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Natural and anthropogenic fragmentation of the birches in the forest-steppe zone of the Altai territory

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The article considers the results of the study of birch forests of forest-steppe zone of the Altai territory. The tendencies of anthropogenic changes in the species composition of birch forests are revealed. The process of fragmentation of birch pegs is analyzed, 3 levels of degradation are described. The synanthropization of birch forests occurs, accompanied by a decrease in their species and phytocenotic diversity. The consequences of synanthropization are the following: the fragmentation of plant populations and their isolation, the replacement of native plant communities by derivative and synanthropic, endemic and stenotopic plants by cosmopolitan and eurytopic ones, and the replacement of autochthonous elements by allochthonous ones. Universal impoverishment and unification of the species composition is accompanied by a decrease in productivity and resistance to external factors. Synanthropization causes leveling of zonal and regional differences of birch forests. As the anthropogenic load increases, the level of biodiversity decreases sharply, and during degradation, there is a transition to the dominance of species that are resistant to the changing ecotope conditions.
Monocenoses – homogeneous forest communities consisting only of forest species – are extremely rare in the study area. They are characterized by a high association between the stand and the stand, the homogeneity of the structure and the conjugation with the ecotope. These are reference sites with a complete absence of anthropogenic transformation. Most forest ecosystems are a subject to varying degrees of human pressure.
Keywords: natural and anthropogenic fragmentation; island effect; birch forest

Introduction

Reducing the area of forest ecosystems and their fragmentation can occur as a result of the impact of both natural and anthropogenic factors (*Bierregaard, Lovejoy,*1992; *Brotons, Monkkonen, Martin,* 2003; *Martín-Queller et all.,* 2017). Natural factors cause the formation of island forests or pegs. Anthropogenic factors (such as felling, grazing, mowing, plowing lands) lead to the fragmentation of forest ecosystems, their isolation, the destruction of migration corridors among individual communities, a decrease in the number of local populations and the intensity of species exchange (*Laurance at all.,* 2002; *Helm, Hanski, Pärtel,* 2006; *Kapos, Reynolds, Sinun,* 2011). Transformation of forest ecosystems often not only leads to changes in their ecological and biological functions, but also has a prolonged genetic effect.
In accordance with the main provisions of the theory of island biogeography (*Simberloff, Abele*, 1975; *Wilcox,* 1983; *Simberloff, Gotelli,* 1984) isolated phytocenoses differ in species diversity and structure, their development differs from typical zonal communities (*Watson,* 2002; *Krauss at all.,* 2004; *Burkey, Reed,* 2006; *Acatov*, 2012; *Ivanov,* 2014; *Resasco et all.,* 2017). Fragmentation in the future leads to a high rate of species extinction, an increase in the biomass density of the remaining species, an active introduction of synanthropic elements (*Malyshev,* 1980; *Dombrovsky, Tyutyunov,* 1987; *Demina at all.,* 2006).

Materials and methods

We have conducted studies of birch forests of forest-steppe zone of the Altai region. Standard geobotanical methods were used to describe plant communities exposed to various types of anthropogenic impacts.

Results and discussion

Birch forests are a zone element of the plant cover in the forest-steppe zone of the Altai Region. They form small island arrays – pegs, scattered among the areas of steppe and meadow vegetation and agricultural land. Arid climate and the peculiarity of the forest-steppe soils cause the formation of birch forests on low relief elements with favorable water regime for the growth

of tree species. Birch forests occupy 45 % of the area of all forests of the region and have great climate control, water protection, soil protection, field protection, anti-erosion, recreational, resource value.

The intensity and character of the agrarian development of the forest-steppe territory of the Altai region have led to the reduction of the territory of the zonal forests, to the emergence of mosaic forest and agricultural land and the prevalence of treeless lands in the landscape.

In the left-bank part of the Ob river the formation of birch pegs occurs in saucer-like depressions of the relief characteristic of these areas – depressions of various shapes and depths, where optimum moisture conditions are created for woody vegetation. Such birch pegs often have a rounded shape, are sharply separated from the surrounding grass vegetation and occur on solodized soils and solods (*Lapshina*, 1963). Their area is 1–5 ha. Pegs, located in smaller depressions, are characterized by greater homogeneity of structure and species composition. In the deep depressions, the central part of the pegs can be swamped and smoothed, therefore such pegs can be represented by several associations that alternate each other.

The woody layer of birch forests is represented by warty birch – *Betula pendula Roth*, fluffy birch – *Betula alba L.*, aspen admixture is possible – *Populus tremula L.*, which is often found in the shores of the right bank of the Ob river. In the undergrowth *Padus avium Mill. Viburnum opulus L., Crataegus sanguinea Pall.* can be found. In the marshy pegs willows are predominated by *Salix alba L., S. cinerea L., S. pentandra L., S. viminalis L*. According to its structure, birch groves are simple, single-tier, often sparse, the crowns' tightness does not exceed 0.5–0.6, and in some places decreases to 0.2–0.3. The height of the trees is 8–15 m. The shrub layer is poorly developed and consists of single specimens of *Caragana arborescens Lam., Salix rosmarinifolia L., Rosa acicularis Lindl., R. majalis Herrm., Cotoneaster melanocarpus Fisch. Ex Blytt,* species of the genus *Spiraea*, which are exposed to open meadows and edges.

Grass cover is well developed and diverse in species composition, reflecting the diversity of habitat conditions. Ecological groups are dominated by mesophytae (50-60%), with the participation of mesoxerophytic, xerophytes, mesohygrophytes, hygrophytes. Meadow-forest and meadow species with a small participation of forest species are represented mostly among forest mesophytes. The diversity of the ecological composition of the birch forest flora shows its variety and reflects its particular location in the forest-steppe zone. Towards the foothills, birch forests of meadow and meadow-steppe species are gradually disappearing from the grass stand, they are being replaced by typical forest species.

Species richness of phytocenoses is 35–70 species. The total projective grass cover is 60-90%. The total quantity of all species which can be seen in the pegs does not exceed 350 species.The highest species diversity is among the families of *Asteraceae, Gramineae, Fabaceae, Rosaceae, Labiatae, Umbelliferae, Ranunculaceae* and a few others. The main dominants of grass cover are *Dactylis glomerata L., Brachypodium pinnatum (L.) Beauv., Calamagrostis epigeios (L.) Roth, C. arundinacea (L.) Roth, Poa pratensis L., P. angustifolia L., Pteridium aquilinum (L.) Kuhn, Carex cespitosa L., C. macroura Meinsh., Rubus saxatilis L., Fragaria vesca L., Iris ruthenica Ker-Gawl., Angelica sylvestris L., Achillea millefolium L., Trifolium pratense L., T. lupinaster L., Vicia cracca L. and etc.* Other species such as *Pulmonaria mollis Wulf. ex Homem., Serratula coronata L., Lathyrus pisiformis L., Adenophora liliefolia (L.) DC., Viola canina L., Agrimonia pilosa Ledeb., Vicia sepium L., Solidago virgaurea L., Sanguisorba officinalis L., Ranunculus polyantnemos L., Geranium pretense L., Heracleum sibiricum L.* are also met constantly in the herbage.

There is a significant similarity in the flora of birch pegs and steppe meadows, which indicates a decrease in the dominant role of the tree tier and its influence on the lower tiers. This is facilitated by long-term human activities (felling, grazing) which lead to the thinning of the stand, lightening spines and creating conditions for the introduction of meadow plants into forest phytocenoses.

Agricultural development of the forest-steppe of the Altai Region led to a change in the botanical and geographical boundaries. The southern boundary of the distribution of birch pegs has moved away to the north, expanding the boundaries of the steppe zone. The pegs themselves have turned into miniature islands scattered among the endless fields where a lot of grass-fescue-feather grass steppes are plowed up. The afforestation of the forest-steppe has decreased over the period of intensive development from 20 to 2–5%, and some areas have become completely treeless.

At present, birch pegs are a subject to various types of anthropogenic influences in the form of cutting, grazing, mowing, trampling, fires (burning), plowing, etc. The destruction of the birch forests and the bleeding of grass cover with livestock lead to the fact that pegs can no longer have a significant effect on the vegetation of the pinhole spaces. Consequently, conditions are created for the further deforestation and the graduation of previously forested areas. In the place of the mixed pegs, grassy meadow steppes, steppe meadows and halophytic complexes are formed.

The destruction of natural grasslands and pastures has led to an increase in pasture pressure on forest ecosystems. A significant part of birch pegs of the forest-steppe zone is subjected to grazing and mowing. First of all, grazing affects the state of underbrush and undergrowth. In the forests used for grazing, renewal is often absent. The undergrowth falls out completely. Natural seed regeneration is disturbed and pneumo shoots develop. As a result of mechanical damage, the processes of growth and development of plants are disrupted. Under the influence of grazing, the capacity of the forest litter is reduced, the soil is compacted and dried up, its water conduction and aeration deteriorates, the process of decomposition of plant residues slows down, which causes worsening environmental conditions for grassy plants and moss cover.

The effect of grazing leads to the simplification of the structure and the formation of floristically poor, less productive forest communities. The species composition is depleted due to the inhibition and loss of rare, shade-loving and stenotopic plant species. The vitality of plants is deteriorating, the composition of dominants, the ratio of ecological-biological and economic-botanical groups are changing; turf is being destroyed, the structure of phytocenoses is being simplified. A decrease in productivity has been observed for all transformed communities (Table 1).

The position of the forest and meadow species is being weakened, synanthropic species are introduced instead of them, and they begin to dominate in the herbage, forming a fairly uniform herbage. Under the influence of grazing, forest cereals are replaced by meadow and meadow-steppe (*Festuca pseuovina Hack. ex Wiesb., Poa angustifolia, Agrostis tenuis Sibth. and etc*). Leveler species are growing abundantly – *Origanum vulgare L., Fragaria vesca, Hypericum perforatum L.,* weed plants are developing – *Chelidonium majus L., Urtica dioica L., Melampyrum cristatum L., Berteroa incana (L.) DC., Agrimonia pilosa, Glechoma hederacea L., Cirsium esculentum (Siev.) C.A. Mey and etc.* Plants react differently to trampling. Shrubs, rosette and squat plants are less damaged when trampling down. Legumes and forbs (*Majanthemum bifolium (L.) F.W. Schmidt , Anthriscus sylvestris (L.) Hoffm., Angelica sylvestris L., Vicia cracca L., V. sepium, Galium aparine L. s.l.*) more suffer from the constant trampling. They are not able to grow quickly with constant biting and thus cannot multiply by vegetative means. Other plants (such as *Artemisia commutata L., A. austriaca Jacq., Achillea millefolium, Plantago media L., P. urvillei Opiz, P. lanceolata L., Prunella vulgaris L., Trifolium pratense, Alchemilla vulgaris L. s.l., Deschampsia cespitosa (L.) Beauv.)* which tolerate grazing and grow quickly in vegetative way are spreading vigorously.

The swamped birch pegs, under the influence of immoderate grazing, turn into a marshy, hummock forest, and then into a swamp. Numerous hummocks from the cattle paths appear on the surface of the soil in such pegs. They accumulate precipitation and increase the overall moisture. Mesophilic undersized species resistant to trampling are growing – *Potentilla anserine L., Plantago media, Cirsium esculentum (Siev.) C.A. Mey.*

Thus the pasture degradation of forest ecosystems leads to the situation when ecological and phytocenotic diversity decreases, the species composition is depleted, the structure is simplified, the transition to the dominance of synanthropic species takes place, and the productivity of communities is reduced. All these factors cause the unification of ecotopes and reduce the water conservation role of forests.

The anthropogenic factor such as plowing has a significant effect on birch forests. The species diversity of the forest community can remain stable only if the extinction of the species is compensated by their immigration from the outside. The destruction of migration corridors during plowing and plowing birch groves lead to the complete isolation of the forest ecosystem and its transformation into an ecological "isolate" (island) with a limited number of external sources of diasporas (*Sokolova,* 2013). Such a decrease in sources of exchange between an isolated community and adjacent territories causes a gradual decrease in species diversity, a decrease in productivity and an increase in the degree of incompleteness (island effect).

An assessment of the condition of birch pegs, which experience a constant impact in the form of plowing, has shown that this type of impact is similar to the effect of grazing and leads to disruption of the structure, changes in the species composition and productivity of birch forests. The species diversity of regularly peeled groves is reduced mainly due to a decrease in the proportion of herbs and an increase in the proportion of cereals (Table 1).

Table 1. Changes in the main phytocenotic characteristics of birch groves under the influence of grazing and plowing

Parameters	Control	Chewing	Grazing
Total number of species	37	23	23
The number of weed species	4	6	7
Total projective cover,%	80	52	48
Average height, cm	60	45	35
Number of tiers	3	3	2
The ratio of botanical groups,%:			
cereals	12	14	15
sedges	5	5	3
legumes	15	16	17
grass	68	65	65
Ratio of life forms,%:			
the trees	8	6	6
shrubs	5	5	6
shrubs	3	4	–
Herbs: perennial	74	77	79
one-biennial	10	8	9
The ratio of ecological groups,%:			
mesophytes	63	60	60
mesoxerophytes	20	25	35
xerophytes	7	6	10
hygrophytes	5	4	2
mesohygrophytes	5	5	5
Productivity, kg / ha dry weight	25	23	15

There is a change in the ratio of life forms towards an increase in the abundance of perennial grasses and shrubs and a decrease in the vitality of trees. The occurrence and projective coverage of mesophytes and mesohygrophytes decreases due to an increase in the proportion of mesoxerophytes and xerophytes. Weed species are introduced into the herbage from the surrounding agricultural fields (*Sokolova*, 2015).

Destruction of prikolnyh upland meadows, which perform a peculiar buffer role between agricultural land and birch pegs, accelerates the degradation of birch forests and contributes to the loss of forest species and the introduction of weed-meadow forbs. The process of degradation depends on the size of the pegs. Faster is the degradation in birch forests, whose area does not exceed 1–5 hectares. With the complete degradation of the grass stand and the destruction of the shrub layer, separate trees remain for some time, which also gradually diminish their vitality and dry out.

Thus, with the increase in anthropogenic load with the island character of the location of birch pegs in the forest-steppe of the Altai Region, the formation of steppe diffuse light forests has occurred, which are characterized by instability, a sharp decrease in the process of renewing the wood edifier - wart birch. Violation of the structure of the spikes has led to the separation between the upper and lower tiers of forest ecosystems. The stand of such "anthropogenic woodlands" is distinguished by unsatisfactory self-renewal, low density and crowns density, monodominant species composition, decrease in species diversity and incomplete structure. The grass cover is characterized by xerophitization processes, which are accompanied by an increase in the proportion of drought-resistant plants, forest fallout and the introduction of more tolerant meadow-steppe, meadow, steppe and weed species. The total projective cover and the height of the grass stand are reduced.

The synanthropization of birch forests occurs, accompanied by a decrease in their species and phytocenotic diversity. The consequences of synanthropization are the following: the fragmentation of plant populations and their isolation, the replacement of native plant communities by derivative and synanthropic, endemic and stenotopic plants by cosmopolitan and eurytopic ones, and the replacement of autochthonous elements by allochthonous ones. Universal impoverishment and unification of the species composition is accompanied by a decrease in productivity and resistance to external factors. Synanthropization causes leveling of zonal and regional differences of birch forests. As the anthropogenic load increases, the level of biodiversity decreases sharply, and during degradation, there is a transition to the dominance of species that are resistant to the changing ecotope conditions.

Monocenoses – homogeneous forest communities consisting only of forest species – are extremely rare in the study area. They are characterized by a high association between the stand and the stand, the homogeneity of the structure and the conjugation with the ecotope. These are reference sites with a complete absence of anthropogenic transformation. Most forest ecosystems are a subject to varying degrees of human pressure.

In accordance with the classification of forest ecosystems by structure (Bellegarde, 1971) and the identification of critical levels of their anthropogenic changes (Ibragimov et al., 1999), we have identified three critical levels of anthropogenic changes in forest ecosystems within the studied territory. The birch groves of the forest-steppe zone of the region are at different critical levels of anthropogenic transformation. The first level corresponds to the anthropogenic destruction of forest communities, accompanied by the loss of maximum biological diversity and productivity, the loss of the natural type of forest.

Forest ecosystems at this level are spread widely. They are open to the penetration of other species of plant communities (pseudo-monocenoses). A dramatic change in the species composition and the formation of a new "anthropogenic" type of forest, where the internal phytomedia and the environment-forming role of the edificatory remain, are observed. The degree of disturbance of the species composition in such forest ecosystems is 25–40%. The number of species at this level may increase due to the introduction of ruderal, steppe and meadow species into the vacated ecological niches.

The second critical level is associated with the disintegration of the indigenous plant community and the suppression of the competitiveness of edificators. Birch pegs corresponding to this level are a combination of forest stand and meadow-forest, meadow and meadow-steppe grass stand. Such phytocenoses can be called amphicenoses. They observe the coexistence of species belonging to different types of vegetation. These communities are forest and meadow, steppe and forest at the same time. The species composition of such communities is characterized by the equal participation of forest and adventive species, the almost complete absence of the influence of the upper tiers on the lower. As a result of such a significant anthropogenic load, smoothing of ecotopological differences and convergence between communities of different areas occur, leading to the formation of communities with a high degree of similarity of species composition and structure. The possibility of self-healing of native forest ecosystems is preserved, but it happens extremely slowly.

The third critical level is characterized by a complete forest ecosystem crisis due to the profound changes ecotope. The birches of this level are characterized by strong sparse tree stand, the lack of a crown density. Trees are often drytop. Living ground cover is almost absent; there are only scattered patches of ruderal vegetation near the tree trunks. In this case, it will take many years to restore the substrate and normalize the growing conditions of woody vegetation.

Conclusion

The process of anthropogenic dynamics of forest ecosystems of the flat part of the Altai Region usually does not proceed according to the type of irreversible changes, but is characterized by the formation of new, derived anthropogenic forest types. Anthropogenic digression is accompanied by demutation (restoration) and the activation of syngenetic processes that counteract the destruction of forest ecosystems. Studies have shown that birch groves have different resistance to anthropogenic influences, due to the possibilities of ecotopes and the availability of environmental resources. The most stable and stable forest ecosystems that are in the best growing conditions are characterized by maximum species and ecobiomorphological diversity, have "protection" in the form of many tiers (undergrowth, underbrush, well-developed stand) with maximum filling with ecological niches.

The resulting anthropogenically modified forest communities are incomplete due to the loss of individual links in the ecosystem. Replenishment of missing elements should occur at the expense of standard ecosystems of specially protected

natural territories. To stabilize environmental conditions, it is necessary to limit logging and grazing, to introduce a protection regime and to preserve the forest cover of the territories, taking into account the specific landscape features of the regions.

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