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Climatically induced trends of change of floristic composition in forest communities in Northern Baikal region (Southern Siberia)

Cambio en la composición florística de las comunidades boscosas inducidas por el clima en el norte de la región Baikal (sur de Siberia)

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SUMMARY

Calculations of the activity indices and species richness of belt-zonal elements of the flora of Baikal region forests have been done in order to reveal the presence of climatogenic changes. The results provided evidence for the weakening status of xerophilic species in the floristic composition of hemiboreal light coniferous forests (with dominance of *Pinus sylvestris*). On the contrary, no significant change has been observed in the floristic composition of mountain light coniferous boreal forests (with dominance of *Larix gmelinii*). Besides, it was found that there was an increase in activity of the species of the dark-coniferous belt-zonal group peculiar to dark-coniferous boreal forests (with dominance *Abies sibirica* and *Pinus sibirica*).

Key words: flora, forests, climate warming, Baikal region, Siberia.

RESUMEN

Se calcularon los índices de actividad y riqueza de especies de los elementos zonales de la flora de los bosques de la región Baikal, con el fin de revelar la presencia de cambios climatogénicos. Los resultados entregan evidencia del estado de debilitamiento de las especies xerofílicas en la composición florística de los bosques de coníferas de luz hemiboreales (con dominancia de *Pinus sylvestris*). Por el contrario, no se observaron cambios significativos en la composición florística de los bosques boreales montañosos de coníferas de luz (with dominance of *Larix gmelinii*). Además, se encontró un aumento en la actividad de especies del grupo zonal de coníferas oscuras, peculiar de los bosques boreales de coníferas oscuras (con dominancia de *Abies sibirica* y *Pinus sibirica*).

Palabras clave: flora, bosques, calentamiento climático, región Baikal, Siberia.

INTRODUCTION

In most regions across the globe, the currently recorded climate warming leads to changes in composition, structure and functioning of plant ecosystems (Gitay *et al.* 2002). Some of previously made predictions as to the magnitude of temperature rise (Budyko and Izrael 1987) and, accordingly, displacement of the boundaries of natural zones by the year 2000 (Kobak and Kondrashova 1992) have lacked support from any known factual evidence. Nevertheless, there are sufficiently dramatic changes in ecosystems which are associated with climate warming, such as displacement of phenological phenomena (Menzel and Estrella 2001), and expansion of thermophilic plant species (Walther 2000, Sobrino Vesperinas *et al.* 2001). On the other hand, many changes have a latent character which manifests itself only through a detailed analysis of the parameters of ecosystems.

The aim of this study is to estimate probable climatic changes on the northern part of Baikal region happened at the recent time. This is supported by analysis of composition and structure of cenoflora of classes of forest vegetation. According to this data the prognosis of future potential climatogenic trends in vegetation dynamics has been discussed.

METHODS

This research was performed on the western macroslope of Ikatskii Ridge (light-coniferous hemiboreal and boreal forests), on Upper-Angara depression, on the western and eastern macroslopes of the southern part of Barguzinsky Range, and on the northeastern macroslope of the Svyatoi Nos Peninsula (dark-coniferous boreal forests) in the northern Baikal region.

The study areas (500 to 1,500 m a.s.l.) were situated in the region where permafrost rocks may have a continuous, discontinuous, or insular distribution. The annual average temperature was varying up 0 ºC to -6.7 ºC, and the annual amount of precipitation varied from 300 to 1,000 mm (Federal Service of Geodesy and Cartography of Russia 1993).

Analysis of floristic composition performed on basis of about 500 geobotanical descriptions of forest phytocenosis (releves), where full floristic composition and cover-abundance of individual plant species was estimated. Releves were performed on the 200 m^2 plots along the altitudinal transects from summit to foothill of mountain macroslopes. Classification of vegetation was generated through the use of the TURBO (VEG) software package (Hennekens 1996) within the framework of the ecologo-floristic approach (the Braun-Blanquet approach) according to which dark-coniferous and boreal light-coniferous forests refer to the class *Vaccinio-Piceetea* Br.-Bl. in Br.-Bl., Siss. *et* Vlieger 1939, and hemiboreal light-coniferous forests refer to the class *Rhytidio rugosi-Laricetea sibiricae* K. Korotkov *et* Ermakov 1999.

The floristic composition of dark-coniferous forests, light-coniferous boreal forests and light-coniferous hemiboreal forests were taken in our study as the cenoflora, which is consistent with contemporary tenets of comparative floristics (Yurtsev 1987, Bulokhov 1993).

The ecologo-geographical groups of species were determined according to (Malyshev and Peshkova 1984). Species of the forest floristic complex were classified into dark coniferous (DC), light coniferous (LC), and preboreal (PB) groups. In addition, the cenofloras included species of the steppe floristic complex with forest–steppe (FS), mountain steppe (MS), and true steppe (TS) groups; the highmountain and mountain zonal complexes combined into the montane group (MM), and the azonal complex classified as the meadow group (MG), separately was singled out aquatichelad group (AH).

The analysis of the relationships of activity ranks and species richness for the ecologo-geographical groups of the cenoflora was carried out following the scheme reported in (Telyatnikov 2001). For the species of the cenoflora the activity indices were determined according to (Yurtsev 1968), and class intervals were calculated for the species richness of the ecologo-geographical groups of species. Accordingly, the activity was calculated as, $R=\sqrt{AB/N}$ [1], where R was a species activity, A was a sum of coverages of the species of the belt-zonal group in a given syntaxon, B was the occurrence frequency of these species, and N was the number of descriptions.

To calculate the class intervals, the following equation was used, $C=(X_{max}–X_{min})/K$ [2], where C was a class interval, X_{max} was the maximum value of partial activity or of the number of species, X_{min} was the minimum value of partial activity or of the number of species, and k was the number of belt-zonal groups.

RESULTS

In light-coniferous hemiboreal forests of class Rhytidio-Laricetea the ranks of activity and species richness coincided with each other in the dark coniferous, preboreal, light coniferous, and forest–steppe groups, but in the mountain steppe and true steppe groups, the ranks of species diversity were higher than the ranks of activity (table 1).

In the cenoflora of light-coniferous boreal forests of class Vaccinio-Piceetea the ranks of activity and species diversity coincided in all constituent zonal elements (table 2). This may be regarded as evidence that this cenoflora had existed for a long time under relatively stable climatic conditions.

Analysis of the activity and species richness of dark-coniferous forests pointed to a consistency of the rank indices both in activity and in species richness for almost all ecologo-geographical groups of species (table 3). The sole exception was provided only by the dark-coniferous group where the activity class of species was more than the class of species richness. Such an exceeding may be a sign the onset of the more favorable conditions for the species of this group in the recent past.

DISCUSSION

Tendencies in the dynamics of climate in certain areas depend on their geographic location (Kislov 2001). For example, recent warming is well manifested in continental regions, Asia in particular, and tendencies characteristic of the Asian continent as a whole can also be observed in central Transbaikalia. Climatic trends in the warm and cold seasons are opposite in this region, with winters becoming warmer and summers becoming colder: over 51 years, the average temperature of the cold season increased by 0.37 ºC and that of the warm season decreased by 0.31 ºC (Kulikov *et al.* 1997). It is apparent that the general climate warming is accounted for by the increase in winter temperatures. In the Baikal region as a whole, the annual average air temperature also increased by 3.5 ºC over 100 years (Gruza and Ran'kova 2004).

Hemisphere predict a 10–20 % increase in the amount of precipitation (Budyko *et al.* 1991, Izrael *et al.* 1999). A trend toward an increase in the annual amount of precipitation (by 33 mm over 50 years) has already manifested itself in central Transbaikalia (Kulikov *et al.* 1997). Similar climatic trends in this region are also described by Bazhenova and Martyanova (2003).

There is a well known concept that the number of species colonizing a certain area is initially small, but they exhibit a high landscape activity; thereafter, along with differentiation of niches, the total species diversity increases, whereas the activity of most species proves to be low. When florocenogenetic changes take place, this is first manifested in a decreasing activity of some species (which will be displaced), and then the total number of species begins to decrease.

There is evidence that dark coniferous, preboreal, light coniferous, and forest–steppe groups exist under relatively stable climatic conditions in light-coniferous hemiboreal forests. Therefore, we may consider that climate warming over the past 50 years has not yet affected the species richness and activity of these groups. Apparently, certain conditions unfavorable for mountain steppe and true steppe groups developed in the ecotopes of this cenoflora in the

Table 1. Species richness and activity indices ecologo-geographical groups of light-coniferous hemiboreal forests.
Riqueza de especies e índices de actividad de grupos ecológico-geográficos de bosques hemiboreales de coníferas.

Index	Belt-zonal group					
	DC	PB	LC	FS	MS	TS
Total coverage of species %	17	64	1496	1074	651.5	195.5
Frequency of species occurrence	9	27	577	621	467	140
Species richness	4	3	35	40	40	21
Activity, points	0.18	0.59	13.27	11.67	7.88	2.36
Species richness class	6	6	1	1	1	3
Activity class	6	6	1	1	3	5
Difference	0	0	0	0	-2	-2

Table 2. Species richness and activity indices of ecologo-geographical groups of light-coniferous boreal forests.
Riqueza de especies e índices de actividad de grupos ecológico-geográficos de bosques boreales de coníferas de luz.

Index	Belt-zonal group						
	MM	MG	MS	FS	PB	DC	LC
Total coverage of species, %	256.5	59.5	29	175.5	95.5	1,004	3,425
Frequency of species occurrence	54	20	17	92	33	150	791
Species richness	6	3	2	9	3	13	52
Activity, points	1.81	0.53	0.34	1.95	0.86	5.97	25.32
Species richness class	7	7	7	7	7	6	1
Activity class	7	7	7	7	7	6	1
Difference	0	0	0	0	0	0	0

Table 3. Species richness and activity indices of ecologo-geographical groups of dark-coniferous forests.
Riqueza de especies e índices de actividad de grupos ecológico-geográficos de bosques boreales de coníferas oscuras.

Index	Belt-zonal groups					
	MM	LC	DC	PB	MG	AH
Total coverage of species, %	81.0	1,344.0	1,169.5	197.5	98.0	51.5
Frequency of species occurrence	18	323	275	16	38	15
Species richness	5	60	41	9	6	7
Activity, points	0.85	14.64	12.60	1.25	1.36	0.62
Species richness class	6	1	3	6	6	6
Activity class	6	1	1	6	6	6
Difference	0	0	+2	0	0	0

near past. As true steppe species belong to arids in climatological terms, such unfavorable conditions can be created by more abundant moisture supply resulting from increasing precipitation and permafrost thawing. Conversely, more mesophilic groups represented by species of the forest floristic complex improve their competitiveness under such conditions. As the observed trends of temperature and humidity are consistent, the activity of the steppe species complex in the cenoflora of class Rhytidio-Laricetea will probably further decrease. Thus, differentiation of the floristic composition with a tendency toward its mesophytization will take place in this cenoflora.

The cenoflora of the dark-coniferous forests includes an extensive variety of shade-loving moderately thermophilic mesophytes and mesohygrophytes. Such species are the most numerous and constitute the core of the dark-coniferous ecologo-geographical group. As regards the other groups forming part of the cenoflora of dark-coniferous forests, high indices of activity and species richness correspond to the light-coniferous ecologo-geographical group. Ecologically, its species are more heliophilic and somewhat more cryophilic. The species of these two belt-zonal groups predominate in the cenoflora of dark-coniferous forests both in the quantity and in the phytocenotic role. The species of the other belt-zonal groups in the cenoflora of dark-coniferous forests are few in number and show low activity.

The territories under study are part of drainage basin of Lake Baikal, which have been designated by UNESCO as

World Heritage Site. Therefore active anthropogenic impact on forest ecosystems was limited in the XX century. The fire and selective logging are basic destabilizing factors for forest ecosystems, but these factors don't brining to irreversible changes of vegetation, soil degradation and soil erosion.

The main assignment of Baikal region forests is the realization of water and soil protective functions, as well as biodiversity conservation. Anthropogenic fire is the particularly strong risk for forest ecosystems of Baikal region. The authors consider that significant purpose in recent time is the maximal decrease of anthropogenic fire, especially in the light-coniferous hemiboreal forests and the strict control for the recreation activity in the Baikal region forests.

CONCLUSIONS

Based on the data received we can conclude that due to climate warming, ecological differentiation takes place in the cenoflora of hemiboreal light-coniferous forests of class Rhytidio-Laricetea. In this class the status of xerophilic species represented by plants of the mountain steppe and true steppe groups weaken due to an increase in moisture supply in habitats on mountain slopes in the lower part of the forest belt.

The observed tendencies of changes in the composition of cenofloras indicate that habitats in the lower band of mountain slopes of ultra continental climatic sectors become wetter due to increasing of precipitation and degradation (thawing) of permafrost.

Current climatic changes have not yet affected the composition of plant species and parameters of their activity in the upper part of the forest belt of ultra continental climatic sectors, which is reflected in the equilibrium between the ranks of activity and species richness in zonal groups of species in the cenoflora of boreal light-coniferous forests of class Vaccinio-Piceetea.

Contemporary climate change is favorable for dark-coniferous species that can be evidence of mitigation of climate continentality in dark-coniferous habitat.

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