DIFFERENTIATION OF THE VACCINIO-PICEETEA AND LOISELEURIO-VACCINIETEA IN MOUNTAINS OF YAKUTIA

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ABSTRACT - Using the Braun-Blanquet approach, 5 associations of boreal forests of the *Vaccinio-Piceetea* and 3 associations of dwarf shrub vegetation (the *Loiseleurio-Vaccinietea*) were distinguished along an altitudinal transect in Yakutia. DCA ordination revealed floristic differences between these two classes. The class *Vaccinio-Piceetea* is indicated by a group of widespread and local character species: *Lonicera caerulea*, *Linnaea borealis*, *Goodyera repens*, *Pyrola incarnata*, *Equisetum scirpoides*, *Orthilia secunda* ssp. *obtusata*, *Moneses uniflora*, *Trientalis europaea*. The class *Loiseleurio-Vaccinietea* is indicated by a group of alpine-subalpine and arctic-alpine species of dwarf shrubs (*Loiseleuria procumbens*, *Arctous alpine*, *Cassiope ericoides*), herbs (*Aconogonon tripterocarpum*, *Hierochloe alpine*, *Calamagrostis lapponica*), and lichens (*Stereocaulon paschale*, *Nephroma arcticum*, *Asahinea chrysantha*, *Flavocetraria nivalis*, *Alectoria ochroleuca*). Subalpine prostrate shrubs - *Betula divaricata*, *Rhododendron aureum*, *Rh. adamsii*, *Betula exilis*, *Sorbaria pallasii* and the subalpine prostrate tree *Pinus pumila* have a special role for indication of the class *Loiseleurio-Vaccinietea*. These species indicate the *Loiseleurio-Vaccinietea* both in typical sites of subalpine-alpine zone and in the transitional elevational zone between subalpine and boreal forests of the class *Vaccinio-Piceetea*. The following three phytocoenotic features differentiate the class *Loiseleurio-Vaccinietea* from *Vaccinio-Piceetea*: 1 - predominance of a layer of achionophilous mesic dwarf shrubs in combitation with a distinct layer of fruticose lichens; 2 - absence of well developed tree layer (cover values less then 25%); 3 - distinct patch structure of ground layer.

KEYWORDS - Braun-Blanquet approach, Eastern Siberia, Phytosociology, Boreal forests, Dwarf-shrub vegetation.

Introduction

Dwarf shrub communities represent a prevalent type of arctic-alpine vegetation in North-Eastern Asia. They are closely related with boreal forests and show strong floristic relationships with them. At the southern boundary of the arctic zone, these two zonal vegetation types are in contact and form various transitional communities. The same regularity is seen at the upper boundary of forests and in the subalpine belt in mountains of the circum-boreal zone. Classification of North-East Asian vegetation has many problems of differentiation between boreal and subalpine dwarf shrub vegetation types because these two types of plant communities predominate over vast territories in plains and mountains. As a consequence, there is no unity of opinion about syntaxonomical position of dwarf shrub communities and some transitional types like, krummholz and forest-tundra. Researchers sometimes place the same communities in the *Vaccinio-Piceetea*, sometimes in the *Loiseleurio-Vaccinietea* classes. The main objectives of the present study are: 1) to analyze diversity of plant communities along an ecological transect crossing altitudinal belts of boreal and subalpine dwarf shrub vegetation in Central and Southern Yakutia; 2) to reveal regional physiognomic features that differentiate boreal and subalpine dwarf shrub vegetation types; 3) to analyze position of transitional boreal-subalpine dwarf shrub communities in the classification system.

The Climate of the Southern Yakutia

Yakutia is the largest Siberian province placed in North-Eastern sector of Eurasia (Figure 1). Its central and southern parts are characterized by landscapes with predominance of light-coniferous (larch) forests forming the transcontinental middle taiga subzone (Andreyev, 1989; Timofeyev *et al.*, 1994). This territory represents a north-eastern part of the Siberian geological platform. In Central Yakutia, the relief combines flat plains and undulating elevated plains with altitudes ranging from 50 to 500 m. Wavy landforms, gentle slopes and poorly developed river valleys prevail in watersheds. The plains of Central Yakutia are surrounded by large mountain systems (the Tcherskogo ridge, Stanovoye and Middle Siberian plateaus) with altitudes up to 2000-2400 m.

The climate of Yakutia is characterised by the highest degree of continentality. Average annual air temperature is -10.3 °C, average temperature of the coldest month (January) is -43.2 °C, average temperature of the warmest month (July) is +18.7 °C. Average annual precipitation varies from 202 mm in the driest central part of the plain to 400 mm in high mountains. Precipitation falls irregularly during the year. Low temperatures and shallow snow cover are characteristic of winter. Severe droughts are typical for the first half of the growing season (late May-mid July), while 75-80% of the annual precipitation falls during the second half of the growing season (late July-September). Ultracontinental climate and widespread permafrost result in high variation in habitat and vegetation types. In Central Yakutia (middle taiga), the combination of typical boreal forests, steppes, wetlands, meadows and occasionally halophytic communities are seen in the same landscapes. Various types of alpine and subalpine vegetation are widespread in high mountain areas.

FIGURE 1 - Map of Eastern Siberia (Yakutia) with position of altitudinal transect.

MATERIAL AND METHODS

The study is based on data from a transect across the southern part of Central Yakutian plain and adjacent mountain area - Stanovoye Plateau. The transect of 500 km length crosses altitudes ranging from 350 m to 1400 m and two main altitudinal zones: boreal (middle taiga) and high mountain. The 144 relevés sampled along this transect represent various types of zonal forest and high mountain vegetation.

Classification was carried out using the Braun-Blanquet approach (Westhoff & van der Maarel, 1973). Units were singled out on the basis of floristic and structural criteria, the former criterion plays the decisive role because it reflects the most substantial vegetation characteristics.

For description of the syntaxa, differential species were used in sense of Westhoff & van der Maarel (1973) and The International Code of Phytosociological Nomenclature (Weber *et al.*, 2000).

The use of TURBO(VEG) and MegaTab software (Hennekens & Schaminee, 2001) for database made it possible to compile a classification. A table of 144 relevés was processed by TWINSPAN (Hill, 1979). DCA ordination of the relevés using DECORANA (Hill, 1979) was carried out in order to show the integrity of the already distinguished vegetation types and their positions along the main gradients.

Syntaxonomic interpretations have been carried out using the available phytosociological literature (Suzuki, 1964; Kielland-Lund, 1981; Ellenberg, 1986; Oberdorfer, 1992; Korotkov *et al.*, 1991; Mucina *et al.*, 1993; Daniels, 1994; Anenkhonov & Chytrý, 1998; Ermakov *et al.*, 2002).

The Braun-Blanquet scale (r, +, 1, 2, 3, 4, 5) was used to estimate species cover-abundance in the relevés and the standard constancy scale (1 (1-20%), 2 (21-40%), 3 (41-60%), 4 (61-80%), 5 (81-100%)) was used in the synoptic table. Species names follow the list of vascular plants of the former USSR (Cherepanov, 1995).

Results

Using the Braun-Blanquet approach, 5 associations of boreal forests of the *Vaccinio-Piceetea* and 3 associations of dwarf shrub vegetation (the *Loiseleurio-Vaccinietea*) were distinguished along the altitudinal transect. The main floristic peculiarities of these syntaxa are represented in Table 1.

The vegetation of lower part of the altitudinal transect (altitudes of 340-550 m) is in the southern part of the Central Yakutian plain, and it is a combination of three associations of coniferous boreal forests covering vast areas on watersheds of middle-taiga subzone and occurring in sites with soils of different fertility, moisture and thermal regimes. The local extreme ultracontinental climate and permafrost result in some regional floristic peculiarities of the *Vaccinio-Piceetea*: (1) predominance of light coniferous trees of *Larix cajanderi* (sometimes *Pinus sylvestris*), forming light open canopy. Siberian spruce (*Picea obovata*) is present in only a few associations but is never abundant; (2) absolute predominance of dwarf-shrub species (*Vaccinium vitis-idaea*, *V. uliginosum*, *Ledum palustre*, *Empetrum nigrum*) in herb layer; (3) the group of typical boreal herbs and shrubs (characteristic species of the class *Vaccinio-Piceetea*) does not contain many species and it does not play a distinct phytosociological role; (4) absence of mesophilous and moderately thermophilous boreal ferns, shrubs and herbs, which are typical plants for regions with a lesser degree of climate continentality, (5) the presence of xerophilous and meso-xerophilous species in various types of boreal forests, (6) prevalence of lichens of the genera *Cladonia* (*C. stellaris*, *C. rangiferina*, *C. arbuscula*, *C. amaurocraea*, *C. mitis*), *Cetraria* and *Flavocetraria* with greater cover than boreal bryophytes (*Pleurozium schreberi*, *Hylocomium splendens*, *Ptilium crista-castrensis*, *Dicranum polysetum*).

Association *Aquilegio parviflorae-Laricetum cajanderi* represents the typical communities of zonal light coniferous taiga of Central Yakutia. They predominate in flat and convex parts of watersheds with well-drained loamy soils and permafrost at a depth of 0.4-0.7 m. *Larix cajanderi* forms a tree layer with lower cover values of 20-40% and a height of 16-18 m. In some places *Betula platyphylla* and *Pinus sylvestris* occur in these communities. A poorly-developed shrub layer is characteristic of this association, with a cover of 1-5%. *Vaccinium vitis-idaea* is the dominant of the herb layer, having cover values of 15-80%. The herb layer consists of mesophilous and xero-mesophilous species. The moss layer is dominated by *Ptilidium ciliare*, *Aulacomnium turgidum*, *A. acuminatum* and *Rhytidium rugosum*. Typical boreal mosses *Pleurozium schreberi*, *Hylocomium splendens*, *Ptilium crista-castrensis* and *Dicranum polysetum* have low cover and constancy. Common boreal lichens (*Cladonia stellaris*, *C. rangiferina*, *C. amaurocrea*, *C. arbuscula*) are also present, though with low cover.

Association *Ledo palustris-Laricetum cajanderi* includes mesophilous larch forests occurring in sites with cool, often water-logged soils. They are correlated with wide depressions on watersheds and higher river terraces. These habitats are characterized by permafrost at a depth of 10-30 cm. *Larix cajanderi* is a single dominant of the tree layer, showing lower cover values of 25-35%. The low shrub layer has a cover of 5-10%, formed by *Duschekia fruticosa*, *Rosa acicularis*, *Salix myrtilloides*. The herb layer has a cover of 30-50% and low species-richness of 8-15

species per 200 m^2. Dwarf shrubs (*Vaccinium vitis-idaea V. uliginosum, Ledum palustre*) are abundant. The lichen-moss layer is well developed (cover values of 70-90%), represented by mosses such as *Aulacomnium palustre, A. turgidum, A. acuminatum, Polytrichum juniperinum, Sphagnum girgensohnii, S. warnstorffii, S. fuscum.* Lichens include *Cladonia stellaris, C. rangiferina, C. arbuscula, Cetraria islandica, Peltigera aphthosa* and *P. canina.*

Association *Saxifrago bronchialis-Pinetum sylvestris* includes *Pinus sylvestris* forests with participation of meso-xerophilous plants. They are typical of extensive areas of sandy deposits widespread in watersheds and higher terraces of the Lena river valley. Communities of the association occupy dry, moderately warm tops of small hills and convex parts of well-drained summits of watersheds with poor sandy soils and permafrost at a depth of 1.4 m. The tree layer has lower cover values (30-40%) and the shrub layer is poorly developed or absent. The herb layer is dominated by *Arctostaphylos uva-ursi* forming dense patches in combination with areas of open sandy soil and sometimes with patches of lichens. Other vascular plants are scattered and have lower cover values. Among them, the facultative psammophytes (*Thymus serpyllum, Potentilla bifurca, Carex vanheurckii, Artemisia commutata, Saxifraga bronchialis, Dianthus versicolor*) predominate. The moss-lichen layer varies in cover values of 5 - 60% depending on the time of the last fire.

The middle part of the altitudinal transect (altitudes of 550-850 m) crosses a forest belt on the north-facing slope of the Stanovoye Plateau. This area is characterized by a more humid and cold climate during summer in comparison with the Central Yakutian plain. As a result, xeric elements disappear in boreal forests and characteristic species of the *Vaccinio-Piceetea* increase. Forests are represented by two associations of spruce-larch forests occurring in different parts of gentle mountain slopes.

Association *Aconito-Laricetum cajanderi* dominates the foothills and mountains. It occupies convex and flat parts of gentle slopes with well-drained soils and permafrost at a depth of 60-80 cm. *Larix cajanderi* and *Picea obovata* form an open tree layer with cover values of 20-40% with a height of 16-18 m. In some places *Betula platyphylla, Pinus sibirica* and *Pinus sylvestris* occur in these communities. Shrub layer (a cover of 1-5%) is dominated by *Duschekia fruticosa, Lonicera caerulea* and *Rosa acicularis. Vaccinium vitis-idaea* is the dominant of the herb layer and shows cover values of 15-80%. A well-developed herb layer is characterized by a cover of 50-60% and species-richness of 10-18 species per 200 m^2. The dwarf-shrubs *Vaccinium vitis-idaea, V. uliginosum, Ledum palustre* play a leading role there. The moss layer is dominated by *Pleurozium schreberi, Hylocomium splendens, Aulacomnium turgidum, A. palustre.* Fruticose lichens *Cladonia stellaris, C. rangiferina, C. amaurocrea, C. arbuscula* and *Cetraria islandica* are constant species in the association but they are never dominants.

Association *Ledo palustris-Laricetum cajanderi* var. *Arctous erytrocarpa* is related to shallow depressions, cool, water-logged soils and permafrost at a depth of 40-70 cm on gentle northern slopes. Unlike the typical association described for Central Yakutian plain, this variant occurs in a more humid climate, as indicated by the presence of *Picea obovata* in tree layer, higher species-richness in the herb layer and predominance of boreal bryophytes *Pleurozium schreberi, Hylocomium splendens, Dicranum polysetum* in moss layer.

Association *Betulo divaricatae-Laricetum cajanderi* forms a higher part of the forest altitudinal belt and it is replaced by krummkholz subalpine communities of *Pinus pumila* at higher altitudes. Community predominates on gentle mountain slopes of different aspects, in sites with permafrost at a depth of 40-60 cm. The main peculiarity of this community is its well-developed shrub layer (cover values of 30-45%) of boreal (*Duschekia fruticosa, Lonicera caerulea, Rosa acicularis, Sorbus sibirica*) and subalpine (*Pinus pumila, Rhododendron aureum, Betula divaricata*) species. The similarity of this association to those of the more humid subalpine belt is indicated by a group of mesic herbs (*Aconitum ranunculoides, Mitella nuda, Equisetum arvense, Corydalis paeoniifolia, Geranium albiflorum, Saussurea parviflora, Bistorta major, Luzula parviflora, Streptopus streptopoides, Tofieldia coccifera, Parnassia palustris, Thalictrum alpinum, Hieracium korshinskyi*) and by occurrence of *Vaccinium myrtillus* and *Abies sibirica.*

The upper part of the altitudinal transect (altitudes of 850-1400 m) crosses a forest belt on the summit of the Stanovoye Plateau. This area is characterized by the coldest climate, moderate precipitation and widespread permafrost at a depth of 20-40 cm. Coniferous trees occur here but they never form a closed canopy (cover values are 10-30%). Dwarf-shrubs (*Vaccinium vitis-idaea, V. uliginosum, Ledum palustre, Arctous erythrocarpa, Empetrum nigrum*, sometimes *Vaccinium myrtillus*), subalpine shrubs (*Betula divaricata, Rhododendron aureum, Rh. adamsii, Betula exilis*) and low prostrate tree (*Pinus pumila*) predominate and form two distinct layers in all communities of subalpine belt. The abumdance of typical boreal elements, including characteristic species of the *Vaccinio-Piceetea*, decreases rapidly there. A characteristic feature of these subalpine communities is a well-developed ground layer of lichens. Phytocoenotic diversity is represented by four associations at different altitudes. All syntaxa described in the subalpine belt of the Stanovoye Plateau have been included in the *Loiseleurio-Vaccinietea* class.

Association *Piceo obovatae-Betuletum divaricatae* occurs at the lowest part of the subalpine belt, in a contact zone with boreal forests of the *Betulo divaricatae-Laricetum cajanderi. Picea obovata* and *Larix cajanderi* occur as scattered trees or sparse groups of trees. *Betula divaricata*, together with the other subalpine shrub *Betula exilis*, comprise a well-developed shrub layer (cover of 20-30%). Species of dwarf-shrubs and fruticose lichens predominate in a ground layer. As a whole, the community is characterized by low values of higher vascular plant species richness (8-15). On warmer southern slopes, it is represented by variant *Pinus sylvestris.*

Association *Cladonio-Pinetum pumilae* is widespread in the lower altitudinal belt of central part of the Stanovoye Plateau where it co-occures with the above association at the upper part of the forest belt. The community occupies flat summits and gentle slopes of different aspects in the Plateau. It is characterized by a well-developed layer (cover of 20-70%, height of 2-7 m) of the subalpine prostrate tree *Pinus pumila.* Subalpine shrubs (*Rhododendron aureum, Betula divaricata, B. exilis*) are typical for this layer as well. Scattered trees of *Larix cajanderi* never form a closed canopy. Dwarf-shrubs (*Vaccinium vitis-idaea, V. uliginosum, Ledum palustre, Empetrum nigrum, Loiseleuria procumbens*) share with *Pinus pumila* and fruticose lichens the role of dominants in the community. As in the previous association (*Piceo obovatae-Betuletum divaricatae*), the *Cladonio-Pinetum pumilae* is characterized by the few species of higher vascular plants, and by the minor num-

ber (or absence) of typical boreal elements. In the warmest parts, on southern slopes, it is represented by variant *Pinus sylvestris*. Association *Pino pumilae-Cassiopetum* occurs at the highest subalpine belt, where it occupies tops of mountains with shallow stony soils at altitudes of 1200-1400 m.

The subalpine prostrate tree *Pinus pumila* and the shrubs *Rhododendron aureum*, *Rh. adamsii*, *Betula divaricata*, *Sorbaria pallasii* form a shrub layer with a height of 0.4-1.2 m and cover of 25-40%. Widespread dwarf-shrubs (*Vaccinium vitis-idaea*, *V. uliginosum*, *Ledum palustre*, *Empetrum nigrum*), together with typical subalpine species (*Cassiope ericoides*, *Arctous alpina*, *Loiseleuria procumbens*) predominate in the herb layer. The latter is also characterized by presence of subalpine herbs (*Aconogonon tripterocarpum*, *Tilingia ajanensis*, *Calamagrostis lapponica*). A well-developed lichen layer includes the widespread fruticose lichens and some subalpine-alpine species (*Nephroma arcticum*, *Asahinea chrysantha*, *Flavocetraria nivalis*, *Alectoria ochroleuca*, *Thamnolia vermicularis*). The variant *Rhododendron aureum* is related to more shallow and stony soils.

Syntaxonomical synopsis

Vaccinio-Piceetea Br.-Bl. in Br.-Bl., Siss. et Vlieger 1939
Ledo palustris-Laricetalia cajanderi Ermakov 2004
Ledo palustris-Laricion cajanderi Ermakov 2004
Ledo palustris-Laricetum cajanderi Ermakov *et al.* 2002
Variant *Arctous erytrocarpa*
Aconito-Laricetum cajanderi prov.
Betulo divaricatae-Laricetum cajanderi prov.
Cladonio-Vaccinietalia Kielland-Lund 1967
Saxifrago bronchialis-Pinion sylvestris Ermakov *et al.* 2002
Saxifrago bronchialis-Pinetum sylvestris
Lathyro humilis-Laricetalia cajanderi Ermakov *et al.* 2002
Aulacomnio acuminati-Laricion cajanderi Ermakov *et al.* 2002
Aquilegio parviflorae-Laricetum cajanderi Ermakov *et al.* 2002
Variant *Rubus saxatilis*
Loiseleurio-Vaccinietea Eggler 1952
Syn. Cetrario-Loiseleurietea Suzuki-Tokyo & Umezu in Suzuki-Tokyo 1964
Vaccinio-Pinetalia pumilae Suzuki 1964
Cladonio-Laricion cajanderi Anenkhonov et Chytrý 1998
Piceo obovatae-Betuletum divaricatae prov.
Cladonio-Pinetum pumilae Sinelnikova 2002
Variant *Pinus sylvestris*
Vaccinio-Pinion pumilae Suzuki 1964
Pino pumilae-Cassiopetum prov.
Variant *Rhododendron aureum*

Ordination

A DCA scatterplot of 144 relevés of coniferous forests and dwarf-shrub vegetation of the altitudinal transect is shown in FIGURE 1. Empirical analysis of the scat-

terplot revealed a strong altitudinal gradient of axis 1 from boreal forests of the Central Yakutian plain (*Saxifrago-Pinetum, Ledo-Laricetum, Aquilegio-Laricetum*) through associations in the forest belt of the Stanovoye Plateau to (*Aconito-Laricetum, Betulo divaricatae-Laricetum*), to subalpine dwarf-shrub vegetation (*Piceo-Betuletum divaricatae, Cladonio-Pinetum pumilae, Pino pumilae-Cassiopetum*) at the summit of the Plateau. Simultaneously, axis 1 showed a clear phytosociological boundary between boreal and subalpine vegetation, which can be interpreted as a syntaxonomical boundary between classes *Vaccinio-Piceetea* and *Loiseleurio-Vaccinietea*.

On axis 2, all relevés were split up into three groups according to soil properties, ranging from association *Aquilegio parviflorae-Laricetum cajanderi* occurring on zonal loamy soils to association *Saxifrago bronchialis-Pinetum sylvestris* occurring on sandy soils. The central position of the axis 2 is occupied by mountain forests together with subalpine dwarf shrub communities formed on similar stony soils.

Discussion

Currently, there are no reliable criteria for consistent differentiation of floristically similar northern boreal forests and subalpine-subarctic dwarf shrub vegetation types. The problem is of special importance for Yakutia and other North-East Asian territories, where the most cryophytic boreal woodlands are characterized by the poorest floristic composition, by an open tree layer (dominated by *Larix cajan-*

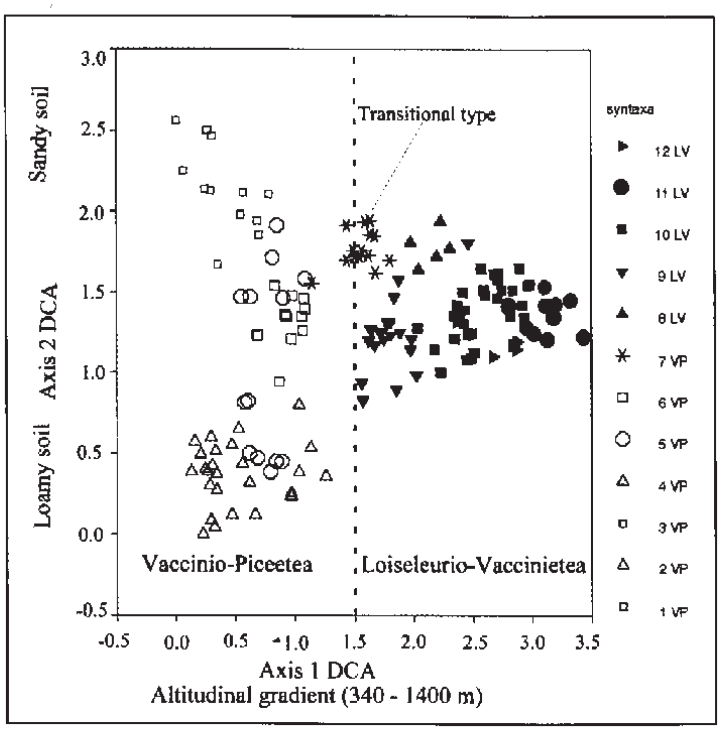

Figure 2 - DCA ordination of 144 relevés ranging along altitudinal transect. Numbers of syntaxa correspond to those in Table 1.

deri) and by predominance of a few widespread dwarf shrubs (*Vaccinium vitis-idaea*, *V. uliginosum*, *V. myrtillus*, *Ledum palustre*, *Empetrum nigrum*). Nominally, these species (or majority of them) are considered as diagnostic of the boreal class *Vaccinio-Piceetea*, but they are also constant species and dominants in some higher units of vegetation of the tundra zone and treeless high mountains. In the Arctic zone of northern Eurasia and northern high mountains are some close vicarious taxa of dwarf shrubs: *Vaccinium vitis-idaea* - *V. minus*, *Empetrum nigrum* - *E. hermaphroditum*, *Vaccinium uliginosum* - *V. microphyllum*, *Ledum palustre* - *L. decumbens*. However, these pairs of vicariants are not are not good differential species for separation of higher units of boreal and subalpine-subarctic vegetation types in middle and northern taiga subzones as well as in transitional hypoarctic and subalpine zones. Thus, for Yakutia, the high constancy and predominance above mentioned dwarf shrubs in communities are not reliable diagnostic features for differentiating the classes *Vaccinio-Piceetea* and *Loiseleurio-Vaccinietea*. TABLE 1 shows syntaxa of forest and non-forest vegetation ranging along an altitudinal gradient where dwarf shrubs play the role of constant species and dominants in all associations. Presence of trees and tree layer should be reliable criteria for differentiation of the *Vaccinio-Piceetea* and *Loiseleurio-Vaccinietea* classes, because mean values of cover of tree layers decline at higher altitudes. But, the presence and degree of canopy closure are not absolute reliable features for differentiating *Vaccinio-Piceetea* and *Loiseleurio-Vaccinietea*. Cover values of tree layers in natural *Vaccinio-Piceetea* communities varies in north and middle taiga woodlands within wide limits of 10-60%. Futhermore, boreal trees (first of all the cryophytic *Larix cajanderi*) penetrate into subalpine and even into alpine belts, where they are able to form stands with a cover of 10-30% in communities otherwise characterized by predominance of arctic-alpine and alpine species and by absence of characteristic *Vaccinio-Piceetea* species. Thus, presence of boreal trees alone and an open tree layer are important, but still insufficient, features for including a plant community in the *Vaccinio-Piceetea*. Similar regularity is characteristic for some boreal mosses like *Pleurozium shreberi* and *Hylocomium splendens*. They are widespread and predominate both in boreal forests and in various treeless subarctic - subalpine communities.

In spite of gradual changes in physiognomy and floristic composition of plant communities along the altitudinal transect, and despite the presence of various distinct transitional vegetation types, a clear regional boundary has been distinguished between boreal and subalpine vegetation after syntaxonomic analysis and ordination were performed. Separation of the *Vaccinio-Piceetea* and *Loiseleurio-Vaccinietea* classes is possible on the basis of combination of both floristic and phytocoenotic criteria.

The main floristic criterion is based on the ratio of alpine-subalpine (arctic-alpine) and boreal species groups. The class *Vaccinio-Piceetea* is indicated by a group of widespread and local character species. For Yakutia, the core of this group is constituted by *Lonicera caerulea*, *Linnaea borealis*, *Goodyera repens*, *Pyrola incarnata*, *Equisetum scirpoides*, *Orthilia secunda ssp. obtusata*, *Moneses uniflora*, *Trientalis europaea*.

The class *Loiseleurio-Vaccinietea* is indicated by a group of alpine-subalpine and arctic-alpine species of dwarf shrubs (*Loiseleuria procumbens*, *Arctous alpine*,

Cassiope ericoides), herbs (*Aconogonon tripterocarpum*, *Hierochloe alpine*, *Calamagrostis lapponica*), and lichens (*Stereocaulon paschale*, *Nephroma arcticum*, *Asahinea chrysantha*, *Flavocetraria nivalis*, *Alectoria ochroleuca*). The subalpine prostrate shrubs (*Betula divaricata*, *Rhododendron aureum*, *Rh. adamsii*, *Betula exilis*, *Sorbaria pallasii*) and subalpine prostrate tree *Pinus pumila* are indicators of the class *Loiseleurio-Vaccinietea*. These species play a key role for indication of the *Loiseleurio-Vaccinietea* both in typical sites of subalpine - alpine zone and in the transitional altitudinal strip to zone of boreal forests of the *Vaccinio-Piceetea*. Additional floristic feature differentiating the *Vaccinio-Piceetea* towards the *Loiseleurio-Vaccinietea* is a large group of moderately thermophilous species (TABLE 1). Their ecological optima are related with North-East Asian boreal forests and they avoid subalpine-alpine conditions.

Some phytocoenotic features may be involved for differentiations of the *Loiseleurio-Vaccinietea* towards the *Vaccinio-Piceetea*: 1, predominance of layer achionophilous mesic dwarf shrubs in combitation with distinct layer of fruticose lichens; 2, absence of well developed tree layer (cover values less then 25%); 3, distinct patch structure of ground layer conditioned by uneven nano-relief related with solifluction processes.

According to these floristic and phytocoenotic criteria, subalpine dwarf shrub communities of ultracontinental sector as well as subalpine krummholz (*Pinus pumila*, *Betula divaricata*, *B. exilis*, *Rhododendron aureum*, *Rh. parvifolium*) should be classified within the arctic-alpine (subarctic-subalpine) class *Loiseleurio-Vaccinietea*.

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TABLE 1 - The main species groups in syntaxa of the *Vaccinio-Piceetea* boreal forest (VP) and dwarf shrub vegetation of the *Loiseleurio-Vaccinietea* (LV)

Syntaxa: 1 - *Saxifrago-Pinetum sylvestris*, 2 - *Aquilegio-Laricetum*, 3 - *Aquilegio-Laricetum* var. *Rubus saxatilis*, 4 - *Ledo-Laricetum*, 5 - *Ledo-Laricetum* var *Arctous erytrocarpa*, 6 - *Aconito-Laricetum*, 7 - *Betulo divaricatae-Laricetum*, 8 - *Piceo-Betuletum divaricatae*, 9 - *Cladonio-Pinetum pumilae* var. *Pinus sylvestris*, 10 - *Cladonio-Pinetum pumilae*, 11 - *Pino pumilae-Cassiopetum* var *Rhododendron aureum*, 12 - *Pino pumilae-Cassiopetum*.

	VP	VP	VP	VP	VP	VP	VP	LV	LV	LV	LV	LV
Syntaxa	1	2	3	4	5	6	7	8	9	10	11	12
Number of relevés	9	16	3	10	8	11	7	5	18	30	10	5
Boreal trees												
Larix cajanderi –tI	V³	V⁴	V²	V³	V⁴	V³	V²	V²	V²	IV	III	II
Picea obovata –tI	IV	.	IV	.	V²	V²	V⁴	IV	I	.	.	.
Pinus sylvestris –tI	V²	.	V⁴	I	I	II	.	IV	V²	.	.	.
Betula platyphylla –tI	I	III	II	IV²	III²	III	I	.	I	.	.	.
Pinus sibirica –tI	.	.	IV	.	.	II	.	.	.	.	.	.
Populus tremula –tI	.	.	II	.	.	I²	.	.	.	.	.	.
Abies sibirica –tII	.	.	.	.	.	.	V²	.	.	.	.	.
Diagnostic species of the Vaccinio-Piceetea												
Lonicera caerulea –sI	II	.	V	.	III	IV	IV	.	+	.	.	.
Linnaea borealis –hI	I	IV	V	III²	IV	V	V²	II	I	+	.	.
Goodyera repens –hI	I	.	II	.	IV	IV	II	.	+	.	.	.
Pyrola incarnata –hI	I	IV	II	I	V	IV	II	.	+	.	.	.
Equisetum scirpoides -hI	IV	I	II	III	V	V	III	.	.	.	.	.
Orthilia secunda ssp. *obtusata* -hI	.	V	II	III	IV	V	V	.	.	.	.	.
Moneses uniflora –hI	.	.	.	+	I	I	III	.	.	.	.	.
Trientalis europaea -hI	.	.	.	.	.	I	.	.	.	.	.	.
Lycopodium annotinum -hI	.	.	.	.	.	.	.	.	.	.	.	.
Widespread boreal-subalpine dwarf-shrub species												
Vaccinium vitis-idaea -hI	V²	V⁴	V³	V⁴	V³	V³	V²	V²	V⁴	V²	V²	V²
Vaccinium uliginosum -hI	V²	I	IV	IV²	V³	V²	V²	V²	V²	IV²	I	V²
Ledum palustre –hI	.	I	.	V³	IV	V²	V²	.	V²	V²	V²	V²
Empetrum nigrum –hI	.	+	.	+	II	II	III	II	IV	II²	V²	V²
Vaccinium myrtillus -hI	.	.	.	.	.	.	IV	II²	I	II²	.	.
Widespread boreal mosses and lichens												
Pleurozium schreberi -mI	II	II	V²	+	III²	V³	V³	V²	V²	IV²	I	.
Hylocomium splendens -mI	II	I	V²	I	V³	V³	V³	.	+	+	.	.
Dicranum polysetum -mI	II	I	V	I	IV	V	.	II	IV	I	.	.
Ptilium crista-castrensis -mI	.	+	.	.	.	+	I	.	III²	I	+	II
Peltigera canina –mI	.	V	.	IV	I	I	.	I	I	.	.	.
Peltigera aphthosa -mI	II	V	V	V²	III²	I	II	II	II	+	II	I
Other constant species of mosses												
Aulacomnium turgidum -mI	II	V²	.	IV³	III³	IV²	.	I	III²	II	+	II
Aulacomnium palustre -mI	.	II	.	III²	IV²	IV²	II	I	III²	I	+	I
Tomentypnum nitens -mI	III	II	II	I	V²	III	IV²	.	I	.	.	.
Ptilidium ciliare –mI	II	V²	II	II	.	II	.	.	II	I	+	II
Aulacomnium acuminatum-mI	III	III²	II	II	I²	+	.	.	.	.	.	.
Subalpine shrubs, differential species of the *Loiseleurio-Vaccinietea*												
Pinus pumila –sI	.	.	.	.	II	.	V²	I	V²	V³	V³	V³
Rhododendron aureum –sI	.	.	.	.	.	.	V²	.	.	III²	V²	.
Betula divaricata –sI	.	.	.	.	.	+	V³	V⁴	V³	V³	V²	V²
Betula exilis –sI	.	.	.	.	.	.	.	III²	I	+	.	.

Sorbaria pallasii –sl	.	.	.	.	.	.	.	.	.	r	III	II
Subalpine dwarf shrubs and herbs, differential species of the *Loiseleurio-Vaccinietea*												
Loiseleuria procumbens -hl	.	.	.	.	.	.	.	.	+	I	II	.
Cassiope ericoides –hl	.	.	.	.	.	.	.	.	.	.	V^2	V^2
Arctous alpina –hl	.	.	.	.	.	.	.	.	.	.	V^2	IV^2
Calamagrostis lapponica -hl	.	II	.	V	.	I	I	II	IV	IV	III	III
Aconogonon tripterocarpum-hl	.	.	.	.	.	.	.	.	.	r	III	III
Hierochloe alpina –hl	.	.	.	.	.	.	.	.	.	.	III	II
Pulsatilla ajanensis –hl	.	.	.	.	.	.	.	III	.	.	II	.
Lichen species, differential of the *Loiseleurio-Vaccinietea*												
Cetraria laevigata –ml	II	.	.	.	II	+	II	II	II	II	III	III
Flavocetraria cucullata -ml	III	.	II	+	II	+	.	II	III	III	V^2	IV
Stereocaulon paschale –ml	.	.	.	.	.	+	.	V^2	III	III^2	IV^2	IV
Nephroma arcticum –ml	.	.	.	.	.	.	I	.	.	.	II	I
Asahinea chrysantha –ml	.	.	.	.	.	.	.	.	I	+	III	III
Flavocetraria nivalis –ml	.	.	.	.	.	.	.	I	II	II	V^2	V^2
Alectoria ochroleuca –ml	.	.	.	.	.	.	.	.	+	.	II	.
Widespread boreal-arctic-alpine lichens												
Cladonia arbuscula –ml	IV	IV	II	III^2	IV	V	IV	V^2	V	V^2	IV^2	V^2
Cladonia rangiferina –ml	III^2	III	V	IV	III	V	II	V^2	V^2	V^2	V^2	III^2
Cladonia stellaris –ml	V^2	III	IV	III	II^2	V	III	V^3	V^2	V^3	V^3	V^2
Cladonia amaurocraea -ml	III^2	II	IV	III^2	II	III	III	V^2	V^2	V^2	IV^2	V^2
Cetraria islandica –ml	V^2	+	V	II	IV^2	IV	III	V^2	V^2	V^2	V^2	V^2
Other local and widespread boreal and meadow species differentiating the *Vaccinio-Piceetea* toward the *Loiseleurio-Vaccinietea*												
Arctous erythrocarpa –hl	IV	III	.	II^2	V^2	III	.	.	.	.	.	I
Carex vanheurckii –hl	V	.	.	+	II	.	.	.	.	.	.	.
Silene repens –hl	IV	I	II	.	.	.	.	.	.	.	.	.
Vicia cracca –hl	III	III	.	+	.	.	.	.	.	.	.	.
Thalictrum minus –hl	I	II	V	.	I	II	III	.	+	.	.	.
Geranium vlassowianum -hl	.	III	V	.	I	+	.	.	.	.	.	.
Festuca jacutica –hl	IV^2	.	V	.	II	.	.	.	.	.	.	.
Aegopodium alpestre –hl	.	.	V	.	.	II	V	.	+	.	.	.
Cypripedium guttatum –hl	.	.	V	.	I	II	I	.	.	.	.	.
Galium boreale –hl	III	IV	V	.	II	+	.	.	+	.	.	.
Sanguisorba officinalis –hl	V	V	V	+	II	+	III	.	.	.	.	.
Chamaenerion angustifolium -hl	I	III	V	+	III	II	.	.	I	r	.	.
Rubus saxatilis –hl	.	+	V^2	.	.	+	I	.	.	.	.	.
Artemisia tanacetifolia –hl	II	IV	V^2	.	.	.	.	.	.	.	.	.
Aquilegia parviflora –hl	II	V	V	.	I	.	.	.	.	.	.	.
Pulsatilla patens –hl	IV	III	V	.	.	.	.	.	.	.	.	.
Zigadenus sibiricus –hl	.	.	V	.	.	+	V	.	.	.	.	.
Maianthemum bifolium –hl	.	I	IV	.	.	+	.	.	.	.	.	.
Viola mauritii –hl	.	+	IV	.	.	+	.	.	.	.	.	.
Pleurospermum uralense -hl	.	+	IV	.	.	+	.	.	.	.	.	.
Limnas stelleri –hl	V^2	V	V^2	III	V	V	V^2	I	.	.	+	.
Pentaphylloides fruticosa –sl	V	.	.	+	III	III	.	.	.	.	.	.
Rosa acicularis –sl	.	V	V	IV	II	V	V	.	I	I	+	I
Atragene sibirica –hl	I	III	V	+	III	IV	II	.	.	.	.	.
Aconitum ranunculoides -hl	.	.	.	.	I	V	V	.	.	.	.	.
Sorbus sibirica –sl	.	.	IV	.	II	II	IV	.	.	.	.	.
Calamagrostis langsdorfii -hl	.	III	II	I	.	IV	I	.	.	.	.	.

Spiraea media –s1	II	IV	V	.	III	III	.	.	.	.	.	.
Salix brachypoda –s1	III	II	.	.	IV	III	.	.	.	.	.	.
Carex amgunensis -h1	I	IV	.	II	.	.	.	.	.	.	.	.
Salix bebbiana –s1	II	IV	II	III	II	+	I	.	.	.	.	.
Polygala comosa –h1	III	.	IV	.	.	.	.	.	.	.	.	.
Carex pediformis -h1	II	I	.	.	II	.	.	.	.	.	.	.
Lathyrus humilis -h1	II	V^2	II^2	II	.	.	.	.	.	.	.	.
Scorzonera radiata -h1	.	III	II	+	.	.	.	.	.	.	I	.

ALPINE HEATHS IN THE WESTERN CARPATHIANS - A NEW APPROACH TO THEIR CLASSIFICATION

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ABSTRACT - Using physiognomic parameters (structure), qualitative and quantitative parameters (presence or absence of significant components (life-forms, chorological elements), abundance of plant species and relation among them (spatial pattern) were classified alpine heaths and contact vegetation habitats. Four clusters were recognized - beside own alpine heath class (*Loiseleurio-Vaccinietea*) also three grassland-like habitats (class *Carici rupestris-Kobresietea bellardii*, class *Caricetea curvulae* and *Nardus stricta*-rich grasslands). Each vegetation type is shortly defined with respect to regional peculiarities in the Western Carpathians.

KEYWORDS - Alpine vegetation, *Loiseleurio-Vaccinietea*, Natura 2000.

INTRODUCTION

In the Western Carpathians alpine heaths were recently classified within the large defined class *Juncetea trifidi*. This class encompassed various stands on soils with acidic to neutral reaction, including alpine grasslands on outcrops and flat to steep slopes, and dwarf scrub heaths forming mosaic vegetation with other above mentioned types. Using floristic criterion there were no sufficient differences, though ecological and physiognomic differences are visible on first look. In the period of mapping programs such as NATURA 2000, there is optimal (and practical) to recognize stands according to their structure and ecological demands, which are connected with following nature protection and management plans.