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# Current vegetation dynamics of the "forest-mountain tundra" ecotones of Lake Baikal coastal ranges

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## ABSTRACT

**During last decades, new trends appeared in the ecotones of the upper boundary of forests at the ridges surrounding Lake Baikal (Khamar-Daban and Baikal'sky Ridge): ones to advance of wood species (*Pinus sibirica* Du Tour, *Abies sibirica* Ledeb., *Larix sibirica* Ledeb., *Larix dahurica* Lawson) out of timber stands into the area of subgoltsy with *Pinus pumila* (Pallas) Regel. up to mountain tundras. In average, this is from 100 to 200 - 300 meters (maximum up to 500 m) in linear distance from the margin of dense timber stand. A burst of forests renewal occurred in 1989-1995, it resulted probably from a high productivity of the seeds of wood species due to warmer winters in 1980ies-1990ies which favoured the formation of favourable climate-edaphic conditions for the development of forest communities above the forests boundary on the ridges surrounding Lake Baikal.**

**Keywords:** Ecotones "Forest-Mountain Tundra"; Sub-Goltsy Belt; Forest Boundary; Baikal Region

## 1. INTRODUCTION

On the background of dynamics and fluctuations of climate during last decades, the interest in the problem of assessment and forecast of climate changes at the regional level increases. Due to this fact, the revealing of the vector of shift of botanic and geographic zones, altitudinal belts become greatly important in studies of spatial differentiation of vegetation at concrete territories, as in different native zones, climate changes impact the communities in different ways. To assess probable responses of the vegetation (ecosystems) to climate changes in a region, detailed studies of the character of vegetation communities formation at topological level of environment organization are required. Rather evident information characterizing these or those spatial changes of vegetation can be revealed from data of studies of spatio-temporal dynamics of forest upper boundary within a concrete mountain system as of a consistent geosystem resulted from matter-energy interactions formed during several centuries. The existing forest boundary under the conditions of altitudinal zonality can be a starting point for past, occurring at present and probable changes in the spatial structure of vegetation at different scenarios of climate changes.

## 2. BACKGROUND

Forest ecosystems of Northern Eurasia are one of the main components of regulation of global climatic processes due to deposition and emission of greenhouse gases. At the same time, the territory of East Siberia is characterized by a wide amplitude of forest vegetation environments and by an exceptional diversity of succession states which are due to natural and anthropogenic factors and can respond to climate changes ambiguously.

The problems of change of forest upper boundary in different environmental zones attract greater attention while studying indicative role of long-living plant species responding to climate changes for centuries [1-4]. There are different interpretations in definition of forest boundary. E.g., Geobotanical Dictionary edited by O.S. Grebenshchikova [5] and in "Common Geographic Dictionary", a forest boundary is determined as the upper limit of forest vegetation in the mountains. Numerous researchers tend to affirm that a forest boundary is a belt of different size between a forest belt and light forest, between a sub-alpine forest and alpine meadow, etc. S.G. Shiyatov [2] believes that up to present time, there is no strict and common definition of what is "forest upper boundary" V.A. Usol'tsev in his paper "Biological Productivity…" [1] does not use the notion "forest boundary" itself, but employs a definition "altitudinal ecotone forest-tundra" referring to the arguments of some researchers on this matter. It is evident that up to present time, the notion "forest boundary" is to be discussed.

Is it possible to consider as a forest boundary a line

(belt?) where timber stand (or light forest) of reproductive age finishes replaced by a belt of regrowth of forest-forming species and/or bushes, meadows and barren lands including *Pinus pumila* (Pallas) Regel, for Baikalian part of Siberia? Can in this case the regrowth of forest-forming species be considered as an indicator of spatio-temporal dynamics of a forest belt under the condition of regional climate change? Probably, there is a sense here, if we have any information on the state of the system "forest-non-forest" in the past—some centuries or decades ago, as a real opportunity to compare it with the present situation.

## 3. AIM AND TASKS OF INVESTIGATION

The aim of our studies is to reveal the spatio-temporal variability of forest upper boundary on the ridges surrounding Lake Baikal for last decades. The revealing of mechanisms of structural-functional organization and dynamics of the Baikal Region forest vegetation depending on local and regional environmental conditions in the past and at present is the main task of the studies. The other tasks are: to obtain at model (key) sites data characterizing the existing shifts of the boundary "forest-mountain tundra". To perform on the base of use of data on timber stand morphology and age structure within the ecotone "forest-tundra" the reconstruction of spatio-temporal dynamics of forest and forest-tundra communities in different mountain areas of Pre-Baikal, as well as to forecast primarily the development of forests at the boundary of forest and mountain tundra in the region.

## 4. RESEARCH METHODS AND AREAS

Main method of our studies was geobotanical field survey using spatial pictures (Landsat TM) taken in different years. Geobotanical descriptions of vegetation were performed along the profile "dense timber stand-light forest-sub-goltsy belt-mountain tundra" taking into account expositions of slopes and common structure of mountain ranges in the studied area.

We used as model areas for our studies central part of Khamar-Daban Ridge (Southern Pre-Baikal) and a northern margin of the territory of Baikal'sky Ridge (North-Western Pre-Baikal, the area of Davan pass). Key sites were upper reaches of basins of the Osinovka, Mishikha and Gramna Rivers.

## 5. KEY SITE—UPPER REACH OF THE OSINOVKA R.

This is the territory of Baikal Biosphere Natural Reserve. We used information for comparative characteristics of spatial variations of forest upper boundary with time from studies by G.I. Galaziy [6]. They represent the peculiarities of structural and dynamic organization of wood vegetation at the vertical boundary of its distribution in the southern part of Khamar-Daban Ridge (upper reach of the Langatuy R.) in 50 km from the point of our studies—upper reaches of the Osinovka R.

The absolute height of our model territory is 1935 m asl. The absolute height of mountains where G.I. Galaziy performed his studies is 1700 m asl (Khamar-Daban Ridge, Langatuy Gate). As data of our studies are obtained in 2008, and materials used in the paper by G.I. Galaziy [6] are dated by 1951, the period for comparison of spatial variability of the forest upper boundary in the middle part of Khamar-Daban Ridge is 57 years. It is to notice that materials obtained by G.I. Galaziy in 1951 and data of our studies are collected for the habitats of similar orography—slopes of northern expositions. This allows to perform a rather correct comparative analysis of data obtained.

### Common Characteristics of the Vegetation in the Studied Area—Upper Reaches of the Osinovka R.

The studied area belongs to the territory of State Forest Resources, this is water protection zone of Lake Baikal basin. According to correlation ecological-phytocenotic map, the plant systems of the territory are represented by mid-mountain, mainly fir (*Abies sibirica* Ledeb.)-cedar (*Pinus sibirica* Du Tour) blueberry (*Vaccinium myrtillus* L.)-short-grasses-green mosses, cedar (*Pinus sibirica* Du Tour) and cedar (*Pinus sibirica*)-spruce (*Picea obovata* Ledeb.) undershrub-green mosses forests and by their birch (*Betula* sp.)-aspen (*Populus tremula* L.) restoring series of moderately cold and humid habitats. In consistence with the map of "Zones and Zonality Types in Russia and in Adjacent Countries" [7], the vegetation of this region is related to boreal (taiga) Tuva-Southern Baikal zonality type, Khamar-Daban subbelt of taiga (*Abies sibirica* Ledeb., *Pinus sibirica* Du Tour) forests of lower and middle parts of the slopes transforming into subgoltsy belt of *Pinus pumila* (Pallas) Regel and of goltsy represented by mountain tundras with synusias of *Pinus pumila* (Pallas) Regel and sedge (*Carex* sp.) groups in combinations with stony placers.

According to "Map of Vegetation of the South of East Siberia" [8], plant communities of the studied area are related to taiga (boreal) vegetation of Ural-Siberian phratry of formations, to South-Siberian formations of mountain taiga dark-coniferous forests. In tail areas and in the lower parts of the slopes of Northern and North-western exposition there form forests of cedar with admixture *Picea obovata* Ledeb, *Larix sibirica* Ledeb., *Abies sibirica* Ledeb., ones of ledum (*Ledum palustre* L.)-blueberry (*Vaccinium myrtillus* L.)-cowberry (*Vaccinium vitis-idaea* L.)-green mosses in combination with bergenia (*Bergenia crassifolia* (L.) Tritsch) cedar forests (*Pinus*

 

*sibirica* Du Tour).

For the valley of lower stream of the Osinovka R. (the territory of Baikalian Biosphere Natural Reserve) systems of fir (*Abies sibirica* Ledeb.)-poplar (*Populus suaveolens* Fischer) and spruce (*Picea obovata* Ledeb.)-fir (*Abies sibirica* Ledeb.) tall grasses forests are characteristic. At middle parts of the slopes of Northern and North-Western expositions, there are cedar (*Pinus sibirica* Du Tour.)-fir (*Abies sibirica* Ledeb.) undershrub-grass green moss forests. The vegetation of upper parts of the slopes are represented by alpine-like and subalpine-like meadow groups in combination with bushes-(*Betula rotundifolia* Spach, *Salix alba* L.) and with *Pinus pumila* (Pallas) Regel related to South Siberia formations, Altay-Tyan'-Shan' phratry of alpine formations of goltsy vegetation. Subgoltsy belt is characterized by bushes of mountain pine in combination with mountain tundras related, according to the map of vegetation [8], to Baikal-Dzhugdzhur formations of Berengy phratry of formations.

Some peculiarities of spatial and cenotic organization of the vegetation in the studied area and its environment were presented in the papers of numerous researchers [9, 10]. It is to notice especially that replacement of wood species (Khamar-Daban) during the Holocene occurred multidirectionally [11], from decrease of spruce (*Picea obovata* Ledeb.) and fir (*Abies sibirica* Ledeb.) components and decrease of cedar fraction (*Pinus sibirica* Du Tour) from the beginning of Mid-Holocene to Late Holocene due to decrease of total humidity and increase of continental character of the climate. During last stages of Late Holocene, increase of areas occupied by second growth began to show. At present, active renewal of fir (*Abies sibirica* Ledeb.) and cedar (*Pinus sibirica* Du Tour) is observed. Probably, there is here overlap of processes of natural replacement of dominant species in forest communities and a relative increase of atmospheric humidity.

## 6. KEY SITE—THE MISHIKHA R. BASIN

These are environments of Lysaya mountain (1624 m high asl). The key site is situated in the northern part of Baikalian Biosphere Natural Reserve. During a long period (>50 years), the territory is under the regime of complete survey with limited entry of natural reserve employees for monitoring of spatio-temporal variations of plant community structures and common state of vegetation.

### Common Characteristics of Regional Vegetation—The Mishikha R. Basin

According to correlated ecological-phytocenotic map [12], plant systems of the territory are represented mainly by fir (*Abies sibirica* Ledeb.)-cedar (*Pinus sibirica* Du Tour) blueberry (*Vaccinium myrtillus* L.)-short grasses-green mosses, cedar (*Pinus sibirica* Du Tour) and cedar (*Pinus sibirica* Du Tour)-spruce (*Picea obovata* Ledeb.) undershrub-green mosses forests and their birch (*Betula sp.*)-aspen (*Populus tremula* L.) regrowth series of moderately cold and humid habitats. According to the map of the vegetation of the south of East Siberia [8], plant communities of the studied area are related to taiga (boreal) vegetation of Ural-Siberian phratry of formations, South Siberia formations of mountain taiga dark-coniferous forests. In tail areas and lower parts of slopes of northern and north western exposition, cedar (*Pinus sibirica* Du Tour) with admixture of spruce *Picea obovata* Ledeb., *Larix sibirica* Ledeb. and *Abies sibirica* Ledeb. ledum (Ledum palustre L.)-blueberry (*Vaccinium myrtillus* L.)-cow-berry (*Vaccinium vitis-idaea* L.)-green mosses forests are formed. For the Mishikha R. valley, systems of fir (*Abies sibirica* Ledeb.)-poplar (*Populus suaveolens* Fischer) and spruce (*Picea obovata* Ledeb.)-fir (*Abies sibirica* Ledeb.) tall grass forests are characteristic. At middle parts of the slopes of northern and north-western expositions there are cedar (*Pinus sibirica* Du Tour)-fir (*Abies sibirica* Ledeb.) undershrub-grasses-green mosses forests. The vegetation of upper parts of the slopes is represented by alpine-like and subalpine-like meadow groups in combination with bushes of *Betula rotundifolia* Spach and with *Pinus pumila* (Pallas) Regel. The subgoltsy belt is characterized by bushes of *Pinus pumila* (Pallas) Regel in combination with mountain tundras. It is to notice that numerous researchers of the Baikal Region vegetation paid attention to the peculiarities of spatial and cenotic organization of the vegetation in the studied area and of its environment [6,9,10]. In data of paleogeographic [11] studies, it is noticed that from the beginning of Mid-Holocene towards Late Holocene, there occurred decrease of spruce (*Picea obovata* Ledeb.) and fir (*Abies sibirica* Ledeb.) components with increase of *Pinus sibirica* Du Tour due to the decrease of total humidity. At present, an active regrowth of *Abies sibirica* Ledeb. with participation of *Pinus sibirica* Du Tour both under timber stand canopy and out of it is observed.

## 7. KEY SITE—THE GRAMNA R. BASIN

The key site—surrounding area of a golets with the absolute height of −1834.2 m asl is situated in the interfluve of upper reaches of the Gramna and Goudzhekit RR. At the northern margin of Baikal'sky Ridge (North-Western Pre-Baikal, Davan pass). Before construction of the Baikal-Amur Railway, the vegetation of the North Pre-Baikal Region was impacted only by natural factors including pyrogenous one. During the railway construction, the vegetation of intermountain notches and moun-

 

tain feet was actively exploited (mainly by timber stands cutting). There were sometimes fires, however, the vegetation of near-top parts of mountain slopes and of subgoltsy belt is kept in its natural state.

### Common Characteristics of Regional Vegetation in the Gramna R. Basin

According to the map of vegetation of the south of East Siberia [8], plant communities of the studied area are related to taiga (boreal) vegetation of Ural-Siberian phratry of formations, to Southern Siberia formations of mountain taiga dark-coniferous (*Pinus sbirica* Du Tour, *Abies sibirica* Ledeb.) forests, to cedar underbrush (*Betula rotundifolia* Spach., *Rhododendron aureum* Georgi) moss-lichen light forests (often together with underbrush bushes) in combination with bushes of *Pinus pumila* (Pallas) Regel and sparse *Larix dachurica* Lawson, birch (*Betula lanata* (Regel) V. Vassil.) of Baikal-Dzhugdzhur formation (Beringia phratry of formations) of mountain taiga and light forests together with mountain tundras represented by non-close groups of *Saussurea pricei* Simps. among stony deposits.

According to the map of zones and types of zonality of vegetation in Russia and in adjacent countries [7], the studied area is related to Pre-Baikalian goltsy-tundra-elfin woodlight forest-taiga type of zonality of vegetation applicable to the Baikal Region.

According to correlation ecological-phytocenotic map [12], plant communities of the territory are represented mainly by a system of mid-mountain fir (*Abies sibirica* Ledeb.)-cedar (*Pinus sibirica* Du Tour) blueberry (*Vaccinium myrtillus* L.)-short grasses-green mosses, cedar (*Pinus sibirica* Du Tour) and cedar (*Pinus sibirica* Du Tour)-spruce (*Picea obovata* Ledeb.) underbrush-green mosses forests and by their pine (*Pinus sylvestris* L.)-larch (*Larix dachurica* Lawson) and birch (*Betula* sp.)-aspen (*Populus tremula* L.) renewed series of humid habitats.

## 8. RESULTS

### 8.1. Key Site—Upstream of the Osinovka R.

Studies performed at the key site by method of field geobotanical survey allowed to reveal the modern structure of plant communities of transition belt along the profile “dense timber stand-subgoltsy belt-mountain tundra” (middle part of Khamar-Daban Ridge, upstream of the Osinovka R., Baikal Biosphere Natural Reserve). Here are geobotanical descriptions upward the profile.

Description No. 1 (51˚31'66"N-105˚25'19"E; height of 1500 m asl)—boundary of transition of dense timber stand to bushes of mountain pine together with fir young growth:

Cedar (*Pinus sibirica* Du Tour)-fir (*Abies sibirica* Ledeb.) with *Betula fruticosa* Pallas with young growth (*Abies sibirica* Ledeb.) and clumps of *Pinus pumila* (Pallas) Regel forest of the upper part of the slope of northern exposition. The second layer is dominated by *Abies sibirica* Ledeb. with rare *Pinus sibirica* Du Tour and sporadically-with *Betula fruticosa* Pallas. Brush layer consists of *Rhododendron aureum* Georgi-synusially, *Ledum palustre* L.-synusially, *Juniperus sibirica* Burgsd.-scarcely, and underbrush are presented largely by *Vaccinium myrtillus* L-everywhere, there is also *Empetrum nigrum* L.-synusially. In the depression there is megasea-synusially, on the knolls within the slope the clumps of *Athyrium distentifolium* Tausch ex Opiz, *Oreopteris limbosperma* (All.) Holub., *Dryopteris* sp., *Dryopteris filix-max* (L.) Schott and *Oreopteris connectilis* (Michx.) Watt. are formed-synusially. *Pulsatilla multifida* (G. Pritzel) Juz. is widely represented. Among mosses, *Dicranum polysetum* Sw. and *Aulacomnium acuminatum* (Lindb. et Arn.) Par. are characteristic.

Description No. 2 (52˚22'29"N-105˚25'26"E; height of 1650 m asl)—belt of *Pinus pumila* (Pallas) Regel, dense timber stand is absent:

Young growth of *Abies sibirica* Ledeb. (age from 5 to 20 years) within the belt (1500 - 1750 m asl) of *Pinus pumila* (Pallas) Regel together with *Salix lanata* L. Species composition of the community is formed by *Rhododendron aureum* Georgi-synusially, *Vaccinium myrtillus* L.-synusially, *Empetrum nigrum* L.-scarcely, *Bergenia crassifolia* L.-scarcely, ferns are represented by *Athyrium distentifolium* Tausch ex Opiz and *Dryopteris filix-max* (L.) Schott-synusially, *Huperzia arctica* (Tolm.) Sipliv. and *Pulsatilla multifida* (G. Pritzel) Juz. occurs everywhere. We have to notice here that among synusiae of *Pinus pumila* (Pallas) Regel, underbrushes and *Bergenia crassifolia* L., young growth of *Abies sibirica* Ledeb. is more developed in difference with its single specimens among *Pinus pumila* (Pallas) Regel and bushes of *Polypodiaphyta ferns*.

Description No. 3—graded surface of the top of mountain Osinovka (absolute height is 1935 m asl)—there synusially situated single brushes of *Pinus pumila* (Pallas) Regel, clumps of *Vaccinium vitis-idaea* L, *Empetrum nigrum* L, *Mosses* sp. and *Carex* sp. around small hollows.

During last decades, trends of advance of *Abies sibirica* Ledeb. out of canopy of timber stands into the belt of *Pinus pumila* (Pallas) Regel up to mountain tundras arose everywhere in the ecotone “forest-mountain tundra”. In average this is 200 - 250 meters, maximally-up to 500 m in linear distance from dense timber stand.

### 8.2. Key Site—Upstream of Mishikha R.

We surveyed at established models of the key site

 

(mountain Lysaya environment) the trends of renewal of *Abies sibirica* Ledeb. in the ecotone "forest-mountain tundra". Below we present some descriptions of models from dense timber stand of *Abies sibirica* Ledeb. with inclusion of *Pinus sibirica* Du Tour up to subgoltsy belt along the profile.

Description No. 1 (51˚31'25"N-105˚30'23"E; the height is 1525 m asl)—the lower part of the slope of mountain Lysaya, at the boundary of transition of dense timber stand to light forest.

*Abies sibirica* Ledeb. Brush herbs forest with young growth of fir *Abies sibirica* Ledeb. forest of the slope of northern and north-eastern expositions. Timber stand of different age (1st layer—up to 50 years, 2nd—up to 35 years, 3rd—up to 15 years) with well-expressed young growth of *Abies sibirica* Ledeb. and including *Pinus sibirica* Du Tour up to 30 years (timber stand density is up to 0.8). At the model site of 10 $m^2$, there are 41 trees aged from 2 to 15 years. Brushes layer consists of *Rhododendron aureum* Georgi (synusially), there are underbrushes *Empetrum nigrum* L. (synusially) and *Vaccinium myrtillus* L.—everywhere. Ground cover is formed by *Bergenia crassifolia* L., *Veratrum lobelianum* Bernh., *Aquilegia sibirica* Lam., *Anemone altaica* Fischer ex C.A. Meyer and *Carex* sp. There are characteristic mosses *Polytrichum juniperinum* Hedw. and *Aulacomnium palustre* (Hedw.) Schwaegr.

Description No. 2 (51˚31'23"N-105˚30'14"E; height is 1595 m asl)—middle part of the slope of mountain Lysaya, within transition belt there is "*Abies sibirica* Ledeb. light forest—subgoltsy belt".

Young growth of different age (2nd layer—up to 18 years, 3rd—up to 15 years) of *Abies sibirica* Ledeb. with single trees up to 25 years (1st layer) on the slopes of northern and north-eastern expositions. At the model site of 10 m² there are 33 trees from 2 to 25 years. Brushes layer is formed by *Pinus pumila* (Pallas) Regel, *Rhododendron aureum* Georgi, *Juniperuus sibirica* Burgsd. together with underbrushes *Vaccinium myrtillus* L., *Vaccinium uliginosum* L. and *Empetrum nigrum* L. There is in the ground cover synusially represented *Bergenia crassifolia* L. together with *Polytrichum juniperinum* Hedw. and *Aulacomnium palustre* (Hedw.) Schwaegr.

Description No. 3 (51˚31'18"N-105˚30'09"E; height up to 1613 m asl)—near-top part of the slope of mountain Lysaya, subgoltsy belt.

Open stand of different age (1st layer—up to 20 years, 2nd—up to 15 years, 3rd—up to 10years) of young growth of *Abies sibirica* Ledeb. among *Pinus pumila* (Pallas) Regel on the slope of northern and north-eastern exposition. At the model site of 10 $m^2$, there are 17 trees from 2 to 20 years. Among brushes, besides *Pinus pumila* (Pallas) Regel, there are *Rhododendron aureum* Georgi and *Juniperuus sibirica* Burgsd. In the ground sparse grasses there are *Pedicularis* sp., *Geranium* spp., *Carex* spp. Together with underbrushes *Vaccinium uliginosum* L., *Empetrum nigrum* L., *Vaccinium vitis-idaea* L. and *Polytrichum juniperinum* Hedw. and *Aulacomnium palustre* (Hedw.) Schwaegr.

Description No. 4 (51˚31'14"N-105˚30'01"E; height is 1624 m asl)—top of mountain Lysaya. Subgoltsy belt with inclusions of mountain tundra.

*Pinus pumila* (Pallas) Regel with single *Abies sibirica* Ledeb. up to 5 - 8 years, rarely-with its clumps (aged up to 15 years) nearer to the beginning of the glacis. There are some groups of *Rhododendron aureum* Georgi, *Ledum palustre* subsp. *decumbens* (Aiton) Hulten. Underbrushes *Vaccinium uliginosum* L., *Vaccinium vitis-idaea* L. occur as small groups together with *Carex* spp., *Pedicularis capitata* Adams and *Huperzia selago* (L.) Bernh. ex Schrank et Mart.—in depressions.

Forest renewal in the ecotone "forest-mountain tundra" in this studied area is characterized by a sufficient sparseness and more by "clumpity" of distribution of *Abies sibirica* Ledeb. fir depending on the exposition of mountain slope and on linear distance from the forest margin. In this case, there is a trend of advance of *Abies sibirica* Ledeb. upward the profile from the margin of dense timber stand into the subgoltsy belt, this is up to 100 - 120 meters. In average, the height of young trees of *Abies sibirica* Ledeb. inhabiting the subgoltsy belt up to 2 - 2.5 m on the slope and up to 1 - 1.5 m on the top of the mountain itself.

### 8.3. Key Site—Upstream of the Gramna R.

We present main characteristics of communities revealed in our studies, common characteristics of modern structure of communities in the studied area. The descriptions are performed at the points with following coordinates: 55˚44'67"N - 108˚51'97"E; 55˚45'00"N - 108˚48'06"E; 55˚46'07"E - 108˚51'95"E; 55˚46'07"N - 108˚51'05"E.

Practically everywhere there is a layer structure of forest communities where the I layer consists of *Abies sibirica* Ledeb., *Pinus sibirica* Du Tour, *Larix dahurica* Lawson, *Picea obovata* Ledeb.; II-of *Pinus sibirica* Du Tour, *Abies sibirica* Ledeb., *Picea obovata* Ledeb., *Larix dahurica* Lawson (often *Betula* sp.) with the *Duschekia fruticosa* (Rupr.) Pouzar and *Betula* sp. at all. The young growth is dominated by *Abies sibirica* Ledeb. and *Larix dahurica* Lawson in different quantitative ratios (variations) depending on their position—slope exposition. *Abies sibirica* Ledeb. and *Larix dahurica* Lawson (rarely *Pinus sibirica* Du Tour) of reproductive age reach and enter the subgoltsy belt. Subgoltsy belt is dominated by *Pinus pumila* (Pallas) Regel together with *Betula* sp., *Rhododendron aureum* Georgi, *Bergenia crassifolia* L. and *Vaccinium vitis-idaea* L. There are characteristic

 

*Dicranum polysetum* Sw., *Hylocomium splendens* (Hedw.) BSG, *Aulacomnium palustre* (Hedw.) Schwaegr. Which are edificators of ground cover of dark-coniferous zonal taiga. They form clumps between stones (boulder pavements) everywhere. There are every- where some species of *Lichens* of the genera *Cladonia* and *Cetraria*.

There is a peculiarity of spatial organization of vegetation in the studied area: availability of young growth of *Abies sibirica* Ledeb. and *Larix dahurica* Lawson (aged from 2 - 3 to 25 years) in the subgoltsy belt. There are single small trees of *Larix dahurica* Lawson and *Abies sibirica* Ledeb. Out of the subgoltsy belt, mainly on "shadowed" slopes, as well as in stony tundra.

## 9. DISCUSSIONS

It results from presented geobotanical descriptions at the key site—upstream of the Osinovka R. (Southern Pre-Baikal, Khamar-Daban Ridge) that during last decades, there are trends to advance of a wood species—Siberian fir out of canopy of timber stand into the belt of mountain pine up to mountain tundras. In average this is 200 - 250 m (and directly-up to 500 m), this is a rather evident confirmation of change in upper forest boundary. We have to notice here that according to data by G.I. Galaziy [1], the manifestation of upper boundary of wood vegetation is found at the height of 1600 m asl (upstream of the Langatuy R., Khamar-Daban Ridge). This is ca. 50 km south-westward of our model site—upstream of the Osinovka R. In the timber stand at the upper forest boundary, there are all forest renewal stages: coming-up, young growth, polewood and young *Abies sibirica* Ledeb. Of the second layer. Regrowth of *Abies sibirica* Ledeb. Out of timber stand boundary suggest favourable conditions during last years resulting in abundant seeds crop. In general, the advance of young growth above the boundary of dense timber stand is a rather slow process from time viewpoint, but under favourable circumstances, one can notice a gradual advance of *Abies sibirica* Ledeb. Into subgoltsy belt, this was just found out for middle part of Khamar-Daban Ridge—our key site. From our viewpoint, this information can be a sort of evidence of occurring shift of upper forest boundary which is probably characteristic for the whole mountain system of Khamar-Daban but with corrections according to environmental conditions, as Khamar-Daban Ridge forms a rather extensive system of Southern Pre-Baikal mountains. Due to this fact, additional studies of the upper forest boundary in other areas of Southern Pre-Baikal ridges are necessary. As rather detailed data obtained 57 years ago [1] for concrete sites—upstream of the Langatuy R., Kamarsky Ridzhe and upstream of the Bystraya R. (western branches of Khamar-Daban Ridge) are available, it is quite probably to obtain some additional information concerning the dynamics of upper forest boundary for the whole region.

During last decades, some tendences of advance of *Abies sibirica* Ledeb. out of timber stand canopy into the belt of *Pinus pumila* (Pallas) Regel up to mountain tundras in the ecotone "forest-mountain tundra" of the Mishikha R. basin (middle part of the eastern coast of Lake Baikal) arose as well. Peak of forest renewal occurred in 1989-1995 and, probably, was due to a high productivity of seeds of fir timber stands in the end of 1980ies and to warm winters of the first half of 1990ies resulting into formation of favourable climate-edaphic conditions of penetration of wood species into subgoltsy belt and mountain tundra.

At the key site—upstream of the Gramna R., there is advance of wood species into subgoltsy belt and mountain tundra, but they depend significantly on heights, exposition and tilt of the slopes, sites of growing of concrete communities. In this case, forest boundary is observed especially distinctly along the slopes of southern expositions, while at "shadowed" slopes, the boundary between forest and mountain tundra is less manifested and is interrupted somewhere. Often wood species penetrate along intermountain crests deeply (often up to hundreds of meters) into subgoltsy belt. The presence of a large amount of well-developed streaks and combs in the mountain system structure favours as well formation of interrupted, with significant heights drops, boundary between forest and subgoltsy belt (often tundra as well); this is manifested by presence of young growth of wood species both in subgoltsy belt and in stony tundras.

## 10. CONCLUSIONS

Summarizing the information above, we have to notice that in all the cases presented, key sites of Southern Pre-Baikal (Khamar-Daban Ridge) and of northern margin of Baikal'sky Ridge (North-Western Pre-Baikal) represent rather well manifested trends of penetration of wood species into subgoltsy belt, and somewhere—into mountain tundra. For Southern Pre-Baikal this is *Abies sibirica* Ledeb., and for North-Western Pre-Baikal this is mainly *Larix dahurica* Lawson, rarer *Abies sibirica* Ledeb. and *Pinus sibirica* Du Tour. We have also to notice that similar trends in formation of ecotones "forest-mountain tundra" were found out before as well for Primorsky Ridge (South-Western Pre-Baikal), where *Pinus sibirica* Du Tour penetrates actively into subgoltsy belt with single occurrence of trees into mountain tundra (environment of Sarminsky golets, upstream of the Sarma R.). Probably, we have to relate such processes to changes in hydrological and temperature regimes of vegetation periods of last decades resulting in formation of more favourable conditions for the growth of wood species in high mountains of the Baikal region.

It is appropriate to tell due to this fact that similar spa-

 

tio-temporal variations in the structure of plant communities in ecotones "forest-mountain tundra" are appropriate as well for some territories of Ural mountain system [3,4].

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