Effect of reindeer overgrazing on vegetation and animals of tundra ecosystems of the Yamal peninsula

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Abstract

Currently, 380 000 domestic reindeers are grazed on 106 000 km^2 of the Yamal peninsula. This unique situation was analyzed from a view of an ecosystem role of indigenous people. Attention was paied to two key points: the impact of overgrazing on (1) vegetation and (2) vertebrates. The results of our 30-years investigations were compared with the published vegetation data from the 1930-ies. In our paper, it is demonstrated, that overgrazing has resulted in a substantial transformation of vegetation, mostly in lichen tundra. Recent situation is close to total extinction of lichen pastures on the Yamal peninsula. Due to overgrazing, total availability of grasses and shrubs have also decreased, in grasses by 1.5-2.0 times, low shrubs - almost 8 times, tall shrubs – 2.0 times. The degradation of vegetation leads to desertification of the peninsula. The area of sandy spots with no vegetation is on average about 5.5% of the peninsula land, however, it could reach up to 19% locally. Overgrazing affected the animal populations too. Since 1990, the peaks of lemmings have never reached former high values and become locally-limited and patchy. This has led to a decrease in the number of predators. The number of other tundra birds decreased as well. The decrease reached almost 2 times lower numbers in geese, 3 times in hygrophillous waders, 5.5 times in Lapland bunting, and 2 times in long-tailed Duck and Willow grouse on watershed. The Nenets themselves can not control reindeer population because of rigid social and psychological attitudes based on their traditions. The main aim of the Nenets reindeer-farming is not to create marketable products for a profit, but increasing the reindeer number of itself. A situation has formed, that, on the one hand, the Nenets are not economically dependent upon the society, and on the other hand, the society contributes to preservation of their traditional farming. The Nenets reindeer-farming, thus become an important factor contributing to rapid transformation of tundra ecosystem.

Key words: indigenous people, anthropogenous impact, vegetation, animals transfer-mation of ecosystem, Nenets

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Introduction

Indigenous peoples of the North are considered an integral part of natural ecosystems because their lives are based on the use of natural resources. Nenets are one of them. They are mainly the nation of reindeer-breeders, which usually graze their reindeer by large herds, driving them from place to place across long distances.

Currently, in the Yamal-Nenets Autonomous Area, over 700 thousand head of domestic reindeer are grazed, that is about 40% of the world total number and about 53% of the Russian number. Of these, 380 thousands (21% of the world number) are concentrated in the Yamal peninsula on pasture area of 106 000 km^2, that represents high number of individuals per unit area (3.6 ind. km^{-2}). Much smaler value is reached for reindeer in Norway and Sweden (1.6 km^{-2}), and Finland (1.8 km^{-2}) (Jernsletten et Klokov 2002). As a result, on the Yamal peninsula, there is extremely high grazing impact found not for a limited area, but a vast territory all through peninsula (*i.e.* 106 000 km^{-2} land). Such huge area of overgrazing represents quite unique situation to tundra biome.

In our study, we analyzed this situation and considered the impact of overgrazing of domestic reindeer on vegetation and animals of the Yamal peninsula. We paid attention only to the main factors related to overgrazing-induced changes in vegetation and animal populations that, though simplifying the overall picture, may contribute to understanding of tundra ecosystem functioning under too intensive grazing.

Material and Methods

Our field investigations on the Yamal were done within the period of 1980-2009. They were organized as a combination of works performed on stationary plots and the observations made during field trips (hiking, boating, cross-country). Totally, 70 plots were explored (total area of 1750 km^2) – *see* Fig. 1.

Our research of vegetation was done on landscape profiles by describing experimental plots of 10×10 m area (total about 2000). Species composition, projecttive cover, height of grass, thickness of moss and lichen mats were evaluated. Aboveground biomass was determined by harvests on the subplots of 25x25 cm made on at leats 5 replicates at each experimental plot. Level of abundance of rodents was determined in points on basis of own and published (Shtro 2003, Shtro et Sosin 2004). These studies brought complex data: trapping, with a dog catching, visual counting on the excursions. The abundance was presented on a four-point logarithmic scale (Pesenko 1982): 0 – depression of number, up to 5 ind. ha^{-1}; 1 – low number, 6-20 ind. ha^{-1}; 2 – middle number, 21-89 ind. ha^{-1}; 3 – high number (peak), up to 90-400 ind. ha^{-1}.

Birds were counted by the method of mapping on large plots with rechecking (plots for passerines and waders 1-15, other species - up to 50 km^2, in total 1750 km^2) and during the observations on the travels. Our investigations were compared with the the results published for the vegetation of the 1930-ies (Andreev 1934).

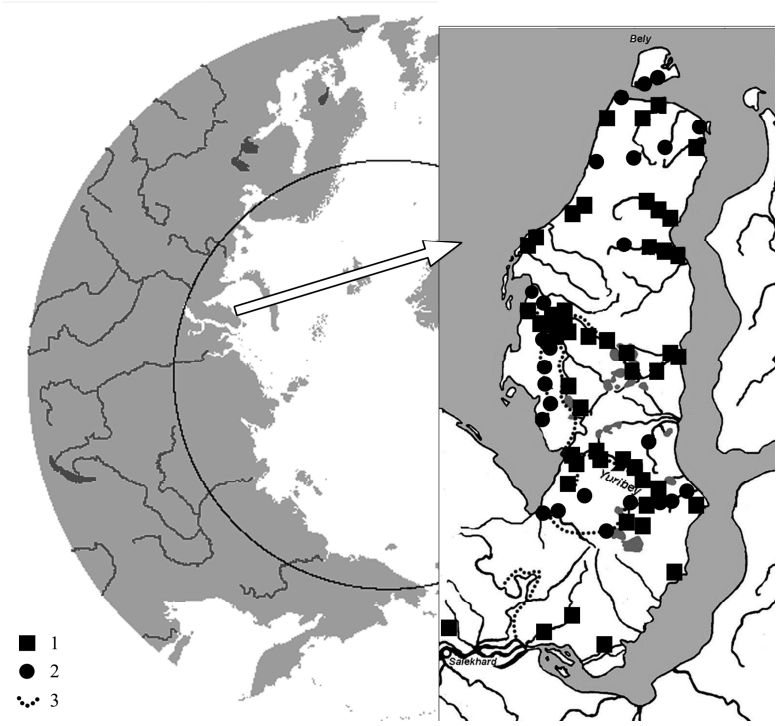

Fig. 1. Map of the research plots at the Yamal peninsula: 1 - stationary plots with 2 and more years researches, 2 - stationary plots with one-year researches, 3 - the main research routes.

Results and Discussion

Effect of overgrazing on the vegetation

At the areas having low potential recovery of tundra vegetation, the overgrazing has resulted in a substantial transformation of vegetation. Lichen tundra was affected worst. Compared with the 1930-ies, the area of lichen tundra decreased 3.5-4 times (Fig. 2), mass of lichens – by 25-30 times, the dominant height – by 2-9 times (Table 1). Also species composition and community structure of lichen tundra changed (Table 2). Instead of forage species (*Cladina*) the inedible lichens (*Sphaerophorus, Alectoria, Flavo-cetraria, Thamnolia* etc., foliose and crus-tose lichen forms) have expanded. Almost everywhere, polygonal lichen tundra and lichen knolls of bogs have a lifeless gray color, owing to cryptogamic groups in combination with crustose and foliose lichens (Fig. 3). According to the calculations, the recovery of overgrazed lichen pastures will require at least 80 years from the complete stopping of grazing (Morozova et Ektova 2012), which is not real. Thus, if the recent rate of grazing continues at the Yamal peninsula, we may assume total extinction of lichen pastures on the peninsula in future.

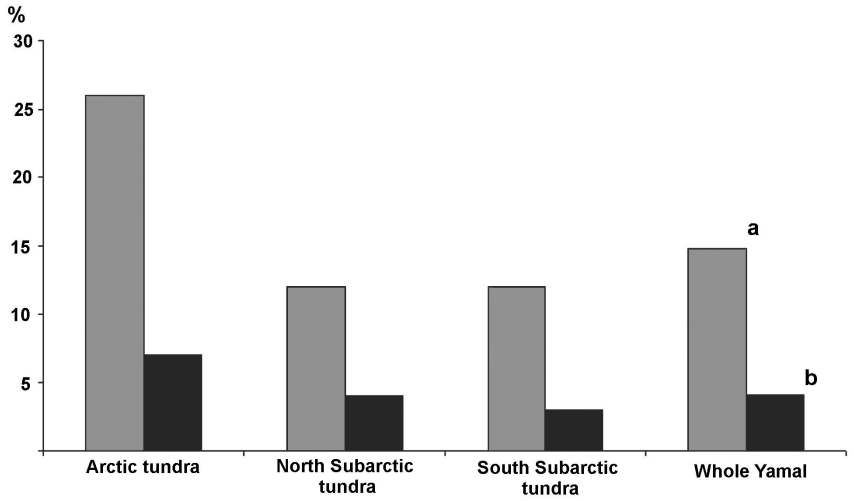

Fig. 2. Change of area of lichen tundra on the Yamal peninsula (% from covered by vegetation land): a – 1930-s (Andreev 1934), b – at present time (data of authors).

Species	Parameters	1930-ies	At present time	
			S. t.	N. t.
Cladina stellaris	Mass (t ha^{-1})	3	0	0
	Height, cm	5-7	0.5-1.0	0.5-1.0
Cladina arbuscula	Mass (t ha^{-1}) ±SD	2	0.15±0.04	0.1±0.06
	Height, cm ±SD	3-4	1.8±0.4	1.5±0.4
Cladina rangiferina	Mass (t ha^{-1}) ±SD	2	0.09±0.02	0.17±0.03
	Height, cm ±SD	4-5	2.1±0.4	1.8±0.6

Table 1. Average air-dry mass and dominant height of *Cladina* lichens in the 1930-ies (lichen tundra on whole the Yamal, by Andreew, 1934) and at present time (in dwarf shrub, moss-dwarf shrub - former lichen tundra in S.t. – southern subarctic tundra, own data 2004-2005; N.t. – northern tundra, own data 2005-2006)

Total phytomass of grasses and shrubs have also decreased substantially since the 1930-ies. It was reduced by 1.5-2.0 times for grasses, almost 8 times for low willows and 2 times for tall willows - (Table 3). In many locations, the tundra herbaceous vegetation is often eaten up to 90%. After such strong grazing, this tundra looks "shaven" as freshly-mown lawn (Fig. 4).

Because of friable and sandy bedrocks, the degradation of vegetation led to formation of the sandy outcrops on high places of relief. The sandy outcrops begins with the formation of reindeer trails (Fig. 5). Upon reaching a certain critical size, diameter of the range of 500-1000 m, an overgrowing of the outcrops becomes impossible because of wind erosion (Kulyugina 2004). It becomes a permanent source of sand, dispersing on the neighboring territory (Fig. 6). Thus, desertification of the peninsula is going (Fig. 7). Recently, the area of sand is on average about 5.5% of the land, in the Middle Yamal locally to 19% (Fig. 8). In result, already there is irrevocably lost about 5830 km^2 of pasture area.

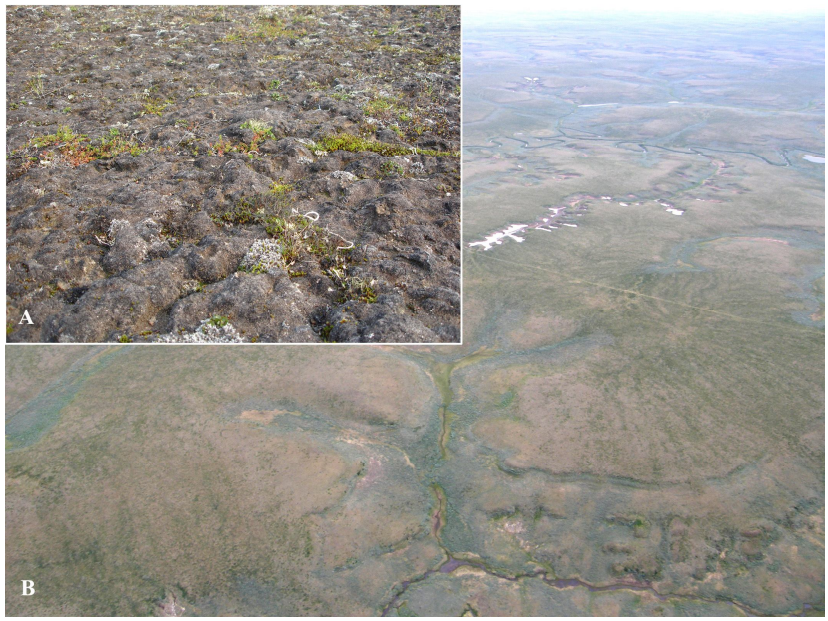

Fig. 3. Cryptogamic crusts on the polygonal tundra of Yamal peninsula: a) view from the ground, b) top view.

Fig. 4. Tundra after intensive reindeer grazing (Western Yamal peninsula, Northern Subarctic Tundra).

Fig. 5. Reindeer trails on the Middle Yamal peninsula.

Fig. 6. Sandy outcrop on the Middle Yamal peninsula. The sand depth, which was excavated by wind, is in man's height 1.96 m.

Species	Parameters	1930-ies	At present time	
			S. t.	N. t.
Cladina stellaris	Occurrence (%) ±SD	≈ 90	0.5±0.7	0.3±0.5
	Cover (%) ±SD	50	0	0
Cladina arbuscula	Occurrence (%) ±SD	≈ 90	49.4±11.2	73.7±12.9
	Cover (%) ±SD	20-40	7.5±3.1	3.4±1.9
Cladina rangiferina	Occurrence (%) ±SD	≈ 80	63.0±12.4	58.2±15.2
	Cover (%) ±SD	20-30	6.9±2.4	1.5±0.4

Table 2. Average occurrence and projective cover of *Cladina* lichens in the 1930-ies (lichen tundra on whole the Yamal peninsula, by Andreew, 1934) and at present time (in dwarf shrub, moss-dwarf shrub - former lichen tundra in S.t. – southern subarctic tundra, own data 2004-2005; N.t. – northern tundra, own data 2005-2006).

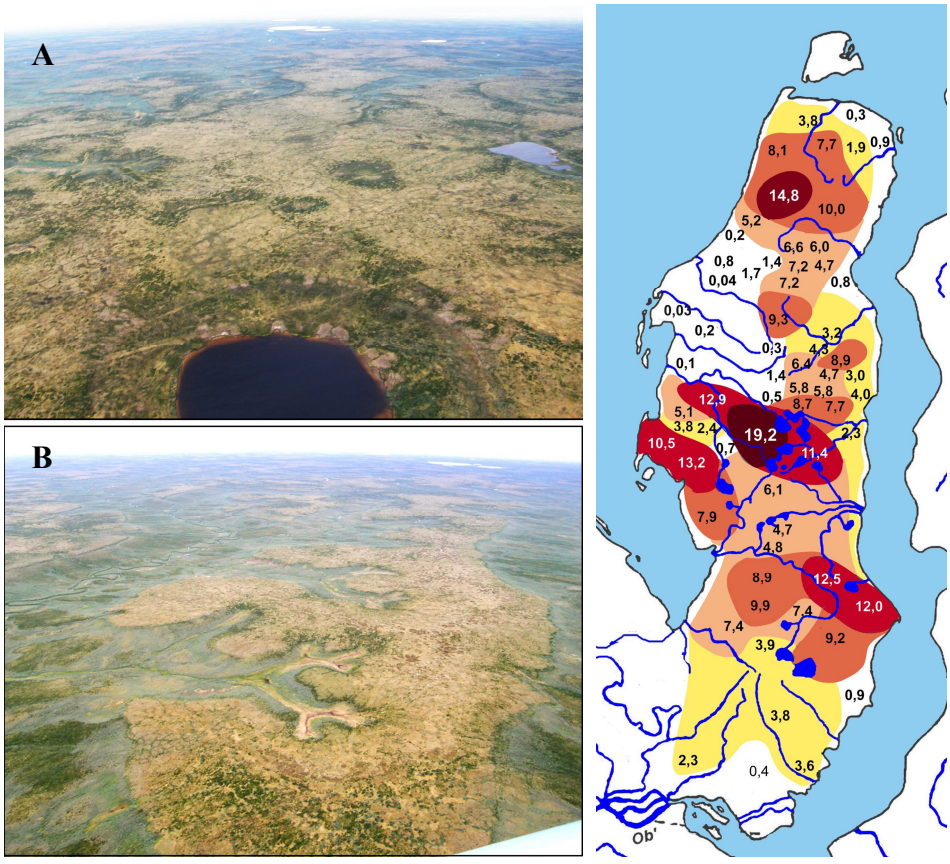

Fig. 7. Top view on sandy outcrops on the Western Yamal peninsula (left- A, B).

Fig. 8. Map sandy outcrops on the Yamal peninsula (right), formed under the influence of grazing reindeer (% of area). (By analysis of images from Google Earth Program; river sand bars are not considered).

Effect of overgrazing on the animals

It is well established that due to their reproduction cycles, lemmings have exceptional significance in biocenosis of tundra. The peaks of their number usually occur at the intervals of 3-4 years. Before 1990, there was just such a situation on the Yamal peninsula (Fig. 9). At the peak, the lemming number was 200-400 ind. ha^{-1} (Danilov 1977, Balakhonov et al. 1997). The peak population densities covered vast area of one or more subzones. After 1990, the peak densities never reached former high values, they approached only twice the middle level, although their cycles remained. The peaks became local and patchy. This disturbance has coincided with a sharp increase in reindeer number and the beginning of irregular grazing (*see* below). An argument that lower peaks of population densities and the patchiness are caused by overgrazing may be supported by the evidence from localities where no domestic reindeer herds are present. At the Belyy Island (73° 29.0 N, 71° 30.0 E, area of 1 810 km^{-2}) located in the Kara sea north of the the Yamal peninsula, the typical peaks of lemming's number still occur (Dmitriev et Emelchenko 2005).

The reduction of the lemming number has affected the following predators. Specialized predators (Snowy Owl-*Nyctea scandiaca*, and Pomarine-Skua *Stercorarius pomarinus*) have almost ceased to nest. Pomarine Skua nested only rarely and patchy (Paskhalny et Golovatin 2010). Single cases of Snow Owl nesting were recorded in 1991 only (Golovatin et Paskhalny 2005). Less specialized predators, such as Rough-legged Buzzard (*Buteo lagopus*) and Long-tailed Skua (*Stercorarius longicaudus*), are nesting there, when there is a high abundance of voles, but with much less density than in the "lemming" years (Table 4).

	1930-ies	At present time
Grass in grass- and dwarf shrub-moss tundra	1.2	0.72±0.14
Grass in grass-moss bogs and boggy tundra	2.7-4.0	1.66±0.71
Leafs of willows in short shrubs (0.3-0.5 m)	4.5	0.57±0.16
Leafs of willows in tall shrubs (1-2 m)	2.2	1.13±0.50

Table 3. Grass and shrubs phytomass (air-dry mass, t ha^{-1}) on the Yamal peninsula in the 1930-ies (by data of Andreev 1934) and at present time (average ±SD by own data, 1995-1997).

	Peaks of lemmings	Peaks of voles	t-test, (f)
Rough-legged Buzzard	5.7±2.3	2.4±1.2	4.61 (24)
Long-tailed Skua	2.2±1.2	0.7±0.5	4.41 (21)

Table 4. Average nesting density (pairs/10 km^2 ± SD) of Rough-legged Buzzard and Long-tailed Skua at years of peaks of lemmings and voles on the Yamal peninsula.

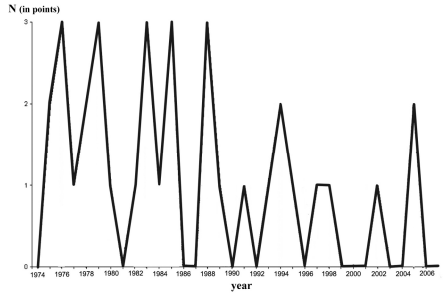

Fig. 9 (left). Dynamic of lemming number on the Yamal peninsula (in points). 0 - no population, 1 - low number, 2 - middle population desity, 3 - high (peak) population density.

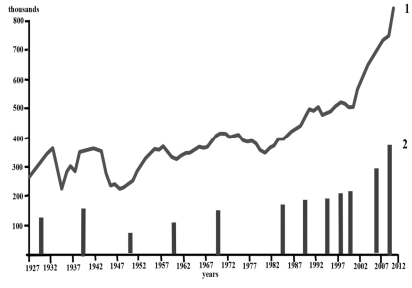

Fig. 10 (right). Dynamic of domestic reindeer number in Yamal-Nenets Autonomous area (1) and Yamal region (2).

Species	watershed			flood plain		
	< 1990	> 1990	t	< 1990	> 1990	t
Arctic Loon (*Gavia arctica*)	0.26±0.16	0.32±0.11	0.60	0.90±0.62	0.75±0.16	0.59
Bewick's Swan (*Cygnus bewickii*)	0.01±0.01	0.08±0,03	3.54**	0.02±0.02	4.58±0.57	15.9***
All geese	0.39±0.14	0.31±0.28	0.58	1.68±0.61	0.95±0.30	2.40*
Pintail (*Anas acuta*)	0.18±0.16	0.04±0,02	1.55	3.00±1.42	2.70±0,86	0.40
Long-tailed duck (*Clangula hyemalis*)	1.67±0.26	0.83±0,56	3.00*	6.40±3,27	5.67±0,35	0.50
Scaup (*Aythya marila*)	0.33±0.29	0.31±0,19	0.13	0.76±0.43	1.17±0.40	1.57
Willow Grouse (*Lagopus lagopus*)	28.38±15.32	10.63±1.24	2.58*	28.64±21,92	35.72±11.73	0.64
Plovers (*Pluvialis sp.*)	1.10±0.45	1.10±0,12	0.01	0.37±0.40	0.18±0.09	1.05
Ringed Plover (*Charadrius hiaticula*)	0.51±0.32	1.22±0.03	5.02**	0.24±0.54	0.25±0.19	0.05
Hygrophilous waders	30.00±8.29	11.38±0,26	5.02**	85.36±19.15	28.52±4.28	6.48***
Lapland bunting (*Calcarius lapponicus*)	40.06±24.80	7.45±3.50	3.68**	78.75±25.52	33.06±18.06	4.13**

Table 5. Average density of birds (ind. km^{-2} ± SD) at basin of the Yuribey river (the Middle Yamal) before (<) and after (>) 1990 (significant difference: * $p \le 0.05$, ** $p \le 0.01$, *** $p \le 0.001$, $f = 7$).

High and rapid increase in the grazing after 1990 affected other tundra birds too. This may be illustrated by the example of the Yuribey river basin on the Middle Yamal peninsula, where our sampling area has the greatest size (in different years, 6-13 plots overall size 120-500 km^2) and longest time of observation (1982-1986, 1991, 1997, 2004-2005). This allowed us to do a representative comparison for different years (Table 5).

Due to dramatic decrease in the area of vegetation cover and number of birds, the inhabitants of watersheds suffered to the utmost. This was understandable, since the vegetation of watershed was reduced due to overgrazing much stronger than at more humid habitats of flood plains (Morozova et Magomedova 2006). The decrease of number of typical tundra birds, such as geese, long-tailed duck, hygrophilous waders, willow grouse, Lapland bunting, is ex-

tremely high (*see* Table 5). Goose broods and molting birds gather in the floodplain off a wide adjacent area. Therefore, the reduction of their numbers indicates the general decrease of geese. The decrease of the total number of the Lapland bunting has affected its situation near a southern border of its area. Thus, former nesting density of 2.6-13.6 pairs km^{-2} reported by Danilov et al. (1984) for the area near Labitnangi town (66° 46' N) in 1970-ies is almost vanished now. Recent nesting density is below 0.1 pairs km^{-2}.

Loons do not suffer from overgrazing, because they are bound closely to lakes by their way of life. An increasing number of of the Bewick's Swan does not relate to overgrazing and is, obviously, a part of a long-term fluctuation that typical for this species (Beekman 1997).

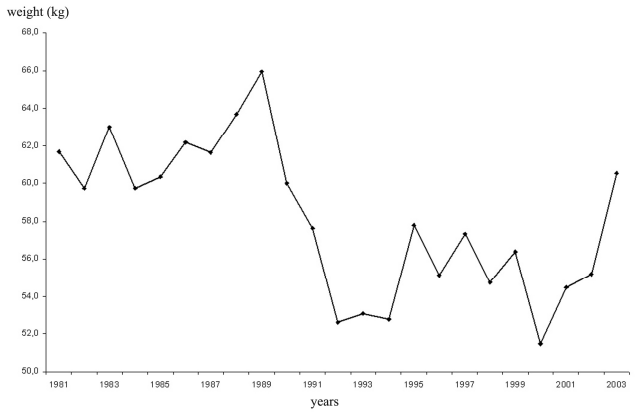

Fig. 11. Change in the average pre-slaughter weight reindeer grazed on the Yamal peninsula in the period 1981-2003 (according to the state inspection of procurement and quality of agricultural production Yamal-Nenets authonomous region).

Concluding Remarks

In the Yamal peninsula, the reindeer husbandry became a strong impact factor at the turn of 19th-20th centuries, when a grazing by large herds appeared there. Until the middle of 20th century, there had been natural mechanisms restraining a growth of the reindeer number. When excessive growth of the reindeer number started, various epizooties happened from time to time. They resulted in mass loss of reindeer. After the development of veterinary disease prevention in 1960-ies, this natural factor ceased to work. That had led to a steady growth in the reindeer number (Fig. 10). Dramatic and uncontrolled growth of the reindeer began at the end of the 1990-ies, when a lot of the reindeer passed into private ownership. Now, the ratio between reindeer from farms, private and commune ownership is 1:3.6:1.3 (Vasil'kova et al. 2011). There are often composite individual-collective herds of 5-7 and even 12 thousand heads. Under the current system of grazing, they run on the same pastures twice per season, and at the same time in the same places, private reindeers graze. Moreover, private owners are trying to go ahead of herds of large agricultural farms. Thus, summer grazing has covered the whole peninsula within last two decades.

Comprehensive major changes in vegetation and animal life occurred soon after 1990. The feeding deterioration affected the reindeer themselves: they became smaller. After 1990 their average live weight declined from 62 to 55 kg (Fig. 11). Such degeneration of reindeer, to a certain extent, can act as one of the regulatory mechanisms in conditions of intensive grazing. On the other hand, it is unlikely that a reduction in mean body weight of the reindeer will reduce mechanical stress on the vegetation in the form of trampling.

In the Soviet Union state-controlled economy, mandatory execution of a plan for the delivery of venison was required. This somewhat affected the growth of the reindeer population. In present situation, the Nenets themselves can not control reindeer population. According to their cultural tradition, the reindeer is a criterion of well being. Therefore, the main aim of reindeer husbandry is not to create marketable products for a profit, but increasing the reindeer number of itself. In a figurative expression: "Nenets live in order to breed reindeer but do not breed reindeer in order to live" (Klokov et Khrushchev 2004). Reindeer, as the basis of the Nenets life-support, satisfies almost all their needs, *i.e.* housing, clothing, transporttation, food, thus making their life isolated from economy the rest society. Owing to that, the Nenets had obtained some advantages in the period of economic perturbations after the disintegration of the Soviet Union. Therefore, they perceive any calls to reduce the reindeer population and reduce their numbers in line with the capacity of pastures as an attack on their well-being.

At present time, the Nenets are not economically dependent upon the society. On the other hand, the society contributes to preservation of their traditional farming. In this situation, there are favorable conditions formed for growth of the Nenets population. This, in turn, creates a necessity of further increase of reindeer population. The Nenets life activity is a part of tundra ecosystem and is limited by its capacity. Natural ecosystems can operate within wide limits, but in extreme climatic zones, when over exploitation occurs, the resistance of ecosystem is negatively affected. This results in a disturbance of the integrity of the system and the destruction of existing relations between its elements, including traditional nature management. The Nenets, with their rigid social and psychological attitudes to the increase of reindeer numbers, and the state protection, become an important factor transforming tundra ecosystem in the Yamal peninsula. Overgrazing and destruction of pasture may destroy the natural basis of their traditional life style. If the rate of grazing is not reduced in the future, the extinction of some natural tundra ecosystem components in the Yamal peninsula will be only a matter of time. The secenarios for such ecosystem changes in future are not very predictable. Anyway, it seems that the Yamal peninsula has become an experimental area for investigation of the processes and change tundra ecosystems under the wide-range and cardinal anthropogenous influence.

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