

# Ecotypification of local populations of rare species *Calvatia gigantea* (Basidiomycota: Agaricales) in ultracontinental zones of Mongolia and Russia

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**Abstract.** Study of the levels of climatic comfort in localities of the rare species *Calvatia gigantea* from Agaricales of Basidiomycota is performed using multimodal ecoinformative approach with maximum entropy method. For numerically exact and correct assessment of the level of climate suitability, we propose recalculate the scale of probability finding of a species into a new scale of climate suitability, with the next intervals: low suitable (1–3 points), ambivalent (4–6 points), and genuine suitable (7–9 points). Also there are two transit zones between these intervals. It has been established that local populations of the species in Altai territorial group differ significantly in levels of climatic comfort (3.2, 5.4, and 6.2 points). Local population near Sharangol in Khentei territorial cluster (Central Mongolia) gets 4.0 points of climate comfort, and local population in Khingan Mountains (Eastern Mongolia) gets 7.3 points, the best result in the set studied. The ecotypification of localities was carried out, according to which all the studied populations of *C. gigantea* are assigned to different ecotypes, since each studied locality is characterized by the unique climatic spectrum and the specific variable of the first rank.

## 1 Introduction

This investigation is performed as the part of international scientific collaboration of scientists from Mongolia and Russia in study of mechanisms and adaptive possibilities of spore organisms in extremal environmental conditions of ultracontinental zones of Asia, and supported RFBR and MCESSM, project 19-54-44022 Mong\_T.

Short-term and long-term forecasts of desertification processes influence on stocks, as well as the details of distribution of medicinal basidiomycetes in the territory of Mongolia and adjacent regions of Russia will be prepared in this cooperation. Also the possibilities of using these species of fungi in the treatment of epidemically dangerous diseases will be studied. The methodical part of the experimental studies is supported by the grant of

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Novosibirsk State University (Russia) «Creation and development of the Laboratory for biogeomodeling and ecoinformatics of Faculty for Natural Sciences» under the TOP-100 program.

The purpose of this study to carry out the ecotypification of local populations of *Calvatia gigantea* (Batsch) Lloyd (Fungi: Basidiomycota: Agaricomycetes: Agaricales: Agaricaceae) – rare species of medicinal basidiomycetes in Mongolia and adjacent regions of Russia by climatic modeling to understand the possibilities of the species adaptation to extreme environmental conditions in ultracontinental zones of Asia, and detect the parts of area with the better climatic situation.

## 2 Material and methods

*Calvatia gigantea* (Batsch) Lloyd (= *Lamgermannia gigantea* (Batsch) Rostk.) is a rare species in Mongolia and adjacent regions of Russia, it is included in Mongolian Red Book [1] and Red Book of Altai Republic in the status 4 (= undefined), has economic value as an edible and medicinal fungi [2]. The study was performed for five local populations of *C. gigantea*, they are listed from west to east: 1) near the confluence of rivers Kyrlyk and Charysh in Ust-Kan district of Altai Republic (Russia) [2], with coordinates 084.83E, 50.90N; 2) the vicinity of Cherga in Shebalino district of Altai Republic (Russia) [2], with coordinates 085.56E, 51.57N; 3) the vicinity of Karakol village in Ongudai district of Altai Republic (Russia) [2], with coordinates 085.92E, 50.82N; 4) the vicinity of Sharagol in Khentei Mountains, the central part of Mongolia [1, 3], with coordinates 106.47E, 49.26N; 5) basin of Galdastaingol river in Grant Khingan Mountains in Eastern Mongolia, with coordinates 119.51E, 46.82N.

Probabilistic models for the area of *C. gigantea* in Mongolia and adjacent regions of Russia are constructed on climatic information of WorldClim, an international database of world climate, available at <http://www.worldclim.org>. Modeling was carried out using a full set of all available climatic and bioclimatic variables with spatial scale 1/60 a degree of parallel and meridian, in MAXENT software based on the maximum entropy method [3]. For the first time we propose to include duplicative coordinates, per one for a location, when solitary modeling is run, to increase its supporting in MAXENT program.

For numerically exact and correct assessment levels of climate suitability, we propose recalculate the scale of probability habitats of a species in MAXENT to a new scale of climatic comfort, with three intervals: low suitable (1–3 points), ambivalent (4–6 points), and genuine suitable (7–9 points). Also there are two transit zones between these intervals. Transit zones are helpful when average estimation for polygons is calculated.

According to the new scale, climatic comfort in habitats and around them is evaluated, as well as numerograms are prepared, in the order: three cells in the northern row (north-western, northern, and north-eastern), three cells in the median (western, central = registration point position, eastern), and three cells in the southern row (south-western, southern, and south-eastern).

Numerograms of climatic situation around each of a local population were compiled separately for Altai territorial group of populations (they are included in the climatic cluster, named Zone\_18 in WorldClim), and for Khentei-Khingan territorial group of populations (they are included in the climatic cluster, named Zone\_19 in WorldClim).

Here we propose to determine an intra-species ecotype as such group of populations, which habitat in unique combination of the most important, or most informative, climate variables. In this case, the main climate variables of top 3 have particular importance.

## 3 Results

The climatic situation around Kyrlyk local population (Altai Republic, Russia) of *C. gigantea* is described by the numerogram 156666666. Except low suitable climatic situation in the north-eastern locus, other loci of the polygone have ambivalent level of climatic comfort. The sum of 48 points gives an average climate score of 5.4 points per locus, which corresponds to the ambivalent interval of climate comfort.

The climatic situation around Cherga local population (Altai Republic, Russia) is described by the numerogram 111118196. Most loci have slightly favorable climate, including the central locus with this population. The climate in the southern locus is highly comfort, and in the eastern locus – comfort, and in the south-eastern locus is ambivalent. The sum of 29 points is the lowest in the test, it gives an average climate score of only 3.2 points per locus, which corresponds to values of the transit zone between low suitable and ambivalent climate.

Climate conditions around Karakol local population (Altai Republic, Russia) is described by the numerogram 171966899. Most loci have a contract score, and maximum difference of 8 points is between north-western locus (1 point) and western locus (9 points). The climate in central locus is ambivalent. The climate situation in southern row of loci is suitable or high suitable. The sum of 56 points gives an average climate score of 6.2 points per locus, which corresponds to values of the transit zone between ambivalent and suitable climate.

Climatic conditions around Sharyngol local population (Khentei Mountains, Central Mongolia), can be described as the numerogram 288282222. Most of loci have low suitable climate (2 points), except central, northern and north-eastern ones, where climate is quite favorable (8 points). The sum of 36 points gives an average climate score of 4.0 points per locus, which corresponds to lower border of the ambivalent climate.

The climatic situation in the vicinity of Galdastaingol population (Great Khingan Mountains, Eastern Mongolia) is described by the numerogram 887868687. Most loci are characterized of low-suitable climate, with except of central, northern and north-eastern loci, where climate is favorable. The sum of 66 points is the higher in the test, and the average climate score is 7.3 points per locus, which corresponds to values of favorable climate.

The list of most informative variables in the top of climatic spectra for regional models, generated separately for each of local populations of *C. gigantea*, with using of duplicate coordinate tags, is presented in Table.

According to ecotype definition given above, all the studied local populations can be considered as different ecotypes. Their key indicators are presented below.

1. Kyrlyk ecotype of *C. gigantea* is diagnosed with the key indicator – amount of precipitation in the warmest quarter of year (bio18\_18; informative influence on the regional model Zone\_18 is 24.2%, Table), and two additional indicators: average annual temperature of surface air (bio1\_18; influence 16.1%) and annual amount of precipitation (bio12\_18; influence 13.0%).

2. Cherga ecotype of *C. gigantea* is diagnosed with the key indicator – maximum average biurnal temperature of surface air in the warmest period of year (bio19\_18; informative contribution in the regional model of Zone\_18 is 29.0%), and two additional indicators: maximum average biurnal temperature of surface air in March (tmax3\_18; the contribution is 13.4%), and annual amount of precipitation (bio12\_18; the contribution is 11.8%).

3. Karakol ecotype of *C. gigantea* is diagnosed with the key indicator – amount of precipitation in the coldest quarter of year (bio19\_18; informative contribution in the regional model of Zone\_18 is 17.2%), and two additional indicators: amount of precipitation in the warmest quarter of year (bio18\_18; the contribution is 16.5%), and maximum average biurnal temperature of surface air in July (tmax7\_18; the contribution is 15.1%).

**Table.** The most informative variables in the top of climatic spectra for regional models, generated separately for each of local populations of *Calvatia gigantea*.

Territorial group:	Altai, Russia			Khentei-Khinggan, Mongolia	
Location:	Kyrlyk	Cherga	Karakol	Sharyngol	Galdastaingol
Numerogram:	156666666	111118196	171966899	288282222	887868687
Climatic variables and its ranks					
bio18_18 / bio18_19	<b>1</b>	4	<b>2</b>	(13)	10
bio1_18 / bio1_19	<b>2</b>	–	12.9	–	7
bio12_18 / bio12_19	<b>3</b>	<b>3</b>	(19–20)	4	–
bio5_18 / bio5_19	(17)	<b>1</b>	(14–15)	–	(12–13)
tmax3_18 / tmax3_19	–	<b>2</b>	6	5	–
tmax1_18 / tmax1_19	(19–21)	5	(11–12)	–	–
bio19_18 / bio19_19	–	(12–13)	<b>1</b>	–	–
tmax7_18 / tmax7_19	(13)	(19)	<b>3</b>	8	11
tmean1_18/tmean1_19	–	–	5	<b>1</b>	6
tmean4_18/tmean4_19	5	–	10	<b>2</b>	8
tmean10_18/tmean10_19	9	–	–	<b>3</b>	<b>2</b>
tmin12_18/tmean12_19	–	–	–	(16–18)	<b>1</b>
bio16_18 / bio16_19	(11)	9	–	–	<b>3</b>
bio9_18 / bio9_19	–	–	–	–	4
tmin5_18 / tmin5_19	(18)	–	(19–20)	9	5

4. Sharyngol-ecotype of *C. gigantea* is diagnosed with the key indicator – average monthly temperature of surface air in January (tmean1\_19; individual contribution in the model Zone\_19 is 29.6%), and two additional indicators: average monthly temperature of surface air in April (tmean4\_19; the contribution is 21.1%) and average monthly temperature of surface air in October (tmean10\_19; the contribution is 16.3%).

5. Galdastaingol-ecotype of *C. gigantea* is diagnosed with the key indicator – minimum average biurnal temperature of surface air in December (tmin12\_19; individual contribution in the regional model Zone\_19 is 23.7%), and two additional indicators: average monthly temperature of surface air in October (tmean10\_19; the contribution is 19.4%) and amount of precipitation in the wettest quarter of year (bio16\_19; the contribution is 16.5%).

## 4 Discussion

According to results of performed ecoinformative assessment, it was found that local populations of *C. gigantea* in Mongolia and adjacent regions of Russia habitat in very contrast ecological conditions. Average climate score variates from 3.2 to 6.2 points in Altai territorial group, and from 4.0 to 7.3 points in Khentei-Khinggan territorial group.

The ecological condition around the local population near Karakol locality has 6.2 points of a suitability, and such value is in the transit zone between ambivalent and suitable

conditions; the local population in the vicinity of Kyrlyk locality (5.4 points) – in ambivalent, and near Cherga locality (3.2 points; minimum value in the test) – in the transit zone between ambivalent and low suitable, closely to low suitable conditions. Sharyngol local population (Khentei Mountains, Central Mongolia) exists in the ambivalent climate (4.0 points, i.e. on the lower border of ambivalent interval). Finally, Khingan site of the range in Eastern Mongolia is in the most comfortable climate – 7.3 points per locus of a small polygon, and this value belongs to the interval of favorable climate. Thus, very contrast environmental conditions in ultra-continental zones of Asia produce high level of difference between habitats of local populations of *C. gigantea*.

The ecotypification of localities was carried out, according to which all the studied populations of *C. gigantea* are assigned to different ecotypes, since each studied locality is characterized by the unique climatic spectrum and the specific variable of the first rank.

Altai territorial group of ecotypes can be determined with amount of precipitation in the warmest quarter of year (variable bio18\_18). In contrast, Khentei-Khingan territorial group of ecotypes is strongly influenced by the average monthly temperature of surface air in October (variable tmean10\_19).

These results confirm the prospects of ecoinformative approaches in the solving of questions with rare species conservation.

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