BIODIVERSITY OF SAYANO-SHUSHENSKY NATURE RESERVE

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Abstract

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The Sayano-Shushensky Nature Reserve is a standard primeval locus of high conservation value which remained undisturbed landscapes within the Altai-Sayan Mountain Land. In the plant cover the altitudinal belts are clearly expressed. The northern part of the Sayan-Shushensky reserve is included in moist areas of the Altai-Sayan forest vegetation zone and the southern part of it is included in insufficiently moist areas of Central Asian forest zone. The ground vegetation of the reserve is presented by high-mountain tundra, meadows and shrub thicket sites, high-mountain open *Pinus sibirica* D u. T o u r. and *Larix sibirica* L e d e b. woodland, dark and light coniferous taiga, coniferous subtaiga, forest-steppe and steppe. As a whole forests occupy somewhat about 60% of the territory.

Ecocenotic groups of species found in individual phytocoenoses in river basins of the northern part of the nature reserve are qualitatively different in composition and share from those ones found in the southern river basins. In the north, the high mountain ecocenotic species group enjoys the greatest abundance, and forest-meadow, taiga, and bog species are also represented substantially. Steppe and forest-steppe species are absent. Alpine, steppe, and forest-steppe species are found in equal shares in the southern part of the forest reserve. Invasive species are quite many. Taiga species contribution is three times less than in the north of the reserve.

Conditions climatically optimal for the greatest species diversity are the result of a perfect balance of heat and moisture characteristics of subtaiga/forest-steppe altitudinal belt complexes (ABC). However, changes in phytochorological- and alpha-diversity of individual phytocoenoses are influenced by ecological and phytocoenotic factors combined. The biggest number of species in the reserve occurs along the forest distribution boundaries - in subtaiga and high mountain open woodland whereas species are the fewest in mountain taiga. Conversely, phytomass loading is the greatest in mountain taiga and it decreases gradually towards alpine tundra and steppes.

Key words: Nature Reserves, Vascular Plant Species of the Nature Reserves, phytochorological diversity, alpha-diversity

Introduction

This research study first attempted to look at the interaction between various biodiversity aspects of the forest reserve - from altitudinal belt complexes (ABC) to species diversity of individual phytocoenoses (alpha-diversity).

Materials and methods

The Sayano-Shushensky Nature Reserve was founded in 1976. Its area is 390,4 thousand ha, its location is 51°45'-52°38' N, 91°05'-92°27' E. It is located on the left bank of the Yenisey river, in the central part of Western Sayan and of Altai-Sayan Mountain Land. The relief is middle- and high-mountainous, and has a maximum height of 2772 m above sea level. The ridges are cut with canyon-like vallies. In the plant cover the altitudinal belts are clearly expressed. The northern part of Sayan-Shushensky reserve (the meteorological station Karakhem) is included in moist areas of the Altai-Sayan forest vegetation zone (Polikarpov et al., 1986; USSR Climate Guide Book, 1967, 1969). Core district is presented by mountain taiga dark coniferous, high-mountain open *Pinus sibirica* D u. T o u r. woodland, high-mountain tundra, meadows and shrub thicket sites. The southern part of Sayan-Shushensky reserve (the meteorological station Ust-Usa) is included into insufficiently moist areas of Central Asian forest zone. On southern macroslope of the Sayansky ridge and northern macroslope of Khemchiksky ridge the light coniferous taiga dominated by Siberian larch prevails. The basis belt is formed by light coniferous herb forests (subtaiga), forest-steppe and steppe.

When studying ground vegetation of the reserve (1979-1999 years) the topoecological profiles have been established in river basins of its northern and southern parts. On sample plots of these transects 296 geobotanical descriptions were made according to methodology of Sukachev, Zonn (1961). The area of wood sample plots makes 25 ha and that one of the non-wood plots (tundra, meadow, steppe) is 0.01 ha. Ground vegetation is differentiated in altitudinal belt complexes (ABC). Species diversity of specific phytocoenoses has been analyzed according to belonging species to different ecological-cenotic groups.

We compiled diagnostic tables for on-ground inventory of the forest reserve ground vegetation (1983). Forest inventory data from the Regional Forest Inventory Enterprise were based upon to built a map of forest cover (Vlasenko, 1996) and rare and endangered species (Vlasenko, 2002), as well as to estimate the aboveground phytomass loading using methodologies of Stakanov et al. (1994) and Titlyanova et al. (1993).

Relative similarity of the nature reserves in floristic diversity was calculated using Jaccard's coefficient.

Phytochorological diversity of the nature reserve was evaluated (Vlasenko, 2003) and species diversity (alpha-diversity) of individual phytocoenoses was analyzed by ecocenotic groups for the humid and arid parts of the reserve. Methodologies of Tchebakova and Parfenova (Tchebakova, 1983; Parfenova et al., 2004) were applied to establish alpha-diversity dependence on climatic factors.

T a b l e 1. Phytomass storage in altitudinal belt complex (ABC) of the Sayano-Shushensky nature reserve

Altitudinal belt complex (ABC)	Area (S), thousand ha / Phytomass storage (M), thousand t. areas coverd by forest (S/M)			S/M Covered by steppe	Total area of ABCs S (thous. ha) M (thous. t) S/M	Density, t/ha of ABC
	wood	young growth, underwood	ground vegetation			
Forest-steppe	2.2/188	2.2/1.7	2.2/5.3	39/81	41.2/277	6.7* 9.3**
Subtaiga	38/3388	38/56	38/178		37.9/3622	95.6*
Taiga mountain	152.7/17779	152.7/8889	152.7/489		152.7/18553	121*
High-mountain open woodland	56.7/3160	56.7/51	56.7/907		56.7/4119	72.6*
High-mountain tundra and meadows					43.3/541	12.5

* For calculation of the phytomass storage, we used V. Stakanov's et al. (1994) methodology

**For calculation of the phytomass storage, we used A. Titlyanova's et al. (1993) methodology

Results and discussion

As a result of the forest reserve inventory the 15 000 elementary forest units were registered. For the purpose of classifying ground vegetation we combined them into 362 associations. The associations were divided into 112 association groups that, in turn, formed 32 association series found in five altitudinal belt complexes (ABC) (Vlasenko, 1996, 2003).

The following ABCs were found in the northern part of the forest reserve: tundra and alpine meadows (1800-2500 m above sea level); subgolets and subalpine open Siberian pine (*Pinus sibirica*) woodlands (1640-1800 m above sea level); and mountain taiga Siberian pine and fir stands (500-1640 m above sea level). Before the Sayan-Shushensky power-station dam had been constructed, on the Yenisey river terraces and south-facing lower parts of slopes the fragments of black taiga (chern) and subtaiga were distributed.

Extremely continental climate in the south of the nature reserve is responsible for slope asymmetry in terms of landscape: mountain taiga ABC of Siberian pine and larch stands (*Larix sibirica* L e d e b.) dominates below ABC of tundra and alpine meadows and that one of subgolets and subalpine open Siberian pine/larch woodlands on northern and eastern slopes, while south- and west-facing slopes are characterized by a combination of Scotch pine, larch and Siberian pine ABCs with ABCs of steppes and steppe-like open Scotch pine and larch woodlands.

The total area of the high-mountain tundra, meadows and shrub thicket sites is 43 278 ha, high mountain woodland - 56 700 ha, mountain taiga - 152 700 ha, subtaiga coniferous lucida - 37 900 ha, forest-steppe - 2 200 ha and steppe - 39 000 ha (Table 1).

As a whole, the forests occupy somewhat about 60% of the territory. They are presented by Siberian cedar, Scotch pine, Siberian larch, fir, spruce, birch, aspen and mixed forest formations. As for forest type groups, stands with shrubs (117 121 ha), low shrubs (60 036 ha), *Carex/ Calamagrostis* (32 168 ha), and *Bergenia crassifolia* [L.] F r i t s c h (21 493 ha) dominate in the forest reserve. Other forest type groups are found much rarely and take totally 29 323 ha.

The greatest phytomass storage is accumulated in mountain taiga - 18 553 t (specific weight-121 t/ha). The phytomass of the high-mountain open woodland is 4119 t (specific weight- 72.6 t/ha), that one of subtaiga is 3622 t (95,6 t/ha), that one of high-mountain tundra and meadows makes 541 t (12,5 t/ha), and that of forest-steppe is 277 t (9.3 t/ha) (Table 1).

According to Sonnikova's (1992) summary, 982 higher vascular plant species there exist in the nature reserve which number makes up 39% of the flora of the Altai-Sayan Mountain Land (Vlasenko, 2003).

For the floristic analysis, its species composition was divided into four altitudinal belt groups: a high mountain, a taiga, a chern (black) taiga, and a subtaiga-forest steppe groups. This division rests on a chorological principle that phytocoenotypes of vegetation groups are joint between each other within an altitudinal belt, or, according to Galanin (1989), a principle of phytochorological diversity.

High mountain group includes species occurring in alpine and subalpine meadows, high-mountain tundra sites, and open woodlands. In high mountains, forest forming woody species quit to be edificators. High mountain shrubs and grass-small shrub and lichen-moss layers become coedificators here.

The environmental role of both dark-needle and light-needle major woody species, or violents, is best exhibited in the **taiga group**. Shade-tolerant perennials prevail in the grass/ small shrub layer, while lichens and mosses occur as a continuous ground cover.

As a result of fir mortality, "canopy windows" occur in stands falling into the **chern taiga group** of species. The group includes open dark-needle stands with grass ground cover and elements of nemoral (relict) complex. The ground patches within "windows" are rapidly colonized by forest forbs which hamper woody species regeneration.

The subtaiga forest-steppe group encompasses species found in light-needle/forbs stands with mesophills and xerophills in the ground vegetation. These are mostly meadows and steppes remarkable for moisture deficit.

The following number of species was found to make phytochorological diversity in different ABCs: 326 for high mountain ABC, 107 species for taiga ABC, no chern taiga, and 484 species for subtaiga/forest-steppe ABC. Among the ecotopes under study (Flora Sibiriae, 1987-1997) the greatest number of species (162) was found on stone outcrops, rocks called kurums. From 33 to 54 species were recorded in excessively wet ecotopes - river and lake floodplains and boggy sites. Invasive species and those preferring shrub thickets and pebble and sandy sites are also quite a few (26, 19, and 19, respectively). Only solitary plants were found of parasitic species and of those characteristic for talus, bight, vacant, and limestone sites.

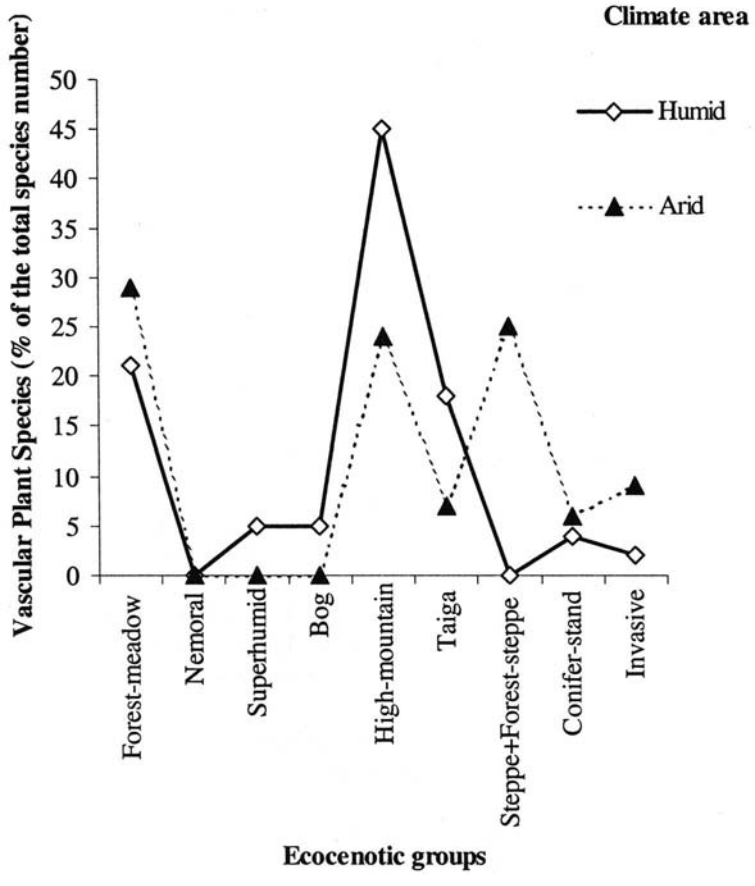

Fig. 1. Proportions of ecocenotic species groups in phytocoenoses of the northern (humid) vs. southern (arid) parts of Sayano-Shushensky nature reserve.

The nature reserve flora is quite close to that one of the Altaisky, Katunsky and Azas nature reserves in species composition (similarity coefficient ranges from 0.45 to 0.47) (Vlasenko, 2003).

A geobotanical study of the northern (humid) part of the reserve revealed 256 higher vascular plant species. The species diversity in ecocenotic groups is as follows (Fig.1): the high mountain group (alpine, subalpine) is the biggest one (45%); forest-meadow species with tall forest grasses and forest and meadow species, account for 21% of the total diversity; taiga group species are 18%; species group in superhumid sites makes 5% and bog species group is also 5%. Other ecocenotic groups are inconsiderable (less than 5% of the total biodiversity).

Of total 407 higher vascular plant species we recorded in the southern part (continental climate) of the reserve. Forest-meadow species with tall forest grasses and forest and meadow species, plus small stream-side, floodplain and shrub/floodplain species account for 29.5%; the 24.5% is made up by steppe and forest-steppe species; 24% - by alpine species; 6.5% is made by taiga species; 6% - by conifer stand species; and 9% are invasive species. Other ecocenotic groups are inconsiderable (less than 5% of the total biodiversity).

The analysis of species composition of individual phytocoenoses has shown minimum number of species (2-8) in tundra, steppe, and mountain taiga, with one absolute dominant. Maximum number of species (63-97) was found to be remarkable for river valleys, in subtaiga forest, and subalpine open woodlands. Typically, a moderate human-caused stress promotes species diversity and forest regeneration damaged by wild fires and forest cuts.

When investigating how individual phytocoenosis species diversity depends on climatic factors related to known topographic characteristics (absolute elevation above sea level, also exposition and angulus of slopes), climatic phytocoenosis parameters, such as annual Radiation Balance, annual precipitation, and Radiation Dryness Index were calculated using data from the Karakhem and Ust- Usa meteorological stations nearest to the transects (USSR Climate Guide- Book, 1967, 1969).

Ordinating the number (N) of phytocoenoses within the radiation balance field has shown the points to be widely scattered. This scattering is attributed not only to climate, but to the combined effect of ecological and phytocoenotic factors. We assumed the curve lining this field to be responsible for maximun climate-related diversity (N). The dependence of the number of species on the available heat and moisture (Dryness Index, DI) in a given site is described by the equation:

$$N = -56.7 + 5.89\ RB + 54.39\ DI - 0.089\ (RB)^2 - 29.64\ (DI)^2;\ R^2 = 0.70.$$

Based on the curve, maximum number of species is found in sites with optimal heat and moisture regimes, which are characterized by Radiation Balance (RB) 33-37 Kcal cm sq./ yr. and Dryness Index (DI) 0.8-1.2. These climatic characteristics are usually realized in the subtaiga/forest-steppe belt (Fig. 2).

The analysis of the drivers of alpha- and phytochorological diversity along the altitudinal gradient suggested that species diversity is an integral indicator of climatic and, to a considerable extent, phytocoenotic conditions. In the light-needle open forest stands with grass ground cover found in subtaiga/forest-steppe ABCs, the greatest species diversity is a result of optimally combined heat, moisture, and moderate environmental pressure of the edificator layer and human activities.

The environmental role of the both dark-needle and light-needle major woody species, or violents, is best exhibited in the taiga. As the edificator layer forms a closed canopy, subordinate vegetation layers suffer from deficit of light, heat, moisture and nutrients resulting in their species composition impoverishment.

Cold and humid climate of high mountains hampers the normal woody species development, which results in open woodland occurrence. High mountain open woodlands are underheated but have enough moisture and mineral nutrients for developing sound subordinate vegetation layers. As a result, species become more diverse as compared to taiga,

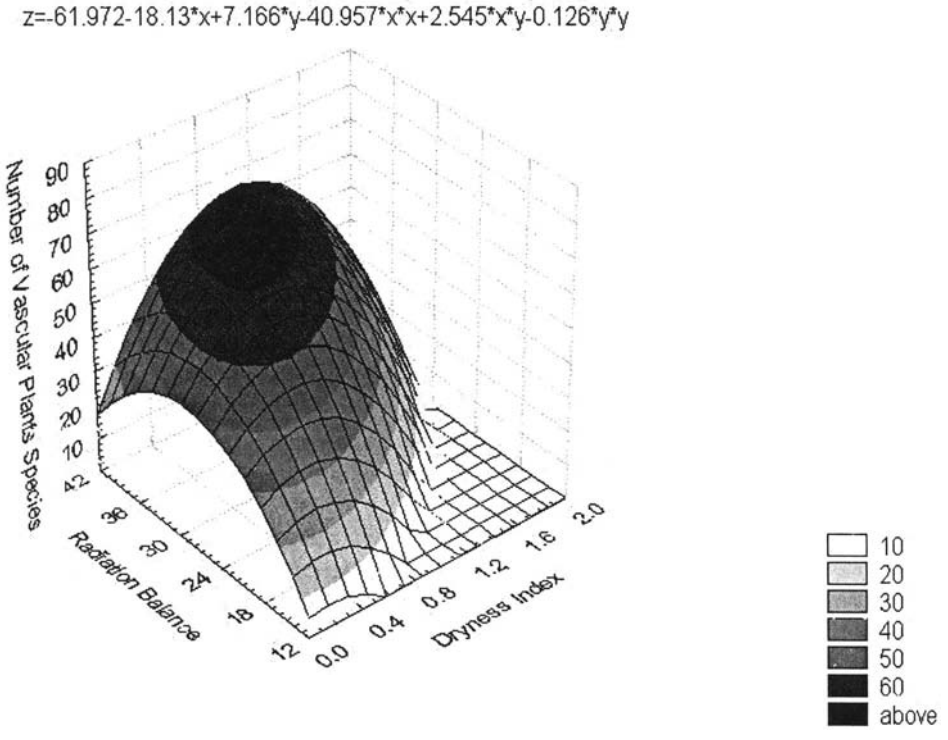

Fig. 2. Dependence of the number of higher vascular plant species on heat (Radiation Balance, Kcal cm sq./yr.) and moisture (Dryness Index) availability in phytocoenoses of Sayano-Shushensky nature reserve.

however, the diversity is twice less than in subtaiga/forest-steppe ABCs. Conversely, phytomass loading is the biggest (121.4 t/ha) in the mountain taiga and it decreases gradually towards the mountain tundra (125 t/ha) and forest-steppe (9.3 t/ha).

Conclusions

1. As Sayano-Shushensky nature reserve is situated in the center of Altai-Sayan Mountain Land and encompasses a big area and, hence, a wide range of geomorphological and ecological conditions, its vegetation cover is highly diverse at all structure levels including ABCs, major woody species composition, typological structure, and higher vascular plant species composition.
2. Ecocenotic groups of species found in individual phytocoenoses in river basins of the northern part of the nature reserve are qualitatively different in composition and share from those ones found in the southern river basins. In the north, the high mountain

ecocenotic species group enjoys the greatest abundance, and forest-meadow, taiga, and bog species are also represented substantially. Steppe and forest-steppe species are absent. Alpine, steppe, and forest-steppe species are found in equal shares in the southern part of the forest reserve. Invasive species are quite many. Taiga species contribution is three times less than in the north of the reserve.

3. Conditions climatically optimal for the greatest species diversity are the result of a perfect balance of heat and moisture characteristic of subtaiga/forest-steppe ABCs. However, changes in phytochorological diversity and species abundance (alpha-diversity) of individual phytocoenoses are influenced by ecological and phytocoenotic factors combined. The biggest number of species in the reserve occurs along the forest distribution boundaries - in subtaiga/forest-steppe and high mountain ABCs, whereas species are the fewest in mountain taiga. Conversely, phytomass loading is the greatest in mountain taiga and it decreases gradually towards alpine tundra and steppes.

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Vlasenko V., Parfenova E.: **Biodiverzita Sajansko-Šušenskej prírodnej rezervácie.**

Sajansko-Šušenská prírodná rezervácia je štandardným pralesom vysokej konzervačnej hodnoty, ktorá v Altajsko-Sajanskej hornatej krajine ostala nedotknutá. V rastlinnom pokryve sú výškové pásy jasné. Severná časť Sajansko-Šušenskej rezervácie je súčasťou vlhkej oblasti Altajsko-Sajanskej lesnej vegetačnej zóny a jej južná časť je súčasťou nedostatočne vlhkej oblasti stredoázijskej lesnej zóny. Nadzemná vegetácia rezervácie sa nachádza na vysokohorských tundrách, lúkach a hustých krovinách, v lesoch s *Pinus sibirica* D u. T o u r. a *Larix sibirica* L e d e b., tmavej a svetlej koniférnej tajge, koniférnej subtajge, lesostepi a stepi. Asi 60% územia sú lesy.

Ekocenotické skupiny druhov, nachádzajúcich sa v jednotlivých fytocenózach v riečnej kotline severnej časti prírodnej rezervácie, sú z hľadiska zloženia kvalitatívne rozdielne. Na severe vysokohorské ekocenotické skupiny druhov majú v hojnom možstve najvyššiu abundanciu a sú tu aj leso-lúčne, tajgové a rašeliniskové druhy. Stepné a lesostepné druhy však chýbajú. Alpínske, stepné a lesostepné druhy sú na južnej strane rezervácie v rovnakom pomere. Inváznych druhov je oveľa viacej. Tajgových druhov je trikrát menej ako na severe rezervácie. Klimaticky optimálne podmienky pre najväčšiu druhovú diverzitu sú lesostepné výškové pásma výsledkom perfektnej rovnováhy tepla a vlahy charakteristickej pre subtajgu. Avšak zmeny vo fytochorologickej a alfa-diverzite jednotlivých fytocenóz ovplyvňujú ekologické a fytocenotické faktory. Najväčší počet druhov v rezervácii sa objavuje pozdĺž distribučných hraníc lesa - v subtajge a vo vysokohorských otvorených lesoch, kým najmenej druhov je v horskej tajge. Naopak, záťaž fytomasy je najväčší v horskej tajge a smerom k alpínskej tundre a stepi sa postupne znižuje.