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ECOLOGICAL DYNAMICS AND FLORISTIC DIVERSITY IN THE BOREAL ECOTONE OF THE VOLGA BASIN: A STUDY OF KNYAGININSKY DISTRICT

Andrej Astashin[1,2*], Ilya Mininzon[3], Oleg Pashkin[1], Olga Vatina[1], Irina Shevchenko[1]

[1]Kozma Minin Nizhny Novgorod State Pedagogical University, 1 Ulyanova str., Nizhny Novgorod, 603005, Russia;*
[2]Nizhny Novgorod State Engineering and Economic University, 22A Oktyabrskaya str., Knyaginino, Nizhny Novgorod Region, 606340, Russia;*
[3]Botanical Garden of the Lobachevsky Nizhny Novgorod State University, 1 Botanicheskiy sad str., Nizhny Novgorod, 603062, Russia;

[*]Corresponding Author Andrej Astashin, email: astashinfizgeo@yandex.ru;

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ABSTRACT

The study aims to refine the floristic composition data of the Knyagininsky district in the Nizhny Novgorod region, a key area representing the botanico-geographical features of the boreal ecotone of the Volga basin. To achieve this, a combination of field research, thematic maps, remote sensing data, and literature review was used. The research involved extensive fieldwork conducted in 2020, surveying 60 observation points in various landscapes affected by different degrees of anthropogenic pressure. The vegetation was thoroughly documented, resulting in the identification of 156 species of higher plants across 126 genera and 51 families, some of which were previously unrecorded in the area. The fact of the growth of a number of species not previously noted in this botanico-geographical area is established. The importance of flora researches for understanding the physico-geographical processes in the region is noted. The well-developed Knyagininsky district of the Nizhny Novgorod region is characterized by a significant presence of feral cultivated species. This indicates a significant change in natural ecosystems, the emergence of free ecological niches in them. Result of the anthropogenic change in the territory is the weakening of the clinal nature of the boreal ecotone.

Keywords: Biodiversity conservation, Forest-steppe transition, Habitat fragmentation, Red-listed species Ecological restoration, Anthropogenic landscape transformation.

INTRODUCTION

The territory of the Knyagininsky district is characterized by a high degree of anthropogenic pressure, which, among other things, causes an acceleration of the dynamics of flora, hat is, the processes of the appearance and/or expansion of the ranges of some and the disappearance and/or reduction of the ranges of other plant species (Gorelkina et al., 2024).

Thus, the work on clarifying the modern floral composition is absolutely necessary and in demand both among botanists and ecologists (Aipeisova et al., 2025), and during landscape research as a basis for monitoring vegetation cover (Maurice et al., 2024), this indicator of the ecological state of the landscape and its dynamics (Chebyshev et al., 2024; Filonova et al., 2024), and can also be used by economic entities and environmental organizations (Baidalina et al., 2024; Bekezhanov et al., 2023; Gorelkina et al., 2024; Mityakov et al., 2024; Mukhambetov et al., 2023; Zhyrgalova et al., 2024).

The results of the work on the botanical research of the territory of the Nizhny Novgorod region, including the boreal ecotone, are reflected in a number of publications, however, although this territory was affected by the routes of geobotanical expeditions, organized by the Association for the Research of Productive Forces of the Nizhny Novgorod province, but the published reports on the routes, in part, concerning the modern territory of the Knyagininsky district, are either fragmentary or general character (Alekhin and Averkiev, 1928; Porkhunov, 1927; Uranov, 1928).

Due to the ecotonic position (Sapanov et al., 2024) of the researched territory and its intensive involvement in economic activity, which significantly distorted the indigenous appearance of vegetation, botanists and landscape scientists refer this territory to different zones (Chebyshev et al., 2024; Gryadunova et al., 2020). So, for example, according to the forest-growing zoning of the region of K.K. Poluyakhtov (1974), the territory of the Knyagininsky district belongs to the subzone of mixed forests. F.N. Milkov (1986) referred the territory of the Knyagininsky district to the forest-steppe zone. Nizhny Novgorod geographer and soil scientist F.M. Bakanina (2003) also referred the territory of the Knyagininsky district to the forest-steppe zone. A.G. Isachenko (1991) referred this territory to the forest-steppe zone (northern, or broad-leaved forest subzone), later A.G. Isachenko (2017) saw the territory of the Knyagininsky district as part of the plain subboreal broad-leaved forest Eastern European landscapes.

The multiplicity of views of specialists on the belonging of the researched territory to a particular zone confirms its transitional nature, combining the features of neighboring zones. The purpose of the research was to refine the data on the floristic composition of the territory of the Knyagininsky district as a representative territory, reflecting the botanico-geographical features of the boreal ecotone of the Volga basin.

RESEARCH METHODOLOGY

Research Design

In 2020, the authors conducted geographico-botanical researches on the studied territory, as a result of which data on the floral composition of the Knyagininsky district were clarified, in particular, the detection points of 156 species of higher plants in 126 genuses, belonging to 51 families belonging to 5 classes were described and mapped. Vegetation descriptions were carried out in all types of tracts – terrestrial and aquatic, subject to anthropogenic transformation to varying degrees – from conditionally indigenous forest and steppe communities to agrocenoses of fields, gardens and plant communities of settlements, roadsides, etc. The initial materials included fieldwork results, thematic maps, remote sensing data (Osintseva et al., 2023), and existing literature. The methodology involved an expeditionary approach using cartographic (Kashina et al., 2022) and geoinformation tools, mathematical analysis, and literature review. In the article authors used the following methods: expeditionary using cartographic, geoinformation, mathematical methods and literature analysis.

Characteristics of the Researched Territory

Knyagininsky district is located in the central part of the Nizhny Novgorod region on the northern spurs of the Privolzhskaya Upland. It is entirely included in the southern part of the boreal ecotone of the Russian Plain (Kolomyts et al., 1993), the strip between the taiga and steppe landscapes. Knyagininsky district is located within the Forest-steppe district, the P'yansko-Volzhskij subdistrict according to the botanico-geographical division of the region (Averkiev, 1954) (Figure 1).

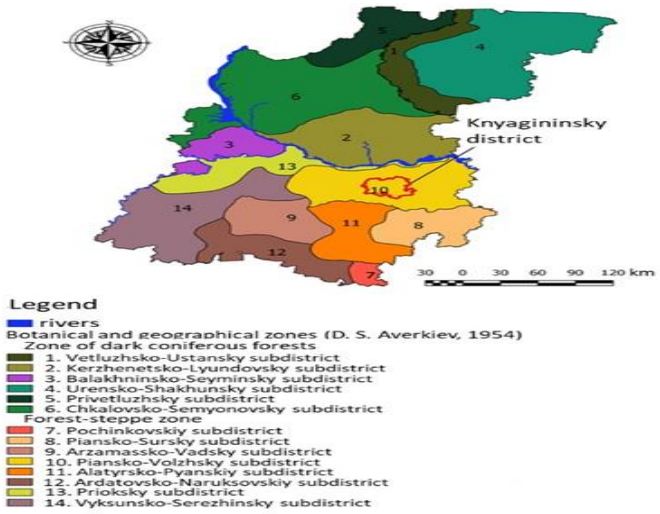

Figure 1. Botanical and Geographical Zoning of the Knyagininsky District within the Boreal Ecotone of the Russian Plain.

The territory of the district is dissected by the valleys of the Imza and Urga rivers, oriented in a submeridional direction. The considered territory is characterized by significant elevation differences (136 m) – from 224 m on the watershed of the Imza and Urga rivers up to 88 m at the water's edge in the Urga river at its intersection with the border of the Knyagininsky district. This led to good drainage of the territory and the active development of erosion. The area of the district is 769.92 km2. Knyagininsky district is a part of the group of low-forest districts of the Nizhny Novgorod region. The total area of forests is 8,400 hectares; forest cover is 11%. The landscape structure of the researched territory is characterized at different hierarchical levels in the works of Nizhny Novgorod landscape scientists (Astashin et al., 2021; Bakanina et al., 2003; Kolomyts et al., 1993). The Nizhny Novgorod region is considered to be floristically researched quite well, however, not only for the region as a whole, but also for none of its subregions (excluding the territory of Nizhny Novgorod and Kerzhensky Reserve), a floristic list of higher plants (a list of species growing there) has been compiled. This significantly complicates the use of botanical material for the needs of regional ecology and physical geography, especially for researching the dynamics of the ecological state and the dynamics of landscapes. Moreover, our long-term experience of field research shows, that route observations even in "well-traveled" places provide new interesting material. Therefore, guided by the central position of the district both in the southern half of the boreal ecotone within the Nizhny Novgorod region and in the aforementioned botanico-geographical subdistrict, we attempted a floristic survey of the Knyagininsky district as a whole. Of course, our data are preliminary; for a complete survey of the territory, route researches are required for at least five years; however, since we have examined all types of tracts of the area: gullies, upland areas, river valleys that are subject to anthropogenic pressure to varying degrees (in total, we have described in detail the flora of 60 observation points), we believe, that the data we have obtained are quite representative.

RESULTS

Plant species have been identified that were not previously noted in this botanico-geographical area in the last published floristic summary of the Nizhny Novgorod region (Averkiev and Averkiev, 1985), including those listed in the Red Book (Chkalov, 2017). In particular, for the first time in the P'yansko-Volzhskij subdistrict Salix viminalis, Orthilia secunda, Thymus marschallianus were noted; the places of growth of plants, listed in the Red Book of the Nizhny Novgorod region – Epipactis palustris, Campanula sibirica, Stipa capillata and Thymus marschallianus, as well as the types of appendices to the Red Book of the Nizhny Novgorod region – Orobanche alsatica and Daphne mezereum (Figure 2) are established. It is noteworthy that Thymus marschallianus is an ordinary species of the Red Book of the Nizhny Novgorod region and a new species for the subdistrict at the same time.

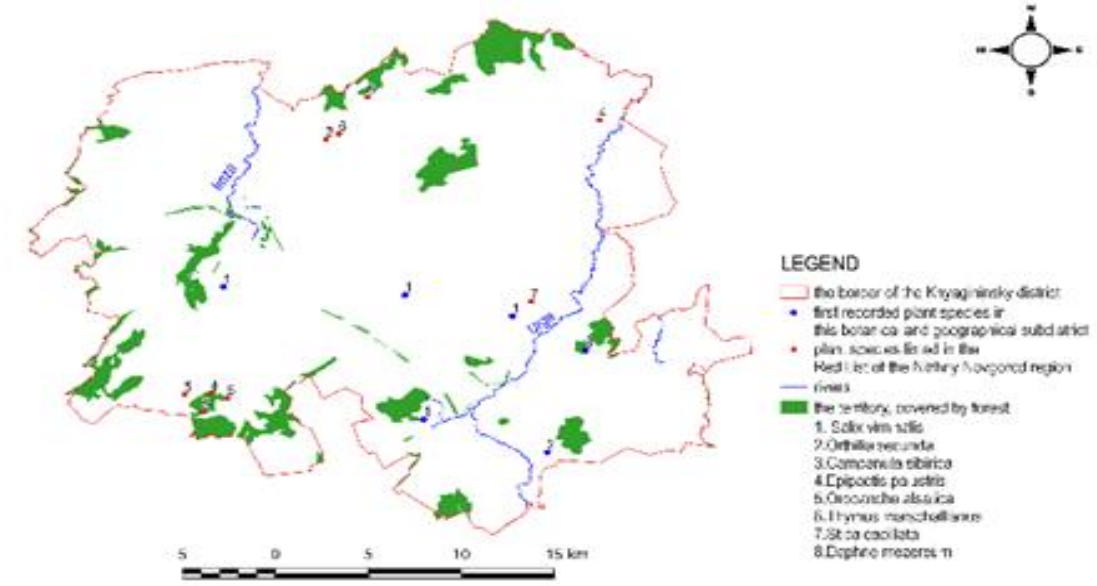

Figure 2. Distribution of Newly Identified and Red-Listed Plant Species in the Knyagininsky District.

In this floristic list, both native and alien wild cultivated and introduced (adventitious) plant species are noted. Higher taxa (classes) are arranged according to the system of A.L. Tahtadzhyan, in accordance with the well-known publication "Flora of the European part of the USSR – Flora of Eastern Europe" (Tsvelev, 2004). In accordance with the same publication, the nomenclature and volume of taxa are given. The arrangement of families within classes, genera within families and species within genera – alphabetically Latin names. The names of the species of the Red List of the Nizhny Novgorod region are typed in bold.

- Classis EQUISETOPSIDA.
- Familia EQUISETACEAE: Equisetum arvense, E. fluviatile, E. sylvaticum.
- Classis POLYPODIOPSIDA.
- Familia ASPIDIACEAE: Dryopteris carthusiana.
- Familia ONOCLEACEAE: Matteuccia struthiopteris.
- Classis PINOPSIDA.
- Familia CUPRESSACEAE: Juniperus communis.
- Familia PINACEAE: Picea x fennica, Pinus sylvestris.
- Classis MAGNOLIOPSIDA.
- Familia ACERACEAE: Acer negundo, A. platanoides.
- Familia APIACEAE: Aegopodium podagraria, Anthriscus sylvestris, Daucus carota, Heracleum sosnowskyi, Pastinaca sativa.
- Familia ARISTOLOCHIACEAE: Asarum europaeum.
- Familia ASTERACEAE: Achillea millefolium, Angelica sylvestris, Arctium lappa, A. tomentosum, Artemisia absinthium, A. marschalliana, A. vulgaris, Bidens sp., Carlina biebersteinii, Centaurea jacea, C. scabiosa, Cichorium intybus, Cirsium arvense, Inula salicina, Lapsana communis, Leucanthemum vulgare, Omalotheca sylvatica, Pilosella sp., Serratula coronata, Solidago canadensis, S. virgaurea, Tanacetum vulgare, Taraxacum officinale, Tripleurospermum inodorum, Tussilago farfara.
- Familia BALSAMINACEAE: Impatiens glandulifera.
- Familia BETULACEAE: Alnus glutinosa, Betula aggr. pendula, Corylus avellana.
- Familia BORAGINACEAE: Cynoglossum officinale, Pulmonaria obscura.
- Familia BRASSICACEAE: Bunias orientalis, Rorippa sp.
- Familia CAMPANULACEAE: Campanula sibirica.
- Familia CANNABACEAE: Humulus lupulus.
- Familia CAPRIFOLIACEAE: Lonicera xylosteum, Sambucus racemosa, Viburnum opulus.

- Familia CARYOPHYLLACEAE: Hylebia nemorum, Saponaria officinalis, Stellaria graminea.
- Familia CELASTRACEAE: Euonymus verrucosa.
- Familia CHENOPODIACEAE: Chenopodium album.
- Familia CORNACEAE: Swida alba.
- Familia EUPHORBIACEAE: Mercurialis perennis.
- Familia FABACEAE: Chamaecytisus ruthenicus, Festuca valesiaca, Genista tinctoria, Lupinus polyphyllus, Medicago falcata, Trifolium pratense, Vicia cracca.
- Familia FAGACEAE: Quercus robur.
- Familia FUMARIACEAE: Corydalis solida.
- Familia GROSSULARIACEAE: Ribes nigrum.
- Familia HYPERICACEAE: Hypericum perforatum.
- Familia LAMIACEAE: Glechoma hederacea, Lamium purpureum, Leonurus quinquelobatus, Origanum vulgare, Phlomis tuberosa, Prunella vulgaris, Stachys officinalis, Thymus marschallianus.
- Familia LYTHRACEAE: Lythrum salicaria.
- Familia ONAGRACEAE: Chamerion angustifolium.
- Familia OROBANCHACEAE: Orobanche alsatica.
- Familia PLANTAGINACEAE: Plantago major, P. media.
- Familia POLYGONACEAE: Rumex confertus.
- Familia PRIMULACEAE: Lysimachia nummularia, L. vulgaris, Primula veris.
- Familia PYROLACEAE: Orthilia secunda, Pyrola rotundifolia.
- Familia RANUNCULACEAE: Anemonoides ranunculoides, Ficaria verna, Ranunculus acris, R. aggr. cassubicus, R. repens.
- Familia RHAMNACEAE: Rhamnus cathartica.
- Familia ROSACEAE: Agrimonia eupatoria, Alchemilla sp., Filipendula ulmaria, F. vulgaris, Fragaria vesca, Geum rivale, G. urbanum, Malus domestica, M. sylvestris, Padus avium, Physocarpus opulifolius, Potentilla anserina, P. argentea, Rosa majalis, Rubus caesius, R. idaeus, Sorbus aucuparia.
- Familia RUBIACEAE: Galium aparine.
- Familia SALICACEAE: Salix acutifolia, S. alba, S. caprea, S. cinerea, S. fragilis, S. myrsinifolia, S. viminalis, Populus tremula.
- Familia SAXIFRAGACEAE: Chrysosplenium alternifolium.
- Familia SCROPHULARIACEAE: Linaria vulgaris, Melampyrum nemorosum, Veronica chamaedrys, V. longifolia.
- Familia THYMELAEACEAE: Daphne mezereum.
- Familia TILIACEAE: Tilia cordata.
- Familia ULMACEAE: Ulmus laevis.
- Familia URTICACEAE: Urtica dioica.
- Familia VIOLACEAE: Viola arvensis, V. canina, V. collina.
- Classis LILIOPSIDA.
- Familia CYPERACEAE: Carex caespitosa, C. pilosa, C. contigua, Scirpus sylvaticus.
- Familia ORCHIDACEAE: Epipactis helleborine, E. palustris, Platanthera bifolia.
- Familia LILIACEAE S.L.: Gagea lutea.
- Familia POACEAE: Agrostis tenuis, Bromopsis inermis, Calamagrostis epigeios, Dactylis glomerata, Elytrigia repens, Festuca pratensis, Phalaroides arundinacea, Phleum pratense, Phragmites australis, Poa pratensis, Stipa capillata.
- Familia TYPHACEAE: Typha angustifolia.

Discussion

The totality of the species we have taken into account fully corresponds to the general botanico-geographical characteristics of the P'yansko-Volzhskij subdistrict, as a territory where the indigenous vegetation is oak forests with a small number of pine forests and with a significant turning into a steppe.

Exactly from the total number of species, mostly meadow and ruderal (which is typical for agriculturally developed area of the Nizhny Novgorod Right Bank), we identified the presence of plant species of three groups of

geographical elements of the land flora (Tolmachev, 1974): 11 nemorose species, 12 steppe and 3 boreal. Boreal plant species are more characteristic of the taiga subzone, nemorose ones are more characteristic of the broad-leaved forests subzone, steppe ones are understood in a generalized sense (southern boreal, typical for the forest-steppe zone and steppe zone). The steppe flora, including the southern pine forest, includes the following plant species: Daucus carota, Campanula sibirica, Carlina biebersteinii, Cynoglossum officinale, Chamaecytisus ruthenicus, Phlomis tuberosa, Thymus marschallianus, Orobanche alsatica, Rhamnus cathartica, Serratula coronata, Stipa capillata, Festuca valesiaca. Nemorose flora is represented by the following species: Acer platanoides, Tilia cordata, Aegopodium podagraria, Corylus avellana, Pulmonaria obscura, Mercurialis perennis, Quercus robur, Corydalis solida, Anemonoides ranunculoides, Ficaria verna, Ranunculus cassubicus. Boreal flora is represented by species: Picea x fennica, Orthilia secunda, Pyrola rotundifolia. All other plant species belong either to the aquatic flora, or are widely spread and are not typical for any one geographical element of the flora.

Thus, researched territory is a typical site of the boreal ecotone, which determines its high importance for the conservation of biodiversity and creates prerequisites for the creation of specially protected natural areas. However, the degree of fragmentation and preservation of the habitat should be considered (Bakka and Kiseleva, 2017; Bakka et al., 2017, 2020).

It should be noted the significant presence of wild cultivated (or previously cultivated) species Heracleum sosnowskyi, Solidago canadensis, Salix × fragilis, Acer negundo, Lupinus polyphyllus, Impatiens glandulifera, Physocarpus opulifolius, Swida alba, Malus domestica is typical for well-developed forest-steppe areas of the Nizhny Novgorod region; it is interesting, that Pinus sylvestris and Picea × fennica are also native to this subdistrict a significant number are wildlings from forest crops. This undoubtedly indicates that intensive human agricultural activity leads to the emergence of free ecological niches in natural ecosystems, which are occupied by alien plant species (Minzon et al., 2019).

On the other hand, we have almost everywhere encountered plant species, included in the Red Book of the Nizhny Novgorod region. This, at first glance, paradoxical result, previously noted by us (Nasiyev, 2016), was also a consequence of anthropogenic pressure: rare plant species are known to be poorly competitive and willingly settle in places with sparse herbaceous cover, which is observed with moderate pasture and recreational pressure (Nasiyev et al., 2022). If we add to this the facts of the growth of forest plant species observed by us even in strongly anthropogenically altered tracts (willows, birch forests with predominantly meadow-ruderal herbage), and the resumption of the main forest-forming species was observed, then we can conclude that the reversibility of anthropogenic digression of a number of ecosystems in the Knyagininsky district.

In the researched area the presence of wildlings from the culture of boreal species (that is more characteristic of the taiga) of Picea × fennica and Swida alba is noticeable. We have already noted earlier (Nasiyev, 2016) that this is one of the results of anthropogenic changes in the territory – the weakening of the clinal character of the boreal ecotone (that is the increase of boreal species to the north and steppe species to the south) due to the spread of boreal species wild from the culture in the southern part of the ecotone.

CONCLUSION

- Thus, as we believe, even a preliminary research of the flora of the Knyagininsky district allows us to draw some interesting conclusions concerning not only floristics, but also the ecological state and physical geography of the territory of this section of the boreal ecotone of the Volga basin.
- Firstly, the transitional specificity of its nature is justified, secondly, it is demonstrated that intensive anthropogenic transformation has only somewhat slowed down the processes of restoration of natural vegetation cover (broad-leaved and mixed forests), and thirdly, the assumption we made earlier is confirmed that anthropogenic processes smooth out the transitional nature of the ecotone: modern human activity (plowing, abandonment of arable land, creation of forest crops) increased the spread of not only steppe, but also boreal plant species.

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