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Biogeographical Diversity of Alpine Tundra Vegetation in the Oceanic Regions of Northeast Asia

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Abstract

The Arctic tundra zone and alpine vegetation belt are characterized by a complex of dwarf-shrub, graminoid and herbaceous tundra communities that occur in conditions of heat deficit and a very short growing season. The effects of these climatic factors in different habitats are strongly controlled by topography. Generally, tundra plant communities occupy their own microhabitats with peculiar environmental conditions that create the highly diverse vegetation mosaic in alpine belts. In oceanic regions of Northeast Asia, alpine vegetation occurs from the temperate to boreal zones of Japan and Russia. This paper focuses on the most peculiar representatives of six alpine vegetation classes. Phytosociological diversity of tundra communities is described, in first approximation, with special reference to their biogeographical distributional patterns.

1. Introduction

According to traditional understanding of vegetation zonation in northern Asia, tundra, as a vegetation type, is characteristic to polar deserts and Arctic tundra zones and to the upper vegetation belts of large mountain systems in the temperate, boreal and subarctic zones.

In northeastern Asia, only Wrangell and Gerald Islands are in the zone of Arctic Deserts (KOLESNIKOV 1961), which are characterized by lack of a closed vegetation cover. Large areas on these islands are covered by talus or rock outcrops. Crustose and foliose lichens (species of *Gyrophora, Lecidea,* and *Rhizocarpon*) are most abundant on the rocky substrates. On sites with accumulations of fine soil, a spare vegetation cover is formed by fruticose lichens (*Alectoria, Cetraria* and *Cladonia*) and mosses (mainly *Andraea papillosa, Pogonatum capillare, Rhacomitrium lanuginosum* and *Tetraplodon mnioides*). Vascular plants are represented by *Douglasia ochotensis, Artemisia glomerata, Papaver polare, Saussurea tilesii, Saxifraga funstonii,* etc. The bryophytes and flowering plants are scattered and not numerous (GORODKOV 1958).

The coast of the Arctic Ocean and all of the Chukotka Peninsula north of 65°N are covered by tundra vegetation. The tundra zone is subdivided into two subzones: typical Arctic tundra along the Arctic coast and lichen tundra as the main zonal vegetation on the Chukotka Peninsula and lower Anadyr River basin (KOZHEVNIKOV 1996). The Far Eastern sectors of the Arctic Polar Desert and Tundra are differentiated from the rest of the circum-Arctic zone by the presence of so-called Beringian plant species, which are also common to Alaskan and eastern-Canadian sectors of the Arctic zone (YURTSEV et al. 1978).

Tundra vegetation is characterized by a closed, one-layer cover composed mainly of perennial plants, especially dwarf-shrubs, mosses and lichens, and by a lack of larger shrubs and trees. Most typical tundra plants have their renewal buds not higher than 20–30 cm above the ground and reproduce mainly vegetatively. All tundra plants are adapted to the short vegetative season with its long period of daylight (KOZHEVNIKOV 1996). Tundra communities vary in composition depending on site edaphic and climatic conditions. Regions along the Arctic coast are characterized by predominance of sedge and heath communities with *Carex* spp., *Eriophorum vaginatum, Vaccinium uliginosum, Betula exilis* and leafy mosses. On the Chukotka Peninsula, sedge communities are also important, but lichen communities with *Cladina* spp. and some ericaceous dwarf-shrubs increase (CAVM 2002).

Tundra communities across the Arctic zone in Asia were described in a series of Russian publications that used a dominance approach to vegetation classification (GORODKOV 1958, YURTSEV et al. 1978, ALEXANDROVA 1980, MATVEEVA 1998). Phytosociological studies in those areas have been carried on recently and concerned several types of Arctic vegetation (RAZZHIVIN 1994, SINELNIKOVA 2001, KUCHEROV & DANIELS 2005). The alpine tundra vegetation in oceanic regions of Northeast Asia in Russia is poorly studied. Several publications from Kamchatka (NESHATAEV et al. 1994), the Sikhote-Alin mountains (GRISHIN et al. 1996) and Commander Islands (KRESTOV 2004) are known at present, but these few do not provide a general view of alpine tundra vegetation of the region.

In contrast, studies of alpine tundra vegetation in Japan are among the most adSvanced phytosociological studies (SUZUKI 1964, OHBA 1967, 1968, 1969, 1974, 1982, NAKAMURA 1986, 1987, 1994, 1997). The hierarchies of alpine vegetation in Northeast Asia were suggested in the series of publications of OHBA (1968, 1969, 1974), who introduced a worldwide-accepted class Carici rupestris-Kobresietea bellardii (OHBA 1974). Our research on northeast Asian alpine tundra vegetation in Sakhalin and Kamchatka since 1999 allowed us to extend considerably a relevé bank for this territory. This paper aims to provide a general overview of phytosociological diversity of alpine tundra communities, with special reference to their biogeographical distributional patterns.

2. Study area

The data were collected in oceanic regions of northeast Asia between Mt. Hakusan in Honshu (2702 m a.s.l., 36.150°N; 136.774°E, Japan) on the south, Mt. Tolbachik in Kamtchatka (3682 m a.s.l.; 55.830°N; 160.330°E, Russia) on the north. Alpine vegetation occurs on high mountains above 3000 m central in Japan and above 1000 m on Kamchatka. High mountains are mainly volcanoes, including the highest peak in the northeast Asia, Kliuchevskoi (4835 m a.s.l.), 6000 years active basaltic volcano in Kamchatka; the basaltic Taisetsu Massif (2290 m) in Hokkaido; and Mts. Ontake (3063 m) and Fuji (3776 m) in Honshu. Mt. Ploskaya (3903 m) in Kamchatka is a dormant volcano with last activity estimated at 1000 years BP. Mts. Lopatina (1608 m) and Chamga (1510 m) in Sakhalin, Hidaka (2052 m) in Hokkaido, Akaishi (3193 m), Kisokomagatake (2956 m) and Hotaka (3190 m) in Honshu were formed during orogenic activity in the Paleozoic and Mesozoic eras. The substrates on which alpine vegetation occurs include, among others, sedimentary, metamorphic, peridotite, serpentinite rocks and intrusive granites.

The climate in the study area is influenced strongly by the Asian monsoon system in combination with two major baric centers, the Siberian high pressure system and the Aleutian depression. Kamchatka’s interior is characterized by a continental boreal climate having low precipitation, high temperature in summer and low temperature in winter. The oceanic side of the peninsula has an oceanic boreal climate characterized by cool foggy summers and snowy winters. The warm sea currents Kuro-shio and Tsushima increase and the cold Pacific current Oya-shio decreases the mean temperature in the island arcs and adjacent mainland areas. Snow is one of the most important climatic factors for alpine vegetation. The Japanese Archipelago has a typical temperate monsoon climate that differentiates the local climates of the Pacific and Japan Sea sides. The pacific side is characterized by well expressed fens and shallow snow cover, the Japan Sea side by heavy snow cover.

3. Phytogeographical notions

Northeast Asia is the one of the important floristic centers of the holarctic kingdom (TAKHTAJAN 1986). The alpine flora of northeast Asia is composed of species with chiefly Euro-Siberian and Sino-Japanese distribution. The species composition of each class, however, is characterized by its own floral elements (SHIMIZU 1983, NAKAMURA 1986, 1997). The establishment of present plant communities went through considerable geological changes, particularly connected with sealevel fluctuations and the cooling period in the Quaternary. Due to the extensive changes in shoreline and wide amplitude of climatic fluctuations, as well as corresponding species migrations, the present alpine communities are composed of circumpolar, amphi-Pacific and northeast Asian elements, with a large fraction of endemic species (SHIMIZU 1983). In the oceanic sector, many species with circumpolar and / or trans-Eurasian Arctic distribution have their southern limits in the oceanic sector of northeast Asia, reaching the Japanese Archipelago (Fig. 1).

Modern species distribution patterns are explained by modern climatic conditions as well as by Pleistocene and Holocene climatic and geological changes. Before 25 million years BP, the whole study area was occupied by a flora that was close to the modern warm-temperate flora. The geological changes, as well as changes in temperature and moisture regimes in the Miocene, Pliocene and Pleistocene, led to changes in sealevel that connected and then disconnected insular areas with the continent via land bridges (GRICHUK 1984) that must be considered as important pathways for intensive floristic exchange between land massifs (TATEWAKI 1963, HULTÉN 1973). The modern pattern of temperatures and precipitation in the region was formed in the early Holocene, when general warming caused expansion of heat-dependent vegetation from Pleistocene refugia. At the same time, vegetation formed on the islands in the Pleistocene became restricted to isolated habitats, of which the alpine belts in large mountain systems became the most important modern refugia.

4. Plant community diversity

The preliminary prodromus of alpine tundra vegetation of the oceanic regions of northeast Asia includes 58 associations classified into 14 alliances, 8 orders and 6 classes. 23 associations are introduced here provisionally.

4.1 Carici rupestris-Kobresietea bellardii Ohba 1974

The communities of this class occur on wind-exposed slopes where shallow snow cover permits cryogenic processes in winter resulting in dry conditions in summer. Hemicryptophytes and deciduous chamaephytes are characteristic life forms. The class includes two orders (Table 1).

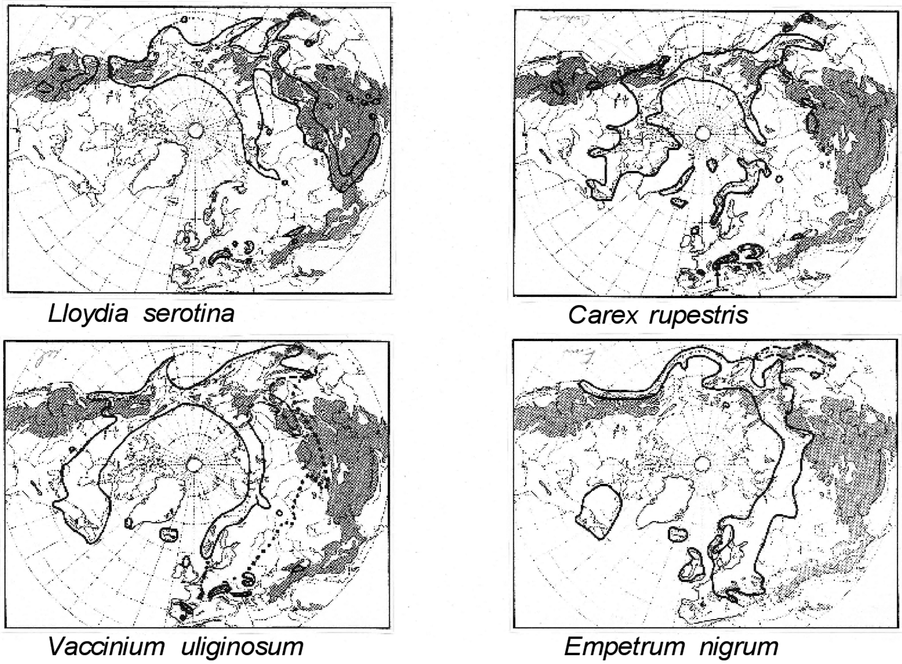

Fig. 1: Distribution map of Alpine plants (HULTÉN 1968)

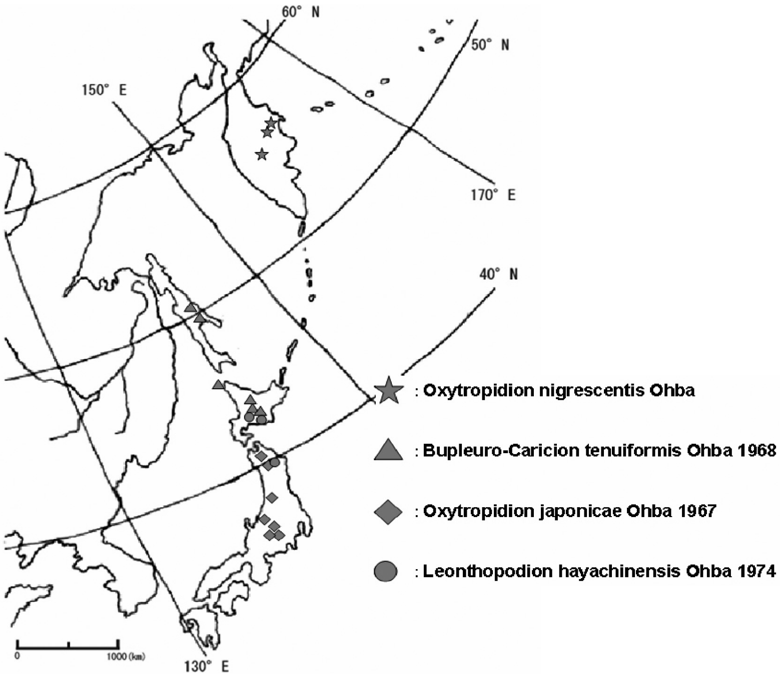

Fig. 2: Distribution of wind-exposed alpine meadows

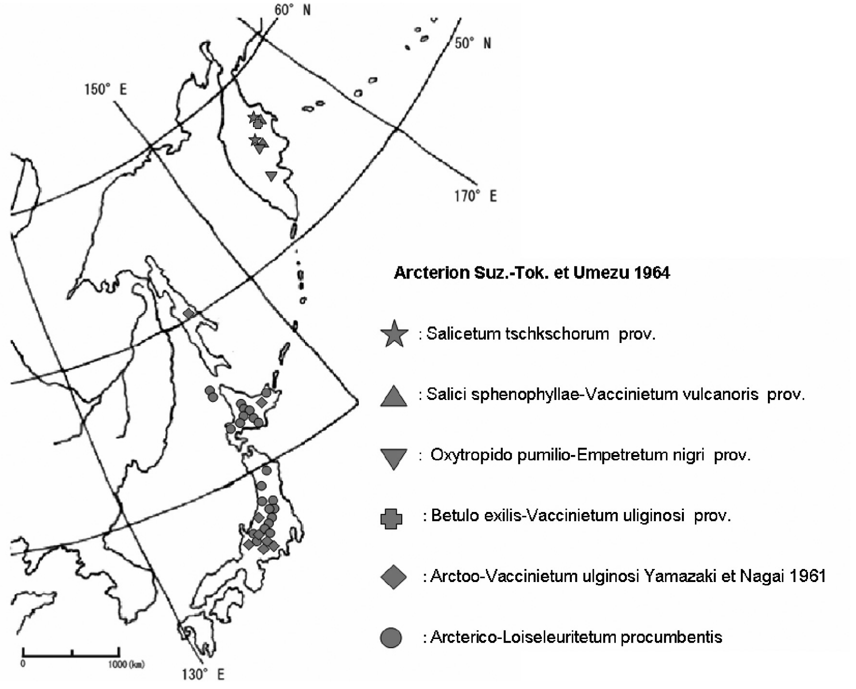

Fig. 3: Distribution of dwarf-shrub alpine tundra

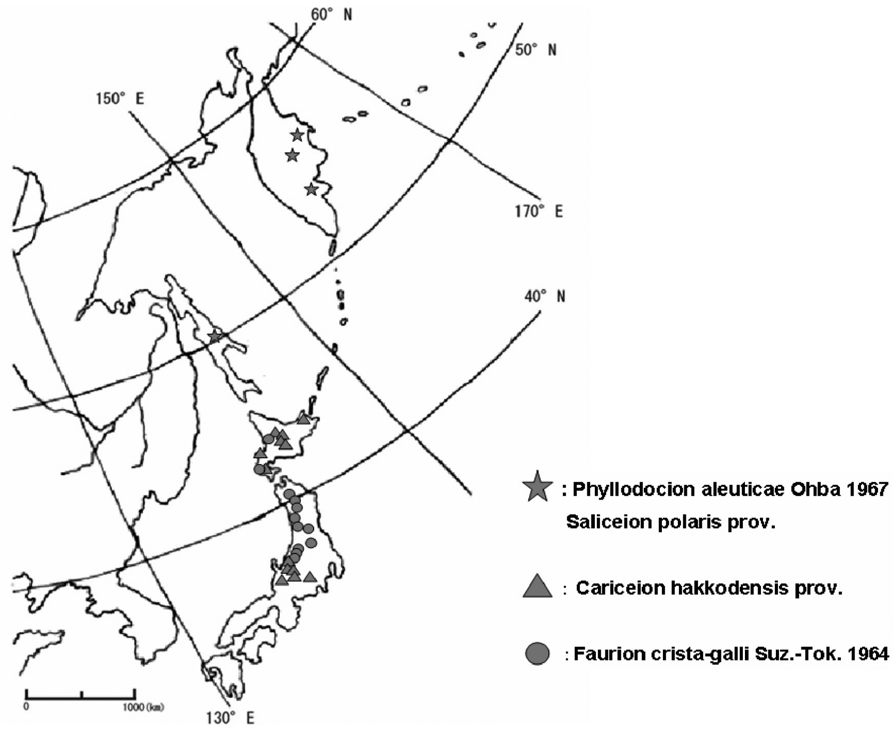

Fig. 4: Distribution of snow-patch alpine tundra

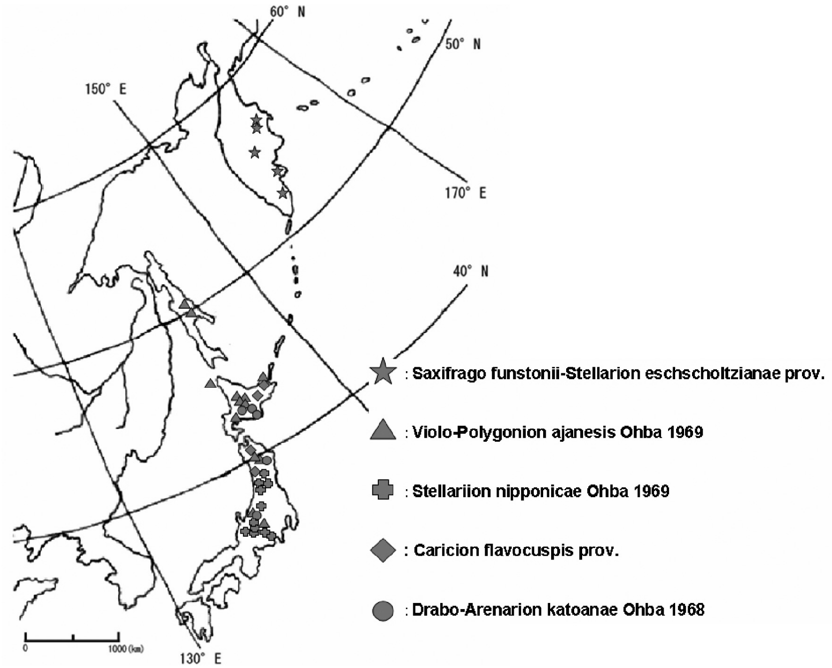

Fig. 5: Distribution of alpine bare land plant communities

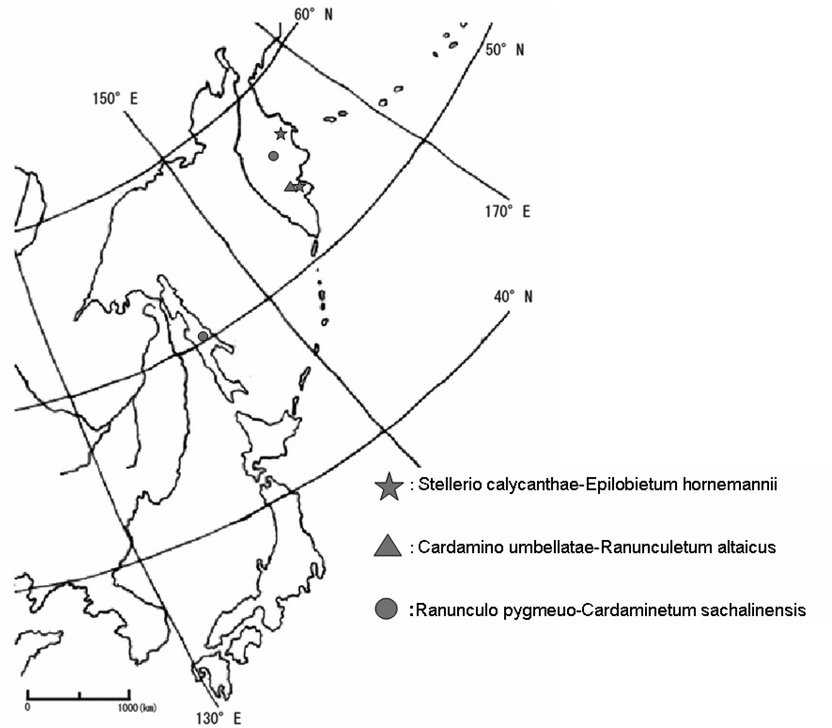

Fig. 6: Distribution of alpine spring-water plant communities

The order Kobresio-Dryadetalia occurs at high latitudes in the circumpolar area. The northern boundary of the Caricetalia tenuiformis is central Sakhalin, within the common range of *Carex tenuiformis, Campanula chamissonis* and *Rhodiola rosea.* Oxytropidion nigrescentis is characterized by *Pedicularis capitata, Pedicularis eryophora, Oxytropis revoluta, Oxytropis pumilio, Carex koraginensis* and *Carex fuscidula.* The alliance Bupleuro-Caricion tenuiformis occurs in central Sakhalin and Hokkaido, and is characterized by *Bupleurum triradiatum, Gentianopsis aurucilata* and *Calamagrostis sugawarae.* The alliance Oxytropidion japonicae occurs in Honshu, isolated from the Hokkaido part of its range, and is characterized by *Oxytropis japonica, Pedicularis apodochila, Artemisia glomerata* and *Agrostis flaccida.* The alliance Leontopodion hayachinensis is characterized by *Aquilegia flabellata* var. *pumila, Pinguicula vulgaris* var. *macroceras* and occurs on ultrabasic rocks.

Table 1: Regional Occurrence of wind-exposed alpine meadows

Vegetation unit	Distribution			
	Kam	Sak	Hok	Hon
Carici rupestris-Kobresietea bellardii Ohba 1974				
Kobresio-Dryadetalia Br.-Bl. 1948				
Oxytropidion nigrescentis Ohba 1974				
Salici arcticae-Kobresietum myosuroidis prov.	+			
Oxytropidio pumilio-Caricetum kamtschaticae prov.	+			
Caricetalia tenuiformis Ohba 1968				
Bupleuro-Caricion tenuiformis Ohba 1974				
Bupleuro triradiati-Caricetum microtrichae prov.		+	+	
Hedysaro sachalinensi-Caricetum rupestris prov.		+	+	
Salici-Oxytropidetum jezoensis Tohyama 1971		+	+	
Oxytropido megalanthae-Caricetum tenuiformis Ohba 1967		+	+	
Leontopodion hayashinensis Ohba 1974				
Leontopodio hayashinensis-Caricetum tenuiformis Ohba			+	+
Saxifragetum nishidae Ohba 1974			+	+
Hypochoerido-Caricetum tenuiformis Ohba 1968			+	+
Caricetum melanocarpae Nakamura 1988			+	+
Oxytropidion japonicae Ohba 1967				
Leontopodietum shinanensis Ohba 1974				+
Saussureo-Oxytropidetum japonicae Ohba 1981				+
Euphrasio insignis-Oxytropidetum japonicae Ohba 1981				+
Leontopodietum fauriei Ohba 1967				+

4.2 Loiseleurio-Vaccinietea Eggler 1952

This class is composed of dwarf-shrub communities and occurs on well drained sites with little exposure to the wind. The species composition is represented by prostrate chamaephytes from the genera *Loiseleuria, Empetrum, Bryanthus, Arcous, Arcterica, Vaccinium* and *Diapensia.* Lichens, such as *Cetraria, Cladina, Cladonia, Stereocaulon, Thamnolia,* have a high constancy. The order Arctericetalia occurs only in the East Asia. Characteristic species of the order and alliance are *Arcterica nana, Arctous alpine* var. *japonica, Bryanthus gmelinii* and *Diapensia lapponica* ssp. *obovata.* The association Salicetum tschuktschorum occurs in boreal alpine tundra. The Arctoo-Vaccinietum uliginosi represents the summergreen dwarf-shrub communities occurring on less stable substrates, as opposed to evergreen communities of the Arcterico-Loiseleurietum procumbentis.

Table 2: Regional Occurrence of dwarf-shrub alpine tundra

Vegetation unit	Distribution			
	Kam	Sak	Hok	Hon
<u>**Loiseleurio-Vaccinetea Eggler 1952**</u>				
Arctericetalia Suz.-Tok. et Umezu 1964				
Arctericion Suz.-Tok. et Umezu 1964				
Salicetum tschuktschorum prov.	+			
Oxytropido pumilio-Empetretum nigri prov.	+			
Salici sphenophyllae-Vaccinietum vulcanoris prov.	+			
Betulo exilis-Vaccinietum uliginosi prov.	+			
Arctoo-Vaccinietum uliginosi Yamazaki et Nagai 1961		+		
Arctoo-Vaccinietum uliginosi Yamazaki et Nagai 1961			+	+
Arcterico-Loiseleurietum procumbentis Ohba ex Suz.-Tok. 1964			+	+

4.3 Phyllodoco-Harrimanelletea Knapp 1954

The Phyllodoco-Harrimanelletea (Table 3) is developed under the influence of the oceanic climatic conditions and is vicarious to European Salicetea herbaceae Br.-Bl. et al. 1947. High winter precipitation in this area and deep snow cover cause the development of snow-patch communities composed of species well adapted to very short growing seasons with peak in late summer. The alliance Phyllodocion aleuticae occupies well drained habitats with late snowmelt. Characteristic species of this alliance include mainly prostrate chamaephytes such as *Phyllodoce aleutica, Phyllodoce caerulea* and *Harrimanella stelleriana* and hemicryptophytes such as *Sibbaldia procumbens* and *Primula cuneifolia.* The Phyllodocion aleuticae includes two suballiances: Salicenion polaris in Kamtchatka and Caricenion hakkodensis in Sakhalin and Japan. Faurion crista-galli indicates those sites that continue to be wet after snowmelt. Common species of this alliance are *Fauria crista-galli, Carex blepharicarpa, Gaultheria adenothrix* and *Heloniopsis orientalis.*

Table 3: Regional Occurrence of snow-patch alpine tundra

Vegetation unit	Distribution			
	Kam	Sak	Hok	Hon
<u>**Loiseleurio-Vaccinetea Eggler 1952**</u>				
Arctericetalia Suz.-Tok. et Umezu 1964				
Arctericion Suz.-Tok. et Umezu 1964				
Salicetum tschuktschorum prov.	+			
Oxytropido pumilio-Empetretum nigri prov.	+			
Salici sphenophyllae-Vaccinietum vulcanoris prov.	+			
Betulo exilis-Vaccinietum uliginosi prov.	+			
Arctoo-Vaccinietum uliginosi Yamazaki et Nagai 1961		+		
Arctoo-Vaccinietum uliginosi Yamazaki et Nagai 1961			+	+
Arcterico-Loiseleurietum procumbentis Ohba ex Suz.-Tok. 1964			+	+

4.4 Dicentro-Stellarietea nipponicae Ohba 1968

The class Dicentro-Stellarietea nipponicae is vicarious to European Thlaspietea rotundifolii Br.-Bl. et al. 1948. It occurs on alpine bare land, including unstable sites such as patterned ground, volcanic desert, rocky slopes created by avalanches, and ultrabasic rocks. Most of the distribution area of this class lies in the Russian Far East and eastern Siberia; some communities occur also in boreal eastern North America. The class includes two orders (Table 4). The Oxygraphiso glacialis-Minuartietalia arcticae occurs at higher latitudes, where it replaces the order Minuartietalia vernae japonicae characteristic to Honshu, Hokkaido and Sakhalin. The alliance Saxifrago funstonii-Stellarion escholtzianae in Kamtchatka occupies elevations from 600 to 1520 m. and is characterized by *Lagotis glauca, Potentilla vulcanicola, Poa malacantha, Poa arctica,* etc. This alliance occurs on volcanic barrens and wet unstable sites around snow patches.

The order Minuartietalia vernae japonicae occurs in Sakhalin and Hokkaido and is characterized by *Festuca ovina* var. *alpina, Potentilla matsumurae, Minuartia verna* var. *japonica, Agrostis flaccida.* It includes four alliances. The Violo-Polygonion ajanensis that occurs on volcanic barrens and limestone is characterized by *Polygonum ajanensis, Saxjfraga sachalinensis, Bupleurum triradiatum, Campanula uyemurae* and *Poa neosachalinensis*. The Caricion flavocuspis occurs on mesic fine volcanic materials at ele

Table 4: Regional Occurrence of alpine bareland plant communities

Vegetation unit	Distribution			
	Kam	Sak	Hok	Hon
Dicentro-Stellarietea nipponicae Ohba 1968				
Oxygrapho glacialis-Minuartietalia arcticae prov.				
Saxifrago funstonii-Stellarion escholtzianae prov.				
Junco biglimi-Lagotisetum glaucae prov.	+			
Ermannio-Papaveretum microcarpae prov.	+			
Minuartio microcarpae-Artemisietum glomeratae prov.	+			
Saxifragetum merckii prov.	+			
Minuartietalia vernae-japonicae Ohba 1968				
Violo-Polygonion ajanensis Ohba 1969				
Oxyrio-Taraxacetum tatewakii prov.		+		
Scorsonero radians-Miyakeetum integrifoliae prov.		+		
Bupleuro ajanensis-Saussuretum kitamurae prov.		+		
Thlaspi cochleariiformis-Artemisietum koidzumii prov.		+		
Drabo ussuriensis-Minuartietum vernae prov.		+		
Potentillo miyabei-Arenerietum merckioidis Nakamura 1988			+	
Papaveretum fauriei Ohba 1969			+	
Thlaspi-Polygonetum ajanensis Ohba 1969			+	
Caricion flavocuspis prov.				
Carici-Saxifragetum merckii Ohba 1969			+	+
Arenerietum merckioidis chokaiensis Ohba 1969			+	+
Reg. ass. Dicentro-Violetum crassae Ohba 1969			+	+
Stellario-Polygonetum ajanensis Ohba 1969			+	+
Drabo-Arenarion katoanae Ohba 1968				
Cerastio-Minuartietum vernae japonicae Ohba 1968			+	+
Arenarietum lanceolatae Ohba 1968			+	+
Saussuretum chionophyllae Ohba 1968			+	+
Sanguisorbo-Minuartietum vernae japonicae Ohba 1968			+	+
Leontopodietum fauriei angustifolii Ohba 1968			+	+
Stellarion nipponicae Ohba 1969				
Dicentro-Violetum crassae Ohba 1969				+
Melandryo-Cerastietum schizopetali Ohba 1969				+
Sedo rosei-Saxifragetum bronchialis funstonii Nakamura 1986				+
Arabido-Polygonetum weirichii Ohba 1969				+
Stellario nipponicae-Caricetum stenanthae prov.				+

vation 1330 to 2230 m on Hokkaido and in Tohoku (northeastern Honshu). The Stellarion nipponicae occurs in central Honshu, from 2410 to 3260 m elevation, on dry unstable volcanic barrens and is characterized by *Stellaria nipponica, Minuartia hondoensis, Cerastium schizopetarum, Polygonum weyrichii* var. *alpinum, Carex stenantha,* etc. The Drabo-Arenarion katoane is characteristic of ultrabasic rocks in Hokkaido and Honshu. *Draba japonica* and *Arenaria katoana* are characteristic species.

4.5 Montio-Cardaminetea Br.-Bl. et Tüxen 1943

This class occurs widely over the Northern Hemisphrere in montane to alpine belts. It combines the various plant communities dependent on water from permanent springs, occurring on wet, oligotrophic sites. Sagino sagioidis-Stellarietalia umbellatae has a wide distribution area in alpine belts from central Eurasia to western North America. Epilobio alpini-Saxifragion porsildianae is characterized by *Saxifraga porsildiana, Saxifraga calycina, Epilobium alpinum.* Characteristic genera of this class are herbs *Epilobium, Saxifgara, Chrysosplenium, Cardamine, Stellaria* and *Ranunculus* and bryophytes *Pohlia, Bryum, Hygrogypnum*.

Table 5: Regional Occurrence of Spring-water plant communities

Vegetation unit	Distribution			
	Kam	Sak	Hok	Hon
Montio-Cardaminetea Br.-Bl. et Tx. 1943				
Sagino-saginoidis-Stellarietalia umbellatae prov.				
Epilobio alpini-Saxifragion porsildianae prov.				
Stellario calycanthae-Epilobietum hornemannii prov.	+			
Cardamino umbellatae-Ranunculetum altaici prov.	+			
Minuartio microcarpae-Artemisietum glomeratae prov.	+			
Ranunculo pygmaei-Cardaminetum sachalinensis prov.	+	+		

4.6 Salicetea arcticae prov.

The class Salicetea arcticae occurs at high latitudes in the Arctic tundra zone, occupying mesic to humid habitats and covering rather extensive areas. The plant communities are composed of prostrate chamephytes and dominated by dwarf-shrub species of *Salix*. The order Salicetalia reticulate-chamissonis is characteristic to the oceanic sectors of the Russian Far East and western Alaska. The Salicetum reticulatae-chamissonis was first described in Kamtchakta. *Salix reticulata* and *Salix arctica* usually dominate the communities, in combination with *Salix chamissonis, Salix sphenophylla* and *Salix ovalifolia*.

Table 6: Regional Occurrence of dwarf willow alpine tundra

Vegetation unit	Distribution			
	Kam	Sak	Hok	Hon
Salicetea arcticae prov.				
Salicetalia reticulato-chamissonis prov.				
Salicion reticulato-chamissonis prov.				
Salicetum reticulato-chamissonis prov.	+			

5. Phytosociological diversity of Alpine Vegetation in Northeast Asia

Phytosociological diversity of the alpine vegetation in the oceanic sector of northeast Asia is much higher than in the continental sectors. The oceanic climatic conditions provide very deep snow cover and better protection of the ground from winter freezing, in northern areas very short growing seasons that reduce competition from other potential dominants and comfortable moisture conditions. During the Pleistocene Maximum ice sheets did not cover northeast Asia, and an arid climate was established on extensive areas of the Asian mainland (GRICHUK 1984). The oceanic sector of northeast Asia in the Pleistocene was likely a very important refugium supporting humidity-dependent vegetation. The sea regression caused the appearance of land bridges between islands and between them and the mainland. Therefore north-south oriented long island arcs could serve as corridors for vegetation migration, especially for drought-tolerant species associated with continental tundra communities.

From the distributional pattern of six classes, the most important boundary line that divides alpine vegetation lies between Sakhalin and Kamchatka. Most southern and northern alliances and orders are geographically isolated in Kamchatka, with greater influence of Beringian floristic centers and Sakhalin-Hokkaido-Honshu influenced mainly by the Sino-Japanese flora. Distribution of the Bupleuro-Caricion tenuiformis of the Carici rupestris-Kobresietea bellardii is restricted to Sakhalin and Hokkaido. The Violo-Polygonion ajanensis occurs on Sakhalin, Hokkaido and Honshu. In contrast to southern regions, Kamchatka is characterized by species with circumboreal and circumpolar distribution, as illustrated by the geographical ranges of shrubby *Salix* and *Betula* species.

Honshu represents the southernmost boundary of alpine vegetation, which in this area does not form an alpine belt but occurs on azonal habitats such as volcanic barrens, rock outcrops and other sites with specific topographic and wind conditions that prevent occurrence of the zonal vegetation. The number of species in vegetation units in southernmost tundra communities however, remains comparable to their northern analogs. The communities of the Carici rupestris-Kobresietea bellardii contain from 15 to 25 species, Loiseleurio-Vaccinietea from 10 to 25 species, and Dicentro-Stellarietea nipponicae from 9 to 14 species.

On the second highest peak of Honshu, Mt. Kitadake (3192 m), there were found several species whose main range lies at high latitudes in Arctic, such as *Saxifraga cernua, S. bronchialis* ssp. *funstonii, Arenaria macrocarpa, Potentilla nivea, Artemisia glomerata, Luzula arcuata* ssp. *unalaschensis, Ptilagrostis mongholica* and *Poa malacantha*. Not only northern elements but also endemic species such as *Saussurea triptera* var. *minor* and *Seseli libanotis* ssp. *japonica* f. *alpicola,* that were differentiated from their low-altitude parents likely in Pleistocene, contribute to the alpine tundra diversity (NAKAMURA 1997). Limestone and ultrabasic rocks on high mountains are among the best low-altitude habitats for alpine vegetation in southern regions.

The alpine belts in modern time generally are being affected by devastating human activity or grazing by livestock. The moderate influence on the alpine belt of tourist activities does not bring fatal destruction to the plant communities. Up to now no evidence of decline of alpine vegetation because of global warming and air pollution has been provided. However, severe climatic influences such as great temperature amplitudes at different time scales, winds, rainfalls, soil erosions and great volcanic activity makes the alpine substrates very dynamic. Appearance of new substrates under the different climatic conditions, a great variety of primary succession paths and the coexistence of species with different geographical ranges leads to diversification of the biota at the species and community levels and to development of plant adaptations to different conditions that makes alpine tundra communities one of the most complicated subjects for study.

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