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RELICT BLACK-ALDER FORESTS OF THE KAZAKH UNDULATING PLAIN AND CHANGES CAUSED BY HUMAN ACTIVITY

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A description is presented of unique relict communities of the black alder in the Bayan-Aul mountain-forest oasis, which is a long distance from the primary range of this species. Stages of their anthropogenic degradation are outlined and conservation measures are recommended.

Isolated stands of pine forests are dispersed on a background of steppe vegetation in the Kazakh (Central Kazakhstan) undulating plain. These are related to the low granite mountains rising above the level of the surrounding area. Relatively many boreal relicts were retained in these pine forests (Denisova, 1971; Karamysheva and Rachkovskaya, 1973); these relicts are evidence of an epoch with a moister and cooler climate, when the boundary of the boreal forest (taiga) zone was farther south than today, and plants typical for this zone migrated into the central region of Kazakhstan.

The occurrence of the black alder in forests on the Kazakh undulating plain is highly unique. This species is found (Komarov, 1936) in Scandinavia, in central Europe and along the Atlantic coast (to Spain), in northern Africa, on the Balkan peninsula, in Asia Minor, in Crimea, and in the Caucasus. According to forest and forest-steppe zones of the European USSR, the range of the black alder extends to the Ural Mountains, then crosses them, and enters western Siberia. The most eastern occurrence of this tree in western Siberia (Krylov, 1930) is along the Tura River near Tyumen (Tyumen Province) and in the Iletsk-Ikovka forest (Kurgan Province).

In Kazakhstan, the black alder is encountered at a considerable distance from its primary range in the Bayan-Aul (Pavlodar Province) and Karkaraly (Karaganda Province) mountain-forest massifs, in the mountains of Ermentau (Tselinograd Province), along the Ilek River (Aktyubinsk Province), and also near the settlement Kushmurin in the Kustanai Oblast (Goloskokov, 1960; Karamysheva and Rachkovskaya, 1973). It is most abundant in the Bayan-Aul mountains where it forms forests extending as narrow bands along mountain streams. The total area of black-alder forests in the Bayan-Aul massif, according to the data of forest management for 1978, is 459 ha.

The growth of the black alder in Kazakhstan is an exceptionally interesting botanical and geographic phenomenon which deserves careful study. Until recently, black-alder forests in central Kazakhstan were described only in very general terms (Karamysheva, 1961; Makulbekova, 1970); their position in the plant cover, floristic composition, and cenotic structure were not studied properly. In this report, data from investigations in 1977-1979 were used to provide a phytocenological description of black-alder forests in central Kazakhstan; changes in them caused by human activity (primarily by pasturing of cattle) were determined, and measures for the conservation of these unique plant communities are outlined.

EXPERIMENTAL PROCEDURES AND STUDY AREA

The investigations were conducted in the Bayan-Aul mountain-forest massif in the northeastern region of the Kazakh undulating plain. The Bayan-Aul mountains are an isolated massif (about 20 by 40 km), composed of solid Paleozoic rock, primarily granite, and to a lesser extent, porphyrite and quartz rock. The highest point is Akpet peak (1027 m above sea

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level). The mountains have been extremely worn down by erosion and are known for the fantastic eroded granite sculptures. The river network is not highly developed, nevertheless, springs giving rise to streams are often encountered. The streams flow along the bottom of valleys, and often disappear when they emerge from them, vanishing into loose alluvial deposits. Closed internal-drainage depressions are filled with lakes, and the largest of these are Dzhasybai, Sabandykul', and Turaygyr. The climate is clearly continental. According to data from the meteorological station Bayan-Aul (Handbook on the Climate of the USSR, 1966, 1968), average annual temperature is 3.3°C, average temperature for January −13.2°C, and and for July 20.5°C. Average annual precipitation is 401 mm. The fact that the meterological station Bayan-Aul is located at the edge of the mountain-forest massif, at the foothills of the mountains, suggests that rainfall in the center of the massif is more abundant.

The area we studied is located in the steppe zone, the subzone of dry fescue—feathergrass steppes (Map of Vegetation of the Steppe Area of the Kazakh Undulating Plain, 1975). But the granite massifs, rising above the surrounding countryside, affect the pattern of zonal plant distribution, and consequently, the Bayan-Aul mountains are classified as a forest belt (Karamysheva, 1961), forming a unique forest oasis within the surrounding steppes.

A total of 39 sample plots, each 0.15-0.2 ha in area, were delineated to study the black-alder forests. The morphology of the soil profile in the sample plots was described; soil samples were taken for mechanical and chemical analysis; tree lists were compiled; the composition of the underbrush and grass and moss—lichen cover was determined with an assessment of individual species according to Drude's scale; and the projective cover was determined. The presence of boreal relicts and synanthropic species was noted particularly to determine the floristic composition of communities on sample plots. Stages of black-alder forest degradation were determined by selecting a series of original communities that had been subjected to various degrees of anthropogenic activity. Indices of the proportion of synanthropic species in the grass cover were used in addition to other criteria to determine the stages of degradation (Abramchuk and Gorchakovskii, 1980; Gorchakovskii and Ryabinina, 1981).

PHYTOCENOLOGICAL CHARACTERISTICS OF BLACK-ALDER FORESTS

Black-alder forests in the Bayan-Aul mountain-forest massif grow in valleys of streams and small rivers, with constant influx of moisture from springs and also from condensation of atmospheric moisture in deep crevices in cliffs. These creeks and rivers do not dry up even in dry periods during the summer, and ground water occurs at a shallow depth where it is accessible to alder root systems. We isolated and described eight black-alder associations.

Ostrich-Fern Black-Alder Forest. This forest is found in valleys of streams and rivers usually near exposed granite cliffs. Moisture is abundant and circulates actively; moisture conditions are rather stable because of the influx of moisture from springs originating at the foot of granite cliffs.

The soil is alluvial soddy-gley loam with buried horizons (I, II). A meadow process is superimposed on the formation of stratified alluvium which produces the humus horizon A_1.

A_0 (0-3 cm). Litter from fern leaves and grasses, not decomposed on top, half-decomposed near bottom, many woody residues.

A_1 (3-12 cm). Dark-gray medium loam with light-gray patches and intercalations of fine-textured, loose, gravelly alluvium, abundant roots. Transition to the following horizon is clear from color and mechanical composition.

I (12-27 cm). Stratified horizontally, consists of alternating layers of the humus horizon, 3-5 mm thick, and layers of gravelly alluvium. Humus intercalations are dark-gray, medium loam, retaining its granular structure; dense, gravelly intercalations, gray, and unconsolidated. Transition is clear from color.

II (27-40 cm). Horizontally stratified, blue-gray dark-gray intercalations of heavy clay loam (structureless, dense) alternate with layers of ocherous gravel. Ocher is predominant color of horizon, layers are 2-3 cm thick; roots, stones and chunks of granite are encountered. The tree stand is pure alder or with admixtures of the European bird cherry *(Padus racemosa)*, aspen *(Populus tremulus)*, and the common birch *(Betula verrucosa)*. Canopy density is 0.6-0.7, and quality class III. Diameter of alders is 28 cm; average height, 18 m,

and growing stock 220-260 m^3 per hectare. Regrowth consists of alder and aspen seedlings of medium density.

The shrub story is of medium density (cover of 20-50%) and consists of: cop.$_1$, *Rabus idaeus*, sp., *Ribes nigrum* and *R. hispidulum*, and sol., *Viburnum opulus* and *Ribes saxatile*.

The grass cover is rather dense (cover of 70-80%, sometimes up to 90%), *Matteuccia struthiopteris* (plants 0.5-1.0 m high), cop.$_3$, clearly predominates. Other components of the grass stand are: cop.$_1$, *Chelidonium majus; sp., Heracleum sibiricum, Urtica dioica, Cicuta virosa, Circaea alpina,* and others. Total number of species is 61, including 16 synanthropic species.

The moss cover is weakly developed (cover up to 5%); mosses are found in beds along stream banks, in depressions, and on rocks and deadwood. Species composition is: sp., *Drepanocladus uncinatus, Marchantia polymorpha*, sol., *Neckera pennata*. Of vegetation not confined to stories, the common hop, *Humulus lupulus*, sp., was found twining around shrubs and tree trunks.

Nettle—lady-fern black-alder forest. This forest is found along banks of streams with only slightly developed valleys and at the bottom of deep, shaded gulches. Moisture is abundant and circulates moderately. Soil is alluvial peat-humus-gley loam with a buried horizon.

A_0 (0-3 cm). Litter from fern leaves, grasses, and alder leaves.

A_1 (3-23 cm). Blue-gray light loam with abundant plant residues, humus, and granite gravel, blocky.

BC_g (23-41 cm). Intercalations of blue-gray, sandy, weakly silted, somewhat smoothed granite gravel, alternating with intercalations of blue-gray-powdery light loam (30-40%) with small blocks.

I_1 (41-50 cm). Buried horizon, dark-gray humified light loam, blocky, dense, with ocherous patches along pores, abundant granite gravel.

The stand is pure alder or with admixtures of the European bird cherry and aspen, quality class II-III. Canopy density is 0.5-0.6. Average diameter of alders is 30 cm, average height 18 m, and growing stock 250-270 m^3 per hectare. Regrowth is primarily alder seedlings.

The shrub story is of medium density (projective cover of 40-60%), consisting of cop.$_1$-cop.$_2$, *Rubus idaeus*, sp.-cop.$_1$, *Ribes hispadulum, Viburnum opulus*, and others.

The grass cover is highly developed (cover of 70-80%), consists of: cop.$_2$-cop.$_3$, *Athyrium filix-femina;* cop.$_1$, *Urticia dioica;* sp.-cop.$_1$, *Filipendula ulmaria* sp., *Equisetum silvaticum, Galium boreale, Circaea alpina,* and others. The total number of species is 51, including 16 synanthropic species.

Mosses are found in small beds; their cover is negligible. Most typical are sp., *Mnium medium* (in water): sol., *Neckera pennata* at the base of tree trunks. The common hop is abundant, *Humulus lupulus,* sp.-cop.$_1$.

Bulrush—Queen-of-the-Meadow Black-Alder Forest. This forest grows at the foot of mountains and on flat slopes in swampy stream valleys with a weakly manifested floodplain (there is only one terrace above the floodplain). Moisture is excessive, almost stagnant. Microrelief is hilly. Soil is alluvial-boggy-peat-gley.

A_0 (0-2 cm). Litter of tree leaves and grass.

A_1 (2-32 cm). Dark-brown peat; wood-grass decomposed to 40%, at a depth of 20 cm, woody residues are encountered; highly permeated by roots; decomposed to more than 50% to the stage of humus at a greater depth; somewhat intertwined with roots; silted; contains much mica; gravel exists; abundant ocherous patches (result of iron oxidation). Peat is washed out and redeposited at the lower boundary.

Cg (32 cm and deeper). Gravel is silted, gleyed.

The stand consists of black alder with admixtures of the European bird cherry, aspen, white birch, and less often, Scotch pine. Quality class IV. Average height of alders is 14-15 cm, diameter 24 cm, and canopy density 0.6-0.7. Growing stock is 200-210 m^3 per hectare.

The shrub story is well developed (cover of 40-70%), and consists of: cop.$_2$, *Rubus idaeus*; cop.$_1$, *Ribes nigrum;* sp., *Crataegus altaica, Viburnum opulus*; sol.-sp., *Ribes hispidulum.*

The grass cover is rather dense (cover of 70-80%), and is characterized by: cop.$_2$-cop.$_3$, *Filipendula ulmaria;* cop.$_2$ *Scirpus silvaticus;* sp.-cop.$_1$ *Athyrium filix-femina, Lysimachia vulgaris, Urtica dioica,* and others. The total number of species is 65, including 21 synanthropic species.

The moss cover is weakly developed (cover of 5-10%), growing on the soil surface are: sp.-cop.$_1$, *Mnium medium, Brachythecium curtum, Aulacomnium palustre, Plagiothecium denticulatum,* and on the roots of trees on the lower trunk: sp., *Nickera pennata.* Vegetation not confined to stories is represented by the common hop., *Humulus lupulus,* sp.-cop.$_1$.

Ground-Ivy Black-Alder Forest. Typical ecotopes are relatively even areas of river and stream valleys. Moisture is abundant with active circulation. Soil is alluvial sod-gley loam with buried horizons.

A_0 (0-1 cm). Thin layer of litter consisting of tree leaves and grass.

A_1 (1-18 cm). Dark-gray medium loam, gravelly-silted, uniform in color, granular, highly aggregated, consolidated, weakly sodded, contains high proportion of woody roots. Transition to next horizon is evident from composition and color.

I (18-31 cm). Dark-gray (almost black) blocky heavy loam, silted, consolidated, about 10% gravel. Transition is clear.

IIg (31-57 cm). Horizon not uniform in color, consists of layers of ocherous, weakly silted gravel and dark blue-gray silty heavy loam, structureless, compact, somewhat plastic. Oxidation occurs along layers of gravel. Transition is clear from color.

IIIg (below 57 cm). Dark blue-gray clay with ocherous diffused rings. Layers of clay 1-6 cm thick alternate with layers of silted dense gravel.

The stand consists of black alder with a limited admixture of the European bird cherry and aspen, quality class IV. Canopy density is 0.5-0.6. Average diameter of alders is 24 cm, average height 14 m, and growing stock 190-210 m^3 per hectare.

The shrub story covers 20-50% of the surface and consists of: sp.-cop.$_1$, *Rubus idaeus;* sp., *Ribes nigrum*, and others.

The grass cover is dense (cover of 70-90%) and low. Major components are: cop.$_2$-cop.$_3$, *Glechoma hederacea;* cop.$_1$, *Geum urbanum*, sp., *Scutellaria galericulata, Myosoton aquaticum, Impatiens nolitangere, Heracleum sibiricum.* A total of 80 species was noted in the association, including 33 synanthropic species.

The moss cover is almost unapparent, small beds of mosses, *Bryum argenteum* (sol.-sp.) and *Hylocomnium splendens* are found in valleys of streams on rocks at the base of trees. The common hop, *Humulus lupulus,* (sol.) rarely encountered, is found primarily in clearings.

Lady-Fern—Ground-Ivy—Nettle Black-Alder Forest. This forest is found in valleys of streams with moderately circulating moisture. Soil is alluvial humus-gley loam with buried horizons.

A_0 (0-2 cm). Litter from alder foliage, grass, and ferns.

A_1 (I) (2-9 cm). Dark-gray (almost black), loose, granular medium loam, contains much humus and plant residues, limited peat formation, abundant tree roots; gravel (about 5%) in thin layers.

I (9-28 cm). Consists of horizontal layers of dark-gray, not-well-defined granular, humified light loam, 1-5 cm thick, and layers of granite gravel, about 1 cm thick, the hue is generally dark.

II (28-70 cm). Mottled, consists of horizontal layers of dirty blue-gray, structureless light humified loam, 3-5 cm thick, and layers of gravel. Loamy layers show signs of gleying. Gravel is oxidized, brown ocher in color.

The stand is of quality class IV, and consists primarily of alder, with minor admixtures of the European bird cherry, aspen, and common birch. Canopy density is 0.4-0.5.

Average diameter of alders is 32 cm, height 15 m, and growing stock 220-220 m^3 per hectare.

The shrub story is of medium density (projective cover of 40-60%) and consists of: cop.$_1$-cop.$_2$, *Rubus idaeus;* sp.-cop.$_1$, *Ribes nigrum, R. hispidulum,* and others.

The grass cover is relatively dense (cover of 60-70%) and consists of: cop.$_2$, *Urtica dioica;* cop.$_1$-cop.$_2$, *Athyrium filix-femina, Glechoma hederacea;* cop.$_1$, *Chelidonium majus;* sp., *Roegneria canina, Geum urbanum, Heracleum sibiricum,* and others. There was a total of 46 species, including 17 synanthropic species.

The moss cover is represented by beds of: sp., *Mnium medium* (in water), *Drepanocladus uncinatus* (in water), *Pleurozium schreberi, Bryum argenteum* (on roots of trees and at the base of trunks). The common hop, *Humulus lupulus,* (sp.-cop.$_1$) entwines shrubs and trees.

Water-Pepper Black-Alder Forest. This forest is found in valleys of rivers and streams with a slow current. Moisture is excessive, almost stagnant. Microrelief is characterized by small hills. Soil is alluvial-bog peat-gley loam with buried horizons.

A_0 (0-1 cm). Litter consisting of tree foliage and grass.

A_T (1-21 cm). Brown wood-grass peat, decomposed to more than 50%, with wood and granite gravel. There are layers of dark blue-gray medium loam with small blocks.

Ig (21-33 cm). Blue-gray, with abundant small ocherous patches of gravelly heavy loam, dense.

IIg (33-43 cm). Mottled, blue-gray clay with abundant ocherous diffuse rings and ortstein. Gravelly dense heavy loam in pores and root passages.

Cg (43-70 cm). Dark blue-gray, porous, gravelly heavy loam with ocherous ortstein (gravel consisting of feldspar and 20% quartz).

The stand is pure alder or with minor admixtures of the European bird cherry, white birch *(Betula pubescens),* and goat willow (*Salix caprea*), quality class IV-V. Canopy density 0.5-0.6. Average diameter of alders is 16 cm, average height 10-12 m. Growing stock is 100-120 m^3 per hectare.

% The shrub story is weakly manifested (cover of 10-20%) and consists of: sol.-cop.$_1$, *Ribes nigrum;* sol.-sp., *Rubus idaeus*, and others. Shrub growth is suppressed because of grazing.

The grass cover is relatively dense (cover of 60-90%) and consists of: cop.$_2$-cop.$_3$, *Polygonum hydropiper;* sp.-cop.$_1$, *Agrostis gigantea;* sp., *Poa trivialis, Scutellaria galericulata, Lysimachia vulgaris, Epilobium adnatum, Polygonum lapathifolium, Geum urbanum, Cicuta virosa, Filipendula ulmaria,* and others. There was a total of 59 species, including 19 synanthropic species.

Moss covers 10-20% of the soil surface and is represented by beds of: cop.$_1$, *Mnium medium, Brachythecium curtum; sp., Drepanocladus uncinatus, and Bryum argenteum.* The common hop, *Humulus lupulus*, (*sp.*), is encountered entwining shrubs and tree trunks.

Nettle Black-Alder Forest. Typical habitat is valleys of streams with moderately circulating moisture. Soil is alluvial sod-humus-gley loam with buried horizons.

A_0 (0-1 cm). Litter consisting of alder leaves and twigs.

A_1 (1-20 cm). Dark-gray granular-highly-consolidated medium loam, highly permeated by tree roots, limited sod formation, contains substantial amounts of humans, limited peat formation.

I (20-33 cm). Dark-gray heavy loam with admixtures of gravel, relatively dense.

IIg (33-60 cm). Stratified horizon, consists of layers of gravel and silty heavy loam, nonuniform in color, with blue-gray streaks and patches.

The stand is of quality class IV, rather thin (canopy density of 0.4-0.5), consists of black alder with minor admixtures of the European bird cherry, and aspen in glades. Average diameter of alders is 12-16 cm, average height 12 m. Growing stock is 170-190 m^3 per hectare.

The shrub story is of medium density (cover of 20-60%) and consists of: cop.$_2$, *Ribes nigrum;* sp.-cop.$_1$ *Rubus idaeus;* sol.-sp. *Ribes hispidulum,* and others.

The grass covers 50-70% of the soil surface. Its composition is dominated by: cop.$_2$-cop.$_3$, *Urtica dioica;* sp., *Myosoton aquaticum, Lysimachia vulgaris, Epilobium adnatum, Filipendula ulmaria, Mentha arvensis, Arctium tomentosum, Geum urbanum, Scutellaria galericulata.* There was a total of 56 species, including 22 synanthropic species.

The moss cover is not evident as a story, and only isolated moss beds are found in depressions in water (sp., *Mnium medium;* sol., *Drepanocladus uncinatus)* and on bark at the base of trunks (sol., *Bryum argenteum, Neckera pennata, Plagiothecium denticulatum).* Vegetation not confined to stories is represented by the common hop, *Humulus lupulus* (sp.).

Pale-Smartweed Black-Alder Forest. It is typical for swampy river and stream valleys. Soil is alluvial-boggy peaty-gley loam.

A_T (0-15 cm). Peaty horizon with dead residues of stems and leaves of grass plants, alder leaves, twigs, with inclusions of loam and gravel. Consolidated owing to grazing.

A_1 (15-22 cm). Dark-gray loam with blue-gray shade, with small inclusions of gravel, small blocks, peat formation.

G (22-45 cm). Heavy, dense blue-gray loam with ocher-yellow patches and gravel layers.

Cg (45 cm and deeper). Blue-gray heavy loam with ocher patches and gravel layers.

The stand is pure alder, quality class V-Va, and thin (canopy density 0.3-0.5). Trunks of alders are twisted at the base, alder consists of regrowth, average diameter is 14-16 cm, average height 8-10 m, and growing stock 60-90 m^3 per hectare.

Shrub story is barely developed (projective cover less than 15%), and is represented by isolated shrubs: sp., *Ribes nigrum* and *Rosa acicularis*

The grass cover is of medium density (cover of 50-60%) and consists of: cop.$_2$-cop.$_3$, *Polygonum lapathifolium;* cop.$_1$, *Bidens tripartita, Glechoma hederacea;* sp., *Mentha arvensis, Myosotis palustris, Epilobium adnatum, Filipendula ulmaria, Chenopodium album, Geranium pratense*, and others. There is a total of 46 species, including 24 synanthropic species.

Moss covers 10-20% of the soil, and consists of: cop.$_1$, *Brachithecium curtum, Mnium medium;* sp., *Bryum argentenum;* sol., *Brachythecium salebrosum.*

According to the data of the chemical analysis, in ostrich-fern and nettle—lady-fern black-alder forests the soils are weakly acidic, very fertile, well moistened, and weakly gleyed, with variable gleying conditions. They are rich in humus, characterized by a high total nitrogen content and its readily assimilated form contain large amounts of phosphorus and potassium, and also of mobile forms of iron. The saturation of the absorbing complex with exchangeable bases is rather low (60%), and potassium predominates in the absorbing complex (because of biogenic accumulation). In the ground-ivy, lady-fern—ground-ivy—nettle, and nettle black-alder forests, soils are similar to those described above, but differ in their lower fertility. Soils in the associations: bulrush—queen-of-the-meadow, water-pepper, and pale-smartweed black-alder forests are characterized by constant excess moisture, gleying is observed at a depth of 20 cm. The humus content is high, but plant residues decompose slowly which results in peat formation. The absorption complex is highly saturated with exchangeable bases. Soils are rich in phosphorus, potassium, and mobile forms of iron. In contrast to black-alder forests found in valleys of the Ilek River, which is the left tributary of the Ural River (Mil'kov, 1950), vigorous peat formation is not observed in the mountain black-alder forests of the Bayan-Aul massif.

The richness of soil and favorable moisture conditions promote the rapid growth of a grass cover in black-alder forests. A total of 137 species of vascular plants, including 10 boreal relicts and 46 synanthropic species, were noted in the grass stand of the studied associations (see Table 1). Most of the boreal relicts in the Bayan-Aul massif are concentrated in black-alder forests. Located in valleys and gulches, black-alder forests fullfill an important water-conserving function, protecting the streams and rivers flowing here from drying out. Local populations had long noted that being in black-alder forests had a therapeutic effect on the human body, apparently, this is determined by the very favorable temperature and moisture conditions, as well as by the abundance of antimicrobial substances released by plants. They also have an aesthetic value, beautifying and increasing the diversity of the local landscape. This was taken into account in determining the necessity of preserving the unique ecosystem of black-alder forests in the Bayan-Aul massif and of protecting plant communities characterized by dominance by the black alder from undesirable anthropogenic activity.

TABLE 1. Floristic Composition of the Grass Cover and Abundance of Species in Black-Alder Forests (synanthropic species are indicated by an asterisk)

No.	Plant name	Black-alder forest							
		ostrich-fern	nettle-lady-fern	bulrush—queen-of-the-meadow	ground-ivy	lady-fern—ground-ivy—nettle	water-pepper	nettle	pale-smartweed
1*	*Agrimonia pilosa*	—	—	—	sol.	sol.	—	—	—
2	*Agrostis alba*	—	sol.	—	—	—	sol.	—	—
3	*A. capillaris*	sol.	—	sol.	sol.	—	—	—	—
4	*A. gigantea*	sol.	sol.	sol.	sp.	sol.	$sp._1$-$cop._1$	sol.	sol.
5	*Alisma plantago-aquatica*	—	—	—	—	—	sol.	—	—
6	*Alopecurus arundinaceus*	—	—	—	—	—	sol.	—	—
7*	*Arabis borealis*	—	sol.	sol.	$sp._1$	—	—	—	—
8	*A. pendula*	sol.	—	sol.	sol.	sol.	sol.	sol.	—
9*	*Arctium tomentosum*	sol.	sol.	sol.	sol.	sol.	—	sp.	sol.
10*	*Artemisia sieversiana*	—	—	—	sol.	sol.	—	sol.	—
11*	*A. vulgaris*	sol.	sol.	sol.	sol.	sp.	sol.	sol.	—
12	*Athyrium filix-femina*	sp.	$cop._2$-$cop._3$	$sp._1$-$cop._1$	sol.	$cop._1$-$cop._2$	sol.	—	—
13*	*Atriplex patula*	—	—	—	sol.	—	—	—	—
14*	*Barbarea stricta*	—	sol.	sol.	—	—	—	—	—
15*	*Beckmannia syzigachne*	—	—	—	—	—	sol.	—	—
16*	*Bidens tripartita*	—	—	sol.	sol.	—	sol.	sol.	$cop._1$
17	*Bromopsis inermis*	—	—	sol.	—	—	—	sol.	—
18	*Calamagrostis epigeios*	sol.	sol.	—	sp.	—	—	sp.	—
19	*Calystegia sepium*	sol.	sol.	sp.	sol.	sol.	—	—	—
20*	*Cannabis ruderalis*	—	sol.	sol.	sol.	sol.	—	sol.	—
21*	*Capsella bursa-pastoris*	—	—	—	—	—	—	—	sol.
22	*Cardamine impatiens*	sol.	—	sol.	—	sol.	—	sol.	sol.
23*	*Carduus crispus*	sol.	sol.	sol.	sol.	sol.	sp.	—	—
24	*Carex acutiformis*	—	—	sol.	—	—	—	—	—
25	*C. juncella*	—	sol.	sol.	—	—	—	—	—
26	*C. karoi*	sol.	—	sol.	—	—	—	—	—
27	*C. pseudo-cyperus*	sol.	—	—	—	—	sol.	—	—
28	*C. rhynchophysa*	—	—	$cop._1$	—	—	—	—	sol.
29	*C. songorica*	sol.	—	sol.	—	—	—	—	—
30*	*Carum carvi*	—	—	—	—	—	—	sol.	sol.
31	*Cerastium arvense*	—	—	—	sol.	—	—	—	sol.
32*	*Chamaenerion angustifolium*	—	—	—	sol.	—	—	—	sol.
33*	*Chelidonium majus*	$cop._1$	sp.	sol.	sol.	$cop._1$	—	sol.	—
34*	*Chenopodium acuminatum*	—	—	—	sol.	—	—	sol.	—
35*	*Ch. album*	sol.	—	sol.	sol.	—	—	—	sp.
36	*Cicuta virosa*	sp.	sol.	$cop._1$	sp.	sol.	sp.	sol.	sol.
37	*Circaea alpina*	sp.	sp.	sol.	sol.	sol.	sol.	sol.	—
38*	*Cirsium incanum*	—	—	—	sol.	sol.	—	sol.	—
39	*Cuscuta europaea*	sol.	—	sol.	—	sol.	—	sol.	—
40	*Cystopteris fragilis*	sol.	sol.	—	—	sol.	—	sol.	—
41	*Delphinium elatum*	sol.	sol.	sol.	sol.	sol.	sol.	—	—
42	*Deschampsia caespitosa*	sol.	sol.	—	sol.	—	—	sol.	—
43	*Epilobium adnatum*	sol.	sol.	sp.	sol.	sol.	sp.	sp.	sp.
44	*E. hirsutum*	—	—	—	—	—	sol.	—	—
45	*E. palustre*	—	sol.	—	sol.	—	—	—	—
46	*Equisetum heleocharis*	—	—	sol.	—	—	—	—	—
47	*E. hiemale*	sol.	—	—	—	—	—	—	—
48	*E. palustre*	sp.	—	sol.	—	—	sol.	—	—
49	*E. sylvaticum*	—	sp.	sol.	sol.	sp.	—	—	—
50	*Eritrichium rupestre*	—	—	—	—	sol.	sol.	—	—
51	*Filipendula ulmaria*	sol.	$cop._2$-$cop._3$	$cop._3$	sp.	sp.	sol.	sp.	sp.

(continued)

TABLE 1 (continued)

No.	Plant name	Black-alder forest							
		ostrich-fern	nettle-lady-fern	bulrush – queen-of-the-meadow	ground-ivy	lady-fern – ground-ivy – nettle	water-pepper	nettle	pale-smartweed
52	*Fragaria vesca*	sol.	sol.	sol.	—	sol.	sol.	—	—
53	*F. viridis*	—	—	—	sol.	—	—	—	—
54*	*Galeopsis bifida*	—	—	sol.	sol.	sol.	—	sol.	—
55*	*Galium aparine*	—	sol.	—	—	—	—	—	—
56	*G. boreale*	sol.	sp.	cop.$_1$	sol.	sp.	sol.	sol.	sol.
57	*G. verum*	—	—	—	—	—	—	sol.	—
58	*Geranium pratense*	—	—	—	sol.	—	—	—	sp.
59	*G. sibiricum*	sol.	sol.	—	sol.	—	sol.	—	sol.
60*	*Geum urbanum*	sol.	sol.	sol.	cop.$_1$	sp.	sp.	sp.	sol.
61*	*Glechoma hederacea*	sol.	sol.	sol.	cop.$_2$-cop.$_3$	cop.$_1$-cop.$_2$	sol.	sol.	cop.$_1$
62	*Heracleum sibiricum*	sol.	sp.	sp.	sp.	sp.	sol.	sol.	—
63*	*Impatiens noli-tangere*	sol.	sol.	sp.	sp.	sol.	sol.	—	—
64	*Inula britannica*	—	—	—	sol.	—	sol.	—	—
65	*Juncus ambiguus*	—	—	—	—	—	—	sol.	sol.
66*	*Lappula echinata*	sol.	—	sol.	sol.	—	—	sol.	—
67	*Lathyrus pratensis*	—	—	—	—	—	—	sol.	sol.
68*	*Leonurus glaucecens*	—	—	—	—	—	—	sol.	—
69	*Ligularia sibirica*	sol.	—	sol.	—	—	—	—	—
70	*Lithospermum officinale*	sol.	—	—	sol.	—	—	sol.	—
71*	*Lycopus europaeus*	—	sol.	sol.	sol.	—	sol.	sol.	sol.
72	*Lysimachia vulgaris*	sol.	sol.	sp.-cop.$_1$	sol.	—	sp.	sol.	sol.
73	*Lythrum salicaria*	—	—	—	—	—	sol.	—	—
74	*Matteuccia struthiopteris*	cop.$_3$	—	—	—	—	—	—	—
75	*Medicago falcata*	—	—	—	—	—	—	sol.	—
76*	*M. lupulina*	—	—	—	—	—	—	—	sol.
77	*Melica altissima*	sol.	—	—	—	sol.	—	—	—
78*	*Melilotus albus*	—	—	—	—	—	—	—	sol.
79*	*M. dentatus*	—	—	—	sol.	—	—	—	—
80*	*Mentha arvensis*	sol.	—	sol.	sol.	—	sol.	sp.	sol.
81	*Myosotis palustris*	sol.	—	—	sol.	—	sol.	sol.	sp.
82*	*M. sparsiflora*	—	—	—	—	—	sol.	—	—
83	*Myosoton aquaticum*	sol.	sp.	sol.	sp.	sol.	sol.	sp.	sol.
84	*Phlomis tuberosa*	—	—	—	—	sol.	—	—	—
85	*Phragmites communis*	—	sol.	sp.	—	—	—	sol.	—
86	*Phalarioides arundinacea*	sol.	—	sol.	—	—	—	—	—
87*	*Plantago major*	—	sol.	—	sol.	sol.	sol.	sol.	—
88	*P. stepposa*	sol.	—	—	sol.	—	—	sol.	sol.
89	*Poa angustifolia*	sol.	—	—	sol.	—	—	—	—
90	*P. nemoralis*	sol.	sol.	—	sol.	sol.	—	sol.	—
91	*P. palustris*	—	—	—	sol.	sol.	—	—	—
92	*P remota*	sol.	sol.	—	sol.	—	—	—	—
93	*P pratensis*	—	—	—	sol.	—	—	sol.	—
94	*P. stepposa*	—	—	—	—	sol.	—	—	—
95	*P. trivialis*	—	—	sol.	—	sol.	sp.	—	—
96*	*Polygonum aviculare*	—	—	—	sol.	—	—	—	sol.
97*	*P. convolvulus*	sol.	sol.	sol.	sol.	—	—	sp.	sol.
98*	*P. dumetorum*	—	—	—	—	—	sp.	—	sp.
99*	*P. hydropiper*	—	—	sp.	—	—	cop.$_2$-cop.$_3$	—	sol.
100*	*P. lapathifolium*	sol.	—	—	sp.	—	sp.	—	cop$_2$-cop.$_3$
101*	*P. minus*	—	—	—	sol.	—	—	sol.	—
102*	*Potentilla anserina*	—	—	—	sol.	—	—	—	sp.

(continued)

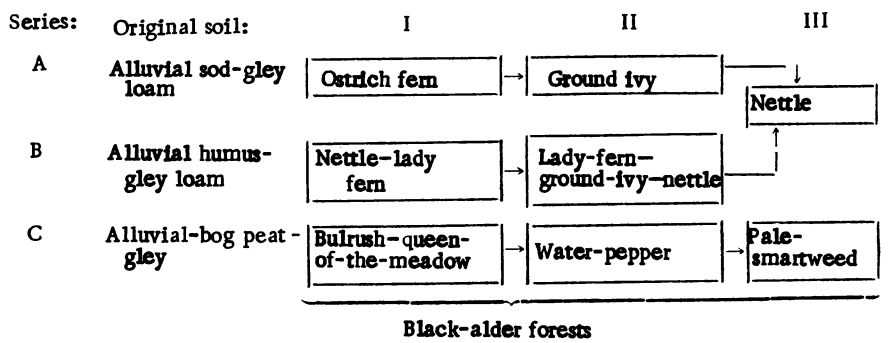
TABLE 1 (continued)

No.	Plant name	Black-alder forest							
		ostrich-fern	nettle–lady–fern	bulrush–queen-of-the meadow	ground-ivy	lady-fern–ground-ivy–nettle	water-pepper	nettle	pale-smartweed
103	*P. argentea*	—	—	—	—	—	sol.	—	sol.
104	*P. humifusa*	—	—	sol.	—	—	—	—	—
105	*Pyrola rotundifolia*	—	sol.	—	—	—	—	—	—
106	*Ranunculus sceleratus*	—	—	—	—	—	sol.	—	sol.
107	*Roegneria canina*	sol.	sol.	sol.	sol.	sp.	—	sol.	—
108	*Roripa palustris*	sol.	—	—	sol.	—	—	—	—
109	*Rubus saxatilis*	—	—	cop.$_1$	sol.	—	sol.	sol.	—
110	*Rumex aquaticus*	—	—	—	sol.	—	—	—	—
111*	*R. confertus*	—	—	—	—	—	sol.	—	—
112*	*R. stenophyllus*	—	—	—	sol.	—	—	—	sol.
113	*Scirpus sylvaticus*	sol.	sol.	cop.$_2$	sol.	—	sol.	—	—
114	*Scrophularia alata*	—	—	sol.	sol.	sol.	sol.	—	—
115*	*Scutellaria galericulata*	sol	sol.	sp.	sp.	—	sp.	sp.	sp.
116	*Senecio jacobaea*	—	—	—	—	—	sol.	—	—
117	*Seseli ledebouri*	—	—	sol.	—	—	—	—	—
118	*Sium sisaroideum*	sol.	—	sol.	sp.	sol.	sol.	sol.	sp.
119*	*Solanum depilatum*	sol.	sol.	sol.	sol.	sol.	sol.	—	sol.
120*	*Sonchus oleraceus*	—	—	—	—	sol.	—	—	—
121	*Stachys palustris*	sol.	—	—	sol.	—	—	—	sol.
122	*S. sylvatica*	—	sol.	sp.	—	—	—	—	sp.
123	*Stellaria media*	—	sol.	—	sol.,	—	sol.	sol.	—
124*	*Taraxacum officinale*	—	—	—	sp.	sol.	sol.	sol.	sp.
125	*Thalictrum collinum*	—	sol.	sol.	sol.	sol.	—	sol.	sol.
126	*Th. flavum*	—	—	—	—	—	sol.	—	—
127	*Th. simplex*	sol.	sol.	sp.	sol.	—	sol.	sol.	—
128*	*Thlaspi arvense*	—	—	—	—	—	—	sol.	sol.
129*	*Trifolium repens*	sol.	—	—	—	—	—	—	—
130	*Turritis glabra*	—	—	sol.	—	—	—	—	—
131*	*Urtica dioica*	sp.	cop.$_1$	sp.-cop.$_1$	sp.	cop.$_2$	sp.	cop.$_2$-cop.$_3$	sol.
132	*Veronica anagallis-aquatica*	—	—	—	—	—	sol.	—	sol.
133	*V. longifolia*	sol.	—	—	—	—	sol.	—	—
134	*Vicia cracca*	—	—	sol.	sol.	—	sol.	—	—
135	*V. sepium*	sol.	—	sol.	sol.	—	—	—	—
136	*Viola canina*	—	—	—	sol.	—	—	—	—
137	*V. hirta*	sol.	sol.	—	sol.	—	—	sol.	—
	Total	61	51	65	80	46	59	56	46
	Including synanthropic species	16	16	21	33	17	19	22	24

Black-alder forests of the Bayan-Aul massif were exposed for a long time (starting with the eighteenth century) to human agricultural activity. The acting factor was grazing by cattle (the cattle drank water and were sheltered from the heat in alder forests), felling of trees and trampling of the ground by people picking berries and collecting mushrooms had a less significant effect. There were no alder forests unaffected by human activity within the massif; they were all subject to anthropogenic degradation to some extent. More extensive changes in vegetation were observed near populated areas.

Grazing of cattle in alder forests was accompanied by damage to and destruction of herbaceous plants, shrubs, as well as seedlings and regrowth, and packing of soil, deterioration in its aeration, and its concurrent enrichment with nitrogen, phosphorus, and potassium. Of all vegetation stories, the grass cover underwent the most extensive grazing-induced transformations, the tree stand less extensive transformations, and the underbrush and moss the least extensive transformations. Changes in the tree story were reduced to an increase in the proportion of aspen and common birch, and also a limited deterioration in the growth of the black alder and a decrease in the productivity of communities formed by it as a result of packing of soil and deterioration of its aeration.

We divided pasture degradation of alder forests into three stages corresponding to limited, moderate, and extensive grazing (see diagram).



The ostrich-fern, nettle–lady-fern, and bulrush–queen-of-the-meadow associations belong to the first degradation stage. They are the closest to the original alder associations that existed here 200-250 years prior, before the appearance of settlements with permanent inhabitants, engaged in raising cattle. These three associations are characterized by variability in moisture conditions in valleys of mountain streams and rivers: ecotopes with actively circulating, abundant moisture (series A), moderately circulating, abundant moisture (series B), and excess, almost stagnatnt, moisture with signs of bog formation and gleying (series C). These associations also contain a considerable number of boreal relicts (10-12 species). There are several synanthropic species (12-16) in the grass cover; most of these are found in isolation and only the stinging nettle and celandine has an abundance of cop.$_1$ in some associations (projective cover from 5 to 25%).

As grazing intensity increases (degradation stage II), there are major changes in the composition and structure of the alder-forest grass cover. Queen-of-the-meadow (*Filipendula ulmaria*) and wood bulrush (*Scirpus silvaticus*) lose their leadership role to water pepper (*Polygonum hydropiper*). The position of the lady fern is weakened, and the stinging nettle comes into the forefront in the grass stand in suitable ecotopes, and the lady fern remains as a codominant. The ostrich fern, which does not tolerate grazing well, disappears from the grass stand and is replaced by ground ivy. Thus, degradation stage II is represented by water-pepper, lady-fern–nettle, and ground-ivy associations. The number of synanthropic species in the grass stand increases (13-29) in this stage, some of them (stinging nettle, celandine, ground ivy, northern bedstraw) become codominants, their abundance is either designated as cop.$_1$ or cop.$_2$ (projective cover is 5-25% or 25-50%). The number of boreal relicts in the grass stand decreases slightly (8-10 species).

An even greater increase in pasture load (degradation stage III) results in the formation of nettle associations in habitats with abundant, actively circulating moisture (series A), and abundant moderately circulating moisture (series B), and in the formation of pale-smartweed associations in habitats with excess, almost stagnant, moisture (series C). At this stage, the number of boreal relicts decreases even more (three-seven species) and the number of synanthropic species increases (15-29), such species as the stinging nettle and pale smartweed become dominants.

Pasture degradation of black-alder forests is a manifestation of synanthropization of the plant cover (see Falinski, 1971, Gorchakovskii, 1979). The grazing of cattle leads to a decline in the natural renewal of the alder and thinning of the stand. The water-conserving role of alder forests decreases, some of the springs dry up, the amount of water in streams decreases, and their currents become slower. The thickness of the litter decreases with grazing, soil is compacted, its aeration deteriorates, decomposition of plant residues slows down, and the sod process weakens. This leads to the unification of ecotopes in series A and B, and the convergence of plant associations in these series. The position of meadow and forest plants weakens, and synanthropic species gradually acquire dominance in the grass stand. Only two associations formed by convergence in place of the three associations, which ressembled the original one. In each of these, synanthropic species dominate the grass stand. In the final analysis, ecotopes converge during pasture degradation, the cenotic diversity of black-alder forests decreases, their floristic composition declines, and productivity drops.

CONCLUSIONS

1. Whereas most boreal relicts are encountered sporadically in the Kazakh undulating plain, the black alder (*Alnus glutinosa*), which has a subordinate role in plant communities, becomes a dominant, which forms forests in the valleys of mountain streams and rivers.

2. Within the Kazakh undulating plain, black-alder forests are most developed in the Bayan-Aul mountain-forest massif, here, there is a rich complex of shrub (*Ribes nigrum, R. hispidulum, Viburnum opulus*) and herbaceous (*Pyrola rotundifolia, Matteuccia struthiopteris, Athyrium filix-femina, Heracelum sibiricum, Circaea alpina,* etc.) boreal relicts, in addition to the black alder. The great diversity of the relief, abundant springs and mountain streams, and the existence of deep shady gulches aided the survival of the black alder, as well as other associated boreal species, in the dry, markedly continental climate.

3. Of synanthropic factors, grazing of cattle had the greatest effect on black-alder communities. Relict black-alder forests in the Bayan-Aul massif are represented by eight associations, found in different stages of pasture degradation. Degradation results in the decline of productivity, simplification of ecological and cenotic diversity, a decrease in the floristic composition, extinction of the boreal relicts, and dominance of syanthropic plant species in the grass cover.

4. In view of the relict nature of the entire ecosystem in black-alder forests in Kazakhstan and its great water-conserving, therapeutic, and aesthetic value, it must be preserved. This may be accomplished by isolating the most preserved areas of black-alder forests in a preserve within the Bayan-Aul natural park.

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