Phytogeography boundaries between Stone-birch and White-birch forests in the North of the Koryak Region

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Abstract. The distribution boundaries of the two birch species communities: Stone-birch (Betula ermanii Cham.) and White birch (Betula platyphylla Sukacz) forests have been firstly reliably established for the North of the Koryak Region. The remote sensing data, aerial observations, original relevés, and itinerary research data were used. A map of the Stone-birch and White-birch forests allocation in the mainland part of the Koryak Region was compiled. It was shown that Stone-birch groves were found in relatively warmer and wetter areas adjacent to the Bering Sea coast. They occupy Southern and South-Eastern slopes of the Koryak Upland spurs; whereas White birch forests are common in the continental districts. They are found in the valleys of the rivers Penzhina, Talovka, Belaya, Oklan, Apukvayam, on the Penzhinsk Upland Ridge slopes. Stone-birch forests do not occur North of 62° northern latitude, do not overcome the boggy depression of Parapolsky Dale, and do not occur to the West of 167° 30’ eastern longitude. The natural phytogeographical boundary between the areas of the two birch formations are the Southern and South-Eastern spurs of the Koryak Upland.

1. Introduction
The data on the distribution patterns of the two birch species in the mainland of the Koryak Region are very few, controversial and doubtful. According to the aerial survey of the 1950s, the Northern border of the stone birch areal had reached 61° 10’ north latitude (N L) [1]. Previously it was considered that the boundary between the areas of two birch formations run along the South-Eastern ranges of the Koryak Upland [1]. Aerial observations of Shamshin [2] showed that the limit of distribution of single groups and individual trees of Betula ermanii was found at 61° 40’ N L. But it is quite impossible and doubtful to determine the birch species from a helicopter or a plane. So, the Northernmost Stone-birch grove firstly found and studied by us was located in the valley of Tyklavayam River at the latitude 61° 18 07’ 07” N L [3]. In Central and Northern parts of the Koryak Upland Betula ermanii is lacking [4]. The Northern border of the Stone-birch (Betula ermanii Cham.) forests distribution runs along the South-Eastern spurs of the Koryak Upland. White birch groves were pointed for the river valleys of the continental districts of the Penzhina River Basin [5, 6]. The goal of our research was to clarify the natural phytogeographical boundaries between the areals of the two birch formations.
2. Methods and Materials

2.1. Study area
Beringian forest-tundra zone is situated on the North-East of Asia. It covers the mainland part of the Kamechatsky Krai and Southern districts of the Chukotka Autonomous Region. The terrain is alpine and mid-mountainous, including the Koryak Upland, Penzhinsky Range and the adjacent intermountain depressions. Zonal vegetation is represented by Siberian dwarf-pine (Pinus pumila) and dwarf-alder (Alnus fruticosus) woodlands; dwarf-birch (Betula middendorfii) shrubs occupy burnt areas and replace zonal vegetation. Willow (Salix pulchra) thickets occur in wet depressions and along streams. Shrubby vegetation alternates with tundra and bogs. Forest vegetation in the North-Western part of the Beringian forest-tundra zone is represented by valley larch forests (Larix cajanderi) and White-birch forests (Betula platyphylla); and in the Southern part – by Stone-birch (Betula ermanii) groves. In floodplains of major rivers, poplar (Populus suaveolens), chozenia (Chosenia arbutifolia), alder (Alnus hirsuta) and willow (Salix udensis, Salix schwerinii) forests are typical.

2.2. Field and aerial studies
The field studies of the vegetation cover of the North of the Koryak Region were carried out in 2010–2019 within 12 key areas. The field study combined itinerary research and sample plots records (relevés). As the birch communities are quite rare in the region the position of all birch groves met during itinerary research was recorded using GPS navigator. Itinerary research was carried out using tracked all-terrain vehicles (600 km), motorboats (700 km), by foot (800 km) and supplemented by the observations from helicopter (1200 km).

The field data on species composition, community structure, and habitats of forest communities were collected on 35 sample plots 20×20 m each. On every sample plots the trees were counted and the height and diameter were measured for every tree. We also measured the height of 3–5 trees with the average diameter, and 1–2 ones with minimal and maximal diameters; the tree age was estimated by counting year-rings on the cores selected from trunks using the Pressler age-drill; the crown density was measured, and the vitality of trees was estimated. For the understory and young tree species the crown density and the height were measured, and the number of individuals was counted. On each sample plot we estimated the coverage of field and ground layers and recorded the species composition. For every species the percentage coverage was estimated. The diagnostic features of soil and the habitat were studied at 5–10 soil pits 0.3–1.0 m depth. Relief parameters were estimated using aviation altimeter, compass and inclinometer.

We used the free remote sensing data space imagery (from different Web Geo Services), aerial observations and aerial photos. As a result, we compiled the map showing the current distribution of the two birch species in the North of the Koryak Region. It is possible to recognize the birch-trees from the helicopter or detect them on space images; but it is quite impossible to identify the tree species exactly. So, the points on the map showing the distribution of two birch species were confirmed by the itinerary research and studies on sample plots.

3. Results and discussion

3.1. Stone-birch forests
Stone-birch forests (Betuleta ermanii) are found as island groves in the Southern part of the Koryak Upland: at the Gooven's Peninsula, on the coast of the Olyutorsky Gulf, and in the Vyvenka River basin; they are confined to Southern and South-Eastern slopes of Pylginsky and Vetveyksky Ranges (figure 1). In the South-Eastern districts of the mainland of the Koryak Region, Stone-birch groves are rarely met. The community diversity of Betula ermanii forests was represented by 6 associations joined into three groups of associations: shrub-rich Stone-birch forests (Betuleta ermanii fruticosus) with closed undergrowth of dwarf-alder (Alnus fruticosus), dwarf-pine (Pinus pumila), mountain rowain (Sorbus sambucifolia), reed-grass-rich ones (Betuleta ermanii calamagrostidosa) with the
dense field layer of *Calamagrostis langsdorffii*, and fern-rich stone-birch forests (*Betula ermanii pteridosus*) with the predominance of *Dryopteris expansa* in the field layer.

**Figure 1.** The map of Stone-birch and White-birch forests distribution in the North of the Koryak Region.

Stone-birch (*Betula ermanii* Cham.) forests of the North of Koryak Region were studied at the Northern border of their area. The species composition, community structure, and habitats of Stone-birch groves were described. Their altitude position and geographical distribution were discussed [3]. The classification of Stone-birch communities of the Olyutorsky Gulf coast was developed using the dominant-determinant approach. Within the study area the community diversity of Stone-birch forests was represented by 3 forest types (groups of associations): fern-rich Stone-birch forests, grass-rich ones, and shrub-rich ones. All the syntaxa were previously described at the Kamchatka Peninsula [7]. The Koryak communities differed from the Kamchatka analogues by floristic composition, lower species diversity and high density of the shrub layer. The most important characteristics of shrub-rich Stone-birch communities were the high abundance of mountain rowan (*Sorbus sambucifolia*), dwarf alder (*Alnus fruticosa*); and for the fern-rich ones – the predominance of *Dryopteris expansa* in the herb layer.

In the North of the Koryak Land, stone birch forms small groves on the Southern and Eastern slopes of coastal ridges, fluvio-glacial hills and rocky cliffs along the river valleys. On the Bering Sea coast (the Olyutorsky Gulf, the Gulf of Korf), *Betula ermanii* groves occur from 10 m above the sea level (lower reaches of the Kultushnaya River) to 25–50 m (in the Srednyaya Lagoon, Lavrova Bay, at the Goven’s Peninsula). In a bit more continental areas, in the vicinities of the Ilirgytkhyn Lake, separated from the Bering Sea by the Pylginsky Range (1357 m a. s. l.), Stone-birch groves are met at the altitude about 180–190 m.
Betula ermanii communities are confined to well-drained stony and gravelly slopes, rocky outcrops, covered with a thin layer of soil, underlain by eluvium-diluvium of rocks. Stone-birch groves are usually found in the lower and middle parts of steep slopes (inclination up to 30–45°). They have an important anti-erosion value. The preference by Stone-birch communities the Southern slopes indicates that the current climate conditions in the South of the Koryak Highlands are extremely severe for them. The Northern boundary of the distribution of Stone-birch forests in Northeast Asia currently is limited to the isotherm of 600 °C by the annual sum of active temperatures (t > +10°C) [8, 9]. The Betula ermanii groves studied were growing at the extreme (minimal) limit of the heat supply.

The Stone-birch forests at the Northern limit of their distribution are represented by low-stock stands of V–Vb yield (bonitet) classes. Within the research area, Stone-birch forests were usually formed by different-aged stands of VI–XII age classes (60–240 years). There was a significant differentiation of trees by morphometric parameters; this was manifested in 1.5–2-fold differences in the trunk diameter for trees of same age. The average annual growth of Betula ermanii stems in diameter was 0.8–1.1 mm. The two generations of birch (80 and 160 years old) were revealed in the fern-rich Stone-birch communities of Srednyaya Lagoon. Their radial growth was 1.6 mm and 1.1 mm per year, respectively. The renewal of stone birch was extremely few: the amount of undergrowth never exceeded 375 exemplars/ha.

In comparison with the Kamchatka analogues, the Stone-birch forests at the Northern limit of distribution are characterized by lower species diversity. They differ by sparse tree stands and dense undergrowth. Infralinal Stone-birch groves are considered to be the remnants of widespread birch forests of the Holocene climate optimum that had ended about 5000 years ago. They survived on the southern maritime slopes of the Koryak Upland ridges and turned into fragmentary and floristically impoverished communities. The relic Stone-birch groves of the Koryak Upland are vulnerable to anthropogenic disturbances. They are regarded as rare and endangered communities needing special protection.

3.2. White-birch forests

White-birch (Japanese-birch, Betula platyphylla) forests are distributed much further North than Stone-birch forests; they tend to be located in areas with a continental climate. They are found in the valleys of the rivers Penzhina, Belaya, Talovka, Oklan, Apukvayam [1, 6]. White-birch forests (Betuleta platyphyllae) are found almost exclusively in the Penzhinskoye forestry, covering an area of 172.1 thousand hectares [10]. We found that these two species of birch had never come into contact: their areals have been isolated by vast swampy depressions, mountain ranges and river valleys.

There are three different forest types (or associations) of Betula platyphylla forests: grass-rich White-birch forests (Calamagrostis langsdorffii predominates), shrub-herb-rich ones (shrubs Spiraea beaverdiana, Lonicera caerulea, Rosa acicularis, Ribes triste and herbs Geranium erianthum, Chamerion angustifolium, Thalictrum minus, are constant), and Siberian dwarf-pine-rich ones (Pinus pumila forms the dense understory). White-birch stands are usually found on floodplain terraces on normally drained light loam and sandy loam soils, underlain by pebbles.

Shrub-herb-rich White birch forests (Betuletum platyphyllae herboso-fruticosum) are derived from the shrub-rich larch forests on the clearcuttings or burned areas. Also they replace corresponding types of larch forests in south-western districts where larch is lacking. The species composition and community structure of undergrowth, field and ground layers are the same as in herb-shrub-rich larch forests. As well as larch stands, they can be found on above-floodplain terraces of river valleys, on normally drained light loam and sandy loam soils underlain by pebbles. The stands are monodominant of V yield (bonitet) class, the crown density of the tree layer is 0.5–0.6.

Siberian dwarf pine-rich White birch forests (Betuletum platyphyllae pumilae-pinosa) are characterized by a high density of the undergrowth formed by dwarf-pine and sparse ground layer (the coverage does not exceed 15%). Field layer is formed by dwarf-shrubs (Vaccinium vitis-idaea, Ledum decumbens, Orthilia obtusata, Pyrola incarnata), mesophytic sedges (Carex pallida, Carex van-
heurckii), grasses (Calamagrostis langsdorffii, Calamagrostis lapponum), horsetails (Equisetum pratense, Equisetum arvense), etc. The moss layer is sparse as well, its coverage does not exceed 10%; green mesophytic mosses are constant (Brachythecium sp., Polytrichum commune, Sanionia uncinata and others). The stands are monodominant of \(V-Va\) yield (bonitet) classes; the crown density of tree layer is 0.6–0.8. They are found on slopes of river valleys and watershed hills. A rough-humus gravelly-sandy soil on alluvium-diluvium of acidic rocks is characteristic for this forest type [6]. Vast areas of White birch forests in Penzhina River basin have burnt.

4. Conclusions

Our study showed that the previous investigators did not exactly define the boundaries between the areas of the two birch species (figure 1). We have firstly studied the distribution patterns of two birches for the North of the Koryak Region using remote sensing imagery and the field data. It can be seen from the map of the Stone-birch and White-birch forests allocation (figure 1), that the Stone-birch groves are found in warmer and wetter areas adjacent to the Bering Sea coast. They occupy Southern and South-Eastern slopes of the Koryak Upland ranges and do not occur north of 61° 30' N L, whereas White birch forests are common in the continental districts and never met in coastal areas. They are found in the valleys of the rivers Penzhina, Talovka, Belaya, Oklan, Apukvayam, on the slopes of the Penzhinskii (Pontaneiskiy) Ridge. Stone-birch forests do not overcome bogs and mires of the Parapolskiy Dale depression, and do not occur to the West of 167° 30' E L, whereas White-birch forests spread much further to the North: the groves of Betula platyphylla (syn.: B. cajanderi) are occasionally met in the valleys of the rivers Main and Anadyr [1]. Their areal extends to the Northern spurs of the Koryak Highland: Rarytkin and Pekulney Ridges and the Anadyr Plateau (Chukotka Autonomous Region) and runs up to the Arctic Circle (66° 33' N L). The natural phytogeography boundary between the two birch formations runs along South-Eastern spurs of the Koryak Upland: the border passes between the Vetveisky and Pylginsky Ridges (figure 1). The areas of two birch species are separated by vast bogs, mountain ranges and wide river valleys.

Acknowledgements

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