Modeling a bioclimate of the range.

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Abstract - Weather and climate play an important role in life of wild animals. However, the descriptive approach prevails in bioclimatic researches. This work considers the size of energy losses as an integrated quantitative parameter of climate influence on animals. The base equations of the energy exchange model of animals are given. The bioclimatic fields of the population range are constructed with the help of this model and of fields of the main climatic factors. The Taimyr reindeer population, that is the largest population in the Eurasian continent, is chosen as the concrete object of the research. The essential difference between bioclimatic field of the range and the individual fields of basic climatic factors is clarified. The hypothesis about influence of a range bioclimate on a territorial distribution of wild animals according to a principle of a minimum of heat dissipation is put forward.

Key words: Bioclimate, range, energy losses model, maps, climate, reindeer.

1. INTRODUCTION

Weather and climate are important ecosystems factors, which define the life of animals. Together with resources of forages, relief of district and human influence, they determine the seasonal distribution of animals on the range, their migration and productivity. However, the empirical approach for estimations of the climate influence on spatial - temporal structure of populations prevails. The attempt to estimate this influence quantitatively is made in our work. As an integrated parameter of influence of a climate on animals the amount of energy losses is accepted (Gorshkov, 1995, Postnikov, 2000). Spatial - temporal distribution of the energy losses depending on meanings actinometry and meteorological factors forms a bioclimatic field for the range of a population of animals. A location and seasonal dynamics of zones of an energy optimum and pessimum of a field define favorable and adverse areas according to the climatic conditions. The opportunities of direct measurement of energy datum of animals in a wild nature are rather limited. For imitation of metabolic reactions in a wide range of climatic conditions the model of energy losses of an animal was made (Michailov and Mordovin, 2004). The closest to our researches is the termoclimatic indexes theory for an animals and men, which used in agriculture, construction, at designing the equipment of the bioclimatic control and heating systems (Hahn, *et. al*. 2003). We use a model as the tool of ecological researches and their appendices. The bioclimatic field of the range with the help of this model and climate data was calculated.

Reindeer was taken as object of imitation, because it is widespread, well investigated and important component northern ecosystems. We used Taimyr reindeer population, as the largest reindeer population in Eurasian continent (Kolpaschikov, 2000; Kolpaschikov e*t. al*., 2002).

2. METHODS AND RESULTS

The equation for full metabolic power Q of an animal reflects energy metabolism of organism and has a kind:

$$\overline{Q}(t) = \frac{1}{\tau}\int_0^{\tau} q\sum_{i=o}^{3} a_i(t)\,dt = (\overline{a_i}(t)\sum_{i=0}^{3}\tau_i + \sum_{j=1}^{3}\overline{a_j}(t)\,\tau_j)\,q$$

Metabolic parameters in the equation are considered as function of time. The fundamental laws of heat exchange are involved for the description of influence of a climate on animals. In works (Michailov and Mordovin, 2004; Mordovin *et. al*. 1990) the detailed conclusion of the equations is given.

$$M + Q_1 + Q_2 + Q_3 + Q_4 + Q_5 = 0,$$

$$\frac{\partial T}{\partial t} + div\vec{U}T = (k_0 + k_T)\nabla^2 T + div\vec{R}\ /\ \rho_B c_B,$$

Where: M - heat production, watt;
Q_1 - radiating balance of a skin surface;
Q_2 - thermal flow on a skin surface;
Q_3 - thermal exchange at breath;
Q_4 - thermal losses from a skin surface on evaporation;
Q_5 - thermal expense for heating of food;
T - temperature, ^{o}K;
U - vector of air velocity in fur, m/c;
ρ_B - density of air, kg/m^3 ;
C_B - heat of air, dg/kg ^{o}K ;
κ_0 - coefficient of molecular temperature conduction;
κ_T - coefficient of turbulent diffusion , m^2/c ;
∇^2 - Laplas operator;
div R - divergence of radiation stream, watt/m^3
τ_i, τ_j - daily budget of time;
a_j - biomechanical coefficient of working energy losses (movement, extraction of a forage and free feeding);
q - basal metabolic rate, watt.

Energy losses model of animals take into account the following weather-climatic, geographical, astronomical and physiological factors: metabolic rate, air temperature, wind velocity, height and density of a snow cover, direct solar radiation, diffusion and long-wave radiation, cloudiness, height of the Sun, astronomically and absolute duration of solar light, geographical coordinates of stations and items of supervision. Therefore the energy losses index can be considered as UTCI-analogue.
The energy losses model is constructed on compartment principle. Thermal resistance is calculated in separate blocks

for sites of a body with different thermal characteristic and for various thickness of fur or size of fatty tissue. Losses of energy are depended on the budget of time and total expenditure in this or that period of activity. The energy losses are defined separately for various sex-age groups of animals. The equations of energy losses are given in the simple algebraic formulas on which the algorithmic model and computer program is made.

Primary factors, determining losses of energy in winter are winds, temperature of air (frost) and snow cover (Mordovin *et. al*. 1990). In summer to major factors determining energy exchange of animals are added direct and diffused radiation, and also cloudiness. Thus, the insolation conditions of reindeers must be taken into account as important factor of spatial distribution of animals in spring and summer.

The information model of a climate for the range of a population includes standard climatic fields constructed on the data of a meteorological network, or on the data of remote sounding of an atmosphere with the help of the space telemetric equipments. In bioclimatic model of a population the entrance climatic information is submitted as temporary series. Spatial - temporary step-type behavior of these data is set according to a type of soluble tasks. The urgent space data which have been removed directly in places of stay of animals are necessary for operative estimations. The National archives data about environment conditions (Veselov, 2000) should be used for retrospection researches of spatial distribution of a population. Forecast data, which are received with the help of climatic models (Anisimov, 2002) are necessary for research ecosystems trends in connection with global changes of a climate.

With a help of the algorithmic model of energy losses and archives data we constructed bioclimatic maps for all seasons of the year.

The bioclimate for the range of a population of animals considerably differs from his climate, and at the same time closely is connected to the basic climatic parameters. The range of taimyr reindeer population is located in a geographical province unique under the climatic characteristics. The range extensive sector of Arctic Region occupying north of Average Siberia, including a tundra zone of Taimyr Peninsula and zone of polar deserts, and also zone of northern taiga by Evenkia and northwest Yakutia covers. Taimyr Peninsula is the region, which takes part in forming the weather of the whole Northern hemisphere. The circulation pole is connected with this province and it is known as Taimyr PC. Area of the positional points PC is nearly ellipse by the form. Main axis of the ellipse is orientated from Taimyr to side of the North Canadian archipelago. The amplitude of "polar flow" on Taimyr region is always more than anywhere. Volatility of temperature regime of the region is about 50% of aggregate volatility of all arctic temperature field, including North-European, East Siberian, Alaska and Canadian regions. Zero isallotherms of Eurasia constructed with help of perennial average annual and average January data goes round Taimyr Peninsula and divides Atlantic and continental sectors of thermal climatic machine.

The map of atmospheric pressure is presented on Fig.1. Average data are presented for the perennial January series of measurements. The distribution of atmospheric pressure defines laws of air masses transformation, and it is most important factor of bioclimate for the population range. The map shows that the winds of south-west directions are

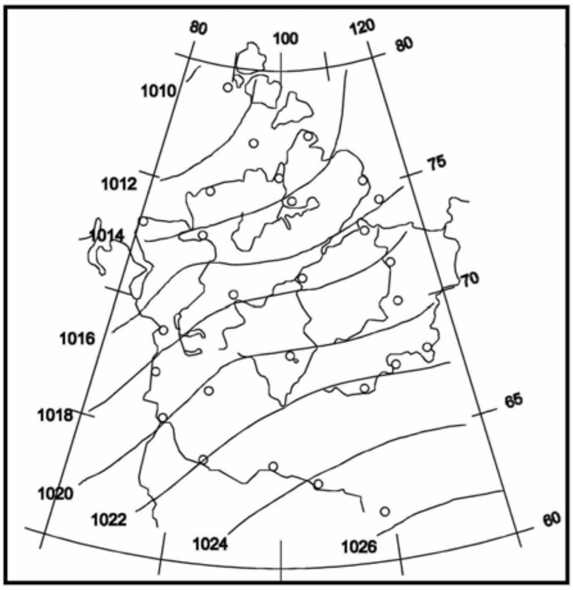

Fig.1. Field of atmospheric pressure for the range of a population, gPa. January.

prevailed in winter on the range of a population. In fact, these directions correspond to the most iterative winds. However, processes of cyclones genesis are differed for the north and south of the range. So in January the cyclones reiterating with a strong winds approaches 8 days per month,

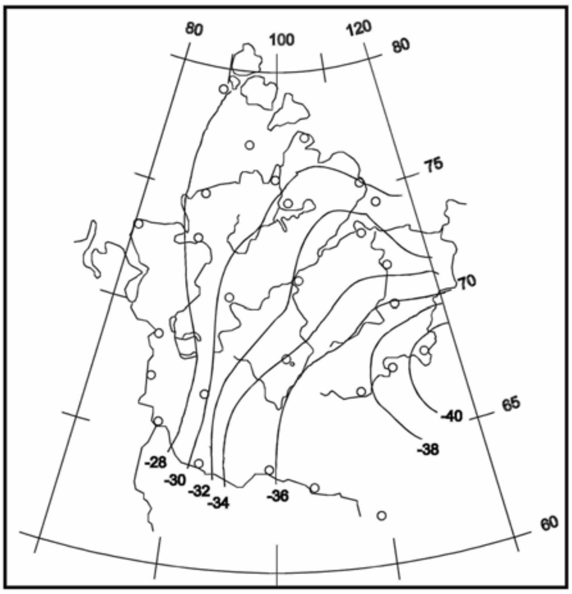

Fig. 2. Temperature field for the range of a population, ^{0}C. January.

while in the east of Putorana (a places of the winter animals allocation) it decreases up to 2 days or is absent at all. From December till March an exclusively stable regime of practically windless weather establish here with the frosts, which achieves -55^{0}C.

Field of energy losses in winter was computed and it essentially differs from the field of a temperature. Unlike isotherms, which reiterate of the continental boundary line (Fig.2), the isolines of an energy field almost perpendicularly cross the continental boundary line (Fig.3). It testifies about

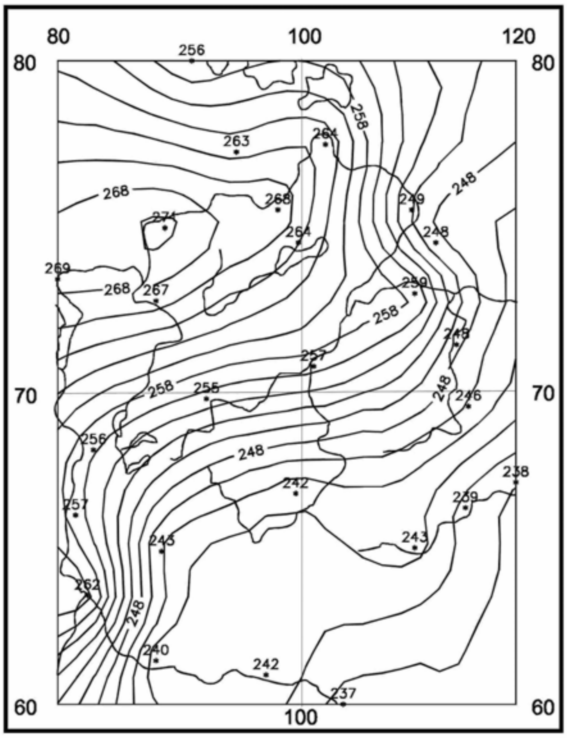

Fig. 3. Bioclimatic structure for the range of a population (an energy looses, Wt.). January.
Points determine arrangement of the meteostations.

significant contribution of non-temperature factors to formation of energy field. Instead of expected minimum of field in the north part of the range in connection with increase of temperature near ocean, the field has a maximum in this area. Minimum of field is located in the south and southeast parts of the range, where basic groupings of animals are hibernated.

Zoogeographical dependence of the field is observed only for energetic distribution and it is coincided in main traits with character of the population distribution inside the annual range. This dependence is not watched for fields of any climatic elements in separately.

The population prefers to hibernate in the zone of an energetic minimum. It allows us to promote hypothesis about influence of an energetic field on the territorial division of animals in according with the principle of minimum of a thermal dissipation.

3. CONCLUSION

The research of seasonal dynamics of the energetic fields and the study of an influence of climatic changing on reindeers is important task for analysis of spatial-temporal dynamics of reindeer populations and forecast. The proposed model approach for calculation of energy losses of animal is based on fundamental biophysical principles and can be used for other reindeer populations of Eurasia and North America as well as for hoofed animals of others species.

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