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RESEARCH ARTICLE

Floristic composition and ecological-biological characteristics of avalanche path vegetation of Central Altai

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Abstract

The article analyzes the floristic composition, ecological groups in relation to soil moisture and substrate, and life forms in the phytocenoses of avalanche paths in Central Altai. It was found that the species composition of the plant communities of the avalanche paths of Central Altai differs significantly. The floristic similarity of the communities, estimated by the index of biotal dispersion (IBD), is weak in all parts of avalanche paths and reaches the highest value (14.2 %) for undisturbed forest communities (Z), and the lowest (9.3%) – in sites X, the central parts of avalanche paths. Data on the higher biodiversity of the central parts of avalanche paths (X) compared to the surrounding forest communities have been confirmed. It was found that family Gentianaceae and genus *Gentiana* indicate the central parts of avalanche paths, where avalanches occur most frequently. Shrub species of genera *Salix* and *Betula* and *Lonicera altaica* are characteristic of the avalanche path vegetation, have a high abundance, indicate frequent avalanching and can be indicators of avalanche ecotopes. At the same time, species of genus *Betula* (*B. humilis*, *B. rotundifolia*) and *Lonicera altaica* have high projective cover at level of the B track, while *Salix glauca* has high projective cover at level of the C track. Using the EcoScaleWin program, geobotanical descriptions on the ecological scales of D.N. Tsyganov were processed to assess the ecological conditions of ecotopes in avalanche paths of Central Altai. In turn, we used the obtained values of ecological scales to identify the dependencies between factors and their influence on the ecotopes using the principal component analysis (PCA). According to the analysis, in the central areas in avalanche paths located on the northwestern slopes, vegetation is influenced to a greater extent by 4 factors: high soil moisture, their nitrogen richness, salt richness, and lower soil acidity. However, in sites X (the central trough) there are more ecotopes, the soils of which are rich in nitrogen and salts, in sites Y (intermediate sections) soil moisture plays an important role. Ecotopes with high shading are typical for forest communities (sites Z). The sites of the avalanche paths studied are located in the forest belt, which is emphasized by the predominance of mesophytes and a high percentage of short-rhizome and long-rhizome herbs in the avalanche paths of Central Altai. Besides, in the central areas of the paths in avalanching sites, there is a high proportion of plants living on waterlogged soils, including cold and moist soils (hygrophytes, hygropsychrophytes, mesohygrophytes, psychrophytes, and mesopsychrophytes), i.e. these ecological groups are indicators of avalanche paths and point out frequent avalanches. On the eastern and southeastern (less often northwestern but then on rocky substrates) slopes in sites X and Y, species of dry and rocky habitats appear in the avalanche paths – xerophytes and petrophytes, many of which are tap-rooted herbs. In the spectrum of life forms of the avalanche paths of Central Altai, in addition to the predominant short-rhizome, long-rhizome and tap-rooted herbs, there is a large proportion of shrubs and brush-rooted herbs in the central parts, indicating frequent avalanches. In open areas, shrubs are abundant in herbaceous-shrubby communities, they are dominant and edificators. In general, short-rhizome, tap-rooted, and brush-rooted herbs (as well as brush-rooted tuber-forming and bulbous), which dominate in shrub-herbaceous cenoses of the avalanche paths, are confined to habitats with poor soil aeration in the X and Y sites; in forest communities (site Z), long-rhizome and loose-bush (also creeping herbs) are characteristic of sufficiently moist and loose soils.

Keywords
Altai Mountains, avalanche path vegetation, ecological group of plants, ecological scales, ecotope, phytoindication, plant communities, plant life forms

Introduction

Avalanche activity in Altai is widespread, especially in the mountainous regions of Central Altai, where avalanche-prone territories occupy significant areas. Although in most cases the transport infrastructure and settlements are located in Altai at a considerable distance from avalanche-prone slopes, nevertheless, there are cases of avalanching on highways (on the Ulagan tract above the Aktash Village). In addition, tourism has been actively developing in Altai in recent years, touristic bases, cable cars and ski trails are being built, and deforestation continues and intensifies. All of these processes can trigger avalanching even in places where there is still no avalanche activity.

The avalanche regime in Altai has not yet been sufficiently studied due to the sparse network of meteorological stations, the complexity of conducting stationary studies, underestimation of avalanche danger and, as a result, poor knowledge of this process. The idea of a relatively small avalanche hazard in the Altai Mountains is aggravated by the specific features of the avalanche regime: the irregularity of avalanching – large breaks between avalanches are replaced by short-term periods of avalanche activity. Such avalanche regime is associated with a strong variability in the variables of avalanche formation, primarily climatic (Revyakin and Kravtsova 1977).

In recent years, studies on the avalanche activity and its regime in Altai using dendrochronology methods have been conducted by a number of authors (Kravtsova 1971; Bykov 2013, 2015; Nikolaeva and Savchuk 2020, 2021; Bykov et al. 2024). Thus, using dendrochronological analysis of the radial increment of coniferous trees on avalanche paths in the Chuya River basin (Central Altai), patterns of avalanche activity and the recurrence of high-magnitude snow avalanches were determined. It is shown that the tree-ring complex indicator (dendrochronological index of avalanche activity) is crucial in detecting avalanche activity on specific avalanche paths. In some cases, the applied dendrochronological method helped to identify the cause (factor) of avalanches.

Considering the complex nature of the avalanche regime in the Altai Mountains, we undertook a geobotanical study of the vegetation cover of several avalanche paths in Central Altai. The advantage of this phytoindication method over expensive and time-consuming instrumental methods is the cheap and quick receipt of information about the environment based on vegetation characteristics (Bulokhov 1996). Patterns in vegetation can be used to further quantify and mapping the frequency and scale of past avalanche events (Simonson et al. 2010).

Most publications provide data on the mechanical effect of avalanches on vegetation and succession processes (Akifyeva 1971; Vosovik et al. 1971; Volodicheva 1971; Kravtsova 1971; Turmanina 1971; Urumbayev 1971; Burrows and Burrows 1976; Fischer 1992; Schweingruber 1996; Kajimoto et al. 2004; Walsh et al. 2004; Rixen et al. 2007; Bebi et al. 2009; Simonson et al. 2010; Nikolaeva et al. 2015; etc.), and on the influence of forest plantations on the avalanche regime (Bebi et al. 2001; Simonson et al. 2010).

Avalanche processes, characteristic of mountainous territories, are one of the limiting factors of ecosystem development in avalanche paths. The ecological impact of the avalanche processes on vegetation has been studied by many scientists (Patten and Knight 1994; Germain et al. 2005; Kulakowski et al. 2006; Stohlgren 2007; Simonson et al. 2010), including few data from Altai (Bykov 2013, 2015; Nikolaeva et al. 2015; Nikolaeva and Belova (Dirks) 2017; Bykov et al. 2022). In addition, avalanches support a unique habitat and high biological diversity in avalanche paths (Rixen et al. 2007).

The phytocenotic characteristics of the vegetation cover of the studied avalanche paths are given by us in a separate publication (Kosachev et al. 2025). Its summary results are given at the beginning of "Results and discussion". In this paper, we focused on identifying the floristic composition, ecological groups, and life forms in plant communities both in individual sites of avalanche path and in the vegetation of the whole avalanche path. Similar work has been started recently in the Altai

Mountains. For example, studies have been conducted on the vegetation of the avalanche paths of the Western (Korgon River basin) and Central Altai (Chuya River basin) (Bykov 2013, 2015), and the Aktru mountain-glacial basin (Central Altai) (Nikolaeva et al. 2015; Nikolaeva and Belova (Dirks) 2017). The last two publications provide a phytocenotic assessment of the habitats in the areas of mudslides and avalanches in the upper reaches of the Aktru River. The floristic composition, ecological groups and life forms of plants for the upper part of the forest belt and the forest-tundra ecotone are described in a comparative aspect. In contrast to this study, in our paper we analyzed the same vegetation components but mainly at the lower level in avalanche transit zone in six avalanche paths of Central Altai.

Materials and methods

In this paper, the floral composition and ecological-biological features of vegetation of 6 avalanche paths in different areas of Central Altai are analyzed (Figs 1, 2; Table 1). Expedition studies were conducted in 2024. The images for the base of the maps (Fig. 2) were taken from Google Earth. Avalanche path levels are indicated in accordance with the work of N. I. Bykov (2013). Geobotanical sites were laid out mainly at level B, the lower part of the transit zone. For the morphologically complex (with 2 intersecting avalanche swaths) avalanche path L12, work was also carried out at levels A – the accumulation zone, and C – the upper part of the transit zone.

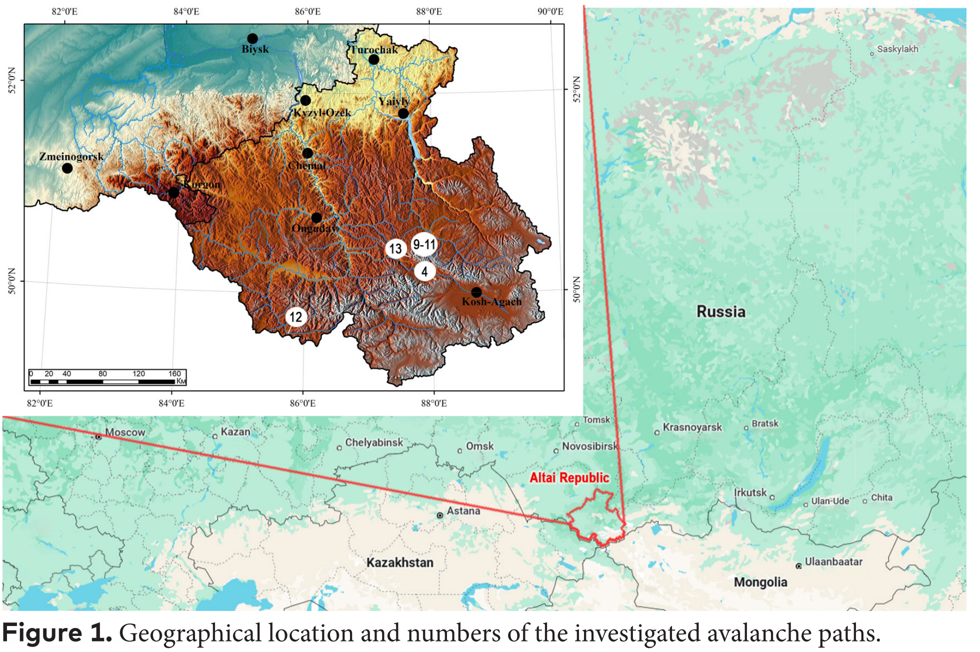

Figure 1. Geographical location and numbers of the investigated avalanche paths.

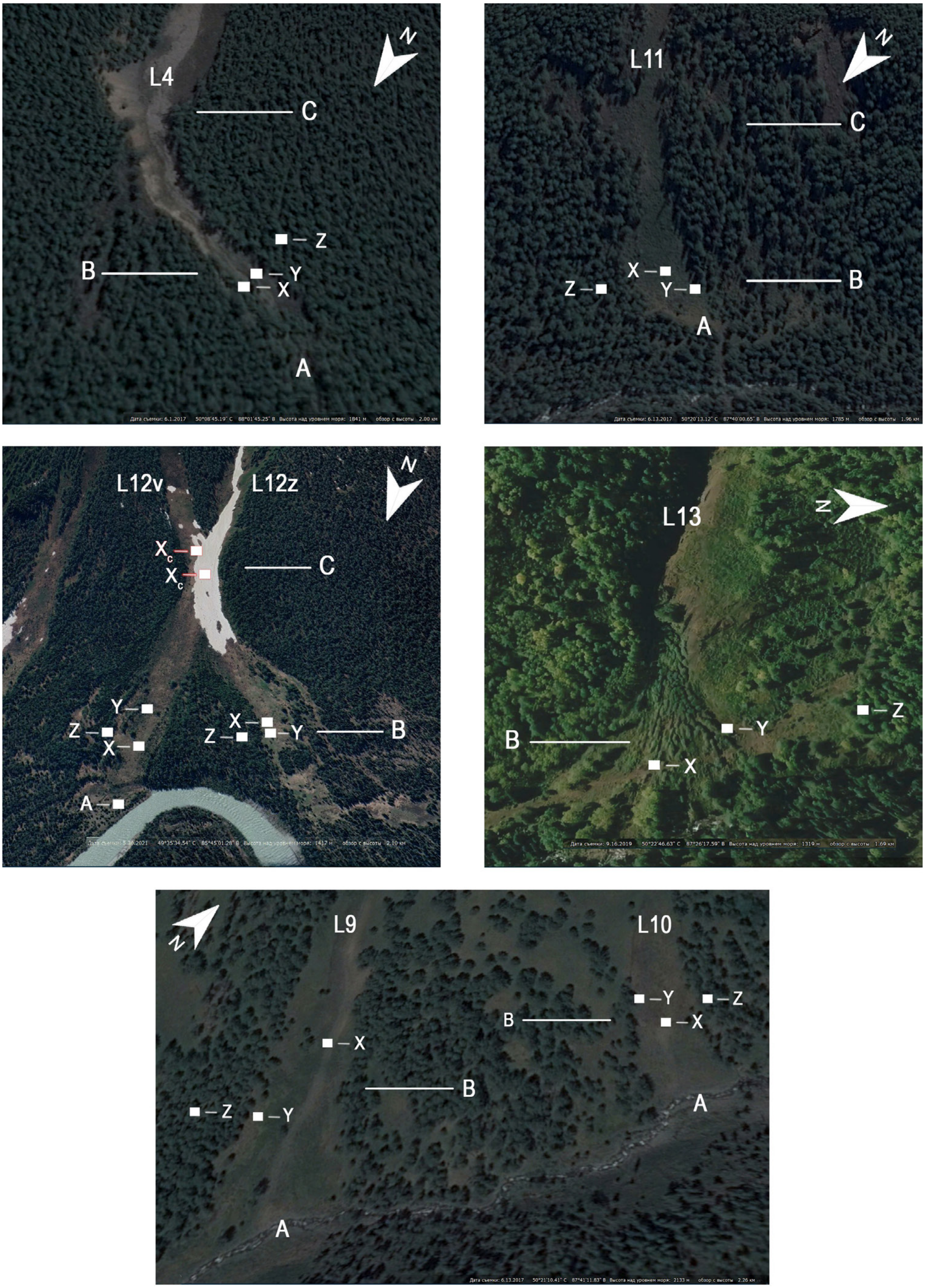

Figure 2. The studied avalanche paths of Central Altai: L4 (North Chuisky Ridge), L11 (Kuraisky Ridge, Korumduayry River valley), L9, 10 (Kuraisky Ridge, Belenkaya River valley), L12v and L12z (Listvyaga Ridge), L13 (Aigulaksky Ridge, Belgebash River valley).

Table 1. Geographical location of the studied avalanche path of the Central Altai

Avalanche path	Level and frequencies of the avalanche path	Coordinates of the sites	Altitude, m	Slope exposure
L4 North Chuisky Ridge	Z	N 50.146056113 E 88.029169233	1841	NW
	X	N 50.146306113 E 88.029197011	1778	
	Y	N 50.14636166 E 88.029113677	1830	
L11 Kuraisky Ridge, Korumduayry River valley	Z	N 50.339333894 E 87.668613690	1727	NW
	X	N 50.338945005 E 87.668419246	1739	
	Y	N 50.338861672 E 87.668085912	1784	
L9 Kuraisky Ridge, Belenkaya River valley	Z	N 50.352528338 E 87.687974802	2037	SE
	X	N 50.353278338 E 87.688669246	2117	
	Y	N 50.352667227 E 87.688308135	2031	
L10 Kuraisky Ridge, Belenkaya River valley	Z	N 50.354667227 E 87.690724802	2104	SE
	X	N 50.354472782 E 87.690669246	2105	
	Y	N 50.354445005 E 87.690335913	2113	
L12v Listvyaga Ridge, Katun River valley	Z	N 49.59521 E 85.75103	1367	N
	X	N 49.59502 E 85.75040	1384	
	Xc	N 49.58963 E 85.75232	1554	
	Y	N 49.59502 E 85.75017	1371	
L12 (intersection avalanche path) Listvyaga Ridge, Katun River valley	Xc12_8	N 49.59040 E 85.75191	1518	N
L12z Listvyaga Ridge, Katun River valley	Z	N 49.59491 E 85.75469	1378	N
	X	N 49.59525 E 85.75385	1356	
	Y	N 49.59441 E 85.75359	1366	
	A	N 49.59639 E 85.75421	1265	

Avalanche path	Level and frequencies of the avalanche path	Coordinates of the sites	Altitude, m	Slope exposure
L13 Aigulaksky Ridge, Belgebash River valley	Z	N 50.38039 E 87.43877	1306	E
	X	N 50.37906 E 87.43938	1275	
	Y	N 50.37950 E 87.43907	1285	

The work is based on 24 geobotanical descriptions (relevés) of communities (8 forest, 16 shrub-herbaceous) (see Suppl. material 1: Appendix 1). Geobotanical descriptions of forest vegetation were performed on sites measuring 25 × 25 m, herbaceous – 10 × 10 m. Geobotanical sites were laid out in areas with different avalanche frequencies (in accordance with the work of N. I. Bykov, 2013): X – avalanche trough with the highest frequency; Y – rarely avalanching; Z – indigenous forest, no avalanching. The coordinates of the sites are given in Suppl. material 1: Appendix 1.

The participation of species in the vegetation cover was assessed on the Braun-Blanquet scale (Mirkin et al. 2001): r – the species on the site is found in single specimens; + – the species projective cover of up to 1 %; 1 – the species projective cover of 1 to 5 %; 2 – from 5 to 25 %; 3 – from 25 to 50 %; 4 – from 50 to 75 %; 5 – above 75 %.

To assess the ecological conditions of ecotopes in the avalanche paths, we used the EcoScaleWin program (Grokhlina et al. 2008; Zubkova et al. 2008; Khanina et al. 2014). Habitats were evaluated based on the amplitude scales of D. N. Tsyganov (1984) in relation to the degree of soil moisture (Hd), soil acidity (Rc), soil salt regime (Tr), soil nitrogen richness (Nt), and habitat illumination-shading (Lc) (Table 4). The amplitude scales of D.N. Tsyganov (1983) contain an assessment of 2072 species of vascular plants, 139 bryophytes and 40 lichens. At the same time, for the data processing, we used the weighted average of the midpoint of the intervals in the EcoScaleWin program. This method allows us to take into account the participation of species in the assessment of the ecotope. For each species, the value of the midpoint of its ecological interval is found, it is multiplied by the digital value of the species' participation, then the sum of the products obtained is divided by the sum of the digital values of the participation. At the same time, the ecotope estimate shifts from the interval midpoint of the maximum overlap towards the amplitudes of species with greater participation. The species with greater participation make a greater contribution to the final value (Zubkova et al. 2008).

The data on the environmental scales was processed in the R software environment. The data matrix was converted in a distance matrix using the Gower-coefficient for a PCA. All analyses were conducted using R v. 3.5.3. Some diagrams were implemented in MS Office Excel 2019.

Climatic conditions of the investigated avalanche paths of the Central Altai

All the avalanche paths studied are located in the Central Altai physical-geographical province (Samoylova 1982). Despite this, the Listvyaga Ridge differs significantly from the North Chuisky, Kuraisky, and Aigulaksky Ridges in climatic conditions and the character of avalanche processes. According to the zoning of Altai by avalanche formation factors, the Listvyaga Ridge belongs to Western Altai, the North Chuisky Ridge belongs to the Central highland region, and the Kuraisky and Aigulaksky Ridges – to the Katunsko-Teletsky region (Revyakin, Kravtsova 1977). In Western Altai, the leading factors of avalanche formation are intense snowfall, spring snowmelt and blizzard snow accumulation. In the Central highland region, these factors are snow accumulation, spring and summer snowmelt, thaws, and blizzard snowdrift. In the Katunsko-Teletsky region, blizzard snow accumulation and spring snowmelt are accompanied by recrystallization of the snow cover due to a sharp decrease in air temperatures.

The Listvyaga Ridge is more humidified than Aigulaksky, Kuraisky and North Chuisky Ridges. At the height of accumulation zone of the avalanche path studied, the average annual precipitation is 550 mm at an altitude of 1340 m above sea level, and in the avalanche starting zone it is about 1400 mm at an altitude of 2250 (Galakhov, Mukhametov 1999). At the same time, it is one of the snowiest mountain ridges in Altai. In winter, at the level of the accumulation zone of the avalanche path studied, the thickness of the snow cover reaches one meter, and in avalanche starting zones at altitudes above 2200 m above sea level – up to 2–5 meters (Revyakin, Kravtsova 1977).

On the North Chuisky Ridge, in the accumulation zones of avalanche paths 4 and 5 (altitudes of 1820 and 1900 mm above sea level, respectively), the annual precipitations are approximately 400 and 450 mm, respectively.

In the basin of the Chibitka River on the Kuraisky Ridge, the annual precipitation is 360 mm at the mouth of its tributary Belaya (altitude of 1780 m), and 470 mm at Aktash mine (altitude of 2280 m) (Galakhov, Mukhametov 1999).

Thus, the annual precipitation at the altitude of avalanche starting zone on the Listvyaga Ridge is an order of magnitude higher than on the Kuraisky Ridge.

The temperature regime of the botanical sites studied depends on the height of the terrain (Table 2).

Table 2. Average annual air temperature at Altai weather stations

Weather station	Altitude above sea level, m	Average annual air temperature, C
Akkem	2050	7.4
Aktru	2150	8.7
Kara-Tyurek	2600	5.2
Katanda	900	14.1
Ust-Koksa	980	14.3
Kosh-Agach	1760	12.5

Results and discussion

All communities form 2 main clusters: forest (sites Z, in one case site X) and shrub-herbaceous (sites X and Y). The cluster of forest communities includes 8 communities; in the shrub-herbaceous – 16 communities.

Forest communities are divided into 2 groups. Group 1 includes communities: forest of *Pinus sibirica*, *Picea obovata* and *Larix sibirica* with *Rhododendron ledebourii*, *Vaccininium vitis-idaea* and moss (L4), overgrown with bushes forest of *Pinus sibirica*, *Picea obovata* and *Larix sibirica* (L10) and overgrown with bushes forest of *Pinus sibirica*, *Picea obovata* and *Vaccinium vitis-idaea* (L11). The group 2 includes communities: forest of *Larix sibirica* and *Pinus sibirica* with *Spiraea chamaedryfolia* (L9), forest of *Abies sibirica*, *Picea obovata*, *Betula pendula* overgrown with *Lonicera altaica* (L12_3), forest of *Picea obovata*, *Abies sibirica* with *Aconitum leucostomum* and *Carex macroura* (L12_6), forest of *Betula pendula* and *Picea obovata* with *Caragana arborescens*, *Spiraea chamaedryfolia* and *Carex macroura* (L13, site Z), forest of *Salix viminalis* and *Populus tremula* with *Cirsium serratuloides* and grasses (L13, site X).

Shrub-herbaceous communities are represented by 3 ecological-cenotic groups, including a total of 16 relevés.

Group 1 includes a community of meadow with *Lonicera altaica* and *Betula rotundifolia* (L12 – eastern, relevé 12_9, site Xc). The group 2 includes communities: thickets of *Caragana arborescens* on a stony-gravelly scree (L4, site Y), thickets of *Potentilla fruticosa* and *Betula humilis* with *Iris ruthenica* and *Poa sibirica* (L9, site Y), thickets of *Caragana arborescens* (L4, site X), thickets of bushes (*Salix jenisseensis*, *Ribes nigrum*, *Lonicera altaica*, *Spiraea chamaedryfolia*) with *Carex macroura* and *Trisetum sibiricum* (L11, sites X and Y), *Abies sibirica*, *Picea obovata*, *Betula pendula* mixed-herb grassy woodlands (L12, site A), *Juniperus sibirica* thickets with *Trisetum sibiricum*, *Thalictrum minus* and *Carex macoura* (L10, site X), *Juniperus sibirica* and *Spiraea chamaedryfolia* thicket with sapling of *Pinus sibirica* (L10, site Y). The group 3 includes communities: overgrown with bushes meadow with *Calamagrostis epigejos* (L13, site Y), thickets of *Betula humilis* with sapling of *Abies sibirica* (L12 western, site Y), thickets of *Spiraea media* in meadow with sapling of *Abies sibirica*, *Betula pendula* and *Picea obovata* (L12 eastern, site Y), meadow with *Lonicera altaica* (L12 eastern, site X), thickets of *Lonicera tatarica*, *Spiraea media* on *Aconitum leucostomum* and grassy meadow (L12 western, site X), overgrown with bushes meadow with *Chamaenerion angustifolium*, *Aconitum krylovii* and *Calamagrostis langsdorffii* (L12, site Xc).

In the studied communities of avalanche complexes of Central Altai and in the forest areas directly adjacent to them, 232 species of higher vascular plants were recorded (see Suppl. material 2: Appendix 2). An earlier study of the avalanche path vegetation of the Korgonsky Ridge indicated 132 species (Bykov 2013).

142 plant species were found at the bottom of the avalanche trough (site with index X) (Korgonsky Ridge – 86): each relevé has from 10 to 55 species, with an

average value of 31.7; and in the site with rare avalanche formation (Y) – 98: from 20 to 34 species, with an average value of 25.9 (Korgonsky Ridge – 66). 157 species found in these sites (XY) belong to 47 families and 145 genera (Fig. 3) (Korgonsky Ridge – 40 and 104, respectively).

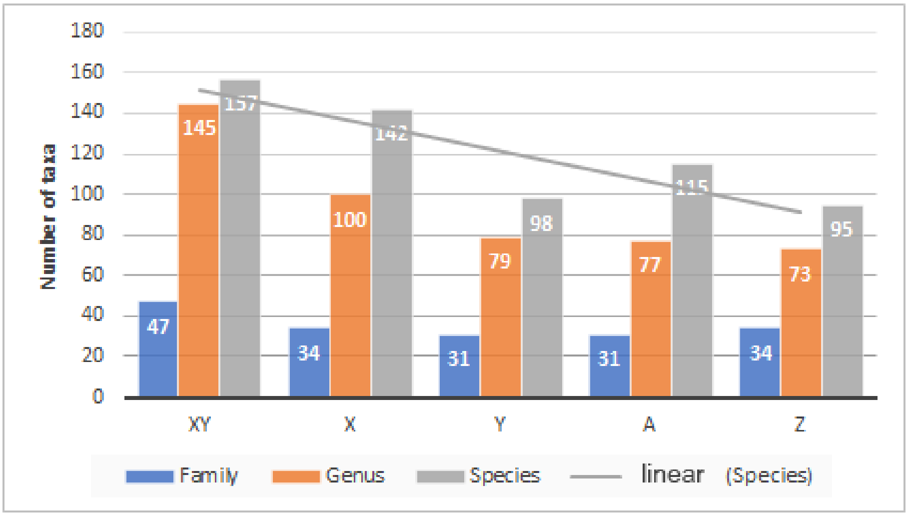

Figure 3. The number of species, genera, and families in the phytocenoses of avalanche paths in Central Altai. The trend line shows a decrease in the number of species in communities from the central part of the avalanche path to the periphery and, in general, from the avalanche transit zone to the accumulation zone and the zone of forest communities.

In the zone of avalanche path accumulation (A) with rare avalanches and longer time period for vegetation restoration, there are 115 species: from 38 to 48, with an average value of 43.5 (47 species were recorded in Korgonsky site). The surrounding forest vegetation (sites Z), as a rule, is characterized by a lower species diversity – 95 species (the number of species ranges from 14 to 44, the average value is 25.3).

In the sites of fairly regular avalanche formation (X), the species identified belong to 100 genera and 34 families, and in the sites Y – 79 genera and 31 families, respectively, in the A zone – 77 genera and 31 families, and in the Z zone – 73 genera and 34 families.

The species diversity of X sites is about 30 % higher, and the generic diversity is 20 % higher than that of Y sites (in Korgonsky site, both species and generic diversity are about 30 % higher).

To evaluate the floristic similarity of all the communities, according to Koch's formula (Vasilevich 1969), we calculated the index of biotal dispersion (*IBD*).

$$IBD = \frac{T - S}{S\,(n - 1)} \cdot 100\% ,$$

where S – the number of species in all relevés, and the value of T is calculated using the formula:

$$T = \sum S = S_1 + S_2 + S_3 + \ldots + S_n ,$$

where S_1, S_2, S_3 ... S_n – the number of species in each relevé; n – the number of relevés.

If all relevés don't have common species absolutely, then $T = S$ and $IBD = 0$. If all the species are the same in all relevés, $T = 100$ %.

The floristic similarity of communities, estimated by the index of biotal dispersion (*IBD*), is small in all zones and reaches the highest value of 14.2 % in forest communities (Z), and the lowest value of 9.3 % in sites X. The floristic heterogeneity of the communities, for which relevés were made on different ridges of Central Altai and on macro slopes with different exposures, is understandable. Thus, the highest difference in the floristic composition in sites X can be explained by the different exposures of the slopes with habitats opened as a result of the destruction of forest vegetation by avalanches. The ecological conditions in these habitats differ significantly on mountain slopes with different exposures, while the tree layer smooths out the impact of environmental factors on the herb layer and forms habitats characteristic of forest vegetation under its canopy, primarily reducing insolation and increasing shading, as well as soil moisture. At the same time, more acidic nitrogen-depleted soils are formed under the forest canopy.

In the spectrum of families, the leading positions are occupied by Asteraceae, Ranunculaceae, Poaceae, Rosaceae, Fabaceae, Apiaceae, Scrophulariaceae s.l. (Table 3). In sites X and Y Caryophyllaceae plays an important role with ranks 8, 8–11. However, in the accumulation zone, the rank drops to 12–18, and this family is practically not represented in the forest vegetation.

Table 3. The spectrum of families in phytocenoses in different areas of avalanche paths in Central Altai

Rank	Sites X	Number of species	Rank	Sites Y	Number of species	Rank	Sites Z	Number of species	Rank	Accumulation zone A	Number of species
1	Ranunculaceae	15	1	Asteraceae	12	1	Asteraceae	13	1	Poaceae	15
2	Asteraceae	14	2	Ranunculaceae	11	2	Ranunculaceae	11	2	Rosaceae	14
3	Poaceae	13	3	Poaceae	10	3-4	Poaceae	7	3	Asteraceae	13
4	Rosaceae	12	4-5	Apiaceae	6	3-4	Rosaceae	7	4	Fabaceae	10
5	Apiaceae	10	4-5	Fabaceae	6	5	Fabaceae	6	5	Ranunculaceae	8
6	Scrophulariaceae s.l.	8	6-7	Rosaceae	5	6-7	Apiaceae	5	6	Scrophulariaceae s.l.	7
7	Fabaceae	7	6-7	Scrophulariaceae s.l.	5	6-7	Ericaceae	5	7	Apiaceae	6

Rank	Sites X	Number of species	Rank	Sites Y	Number of species	Rank	Sites Z	Number of species	Rank	Accumulation zone A	Number of species
8	Caryophyllaceae	6	8-11	Caryophyllaceae	4	8	Pinaceae	4	8	Salicaceae	5
9	Lamiaceae	5	8-11	Lamiaceae	4	9	Scrophulariaceae s.l.	3	9	Lamiaceae	4
10-11	Gentianaceae	4	8-11	Pinaceae	4	10-11	Betulaceae	2	10-11	Pinaceae	3
10-11	Pinaceae	4	8-11	Geraniaceae	4	10-11	Geraniaceae	2	10-11	Geraniaceae	3

The leading positions of fam. Asteraceae and Poaceae are common and characteristic of Holarctic flora. And the presence of Ranunculaceae in the leading triple of families in the X, Y and Z sites indicates the high-altitude nature of the flora of avalanches. The high position of Rosaceae, especially in the accumulation zone of avalanche complexes, is typical for boreal flora, in which forest species are abundant. A spectrum of other families characterizes the flora of the avalanche paths as mountain-Asian. Among the features of the spectrum, one can note the presence of Gentianaceae in 11 main families in sites X, which is associated with excessively moistened habitats in the center of trough of the avalanche paths, as well as the high position of Ericaceae in the forest communities (Z), associated with a large concentration of species of this family in the forest of *Pinus sibirica*, *Picea obovata* and *Larix sibirica* with *Rhododendron ledebourii*, *Vaccininium vitis-idaea* and moss on the northwestern macro slope of the North Chuisky Ridge (L4).

As already noted for the Korgonsky Ridge (Bykov 2013), during the transition from sites X to sites Y, almost all families reduce their diversity: Fabaceae – from 7 to 6 (Korgonsky – from 6 to 3), Caryophyllaceae – from 6 to 4 (Korgonsky – from 3 to 1), Poaceae – from 13 to 10 (Korgonsky – from 9 to 6), Ranunculaceae – from 15 to 11 (Korgonsky – from 7 to 5), Asteraceae – from 14 to 12, Apiaceae – from 10 to 6 (Korgonsky – from 5 to 3). This confirms the opinion of Bykov (2013) about the importance of indicators of avalanche intensity already at the family level.

The generic spectrum in the flora of the avalanche paths follows, in general, the spectrum of the families (Table 4).

The largest genera of the respective families have the highest ranks. In the avalanche paths, Asteraceae is represented mainly by the East Asian genus *Saussurea*, which has a secondary center of species diversity in the Altai Mountains. Families Ranunculaceae, Scrophulariaceae s.l., Rosaceae – by genera *Aconitum* and *Thalictrum*, *Pedicularis*, *Spiraea*, *Potentilla*, respectively, emphasizing the forest and alpine character of the vegetation of the avalanche paths. The genus *Poa* also has one of the centers of species diversity in the Altai Mountains and always plays a significant phytocenotic role here. From Poaceae, *Calamagrostis* and *Elymus* are also widespread in mountain meadow-forest communities. As indicated by V. I. Troshkina

(2018), representatives of the genus *Geranium* play a significant role in the formation of forest, meadow, and steppe communities of the Altai Mountain Country, which is fully reflected in the generic spectrum of the flora of the avalanche paths. There is a naturally high participation of *Betula* and *Salix*, which form or are part of the forest and shrub vegetation.

Table 4. The spectrum of genera in phytocenoses in different areas of avalanche paths in Central Altai

Rank	Sites X	Number of species	Rank	Sites Y	Number of species	Rank	Sites Z	Number of species	Rank	Accumulation zone A	Number of species
1	Aconitum	5	1-3	Poa	4	1	Saussurea	5	1-2	Aconitum	4
2-3	Poa	4	1-3	Saussurea	4	2	Aconitum	4	1-2	Salix	4
2-3	Pedicularis	4	1-3	Geranium	4	3-4	Poa	3	3-8	Poa	3
4-11	Saussurea	3	4-5	Aconitum	3	3-4	Pedicularis	3	3-8	Geranium	3
4-11	Betula	3	4-5	Spiraea	3	5-11	Geranium	2	3-8	Potentilla	3
4-11	Carex	3				5-11	Spiraea	2	3-8	Cirsium	3
4-11	Gentiana	3				5-11	Rubus	2	3-8	Vicia	3
4-11	Geranium	3				5-11	Juniperus	2	3-8	Elymus	3
4-11	Thalictrum	3				5-11	Equisetum	2			
4-11	Spiraea	3				5-11	Calamagrostis	2			
4-11	Salix	3				5-11	Betula	2			

In sites X, *Gentiana* has a high rank in the spectrum, characteristic of the mountain meadow-forest vegetation of the temperate zone of Eurasia. In the forest vegetation (sites Z), representatives of *Equisetum*, *Rubus* and *Juniperus* are of no small importance.

Thus, it can be noted that the floristic composition of the plant communities of the avalanche paths and adjacent forest vegetation is diverse and heterogeneous, and there is a pattern in the decrease in the floral diversity of herbaceous-shrubby communities from the central part to the periphery and further to the forest vegetation.

Ecological Analysis

The ecological analysis was performed based on the classification of A. V. Kuminova (1960).

We considered it successful to identify the corresponding ecological groups in relation to moisture and substrate (see Suppl. material 3: Table S5; Fig. 4). This division takes into account zonation and the nature of the substrate, which made it possible to clarify the ecological characteristics of habitats of the avalanche paths.

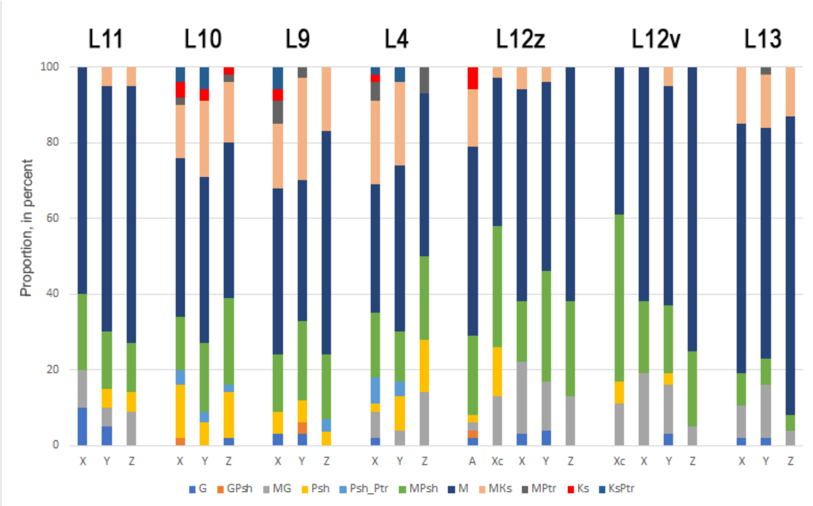

Figure 4. The spectrum of ecological groups in the phytocenoses of the avalanche paths in Central Altai: G – hygrophytes, GPsh – hygropsychrophytes, MG – mesohygrophytes, Psh – psychrophytes, Psh_Ptr – psychrophyte-petrophytes, MPsh – mesopsychrophytes, M – mesophytes, MKs – mesoxerophytes, MPtr – mesopetrophytes, Ks – xerophytes, KsPtr – xeropetrophytes.

As the spectrum of ecological groups shows, mesophytes predominate in the studied communities, as well as in the avalanche paths of the Korgonsky Ridge (Bykov 2013). The proportion of plants living in waterlogged soils, including cold and moist soils (G, GPsh, MG, Psh, MPSh), is higher in sites X, and the proportion of mesophytes (M) is higher in sites Z in the forest communities. The exception is avalanche path 10 (L10), located at altitudes from 2104 to 2113 m above sea level on the southeastern slope. Here, in sites X, Y, and Z, the percentage of participation of both mesophytes (M) and plants of waterlogged soils (G–MPSh) is approximately the same, which is due to a sparse forest stand and, as a result, a high percentage of crown transparency (about 50 %). Therefore, in addition to mesoxerophytes, there are even species of dry habitats – xerophytes (Ks) (*Allium rubens*), in the ecological spectrum in the forest. By the way, in the avalanche paths on the Korgonsky Ridge, plants of dry habitats – xerophytes – are not recorded at all, which indicates more humidified ecotopes of the avalanche paths in this ridge located in Western Altai. Sites Y on the periphery of the avalanche path are characterized by the fact that the proportion of mesophytes (M) in them is less than in forest cenoses but greater than in sites X, and, on the contrary, the proportion of plants of waterlogged soils (G–MPSh) is greater than in forest cenoses but less than in sites X. Considering that both sites X and Y belong to the avalanche transit zone, the differences in the spectrum of ecological groups with undisturbed forest cenoses become obvious. With an increase in the level of sites X from B to C, the proportion of mesohygrophytes (MG) and mesopsychrophytes (MPSh) increases in avalanche paths L12, while the percentage of mesophytes (M) decreases.

There is a significant participation of petrophyte species (Psh_Ptr, MPtr, KsPtr) in avalanche paths L9, L10, and L4, which is associated with a high percentage of substrate rockiness, especially in avalanche path L4, where signs of mudslide are noted in the avalanche trough or directly next to it.

Xerophytes (Ks) are found in communities of the same avalanche paths, as well as in the accumulation zone of the L12z avalanche path. This is due to the southeastern exposure of the slope of avalanche paths L9, L10, as well as a large percentage of stones and rubble in avalanche paths L4, L12z (which ensures good drainage of the substrate). In addition, the accumulation zone of L12z is located at the bottom of the slope on the Katun River terrace at an altitude of 1265 m above sea level, where dry and well-warmed habitats are found.

Results of estimation of the ecological conditions, obtained using the EcoScaleWin program, are presented in Table 6.

Table 6. Indicators of ecological scales of D.N. Tsyganov for ecotopes in avalanche paths in Central Altai

Avalanche paths	Sites of avalanche paths	Ecological scales				
		Hd (23)	**Tr (19)**	**Rc (13)**	**Lc (9)**	**Nt (11)**
L4	X	11.98 dry forest meadow	6.13 quite rich soils	7.15 slightly acidic soils/ neutral soils	3.48 semi-open spaces /light forest	5.58 nitrogen-poor soils / quite nitrogen-rich soils
	Y	11.91 dry forest meadow	6.25 quite rich soils	6.98 slightly acidic soils (pH=5.5-6.5)	3.63 semi-open spaces / light forest	6.38 quite nitrogen-rich soils
	Z	12.86 wet forest meadow	4.76 poor soils	6.50 slightly acidic soils (pH=5.5-6.5)	4.34 light forest	4.92 nitrogen-poor soils
L9	X	12.09 wet forest meadow	6.47 quite rich soils	6.94 slightly acidic soils (pH=5.5-6.5)	3.02 semi-open spaces / light forest	6.22 quite nitrogen-rich soils
	Y	12.22 wet forest meadow	6.57 quite rich soils	7.84 slightly acidic soils / neutral soils	2.95 semi-open spaces	5.95 nitrogen-poor soils / quite nitrogen-rich soils
	Z	12.26 wet forest meadow	5.95 poor soils / quite rich soils	7.34 slightly acidic soils / neutral soils	3.56 semi-open spaces / light forest	6.37 quite nitrogen-rich soils

Avalanche paths	Sites of avalanche paths	Ecological scales				
		Hd (23)	**Tr (19)**	**Rc (13)**	**Lc (9)**	**Nt (11)**
L10	X	11.34 dry forest meadow / wet forest meadow	6.42 quite rich soils	7.79 slightly acidic soils / neutral soils	3.12 semi-open spaces / light forest	4.65 nitrogen-poor soils
	Y	11.36 dry forest meadow / wet forest meadow	6.67 quite rich soils	7.79 slightly acidic soils / neutral soils	2.97 semi-open spaces	5.36 nitrogen-poor soils / quite nitrogen-rich soils
	Z	12.25 wet forest meadow	6.3 quite rich soils	7.01 slightly acidic soils / neutral soils	3.49 semi-open spaces / light forest	5.36 nitrogen-poor soils / quite nitrogen-rich soils
L11	X	12.51 wet forest meadow	6.14 quite rich soils	7.45 slightly acidic soils / neutral soils	3.62 semi-open spaces / light forest	6.66 quite nitrogen-rich soils
	Y	12.43 wet forest meadow	5.78 poor soils / quite rich soils	7.17 slightly acidic soils / neutral soils	3.91 semi-open spaces / light forest	5.96 nitrogen-poor soils / quite nitrogen-rich soils
	Z	12.40 wet forest meadow	5.83 poor soils / quite rich soils	7.78 slightly acidic soils / neutral soils	4.12 light forest	6.00 nitrogen-poor soils / quite nitrogen-rich soils
12z	A	11.50 dry forest meadow	6.63 quite rich soils	6.91 slightly acidic soils (pH=5.5-6.5)	3.16 semi-open spaces / light forest	5.63 nitrogen-poor soils / quite nitrogen-rich soils
	X	12.37 wet forest meadow	6.55 quite rich soils	6.81 slightly acidic soils (pH=5.5-6.5)	3.68 semi-open spaces / light forest	6.43 quite nitrogen-rich soils
	Y	12.79 wet forest meadow	6.4 quite rich soils	7.26 slightly acidic soils / neutral soils	3.87 semi-open spaces / light forest	5.96 nitrogen-poor soils / quite nitrogen-rich soils
	Z	12.98 wet forest meadow	5.63 poor soils / quite rich soils	6.33 slightly acidic soils (pH=5.5-6.5)	4.62 light forest	5.80 nitrogen-poor soils / quite nitrogen-rich soils

Avalanche paths	Sites of avalanche paths	Ecological scales				
		Hd (23)	**Tr (19)**	**Rc (13)**	**Lc (9)**	**Nt (11)**
12_4 12_5 12v	X	12.67 wet forest meadow	6.36 quite rich soils	7.05 slightly acidic soils / neutral soils	3.64 semi-open spaces / light forest	6.88 quite nitrogen-rich soils
	Y	12.56 wet forest meadow	6.19 quite rich soils	6.97 slightly acidic soils (pH=5.5-6.5)	3.85 semi-open spaces / light forest	6.42 quite nitrogen-rich soils
	Z	12.55 wet forest meadow	6.2 quite rich soils	6.37 slightly acidic soils (pH=5.5-6.5)	3.81 semi-open spaces / light forest	5.72 nitrogen-poor soils / quite nitrogen-rich soils
	Xc	13.01 wet forest meadow / damp forest meadow	5.91 poor soils / quite rich soils	6.19 slightly acidic soils (pH=5.5-6.5)	3.61 semi-open spaces / light forest	6.54 quite nitrogen-rich soils
12_8	Xc	12.43 wet forest meadow	6.44 quite rich soils	6.64 slightly acidic soils (pH=5.5-6.5)	3.53 semi-open spaces / light forest	6.75 quite nitrogen-rich soils
13_3	X	12.51 wet forest meadow	6.80 quite rich soils	7.55 slightly acidic soils / neutral soils	3.51 semi-open spaces / light forest	6.95 quite nitrogen-rich soils
13Ax	Y	12.70 wet forest meadow	6.82 quite rich soils	7.45 slightly acidic soils / neutral soils	3.60 semi-open spaces / light forest	6.86 quite nitrogen-rich soils
13	Z	12.16 wet forest meadow	6.27 quite rich soils	6.89 slightly acidic soils (pH=5.5-6.5)	3.77 semi-open spaces / light forest	5.68 nitrogen-poor soils / quite nitrogen-rich soils

Note: number of gradations is indicated in parentheses after the scale code, and the calculated value on the ecological scale is indicated in the cells.

The indicators of soil moisture (Hd) are comparable with the proportion of xerophytes (Ks), mesoxerophytes (MKs), xeropetrophytes (KsPtr) and mesophytes (M), shown in Fig. 1. According to soil moisture, habitats are divided into two main and two intermediate types. The predominant main type is “wet forest meadow”, typical for most communities, the second main type is "dry forest meadow" (sites X, Y in avalanche path L4; A – in avalanche path 12). The first intermediate type is "dry forest meadow / wet forest meadow" (sites X, Y in avalanche path L10) and the second is "wet forest meadow / damp forest meadow", typical for site Xc in avalanche path 12v, which is located higher than the other sites closer to the subalpine belt.

According to the factor of the soil salt regime (Tr), habitats are divided into 2 main types: 1) "quite rich soils", typical mainly for sites X and Y, 2) "poor soils" (only site Z in avalanche path L4). The intermediate type – "poor soils / quite rich soils" – includes ecotopes of sites Z, less often Y (L11), Xc (L12v).

The attitude of ecotopes to the factor of soil nitrogen richness (Nt) is consistent with the soil salt regime. In ecotopes with "poor soils" (sites Z), there is a low nitrogen content in the soils ("nitrogen-poor soils") or an "nitrogen-poor soils / quite nitrogen-rich soils" (this type is also noted for sites Y). Conversely, in ecotopes with "quite rich soils" (sites X, less often Y and Z), the soils are sufficiently supplied with nitrogen ("quite nitrogen-rich soils").

There are only two types of ecotopes in relation to soil acidity (Rc). Sites X and Y are characterized by an intermediate type – "slightly acidic soils / neutral soils", and sites Z – "slightly acidic soils" (pH = 5.5–6.5).

According to the factor of habitat illumination-shading (Lc), most ecotopes belong to the intermediate type of "semi-open spaces/light forests" (all sites X and Y, except for avalanche path L9, where the site belongs to the type of "semi-open spaces"). Some sites of Z are associated with the same type, where larch-dominated forests or mixed spruce-birch forests with more sparse stands on the southeastern slopes are observed (L9, 10, 13). In other avalanche paths, the Z sites are of the "light forests" type.

To identify the dependencies between the factors and their influence on ecotopes, a principal component analysis (PCA) was performed in the R program (Fig. 5). The arrows indicate the directions of the initial coordinate axes. Their locations relative to the axes show how much each factor contributes to the first and second main components.

For the analysis, we included a qualitative feature in the matrix – the relation to a specific site – X, Y, Z, or A. In the graph below, this ratio is well represented by the first main component. Here, all the relevant sites form groups (highlighted in different colors). The other factors have approximately the same effect on the sites (the arrows have the same length), but their directions are different.

Four factors (Nt, Hd, Lc, Tr) are directed upwards and have a coordinated effect on sites X in avalanche paths L12 (L12_9Xc, L12Xv, L12_8Xc, L12Xz, L11X), on sites Y (L12Yv, L12Yz, L13Y, L11Y), on sites Z (L12Zz, L12Zv, L4Z, L9Z, L11Z). The consistency of factors of soil moisture and their nitrogen richness confirms the data of S. A. Nikolaeva and M. N. Belova (Dirks) (2017) that the values of moisture and trophicity of soils are interdependent. However, there are more nitrogen-rich ecotopes in sites X, and soil moisture plays an important role in sites Y. And the forest communities of these avalanche paths are characterized by ecotopes with high shading. At the same time, the ecotopes of these avalanche paths also positively correlate with the factor of soil acidity (Rc).

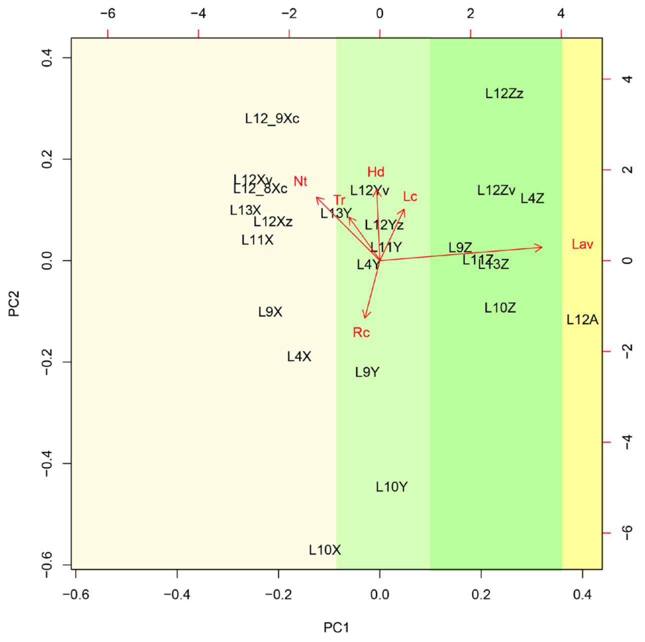

Figure 5. Principal Co-ordinate Analysis of a matrix of pair-wise Gower distances based on 5 ecological factors (Nt, Hd, Lc, Rc, Tr) and 1 feature (Lav) – the relationship to one of the sites (X, Y, Z and A), assessed for 24 plant communities from 7 avalanche paths of Central Altai. The color shows the areas corresponding to X, Y, Z, and A obtained as a result of the analysis.

This is explained by the location of these sites on the north-western slopes of the ridges.

The remaining ecotopes in sites X in avalanche paths L9, L4, especially L10, in sites Y in avalanche paths L4, L9, especially L10, in sites Z in L13 and L10, as well as site A in avalanche path L12, have a negative correlation with these factors, and to a large extent with the factor of soil acidity. That is, these habitats with neutral, dry soils are more illuminated, but at the same time the soils are less rich in nitrogen. They are located on the southeastern and eastern slopes of the mountains, as well as one site (L12A) on the river terrace at the foot of the slope.

From the ecological analysis of the avalanche path vegetation of Central Altai, it follows that the proportion of species indicating a good state of nitrogen and water supply in sites X and Y is noticeably and significantly higher than in the surrounding forest (sites Z). In addition, the central (X) and intermediate (Y) parts of the avalanche path are characterized by lower soil acidity due to the absence of coniferous trees. This suggests that the higher proportion of nitrogen and water supply indicators, at the same time lower soil acidity and illumination, are due to a high degree to the general ecological feature of the central part of the avalanche zone, rather than the avalanche event itself. This pattern is also inherent in habitats in the northern limestone Alps (Germany), where vegetation was studied 5 years after an avalanche passed through an oak-beech forest (Fischer 1992).

Analysis of plant life forms

In nature, a plant is always affected by a sum of factors that interact and modify each other. Life form reflects the adaptability of plants to certain environmental conditions or to a set of factors. For the analysis of life forms, we have chosen the classification of I. G. Serebryakov (1962).

In the glacial zone of the Altai-Sayan Mountain Region, the most common plant life forms (Kuminova 1960; Revyakina 1996; Bykov 2013; Nikolaeva and Belova (Dirks) 2017) are short-rhizome, long-rhizome, and tap-rooted herbs. In addition, as we found out, the participation of shrubs and brush-rooted herbs is significant. The representation of other life forms is very diverse but significantly less in percentage terms (Suppl. material 4: Table S7; Fig. 6).

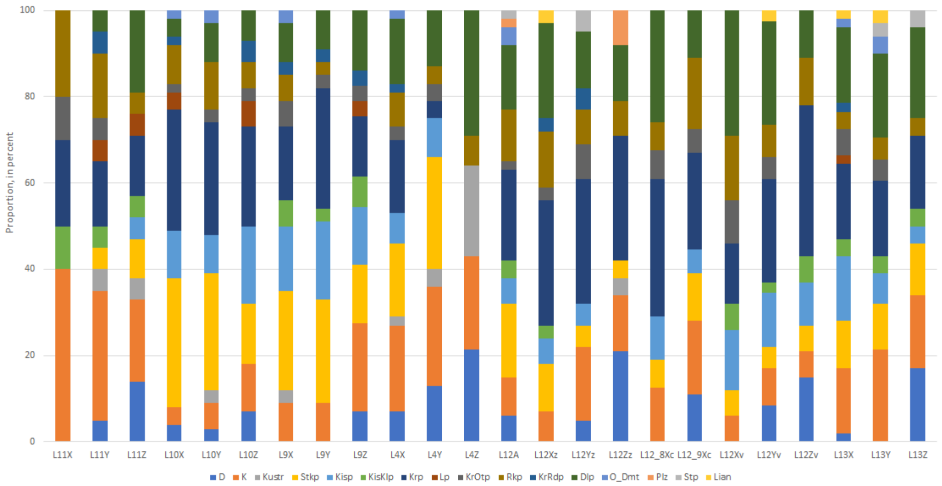

Figure 6. The spectrum of plant life forms in the phytocenoses of avalanche paths in Central Altai. D – trees, K – high bushes, Kustr – low bushes, Stkp – tap-rooted herbs, Kisp – brush-rooted herbs, KisKlp – brush-rooted tuber-forming herbs, Krp – short-rhizome herbs, Lp – bulbous herbs, KrOtp – root sprouting herbs, Rkp – loose-bush herbs, KrRdp – short-rhizome loose-turf herbs, Dlp – long-rhizome herbs, O_Dmt – annual-biennial herbs, Plz – creeping herbs, Stp – stolon-forming herbs, Lian – liana-like herbs.

As a rule, the proportion of long-rhizome herbs in the X-Y-Z series increases, while they are characteristic of undisturbed communities, which are forest communities. Ecologically long-rhizome herbs are confined to well-aerated, loose and quite moistened soils (Antipova 2008). The participation of such plants is also high in sites X and Y in avalanche path L12, where moist high-grass forest meadows are developed; namely in such communities, there is an ecological optimum for long-rhizome herbs (Baisheva et al. 2012). On the contrary, the proportion of short-rhizome herbs increases from sites Z to X, with the exception of the same avalanche path L12, in forest communities of which, the proportion of such plants is significant (probably due to the large percentage of long-rhizome herbs in communities in sites X and Y).

The proportion of tap-rooted herbs is higher in avalanche path communities located on dry slopes on the eastern (L13) and southeastern macroslopes (L9, L10), on the Katun River terrace (L12, site A), as well as in avalanche path 4 (L4), where the substrate is predominantly stony-gravelly. This is consistent with studies indicating that the proportion of tap-rooted herbs is higher in steppe and petrophytic communities (Antipova 2008; Oleynikova 2015). Tap-rooted herbs are well adapted here, as they are able to extract the necessary moisture from deep horizons of the soil, being out of competition with other plants (Antipova 2008).

Shrubs (high bushes) are widely represented in all cenoses in the avalanche paths studied. They often form a layer in forest communities and are abundant, dominant and edificators in open areas as part of herbaceous-shrubby communities. As a rule, avalanches do not destroy the shrub layer, on the contrary, thickets of shrubs indicate frequent avalanches. In addition, by the characteristic crown of the shrubs (as if "trimmed" at a certain level), we can find out how high the snow cover is in a given avalanche path in a given site.

Low bushes have a large share in the herb cover in the cedar-spruce-larch rhododendron arctous-lingonberry-mossy forest (L4), which is characterized by high crown density, high soil moisture and a high value of the projective cover of moss (Suppl. material 1: Appendix 1).

A group of brush-rooted herbs plays an important role in the plant cenoses of the avalanche paths. The decisive factor in the formation of the brush root structure was the abundance of mineral salts in the surface layer of the soil, poor aeration, low temperature, abundant water supply, causing increased regrowth of adventitious roots, and the presence of a barren, poorly aerated podzolic horizon, negatively affecting the development of deep root systems of herbaceous plants (Serebryakov 1955). Brush-rooted herbs are especially represented in avalanche paths L9, L10, L12, L13.

Conclusions

The conducted analyses of the floristic composition and ecological-biological features of the vegetation cover in the avalanche paths of Central Altai showed patterns in the distribution of taxa, ecological groups and plant life forms in the sites of the avalanche paths, depending on environmental factors on slopes with different exposure and different heights above sea level.

We have confirmed the evidence of higher biodiversity in the central sites of avalanche paths (X) compared to the surrounding forest communities (for example, Rixen et al. 2007; Bykov 2013; Nikolaeva and Belova (Dirks) 2017). When moving from sites X to sites Y and further to undisturbed forest communities (Z), almost all families reduce their diversity. For the first time, such a pattern was observed for the Korgonsky Ridge (Bykov 2013). It was found that family Gentianaceae and genus *Gentiana* indicate the central parts of avalanche paths, where avalanches occur most frequently. Shrub species of genera *Salix* and *Betula*, *Lonicera altaica* are characteristic of avalanche path vegetation. They have a high abundance, indicate frequent avalanches and may be indicator species of avalanches in the Altai Mountains. At the same time, species of genus *Betula* (*B. humilis*, *B. rotundifolia*) and *Lonicera altaica* have high projective cover at transit level B, while *Salix glauca* has high projective cover at transit level C.

It was found that the species composition of the plant communities of the avalanche paths of Central Altai differs significantly. The floristic similarity of communities, estimated by the index of biotal dispersion (*IBD*), is small in all sites and reaches the highest value of 14.2 % for forest communities (Z), and the lowest value of 9.3 % in sites X.

The studied sites of the avalanche paths are located in the forest belt, which is emphasized by the predominance of mesophytes and a high percentage of short-rhizome and long-rhizome herbs in the avalanche paths of Central Altai. In addition, in places of avalanching in sites X and Y, there is a high proportion of plants living on waterlogged soils, including cold and moist soils (G, GPsh, MG, Psh, MPSh), i.e. these ecological groups are indicators of avalanche paths, indicate frequent avalanches. On the eastern and southeastern (less often northwestern, but then on rocky substrates) slopes in sites X and Y, species of dry and rocky habitats – xerophytes and petrophytes – appear in avalanche paths, many of them are tap-rooted herbs.

According to the principal component analysis (PCA) of ecological groups, 4 factors affect the sites X and Y in avalanche paths located on the northwestern slopes of the Listvyaga Ridge to a greater extent: high soil moisture, their nitrogen richness, salt richness, and lower soil acidity. But in sites X there are more ecotopes, the soils of which are rich in nitrogen and salts, in sites Y – soil moisture plays an important role. Ecotopes with high shading are typical for forest communities.

In the spectrum of life forms of avalanche paths in Central Altai, in addition to the predominant short-rhizome, long-rhizome and tap-rooted herbs, there is a large proportion of shrubs and brush-rooted herbs in sites X and Y, indicating frequent avalanches. In open areas, shrubs are abundant in herbaceous-shrubby communities, they are dominant and edificators.

In general, short-rhizome, tap-rooted and brush-rooted herbs (also poorly represented tuber-forming and bulbous brush-rooted herbs), the dominant in shrub-herbaceous cenoses of avalanche paths, are confined to habitats with poor soil aeration in sites X and Y. In forest communities (sites Z), long-rhizome and loose-bush (also creeping) herbs are characteristic of quite moist and loose soils.

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Supplementary material 1

Appendix 1. Geobotanical relevés of communities of avalanche path vegetation of Central Altai

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Data type: table

Link: https://journal.asu.ru/biol/article/view/18175/15588

Supplementary material 2

Appendix 2. Family composition in phytocenoses of avalanche paths in Central Altai

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Data type: table

Link: https://journal.asu.ru/biol/article/view/18175/15589

Supplementary material 3

Table S5. Ecological composition of the avalanche path vegetation of Central Altai

Authors: Petr A. Kosachev, Nikolay I. Bykov, Tatiana I. Grokhlina, Natalia V. Ovcharova

Data type: table

Link: https://journal.asu.ru/biol/article/view/18175/15590

Supplementary material 4

Table S7. The composition of the life forms of the avalanche path vegetation of Central Altai

Authors: Petr A. Kosachev, Nikolay I. Bykov, Tatiana I. Grokhlina, Natalia V. Ovcharova

Data type: table

Link: https://journal.asu.ru/biol/article/view/18175/15591