Climatic modeling of the distribution of *Oxytropis triphylla* (Fabaceae) by maximum entropy method

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Abstract. Predictive spatial models of the distribution of *Oxytropis triphylla* (Pall.) Pers. (Fabaceae), an endemic species of Baikal Siberia, were generated in MAXENT computer program using maximum entropy method. Long-term data of air temperatures for every month of the year were downloaded from the world database of open access WorldClim. Modeling was performed separately for minimum, average and maximum temperatures. Each variable contribution to the modeling was the basis to select the key variables having higher influence on the obtained models. The selected 10 key variables are the following: minimum temperatures of December and January; average temperatures of October, December, January and February; maximum temperatures of November, December, January and February. Then a model of the second level was calculated using only the ten key variables. There are three northern localities in the zone of adverse temperature effects: cape Malyi Cheremshanyi, Chencha and Sakhuli villages (all of them are in the Republic of Buryatia). It has been experimentally confirmed that the values of the key variables along the coasts of the Maloe More of Lake Baikal (Irkutskaya Oblast) are the most favorable for habitation of *O. triphylla* in this part of its range.

1 Introduction

The results of modeling the distribution of plants and animals according to climatic and bioclimatic variables by the maximum entropy method have been published in many foreign journals as well as in Russian scientific publications in the last few years [1–3]. Interest to the implementation of such studies is due to the high information content of the predictive models obtained. In this study, the maximum entropy method was used to conduct a quantitative analysis of the climatic temperature factors that limit the range of *Oxytropis triphylla* (Pall.) Pers., the endemic species of Baikal Siberia [4, 5].

2 Materials and Methods

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Specimens of *O. triphylla*, stored in the herbarium collections of Central Siberian Botanical Garden of SB RAS (Novosibirsk, Russia), Siberian Institute of Plant Physiology and Biochemistry of SB RAS (Irkutsk, Russia) and V.L. Komarov Botanical Instutute of RAS (Saint-Petersbourg, Russia) were taken as the materials for the study. For the construction of the predictive models, 45 localities were chosen. Accurate geolocation references were determined for these localities. The predictive spatial models were generated in the MAXENT computer program by the maximum entropy method [6–9]. Values of climatic indicators were downloaded from the world database of open access WorldClim – http://worldclim.org/.

3 Results and Discussion

Initially, climate models were constructed separately for minimum, average and maximum temperatures of each month of the year. The variables contribution to the modeling was the basis to select the set of the key variables having higher influence on the models obtained. The selected ten key variables are the folowing: minimum temperatures of December and January; average temperatures of October, December, January and February; maximum temperatures of November, December, January and February. Then a model of the second level was calculated using only the ten key variables (Fig. 1).

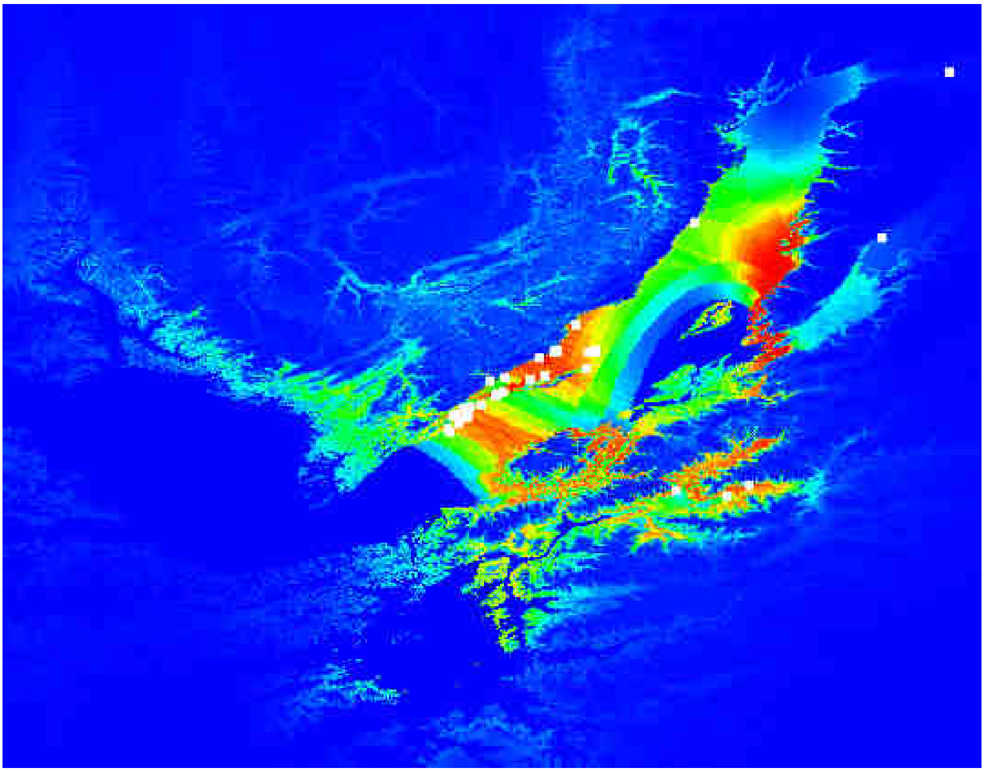

Fig. 1. The predictive spatial model of *Oxytropis triphylla* range constructed on 10 key temperature indicators. Explanations are given in the text.

In Fig. 1, the areas with the temperature regimes which determine the probability of finding *O. triphylla* within the interval of 0.93–1.00, or 93–100% are coloured in red; with probability 0.86–0.92 are coloured dark orange; with probability 0.78–0.85 – orange; and 0.70–0.77 – yellow. Thus, red-orange-yellow gamma indicates the favorable parts of Baikal

Siberia where this species may be found. Different tones of the colour blue indicate areas that are unfavorable for habitats of the species: in the dark blue areas the probability of finding varies in the range 0.00–0.08; in the pure blue areas – 0.09–0.15; in the light blue – 0.16–0.23; in the very light blue – 0.24–0.31.

Different tones of the green colour indicate areas with the probability of finding the species from 0.32 to 0.69. Green coloured areas may be considered as neutral and even close to favorable for the species. White squares correspond to geographical points where the herbarium specimens were collected and included in the modeling (45 localities). Some of them are located very closely to each to other; thus, they look as the same white square.

According to the obtained predictive spatial model, the main fragment of the range of *O. triphylla* is located in the middle part of the Western coast of Lake Baikal (38 localities). Therefore, it can be considered experimentally confirmed that values of the key temperature variables near the coasts of the Maloe More of the Lake Baikal (Irkutskaya Oblast) are the most favorable for habitation of *O. triphylla* in this fragment of its range. Accordingly, new populations of this endemic species may be found in this territory.

Another range fragment includes only three localities in Southern Buryatiya. These localities are placed a long distance from the main part of the range described above (150–200 km). Regimes of key temperature indicators in Southern Buryatiya allow predicting a high probability to find *O. triphylla* in a new neighbouring locations.

Three northern localities (cape Malyi Cheremshanyi on the Western Coast of Lake Baikal, Chencha and Sakhuli villages – all in the Republic of Buryatia) are disposed far from the main part of the range. According to the predictive spatial model in Fig. 1, these populations inhabit the zone of adverse temperature effects, especially in the neighborhood of Chencha and Sakhuli villages.

The contribution of variables to the construction of the predictive spatial model for *O. triphylla* is presented on the column diagram in Fig. 2, where the dark blue colour columns show the value of the variable when it is taken into account independently of the others; the light-blue colour columns show the result of excluding the variable from the prediction across the entire set of variables; the lower (red) column demonstrates the total contribution of all the variables to the constructed model.

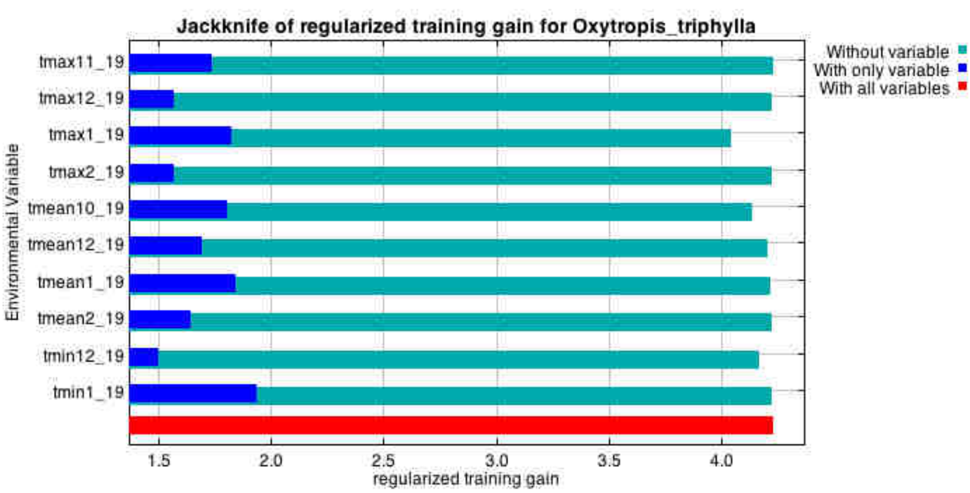

Fig. 2. The diagram of contribution of key temperature indicators to the spatial predictive model of *Oxytropis triphylla*.

According to the individual contribution, the three leading variables are the following (in descending order of values): the minimum temperature in January (tmin1_19), the average temperature in January (tmean1_19) and the maximum temperature in January (tmax1_19).

Consequently, favorable temperature regimes in January largely determine the parts of the range with a high probability of *O. triphylla* finding. The average temperature in October (tmean10_19) and the maximum temperature in November (tmax11_19) also have high significance. The elimination of any variable from the full set of indicators leads to decreasing the training role of the full set, the most noticeable after excluding the maximum temperature of January (tmax1_19), the minimum temperature of December (tmin12_19) and the average temperature of October (tmean10_19).

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