Forest ecosystems in the upper reaches of the Malka River (Central Caucasus): typology, floristic composition, current state

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Abstract. According to the results of the study, it found that in the upper reaches of the Malka River, the most common is the group of birch forests with tallgrass vegetation cover, including *Betuletum calamagrostioso-herbosum*. Smaller areas occupied by group of complex herbaceous birch forests, represented by *Pineto-betuletum calamagrostioso-herbosum* and a group of pine forests with herb-rich vegetation cover, including *Pinetum calamagrostioso-herbosum*. Forest stands are mainly single-storey, medium and low-density, bonitet classes II-IV. The floristic composition of the Malka River basin forests includes 101 species from 68 genera and 38 families. Forest ecosystems of the study area are home to four species of vascular plants included in the list of protected taxa of the Kabardino-Balkarian Republic: *Betula raddeana* Trautv, *Vaccinium myrtillus* L., *V. vitis-idaea* L., *Allium victorialis* L. Among protected lichen species, we found – *Leptogium burnetiae* C. W. Dodge, *Letharia vulpina* (L.) Hue, *Lobaria pulmonaria* (L.) Hoffm.), *Lobarina scrobiculata* (Scop.) Nyl.), *Sticta sylvatica* (Huds.) Ach. and *Usnea florida* (L.) Weber ex F. H. Wigg. The article analyzes the geographic spectrum of the forest flora of vascular plants and lichens, including 12 geographic elements, with the boreal geoelement predominating. The lichen flora dominated by boreal geoelements.

1 Introduction

The Malka River originates on the northern slopes of Mount Elbrus from the confluence of the Kyzylsu and Karakayasu Rivers, taking tributaries of mountain streams, rivulets. The basin of the river in its upper course covers the northern part of the National Park " Prielbrusie" and adjoining territories - the reserve "Malkinskiy", vicinities of the village Khabaz. Relatively steep near-valley slopes are covered with forest vegetation. In contrast to the forests of the southern Prielbrusie (valley of the Baksan River), the northern forests are rather well-preserved, which is due to an insignificant anthropogenic load in the absence, until recently, of federal road communications. Only in 2010, a road was built that goes to the upper river to the mineral springs, which increased the recreational impact on the surrounding ecosystems. During the season, more than a thousand unorganized tourists camp at the springs of Dzhily-Su.

Subalpine forests in the upper reaches of the Malka River, which are of great ecological importance, represented by both pure and mixed birch and pine forest stands. On the one hand, they fulfil an anti-erosion and environmental protection role and, on the other hand, they provide habitat for a number of mammal and bird species, in particular, those listed in the Red Books of Russia [1] and the Kabardino-Balkarian Republic [2]. The forests of the northern Prielbrusie are considered unstudied. We could not find any publication devoted to their study. Various aspects of the study of forest ecosystems in the southern Prielbrusie reflected in publications [3-6].

Complex orographic conditions of the area contribute to a great diversity of plant, including forest, communities. In this regard, the establishment of the typological structure of forests in the upper reaches of the Malka River, assessment of their species diversity and current state are relevant.

In connection with the above, the purpose of this work is to assess the typological structure, floristic composition, and current state of birch and mixed forests in the basin of Malka River.

2 Materials and methods

2.1. Study area

Were the studies carried out in 2016-2019 by a detailed route method in the basin Malka River within the altitudes of 1100-2000 m above sea level (figure). Landscapes are relatively steep near-valley slopes of ridges, under pine and birch forests on mountain-meadow and mountain-brown forest soils. The total forested area of the upper Malka River is 311 km^2.

We conducted studies the studies in the Central Caucasus (between 42°54'-44°01' N and 43°52'-43°03' E) within the elbrusskiy variant of vertical zonation of the northern macroslope in the Central Caucasus in 2016-

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2019. The lack of broad-leaved forest belt and pronounced xerophytization of landscapes determine the peculiarities of the elbrusskiy variant of vertical zonation [7]. Its belt spectrum consists of meadow steppes (forest-steppes), steppe meadows, subalpine, alpine, subnival and nival belts.

The mountainous relief, altitude above sea level, and the arrival of western air masses from the Atlantic form a relatively cold and humid continental climate of the study area in mountain regions. The climate of the lowland regions is continental, relatively hot and dry.

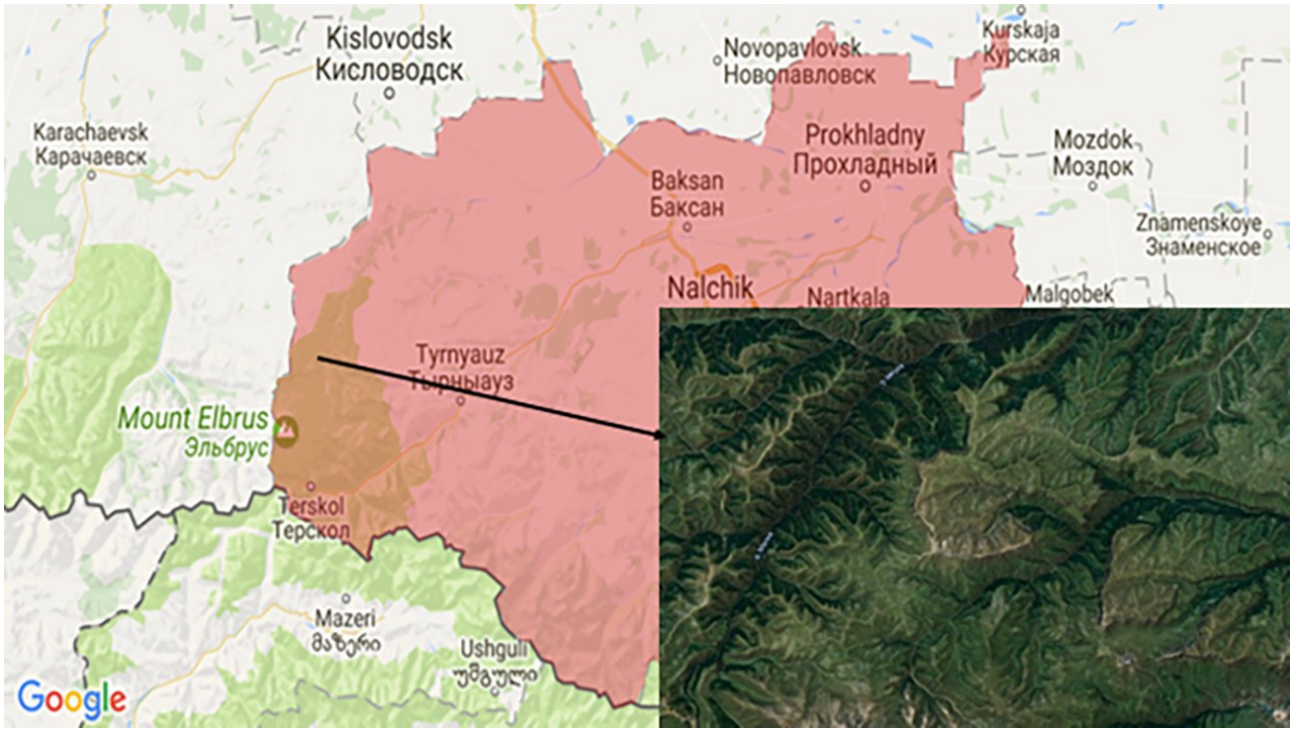

Fig. 1. Study area forested areas of the Malka River basin

2.2 Data collection and measurements

To study the composition and structure of the forests of the study area, we carried out geobotanical descriptions on sample plots of 30×30 m in size using standard methods accepted in geobotany and forest inventory [8-11]. We established 31 model plots. Based on the tier structure of vegetation, a complete floristic list compiled, and forest taxation characteristics were determined. The stand structure, stand shape, crown density, average height, average diameter, number of trunks, and fullness were evaluated. The species affiliation of vascular plants was determined according to A.I. Galushko [12].

In addition to species composition and projective cover, the average height and the number of specimens of each species on the site recorded for the undergrowth. The total projective cover, species composition, and projective cover of individual species were determined in the study of the dwarf shrub–herb layer.

The dominant approach used to classify forest vegetation, and forest type considered as a type of forest biogeocenosis. Groups of forest types distinguished by the species composition of the stand, as well as by the groups of dominant species in the herb-bush and moss tiers. One forest type included phytocenosis that were similar in the species composition of the stand tiers [10, 11]. Latin names of vascular plants and mosses given according to PlantList [13].

The lichen flora of the sample areas derived from woody and soil substrates. The collected material cameralized using comparative-morphological and comparative-anatomical methods using light microscopy. The lichens nomenclature of taxa generally follows recently published checklists for Scandinavia and North America [14, 15].

For the phytogeographic analysis of the flora of vascular plants, the geographic element spectrum in the work based on the scheme compiled by N.N. Portenier for the Northern Caucasus [16]. The geographic elements of the lichen flora distinguished based on the zonal principle developed by Oxner [17, 18] and developed in the works of several authors [19, 20].

The study of understory regeneration of forest-forming species on the territory of the northern section of the National Park “Prielbrusie” conducted by laying test plots of 3×3 m, laid one by one along the diagonal of the test area, for 40-45 per one ha. The number, height, diameter, and age of shoots and undergrowth were recorded [21]. When undergrowth and shoots were recorded, they were distributed by height into four groups: I – 0-0.50 m; II – 0.51-1.00 m; III – 1.01-1.50 m; IV – more than 1.50. We visually evaluated its distribution in the sample area, as well as its qualitative condition. To

assess natural regeneration, we used the scale proposed by S.M. Bebia [22].

3 Results

3.1. Floristic composition and ecosystem diversity of forests in the Malka River basin

The studied forest biogeocenoses, located in the conditions of a specially protected natural area, did not experience logging, but asubjected to recreational pressure. According to the results of the studies, it found that in the upper reaches of the Malka River; most of the area is birch forests, represented by a group of high-grass birch forests. Forest massive areas are located on slopes of western, northern and north-western exposures. We found 3 species of birch trees: *Betula litvinowii* Doluch., *B. pendula* L., *B. raddeana* Trautv. The accompanying species is *Pinus sylvestris* L. Undergrowth is almost absent, with isolated sightings of *Salix caprea* L., *Sorbus aucuparia* L., *Rubus idaeus* L., *Lonicera steveniana* Fisch. ex Pojark. The ground cover is rich in species, multilayer.

In the group of birch forests with tallgrass vegetation cover, according to the results of the research, one type of forest described: *Betuletum calamagrostioso-herbosum*.

Forest stands grow on slopes of steep 15°-20°, western, northern and northwestern exposures. The stands are pure, represented by *Betula raddeana*, also occur *B. litwinowii*, *B. pendula*. Crown density is 0.5-0.6.

Undergrowth layer poorly expressed, *Salix caprea*, *Rubus idaeus* occur sporadically on test plots. *Betula raddeana, B. litwinowii, P. sylvestris* were recorded in the undergrowth.

The dwarf shrub–herb layer with total projective coverage up to 80%, two or three tiers, up to 1 m high. *Calamagrostis arundinacea* dominates (projective coverage – 40-70%), the following species are also noted: *Aconitum nasutum* Fisch ex Rchb., *Veratrum lobelianum* Bernh., *Valeriana tiliifolia* Troitzk, *Betonica macrantha* C. Koch., *Lapsana communis* ssp. *grandiflora* (M. Bieb.) P. D. Sell, *Fragaria vesca* L., *Geranium sylvaticum* L., *Carum carvi* L., *Heracleum* sp., *Epilobium angustifolium* L., *Milium effusum* L., *Festuca drymeja* L., *Cirsium arvense* L., *Primula veris* ssp. *macrocalyx* (Bunge) Lüdi. The moss layer not developed in the communities.

A group of complex herbaceous birch forests, including *Pineto-betuletum calamagrostioso-herbosum*, occupies small areas in the study area. Forest areas of complex birch forests are located on slopes of western, northern and northwestern exposures, with a steepness of 20°-30°. The stands of complex composition, in addition to *Betula raddeana*, *B. litwinowii*, *B. pendula* in its formation involves *Pinus sylvestris*. Plantations of different age, two-tiered, III-IV bonitet classes, crown closeness – 0.5. Undergrowth is rare (projective coverage – 10%), formed by *Salix caprea*, *Lonicera steveniana*.

The dwarf shrub–herb layer with the total projective cover is 60-80 %. *Calamagrostis arundinacea* dominates here, *B. macrantha*, *Vaccinium myrtillus* L., *Equisetum sylvaticum* L., *Hesperis matronalis* L., *Ranunculus repens* L., *Seseli alpinum* M. Bieb., *Oxalis acetosella*, etc. Moss layer in communities makes up 5%.

The background vegetation in the Malka River gorge also created by small area pine forests, the main massifs are represented by a group of pine forests with herb-rich vegetation cover, including *Pinetum calamagrostioso-herbosum*.

Forest stands are clean, single-tiered, formed by *Pinus sylvestris*, single *B. pendula* noted. Forest areas are located on slopes of northern and north-eastern exposures, with a steepness of 20°-40°. Closure of crowns – 0.6.

The undergrowth layer is not expressed, projective cover is less than 10%, includes *Juniperus communis* L., *Rhododendron luteum* Sweet. Forest regeneration is very weak; the undergrowth is reliable, represented by *Pinus sylvestris*.

The dwarf shrub–herb layer with the total projective cover – up to 80%. In its composition registered: *Vaccinium myrtillus*, *F. vesca*, *C. arundinacea*, *Vicia cracca* L., *Poa annua* L., *Thalictrum foetidum* L., *Lathyrus pratensis* L., *O. acetosella* L., *Gymnocarpium dryopteris* (L.) Newman, *Dryopteris filix-mas*, *Bupleurum falcatum* ssp. *polyphyllum* (Ledeb.) H.Wolff etc.

In the moss layer (total projective coverage – 5-10%) we observed *Pleurozium schreberi* (Willd. ex Brid.) Mitt., *Dicranum scoparium* Hedw.

Below are the taxation characteristics of the sample areas of the selected forest types (Table 1).

Table 1. Taxation indicators of selected forest types of the Malka River basin

Forest type	Plant layer	H average, m	D average, m	Tree cover	Stems number, pcs/ha
Betuletum calamagrostioso-herbosum	1	16	33	0.35	305
Pineto-betuletum calamagrostioso-herbosum	1 2	12 9	46 26	0.4	333
Pinetum calamagrostioso-herbosum	1	12	17	0.7	688

A comparison of the identified forest types in terms of floristic similarity shows that the closest forest types are *Betuletum calamagrostioso-herbosum* and *Pineto-betuletum calamagrostioso-herbosum*, which explained by similar growing conditions. *Pinetum calamagrostioso-herbosum*, occupying the slopes of the northern exposition, differ in their floristic composition, and the similarity coefficient between this type of forest and *Betuletum calamagrostioso-herbosum* and *Pineto-betuletum calamagrostioso-herbosum* is rather low (Table 2).

In the flora of birch and pine forests of the Malka River basin, according to the results of our studies, 101 species of vascular plants from 68 genera and 38 families identified.

Table 2. Sorensen's floristic similarity coefficient between forest types of the Malka River basin

Forest type	*Betuletum calamagrostioso-herbosum*	*Pineto-betuletum calamagrostioso-herbosum*	*Pinetum calamagrostioso-herbosum*
Betuletum calamagrostioso-herbosum	1,000	0,629	0,389
Pineto-betuletum calamagrostioso-herbosum	0,629	1,000	0,431
Pinetum calamagrostioso-herbosum	0,389	0,431	1,000

This number includes all plants growing in natural ecosystems, including horsetails (1), ferns (3), gymnosperms (3), and angiosperms (94). The most species-rich families: *Asteraceae* (12), *Ericaceae* (10), *Poaceae* (5), *Rosaceae* (6), *Ranunculaceae* (5). These families include 45% of species of birch and pine formations. Large genera of the flora: *Betula*, *Poa*, *Geranium, Pyrola, Trifolium.*

The lichen flora of the Malka River headwaters forests represented by 37 species (Table 3).

Table 3. Lichens flora of forest areas of the Malka River basin

Species	**Ecogroup**	**Geographic element**
Anaptychia ciliaris (L.) Körb.	epiphyt	nemoral
Bryoria fuscescens (Gyeln.) Brodo et D. Hawksw.	epiphyt	boreal
Cetrelia cetrarioides (Delise et Duby) W.L. Culb. et C.F. Culb.	epiphyt	nemoral
Cetraria islandica (L.) Ach.	epigeous	boreal
Cladonia rangiferina (L.) F.H. Wigg.	epigeous	boreal
Evernia divaricata (L.) Ach.	epiphyt	boreal
E. prunastri (L.) Ach.	epiphyt	nemoral
Heterodermia speciosa (Wulfen) Trevis.	epiphyt	nemoral
Hypogymnia austerodes (Nyl.) Räsänen	epiphyt	hypoarctomontane
H. physodes (L.) Nyl.	epiphyt	boreal
H. tubulosa (Schaer.) Hav.	epiphyt	boreal
Icmadophila ericetorum (L.) Zahlbr.	epixyl	hypoarctomontane
Imshaugia aleurites (Ach.) S.L.F. Mey.	epiphyt	boreal
Lecanora allophana Nyl.	epiphyt	nemoral
Leptogium burnetiae C.W. Dodge	epiphyt	nemoral
L. saturninum (Dicks.) Nyl.	epiphyt	boreal
*Letharia vulpina (*L.) Hue	epiphyt	boreal
Lobaria pulmonaria (L.) Hoffm.	epiphyt	nemoral
Lobarina scrobiculata (Scop.) Nyl.	epiphyt	nemoral
Melanelia olivacea (L.) Essl.	epiphyt	boreal
Phaeophyscia ciliata (Hoffm.) Moberg	epiphyt	nemoral
Physcia stellaris (L.) Nyl.	epiphyt	nemoral
Peltigera aphthosa (L.) Willd.	epigeous	hypoarctomontane
P. collina (Ach.) Schrad.	epigeous	hypoarctomontane
P. malacea (Ach.) Funck	epigeous	boreal
P. venosa (L.) Baumg.	epigeous	hypoarctomontane
Platismatia glauca (L.) W.L. Culb. et C.F. Culb.	epiphyt	boreal
Pseudevernia furfuracea (L.) Zopf	epiphyt	nemoral
Solorina crocea (L.) Ach.	epigeous	arctic-alpine
S. saccata (L.) Ach.	epigeous	arctic-alpine
Stereocaulon paschale (L.) Hoffm.	epigeous	boreal
Thamnolia vermicularis (Sw.) Ach.	epigeous	arctic-alpine
Vulpicida pinastri (Scop.) J.-E. Mattsson et M.J. Lai	epiphyt	boreal
Usnea cavernosa Tuck.	epiphyt	boreal
U. dasopoga (Ach.) Nyl.	epiphyt	boreal
U. hirta (L.) Weber ex F.H. Wigg.	epiphyt	boreal
U. florida (L.) Weber ex F.H. Wigg.	epiphyt	boreal

Most of them are epiphytes – 78% of the total number, followed by epigeous and epilithic species – 15 and 7%, respectively. The following protected species found: *Leptogium burnetiae* C. W. Dodge, *Letharia vulpina* (L.) Hue, *Lobaria pulmonaria* (L.) Hoffm., *Lobarina scrobiculata* (Scop.) Nyl., *Sticta sylvatica* (Huds.) Ach. and *Usnea florida* (L.) Weber ex F. H. Wigg.

3.2. Phytogeographic analysis of the forest flora of the Malka River basin

According to the scheme of geographical elements proposed by N.N. Portenier [16], 12 geoelements (Holarctic, Boreal, Panboreal, Circumboreal, Pluri-regional, Euxinian, Euro-Siberian, Caucasian-European, Caucasian, Palearctic, Iranian-Turanian, Caucasian-Armeno-Iranian) are identified in the forest flora of the

study area, the characteristics of geoelements are given below.

1. Holarctic element. There are four such species in the forest flora of the studied area, which is 3.96% (*Moneses uniflora, Orthilia secunda, Rumex scutatusp* ssp. *hastifolius, Equisetum sylvaticum*)

2. Palaearctic element. We noted nine species (8.91%) in the forest flora of the Malka River basin – *Geranium collinum, Plantago major, Ranunculus repens, Trifolium campestre, Thalictrum foetidum*, etc.

3. Boreal element. Five such species (4.95%) are found in the forest flora of the studied area: *Pyrola chlorantha, Pyrola minor, Vaccinium vitis-idaea, Poa nemoralis*.

4. Circumboreal element. One of the smallest by number of species element of forest flora, Malka river basin, presented by one species (0.99%) – *Linnaea borealis.*

5. Panboreal element. One species – *Gymnocarpium dryopteris* found in the forest flora of the studied area.

6. Euro-Siberian element. In the forest flora of the studied area, we noted 25 such species (23.76%) – *Betula pendula*, *Geranium sylvaticum*, *Rubus idaeus*, *Calamagrostis arundinacea*, *Cruciata laevipes*, *Polygonatum verticillatum*, *Pyrola media*, *Solidago virgaurea*, *Pulmonaria mollis*, etc.

7. Euro-Caucasian element. Eleven such species (10.89%) were identified – *Platanthera chlorantha*, *Berberis vulgaris*, *Rhododendron luteum*, *Sorbus aucuparia*, *Allium victorialis*, *Astragalus cicer*, *Pilosella officinarum*, etc.

8. Caucasian element. We noted 40 such species (39.60%) in the study area – *Betula litwinowii*, *B. raddeana*, *Aconitum orientale*, *Arnebia pulchra*, *Astrantia maxima*, *Geranium ruprechtii*, *Hedysarum caucasicum*, *Ligularia subsagittata,* etc.

9. Euxine element. We recorded one species (0.99%) – *Carum meifolium* in the forests of the upper Malka River.

10. Pluri-regional element. One species (0.99%) belonging to this geoelement – *Poa annua* – was found in the studied area.

11. Iranian-Turanian element. We recorded two species (1.98%) – *Betonica macrantha* and *Euphorbia iberica* in the forests of the Malka River headwaters.

12. Caucasian-Armeno-Iranian element. One such species, *Juniperus communis* var. *saxatilis* Pall., recorded in the forest flora of the Malka River basin.

The core of the studied lichen flora is the boreal element – 18 species (Figure 2). Among boreal lichens, the Holarctic distribution group is represented by nine species, eight of which are distributed circumboreally: *Evernia divaricata*, *Imshaugia aleurites*, *Melanelia olivacea*, *Vulpicida pinastri*, *Usnea cavernosa*, *U. dasopoga*, *U. hirta*, *U. florida*. *Hypogymnia tubulosa* is a species with considerable disjuncture of areal in Holarctic, its range covers Europe, Asia, North America, in its distribution gravitates to oceanic areas.

Boreal species of multiregional distribution are bipolar. Species of this group are widely distributed in green-moss forest type, where they play an important phytocenotic role, being subdominants in epiphytic, epixilic and epigeic communities. Such species as *Bryoria fuscescens*, *Hypogymnia physodes*, *Platismatia glauca* form trunk sinusia. *Cetraria islandica*, *Cladonia rangiferina*, *Peltigera malacea*, *Stereocaulon paschale* dominate in the ground cover. On decaying wood the above mentioned *H. physodes*, and also *Leptogium saturninum* occur. *Pseudevernia furfuracea* selects habitats with favorable temperature conditions.

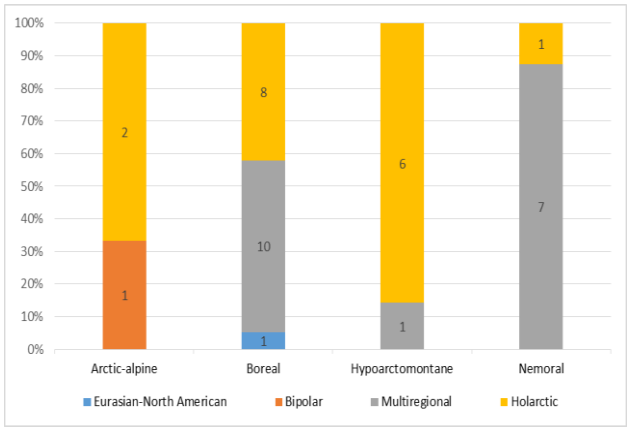

Fig.2. Composition of geographic elements and species distribution groups in the lichen flora of the Malka River basin forests

3.3. Undergrowth accounting in forest areas of the Malka River basin

It is known that the number of undergrowth depends on many factors [23, 24], including the type of forest and crown cover [25], in this regard, the intensity of reforestation was evaluated in the most common types of forests in the study area. When studying regeneration, we evaluated the quantitative and qualitative condition of the undergrowth on the sample plots, its age structure, and the nature of distribution on the sample area. According to the results of the studies, it was found that forest regeneration in forest areas of Malka river basin is very weak (Table 4). The ability of forest forming species to natural regeneration, along with climatic parameters of environment and soil conditions, is influenced by relationships between species of forest biocenosis tiers. In our opinion, the very weak forest regeneration on the sample plots of the study area is due primarily to the fact that the well-developed multilayer ground cover (total projective cover – up to 80%), prevents the emergence of seedlings or inhibits their growth.Low density of the stand on these plots contributes to the good development of the grass layer.

The quality of undergrowth subdivided into reliable, doubtful, and shrunken. For the majority of sample plots, we noted the growth of reliable undergrowth. Undergrowth distribution on forest plots predominantly clustered, confined to natural "windows" of the stand, to forest edges.

Table 4. Number of undergrowth in the studied forest types of the Malka River basin

Forest type	Undergrowth distribution, thousand pcs/ha				Total quantity of reliable undergrowth, %
	0-0.5 m	0.51-1 m	1.01-1.5 m	1.5 m	
1	-	-	-	0.078	95
2	-	-	-	0.122	97
3	-	-	-	0.350	98

AUC: 1 – *Betuletum calamagrostioso-herbosum;* 2 – *Pineto-betuletum calamagrostioso-herbosum;* 3 – *Pinetum calamagrostioso-herbosum*

4 Conclusions

The main diversity of forests in the upper reaches of the Malka River represented by three forest types, which are included in three groups. The types of birch and pine forests differ in the species composition and dominants of the lower tiers of stands, which reflects the peculiarities of habitats.

The most widespread in the territory of the Malkinskiy Zakaznik is a group of birch forests with tallgrass vegetation cover, formed by *Betula raddeana*, a species included in the Red Book of the Russian Federation, the Red Book of the KBR, status – rare species. The ground cover in this group is formed representatives of forest tall grasses – *Calamagrostis arundinacea*, *Aconitum nasutum*, *Geranium sylvaticum* and others. S.Kh. Shkhagapsoev and L.B. Kurasheva [6] also distinguish birch forests with rhododendron undergrowth and subalpine bilberry forests for the territory of Kabardino-Balkaria, which not found in the upper reaches of the Malka River.

The flora of vascular plants of the Malk River headwaters consists mainly of Caucasian (39.6%), Euro-Siberian (23.76%), Euro-Caucasian (10.89%), and Palaearctic (8.91%) geoelements. Half of the geoelements of the forest flora of the upper Malka River is associated in its distribution with the Caucasian floristic province (Caucasian, Euro-Caucasian, Iranian-Iranian, Caucasian-Armeno-Iranian).

The lichen flora is dominated by the boreal geo-element (48.65%), indicating that, despite the relatively southern location of the mountainous part of Kabardino-Balkaria, a pronounced connection with the lichen flora of more northern regions is typical.

The obtained data characterize the current state and typological diversity of forests in the upper reaches of the Malk River and can subsequently serve as a basis for the assessment of successional changes in the forest cover and the dynamics of vegetation diversity.

Flora of birch and pine forests of the Malka River basin includes relicts, endemics, protected species of plants and animals; therefore, their preservation is the most important nature protection task. Large mammals such as bears, wild boars, roe deer, and a considerable number of bird species (snake eagle, peregrine falcon, golden eagle, black vulture, and Caucasian grouse) found in birch forests bordering the belt of broad-leaved forests. A number of bird species nesting, others are migratory. Suitable habitats are preserved here for such rare mammal species as the Caucasian otter and the European mink, as well as, numerous in the past, the red deer, the Caucasian tour.

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