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The current state of Taimyr reindeer (Taimyr-Evenk population) and the probable reasons for its reduction

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Abstract. The North Siberian plain is the main fawning ground and summer feeding of wild reindeer of the Taimyr tundra population. After an explosive increase in numbers in 2000, when the population increased to 1 million of individuals, there is a decrease in the deer number. According to aerial surveys in 2017, it amounted to 404-442 thousand of individuals, in 2019, according to research staff members of the Taimyr Nature Reserves, it decreased to 250-280 thousand. Based on mathematical modeling and analysis of information obtained when marking 17 deer with collars with satellite transmitters, the paper considers version of the population response to environmental factors. Against the background of tundra “greening”, the growth of plant biomass, the length of deer stay in Taimyr did not increase, but, on the contrary, it decreased almost three times and averages 63 days in comparison with the 1960s. The questions solved in this paper consider the reasons why deer leave their former feeding grounds in the middle, or even at the beginning of August and if a significant reduction in the volume of deer hunting will lead to a completely opposite effect.

1. Introduction

Discussions on the development of the Arctic sector of the Krasnoyarsk Territory are becoming more acute every year. Not only the economic future of the region, but also the solution of socially significant issues for peoples living in the Arctic depends on the success of such an ambitious project. Against the background of the intensification of the economic development of Taimyr, and as a result, the transformation of ecosystems of the Arctic and subarctic tundra, the primary task for the scientific community, representatives of regional and federal authorities, as well as indigenous peoples of the north, is to preserve the biological diversity of the region and biological resources. The use of reindeer resources in Central Siberia is the main source of well-being for most farms and the indigenous population of the North of the region. Reindeer is considered not only as the most important link in the Arctic communities, but also as a key component of the food security of the indigenous people of the northern territories.

The Taimyr-Evenki population of wild reindeer (*R. t. tarandus* L., 1758) is the largest in Russia. However, its uniqueness lies not only in its number, but also in the vastness of its range of more than 1.5 million km². Most of the year, animals are in motion, passing up to 6.5 thousand km per year. Despite the keen interest in the reindeer, a number of issues of its ecology are still poorly studied. The abundance data vary, and the predictive estimates are extremely contradictory: from the complete loss



of the commercial value of the species to a completely optimistic scenario [1]. Obviously, the rational use of resources is impossible without the study and understanding of population adaptations occurring both against the background of increased operational load and global climate change.

The purpose of the study is to analyze the current state of the reindeer of the Taimyr (Taimyr-Evenki population) and consider the most probable reasons for the reduction in its number.

2. The Taimyr Peninsula as habitat reindeer

The Taimyr Peninsula is the northernmost territory of Eurasia, it is located between the Yenisei Gulf of the Kara Sea in the west and the Khatanga Gulf of the Laptev Sea in the east. The extreme northern point is Cape Chelyuskin, the southern border is associated with a ledge of the Central Siberian plateau. The length of the peninsula from north to south is about 500 km, from west to east more than 1000 km, the total area of about 400 thousand km².

In geological and geomorphological terms, the territory of Taimyr can be divided into several parts: the coastal plain, the Byrranga mountains and the North Siberian lowland. The coastal plain is represented by structures of the Caledonian folding and is expressed in the relief by a strongly destroyed low mountains, with heights of not more than 300 m. Byrranga mountains are folded-block mountains formed in the Hercynian era simultaneously with the Ural Mountains. They are represented by a system of ridges and plateau massifs, stretching over a wide strip (70-100 km) from the southwest to the northeast and occupy a large part of the Taimyr Peninsula. The north-eastern part of the Byrranga mountains is a plateau with absolute heights of up to 1146 m (Lednikovaya city).

The North Siberian lowland is extended by a wide strip from the south-south-west to the north-north-east; in the west, in the lower Yenisei, it gradually merges with the West Siberian lowland. In the south, a flat plain adjoins a ledge of the Central Siberian plateau. The relief of the North Siberian Lowland is formed by Quaternary glaciations and marine transgressions; on the whole, it is hilly-lumpy with extensive alluvial depressions and flat accumulative plains. The entire lowland is crossed by a sublatitudinal system of moraine ridges with absolute heights of 150-250 m [2].

Due to the fact that the Taimyr Peninsula is located in the Arctic and Subarctic zones, its climate is particularly severe. Winter is long and frosty, the warm period lasts no more than 2-2.5 months (end of June - beginning of September), constant winds are especially strong in winter [2].

The vegetation of the Arctic zone is represented by 50-60 species of vascular plants of cryophytic arctic and arctoalpine grasses, undersized (5-10 cm), often cushion-shaped, as well as turf. The most characteristic of the polar-desert landscapes are a variety of mosses and lichens, among which there are a lot of scale, developed on polygonal surfaces and a few flowering plants.

The vegetation of the Byrranga mountains is expressed in altitudinal zonation. In the lower zone of the mountains, moss-grass-dryad and grass-dryad communities (on gravelly slopes and plateaus) or dryad-moss communities (on fine-grained surfaces) are developed. Above 200–300 m, the dryad is replaced by *Salix polaris*, moss tundras with this willow are characteristic of fine-grained areas, whereas on the gravelly slopes and high plateaus, dryad tundras are replaced by incomplete (covering less than 20%) grass tundra. At levels of 550–700 m, blocky collapses are developed with separate flowering plants and bushy lichens in the niches between the stones, or raw moss-grass groups (*Phippsia algida*, species of the genera *Saxifraga* and *Draba*) [3].

The flora of the subarctic landscapes of Taimyr consists of the following genetic elements: hypoarctic, arctic, arctoalpine shrubs, shrubs, perennial grasses, mosses and lichens [3]. About 350 species of higher plants (46 families) grow floristically within the tundra zone. The following families are most richly represented: cereals - 60 species, cruciferous - 34 species, sedge - 33 species, compound flowers - 30 species, cloves - 25 species, saxifrage - 22 species, willow - 18 species. Among the genera, sedges, willows, saxifrages, as well as nibs, buttercups, mytniks and bluegrasses, are most widely developed [4].

Wild reindeer feeding on the territory of Taimyr has been studied quite well [5-7]. The deer's ration is based on rags and green grassy feeds. Even in the snowy season, they account for 42.8 to 68.5%. In the summer, vascular plants occupy almost 90%. The deer of the Taimyr-Evenki population are

characterized by insignificant consumption of lichens. In the average annual diet, they make up 18.2%. Of the group of herbaceous plants, sedge (sedge and cotton grass) occupy the greatest importance in the nutrition of deer. Cereals and herbs are eaten mainly in the snowless period. On mosses, 20 species were eaten, in all seasons it accounts for 3.5-8.0% and they serve as the usual feed component.

Shrubs during the growing season play a significant role in the nutrition of deer. Of these, willows account for more than 90%. Leaves of dwarf birch (*Betula nana*) are eaten in a much smaller volume (up to 8.6%). In general, it should be noted that in the diet of wild reindeer, the population in question, plants prevail that give the largest biomass reserves and ensure its constant renewal and maximum growth.

3. Materials and methods

The material used in this publication includes both previously published data on the number and commercial seizure of reindeer, as well as personal studies of the authors carried out in 2014-2019. In addition, departmental archival materials of the State Hunting Supervision of the Krasnoyarsk Territory are involved in the work.

The study used a set of methodological techniques. For remote monitoring of animals, specialized collars were used with radio beacons of the Argos satellite system manufactured by ES-PAS LLC (Moscow). As part of the work carried out in 2015-2016, 8 Argos radio beacons were used to ensure the determination of Doppler positions, and 2 radio beacons with built-in receivers of GLONASS and GPS navigation systems. In 2017-2019 used 7 Argos beacons without navigation receivers. In the spring of 2015, 7 deer were caught in the area of the Essei Lake (Lake Tise-Suoh, 68 ° 15'42" N; 103 ° 51'32.33" E) and 3 deer - at Lake Talah (68 ° 46'27" N; 103 ° 47'49" E). In the spring of 2017, 4 deer were caught near Lake Essei (Lake Khaptarakh, 68 ° 40'29" N; 103 ° 9'38" E), 2 deer - at the lake Dupkun (68 ° 7'50" N; 99 ° 9'30" E) and one deer at the Heta river crossing near New village (71 ° 44'51" N; 101 ° 11'13" E).

Along with traditional methods, such as tracking, in the spring of 2019, special techniques were used: tracking with registration of animal movement rates [8, 9] and their visual stationary tracking. The techniques are covered in some detail in the literature, below are only some clarifications of their application. In case of visual stationary registration of migratory deer, the distinction into the main age and sex groups was carried out according to external signs using binoculars. Widely used photography and video. Accounting was carried out around the clock throughout the study period.

Route tracking along the tracks of migratory animals was first described in the Russian literature by G. G. Shubin and Yu. P. Yazan [10]. Routes were laid across the path of migratory animals. When counting, we made several (from 3 to 5) control intersections of the migration route after 1-3 km, which made it possible to track the speed of animals, varying the width of the migration front.

4. Results and discussion

The issue of abundance and its dynamics is currently a key one for the protection and rational use of deer of the Taimyr-Evenki population. In 2017, employees of the Taimyr Nature Reserves conducted summer aerial surveys in the main habitats of the species. As a result, the number of wild reindeer was estimated at 384.4 thousand individuals in six examined regions [11]. At the same time, the area covered by the accounts made up 32% of the total area of the peninsula and about 50% of the summer habitats of the species. As a result of the incomplete coverage of the territory with counts, as the authors themselves note, the underestimation could be from 5 to 15% of the total number of deer recorded, i.e. the number of deer, according to the minimum estimate, was about 404-442 thousand species.

In 2019, L. A. Kolpashchikov and M. G. Bondar noted in their reports that the deer population of the Taimyr-Evenki population was reduced to 250-280 thousand individuals. Based on the data from three reports and materials of previously published works [12, 13], we combined the dynamics of the number and production of deer in the population in question and made the graphs (figure 1). Some hunting indicators differ from official sources, but we deliberately illustrate exactly the data on the

basis of which employees of the Taimyr Nature Reserves made a conclusion about the “catastrophic decline in numbers” and its causes.

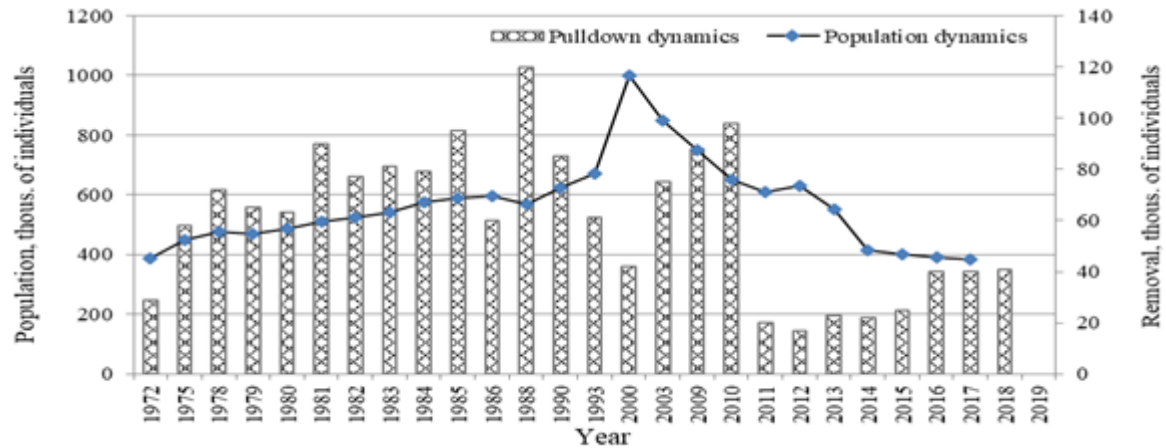


Figure 1. Population dynamics and commercial hunting of wild reindeer Taimyr-Evenk population.

Based on the data, we will consider a model of the dynamics of the population of wild reindeer. The technical problem in the analysis is that in the initial time series of data on the number and volume of production, there are a large number of years for which there are no accounting results. To “repair” (reproduce) the data, one can interpolate the indicators in the “empty” years. Then one can design the model. It should be noted that deer are a fairly long-lived species and the population size in the current year will depend on the population size in the previous several years. In addition, the number of deer will depend on the level of seizure in the population as a result of exposure to predators or hunting.

Moreover, it is unclear what, in this case, the sign of the coefficient can be for a variable characterizing the removal of individuals. It can be negative when withdrawal decreases the population, or even positive when sick or weakened individuals are withdrawn and the food supply for the remaining individuals in the population expands [14].

To build the model, the following procedure was used:

- to reduce the variance of time data, a transition was made to the logarithmic scale for the dynamics of deer $N \rightarrow \ln N$, for the dynamics of hunting $Y \rightarrow \ln Y$
- to remove high-frequency fluctuations in the data, most often associated with accounting errors, data were smoothed using the Hannah filter [15]:

For the row of deer dynamics:

$$L(i) = 0.24 \ln N(i-1) + 0.52 \ln N(i) + 0.24 \ln N(i+1) \quad (1)$$

For hunting row:

$$Z(i) = 0.24 \ln Y(i-1) + 0.52 \ln Y(i) + 0.24 \ln Y(i+1) \quad (2)$$

To assess the level of seizure of individuals in the population, an indicator of relative seizure of individuals in the year was introduced $W(i) = Z(i)/L(i)$.

To assess the impact of data from previous years on current indicators of the population size and seizure rate, we calculated the lag of the population dynamics by the partial autocorrelation function (PACF) [16]. Figure 2 shows the calculated PACF for the “repaired” time series of deer numbers.

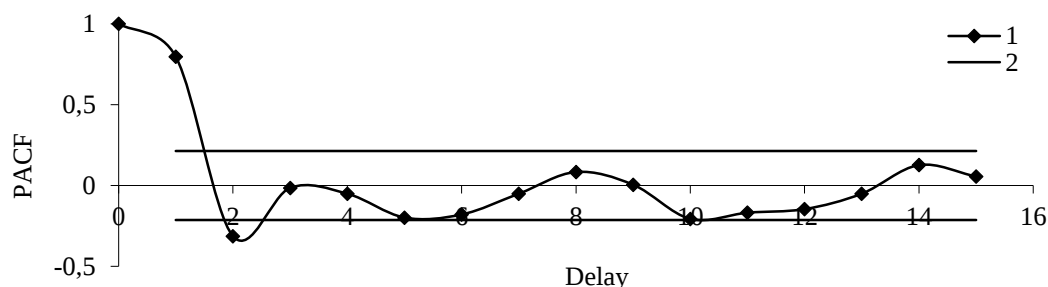


Figure 2. Partial autocorrelation function (PACF) of deer's population dynamics time series: 1 – PACF, 2 - confidence intervals.

As it can be seen, the first two members of the PACF are significant, that is, the current density depends on the densities of the previous two years. Then autoregressive distributed lag (ADL) - model [17] can be written as follows:

$$L(i) = a_0 + a_1L(i-1) + a_2L(i-2) + b \ln W(i-1) \quad (3)$$

According to the accounting data, it is possible to determine the values of the components of the time series $\{L(i)\}$ and $\{Z(i)\}$ and calculate the values of the series $\{W(i)\}$. Then in equation (1) the coefficients a_0 , a_1 , a_2 , b will become unknown. They can be found by solving equation (1) with respect to these coefficients, which in this case can be considered as a linear regression equation. The solution gives the following values of the coefficients and their errors, given in table 1.

Table 1. Calculations of the characteristics of the ADL-model of the number of deer in the Taimyr (Taimyr-Evenki) population.

Variable	Coefficient value	Std.Err.	Student's test t(33)	p-level
Fixed term a_0	0.319	0.245	1.301	0.202
$W(i-1)$	0.072	0.021	3.493	0.001
$L(i-2)$	-0.575	0.117	-4.910	0.000
$L(i-1)$	1.550	0.110	14.126	0.000
R^2	0.960			
F-ratio test	266.300			

The value of the determination coefficient is $R^2 = 0.96$, that is, the model explains almost the entire low-frequency dispersion of the deer population numbers (high-frequency fluctuations were smoothed out by the Hann filter). All values of the model coefficients are significant by the t-criterion. As it follows from the table 2, the current number of deer depends on the number of deer during the previous two years (this is the so-called Yule model [18]) and on the proportion of individuals taken out of the population per year (i-1). A positive feedback is characteristic of the relationship between the population numbers in years i and (i-1): the larger the number per year (i-1), the greater the number per year i . A negative feedback is characteristic of the relationship between the population numbers in years i and (i-2): the larger the number per year (i-2), the smaller the number per year i . The population size in year i and the share of seizures per year (i-1) are also associated with positive feedback: the higher the share of seizures per year (i-1), the greater the population size in year i .

Figure 3 shows the dynamics of the number of “repaired” accounting data and model data.

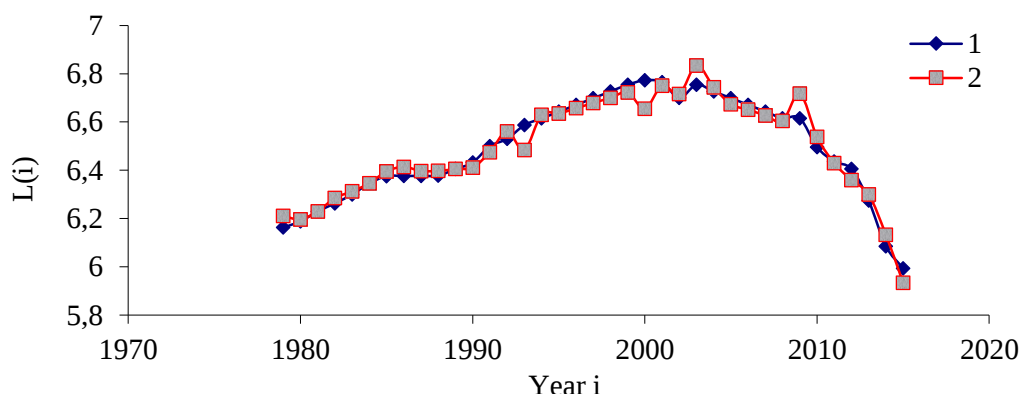


Figure 3. The population dynamics of deer for natural (1) and model (2) data.

The cross-correlation function of the data and the model (figure 4) has a maximum very close to 1 at a shift of 0, i.e., the maxima and minima of the data series and model series coincide.

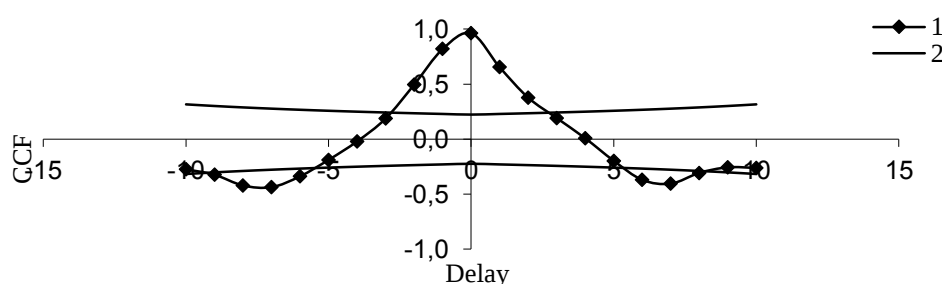


Figure 4. The cross-correlation function (CCF) for natural (1) and model (2) data: 1 – CCF, 2 – confidence intervals.

As you know, the spectrum of the Yule model is characterized by the presence of a maximum, that is, there must be periodic endogenous fluctuations in the number of the simulated population. Figure 5 shows the spectrum of a number of “repaired” deer numbers.

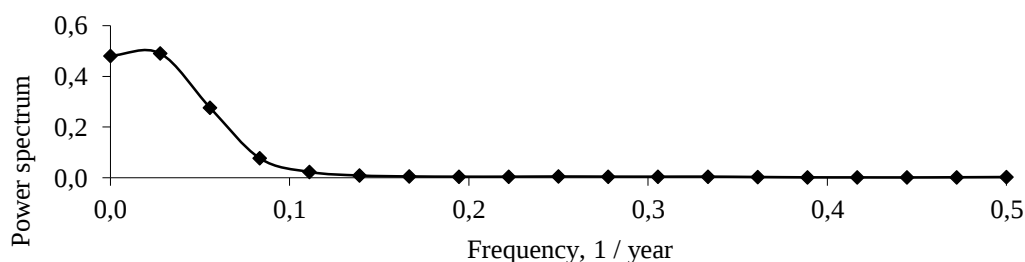


Figure 5. The spectrum of time series for deer's population in Yrs. 197.

The maximum spectral power is observed at a frequency of 0.028 1/year, that is, the period of fluctuations in the deer population is 36 years. Indeed, deer population minimums were observed in 1972 and 2015, that is, after 43 years, which agrees quite well with the calculated data.

Let us consider some environmental features to one degree or another related or affecting the considered dynamics of the number of wild reindeer of the Taimyr-Evenki population. In particular, the reduction in numbers is currently accompanied by an increase in the barrenness of females, a decrease in the proportion of yearlings, and a change in the spatiotemporal distribution of animals [1,

12]. The main factors that violate the natural state of the spatial structure of the population and lead to a decrease in its number, according to these researchers, are large-scale poaching and wolf predation against the background of low productivity of the population. Illegal prey of animals is certainly a negative phenomenon, however, against the background of this, the authors point to over-fishing, which is also associated with a significant excess of the limit and the standard for allowable seizures.

However, the first thing that should be explained is how the number of deer in 2 years decreased from 442 to 280 thousand species with a significant increase in protection in these years, including regular duty on winter roads (ways of exporting products) and in places of crossing deer across large rivers. The second reason why in the 60-70s of the last century the installed Taimyr deer capacity was 330-350 thousand species and the question was raised about the increased exploitation of wild reindeer resources in order to prevent depletion of the region's pastures [19]. Moreover, despite the increase in fishing load (up to 80-100 thousand species), it was not possible to stabilize the population at the indicated level. By 2000, due to the collapse of the state procurement system and a significant decrease in production volumes, a "population explosion" took place, the number of deer reached a record high of 1 million species (figure 1).

Today, some researchers probably feel that due to the increase in temperature and the "greening" of the tundra, the growth of plant biomass, the trophic capacity of Taimyr's deer pastures increases. Otherwise, how can one explain that in the middle of the last century the number of deer of 350 thousand was considered the norm, and today there is talk of environmental tragedy and the inevitability of losing the commercial value of reindeer, without taking urgent measures to limit the allowable withdrawal? We analyzed the results of tagging deer with satellite transmitters and came to a completely unexpected conclusion: their duration in Taimyr today is on average 63 days (table 2), which is three times less than in the 1960s.

Table 2. Characteristics of the stay of wild reindeer in Taimyr based on tagging with collars with satellite transmitters.

№ Collar	Date of marking	Point / Date of entry	Point / Date of leaving	Duration of stay, days	Total length of movement, km
2015 r.					
144921	11.04	71° 56' 51"N 102° 12' 24"E / 11.06	71° 55' 39"N 102° 14' 39"E / 9.08	59	1195.38
144922	11.04	71° 45' 37"N 100° 50' 53"E / 19.06	72° 21' 34"N 103° 45' 31"E / 9.08	51	934.52
112854	12.04	68° 07' 50"N 104° 15' 03"E / 25.04	—	—	—
110724	12.04	71° 05' 27"N 98° 26' 00"E / 6.06	70° 51' 27"N 97° 55' 06"E / 22.08	77	1235.79
147057	12.04	71° 41' 20"N 100° 30' 08"E / 12.6	72° 13' 13"N 102° 00' 07"E / 7.08	56	1321.09
112860	13.04	70° 52' 28"N 97° 55' 06"E / 27.05	71° 39' 31"N 100° 10' 18"E / 9.08	74	1272.0
112862	14.04	71° 35' 23"N 99° 43' 40"E / 17.06	71° 41' 22"N 101° 01' 15"E / 31.07	45	989.8
147056	19.04	71° 55' 29"N 106° 00' 00"E / 12.06	72° 13' 47"N 112° 02' 39"E / 20.08	69	929.12
108969	19.04	71° 31' 26"N 99° 54' 01"E / 6.06	71° 11' 11"N 99° 06' 16"E / 27.08	82	1096.08
112853	19.04	71° 32' 53"N 99° 25' 40"E / 28.05	71° 09' 21"N 99° 11' 16"E / 12.08	76	1503.3
2016 r.					
112853	19.04.15	71° 22' 07"N 102° 03' 06"E / 7.06	—	—	—
112860	13.04.15	71° 28' 34"N	—	—	—

100° 33' 37"E / 6.06					
2017 r.					
170856	5.05	69° 58'40"N	—	—	—
		96° 39' 07"E / 10.06			
170857	5.05	71° 32'53"N	71° 44'18"N	69	1127.12
		100° 07' 57"E / 5.06	100° 55' 08"E / 13.08		
111354	6.05	70° 49'13"N	71° 09'35"N	97	1224.44
		96° 25' 25"E / 23.06	94° 01' 50"E / 28.09		
61928	6.05	71° 37'32"N	71° 41'50"N	66	1222.62
		100° 14' 06"E / 7.06	100° 11' 22"E / 12.08		
61745	30.05	71° 39'50"N	71° 49'16"N	53	1207.48
		100° 18' 23"E / 24.06	101° 08' 41"E / 16.08		
170858	31.05	71° 37'45"N	71° 50'23"N	69	1059.26
		99° 53' 08"E / 8.06	101° 52' 45"E / 16.08		
111353	25.06	71° 45'18"N	71° 45'27"N	54	970.31
		101° 11' 39"E / 25.06	101° 28' 45"E / 18.08		
2018 r.					
170857	5.05.17	71° 33'2437"N	71° 48'26"N	52	680.34
		100° 18' 36"E / 7.06	101° 38' 48"E / 29.07		
61928	6.05.17	71° 33'39"N	71° 41'25"N	54	754.77
		99° 53' 23"E / 8.06	99° 52' 58"E / 1.08		
61745	30.05.17	71° 31'04"N	72° 00'20"N	57	746.44
		100° 02' 46"E / 9.06	100° 52' 22"E / 5.08		
170858	31.05.17	71° 30'20"N	71° 40'41"N	49	643.44
		100° 19' 06"E / 9.06	101° 49' 28"E / 28.07		
111353	25.06.17	71° 39'24"N	72° 07'20"N	49	641.06
		100° 54' 05"E / 17.06	101° 39' 56"E / 5.08		
Options		Me	Me	m±se	m±se
		7.06	12.08	62.9±3.1	1042.2±56.59

At that time, deer reached the northern regions of Putoran and the lowlands of Taimyr in mid-March, and mass migration took place from April to early May [20]. A few years later, A. B. Kretschmar [21] noted its delay by almost a month. Currently, deer cross the Heta-Khatanga river in the first, and sometimes in the second decks of June (Me = 7.06). The vast majority of animals had previously left the Taimyr Lowland only by October [6], and the arrival of deer mass in early October 1974 was perceived by the reindeer herders of the Khatanga region as a natural disaster, as a result of which, they lost 6 thousand domestic deer [19].

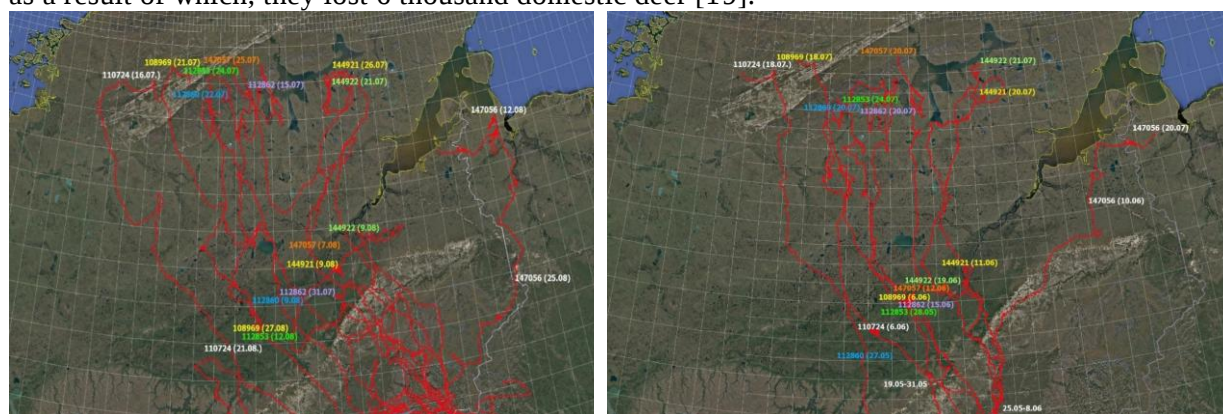


Figure 6. Spatial-temporal distribution of wild reindeer in Taimyr in 2015 according to the results of tagging with collars with satellite transmitters: numbers - numbers of collars, numbers in brackets or numbers with a dot - the date the animal was in this geographical location.

In 2015-2018 deer, barely reaching the northern end of the Byrranga Mountains, turned and walked in the opposite direction, crossing the Hetu-Khatanga in the middle, or even in early August, leaving the plain pastures of Taimyr (table 2, figure 6). A reduction in the length of the course of the deer is observed even in a short time interval. So, in 2015, it amounted to $1,164.1 \pm 68.5$ km in Taimyr, and in 2018 - 693.2 ± 27.4 km at $P < 0.001$. What makes the deer leave the traditional places of calving and summer feeding in such a short time today?

Changes in Arctic communities under the influence of climate are shown primarily for the North American sector of the Arctic [22]. According to some of our experts, there has been no apparent change in the deer's food base, and the stocks of cereals and sedges annually "are far from exhausted" [1, 11, 12]. However, animal behavior serves as a more subtle indicator of environmental changes than our visual perception. According to A. A. Tishkov et al. [23, 24], the cascading, cumulative and synergetic effects of climate change and partly anthropogenic transformation, expressed in the trends in the productivity of Arctic ecosystems, in turn, influence the formation of other biota trends.

In the context of the problem under discussion, a number of questions involuntarily arise. Is not a reduction in numbers, an increase in the share of barrenness of females, and a decrease in the proportion of yearlings a response of the population to the capacity of Taimyr lands? Maybe the population is striving for the optimal number, which was calculated by the staff of the Research Institute of Agricultural Sciences of the Far North in the 60-70s of the twentieth century? And will not a significant reduction in the volume of deer production lead to the completely opposite effect?

5. Conclusion

Thus, the decline in numbers in the tenths of the 21st century can be explained by the natural fluctuations in the population size and it is reasonable to assume that in the absence of new dynamics factors, the number of deer will recover in 10-15 years. Meanwhile, it should be noted that with an increase in the pressure of predators (wolves, hunting), the sign of the coefficient b for the variable $\ln W$ (the logarithm of the share of seized individuals in the population) can change from positive (now $b = 0.072$) to negative, and then with an increase in seizure will start to die out. Monitoring and control of permissible seizures, of course, are the most important components of maintaining the Taimyr-Evenki wild reindeer population at the commercial level.

However, the questions of what is considered the optimal or initial number of the population in question and what is the modern trophic capacity of Taimyr are no less relevant in the changing conditions of the Arctic.

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