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Species and functional diversity of forest communities with wild fruits plants in Central Kazakhstan

The alpha-, beta-, gamma-, and functional diversity of forest communities of Central Kazakhstan, which are habitats of wild fruit plants, were analysed. Forest communities were studied in seven sites represented by mountain forests, island forests, and steppe kolki. A total of 41 relevés were collected and analysed. We counted 195 species of vascular plants, including 10 species of fruit plants: *Crataegus sanguinea* Pall., *Lonicera tatarica* L., *Ribes aciculare* Sm., *Ribes nigrum* L., *Ribes saxatile* Pall., *Rosa acicularis* Lindl., *Rosa laxa* Retz., *Rosa majalis* Herrm., and *Rosa spinosissima* L. Results of non-metric multidimensional scaling revealed no dividing of relevés between the studied sites. Cluster analysis using Ward's method identified 4 groups of relevés. No statistically significant differences in alpha-diversity indices were found between the groups. Beta-diversity assessment based on Jaccard distance showed that the groups differed well in species composition. The results of functional diversity analysis based on ecological-coenotic groups and the calculation of indicator species values showed differences in the structure of the four community groups. It was shown that *Rosa majalis* is a significant indicator species for the mountain-forest massif of Karkaraly, and *Ribes nigrum* — for steppe kolki with predominance of forest species. Other fruit species were found in all analysed groups of communities and did not show specific coenotic predilection.

Keywords: communities, biodiversity assessment, indVal, ecological-coenotic structure, GBIF.

Introduction

Forests in Central Kazakhstan cover less than 2 % of the area [1]. Forest habitats in this territory are represented by relatively small steppe kolki and larger mountain-forest areas confined to the lowlands of the Kazakh Shallow Forest (Sary-Arka) [2]. The mountain-forest areas located within the Ob-Irtysh interfluve are relicts of a formerly continuous forest territory connected with the forests of Western Siberia and Altai during the cold and wet Pleistocene epochs. Due to this, they have preserved a complex of boreal (and other forest) plant species considerably distant from the main range [3].

Forest communities in Central Kazakhstan are still poorly explored. The floristic diversity of some mountain-forest massifs has been studied [4–6]; a few assessments of species and functional diversity of forest communities are available [7]. At the same time, forest areas of Central Kazakhstan are key habitats for most species of wild fruit plants of the genera *Rosa*, *Ribes*, *Lonicera*, and *Crataegus* [8–9]. Studying the natural habitat of these species is relevant for assessing ecosystem services for the use of wild fruit plants as genetic, food and medicinal resources. The aim of the study was to assess the diversity and structure of forest communities with wild fruits in Central Kazakhstan.

Materials and methods

The climate of Central Kazakhstan is sharply continental, with hot, temperate summers and cold, snowy winters. The average temperature in winter is about –13 °C, in summer—about +24 °C, and annual precipitation is 180–250 mm [10]. Steppe and semi-desert vegetation prevails [11].

Field studies were carried out in 7 areas (Fig. 1) located in the Karagandy, Ulytau, and Akmola regions.

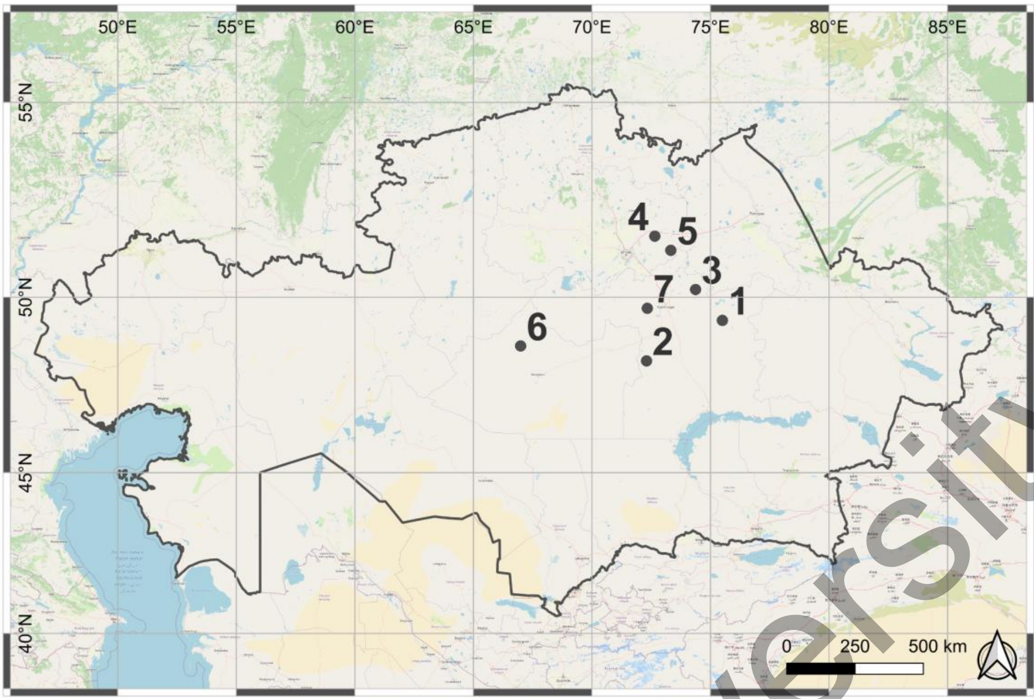

Figure 1. Study areas. 1 - Karkaraly National Park (mountain forests); 2 - Ortau mountain forests; 3 - island pine barrens near Kerney settlement; 4 and 5 - Buiratau National Park: 4 - steppe kolki near Ereimentau town; 5 - steppe kolki near Belodymovka village; 6 - steppe kolki Ulytau National Park; 7 - steppe kolki near Koyandy hill.

We studied 41 vegetation plots of 100 m^2 following the standard relevé method [12]. All vascular plants and their abundance according to the Braun-Blanquet cover-abundance scale were recorded in herb, shrub, and tree layers. In Karkaraly, 17 vegetation relevés were performed: 7 in Ortau, 4 near Kerney, 3 near Ereimentau, 4 near Belodymovka, 4 in Ulytau, and 2 near Koyandy. Most of the studied tree stands were small-leaved (*Betula pendula* Roth and *Populus tremula* L.)*;* 3 sample plots were described in pine forests (*Pinus sylvestris* L.), and 2—in black alder forests (*Alnus glutinosa* (L.) Gaertn.). All data collected were digitised, standardised according to the Darwin Core [13] and published through the Global Biodiversity Information Facility (GBIF) portal [14].

Data analysis was performed using the R environment [15]. At the first step to visualise the gradient of vascular plant species composition across the study areas, we used non-metric multidimensional scaling (NMDS) calculated in the vegan package, *metaMDS()* function [16]. After that, Ward's cluster analysis with Hellinger distance was performed for grouping of relevés (*vegdist()* and *hclust()* functions). For each group, we assessed alpha, beta, and gamma diversity. Alpha diversity scores were calculated as species richness, the Shannon index, and the Simpson index [17]. The significance of differences in alpha diversity scores between groups was assessed using one-way ANOVA (*aov()* function). Group-level species beta-diversity was measured using the Jaccard's distance. Gamma diversity was estimated as the total number of species in each group [18]. Functional diversity was estimated based on the diversity of ecological-coenotic groups (ECG) [19]. The ECGs published in [20] were used; calculations were made taking into account species abundance. For each group, indicator species values were calculated using the Indval.g algorithm implemented in the *multipatt()* function of the Indicspecies package [21].

Results and Discussion

A total of 195 vascular plant species were recorded in our relevés. The following species of wild fruit plants were counted: *Crataegus sanguinea* Pall., *Lonicera tatarica* L., *Ribes aciculare* Sm., *Ribes nigrum* L., *Ribes saxatile* Pall., *Rosa acicularis* Lindl., *Rosa laxa* Retz., *Rosa majalis* Herrm., and *Rosa spinosissima* L.

At the level of 7 study areas, the NMDS analysis did not result in a clear division of vegetation relevés (Fig. 2). Relevés from the Karkaraly and Ortau mountain forests and black-alder stands from the Belodymovka were placed in the left part of the ordination diagram. Island pine barrens and steppe kolki were in the right part of the diagram.

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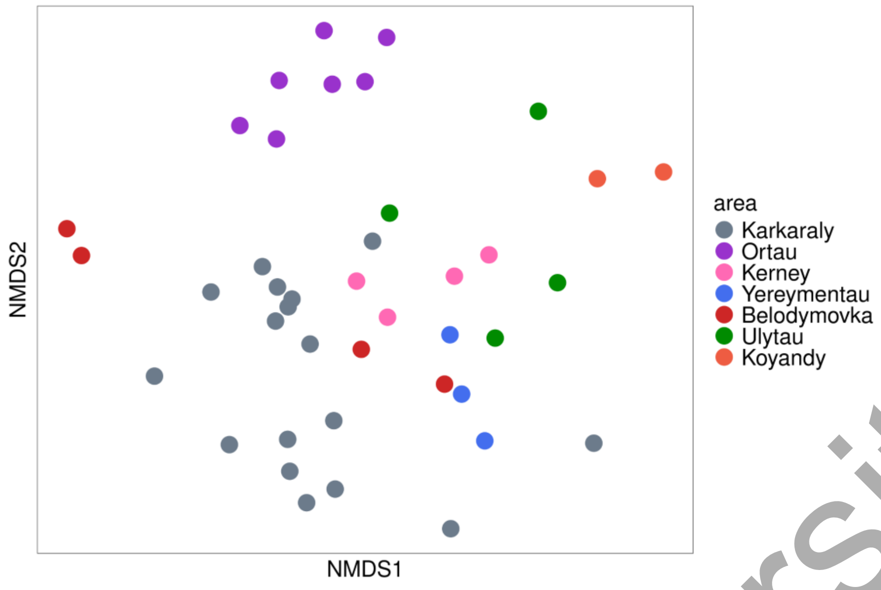


Figure 2. NMDS ordination of 41 vegetation relevés from forests of Central Kazakhstan.

As a result of cluster analysis, 4 groups of relevés were divided (Fig. 3). Cluster 1 grouped most of the relevés from Karkaraly mountain forests. Cluster 2 was composed of the relevés in steppe kolki described in Yereymentau, Belodymovka, Ulytau, and Karkaraly. Cluster 3 was related to black-alder stands near the Belodymovka study area. Cluster 4 grouped relevés belonging to the Ortau mountain forests, island pine barrens near Kerney, and steppe kolki from Koyandy and Ulytau.

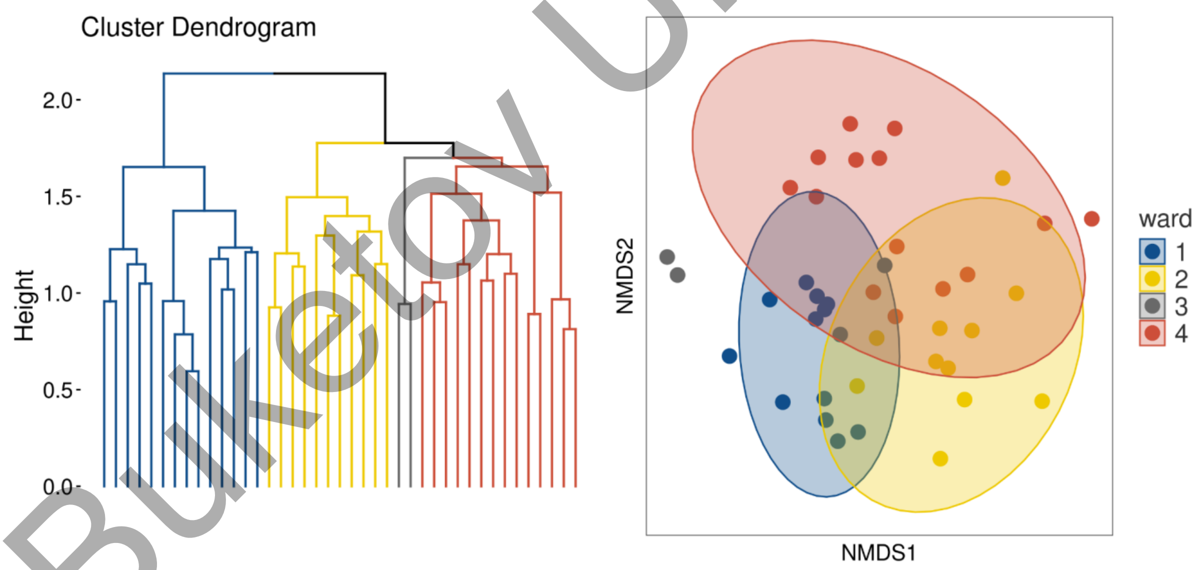
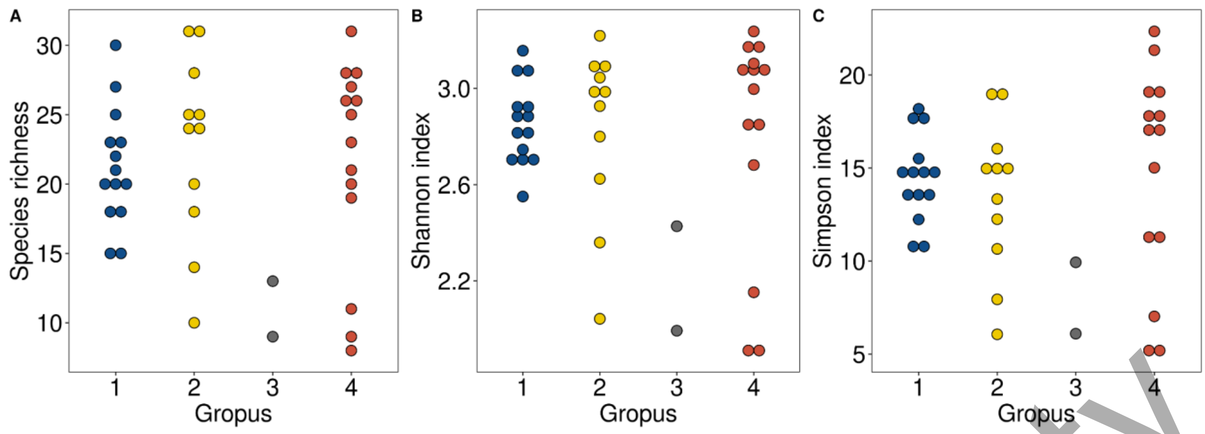


Figure 3. Results of cluster analysis of 41 vegetation relevés from forests of Central Kazakhstan. Cluster diagram (left) and clusters in the NMDS diagram (right)

No significant differences in alpha diversity scores were found between groups 1, 2, and 4 ($P>0.05$, Fig. 4). Overall, group 1 had narrower ranges in species richness, Shannon, and Simpson indexes than groups 2 and 4. Group 3 was not included in the comparisons due to the small sample size (only 2 relevés). More relevés are needed to characterise this group. However, black alder forests are a rare community type in Central Kazakhstan, and *Alnus glutinosa* is a protected tree species [22]. The total number of species (gamma diversity) was 108 in Group 1, 112 in Group 2, 16 in Group 3, and 114 in Group 4.



The results of the beta-diversity assessments found differences in species composition between groups 1, 2, and 4 (Table 1). The large distances of Group 3 with other groups may be related both to insufficient sample size and to the specific species composition of black-alder forests.

Table 1

Jaccard distances for divided vegetation groups

	Group 1	Group 2	Group 3	Group 4
Group 1	0			
Group 2	0.63	0		
Group 3	0.92	0.93	0	
Group 4	0.64	0.57	0.92	0

The results of the functional diversity assessment showed that the analysed groups of relevés differed in the composition and abundance of ecological-coenotic groups.

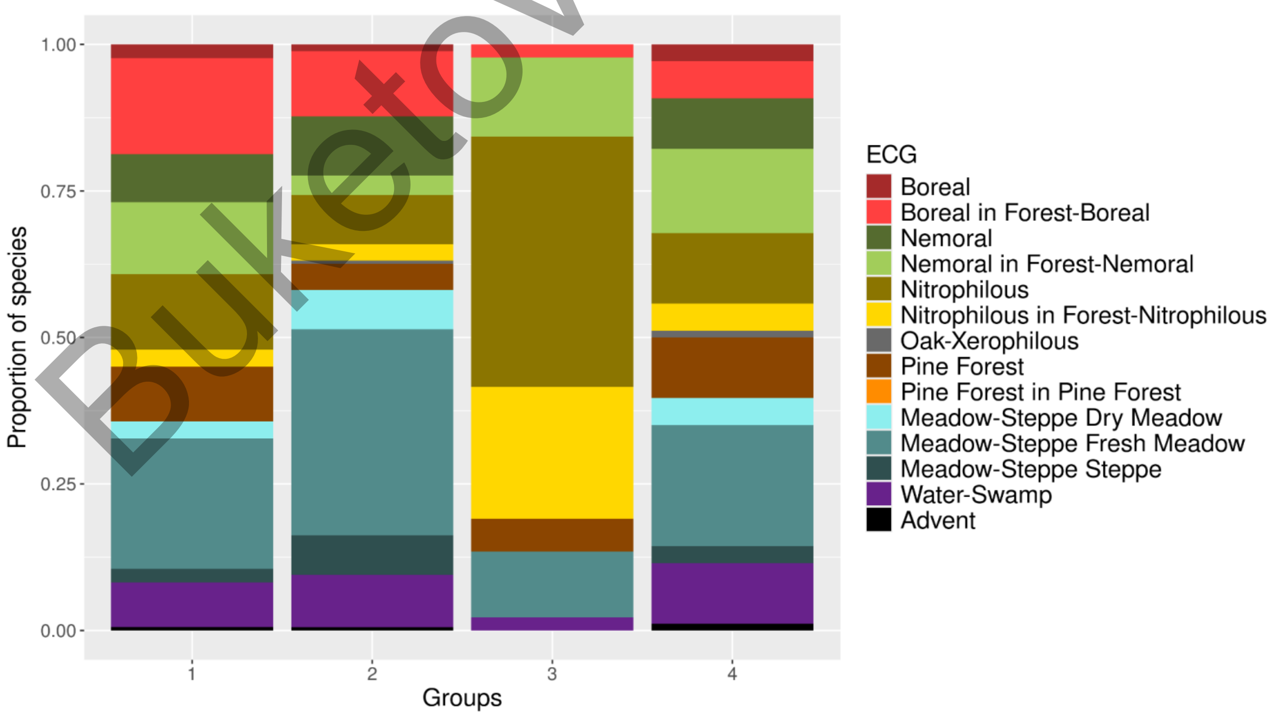


Figure 4. Diversity of ecological and coenotic groups in forests of Central Kazakhstan.
For a detailed description of the groups, see [20].

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The structure of forest communities in Group 1 (Karkaraly mountain forests) is dominated by forest-related species, with considerable participation of boreal species. This result confirms the evidence of the long presence of forests in this area [3]. Nitrophilous species were expectedly dominant in the ECG structure of group 3 (black alder forests), and the participation of steppe species was minimal. Relevés of steppe kolki were divided into two groups that differ in the ECG structure. Steppe species predominate in Group 2, and boreal and nemoral species predominate among forest species. In group 4, the participation of forest species is higher than that of steppe species. The most represented are nemoral species; compared to group 2, the participation of pine-forest species is higher. The reasons for these differences require further research. It is likely that differences in the structure of ECGs may be related to the area and age of steppe stakes, pasture load, or fire frequency.

The results of calculating indicator species in the analysed groups agree well with the estimates of functional diversity (Table 2). Most of the significant indicators for Group 1 are represented by forest species. In Group 2, all indicator species were steppe ECG. In Group 3, two of the three significant indicators were nitrophilous forest species. In Group 4, both forest and steppe species were indicator species.

Table 2

Indicator species values for analysed groups of relevés

species	ECG code	Indval.g value	p-value
Group 1			
Clematis sibirica (L.) Mill.	Boreal	0.535	0.030
Rosa majalis Herrm.	Nemoral	0.675	0.015
Equisetum pratense Ehrh.	Nemoral In Forest-Nemoral	0.661	0.005
Prunus padus L.	Nitrophilous In Forest-Nitrophilous	0.711	0.005
Geum rivale L.	Nitrophilous In Forest-Nitrophilous	0.535	0.025
Potentilla argentea L.	PineForest	0.823	0.005
Veronica pinnata L.	PineForest	0.655	0.005
Vicia sepium L.	Meadow-Steppe FreshMeadow	0.655	0.005
Ligularia spp.	Meadow-Steppe FreshMeadow	0.607	0.015
Thalictrum foetidum L.	Meadow-Steppe DryMeadow	0.580	0.030
Group 2			
Plantago maxima Juss. ex Jacq.	Meadow-Steppe FreshMeadow	0.853	0.005
Scrophularia nodosa L.	Meadow-Steppe FreshMeadow	0.618	0.010
Achillea millefolium L.	Meadow-Steppe FreshMeadow	0.558	0.050
Artemisia dracunculus L.	Meadow-Steppe DryMeadow	0.522	0.030
Filipendula vulgaris Moench	Meadow-Steppe Steppe	0.624	0.010
Group 3			
Humulus lupulus L.	Nitrophillous	0.816	0.01
Cardamine amara L.	Nitrophilous InForest-Nitrophilous	1.000	0.01
Galeopsis bifida Boenn.	Meadow-Steppe FreshMeadow	0.707	0.01
Group 4			
Senecio jacobaea Loscos & Pardo	Nemoral	0.593	0.025
Poa nemoralis L.	Nemoral InForest-Nemoral	0.683	0.035
Ribes nigrum L.	Nitrophillous	0.612	0.030
Pentanema britannicum (L.) D.Gut.Larr., Santos-Vicente, Anderb., E.Rico & M.M. Mart.Ort.	Nitrophillous	0.595	0.045
Calamagrostis epigejos (L.) Roth	PineForest	0.628	0.025
Cuscuta europaea L.	Meadow-Steppe FreshMeadow	0.598	0.010
Crepis tectorum L.	Meadow-Steppe DryMeadow	0.756	0.005
Turritis glabra L.	Meadow-Steppe DryMeadow	0.566	0.025

It should also be noted that among the significant indicator species, 2 fruiting plants were recorded: *Rosa majalis* for Group 1 and *Ribes nigrum* for Group 4. This result shows that these species have specific requirements for habitat conditions, unlike other fruiting species that occurred in different community groups.

Conclusions

Our study provides, for the first time, quantitative forest biodiversity assessments in Central Kazakhstan. We found that the studied forests are diverse in species diversity and composition of the herbaceous layer. Using quantitative analysis methods, 4 groups of forest communities were obtained: (1) forests of the Karkaraly mountain-forest massif dominated by forest species; (2) black alder forests dominated by nitrophilous species; (3) steppe kolki dominated by steppe species; (4) steppe kolki dominated by forest species. The identified groups do not differ in alpha diversity metrics but differ significantly in species composition. It is also found that most of the fruiting species are found in all community groups. Strict cenotic confinement is shown for *Rosa majalis* (Karkaraly mountain forests) and *Ribes nigrum* (kolki dominated by forest species). These species were significant indicators in corresponding groups of forest communities.

Obtained results are relevant for prognosing potential habitats for wild fruit plants. Vegetation relevés will be used for further studies of forest biodiversity in the Karkaraly State National Nature Park. Primary data available through GBIF contributes to filling gaps in Kazakhstan's digital biodiversity map.

Acknowledgements

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Author contributions

The manuscript was written through contributions of all authors. All authors have given approval to the final version of the manuscript. CREDIT: **Ivanova N.V.** – Field data collection, Data digitization, Data analysis, Preparing of the manuscript; **Shashkov M.P.** – Field data collection, Discussion of results, Manuscript editing.

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Орталық Қазақстандағы жабайы жеміс өсімдіктері бар орман қауымдастықтарының түрлік және құрылымдық әртүрлілігі

Жұмыста жабайы жеміс өсімдіктерінің мекендейтін жері болып табылатын Орталық Қазақстанның орман қауымдастықтарының альфа-, бета-, гамма- және құрылымдық әртүрлілігіне талдау жүргізілді. Орман қауымдастықтары жеті аумақта зерттелді, олардың қатарына таулы-орман массивтері, аралдық қарағайлы ормандар және далалық тоғай алқаптары кіреді. Барлығы 41 сипаттама талданды. Барлық сипаттамалар бойынша 195 тамырлы өсімдік түрі тіркелді, олардың ішінде 10 жабайы жемісті түрлер: *Crataegus sanguinea* Pall., *Lonicera tatarica* L., *Ribes aciculare* Sm., *Ribes nigrum* L., *Ribes saxatile* Pall., *Rosa acicularis* Lindl., *Rosa laxa* Retz., *Rosa majalis* Herrm., және *Rosa spinosissima* L. NMDS зерттелген учаскелердің сипаттамалары арасында айқын бөліну болмағанын көрсетті. Вард әдісімен жүргізілген кластерлік талдау негізінде төрт топ анықталды. Бұл топтар арасында альфа-әртүрлілік бағалау көрсеткіштері бойынша статистикалық тұрғыдан маңызды айырмашылықтар анықталмады. Жаккард қашықтығы бойынша есептелген бета-әртүрлілік нәтижелері анықталған топтардың түрлік құрамы тұрғысынан жақсы ерекшеленетінін көрсетті. Қауымдастық құрылымының әртүрлілігі эколого-ценоздық топтар мен индикаторлық түрлерді талдау арқылы бағаланды. Нәтижесінде төрт қауымдастық тобының құрылымында айырмашылықтар бар екені анықталды. *Rosa majalis* Қарқаралы таулы-орман алқаптарына тән индикаторлық түр ретінде ерекшеленсе, *Ribes nigrum* орманды түрлер басым дала тоғайларына тән түр болып табылды. Қалған жемісті түрлер барлық зерттелген қауымдастық топтарында кездесіп, айқын ценоздық бейімділік көрсетпеді.

Кілт сөздер: қауымдастықтар, биологиялық әртүрлілікті бағалау, indVal, экологиялық-ценотикалық құрылым, GBIF.

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Видовое и структурное разнообразие лесных сообществ Центрального Казахстана с участием дикорастущих плодовых

В работе проведен анализ альфа-, бета-, гамма- и структурного разнообразия лесных сообществ Центрального Казахстана, являющихся местообитаниями диких плодовых растений. Лесные сообщества исследованы на семи участках, представленных горно-лесными массивами, островными борами и степными колками. Всего проанализировано 41 описание. Во всем массиве описаний учтено 195 видов сосудистых растений, в том числе 10 видов плодовых: *Crataegus sanguinea* Pall., *Lonicera tatarica* L., *Ribes aciculare* Sm., *Ribes nigrum* L., *Ribes saxatile* Pall., *Rosa acicularis* Lindl., *Rosa laxa* Retz., *Rosa majalis* Herrm., и *Rosa spinosissima* L. Результаты неметрического многомерного шкалирования не выявили разделения описаний между исследованными участками. При помощи кластерного анализа методом Варда выделено 4 группы описаний. Между группами не выявлено статистически значимых различий по показателям альфа-разнообразия. Оценка бета-разнообразия на основе расстояния Жаккара показала, что выделенные группы хорошо различаются по видовому составу. Результаты анализа структурного разнообразия на основе эколого-ценотических групп и расчета индикаторных видов показали различия в структуре четырех групп сообществ. Показано, что *Rosa majalis* является значимым индикаторным видом для горно-лесного массива Каркаралы, а *Ribes nigrum* — для степных колков с преобладанием лесных видов. Остальные виды плодовых встречались во всеханализируемых группах сообществ и не показали специфической ценотической приуроченности.

Ключевые слова: сообщества, оценки биоразнообразия, indVal, эколого-ценотическая структура, GBIF.

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