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AGE STRUCTURE OF POPULATIONS OF THE GENUS *GENTIANA* L. IN THE HIGHLANDS OF THE UKRAINIAN CARPATHIANS

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Under increasing anthropogenic pressure, the issue of biodiversity conservation, restoration, and protection is becoming increasingly important. The article analyzes the age structure and population status of rare species of the genus *Gentiana* L. Specifically, *Gentiana acaulis* L. and *Gentiana punctata* L., *Gentiana lutea* L., and *Gentiana laciniata* Kit. ex Kanitz. The studied species grow in the highlands of the Ukrainian Carpathians and belong to vulnerable and endemic plants. They are rare and listed in the Red Data Book of Ukraine as well as the Red List of the International Union for Conservation of Nature.

After studying the populations of the genus *Gentiana* L. in the highlands of the Ukrainian Carpathians, it was found that the largest population was *G. punctata*, while the smallest was *G. acaulis*. In contrast, *G. lutea* is characterized by the presence of isolated populations with a relatively large area (ranging from 4 to 45 ha) and density (1.9–6.7 individuals/m²). Thus, *G. punctata* and *G. acaulis* have formed so-called metapopulation structures, consisting of small populations. The age structure of *Gentiana laciniata* Kit. ex Kanitz is characterized by a small, isolated population, where pre-generative age groups predominate.

Each year, the population size and density of the genus *Gentiana* L. decrease, and their structure is also disrupted. The main reasons for this decline include the use of *G. lutea* and *G. punctata* rhizomes for traditional and official medicine, cattle grazing, and trampling of trails by tourists. In addition to anthropogenic impacts, natural factors also influence population structure, such as a lack of pollinating insects, temperature variations, the presence of pests, and slope exposure. Another important factor contributing to the decline in populations is their low ecological plasticity, which makes adaptation to changing environmental conditions difficult. **Key words:** population, age structure, rare species, *Gentiana punctata* L., *Gentiana acaulis* L., *Gentiana lutea* L., and *Gentiana laciniata* Kit. ex Kanitz.

Вікова структура популяцій роду *Gentiana* L. у високогір'ї українських Карпат. Глушак Д.Д., Гнєзділова В.І., Різничук Н.І., Мельніченко Г.М.

В умовах зростаючого антропогенного тиску питання збереження, відновлення та захисту біорізноманіття набуває дедалі більшого значення. У статті проаналізовано вікову структуру та стан популяцій рідкісних видів роду *Gentiana* L. А саме, *Gentiana acaulis* L. та *Gentiana punctata* L., *Gentiana lutea* L. та *Gentiana laciniata* Kit. ex Kanitz. Досліджувані види зростають у високогір'ї Українських Карпат і належать до вразливих та ендемічних рослин. Вони є рідкісними і занесені до Червоної книги України та до Червоного списку Міжнародного союзу охорони природи.

Дослідивши популяції роду *Gentiana* L. у високогір'ї Українських Карпат, було виявлено, що найбільшою виявилась популяція *Gentiana punctata*, а найменшою – *Gentiana acaulis*. А от для *Gentiana lutea* характерною є наявність ізольованих популяцій з порівняно великою площею (від 4 до 45 га) та щільністю (1,9–6,7 особини/м²). Так *Gentiana punctata* та *Gentiana acaulis* сформували так звані метапопуляційні організації, склад яких налічує малі популяції. Вікова структура *Gentiana laciniata* Kit. ex Kanitz характеризується невеликою, ізольованою популяцією, в якій переважають передгенеративні вікові групи.

З кожним роком чисельність і щільність популяцій роду *Gentiana* L. зменшується, а також порушуються їхня структура. Основними причинами є використання кореневищ *Gentiana lutea* та *Gentiana punctata* для потреб народної та офіційної медицини, випасу рогатої худоби, витоптування стежок туристами. Крім антропогенних впливів на структуру популяції впливають і природні чинники: недостатня кількість комах запилювачів, температура, наявність шкідників, експозиція схилу. Ще одним важливим фактором, який впливає на зменшення кількості популяцій є їхня низька екологічна пластичність, що сприяє складності пристосування до змінних умов навколишнього середовища. **Ключові слова:** популяція, вікова структура, рідкісні види, *Gentiana punctata* L., *Gentiana acaulis* L., *Gentiana lutea* L. та *Gentiana laciniata* Kit. ex Kanitz.

General statement of the problem. Under the conditions of increasing anthropogenic pressure, the issue of conserving, restoring, and protecting biodiversity is becoming increasingly important, especially the populations of rare plant species as components of natural mountain and high-altitude ecosystems. The species of the genus *Gentiana* L. growing in the highlands of the Ukrainian Carpathians are classified as vulnerable and endemic. They are listed in the Red Data Book of

Ukraine and the Red List of the International Union for Conservation of Nature [1, 2].

The specific features of their biomorphology, age and spatial structure, density and population size, individual ontogenesis, as well as conservation and survival strategies in the conditions of the Ukrainian Carpathians remain insufficiently studied.

Plants of all species of the genus *Gentiana* L. have significant ornamental value, and some are medicinal.

The mass picking, trampling, and uprooting of the highly popular medicinal plants *Gentiana acaulis* L., *Gentiana punctata* L., *Gentiana lutea* L., and *Gentiana laciniata* Kit. ex Kanitz by locals and tourists have led to the destruction of certain populations of these species [3].

The reduction of their range is leading to the gradual disappearance of these plant species in the Ukrainian Carpathians. In this regard, there is a need to study the current state of rare plants and to identify the causes of the reduction in their range and population size in the Ukrainian Carpathians.

Analysis of recent research and publications.

Many Ukrainian scientists (Chopyk V.I., Malynovskyi K.A., Moskaliuk B.I., Kryz O.P., Cherepanin R.M., Kiyak V.G., and others) have devoted significant attention to studying the genus *Gentiana* L. To date, the distribution and ecological-biological characteristics of the species of this genus have been described and studied. However, proper attention is not given to the conservation of the genus and the preservation of populations in the highlands of the Ukrainian Carpathians. An analysis of literary sources and our own expedition research indicates a decline in the number of habitats of *Gentiana* L. representatives and a disruption of their population structure.

The purpose of the article. The purpose of the study was to determine the age structure and condition of populations of rare species of the genus *Gentiana* L. based on comprehensive population research. The object of the study: high-altitude species of the genus *Gentiana*: *G. punctata* L., *G. acaulis* L., *G. lutea* L., and *G. laciniata* Kit. ex Kanitz.

Presentation of the main research material. The research was conducted in various areas: the Chornohora, Svidovets, and Maramureș massifs, at altitudes ranging from 1400 to 2000 meters above sea level. Route and stationary research methods were applied, aimed at studying the structure and dynamics of populations of rare and endemic plant species [3, 4].

The genus *Gentiana* L. plays an important role in human life. These are primarily medicinal plants that have been used in the folk medicine of various countries for thousands of years (China, India, and others). Significant changes have occurred in the populations of certain species of the genus *Gentiana* L. in the Ukrainian Carpathians, specifically *G. punctata* L., *G. acaulis* L., *G. lutea* L., and *G. laciniata* Kit. ex Kanitz. These species are found only in the highlands of the Carpathians in Ukraine, which is why they are listed in the Red Data Book of Ukraine. *G. punctata* is classified as vulnerable, while *G. acaulis* is considered a rare species [2].

Gentiana punctata L. is a perennial, mid-European, high-altitude species. It is found in the subalpine and alpine zones. In the Ukrainian Carpathians, it grows in the Gorgany, Chornohora, Maramureș Alps, Svidovets, and Chivchyn Mountains. This medicinal, red-listed species is widely used by the local population for folk medicine purposes [2].

Gentiana acaulis L. is a mid-European high-altitude species, with its range extending across the Alps and the mountains of Southern Europe. In Ukraine, it is found only in the Carpathians, where the eastern boundary of its distribution lies, specifically in Chornohora, Svidovets, Maramureș, Chivchyn, Gorgany, and the Beskids. The species grows on rocks, stony soils, fresh grass-covered rocky slopes, and high-altitude meadows within the altitude range of 1250-1950 meters above sea level [2].

Gentiana lutea L. is a high-altitude subalpine relict species found in Europe, particularly in the southern and central parts of the continent. A small part of its range also extends into the northwestern part of Minor Asia. In Ukraine, *Gentiana lutea* L. grows only in the Ukrainian Carpathians, specifically in Chornohora, Svidovets, Maramureș Alps, and Gorgany, within the altitude range of 1650-1920 meters above sea level. It is a perennial plant, rare and listed in the Red Data Book of Ukraine (Category I), and is both a nectar-producing and ornamental plant [2].

Gentiana laciniata Kit. ex Kanitz is an endemic high-altitude species that grows in the eastern Carpathians, specifically in the Borzhava, Svidovets, Chornohora, Maramureș massif, and Chivchyn mountains, within the altitude range of 1680-2000 meters above sea level. It thrives on scree, rocks, stony soils, and high-altitude meadows of the subalpine and alpine zones. *Gentiana laciniata* is a high-altitude species with a disjunctive range [2].

The results of the analysis of the ontogenetic structure of the *Gentiana lutea* populations are presented in Table 1.

The study of the age structure showed that the populations of *G. lutea* are normal and full-membered. In the first population, immature individuals dominate, while in the second population, generative individuals prevail. Juvenile, immature, and virgin individuals in both associations make up more than 50% of the total population across all age groups. Therefore, it has been determined that the number of generative individuals represents an average proportion, ranging from 23.6% to 43.7% (Table 1). The number of senile individuals is 0.5%. A noticeable pattern can be observed here: with intensive grazing, younger age groups begin to play a significant role in maintaining the population.

According to the results of the conducted research, 31 habitat of *Gentiana punctata* has been identified in the Ukrainian Carpathians. The largest population of *G. punctata* is located on Mount Breskul, while smaller populations of the Chornohora metapopulation are found on Mounts Hoverla and Hutin Tomnatyk. During the study, a metapopulation was discovered on Mount Pip Ivan Maramureș, which is characterized by the highest density (7.2 individuals per m²), but occupies a relatively small area compared to other populations (Table 2).

The maximum in the ontogenetic spectrum is observed in the pre-reproductive group: 63.5% on Mount

Table 1

Population parameters of *Gentiana lutea* L.

Habitat, slope exposure, altitude above sea level	Habitat area, m ²	Number of mature individuals, pcs.	Number of pre-reproductive individuals, pcs.	Number of generative individuals, pcs.	Regeneration index, %	Population regeneration coefficient, %	Replacement index, %
1. Mount Pip Ivan, Maramureș, southwest, 1900 m	360	780	270	220	1,22	0,28	0,34
2. Mount Petros, southeast, 1600 m	250	600	370	420	0,88	0,7	0,61

Table 2

Population parameters of *Gentiana punctata* L.

Habitat, slope exposure, altitude above sea level	Habitat area, m ²	Number of mature individuals, pcs.	Number of pre-reproductive individuals, pcs.	Number of generative individuals, pcs.	Regeneration index, %	Population regeneration coefficient, %	Replacement index, %
1. Mount Breskul, northwest, 1900 m	210	420	630	350	1,8	0,83	1,5
2. Mount Pip Ivan, Maramureș, southwest, 1850 m	850	350	770	230	3,34	0,62	2,2

Table 3

Population parameters of *Gentiana acaulis* L.

Habitat, slope exposure, altitude above sea level	Habitat area, m ²	Number of mature individuals, pcs.	Number of pre-reproductive individuals, pcs.	Number of generative individuals, pcs.	Regeneration index, %	Population regeneration coefficient, %	Replacement index, %
1. Mount Pip Ivan, Maramureș, southwest, 1900 m	480	700	625	450	1,38	0,64	0,88
2. Mount Hoverla, northeast, 2000 m	750	450	780	310	2,51	0,68	1,73

Breskul and 77.1% on Mount Hoverla, where virginile period plants dominate. In the population on Mount Pip Ivan Maramureș, compared to the Hoverla and Breskul populations, the percentage of generative individuals is lower (18.76% and 33.1%, respectively). The post-generative group plants in the Pip Ivan partial population (10%) are twice as numerous as in the Breskul population (5.2%). Thus, the *G. punctata* population on Mount Breskul can be classified as a young, thriving population, which is explained by the high percentage of seedlings and generative individuals, as well as the large area of the population. However, the partial population on Mount Pip Ivan Maramureș is also young and exhibits

high vitality, as indicated by the high individual density and their generative reproduction.

When studying *Gentiana acaulis*, the highest density was found in the subpopulation on Mount Petros, which undergoes intensive grazing. In the subpopulation on Mount Hoverla, anthropogenic pressure is exerted through excessive recreational impact. As a result, the density is somewhat lower, reaching up to 3 individuals/m² (Table 3).

When studying the Maramureș population of *Gentiana acaulis*, the average population density is 3.9 individuals per m². The population is characterized as normal and full-membered, with a predominance of

Table 4

Population parameters of *Gentiana laciniata* Kit. ex Kanitz

Habitat, slope exposure, altitude above sea level	Habitat area, m ²	Number of mature individuals, pcs.	Number of pre-reproductive individuals, pcs.	Number of generative individuals, pcs.	Regeneration index, %	Population regeneration coefficient, %	Replacement index, %
1. Mount Hoverla, northeast, 1900 m	80	300	150	210	0,71	0,7	0,5
2. Mount Turkul, southwest, 1800 m	150	280	100	180	0,55	0,64	0,35

generative individuals in the age spectrum (43.1%). In the Hoverla population of *Gentiana acaulis*, generative reproduction is suppressed. The average population density is 1.5 individuals per m². This population is regressive and is characterized by a predominance of virginile individuals in the age spectrum, making up 55%. In all the studied populations of *G. acaulis*, the maximum in the age spectrum is observed in the pre-reproductive group.

Two populations of *Gentiana laciniata* Kit. ex Kanitz were studied on the Chornohora Ridge, specifically on Mount Hoverla and Turkul. These two populations occupy small areas (around 0.1 ha), and they have incomplete age spectra, lacking immature and juvenile plants.

This is one of the main reasons for the small population size. On Mount Hoverla, the population density varies from 4 to 9 individuals per m², while on Mount Turkul, it ranges from 6 to 15 plants per m². The density is predominantly 5-10 plants per m² (Table 4). In most cases, individual plants of *Gentiana laciniata* Kit. ex Kanitz are encountered, usually as fragments of destroyed populations. The population of *Gentiana laciniata* Kit. ex Kanitz is the smallest of the studied populations of the *Gentiana* genus. The number of individuals decreases each year, leading to the eventual complete disappearance of the population in the Ukrainian Carpathians [5].

The age structure of *Gentiana laciniata* Kit. ex Kanitz is characterized by a small, isolated population, where pre-reproductive age groups – seedlings and virginile – predominate. As a result, a left-skewed age spectrum is observed. Overall, the population is characterized as normal and full-membered, even with a small

population size. Deviations from the state of a normal full-membered population with a peak in the number of virginile or generative individuals are mainly an indicator of the unfavorable impact of exogenous factors, mostly of anthropogenic origin.

Conclusions. Thus, after studying the populations of the *Gentiana* genus in the highlands of the Ukrainian Carpathians, it was found that the largest population was *G. punctata*, while the smallest was *G. acaulis*. On the other hand, *G. lutea* is characterized by isolated populations with relatively large areas (from 4 to 45 hectares) and densities (1.9–6.7 individuals/m²). Both *G. punctata* and *G. acaulis* formed what are known as metapopulation organizations, consisting of small populations.

However, each year, the number and density of the *Gentiana* genus populations are decreasing, and their structure is being disrupted. The main reasons for this are the use of the rhizomes of *G. lutea* and *G. punctata* for folk and official medicine, cattle grazing, and trampling of trails by tourists. In addition to anthropogenic impacts on population structure, natural factors also play a role: insufficient numbers of pollinating insects, temperature, the presence of pests, and slope exposure. Another important factor contributing to the decline in population numbers is their low ecological plasticity, which causes difficulty in adapting to changing environmental conditions.

Prospects for using the research results. The research results can be used for further monitoring of the populations status of rare species in the Ukrainian Carpathians, biodiversity conservation measures within the nature reserve fund, and ecological education.

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