# Use experience of collars with radio beacons of Argos satellite system produced by ES-PAS Ltd. for the study of reindeer Taimyr-Evenk population

# Use experience of collars with radio beacons of Argos satellite system produced by ES-PAS Ltd. for the study of reindeer Taimyr-Evenk population

**A P Savchenko[1], A L Salman[2], P A Savchenko[1], I A Savchenko[1], S A Dubintsov[1] and A N Muravyov[1]**

[1]Institute of Ecology and Geography, Siberian Federal University, 79, Svobodnyi avenue, Krasnoyarsk, 660041, Russia
[2]ES-PAS Ltd., Moscow

E-mail: zom2006@list.ru; a.salman@es-pas.com; 09petro@mail.ru; rangifer@mail.ru; dubintsovsa@gmail.com; sasha-mu@yandex.ru

**Abstract.** The use of reindeer resources in Central Siberia - the main welfare source for the majority of farms and the indigenous population of the North region. Protection and rational use of Taimyr-Evenk reindeer population inhabiting the Krasnoyarsk territory on the area of more than 1.5 million km$^2$ are impossible without the use of modern remote sensing methods. It provides objective and live data information about the spatial and temporal location of animals at different stages of their life cycle. Monitoring carried out with the use of modern technical devices allows to solve not only applied control problems, but also to obtain new unique knowledge about the biology of this species. The basis for this message was the materials on the use of collars equipped with satellite transmitters of the Argos system and worn on deer. A total number of collars was 17, which were worn on reindeer in their wintering grounds, except for one, which a half-grown female was marked during the crossing of the Heta river. From a technical point of view, it was important to trace the total duration of the beacon and the viability of the battery packs in extreme temperature amplitude and also to establish reliability of the device protection from physical and mechanical influence during migrations of animals. The maximum duration of signal receipt with using the new battery packs in 2015-2016 amounted to 438 and 444 days, in 2017-2018 – 539 days. The maximum length of the deer during the satellite direction finding was 9538 km. The average speed was 13.5 km / day; the maximum was up to 45 -72 km / day in azimuth. Used collars with radio beacons of Argos satellite system produced by ES-PAS Ltd. (Russia), showed a high degree of functional reliability.

## 1. Introduction

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 region. Deer resources are 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.

Despite the keen interest in the reindeer [1–7], a number of issues in its biology remain poorly studied. One of the reasons is the wide range (more than 1.5 million km$^2$) of the reindeer population inhabiting the Krasnoyarsk territory. This requires the use of modern remote sensing methods [1],

including space technologies, which make it possible to obtain objective and operational information on the spatio-temporal movement of animals.

Argos – worldwide satellite location and data collection system is formed by government agencies in France, the USA, the European Union and India. It is designed to study and protect the environment. The system is able to regularly determine the coordinates of a moving object anywhere in the world based on signals of extremely low power emitted by a satellite beacon. Low energy consumption allows the use of miniature devices that can operate offline for many months.

The satellite beacon used as part of the Argos system periodically emits short messages at the same frequency. One of the satellites, flying over the beacon, receives messages and provides a measurement of the frequencies at which the signals arrive aboard spacecraft. The frequency of the received signal depends on the parameters of the mutual movement of the transmitter and receiver (the Doppler effect). In the event that a spacecraft manages to receive several messages in one flight over a radio beacon, the satellite system calculates the coordinates of a moving object with an accuracy of several hundred meters.

Wild reindeer is a very favorable object for remote observation, since it mainly moves in open areas without dense vegetation. As a result, during most satellite flights, spacecraft are in the line of sight relative to the antenna of the beacon, and messages are transmitted unhindered to the satellites. In addition, deer observation projects are carried out mainly at high latitudes, where the number of daily flights of spacecraft in the Argos system is significantly higher compared to the equatorial zone. All these prerequisites make it possible to ensure high-quality observation of wild reindeer with the daily receipt of dozens of Doppler positions of each animal studied. Monitoring carried out using modern technical means makes it possible to solve the issues of protection and rational use of wild reindeer on a fundamentally new level.

The purpose of the research is to study the effectiveness of using collars with beacons of the Argos satellite system manufactured by ES-PAS Ltd. to study the reindeer of the Taimyr-Evenk population.

## 2. Materials and methods

For remote monitoring of animals, specialized collars were used with radio beacons of the Argos satellite system manufactured by ES-PAS Ltd (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 7 Argos beacons without navigation receivers were used. In the event that the intensity or accuracy of the Doppler positions was still insufficient to solve the tasks, a navigation receiver was additionally built into the beacon, which made it possible to determine the location of a moving object with higher quality. In this case, the beacon independently determined its coordinates using satellite navigation systems, and then embedded information about its location in messages transmitted to the spacecraft of the Argos system. As a result, the remote user received both Doppler and navigation coordinates of the object under study.

Russian-made radio beacons significantly differ from similar equipment manufactured abroad. All electronics are integrated into a monoblock, completely filled with technical resin and located under the face of the animal. A shortened antenna is used, placed inside the monoblock. Special methods for optimizing energy consumption are applied. Specialized data encoding is provided, which allows the user to recover information in the event that bit errors occurred during its transmission. Constant control of the temperature regime is carried out, at which the electronic components function. All these technical features made it possible to give mechanical strength to the product, to optimize its functioning strategy, to ensure the reliability of the transmitted data, to achieve operability at low ambient temperatures.

To assess the influence of weather phenomena on the course and nature of deer movements, a general idea of the dynamics of snow cover, air temperature, Rosgidrodromet data, modeling schemes from the Ventusky program, and daily satellite images from the Google program were used. The paper presents temperature characteristics for two weather stations located in the village Essen (68°27'.52" N; 102°11'18" E) and village Khatanga (71°58′ 41" N 102°28′27" E) in a straight line removal of 391 km.

## 3. Results and discussion

In 2015, deer were caught in the area of Lake Tise-Suokh (68°14'6.42" N; 103°51'32.33" E): 04/11/15, a young male (with horns) is marked with a satellite transmitter ID No. 144921 and an adult male (without horns) - ID No. 144922; 04/12/15, Vazhenka - ID No. 112854, ID No. 110724 and ID No. 147057; 04/13/15, Vazhenka - ID No. 112860); 04/14/15, an adult male - ID No. 112862. At the lake Talakh were captured: 04/19/15, the Vazhenka marked with a satellite transmitter ID No. 108969, the Vazhenka - ID No. 147056 and the Vazhenka - ID No. 112853.

In the spring of 2017, 6 deer were captured in Evenkia and one individual in the Taimyrsky Dolgano-Nenetsky District. At the village Chirinda, Lake Hekchekit, Dyupkun (6 68°12′ N 99°09′ E; 05/05/2017) deer marked with collars with satellite transmitters No.170856; May 6, 2017 - No. 111354; at Lake Yessey.

(68°33′ N 102°57′ E) were marked on 05/05/2017 with collar No. 170857; May 6, 2017 - No. 61928; 05/30/2017 - No. 61745; 05/31/2017 - No. 170858; at Novoe in a mouth of the river Bulun (71°45′ N 101°12′ E) 06/25/2017 a young female was captured and tagged with a collar No. 111353.

Analysis of the deer movement tracks marked with satellite transmitters revealed two main habitats of the tundra reindeer of the Taimyr-Evenk population - western (Yenisei-Putorana) and eastern (Upper Taimyr-Essen). Although in 2017, individual animals (lilac color of the track) during wintering reached the foothills of the Putorana Plateau (figure 1).

Consider the natural conditions of the eastern deer habitat in the spring, where most of the animals were tagged. Wintering places are located on the border of the Krasnoyarsk Territory and the Republic of Sakha (Yakutia) in the northwestern spurs of the Vilyuy Plateau, represented by larch taiga and forest-tundra. The average elevation there ranges from 600 to 800 m. The climate here is extremely continental, in terms of large annual temperature fluctuations and the relatively small amount of precipitation. It was there that permafrost was discovered with a thickness of up to 1.5 km, the largest in the world [8]. The average annual precipitation is 200–250 mm with a maximum in the spring and summer months. Snow cover lasts for 220–250 days a year, its height is not great, which favors the search and extraction of food for deer.

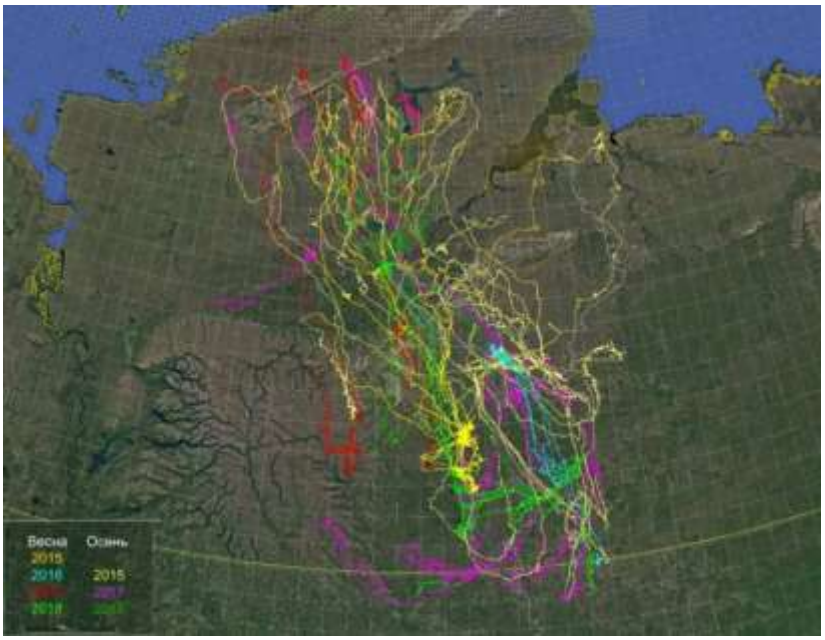


**Figure 1.** Seasonal movements of wild reindeer of the Taimyr-Evenk populations in 2015-2018.

Spring migration of deer of the Upper Taimyr-Essen group begins in mid-March. In the second half of March there is an accumulation of herds of wild reindeer in the area of Lake Yessey. This is one of the largest lakes in the Krasnoyarsk Territory, located in the north-east of Evenkia in the Kotuy River

basin. The water edge is located at an altitude of 266 m above sea level. Lake Yessey is located in the western part of the intermountain basin Yessey. It is stretched from north to south; its northern part is much wider than the southern. The area of the water mirror is 238 km$^2$, length - 23 km, width - 19 km, depths - up to 6 m. The banks are embayed. Along the banks there is tundra and forest-tundra vegetation. Freeze-up begins in the second half of September and lasts until mid-June.

From Lake Yessey deer go north in several streams. One goes north-east along the valley of the Kotuy River, crossing such large tributaries as Tukalan, Bysyttakh, Kochokon, Verknyaya Kale, Kotuykan, Medvezhya. Valley of the Kotuy River cuts a hill with flat peaks representing a degradation between the Anabar Plateau and the Putorana Plateau, with average heights of 300-400 m. In this section the Kotuy River flows almost everywhere in a canyon with steep, often sheer cliff slopes (figure 2).

**Figure 2.** A three-dimensional relief model of a section of the Kotuy River in a slide between Putorana Plateau and Anabar Plateau.

The Kotuy basin is characterized by a long winter with severe frosts and winds. The average January temperature is minus 32ºC, and the average July temperatures - 15-18ºC. The absolute maximum temperature, according to the nearest weather station in the village Yessey, during the operation of the transmitters, amounted to 32.1ºC in the first ten days of July and the minimum - minus 48.5ºC (table 1). Summer is short, cold and rainy. The duration of the period with negative temperatures is 8–9 months. The Kotuy River is characterized by high floods, due to its narrow valley, as well as the fact that its upper reaches are on the Putorana Plateau. Freeze-up begins in late September and lasts an average of 235 days until mid-May [8].

**Table 1.** Temperature range during years of operation of collars with satellite transmitters.

| **Yessey 2015-2016** | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Month | Decade | TºC D | TºC min | TºC max | Month | Decade | TºC D | TºC min | TºC max |
| July | 1 | 18.5 | 1.7 (2.07) | 32.1 (5.07) | January | 1 | -18.2 | -40.0 (1.01) | -2.0 (4.01) |
| | 2 | 18.4 | 8.8 (19.07) | 28.0 (15.07) | | 2 | -35.0 | -43.3 (13.01) | -22.5 (18.01) |
| | 3 | 15.8 | 2.0 (27.07) | 28.0 (21.07) | | 3 | -23.2 | -44.5 (28.01) | -9.0 (25.01) |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| August | 1 | 13.6 | 1.5 (4.08) | 21.3 (6.08) | February | 1 | -29.1 | -44.0 (9.02) | -14.8 (1.02) |
| | 2 | 10.5 | 3.0 (19.08) | 17.0 (11.08) | | 2 | -26.8 | -47.9 (12.02) | -4.6 (14.02) |
| | 3 | 10.6 | -3.0 (21.08) | 20.7 (27.08) | | 3 | -25.4 | -42.2 (23.02) | -9.0 (29.02) |
| September | 1 | 11.3 | -4.5 (2.09) | 25.8 (3.09) | March | 1 | -22.3 | -43.5 (4.03) | -7.5 (8.03) |
| | 2 | 2.2 | -3.4 (18.09) | 10.3 (11.09) | | 2 | -23.8 | -48.5 (12.03) | 0.8 (19.03) |
| | 3 | 0.1 | -11.4 (25.09) | 8.5 (28.09) | | 3 | -11.0 | -34.9 (28.03) | 6.5 (22.03) |
| | | | | **Khatanga 2017** | | | | | |
| January | 1 | -36.9 | -47.2 (6.01) | -14.9 (8.01) | July | 1 | 8.7 | 0.7 (4.07) | 21.0 (10.07) |
| | 2 | -27.3 | -35.5 (17.01) | -13.2 (20.01) | | 2 | 13.9 | 6.3 (20.07) | 22.4 (16.07) |
| | 3 | -21.6 | -34.5 (25.01) | -13.1 (27.01) | | 3 | 12.6 | 5.6 (26.07) | 23.5 (21.07) |
| | | | | **Khatanga 2018** | | | | | |
| January | 1 | -27.1 | -43.5 (10.01) | -8.1 (2.01) | July | 1 | 11.3 | 6.0 (8.07) | 22.2 (1.07) |
| | 2 | -39.8 | -51.5 (18.01) | -29.8 (13.01) | | 2 | 8.5 | 1.8 (20.07) | 16.8 (18.07) |
| | 3 | -23.0 | -35.3 (31.01) | -13.1 (25.01) | | 3 | 8.8 | 4.0 (23.07) | 19.4 (28.07) |

During migrations, only a part of deer walks along the Kotuy ice and crossing large inflows, in spring the time of movement of the second wave of animals coincides with the flood and high water level on the rivers, which forces them to swim the watercourses.

Within this migration site, altitudinal zonation is well defined. The upper border of the forest passes at an altitude of about 300 m above sea level, but individual trees and larch elfin trees are found up to 400 m. The main plant communities are represented by larch forests and grass-shrub-moss ground cover. In the floodplain of Kotuy and its inflows, the shrub layer of alder forest, Yenisei and Boganidae osier can reach up to 3 m in height, therefore deer often move beneath the canopy of tangled vegetation.

The second stream of migratory deer of the Upper Taimyr-Yessey group passes northwest of the Kotuy valley through the Kes-Kireke hill and further along the Maimecha river valley. This site is also characterized by a high ruggedness of the relief with height fluctuations from 50 to 762 m with a gradual decrease to the North Siberian lowland. Most river valleys have a V-shaped profile with steep slopes. Even the Maimecha Valley rarely has a bottom width of more than 1 km. Freeze-up starts in late September and lasts until early June. Natural settings of the Maimecha River are similar to the Kotuy valley, especially when you consider that deer appear there later. The vegetation of the studied area is represented by forest and tundra communities. Among woody plants, Larix gmelinii predominates almost exclusively, Siberian spruce and betula tortuosa are less common. The height of the main tree layer is on average 8-12 m, sometimes up to 20 m, and on convex watersheds and slopes - 5-10 m. Tundra vegetation is represented by moss, shrub and lichen types. Shrub communities in the Maimecha river valley occupy almost the entire flood plain. These are tall (up to 3-4 m) shrubs of osier willow [9].

After passing the plateau, the front of deer migration noticeably widens (figure 2), which can be explained by geomorphological conditions: the relief is represented by wide river valleys and thermokarst lakes, with heights ranging from 50 to 150 m.

The first reindeer herds approach the Kheta and Khatanga rivers at the end of May - in early June and cross them on ice. In early June, the ice conditions on these rivers no longer allow animals to cross them, so deer are forced to swim the rivers. The width of the Kheta river bed in the places of deer

migration ranges from 350 m (in the area of the village Kotaryk) to 470 m (in the area of the village Kresty), and Khatanga river near the village of the same name reaches 1 km.

After passing large water barriers, migrating deer go to the area of Lake Labaz located in the North Siberian Lowland. The relief is represented by wide floodplain valleys with a large number of thermokarst lakes. Average heights range from 50 to 120 m. The vegetation consists of larch woodlands, dwarf arctic birches. The floodplains of the rivers are covered with almost continuous thickets of willow and alder.

Labaz Lake is one of the largest freshwater lakes in Taimyr (470 km²), has a rounded shape with several bays - Kholu-Khargy in the southwest, Western Bay and Northern Bay. The lake is connected by a small channel with Lake Orto-Kiuiol and has many inflows with open water during the course of deer.

From the lake Labaz reindeer migration proceeds crossing the left inflow of Khatanga river Nova, northeast to the world's northernmost largest lake Taimyr located within the Byrranga Mountains. The lake is stretched from southwest to northeast for 180-190 km. The basin of the lake is a greatly expanded section of the river Taimyr, which filled the tectonic crack that formed during the melting of the ice sheet. For nine months of the year, the northern part of the lake is covered with thick ice. The average annual temperature there does not exceed minus 13ºC. In July-August, stormy winds are characteristic.

In river valleys, deeply cutting through the Byrranga mountain ranges, deer move to the Kara Sea, but judging by the received tracks, they do not go to the coast in the latter, turning 125-130 km from it. The Byrranga Mountains are a system of ridges stretching from north-east to south-west, divided by trough valleys, caravans and circuses. Average heights range from 500 to 700 m.

From tagging sites located in the area of Lake Yessey, to the places of summer breeding and feeding in Taimyr by the third decade of July (100-111 days from the date of their labeling) reaches 90% of tagged individuals. By the first decade of September and October (days 149 and 179, the reverse migration cycle), up to 70% of tagged deer with clearly working collars are preserved. In 2015, the arrival of satellite signals from deer from wintering places (244th day) at the end of December was noted from the Yessey (6 individuals) and Khatanga (1 individual) sites. A sharp decrease in the number of tagged deer occurs at the beginning of spring migration, which is associated with their shooting, and not with a decrease in the quality of the incoming radio signal from the collar. By the third decade of April (370-375 days) out of 10 tagged deer in the spring of 2015, only 2 (20%) remained, out of 7 tagged in 2017 - 3 or 43%, respectively.

The maximum duration of signals from deer with satellite transmitters and using upgraded battery packs in 2015-2016 amounted to: 438 (No. 112853) and 444 (No. 112860) days, in 2017-2018 - 539 days. The largest values of the total length of the deer running along the tracks during the satellite direction finding were: 9537.9 km (tagged May 6, 2017, No. 61928); 9,267.3 km (05/05/2017, No. 170857) and 9,045.3 km (05/31/2017 - No. 170858). All of these deer were captured in the vicinity of Lake Yessey. The speed of movement varies both in individual sections and in the seasons of the year, averaging 13.5 km/day, while the maximum can reach 45-72 km on bearing.

## 4. Conclusions

When developing the Argos satellite collar, the engineers had the task not only to fix it firmly and safely on the deer's neck, but also to create a transmitter with high resistance to natural (mountain conditions, rugged terrain, water obstacles, shrub and woody vegetation) and weather conditions, in particular, the high amplitude of daily and especially seasonal temperatures.

Initially, the declared operating period of the built-in battery was 1 year, but in practice the time interval reached a value of 1.5 years, which made it possible to trace the full annual cycle of wild reindeer migration and its main life stages.

All electronic modules and a battery placed in sealed enclosures made of shockproof and waterproof polymer reliably protected the transmitter from external influences. In the North of the Krasnoyarsk Territory (Taimyr, Evenkia) in the winter and in the spring-summer months at high temperature

amplitudes, the devices showed uninterrupted operation. So, during the wintering of wild reindeer near the border of the Krasnoyarsk Territory and Yakutia in the second decade of March 2016, the air temperature ranged from minus 48.5° C (12.03) to 0.8° C (19.03). The maximum low temperature - down to minus 56.6° C was noted on January 18, 2018. Despite such frosty weather, the signal continued to be received, although with a somewhat rarer long time interval.

In the summer months, in the places of calving and summer running of reindeer, it was really hot. Repeatedly, in June and July 2017-2018, according to the weather station in the village Khatanga, the air temperature reached 30° C, and the positive maximum was 31.7° C (06/15/2018). Such significant amplitude of daily and seasonal temperatures, throughout the entire period of research, did not affect the clarity of the signal of radio beacons, which regularly came online to the data center.

Thus, collars with radio beacons of the Argos satellite system manufactured by ES-PAS Ltd. confirmed a high degree of reliability in extreme conditions of the Far North of the Krasnoyarsk Territory. Ground surveys, a survey of local residents and helicopter crews circling the territory during this period, showed both a clear coincidence of the movement of tagged individuals with the general course of the deer's migration flow and their stop at the main river crossing the Kheta and Khatanga rivers.

In the midst of deer migrations, their activity and movement speed almost double, which causes an increase in the daily grazing area compared to the winter season. By the end of the spring-summer period of migrations, deer of the Upper Taimyr-Yessey group reach 74° north latitude. The quantitative values recorded in the database allow the most accurate characterization of the spatiotemporal distribution of reindeer reflected on cartographic materials. An analysis of the data from satellite transmitters that marked the wild reindeer of the Taimyr-Evenk population in 2015-2017 allowed not only to obtain generalized information about the location and diurnal course of animals, but also to analyze the physical and geographical conditions of their main migration path.

Currently, the manufacturer continues to improve its equipment, regularly upgrading beacons. For example, the devices of 2017 were already significantly different from the equipment used in 2015. In particular, new principles of energy consumption were applied, the radiating antenna was further shortened, and an external plastic casing was added. These measures made it possible to increase the mechanical strength of the products, which increased the duration of the operation of the beacons, and made the collars more convenient and less traumatic for animals.

As a result of the work performed, the Argos / GLONASS / GPS collars worked for about 9 months, providing accurate information about the location of animals 200-250 times a day. Argos collars functioned on animals for 444 days. Argos collars made in 2017 worked for 539 days (probably longer since the collar brought by the hunter from the deer to the village of Khatanga issued a signal for another two months).

The formed geographic information system (GIS) of hunting grounds and hunting resources is aimed at more efficient use of monitoring data, the status and use of hunting grounds, this will update the data on the current status of groupings, which is extremely important when addressing the protection and rational use of wild reindeer Taimyr-Evenk populations on a fundamentally different basis.

## References

[1] Buyanov I Y 2015 The study of migration, season positioning and daily activity of the reindeers using collars with satellite tags and by means of aerial surveys *National Association of Scientists (NAU)* **9** 92-4

[2] Chan K-S, Mysterud A, Øritsland N A , Severinsen T, Stenseth N Chr 2005 Continuous and discrete extreme climatic events affecting the dynamics of a high-arctic reindeer population *Oecologia* **145** 556-63

[3] Mikhailov V V , Kolpashikov L A 2013 Controlling the Taimyr population of wild reindeers *In the world of scientific discoveries* **3.3.(39)** 265-92

[4] Makeev V M, Kolpashikov L A , Klokov K B , Mikhailov V V 2014 *The reindeer in the conditions of climate changes* (Saint-Petersburg: GPA) p 243

[5] Savchenko A P 2012 *The Red Book of the Krasnoyarsk Territory: rare and endangered species* (Krasnoyarsk: SFU) p 205
[6] Shapkin A M and Ivanova R G 2016 Prediction the number of the Taimyr wild reindeer (Rangifer tarandus L.) population on the basis of a linear trend *Genetics & Animal Breeding* **2** 26-30
[7] Parmuzin Yu P 1964 *Central Siberia: Nature sketch* (Moscow:Mysl) p 312
[8] Pospelov E B 2007 *Flora of vascular plants of Taimyr and cross-border territories* (Moscow: Partnership of scientific publications of KMK) p 457