

Comparative Analysis of External Factors Affecting the Population of Wild Reindeer in Taimyr

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Received April 1, 2015; in final form, June 30, 2015

Abstract—This paper surveys external ecological factors that have an impact on the population of wild reindeer on the Taimyr Peninsula. These factors are estimated according to their influence on the abundance of the reindeer population. The key factors are examined with relation to bioenergetics. The population conservation strategy in view of the potential resumption of anthropogenic influence due to further industrial development of Taimyr is proposed.

Keywords: *Rangifer tarandus*, population, Taimyr Peninsula, abundance dynamics, external factors, anthropogenic factors, poaching, energy expenditures

DOI: 10.1134/S1995425516010091

The Taimyr population of wild reindeer (*Rangifer tarandus* L.) is the largest in the world and accounts for a large part of the entire herd of wild reindeer in Eurasia (Danilkin, 1999). According to the data of the Agricultural Research Institute of the Far North and the International Centre for Reindeer Husbandry and

CARMA, at the turn of the century, the number of reindeer reached 1 million individuals (Fig. 1). This provision makes the Taimyr population of wild reindeer the biggest commercial resource in Russia. It is still the basis for existence of the indigenous population of Taimyr consisting of different national cultures

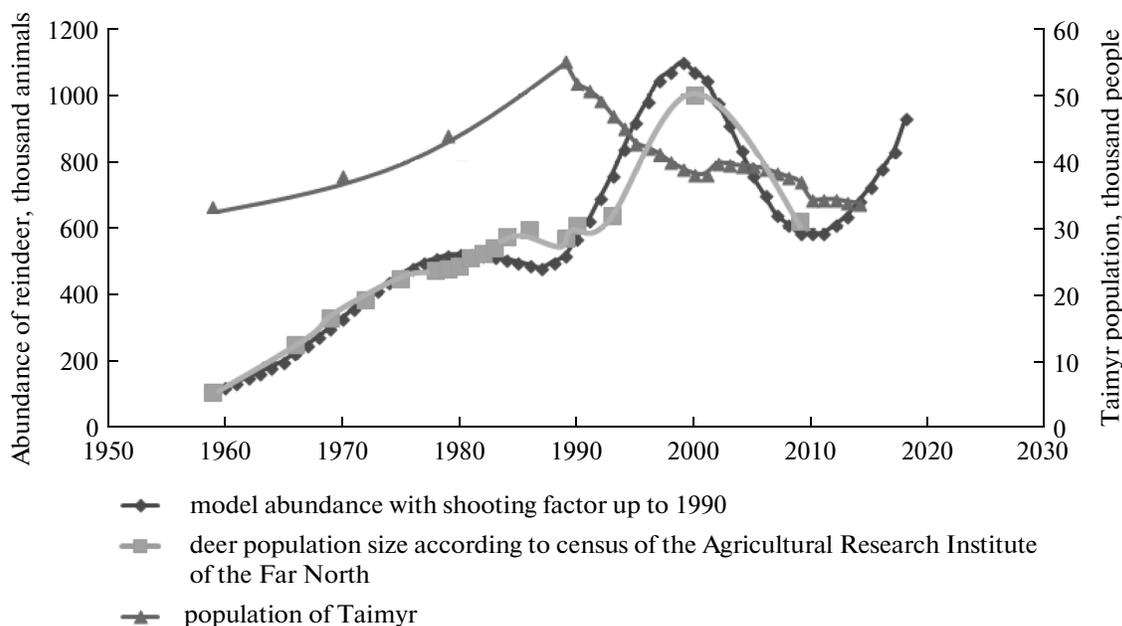


Fig. 1. Model and calculation dynamics of wild reindeer herds in Taimyr and population dynamics of the Taimyr district (according to All-Union and All-Russian censuses and population censuses for municipalities).

to varying degrees dependent on this resource. According to the census data for the period from 1974 to 1996, 1.6 million deer were caught in Taimyr. The currently observed decrease in the number of wild reindeer across the entire circumpolar region is taking place on the Taimyr Peninsula too. Against the background of the fact that many populations of wild reindeer are endangered (those of Altai, Sayan (Bondar and Vinogradov, 2013), Kamchatka, Sakhalin, etc.), the Taimyr population seems to be doing well. However, the large scale of fluctuations in the population dynamics and the potential future growth of the industrial development of the region can present threats posed by factors previously not taken into account.

According to some authors (Baskin, 2009), there are three migratory populations within the region: West Taimyr, Purinskaya, Dudyptinskaya, and Popigaiskaya, along with local small nonmigratory populations. Taking into account not only seasonal but also long-term migrations of reindeer across the peninsula (Geller et al., 1974; Syroechkovskii, 1986; Malygina et al., 2013), and because of insignificant migrations from and to Northwest Yakutia, in the first approximation, we considered the wild reindeer population of the entire Taimyr as a closed system. It is possible that it can be part of a more widespread metapopulation, but this issue requires a more in-depth study.

Earlier, the authors considered the population of wild reindeer in Taimyr as being in a dynamic steady state, to describe the population dynamics of which one could use a retardation logistic growth model (Malygina et al., 2013). This model was constructed and verified on the basis of our own and published data on the sex and age structure, as well as expert estimates. Reasonably chosen values of the parameters in the model and its computer simulation yield a population dynamics of wild reindeer in the form of 23-year damping cycles. Carried out under the given parameters, the experiments reflect the observed and potential cyclic population dynamics of wild reindeer in Taimyr, which speaks in favor of the chosen model and its assumptions. The results of simulations showed that shooting was a determining factor in curbing the growth of the Taimyr population at least until the 1990s (in the socialist era) (Fig. 1). Further unrestrained growth of the number of reindeer and the subsequent recession prove our hypothesis that the population of wild reindeer in Taimyr is a metastable system possessing mechanisms of self-regulation and not requiring artificial regulation of its abundance.

In this paper, we attempt to assess the impact of all external factors on the population in terms of conserving the wild reindeer herd and providing an optimal management strategy.

All the external factors affecting the population can be classified according to the following two criteria: in terms of their source as natural and human factors and in terms of their mechanism as factors of direct regulatory impact and environmentally mediated factors.

Natural Factors

1. Indirect—Environmental Factors (EF)

- 1.1 feed factor—state of pastures;
- 1.2 temperature factor;
- 1.3 snow cover depth in winter;
- 1.4 overflow and passability of rivers in spring and summer.

2. Direct—Predation Factors (PF)

- 2.1 wolves;
- 2.2 midges;
- 2.3 diseases.

Anthropogenic factors

3. Indirect—factors of economic development (DF)

- 3.1 domestic reindeer husbandry;
- 3.2 industrial objects;
- 3.3 disturbance coming from human presence and transport.

4. Direct—Shooting Factors (SF)

- 4.1 legal shooting by local residents;
- 4.2 legal shooting by visiting hunters;
- 4.3 illegal shooting;
- 4.4 market value of velvet antlers and venison.

Assessment of risks to the population from the thus typified external factors makes it possible to project risks on orthogonal factor scales. The direction of the averaged vector of these projections (to which quadrant the averaged vector is pointed) makes it possible to choose the best strategy in relation to the population. This method is used in economic analysis when choosing strategies for company development and is called SPACE analysis. Adjusted for the ecological character of the problem, the strategies we selected here can be summarized as follows:

—a saving strategy designed to ensure that environmental factors are not becoming critical for reindeer populations, that is, “relief” for wild deer in their natural habitat;

—a restrictive strategy aimed at restraining the impact of negative external factors coming from the natural and artificial environment;

—a regulatory strategy designed to fully regulate both the direct and indirect human impact on the population;

—a conservative strategy aimed at protecting the reindeer population from direct extermination and harmonization of environmental conditions for wild reindeer through shifting their behavioral pattern (getting accustomed to the presence of people).

NATURAL FACTORS

Indirect—Environmental Factors (EF)

Feed factor—state of pastures. In contrast to the Yamal Peninsula, which is dominated by sandy-alluvial rocks, Taimyr vegetation is less vulnerable. In Yamal, the domestic reindeer herd significantly exceeded the reindeer capacity of the Yamal tundra

(Kryazhimskii et al., 2011), and the area of once abundant lichen pastures decreased by 3.5–4 times, about 13% of them turned into sandy outcrops, and also the total supply of green fodder decreased by 1.5–2 times (Morozova and Malygina, 2013). Our research (Kryazhimskiy et al., 2012; Malygina et al., 2013) suggests that the Taimyr population of wild reindeer, although being more numerous, poses less stress on the vegetation. This is possible thanks to the constant movement of animals over the summer pastures and a gradual change over several years in the migration routes across the entire peninsula along eastern, central and western migration corridors, so that the food supply is protected from overgrazing and trampling. At the same time, a periodic (every 23–25 years) population decline may occur following the decline of vegetation production, thus balancing the system “reindeer abundance—plant resources.” The same pattern is detected in the Lapland Nature Reserve (Abaturov and Lopatin, 1999; Danilkin, 1999). When observed in mainland populations, winter die-off occurs mainly among juveniles. In Taimyr, this die-off was registered in the winter of 1968/1969 near Pyasin Island (Geller and Pavlov, 1972; Danilkin, 1999).

Thus, we assume that the feeding factor plays a major role in self-regulation of the number of wild reindeer in Taimyr, and therefore it is not threatening (two points).

Temperature factor. Temperature trends indicate that in the next half-century the Taimyr Peninsula is going to face noticeable warming: average negative isotherms should shift 400–600 km to the northeast (Klimenko et al., 2001), which will undoubtedly affect the state of vegetation, that is, improve forage conditions and increase reindeer capacity of the Taimyr tundra. Earlier, the authors considered the possibility of saving the Yamal livestock as a result of the regional warming (following global warming) and concluded that it is extremely unlikely (Kryazhimskiy et al., 2012) because of a strong disturbance of the vegetation cover, which is not noted for Taimyr. Thus, the expected climatic changes can only be favorable for the food resources of the population. Recent decades have been marked by the emergence of so-called small local populations, which do not migrate and remain in the same area throughout the year (Malygina et al., 2013), thus indicating a general improvement in living conditions.

Up to 60% of calves in the Taimyr Peninsula die during the year (Danilkin, 1999), largely because of the harsh climate. In the case of moderation of climate conditions, the calf mortality should decrease, which would certainly affect the rate of population growth and population recovery.

At the same time, the climate shift toward positive temperatures will reduce energy losses in the winter, but it can become a limiting factor for energy consumption in the summer because of the adaptive responses of reindeer aimed at forced maintenance of

the stable state of the body with respect to the upper limit of the thermoneutral zone (Movrodin et al., 2008). Thus, the expected climatic changes may act on the reindeer population in two ways.

In general, as very important but not critical for reindeer under conditions of Taimyr, the climatic factors receive an integral estimation of two points.

Snow cover depth in winter. The snow cover depth affects the ability of reindeer to move and forage. The existing estimates of energy costs for reindeer indicate that, with an increase in the snow cover depth, the energy costs for both movement and foraging increase nonlinearly (Movrodin et al., 2008). Detailed observations over a wild population slightly migrating in the Sayan Mountains indicate that in winter the animals move to the windward slopes of the mountain plateaus and ridges with minimal snow cover (Bondar and Vinogradov, 2013).

With the prospect of climate changes leading to an increase in the accumulation of snowfall and an increase in the snow cover thickness, which has already been observed in Fennoscandia (Kivinen and Rasmus, 2014), the effect of this factor will increase (three points).

Overflow of rivers and their passability in spring and summer. No special studies regarding this issue have been carried out. According to the literature, as well as our own observations, deaths at crossing occur mainly among juveniles and account for a small share in the overall, but only recorded, mortality among reindeer. Since it is difficult to determine the number of reindeer that drowned in crossings, there are reasons to consider this factor as significant in the overall mortality of juveniles as the temperature. In addition, the expected overall warming must be accompanied by an increase in humidity, so the negative role of this factor will increase (two points).

Direct Effect—Predation Factors (PF)

Wolves. The range of polar wolves completely coincides with the southern boundary of the winter distribution of the Taimyr population of wild reindeer.

In the spring migration, predation of wolves has the most intense impact on in-calf females hurrying to places of calving, therefore being the first to come to Taimyr. In the pauses between the migratory waves and at the end of the migration, wolves intensely exterminate straggling calves, weak individuals, and males passing the last. In the autumn migration, wolves often prey on mature bulls that during the rut mainly have a specific behavior pattern which suppresses the “sense of danger.” It has been determined that the presence of predators limited in their movement by their broods within 50 km from the forest border makes reindeer females choose their calving places farther from that border (Heard and Williams, 1992; according to Baskin, 2009). The same pattern was identified for Taimyr.

Over the entire period of work, we only twice witnessed single wolf individuals, in August 1991 and 1996 on the Upper Taimyr River (Cape Rysyukov). Given the territorial coverage of our observations (typical tundra zone) and abundance of food (concentration of reindeer) in this period in the East Taimyr, we never identified scavenger wolves on the shooting sites in 1990–1991. Survey data did not indicate any wolves either, even though production of wild reindeer at the Taimyrsky Gospromkhoz resulted in butchery waste at the shooting sites. Wolves were using it and started to winter in the Pyasin Valley. They appeared in November–December and stayed for the whole winter, feeding on the production waste, as well as on wounded animals straggling from the reindeer herd passing to the south. In addition, predators are constantly visiting and ruining the hunting paths.

The wolf issue in Krasnoyarsk krai was always dealt with spontaneously. In the absence of centralized administration over hunting of wolves, mainly juveniles were caught, while the population core of mature individuals stayed intact. The population of wolves quickly recovered, the rate of killing the predators did not exceed the population growth. Wolf resources in the former Krasnoyarsk krai were estimated to be 7500 individuals. The average annual catch of wolves in Krasnoyarsk krai in the years of their high abundance was 700–1200 individuals. In 1961, 490 (44.1%) out of 1112 wolves were caught with traps and loops. With good material incentives for hunters and allocation of funds for the rental of air transport, the annual catch of wolves in the mid-1980s exceeded one thousand individuals. Over three years, from 1983 to 1985, 3196 predators were killed.

In contrast to the tundra to the west of Gydan, Taimyr never had intense wolf control, and the abundance of these predators did not change significantly. The average annual provision of wolf pelts from the tundra and forest tundra of Krasnoyarsk krai in the postwar period ranged from 89 to 194 over five-year periods, on average about 150. The decades-long relative numerical constancy of the Taimyr wolf population was due to the insufficiency of removal, which probably did not exceed one-third of the population.

The wolf inhabits the territory of Taimyr everywhere but unevenly. In the Arctic tundra, in particular, in the basin of the Bikada River, its density is 1.5 individuals per 1000 km²; in the tundra forests of the West Taimyr, it is 2.5; and in the Putoran Mountains, it reaches 10 nonmigratory animals. The sizes of the habitat areas of wolf families vary in the summer in the range of 100–150 km². According to E.E. Syroechkovsky (1986), the number of wolves in Taimyr is estimated at 1500 animals, while the zone of typical tundra is inhabited by only 300–400 wolves (Geller et al., 1974; Syroechkovsky and Rogacheva, 1975).

In case of a dynamic equilibrium in the wolves–deer system of 1 : 100 (Pimlott et al., 1969), the Taimyr

population of wild reindeer can support thousands of wolves, thus being little pressed by these predators. Polar wolves have the maximum supply of potential victims (28 t of consumed biomass per wolf). At such a high density of reindeer and low density of predators, polar wolves eliminate only 4% of the total population of the tundra reindeer (Syroechkovsky, 1986). Kolpashchikov and Dorogov (1986) believe that, in the entire range of the Taimyr population, wolves annually consume 15000–30000 wild reindeer.

Given the small share of reindeer removed from the tundra populations by polar wolves, the latter can play a certain selective health-improving role, but as a whole the proportion of the wolf factor, along with other large predators (bears, wolverines, polar foxes, and birds of prey), in the dynamics of populations of wild reindeer in Eastern Taimyr is negligible (one point).

Diseases. Although the Taimyr population is a natural focus of brucellosis, there is just a single case of mass deaths of reindeer (about 28000 individuals, of which 80% were juveniles, 5.5% of the population) from bronchopneumonia as a result of a sharp cold snap in July 1979 (Zabrodin and Pavlov, 1983, according to Danilkin, 2009). There is a history of infectious outbreaks and reindeer die-off from foot-and-mouth disease and anthrax in 1899, the 1930s, and the 1960s, on average every 30–40 years (Laishev et al., 2002, cited by Danilkin, 2009). Wild deer are less susceptible to infections than domestic ones thanks to living at a lower population density, dispersal of herds under poor feeding states of pastures, and their fast changing. Thus, diseases affect the abundance of the Taimyr population occasionally and on a small scale (one point).

Midges. A significant part of the population is infected with the larvae of the subcutaneous gadfly (Zabrodin, 1975, cited by Danilkin, 2009), which does not affect the population noticeably. A more significant role is that of blood-sucking insects whose action in the summer is short (about two weeks in July) but significantly determines the redistribution of the daily activity in favor of a protective reaction, which affects normal grazing and accumulation of fat reserves and may affect the survival of the animals in the winter. It is obvious that blood-sucking insects make a partial contribution to the summer mortality of calves, although there are no accurate estimates of energy loss and demographic damage to reindeer from insects. The regularity of the effect of the midge factor suggests that reindeer are quite adapted to it, and that its negative impact is insignificant (one point).

ANTROPOGENIC FACTORS

Indirect—Factors of Economic Development (DF)

Domestic reindeer husbandry. At the beginning of the 1990s, domestic reindeer in East Taimyr numbered

13113 animals and were concentrated in the upper reaches of the Khatanga River. They belonged to four state farms: Popigaisky, 6786; Arktichesky, 2322; Novorybinsky, 2911; Tsentralny, 1904 (operational reports of the Khatanga Veterinary Service, 1990). However, as the number of wild reindeer increased, the number of domestic reindeer decreased. In recent decades, domestic reindeer husbandry in the Khatanga district has been reduced to a minimum owing to the large increase in the number of wild reindeer.

Calculations of the dynamic behavior of the human–reindeer composite system based on the model of minimization of economic risks prove that coexistence of hunting and domestic reindeer husbandry is possible only in a state of unstable equilibrium, which is easily perturbed in either direction at the slightest change in environmental conditions or economic policy. The example of Taimyr shows that attempts to introduce nomadic herding reindeer husbandry in the Soviet era were not crowned with success and that the main obstacles to it are the remoteness of the forest border from the sea and, most importantly, the presence of a large population of wild reindeer (Berman, 2013) (one point).

Industrial objects. In general, the industrial development of Taimyr is in its infancy (Pavlenko, 2013): the proportion of the territory occupied by industrial facilities is negligible; there is almost no network of roads. Thus, there is no loss of ungulates on the roads from direct collisions with vehicles as in other densely populated areas, as well as no deaths from poisoning by pesticides and fertilizers (Danilkin, 2009) owing to the absence of agricultural infrastructure.

However, the Norilsk Mining and Metallurgical Plant (NMMP), as the largest industrial facility on the peninsula, has a negative effect on the spatial distribution of reindeer. At least, in the initial period of its operation, thousands of migrating animals died in service facilities of the plant and several local (nonmigratory) populations in the area of the NMMP disappeared.

This factor, preventing the movements of herds, along with the Mesoyaha–Dudinka–Norilsk gas pipeline, eventually led to a change in the migration routes of reindeer in the West Taimyr.

Furthermore, the NMMP is the biggest source of pollution in the form of sulfur dioxide, nickel, copper, cobalt, lead, phenol, nitrogen and carbon oxides, and hydrogen sulfide. The bulk of the emissions into the atmosphere come from sulfur dioxide, 96.1%. The total annual emission of pollutants by the industrial enterprises of Norilsk Nickel exceeds 2 million tonnes. The impact of pollution on the biological productivity of phytocenoses has not been studied, but because of the vastness of the range of the entire reindeer population, the role of this pollution is rather insignificant.

Another industry factor preventing migration is extended navigation on the Yenisei River. Breakage of

ice on the river by icebreakers hinders the natural course of reindeer and can lead to death of animals when they cross the channel of the Yenisei River clogged with ice floes (Shapkin, 2012). But this factor is local. In general, the negative impact of industrial facilities on the population of wild reindeer is not critical, so we assign it a value of two points.

Disturbance from human presence and transport. Industrial development of Taimyr began in the middle of the 20th century and intensified with the opening of the Norilsk Metallurgical Plant. Although the presence of humans is local, the development of means of transport makes the entire territory of the region accessible, which reinforces the disturbance to wild reindeer.

With the full-scale experiment, we attempted to evaluate the effect of disturbance on the daily energy budget of the animals in the early and late summer. Changes in the budget were estimated as a result of observations over the distribution of time spent on different types of reindeer activity. A total of 36 continuous observations on the Taimyr Peninsula in the period of 1984–1989 covered 133 animals. Averaged results were used in the analysis.

Observations were carried out in without nuisance (control) and with nuisance (humans). Then we calculated the energy consumption and the resulting energy gain for the observed individuals. On the basis of changes in the daily time budget in the animals that were under constant surveillance for several days, the energy consumption of reindeer was calculated according to the monograph of A.Ya. Sokolov and A.V. Kushnir, “Thermoregulation and Bioenergetics of Wild Reindeer.”

In the early summer, the dietary dominant of the wild reindeer behavior is so strong that they hardly respond to external stimuli and their time and energy budget scarcely change. These observations of the author on the dynamics of the daily time budget of reindeer for different types of activity at constant external disturbance in the late summer suggest that the time spent on the movement of reindeer because of disturbance is compensated by resting time but not feeding time (Fig. 2). As a result, animals lose twice the free energy required for plastic processes (Table 1).

The energy consumption of wild reindeer, caribou, and other mammals under the influence of disturbance was calculated by Canadian researcher V. Gayst. It is 64 kcal/min for running and 20 kcal/min for walking per 90 kg of live weight of the animal (Leist, 1971, cited by Shiedeler, 1986). The corresponding rates of energy consumption according to Gold’s Step (1973) were identified by Dag and deVos, reaching approximately the same values, 57.5 and 21.6 kcal/min (Dag and deVos, 1968; Gold, 1973, cited by Shiedeler, 1986).

Also, the effect of working motors can also be defined as direct disturbance. The indirect effect of a working Buran as a sound stressor consists in the fact

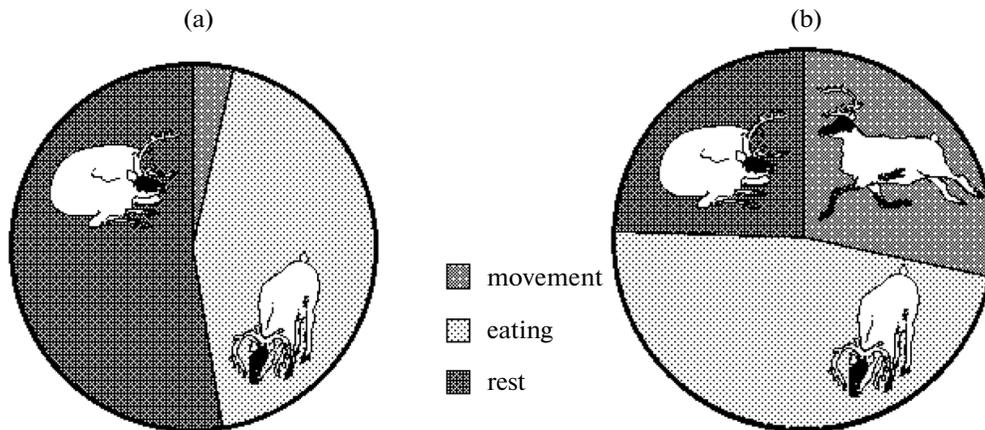


Fig. 2. Average daily distributions of time budgets of wild reindeer in late summer without nuisance (a) and with nuisance (b).

that animals associate it with such a negative phenomenon as hunting. The problem of influence of snowmobiles on caribou was discussed and presented in the materials of a number of foreign authors: Miller-Wille (1975, cited by Shiedeler, 1986) noted that a more intense use of snowmobiles by Finnish herders evoked in domestic reindeer, which are less susceptible to the negative influence of the stimuli of human origin, increased fearfulness and feverish and ungrounded movements; Valkenburg and Davis (1985, cited by Shiedeler, 1986) noted that caribou from the West Arctic and Delta herds had a sharper reaction to a helicopter when locals were more frequently using snowmobiles for hunting within the reindeer range. Research materials of the same authors (1984) showed that the reaction of caribou to snowmobiles during a hunt is stronger than the reaction to aviation. Stevenson and Hatler (1985, cited by Shiedeler, 1986) noted that the disturbance caused by snowmobiles was the reason for the splitting of stable groups and herds of mountain caribou in the range of the Telkva territory and the center of the British Columbia, which, in turn, caused serious problems for their protection. Edmonds and Bloomfield (1984, cited by Shiedeler, 1986) believe

that the intense use of snowmobiles in the western part of the province of Alberta has caused significant stress in caribou not only because of the direct disturbance and increasing poaching but also owing to the fact that tracks of snowmobiles facilitate the movement of predators in deep snow.

According to the materials of a number of researchers (Calef et al., 1976; Roseneau and Curatalo, 1976; Gunn et al., 1985; Lent, 1966; Bergerud, 1978; Bergerud et al., 1984; Valkenburg and Davis, 1985, cited by Shiedeler, 1986), the stress from working aircraft causes increased energy consumption and behavioral problems when reindeer escape. This can lead to injuries and others problems, including irreversible, physiological changes in the respiratory, digestive, and reproductive systems of reindeer and increased mortality of adults, juveniles, and newborns.

Danilkin (2009) provides the most obvious evidence of the negative impact of disturbance alone on the population reproduction by the example of saiga antelope, in which year-round pursuit by people on vehicles results in disturbed processes of feeding and reproduction, changes in daily activity, timing and routes of migrations, calving sites, and rutting periods.

Table 1. Estimates of average daily metabolized energy expenditure calculated according to Sokolov and Kushnir (1997) on the basis of average daily time budgets

Energy, kcal/(kg ^{0.75} days)	Early summer		Late summer	
	without nuisance	with nuisance	without nuisance	with nuisance
Type of behavior				
Movement	11.55	13.80	11.55	90.81
Feeding	100.99	112.52	100.99	108.83
Rest	87.95	78.42	87.95	40.96
Σ expenditure	200.49	204.73	200.49	240.60
Metabolized	250.00	278.54	250.00	269.41
Free energy	49.51	73.81	49.51	28.81

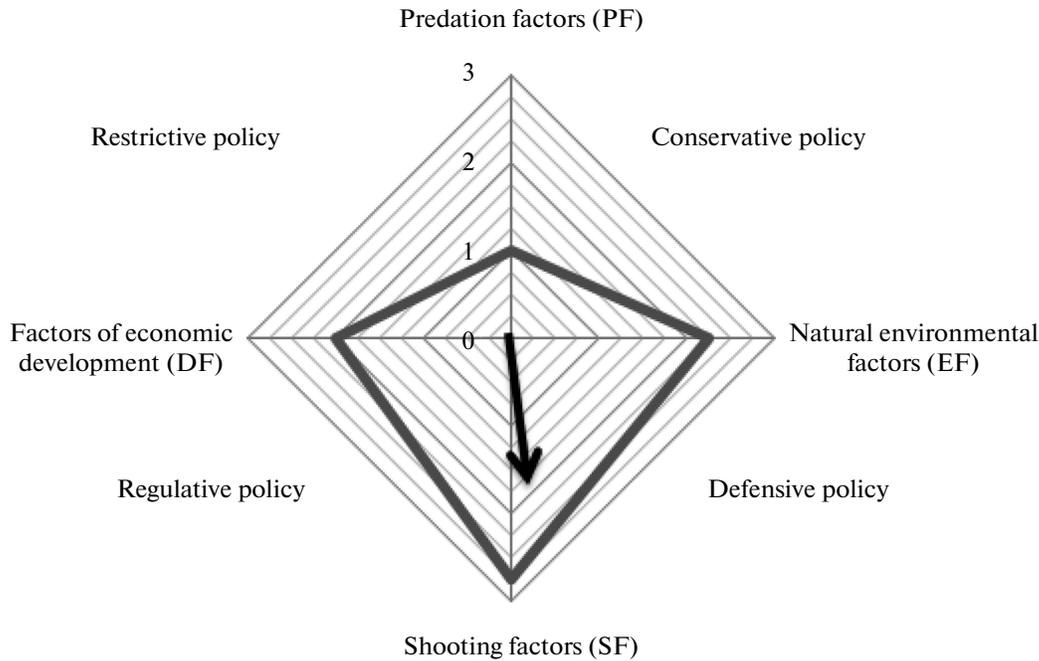


Fig. 3. Diagram of SPACE analysis for external factors for the Taimyr population of reindeer.

Ultimately, this leads to an increase in barrenness and multiple growth of juvenile die-off (Danilkin, 2009). A similar defensive behavior (and, therefore, its consequences) has been observed in migrating herds of wild reindeer, which leads to a reduction in the level of reproduction.

Since the growth of the population is determined by the balance of births and deaths, the gradual reduction in biological production first reduces the rate of reproduction of the population and then can lower the birth rate below the death rate. Thus, the factor of disturbance is very significant for the “energy security” of reindeer, so we assign it a value of three points.

Direct—Shooting Factors (SF)

Legal shooting. According to estimates of experts, in general in Taimyr in the 19th century, hunters took up to 37000 animals per year; in the 20th century, as industrial development and settlement of the peninsula progressed, the catch increased from 10000 animals per year in the 1930s to 17000–80000 animals per year in 1971–1984 (a total of 820000 animals were caught within this period). In 1966–1984, on average 11.5–16% of the stock was harvested from the population, which had both negative and positive effects. The negative effects are selective harvesting, which first leads to a decrease in the average weight of males and then females and embryos, a shift of the sex ratio toward males, and a decrease in the productivity of the population. On the other hand, after following the scientific advice on the industry, even upon its high intensity, natural mortality significantly declined, the pro-

portions of older animals and dry females decreased, and the intensity of reproduction increased. During the period from 1974 to 1986, 1.6 million animals were caught in Taimyr, and the maximum catch was achieved at the end of the Soviet period: in particular, 130000 animals in 1988. The maximum legal catch in Taimyr can be estimated at around 200000 animals, which corresponds to the specified but seldom fully implemented quotas (Shapkin, 2012).

Since the native population of Taimyr is small (about 10000 people) and the economy of indigenous peoples has been historically set up in a way that prevents excessive pressure on ecosystems (Malygina and Maklakov, 2014), the legal shooting by local residents is the smallest threat to the wild population (one point). In 2010, all the family-tribal and cooperative farms of Taimyr took more than 11 000 reindeer (Novozhilova, 2010, cited by Shapkin, 2012).

Of somewhat greater danger is the legal shooting in terms of the quota by visiting hunters. In our previous work, we show that, during the Soviet era, the system of annual procurement of migrating herds at crossings could effectively restrain the natural growth of the population of deer (Malygina et al., 2013). In addition, together with the shift of seasonal migration routes and stopping of the system of regular catches at crossings in the crucial year of 1990, the population of Taimyr itself began to decline (Fig. 3), while the number of reindeer started to grow. Resources of tundra reindeer in Taimyr are currently in use by farms of all forms of ownership, also illegally. Thus, the current legal shooting by hunters not related to the traditional

way of life of the indigenous population is estimated at two points.

Illegal shooting. According to estimates of experts, in Russia as a whole, the reindeer poaching reaches 57.6% of the total noncommercial mortality, accounting for more than 20000 animals per year in Taimyr, which may exceed the legal shooting. Obviously, the intensity of illegal hunting is proportional to legal hunting and to the size of the nonindigenous population of the peninsula and is exacerbated by the proliferation of vehicles linked to the industrial development of the Far North, such as helicopters, snowmobiles, and all-terrain vehicles. Owing to the worsening of the economic situation of the population and the weakening of legal protection capabilities in the post-Soviet time, the level of the real catch of ungulates is estimated to be 200–500% of the recommended norms for harvesting (Waisman, 2005, cited by Danilkin, 2009). According to expert estimates, with the official catch of 25000–30000 animals per year, the total harvest from the Taimyr population, taking into account perishing of wounded animals, was 80000–90000 animals per year. Thus, the factor of poaching is at least two times more significant than the intensity of the impact of the legal hunting factor.

The pooled data of the authors on noncommercial mortality rates in the period of the greatest commercial load in the area indicate that of 64 reported cases only four are due to deaths from natural environmental factors (death of animals in river crossings), ten from predators, and 50 as a result of shooting by poachers. These results indicate that the mortality factor is at least five times greater than the factor of natural predation, so poaching must be assigned the highest rating of danger (five points).

Market value of velvet antlers and venison. In the season of 1991–1992, farms of the Khatanga district began harvesting velvet antlers. As a result, about 9000 animals were shot in 1992, 2040 of which were shot in the summer for velvet antlers. Although now there is almost no state record keeping, it is clear that the market value directly affects the intensity of legal and illegal production (three points).

RESULTS AND DISCUSSION

The considered external factors received the following estimates based on the five-point scale (Table 2).

Initial data for SPACE analysis provide the coordinates for the direction of the decision vector $\{0.25 : -1.75\}$ and lead to the choice of defensive strategies (Fig. 3). The shooting factor, especially its illegal component, turned out to be the most significant for the Taimyr population. Its combination with the expected-to-intensify economic activity manifested in the form of increased disturbance to deer from human presence is the most dangerous to the population. This is due to the energy consumption of wild reindeer in

their defensive behavior against the disturbance caused by humans. The increase in such costs in the energy balance of animals implies reduction of plastic processes in the body, most of which in the late summer is aimed at solving problems of reproduction. Possible reduction in the growth rate, which can be lower than the necessary level of reproduction, can lead to the decline in the population abundance. In particular, R. Boertje theoretically calculated the energy needs of female caribou in Alaska: 222–278 kcal/(kg^{0.75} days) in the summer (feeding of calves and accumulation of fat deposits) and 147.6–152.4 kcal/(kg^{0.75} days) in the winter (Boertje, 1985), which corresponds to the measurements of Sokolov and Kushnir for the Taimyr population (Sokolov and Kushnir, 1997); however, they were carried out on males.

Thus, the synergistic effect of a combination of disturbance factors and poaching entails the greatest energy losses for the population, which are not possible to predict without knowing the intensity and nature of the development of the region.

However, a favorable feature of the behavior of wild reindeer is that they quickly adapt to stimuli that do not pose a threat to them. A number of authors assume (and their assumptions are confirmed by information and research materials) that, under prolonged exposure to aircraft sounds, wild reindeer are observed to adapt to this kind of nuisance (Klein, 1973; Bergerud et al., 1984; Valkenburg and Davis, 1985, cited by Shiedeler, 1986).

According to Dean and Fracy (1970), Reimers (1980), Scogland and Molmen (1980), and Socolski (1984) (cited by Shiedeler, 1986), caribou of Norway undisturbed by humans in the province of Svalbard (compared with the territory of Hardangervidda), foraged significantly better, digging holes for lichens in the winter and more intensely grazing in the summer. This helped them to survive the harsh winter. Hikers and climbers in the region of Dovrefjell caused much greater concern to caribou than any type of transport. While buses and other vehicles used on the roads of the McKinley National Park (Canada) caused some concern to caribou coming to roads and roadsides, this effect was dramatically enhanced when passengers exited the vehicles.

As an example of striking adaptation to the effect of the complex factor of disturbance, one may mention materials of research of the Delta herd in the United States, in Alaska (Valkenburg and Davis, 1985; Boertje, 1985, cited by Shiedeler, 1986). For a long time, the range of this herd was in the area of military maneuvers of the United States Army. Thus, caribou of the Delta herd were under bombardment, shelling, and impact of fires, low-flying civilian and military aircraft and helicopters, and roads and railways. Research data did not confirm their harmful effect on the state of the herd, which now prospers.

Table 2. Estimation of external factors affecting Taimyr reindeer population

Categories	Factors	Points	Average
Natural environment factors (NF)	Feeding factor—states of pastures	2	2.25
	Snow cover depth in winter	3	
	Temperature factor	2	
	Overflow of rivers and their passability in spring—summer	2	
Predation factors (PF)	Wolves	1	1
	Midges	1	
	Diseases	1	
Factors of economic development (DF)	Domestic reindeer husbandry	1	2
	Industrial objects	2	
	Factor of disturbance from human presence and transport	3	
Shooting factors (SF)	Legal shooting by locals	1	2.75
	Legal shooting by visiting hunters	2	
	Illegal shooting	5	
	Market value of velvet antlers and venison	3	

According to the materials of our own observations and surveys of workers at the Khatanga Airport (Khatanga, Krasnoyarsk krai) carried out in the period of 1980–1991, a herd of wild deer numbering up to 50 individuals not responding to the constant roar of take-offs and landings of aircraft and helicopters was observed near the airport (Malygina, 2014a).

Thus, there is every reason to believe that deer can adapt to the presence of humans, provided that in most cases the latter do not pose a danger to them. Such a situation can be created under administrative measures restricting legal and completely eliminating illegal shooting.

This defensive policy requires a network of protected natural areas, which has expanded to the north in recent years. In terms of the territory covered by reserves (10%), the Taimyr Peninsula occupies first place among all regions of Russia. At the same time, in Alaska, 25% of the territory is under the protection and there are 13 national parks. The wildlife refuges (Pyasinsky, Purinsky, Bikada, North Zemelsky, and Brekhovskie Islands) and reserves of Taimyr (Putoransky, Taimyrsky, and Great Arctic) are located in an environmentally sound way in the areas of calving or summering of migrating herds of wild deer and are key to environmental sustainability of the Taimyr population. However, even the legal status does not save these sites from the invasion of poachers, especially in helicopters, which is confirmed by the final episode of the table of documented cases of noncommercial deer mortality (see Table 2). From this, we can conclude that, in the other territories, poaching is even much more common. The author's experience suggests that the technical ability to control such vast spaces and

environmental law enforcement practice in Taimyr are still poorly implemented. The protective policy requires not only strict adherence to the rules of specially protected natural areas but also monitoring the abidance of quotas for legal shooting of deer in the unprotected areas.

Modernization of the control system is possible through the introduction of technological innovations in the form of geoinformation monitoring systems (Malygina and Maklakov, 2014). Integrated use of satellite surveillance in such a vast area and unmanned aerial vehicles should be aimed at both estimation of the size and condition of the deer population and the control over their harvesting through video surveillance, recording routes, and identification of vehicles. Of course, this will only make sense under strict abidance of the rules.

Consistent implementation of policy enforcement in the course of development of Taimyr will give this region a tourist and recreational value as the least disturbed, logistically accessible, and diverse landscape northern territory. The Taimyr Nature Reserve has naturally become a key unit of the tourism and recreation cluster (Malygina, 2014b). Safe for deer, the human presence in the protected areas will accelerate conditioning of the optimal non-energy-consuming behavior pattern in deer.

Involvement of representatives of indigenous peoples in environmental and tourism and recreation activities will have both social and ecological importance for the regions of the North. This approach solves the problem of employment of the indigenous population, raising its level of education, and preservation of ethnic cultures and natural ecosystems both

in the tribal lands and in the region as a whole. Another primary task of the state is to monitor the compliance with environmental regulations with the assistance of modern means of space and unmanned surveillance. In this case, herds of wild deer will remain a regular part of the Taimyr landscape even under the active development of the Far North.

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Translated by K. Lazarev