, Vol. 17, No. 6, pp. 830–838. © Pleiades Publishing, Ltd., 2024.
Russian Text © The Author(s), 2024, published in Sibirskii Ekologicheskii Zhurnal, 2024, No. 6, pp. 913–922.

Influence of the Introduction of Sika Deer on the Current State of the Number and Distribution of Ungulate Mammals in the Ussuriysky Nature Reserve (Russian Far East)

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Received April 4, 2024; revised May 27, 2024; accepted June 7, 2024

Abstract—The results of long-term observations are summed up, making it possible to assess patterns and identify the reasons for changes in the numbers, current distribution, and interspecific relationships of ungulates in the Ussuriysky Nature Reserve. A comparison of archival materials and data from the last decade shows that changes in the abundance and distribution of most ungulate species in the reserve are inextricably linked with the increase in the number of sika deer. After the introduction of this species into the territory over 70 years, its number increased from 25 to 1180 individuals, and the population density reached an average of 30 individuals/1000 ha. Over the same period, the number of red deer in the Ussuriysky Nature Reserve decreased from 450 to 130 individuals, that is, more than three times. In the Suvorovsky forestry, there is currently a decrease in the number by about half (from 250–280 to 110 individuals); in the Komarovsky forestry, the number has decreased by about 10 times (from 180–200 to 15–20 individuals). The number and distribution of roe, musk deer, and wild boar in the territory has not changed as obviously. The current number of roe in the reserve is 170 individuals, with a population density of 4 individuals/1000 ha. The number of wild boars is about 200 individuals, with a population density of 4–5 individuals/1000 ha. The accounting methodology that was developed and applied has made it possible to obtain reliable data on the number and distribution of ungulates throughout the Ussuriysky Nature Reserve. There are concerns about a further increase in the number of sika deer in connection with the implementation of biotechnical measures in the reserve.

Keywords: winter route census, track-making activity, abundance, ungulate animals, Ussurisky Nature Reserve

DOI: 10.1134/S1995425524700586

INTRODUCTION

As is known, the dynamics of animal numbers and their distribution in their habitat is one of the most complex problems of modern ecological science. This problem has theoretical and applied significance, since its solution will determine the understanding of many important aspects of the functioning of animal communities and the development of measures to preserve biodiversity. The main task of specially protected natural areas is the protection of unique and typical natural complexes, objects of both flora and fauna, and natural ecological systems in order to maintain them in their original state.

The Ussuri Nature Reserve was created in 1934 with the aim of preserving in their original state the unique mountain–forest ecosystems of the western macroslope of Sikhote-Alin and their flora and fauna, related to the Manchurian complex, with a high level of endemism. Broadleaf–Korean pine forests are the background of the reserve, located on slopes of varying exposure in the altitudinal zone from 60 to 600 m above sea level. The vegetation cover of the Ussuri Nature Reserve, which consists of two forestries—Komarovsky (Ussuri Urban District) and Suvorovsky (Shkotovsky District), which was annexed in 1972—is formed mainly by coniferous forest-forming species. Until 1972, the area of the reserve was 16679 ha of forests, almost unaltered by human activity—the "old" territory. In 1973, it increased almost 2.5 times and amounted to 40432 ha. Currently, the Ussuri Nature Reserve is part of the Land of the Leopard National Park; its area is 41234 ha, and the area of the protected zone is 57800 ha. Geographic coordinates are 43.40490 N, 132.32440 E.

During the creation of the Ussuri Nature Reserve, the fauna of ungulates was formed by the following species: the red deer *Cervus elaphus* (Linnaeus, 1758), boar *Sus scrofa* (Linnaeus, 1758), roe deer *Capreolus pygmagus* (Pallas, 1771), and musk deer *Moschus moschiferus* (Linnaeus, 1758). Before the introduction of the sika deer *Cervus nippon* (Temminck, 1838), the red deer was dominant (*Letopis'...*, 1974).

Until the end of the 1970s, isolated encounters of the Amur goral *Naemorhedus caudatus* were recorded on the rocky outcrops of Zmeinaya Mountain (Shkotovsky District) (Milne-Edvards, 1867). Unfortunately, after additional territory was added to the reserve, traces of the goral activity were no longer recorded. The supposed reasons for this are the proximity of a highway, logging, and uncontrolled hunting in the adjacent territory (Maslov, 2012a, 2012b).

In 1950–1952, a total of 25 sika deer were brought to the reserve from the Silinsky deer park as part of a regional program to restore the species within the boundaries of its historical range. The sika deer is a representative of the Manchurian fauna. Historically, it inhabited mainly broadleaf forests, preferring oak forests associated with the sea coast. In Korean pine–broadleaf formations, according to a number of authors, it is significantly rarer (Przhevalsky, 1870; Yankovsky, 1882; Abramov, 1928; Bromley and Kucherenko, 1983; etc.). Meanwhile, in the original territory of the Ussuri Nature Reserve, forests with a predominance of Korean pine and dark coniferous trees occupy more than 91% of the total area (Manko et al., 2010).

The introduction of this species of ungulates into suboptimal habitats was initially carried out using biotechnical measures (keeping in enclosures, feeding, and laying salt licks), which made it possible to retain the deer in the area of introduction. In order to disperse the animals throughout the entire territory of the reserve and to activate the mechanisms of natural selection, feeding was stopped in the early 1970s. By 2012, the sika deer had populated almost all forest formations of the reserve and had become the most numerous species in the fauna of ruminant ungulates there (Maslov, 2009, 2012b).

From 1974 to 2012, winter route censuses (WRCs) of animals in the Ussuri Nature Reserve were conducted in accordance with the generally accepted methodology (Formozov, 1932; Malyshev, 1936; Pereleshin, 1950; etc.). From 1974 to 2012, the reserve's White Trail consisted of two sections: the "southern circle" (36 km) and "northern circle" (34 km), which passed through the "old" territory of the reserve (*Letopis'...*, 1974–2020). Forest management maps were used when plotting routes. The data from the surveys were entered into tables, with the number of intersections of tracks of one type or another noted for each kilometer of the route. However, the 70-km long "white trail" was laid out as a closed route only on the territory of the Komarovsky forestry. The results obtained during the specified period are reflected in the publications (Abramov and Kovalev, 2004; Maslov and Litvinov, 2005; Litvinov, 2008; Maslov, 2009a, 2009b, 2012b).

The situation with the numbers of most animal species, primarily ungulates, in the Suvorovsky forestry in 1998–2010 was assessed only based on data from ranger trails and surveys under the Amur tiger *Panthera tigris altaica* (Tem.) population-monitoring program (Mikel et al., 2010).

It was not possible to extrapolate the data due to the different living conditions of the animals (the habitats in the two forestries differ significantly). Further extending the routes was not possible for technical reasons.

In 2012, a decision was made to change the methodology for conducting the WRC, creating a "synthetic" network of routes that meets the requirements of all types of track counts, including monitoring the Amur tiger population in the reserve. Changes in the methodology of the white trail surveys made it possible to obtain more complete data on the number and distribution of ungulates throughout the entire territory of the Ussuri Nature Reserve.

The purpose of this work is to assess the current state of the number and distribution of ungulates in the territory Ussuri Nature Reserve based on the results of winter route surveys for 2013–2020.

MATERIALS AND METHODS

The routes on the territory are laid out taking into account the proportional content of land types characteristic of each forestry, exposure, and slope steepness (Fig. 1). In the Komarovsky forestry, ten routes were laid out, passing through the areas of the main watercourses. There are nine similar routes in Suvorovsky forestry.

Each counter had a detailed map with a designated route, instructions, and a card in which the results of the count were recorded. Along the routes, all encounters with daily animal tracks were recorded using GPS. Based on the divergence of the tracks of ungulates, the specific number of individuals in a group of animals was determined, which made it possible to calculate the number of individuals per 10 km of the route (N). For this purpose, additional recommendations were introduced into the data recording methodology and new registration cards were developed.

The change in methodology made it possible to compare the results of animal counts in both forestries and conduct monitoring throughout the entire territory of the Ussuri Nature Reserve. The survey routes cover 16700 ha—41% of the total area of the reserve (8500 ha in the Komarovsky forestry and 8200 ha in the Suvorovsky forestry). The extrapolation coefficient was 2.4.

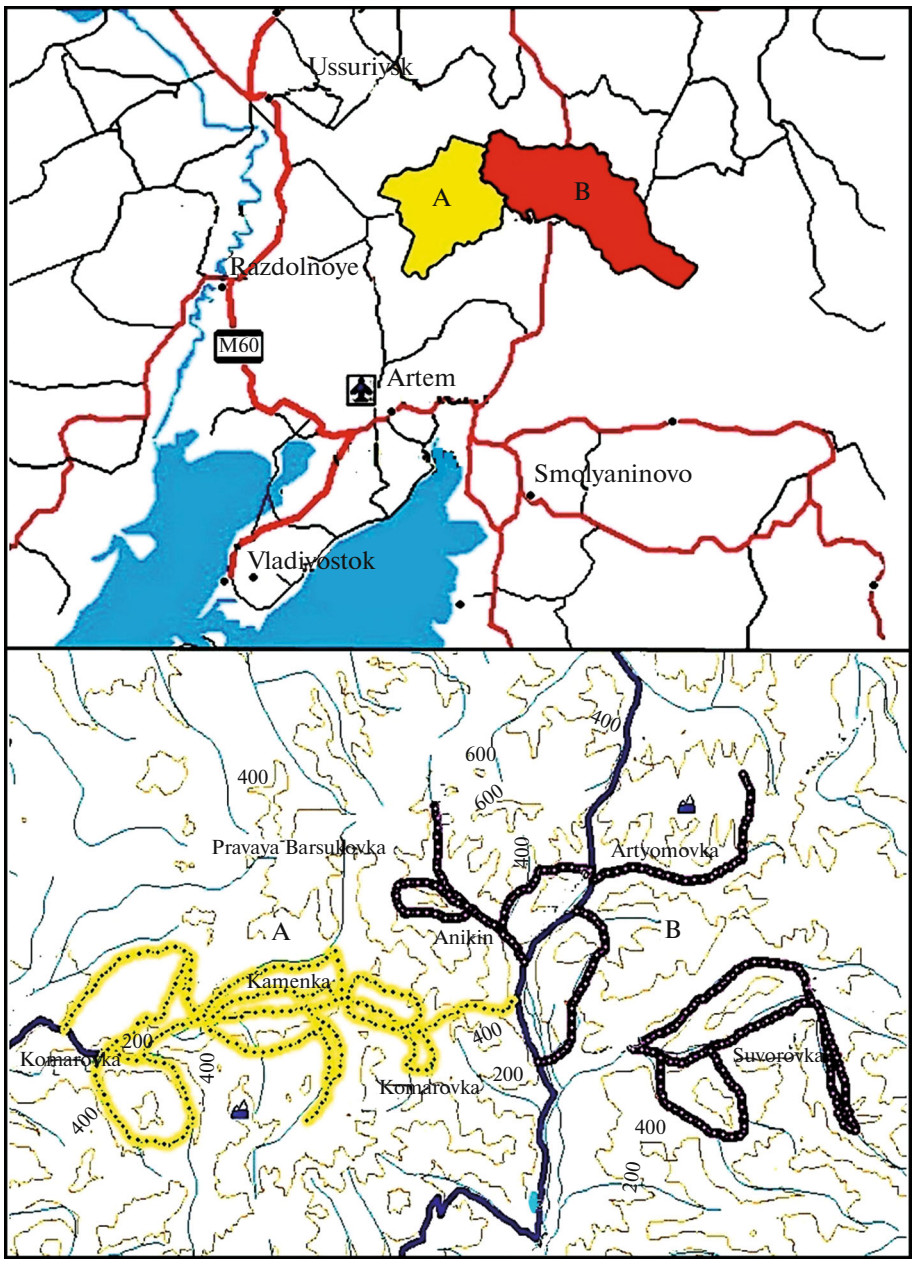

Fig. 1. Map of Ussuri Nature Reserve and winter route (WRC) trajectories, shown using MapSours Trip Waypoint Managar software: (A) survey routes in Komarovsky forestry (Ussuriysk urban district); (B) survey routes in Suvorovsky forestry (Shkotovsky district).

When analyzing the number of ungulates based on archival data, we mean the number of tracks per unit route (track-making activity).

RESULTS

After the cessation of feeding and until the mid-1970s, the main part of the group of sika deer lived in the area of the village of Komarovo-Zapovednoye (the "old" territory); here there were at least 120 individuals. By 1980, the number of deer reached 200 individuals, and from 1990 to 2000 it increased to 250–300 individuals. At the same time, sika deer were dispersing throughout the entire territory of the Ussuri Nature Reserve and its environs (Maslov, 2009). By 2011, the total number of deer in the reserve was estimated at 310–350 individuals (in the Komarovsky forestry 250–270 individuals) (Maslov, 2012b).

The number of sika deer in the Komarovsky forestry currently remains stably high, with a tendency to further increase. In winter, on the slopes of southern exposures, combined groups of deer from 10 to 60 individuals were

Fig. 2. Group of sika deer. Ussuri Nature Reserve, Komarovsky forestry, Pokorsky spring, southern exposure, February 5, 2016. Photo by M. Maslova.

noted (Fig. 2). The main factor determining the stationary distribution and limiting the number of sika deer in winter is the height and structure of the snow cover.

In the spring and summer, the distribution of sika deer, with maximum diversity and availability of vegetation, is diffuse. The highest density of traces of the vital activity of these deer is recorded in floodplain biotopes; along river banks and in open, windy areas of watershed ridges; and on northern, eastern, and western slopes, especially on terraces. The lowest density is on steep slopes of southern exposure, where herbaceous vegetation is represented by a small set of species (Maslov, 2012b).

The increase in the number of sika deer in the Suvorovsky forestry occurred due to migration from the Komarovsky forestry and the adjacent territory of the Orlinoye State Forestry Reserve. The first small groups of deer in the lower reaches of the Suvorovka and Artemovka rivers were noted in 1976 and 1979. During these same years, the formation of small groups of deer was observed in the adjacent territory in the Mikhailovsky district (*Letopis'*..., 2010–2020). By 2000, deer began to move upstream along the Suvorovka River, and individual specimens were noted in the area of the Chertov Klyuch (Devil's Spring). By 2010–2012, deer had populated almost the entire forestry area. By 2011, there were 60–80 of them in the Suvorovsky forestry (Maslov, 2012b).

Since 2017, sika deer have become the dominant ungulate. Groups of 7 to 14 individuals were periodically seen in the middle reaches of the Suvorovka River in fir–spruce forests that are unsuitable for this species to live in.

During winter route counts in the Komarovsky forestry from 2013 to 2020, between 20 to 46 individuals per 10 km of route ($m = 31 \pm 2$) (Fig. 3) and between 25 to 56 individuals per 1000 ha ($m = 38 \pm 2$) (Table 1) were recorded. In the Suvorovsky forestry, these figures ranged from 5 to 13 individuals per 10 km of route ($m = 9 \pm 0.5$) and from 4 to 13 individuals per 1000 ha ($m = 9 \pm 0.6$).

DISCUSSION

We assessed the impact of the introduction of sika deer on the current state of the number and distribution of ungulates in the Ussuri Nature Reserve. Understanding the mechanisms and full dynamics of this process requires further research on each specific species. The data below show how much the number and ratio of ungulate species in the study area has changed over 70 years. The accounting methodology used for the period from 2013 to 2020 made it possible to assess not only the track-making activity of ungulates, but also their actual numbers.

Red deer. Before the introduction of the sika deer, the red deer was the dominant ungulate throughout the entire territory of the Ussuri Nature Reserve. It preferred valley and riverine forests with Mongolian oak and Korean pine (Abramov and Kovalev, 2004). During the years of formation of the reserve, accord-

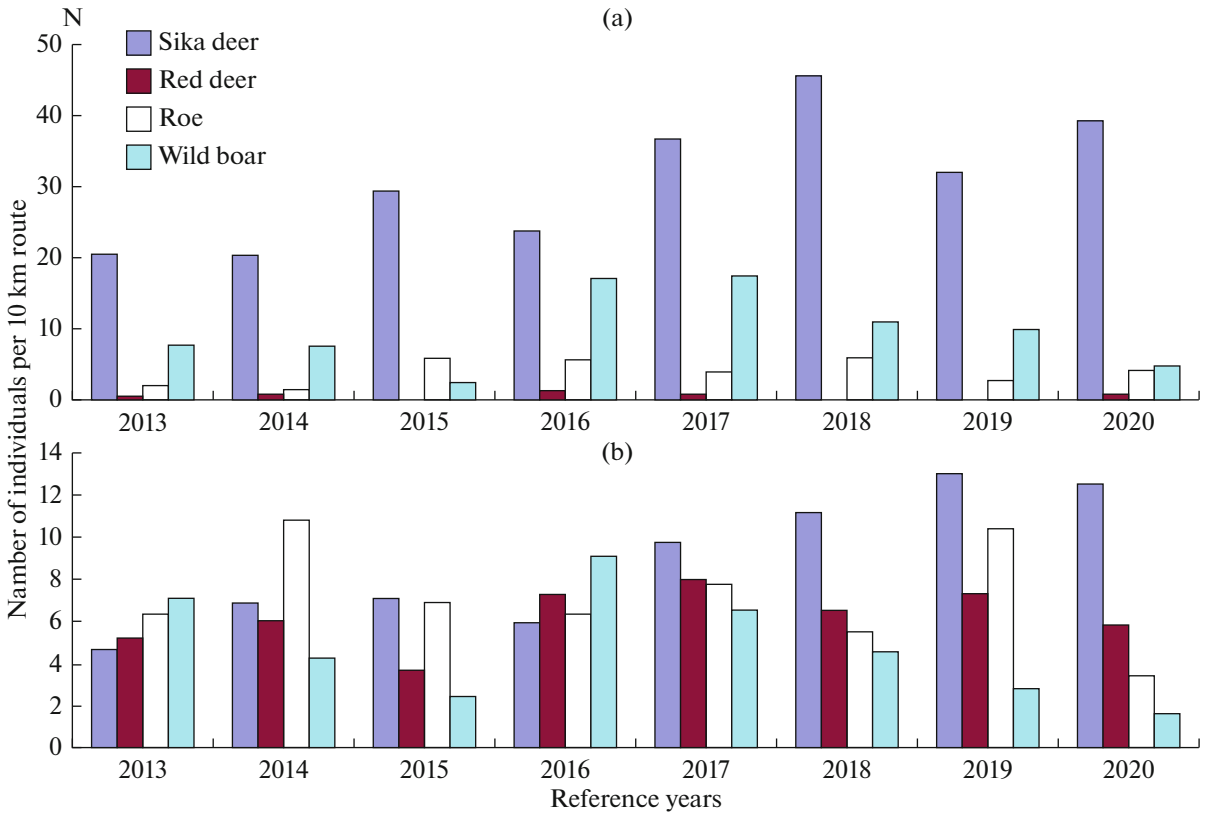

Fig. 3. Dynamics and ratio of the number of ungulates in the Ussuri Nature Reserve on stationary winter routes from 2013 to 2020: (a) Komarovsky forestry (Ussuriysk urban district); (b) Suvorovsky forestry (Shkotovsky district).

Table 1. Number and population density of ungulates in the Ussuri Nature Reserve based on the results of winter route surveys for the period from 2013 to 2020

Years	Length of route (km)	Sika deer		Red deer		Roe		Boar	
		n	individuals/ 1000 ha	*n*	individuals/ 1000 ha	*n*	individuals/ 1000 ha	*n*	individuals/ 1000 ha
Komarovsky forestry									
2013	105	215	25	4	0.5	23	33	81	10
2014	109	223	26	10	1	16	2	85	10
2015	105	310	36	3	0.4	61	7	73	9
2016	105	250	29	15	2	59	7	181	21
2017	104	387	46	11	1	41	5	185	22
2018	104	475	56	3	0.4	61	7	114	13
2019	99	317	37	1	0.2	27	3	97	11
2020	99	392	46	8	1	40	5	51	6
Suvorovsky forestry									
2013	76	36	4	40	5	49	6	54	7
2014	95	66	8	58	7	102	12	41	5
2015	87	62	8	38	5	50	6	22	3
2016	87	51	6	64	8	56	7	80	10
2017	87	86	10	69	8	68	8	57	7
2018	87	97	12	52	6	44	5	37	5
2019	80	105	13	58	7	83	10	22	3
2020	80	100	12	46	6	30	4	13	2

n is the number of individuals on the route.

ing to the estimates of the same authors, the population density of red deer was more than 10 individuals/1000 ha; i.e., it was quite high (about 200 individuals/16000 ha). In the old territory (Komarovsky forestry), the number of red deer, starting from the moment the reserve was founded (reliably since 1974), has decreased by more than 10 times in 25 years (Abramov and Mikell, 2001). According to archival data, a decrease in the number of red deer tracks was observed simultaneously with an increase in the number of sika deer from 1988 to 1995. In 1986–1987, the indicator for red deer was 9–13 tracks/10 km, in 1989 3–5 tracks/10 km, and by 2000 2–3 tracks/10 km. In the period from 2000 to 2011, the number of red deer was approximately 20 individuals (Maslov and Litvinov, 2005; Maslov, 2012b). From 2012 to 2020, there were no significant changes, and up to 11–15 animals were registered annually in the Komarovsky forestry area. It should be noted that the tracks of the red deer were most often found on the plateau, at the tops of the main watercourses along the border of the reserve and in the upper part of the steep southern slopes, which the sika deer avoids.

According to a number of authors, the decline in the number of red deer is associated with the introduction of sika deer (Moskaluk et al., 1999; Abramov and Kovalev, 2004). Due to its large herd size, it pushed the red deer out of the central part of the old territory, where the best winter feeding grounds are located, to the periphery. The same was noted in the Lazovsky State Nature Reserve, where the red deer was forced into areas adjacent to the upper parts of the watercourses (Aramilev, 2009). The situation was aggravated by intensive logging in the border zone and poorly controlled hunting along the borders of the Ussuri Nature Reserve (Maslov and Kovalev, 2013). In winter, the red deer actively moves to clearings rich in branch food and to thickets of wintering horsetail in the valleys of the Volkha and Barsukovka rivers outside the reserve, to the territory of hunting grounds, and becomes an object of hunting (Maslov, 2008b).

In the annexed territory, in the Suvorovsky forestry, the population density of red deer was somewhat lower (about 8 individuals/1000 ha) (Abramov and Mikkel, 2001; Abramov and Kovalev, 2004). After joining the reserve and strengthening protection, the number of red deer increased to 10–12 individuals/1000 ha. This number of red deer remained, with minor fluctuations, until 2000 (*Letopis'*..., 1974–2020). There are several reasons for this. First, in most of the forestry there was no or rare sika deer and, second, along the borders of the reserve, a number of highly organized hunting farms were created that were interested in preserving this game species. With the beginning of the new millennium, most hunting grounds were reorganized and protection was relaxed. Along with large-scale logging along the forestry boundaries, this led to a decrease in the number of red deer, both in the surrounding area and in the reserve. Thus, the number of red deer in the territory of the Suvorovsky forestry by 2007 was estimated at 150–170 individuals/24000 ha (6–7 individuals/1000 ha) (Litvinov, 2008). By 2011, the number of red deer in this area had decreased to 100–130 individuals, alongside the beginning of an increase in the number of sika deer (Maslov, 2012b). This number, with minor fluctuations, remained until 2019–2020. The main population of red deer, especially in the summer–autumn period, is concentrated in the upper reaches of the rivers along the border of the reserve. The reason for the reduction in numbers in the Suvorovsky forestry area is overfishing in the border zone and weak control in hunting grounds after their reorganization. The situation is aggravated by the growing number of sika deer, which is beginning to displace red deer from floodplain areas—the main wintering grounds. The decrease in the number of red deer on the routes is parallel to the increase in the number of sika deer. This is evidenced by a significant decrease in the number of registered roaring stags at stationary listening points (*Letopis'*..., 2010–2020).

It should be taken into account that, in the Suvorovsky forestry, due to the difficulty of access, winter surveys were not carried out in the upper part of the rivers. Therefore, for a more complete assessment of the number of red deer, further research is needed in this area.

In the winter of 2013–2020, in the Komarovsky forestry in different years, the number of red deer was from 0.1 to 1 individual/10 km of the route ($m = 0.6 \pm 0.1$). The population density ranged from 0.2 to 2 individuals/1000 ha ($m = 0.9 \pm 0.1$). In the Suvorovsky forestry, these indicators varied from 4 to 8 individuals/10 km of route ($m = 6 \pm 0.2$). The population density ranged from 5 to 8 individuals/1000 ha ($m = 6 \pm 0.2$).

Roe. As a nomadic species, roe can temporarily move to more comfortable conditions, so its numbers in a limited area, in this case in the Ussuri Nature Reserve, often depend on the depth of snow during the survey period. Optimal habitats for roe deer, with low snow cover in winter and open spaces, are located outside the reserve.

In the first years of counting in the Komarovsky forestry (1975–1978), there were 4 to 9 tracks of animals of this species per 10 km of counting routes. This situation persisted until the end of the 1990s (*Letopis'*...., 1974–2020). Since 2002, the population has begun to decline throughout the entire habitat of roe deer in Primorsky krai (Mikell et al., 2010). According to WRC data in the Ussuri Nature Reserve, the number of roe deer tracks from 2003 to 2010 was within 2–4 tracks/10 km of route (*Letopis'*..., 1974–2020). The lack of optimal biotopes for roe deer and competitive relations with sika deer should be considered factors influencing their numbers in the Komarovsky forestry. The aggravation of these interspecies relations was also noted in the Lazovsky State Nature Reserve, where

the roe deer was "squeezed out" to the periphery of the territory (Makovkin, 1999; Konkov, 2004, 2009). By 2013, according to the results of the WRC in the Komarovsky forestry, 3 tracks/10 km of the route were noted.

The number of roe deer is also low in the Suvorovsky forestry. However, in local areas along the Shkotovo-Ivanovka highway, in the fields adjacent to the reserve, roe deer are common and even numerous. The number of its traces decreases with distance from the Artemovka River valley and in the upper third of its tributaries. Thus, all the noted roe deer of the Suvorovsky forestry are concentrated in sparse plantations along the Artemovka River valley and the wide floodplains of the tributaries flowing into it. First and foremost, this is the floodplain of the Suvorovka River. In the reserve, on routes passing through these areas, from 2003 to 2010, up to 20 tracks/10 km of route were noted, while in the upper part of the rivers the indicator did not exceed 0.5–1 (*Letopis'...*, 1974–2020). By 2013, according to WRC results, the figure was 7 tracks/10 km of route.

In 2013–2020, in the Komarovsky forestry, the number of roe deer in different years ranged from 2 to 6 individuals/10 km of the route ($m = 3.9 \pm 0.3$). The population density ranged from 2 to 7 individuals/1000 ha ($m = 4.8 \pm 0.4$). In the Suvorovsky forestry, the figures varied from 3 to 11 individuals/10 km of route ($m = 7.2 \pm 0.4$). Population density ranges from 4 to 12 individuals/1000 ha ($m = 7.3 \pm 0.5$).

Boar. Due to their high fertility, wild boars are capable of increasing their numbers many times over a short period of time. In case of diseases and other unfavorable conditions, thanks to the herd nature, their numbers also decrease quickly. Wild boars are difficult to count due to their high mobility and ability to migrate in search of fattening food. In a small area of the reserve, the survey data is reliable only at the time of the survey and becomes outdated within just a few days.

According to different types of surveys, wild boar numbers range from 1–2 tracks per 10 km of route to 35–40 or more over the course of one season. Thus, an increase in wild boar numbers in limited areas over a short period of time is often associated with migration rather than population status.

According to published data, in the Ussuri Nature Reserve area, the highest number of wild boars was recorded in 1999 (30 tracks/10 km of routes), and the lowest was in 2003 (0.9) (Mikell et al., 2010). At the same time, the average number of tracks/10 km of route across 13 sections varied significantly less: from 2 to 5 over 13 years. The number of wild boars does not depend on the number of competing species.

During winter route surveys in 2013–2020 in the Komarovsky forestry, wild boar counts ranged from 3 to 18 individuals/10 km of route in different years ($m = 9.8 \pm 0.9$). The population density ranged from 6 to 22 individuals/1000 ha ($m = 12.7 \pm 0.9$). In Suvorovsky forestry, these indicators varied from 2 to 9 individuals/10 km of route ($m = 4.8 \pm 0.4$). Population density is from 2 to 9 individuals/1000 ha ($m = 4.9 \pm 0.5$).

Musk deer. Until 1999, traces of musk deer in the Ussuri Nature Reserve were annually noted on survey routes in characteristic habitats (from 1 to 4/10 km of the route). Since 2000, musk deer have been encountered as single specimens no more than once every 2–3 years (Maslov et al., 2023). The low numbers of musk deer during this period are evidenced by data obtained using camera traps installed as part of a program to study and preserve the Amur tiger in the Russian Far East (Rozhnov et al., 2012). Traces of musk deer were noted only twice during the 8-year research period: in 2014 and 2016 (1 and 2 individuals, respectively). The decrease in the number of musk deer in the Ussuri Nature Reserve occurred alongside an increase in the number of sable and a decrease in the number of alternative food sources for medium and small predators. It is possible that the increase in the number of sika deer during this period also influenced the situation.

CONCLUSIONS

Currently, the predominant species among the ungulates of the Ussuri Nature Reserve is the sika deer. Since the introduction of this species into the territory over 70 years ago, its numbers have increased from 25 to 1180 individuals, and the population density has reached an average of 30 individuals/1000 ha. It should be noted that in the Komarovsky forestry the population density for the period 2013–2020 reached 56 individuals/1000 ha and in the Suvorovsky forestry 13 individuals/1000 ha (and continues to grow).

Since 1950, the number of red deer in the Ussuri Nature Reserve has decreased from 450 up to 130 individuals, that is, more than three times. In the Suvorovsky forestry, the number has currently decreased by approximately half (from 250–280 to 110 individuals), while in the Komarovsky forestry, the number has decreased by approximately 10 times (from 180–200 to 15–20 individuals).

The dependence of changes in the number of roe deer and wild boar on the number of sika deer is not as obvious. The current population of roe deer in the reserve is 170 individuals, with a population density of 4 individuals/1000 ha. The population of wild boar is about 200 individuals with a population density of 4–5 individuals/1000 ha.

In 2021, the Ussuri Nature Reserve was transferred to the Ministry of Natural Resources of Russia under the management of the Federal State Budgetary Institution Land of the Leopard, which began feeding animals in winter and laying salt licks in order to increase the number of ungulates associated with the reintroduction of the Far Eastern leopard *Panthera pardus orientalis* (Slegel).

Further monitoring of the state and dynamics of the population groups of ungulates in the Ussuri Nature Reserve is necessary; it will allow us to compare the results with new indicators and conduct an analysis of the consequences of biotechnical measures.

Undesirable consequences of the increase in the number of sika deer may include a destructive effect on vegetation (Moskaluk et al., 1999) and the displacement of other deer species. The negative impact of this deer on the population of red deer is clearly visible both in the Komarovsky and Suvorovsky forestries of the reserve. Further research is needed for a detailed analysis.

ACKNOWLEDGMENTS

We are sincerely grateful to the staff of the Ussuri Nature Reserve for their assistance in collecting material, as well as to the administration of the Land of the Leopard national park for the opportunity to continue research on the territory of the Ussuri Nature Reserve.

AUTHOR CONTRIBUTION

M.V. Maslov carried out calculations, organized and participated in research, and wrote the article. T.O. Markova designed, illustrated, and authored the article. E.A. Litvinova processed archival materials and authored the article. M.N. Litvinov was a research participant and author of the article.

FUNDING

This work was carried out as part of the State Task of the Ministry of Science and Higher Education of the Russian Federation, topic no. 124012200183-8.

ETHICS APPROVAL AND CONSENT TO PARTICIPATE

This work does not contain any studies involving human and animal subjects.

CONFLICT OF INTEREST

The authors of this work declare that they have no conflict of interest.

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