Botanica Pacifica. A journal of plant science and conservation. 2022. 11(2): 71–79
DOI: 10.17581/bp.2022.11219

RESEARCH PAPER

Botanical and geographycal diversity of the nature reserves of the Amur Region (Russia)

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Manuscript received: 18.05.2022
Review completed: 15.10.2022
Accepted for publication: 02.11.2022
Published online: 06.11.2022

ABSTRACT

There are 3 state nature reserves on the territory of the Amur Region, Zeya, Nora and Khingan. Medium-scale (M 1:300000) vegetation maps of the reserves were made to analyze the geographical features of vegetation. The maps have a common legend, which is constructed according to the zonal-typological principle. It contains 43 names of mapped polygons. We assessed the environmental factors according to Landolt's scales. Vegetation of plains occupies 61 % of the total area of the reserves, vegetation of mountains and hills 39 %. Boreal vegetation covers 68 % of the total area of the reserves, nemoral vegetation 7 %, alpine and subalpine vegetation 2 %, and intrazonal vegetation 23 %. Alpine and subalpine vegetation is found only in the Zeya Reserve. Temperate and intrazonal vegetation occupies the largest areas in the Khingan Reserve: 99 and 60 %, respectively. The share of boreal vegetation in the Zeya Reserve is 70 %, in the Nora Reserve 80 %. In the regional aspect, the representation of vegetation of Amur Region in nature reserves is very small, therefore additional measures for vegetation conservation at regional scale is required.

Keywords: Khingan State Nature Reserve, Nora State Nature Reserve, Zeya State Nature Reserve, vegetation map, cartographic analysis, geographical factors, gradient analysis, vegetation zone, spatial pattern

РЕЗЮМЕ

Борисова И.Г., Астапова Е.С. Ботанико-географическое разнообразие заповедников Амурской области, Россия). На территории Амурской области находятся 3 государственных природных заповедника – Зейский, Норский и Хинганский. Для анализа географических особенностей растительности заповедников были составлены среднемасштабные (М 1:300000) карты растительности. Карты имеют общую легенду, которая построена по зонально-типологическому принципу. Она содержит 43 названия картографируемых полигонов. Экологические факторы мы оценивали по шкалам Ландольта. Растительность равнин занимает 61 % от общей площади заповедников, растительность гор и холмов – 39 %. Бореальная растительность занимает 68 % от общей площади заповедников, неморальная – 7 %, альпийская и субальпийская – 2 %, интразональная – 23 %. Альпийская и субальпийская растительность встречается только в Зейском заповеднике. Умеренная и интразональная растительность занимает наибольшие площади в Хинганском заповеднике: 99 и 60 %, соответственно. Доля бореальной растительности в Зейском заповеднике составляет 70 %, в Норском заповеднике – 80 %. В региональном аспекте представленность растительности Амурской области в заповедниках очень мала, поэтому требуются дополнительные меры по сохранению растительности в региональном масштабе.

Ключевые слова: Хинганский государственный природный заповедник, Норский государственный природный заповедник, Зейский государственный природный заповедник, карта растительности, картографический анализ, географические факторы, градиентный анализ, зона растительности, пространственная схема

Zeya Nature Reserve (central point coordinates 53°57'46"N 127°22'21"E), Nora Nature Reserve (52°30'4"N 130°17'33"E) and Khingan Nature Reserve (49°1'1"N 130°26'49"E) are located in the Amur Region, the Russian Far East. Their total area is 407671 ha, which counts 1.1 % of the total area of the Region) (Fig. 1). The Zeya Nature Reserve occupies the low and middle eastern part of the Tukuringra Mountain Range with altitudes varied between 250 and 660 m. The Nora Nature Reserve is located on the northeastern edge of the Amur-Zeya Plain, one of the most extensive inter-mountain depressions in the Amur River Basin. The Khingan Nature Reserve is located at the meeting of the Khingan Mountains and the Arkhara Lowlands. The lowland part comprises 30 % of the reserve with elevations about 200 m a.s.l., the rest of the territory is floodplain terraces of the Amur River.

Zeya and Nora Nature Reserves belong partly to the Circumboreal and partly to the East Asian floristic regions, and Khingan Nature Reserve belongs to the East Asian floristic region according to Takhtajan (1978). The first two reserves belong to the southern taiga subzone of coniferous forest zone, and Khingan Reserve – to the northern subzone of the mixed coniferous-broadleaved forest zone according to the botanical-geographical zoning by Kolesnikov (1969). The Amur Region is influences by the East Asian monsoon in its south-eastern part and borders with the ultra-continen-

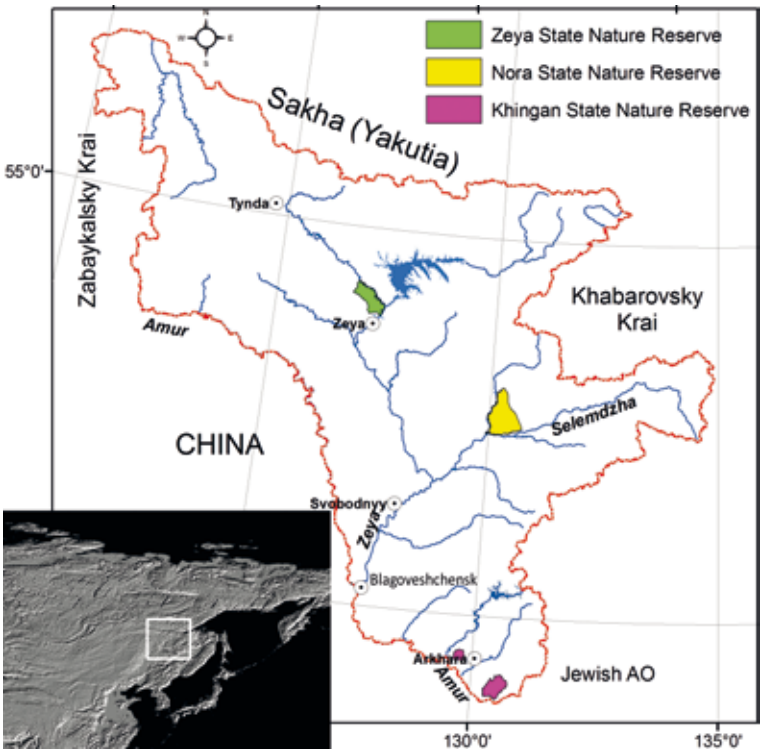

Figure 1 Location of the nature reserves in the Amur Region

tal regions of Transbaikalia on the west. All of these cause a great variety of environmental conditions in the region.

The diversity of flora and vegetation of the nature reserves is associated with their location on the territory of mixing of four flora types (Manchurian, Okhotsk, Daurian and Siberian), as well as on the territories with large climatic variation due to dissected mountain and plain terrain.

Currently, an extensive knowledge about the flora and vegetation of protected areas in the Amur Region has been accumulated (Stetsura 1984, Starchenko & Chuvasheva 1993, Petelin & Gubanov 1997, Kudrin 1998, Akhtyamov & Baburin 1998, Stupnikova 2002, Korotkov & Shirokov 2003, Kudrin & Yakubov 2013, Veklich 2009, 2016, Veklich & Darman, 2013, 2019, Veklich et al. 2019, Dudov 2016, 2018, Khatancharoen et al. 2021). However, a comparative botanical-geographical analysis of these areas accounting their regional specificity and cartographic material has not been implemented.

The object of the present study is the vegetation of the nature reserves of the Amur Region, its composition, structure, geographical specificity, cenotic diversity, and representation of protected areas in the regional context.

The aim of the study is to carry out a botanical and geographical comparative analysis of the protected areas of the Amur Region as part of an extensive mountain-plain territory of the south of the Russian Far East based on modern research methods and technologies.

MATERIAL AND METHODS

The work is based on the cartographic analysis of the structural organization of vegetation of the nature reserves in the Amur Region. Medium-scale (M 1:300000) vegetation maps with a common legend were made to analyze the geographical features of vegetation. As the base map, we used the vegetation map of the Nora Reserve (Borisova 2020). The medium-scale vegetation map for Zeya Reserve was generalized from the large-scale map by Dudov (2018). Medium-scale vegetation map for the Khingan Reserve was made in this study on the basis of interpretation of Landsat and Aster satellite images freely available on the web-service of the US Geological Survey http://earthexplorer.usgs.gov (USGS 2022), topographic and forest management maps in ArcGIS 10.2.2. The methods of image classification and training sampling were used.

The general legend for the three maps was compiled according to the regional-typological principle and contains 43 names of mapped polygons types. Ecological-phytocenotic classification at levels of association class, formation, and vegetation type (Sukachev 1961) was used for the legend construction. The relation of vegetation types and formations to the relief macroforms (plains, mountains and hills) is reflected in the main headings of the legend. Systematization of plant communities was carried out on the basis of dominance of species of a certain life form within the main layers of plant communities. The map polygons show the classes of associations and their combinations. Heterogeneous vegetation of floodplains reflects the ecological and successional sequences and combinations of plant communities. Dominant and characteristic plant species in the legend indicate the geographical relationships of vegetation types between nature reserves.

We used the number of mapped units as a measure of beta diversity that indicates the degree of spatial and temporal differentiation of the territory on the gradients of environmental factors during natural evolution (Whittaker 1980). The most important habitat factors are: heat supply (the most complex gradient affected by altitude above sea level, distance from the Pacific coast and slope exposure), soil richness and moisture, soil granularity and cryogenic conditions. Habitat factors of plant communities were evaluated according to Landolt's scales (Landolt 1977) with our additions and amendments. The following scale grades were used:

Heat availability: 1 – harsh thermal zone and subzone; 2 – very cold thermal zone and subzone; 3 – cold and moderately cold thermal zone and subzone; 4 – cool and moderately cool thermal zone and subzone; 5 – moderately warm and warm thermal zone and subzone.

Soil moisture regimes: 1 – moderately dry; 2 – medium; 3 – moist; 4 – periodically wet; 5 – waterlogged.

Soil nutrient regimes: 1 – very poor; 2 – poor; 3 – medium; 4 – rich; 5 – very rich.

Soil granular composition: 1 – coarse; 2 – coarse with fine-grained gravel; 3 – sandy; 4 – clayey; 5 – loamy.

Cryogenic conditions: 1 – perennial frozen rocks without seasonally thawed layer; 2 – perennial frozen rocks

with seasonally thawed layer up to 0.5 m; 3 – perennial frozen rocks with seasonally thawed layer up to 3–5 m; 4 – seasonal freezing; 5 – without seasonal freezing.

Plant names in this work were given according to Cherepanov (1995) and moss names according to Cherdantseva et al. (2018). Own field data obtained during the study of the vegetation cover of the Zeya and Nora Nature Reserves from 1988 to the present were used.

RESULTS AND DISCUSSION

The main vegetation pattern of the Zeya Reserve is defined by altitudinal zonality that includes 5 belts (Gubanov 1981): Mongolian oak–Daurian birch forests (250–500 m a.s.l.); larch forests with Ajan spruce (up to 900 m a.s.l.); dark coniferous forests of Ajan spruce ((900–1100 m a.s.l.), Siberian dwarf pine thickets (1100–1300 m a.s.l.), a fragmentary mountain tundra alternated with the thickets of the Siberian dwarf pine (above 1300 m a.s.l.).

The main vegetation type of the Nora Nature Reserve is the larch forest that occupy 42 % of its area (Borisova 2020). The transition between Manchurian and Okhotsk floristic complexes and the East Siberian boreal floristic complex is characteristic of this area. Subnemoral larch forests with temperate species in the understorey occupy 0.5 % of the reserve territory and are located in the southwestern and southern parts of the Reserve. This is associated with a change in the heat supply of habitats and a gradual decrease of hemiboreal and temperate species in plant communities.

Vegetation of the Khingan Nature Reserve differs significantly from two above-mentioned reserves. Relict temperate mixed Korean pine–broadleaved forests, Mongolian oak, Mongolian oak–Daurian birch and Daurian birch forests occupy significant areas on the territory of the Reserve. Mountain larch forests, typical for the Bureya Mountain Range, occupy smaller areas. Floodplain meadow and steppe vegetation occupies significant areas.

Historical conditions of development, natural selection processes and formation of the species composition of flora under the influence of physical and geographical processes have led to the significant differences between three nature reserves in the Amur Region. A variety of vegetation types ranging from mountain tundras to steppe meadows and temperate forests reflects the altitudinal and latitudinal zonality that causes uneven heat and moisture supply. The vegetation changes from boreal to temperate along the latitudinal gradient that can be indicated in the flat areas of the Nora and Khingan reserves. Vegetation of Zeya Reserve in mountainous areas varies along the altitudinal gradient representing very specific Okhotsk type of the altitudinal zonality typical for the areas of the Russian Far East with monsoon climate.

In general, vegetation of plains accounts for 61 % of the total area of reserves, and vegetation of mountains and hills 39 %. Boreal vegetation accounts for 68 % of the total area of the reserves, temperate vegetation 7 %, glacial and subalpine vegetation 2 % and intrazonal vegetation 23 %.

Alpine and subalpine vegetation types occur only in the Zeya Nature Reserve. Temperate (nemoral) and intrazonal vegetation are found in the Khingan (99 %) and Nora (60 %) reserves. Mountain boreal forests are characteristic of the Zeya Reserve (70 %), and plain boreal forests of the Nora Reserve (80 %).

The significant differences in the spatial variation of vegetation in the reserves is shown on the maps (Fig. 2). The scale of maps allows to demonstrate only most remarkable plant communities, which, in turn, show significant geographical features of vegetation cover on the latitudinal and altitude-exposure gradients.

For Zeya and Nora reserves, located in the southern taiga subzone, summer-green forests of *Larix gmelinii*, a species least demanding to summer soil warming and most resistant to winter frost, are typical. *Pinus sylvestris* forests and larch-pine forests with *Rhododendron dauricum* are common in drier and warmer habitats. On plains and slopes with a permafrost close to the surface and a constant excess of moisture, boreal-hyparctic and hyparctic shrubs (*Betula divaricata* Ledeb., *Salix myrtilloides* L.) and subshrubs (*Ledum palustre* L., *Chamaedaphne calyculata* (L.) Moench, *Vaccinium uliginosum* L.) are abundant under the larch forest canopy. Mountain larch forests differ from plain forests by participation the Siberian dwarf pine (*Pinus pumila* (Pall.) Regel) in their undergrowth, together with some alpine and subalpine species (*Empetrum subholarcticum* V. Vassil.) descend to the middle belt. Dark coniferous forests of *Picea ajanensis* (Lindl. et Gord.) Fisch. ex Carr.), *P. obovata* Ledeb. and *Abies nephrolrpis* (Trautv.) Maxim. forest communities may also be present in this belt.

In the Khingan Reserve located in the subzone of the temperate mixed coniferous-broadleaved forests, Mongolian oak forests (*Quercus mongolica* Fisch. ex Ledeb.) prevail. The second largest area is occupied by stands of aspen (*Populus tremula* L.) and birch (*Betula platyphylla* Sukacz.). Forests with conifers (*Pinus koraiensis* Siebold et Zucc., *Picea ajanensis*, *P. obovata*, *Abies nephrolepis*) occupy only 8.5 % of the Reserve area, but they are the most valuable as they accommodate a highest species diversity. This is especially true for forests with Korean pine.

The presence of bogs and marshes depends on permafrost conditions of territories. The largest areas of bogs and marshes are characteristic of the Nora Reserve (60 % of its total area), where permafrost is ubiquitous on wide interfluvial plains.

The presence of dry steppe meadows depends on local contrast climatic conditions in the wide river valleys (especially on dryness of summer and number of hot days). The greatest steppification within the reserves is indicated on steep insolated slopes and alluvial plains in the Amur River Valley. The largest areas of steppified meadows are in the Khingan Reserve, 22 % of the reserve's area. Impoverished variants of steppe meadows and rock communities are found in the Zeya Reserve. They are confined to steep southern slopes and rocky ledges in the canyon-like part of the Zeya water reservoir.

The number of mapped units in the reserves is the same (19), but there is a difference in the combination of plant communities in the reserves. About 25 % of the total number of plant communities in all reserves represented in the legend are found only within one reserve (Fig. 3). These are

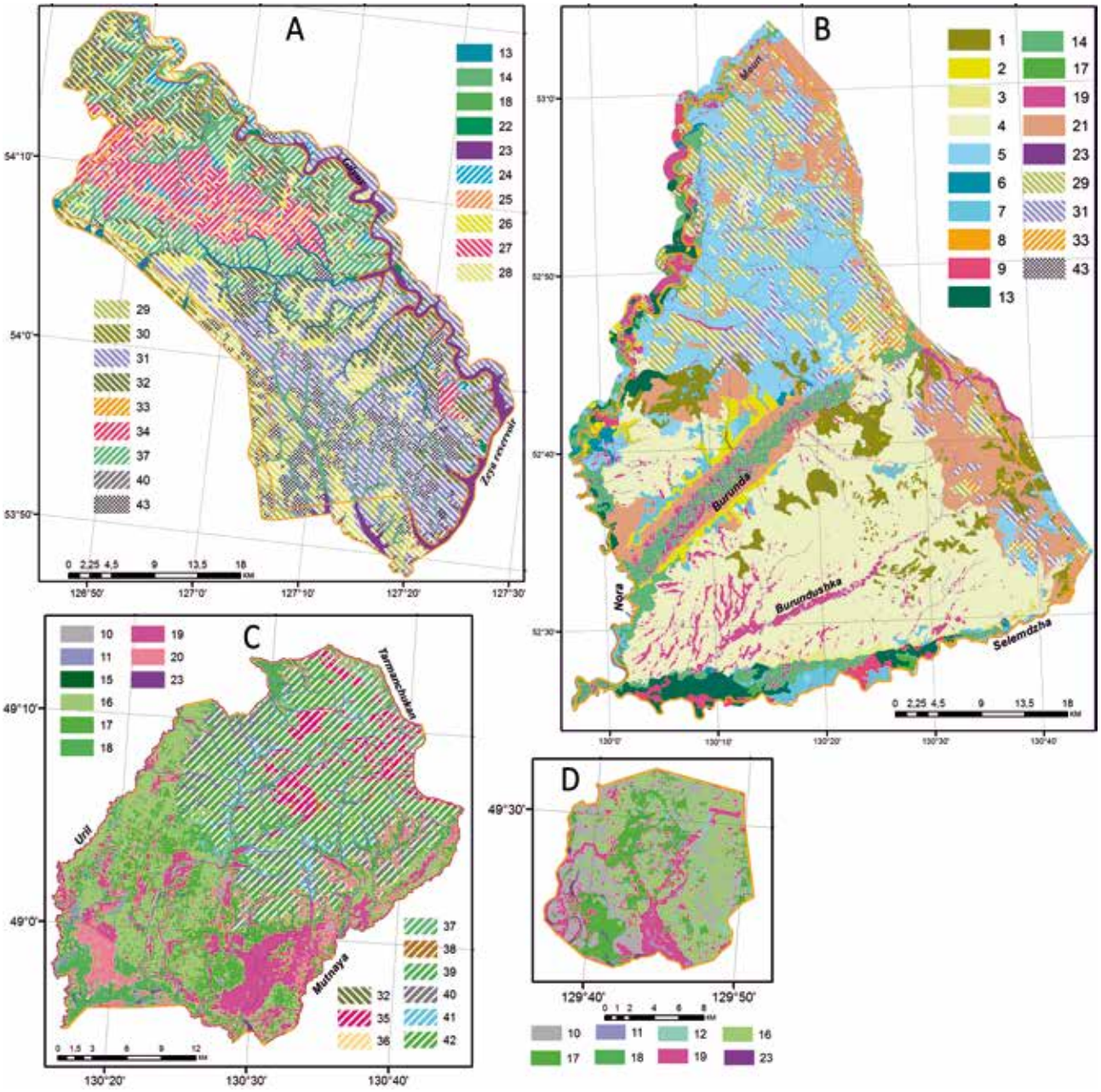

Figure 2. Vegetation maps of the Zeya (A), Nora (B) and Khingan (C – main and D – Lebedinskoe clusters) State Nature Reserves

LEGEND TO VEGETATION MAPS OF AMUR REGION RESERVES.

VEGETATION OF THE PLAINS

Boreal forests and larch peatmoss bog forest

Primary larch (*Larix gmelinii*) forests and woodlands:

1. Larch forests with undershrubs (*Ledum palustre*, *Vaccinium vitis-idaea*, *V. uliginosum*) and mosses (*Pleurozium schreberi*);

2. Larch forests with shrubs (*Lonicera edulis*, *Rhododendron dauricum*, *Ribes pallidiflorum*, *Spiraea salicifolia*), undershrubs (*Vaccinium vitis-idaea*) and herbs (*Carex vanheurckii*, *Maianthemum bifolium*, *Polygonatum odoratum*, *Pteridium aquilinum*, *Trientalis europaea*)

3. Larch forests mixed with *Quercus mongolica* and *Betula davurica* with nemoral herbs (*Adenophora pereskiifolia*, *Campanula punctata*, *Doellingeria scabra*, *Geranium maximowiczii*, *Lilium buschianum*, *Smilacina davurica*, *Vicia pseudorobus*)

4. Larch wet open forests with hygric shrubs (*Betula divaricata*, *Salix myrtilloides*, *Vaccinium uliginosum*), undershrubs (*Chamaedaphne calyculata*, *Ledum palustre*, *Rubus arcticus*), sedges, grasses and herbs (*Carex cespitosa*, *C. minuta*, *C. schmidtii*, *Eriophorum brachyantherum*, *E. komarovii*, *Sanguisorba tenuifolia*), mosses (*Aulacomnium palustre*) and sphagnum (*Sphagnum divinum*, *S. orientale*)

5. Larch wet open forests with sphagnum (*Sphagnum divinum*, *S. orientale*) in combination with hygric shrub thickets (*Betula divaricata*, *B. ovalifolia*, *Salix brachypoda*, *S. myrtilloides*, *Vaccinium uliginosum*)

Secondary larch (*Larix gmelinii*) forests

6. Mixed larch (*Larix gmelinii*) and birch (*Betula platyphylla*) forests with shrubs (*Ribes pallidiflorum*, *Rosa acicularis*, *R. davurica*, *Spiraea salicifolia*), grasses and herbs (*Calamagrostis langsdorffii*, *Convallaria keiskei*, *Equisetum sylvaticum*, *Filipendula palmata*, *Galium boreale*, *Maianthemum bifolium*, *Pteridium aquilinum*)

7. Birch (*Betula platyphylla*) forests with herbs (*Convallaria keiskei*, *Equisetum sylvaticum*, *Maianthemum bifolium*, *Paris hexaphylla*, *Polygonatum odoratum*, *Pteridium aquilinum*) in combination with hydric shrub thichets (*Betula divaricata*), willow thichets (*Salix abscondita*, *S. rorida*, *S. schwerenii*) and meadows

Pine (*Pinus sylvestris*) forests

8. Pine (*Pinus sylvestris*) forests mixed with larch with shrubs (*Rhododendron dauricum*, *Rosa davurica*, *Spiraea salicifolia*) and herbs (*Calamagrostis langsdorffii*, *Convallaria keiskei*, *Fragaria orientalis*, *Iris uniflora*, *Maianthemum bifolium*, *Sanguisorba parviflora*)

Fir-spruce (*Picea ajanensis*, *P. obovata*, *Abies nephrolepis*) forests

9. Fir-spruce forests with small herbs (*Gymnocarpium dryopteris*, *Linnaea borealis*, *Maianthemum bifolium*, *Mitella nuda*, *Orthilia secunda*, *Smilacina davurica*, *Trientalis europaea*) and green mosses (*Pleurozium schreberi*, *Rhytidiadelphus triquetrus*)

Temperate (nemoral) forests

Oak (*Quercus mongolica*) und birch (*Betula davurica*, *Betula platyphylla*) forests

10. Oak (*Quercus mongolica*), oak–Daurian birch (*Betula davurica*) and Daurian birch dorests often mixed with linden (*Tilia amurensis*) with shrubs (*Lespedeza bicolor*, *Corylus heterophylla*), mesic herbs (*Atractylodes ovate*, *Doellingeria scabra*) and steppe grasses (*Arundinella anomala*, *Spodiopogon sibiricus*)

11. Birch (*Betula platyphylla*) and aspen (*Populus tremula*) forests with herbs (*Adenophora pereskiifolia*, *Bupleurum longiradiatum*, *Convallaria keiskei*, *Vicia pseudorobus*)

Secondary oak (*Quercus mongolica*) forests

12. Birch (*Betula davurica*, *B. platyphylla*) and aspen (*Populus tremula*) forests with shrubs in combination with open oak (*Quercus mongolica*) –Daurian birch (*Betula davurica*) forests, shrub thickets and meadows

Forest vegetation of flood-plains

13. Series of communities: willow (*Salix abscondita*, *S. rorida*, *S. schwerenii*) → *Chosenia arbutifolia* → poplar (*Populus suaveolens*) → larch (*Larix gmelinii*) → spruce (*Picea ajanensis*, *P. obovata*) and fir (*Abies nephrolepis*) – spruce (*Picea ajanensis*, *P. obovata*) forests

14. Series of communities: willow (*Salix abscondita*, *S. rorida*, *S. schwerenii*) → poplar (*Populus sauveolens*) → birch (*Betula platyphylla*) → larch (*Larix gmelinii*) with fragments of meadows (*Adenohpora pereskiifolia*, *Calamagrostis langsdorffii*, *Carex schmidtii*, *Galium boreale*, *Iris setosa*, *Sanguisorba parviflora*, *Vicia amoena*)

15. Mixed poplar (*Populus suaveolens*) – alder (*Alnus hirsuta*) – bird cherry (*Padus asiatica*) – maakia (*Maackia amurensis*) – willow (*Salix abscondita*, *S. rorida*, *S. schwerinii*, *S. udensis*) woods with sparse herb cover (*Cardamine leucantha*, *Filipendula palmata*, *Urtica angustifolia*)

Shrub, meadow, marsh, semi-aquatic and aquatic vegetation

16. Dry meadows of grasses (*Agrostis trinii*, *Arundinella anomala*, *Koeleria cristata*, *Poa angustifolia*, *Spodiopogon sibiricus*) and herbs (*Adenophora verticillata*, *Aster maackii*, *Clematis mandshurica*, *Lathyrus komarovii*, *Paeonia lactiflora*, *Patrinia scabiosifolia*, *Veronicastrum sibiricum*, *Vicia amoena*)

17. Seasonally wet grasslands of reed (*Calamagrostis angustifolia*) and sedge (*Carex appendiculata*) with the participation of herbs (*Hemerocallis minor*, *Iris ensata*, *Lysimachia davurica*, *Pedicularis spicata*, *Sanguisorba tenuifolia*, *Scutellaria scordiifolia*) and willows (*Salix bebbiana*, *S. brachypoda*)

18. Humid grasslands of reed (*Calamagrostis angustifolia*, *C. langsdorffii*) and sedge (*Carex schmidtii*) with shrubs (*Betula fruticosa*, *Salix brachypoda*, *Spiraea salicifolia*), undershrubs (*Vaccinium uliginosum*) and herbs (*Adenophora verticillata*, *Geranium wlassovianum*, *Lysimachia davurica*, *Valeriana amurensis*, *Vicia amurensis*)

19. Eutophic tussock sedge (*Carex appendiculata*, *C. meyerana*, *C. schmidtii*) and reed (*Calamagrostis langsdorffii*) fens with hygric herbs (*Cicuta virosa*, *Comarum palustre*, *Pedicularis grandiflora*, *Sanguisorba parviflora*)

20. Hygric herb (*Calamagrostis langsdorffii*, *Carex meyerana*, *Comarum palustre*, *Eriophrum polystachyon*, *Stachys aspera*) and moss (*Leptodictyum riparium*, *Pohlia nutans*, *Sphagnum orientale*) marshes in combination with shrub thickets (*Betula fruticosa*, *Salix myrtilloides*)

21. Wet shrub thickets of willows (*Salix brachypoda*, *S. myrtilloides*) and birches (*Betula fruticosa*, *B. ovalifolia*) with undershrubs (*Chamaedaphne calyculata*, *Vaccinium uliginosum*), sedges (*Carex appendiculata*, *C. schmidtii*) and herbs (*Caltha palustris*, *Filipendula palmata*, *Sanguisorba tenuifolia*, *Veratrum dahuricum*)

22. Dry Daurian birch (*Betula davurica*) woodland fringes with sparsely standing trees with xero-mesophytic herbs (*Bupleurum scorzonerifolium*, *Filifolium sibiricum*, *Koeleria cristata*, *Orostachys spinosa*, *Sedum aizoon*, *Thymus amurensis*) on insolated slopes in combination with very dry moss-lichen communities on the rocks

23. Near-water communities of *Bidens radiata*, *Calamagrostis* spp., *Calla palustris*, *Carex* spp., *Comarum palustre*, *Iris laevigata*, *Scirpus radicans* and aquatic communities of *Hydrilla verticillata*, *Nymphaea tetragona*, *Potamogeton manchuriensis*, *Trapa* spp.

VEGETATION OF MOUNTAINS AND HILLS

Alpine and subalpine vegetation

24. Golets-type mountain complex: undershrub communities (*Arctous alpina*, *Cassiope ericoides*, *Diapendia obovata*, *Rhododendron parvifolium*, *Vaccinium uliginosum*) with lichens (*Alectoria ochroleuca*, *Cladonia arbuscula*, *C. uncialis*, *Flavocetraria nivalis*) in combination with sedge communities (*Carex rigidiodes*, *C. rotundata*, *Eriophorum humile*, *E. vaginatum*) with sphagnum mosses (*Sphagnum aongstroemii*, *S. fallax*, *S. lenense*, *S. magellanicum*), communities of lichens on rocks and rock-fields, communities of mosses (*Aulacomnium turgidum*) and lichens, communities of prostrate Siberian dwarf pine (*Pinus pumila*), shrubs (*Betula divaricata*), tundra communities and the rock fields

25. Siberian dwarf-pine (*Pinus pumila*) elfin woods with shrubs (*Betula divaricata*, *Salix divaricata*, *S. rhamnifolia*), undershrubs (*Ledum palustre*, *Vaccinium vitis-idaea*), mosses (*Dicranum spadiceum*, *Hylocomium splendens*, *Pleurozium schreberi*, *Polytrichum commune*, *Ptilidium ciliare*) and lichens (*Cladonia rangiferina*, *C. stellaris*, *C. uncialis*) in combination with the rock fields

26. Open larch (*Larix gmelinii*) forests with shrubs (*Betula divaricata*, *B. exilis*) in combination with elfin woods of *Pinus pumila* with sphagnum (*Sphagnum lenense*, *S. magellanicum*) and mosses (*Aulacomnium turgidum*), herb communities (*Calamagrostis purpurea*, *Carex pallida*, *Chamaenerion angustifolium*, *Ligularia sibirica*, *Solidago spiraeifolia*) and birch (*Betula lanata*) woodlands

27. Spruce (*Picea ajanensis*) open woodlands mixed with birch (*Betula lanata*) in combination with *Rhododendron aureum* and *Pinus pumila* thickets with *Diphasiastrum alpinum*, *Lycopodium dubium*, *L. lagopus* and green mosses (*Dicranum flexicaule*, *D. scoparium*, *Pleurozium schreberi*, *Polytrichum commune*)

Boreal vegetation

Larch (*Larix gmelinii*) forests and open woodlands

28. Larch (*Larix gmelinii*) forests with undershrubs (*Ledum palustre*, *Vaccinium vitis-idaea*) and mosses (*Hylocomium splendens*, *Pleurozium schreberi*, *Ptilium crista-castrensis*) in combination with elfin woods (*Pinus pumila*)

29. Larch (*Larix gmelinii*) forests with *Rhododendron dauricum*, undershrubs (*Vaccinium vitis-idaea*) and herbs (*Calamagrostis lapponica*, *C. purpurea*, *Carex globularis*, *Linnaea borealis*, *Maianthemum bifolium*, *Pyrola rotundifolia*)

30. Larch (*Larix gmelinii*) forests and open forests with hygric shrubs (*Salix myrtilloides*, *S. brachypoda*, *Spiraea salicifolia*), subshrubs (*Chamaedaphne calyculata*, *Vaccinium vitis-idaea*, *V. uliginosum*), herbs (*Carex globularis*, *Equisetum arvense*, *Rubus arcticus*, *Smilacina trifoliata*, *Spiranthes sinensis*) and mosses (*Hylocomium splendens*, *Sphagnum girgensohnii*, *S. rubellum*)

Secondary larch forests

31. Birch (*Betula platyphylla*) and larch (*Larix gmelinii*) forests with *Vaccinium vitis-idaea* and herbs (*Calamagrostis purpurea*, *Carex globularis*, *Linnaea borealis*, *Maianthemum bifolium*, *Pyrola rotundifolia*)

32. Larch (*Larix gmelinii*) forests with a mix of spruce (*Picea ajanensis*, *P. obovata*), birch (*Betula platyphylla*) and aspen (*Populus tremula*) with *Rhododendron dauricum*, *Calamagrostis purpurea* and green mosses (*Hylocomium splendens*)

Pine (*Pinus sylvestris*) forests

33. Pine and larch-pine forests with shrubs (*Betula divaricata*, *Rhododendron dauricum*), undershrubs (*Ledum palustre*, *Vaccinium vitis-idaea*), herbs (*Calamagrostis brachytricha*, *Carex chloroleuca*, *C. lanceolata*, *Euphorbia discolor*, *Iris uniflora*, *Lupinaster pentaphyllus*, *Sanguisorba officinalis*, *Saussurea*

recurvata, *Vicia popovii*, *Viola dactyloides*) and green mosses (*Dicranum polysetum*, *D. scoparium*, *Pleurozium schreberi*)

Fir–spruce (*Abies nephrolepis*, *Picea ajanensis*, *P. obovata*) and spruce forests

34. Spruce (*Picea ajanensis*, *P. obovata*) forests with *Vaccinium vitis-idaea*, ferns (*Diplazium sibiricum*, *Dryopteris expansa*, *Gymnocarpium dryopteris*) small herbs (*Carex falcata*, *C. globularis*, *Linnaea borealis*, *Lycopodium annotinum*, *Oxalis acetosella*, *Veratrum lobelianum*) and green mosses (*Hylocomium splendens*, *Pleurozium schreberi*, *Ptilium crista-castrensis*, *Sphagnum girgensohnii*)

35. Fir (*Abies nephrolepis*) and spruce (*Picea ajanensis*, *P. obovata*) forests with a mix of *Pinus koraiensis* and broadleaved deciduous trees with shrubs (*Berberis amurensis*, *Deutzia amurensis*, *Philadelphus tenuifolius*) and herbs (*Carex xyphium*, *Circaea caulescens*, *Mitella nuda*, *Oxalis acetosella*, *Viola selkirkii*)

36. Spruce (*Picea ajanensis*, *P. obovata*) and larch (*Larix gmelinii*) forests with ferns (*Diplazium sibiricum*, *Leptorumohra amurensis*, *Pseudocystopteris spinulosa*), small herbs (*Carex globularis*, *C. ussuriensis*, *Maiantemum bifolium*, *Oxalis acetosella*) and green mosses (*Rytidiadelphus triquetrus*, *Sphagnum girgensohnii*)

Secondary dark coniferous forests

37. Larch (*Larix gmelinii*) and birch (*Betula platyphylla*) forests with a mix of aspen (*Populus tremula*) with shrubs (*Rhododendron dauricum*, *Ribes pallidiflorum*, *R. paucifolium*, *Rosa acicularis*, *Spiraea media*) and herbs (*Convallaria keiskei*, *Lathyrus humilis*, *Vicea ramuliflora*)

NEMORAL VEGETATION

Korean pine–broadleaved deciduous and broadleaved deciduous forests

38. Korean pine (*Pinus koraiensis*) forests with the participation of broadleaved deciduous trees (*Acer mono*, *Fraxinus mandshurica*, *Maackia amurensis*, *Phellodendron amurense*, *Quercus mongolica*) and spruce (*Picea ajanensis*) with shrubs (*Deutzia amurensis*, *Eleutherococcus senticosus*, *Lonicera chrysantha*, *Philadelphus tenuifolius*) and herbs (*Cacalia auriculata*, *Thalictrum contorum*)

39. Mixid coniferous (*Abies nephrolepis*, *Picea obovata*) – broadleaved deciduous (*Acer tegmentosum*, *A. ukurunduense*, *Betula costata*, *Juglans mandshurica*, *Phellodendron amurense*, *Tilia amurensis*) forests with woody vines (*Actinidia kolomikta*, *Schisandra chinensis*, *Vitis amurensis*)

40. Mongolian oak (*Quercus mongolica*) forests with a mix of Daurian birch (*Betula davurica*) with shrubs (*Corylus heterophylla*, *Lespedeza bicolor*) and herbs (*Dictamnus dasycarpus*, *Doellingeria scabra*, *Lathyrus humilis*, *Polygonatum odoratum*, *Pteridium aqulinum*)

41. Mixed coniferous (*Pinus koraiensis*, *Abies nephrolepis*, *Picea ajanensis*, *P. obovata*) – broadleaved deciduous (*Fraxinus mandshurica* and *Ulmus japonica*) valley forests with hygro-mesic herbs (*Aruncus dioicus*, *Athyrium filix-femina*, *A. rubripes*, *Cacalia auriculata*, *Filipendula palmata*, *Matteuccia struthiopteris*, *Osmundastrum asiaticum*, *Thalictrum contorum*)

Secondary small-leaved and broad-leaved deciduous forests

42. Deciduous (*Betula platyphylla*, *Populus tremula*, *Quercus mongolica*, *Tilia amurensis*) forests with *Corylus heterophylla*

Disturbed vegetation

43. Burn woods, roads and quarries

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plain larch forests and open forests in the Nora Reserve; mountain tundra, Korean pine forests, larch and spruce open forests with stonebirch woodlands, mountain larch and spruce forests in the Zeya Reserve; coniferous–broadleaved and Korean pine forests, steppe grasslands and herb-moss bogs in the Khingan Reserve.

Similar plant communities in all the reserves, but in different combinations are noted (Fig. 3). For example, humid shrubby grasslands dominated by reed (No. 18 in the map legend), secondary forests in place of dark coniferous forests (No. 37) and oak, oak-birch and black birch forests (No. 40) are typical for the Zeya and Khingan reserves. Periodically over-wetted reed grass and sedge meadows (No. 17), moss-grass lowland bogs (No. 19) and water and water-related communities (No. 23) are typical for Khingan and Nora reserves. Communities of the same type are somewhat more represented in the Nora and Zeya nature reserves. These are sequences of forest communities in the river floodplains (No. 13 and 14), larch forests (No. 29), their derivatives (No. 31), pine and larch-pine forests (No. 33 in the legend).

A circular vector diagram (Fig. 4) shows the distribution of the mapped plant communities along the gradients of environmental factors. Each vector corresponds to the particular plant community reflected in the map lagend and is divided into five grades, from zero at the center to five at the end, according to Landolt's (1977) scale. The grades are not labelled to avoid unnecessary cluttering of the figure.

The diagram shows correlation between heat availability and cryogenic conditions of soils in the pine, fir-spruce, and larch underthaw forests and their derivatives in the Nora Reserve; correlation between heat availability and granular composition of soils, soil nutrient regime and cryogenic conditions of soils of coniferous-broadleaved forests in Khingan Reserve and correlation between soil granular composition and heat content for alpine and subalpine vegetation and between heat availability and soil moisture regime in Zeya Reserve for mountain forests.

The diagram also shows the complex gradient combining the soil nutrient and moisture regimes, or heat availability and cryogenic conditions.

The diagram shows habitat conditions of plant communities. Oak forests (No. 10 and 40 in the legend), as well as steppe meadows (No. 16 and 22) occupy warm and dry habitats in Khingan and Zeya reserves. Alpine and subalpine plant communities (No. 24–27) of the Zeya Reserve and larch marshes (No. 5) of the Nora Reserve appeared to survive in the harshest environment. Korean pine–broadleaved and broadleaved forests and their derivatives (No. 10, 12, 38–42) of the Khingan Reserve demand high heat supply and soil richness. Other plant communities occupy intermediate habitats.

Specificity of vegetation of the reserves in the Amur Region is the position of main temperate dominants and their associated species complexes near the northern edges of suitable habitats. Communities of *Abies nephrolepis*, *Betula davurica*, *Picea ajanensis*, *Pinus koraiensis*, *P. sylvestris*, *Quercus mongolica*, *Tilia amurensis*, as well as steppe communities, occur in the Amur Region in specific conditions characterized by slightly increased heat supply in the river valleys and on the landforms affected by the Pacific (Sochava 1980).

Thus, according to the results of cartographic and gradient analyses by environmental factors, plant communities of the considered reserves have pronounced features of both zonal (boreal, temperate, mountain-tundra) and intrazonal vegetation. Botanical and geographical features of flora and vegetation of the reserves demonstrate the influence of specific river valley environment and the Pacific effect.

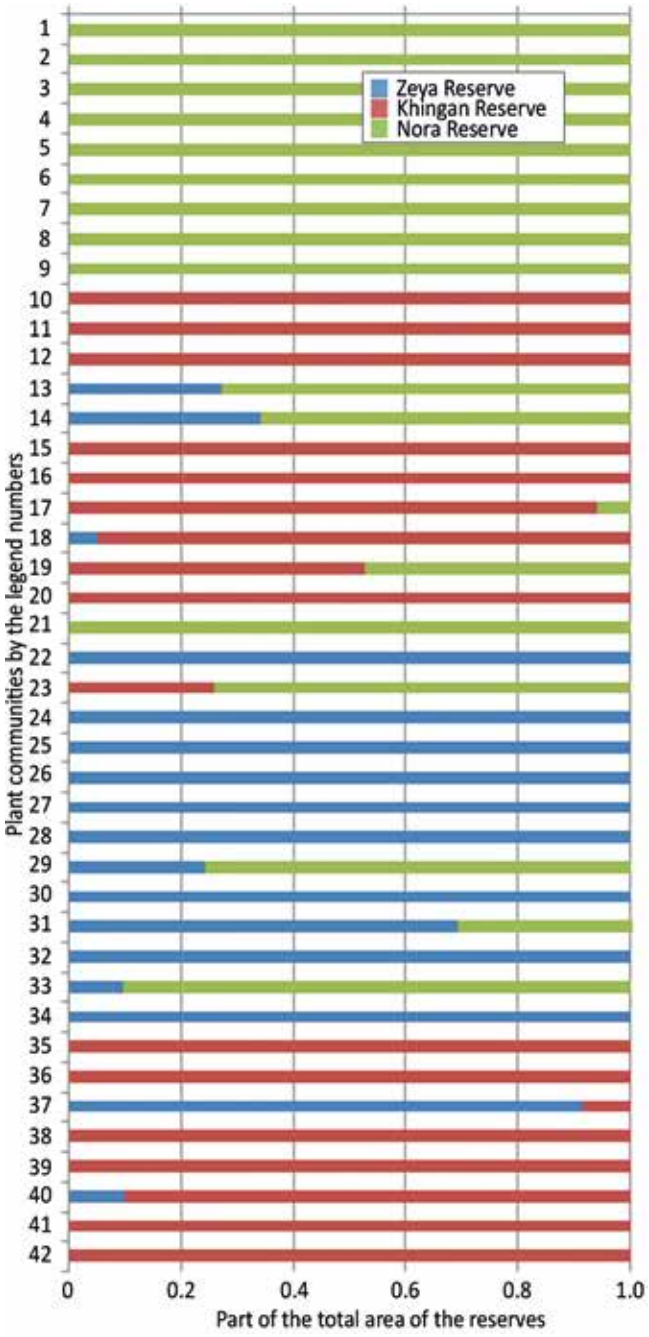

Figure 3 Histogram of the fractional participation of mapped areas of plant communities in the Nature Reserves of the Amur Region

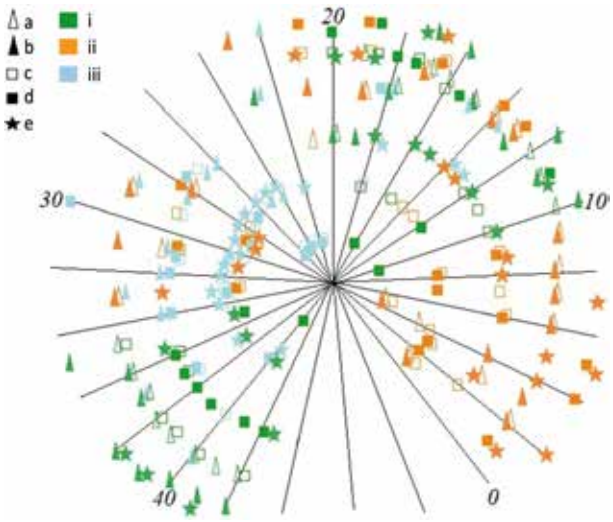

Figure 4 Diagram of the distribution of plant communities along the gradient of environmental factors in the Nature Reserves of the Amur region. Axes 1 to 43 are the numbers of the map legend names; environmental parameters: a – cryo-conditions, b – heat availability, c – soil nutrient regime, d – soil moisture regime, e – soil granular composition; nature reserves: i – Khingan Nature Reserve, ii – Zeya Nature Reserve, iii – Nora Nature Reseve. Additional explanations are in the text

The representation of plant communities of the nature reserves in the regional aspect is characterized by a small share (less than 10 %) of their participation in the structure of the vegetation cover of the Amur Region (Fig. 5). Five classes of associations are an exception. Among them, there are the most valuable indigenous communities – fir-spruce and spruce green-moss and small-herb green-moss forests (66.7 %), open spruce forests with Siberian dwarf pine in combination with groves of stone birch (33.6 %) and grass-herb meadows (almost 13 %). There are plant communities that grow only on the territory of the Khingan Reserve: mixed forests of *Fraxinus mandshurica* and *Ulmus japonica* with hygric tall forbs in the river valleys. Some vegetation types, such as upper sphagnum bogs with larch and Siberian dwarf pine, mountain tundras in combination with alpine and subalpine meadows, Scots pine taiga forests, indigenous polydominant valley forests characteristic of large rivers Amur, Zeya and Bureya, are not represented in the reserves.

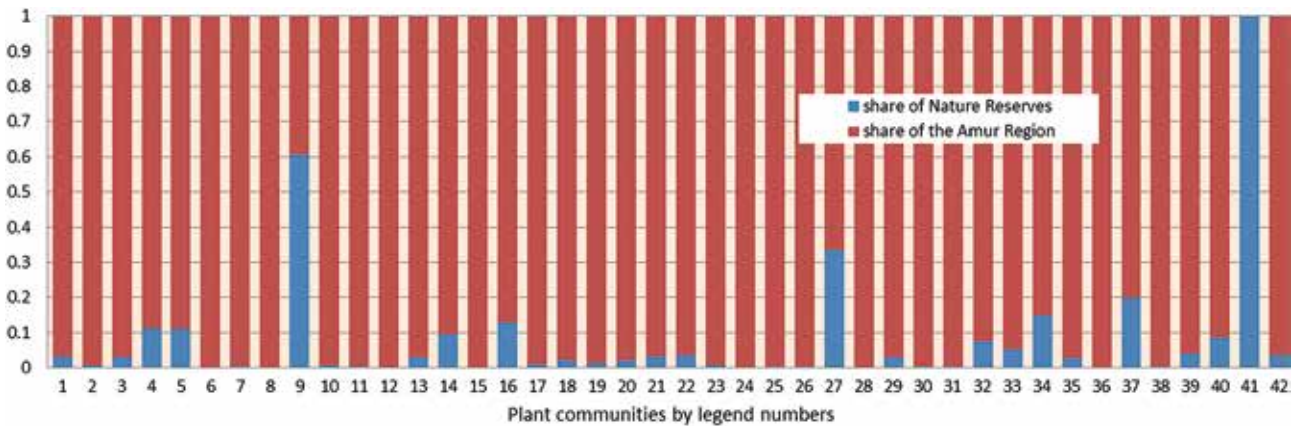

Figure 5 Equity participation of plant communities in Reserves and on the territory of the Amur Region

CONCLUSION

Considering the territories of nature reserves in the Amur Region in zonal scales and climatic conditions, it is possible to highlight their significant botanical-geographical features. Botanical-geographical regularities in the Amur region reserves are manifested on the latitude-zonal and altitude-latitude gradients. Along the latitudinal gradient the boreal communities changes to the temperate. Similar plant communities of reserves can differ in species richness. Along the elevation gradient the diversity of plant communities increases. Specific features of vegetation of the reserves are also manifested due to the effect of the Pacific and river valley influence. Dominant forest species (*Abies nephrolepis*, *Betula davurica*, *Picea ajanensis*, *Pinus koraiensis*, *P. sylvestris*, *Quercus mongolica*, *Tilia amurensis*) in all reserves occur at the northern borders of their distribution ranges.

Comprehensive botanical and geographical analysis of protected areas of the Amur Region has revealed the structure and regional features of plant diversity of nature reserves and the representation of plant communities on the territories of nature reserves that shows the gaps in conservation of vegetation in nature reserves and gives the ideas on its possible improving.

ACKNOWLEDGEMENTS

This work was performed within the state assignment of the Botanical Garden-Institute FEB RAS under the research project 122040800089-2 "Vegetation cover of East Asia and current climate trends: integrative modeling based on remotely sensed and ground-based data".

The authors declare that they have no conflict of interest.

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