Biol. Stud. 2018: 12(1); 73–86 • DOI: 10.30970/sbi.1201.544
www.http://publications.lnu.edu.ua/journals/index.php/biology

UDC 574.3.063.6:581.524.44](234.421.1)

EFFECT OF CLIMATE CHANGES ON THE HABITAT OF RARE ARCTIC-ALPINE PLANT SPECIES IN THE HIGH MOUNTAIN PART OF THE UKRAINIAN CARPATHIANS

R. M. Cherepanyn

Vasyl Stefanyk Precarpathian National University
57, Shevchenko St., Ivano-Frankivsk 76018, Ukraine
e-mail: roman.cherepanyn@gmail.com

8 types of habitats to which rare arctic-alpine plant species are confined were determined in the high mountain part of the Ukrainian Carpathians. The environmental conditions in the alpine heaths are transformed due to climate changes. *Rhododendron myrtifolium* penetrates into plant community *Loiseleurio-Cetrarietum* on the Brebenskul Mt. that leads to a displacement of *Loiseleuria procumbens* from dominant position. Increasing of cover of *Loiseleuria procumbens* and occupation by its populations of vacant ecological niches are observed in the community of *Dryas octopetala* on the Brebeneskul Mt. High mountain meadows are overgrowing by *Pinus mugo*, *Alnus viridis*, *Juniperus communis* var. *saxatilis* on the border of subalpine and alpine belts. The area of the *Cerastium alpinum* subsp. *lanatum* population on the Rebra Mt. decreases from the periphery to the center of the habitat due to overgrowing of the screes by *Vaccinium myrtillus*, *Vaccinium vitis-idaea*, *Salix silesiaca*, *Juncus trifidus* etc.

Active raised bogs, mineral-rich springs and springfens are between the first undergoing transformation as a result of climate change. Communities *Eriophoro vaginati-Sphagnetum recurvi* on the Breskul Mt. and *Empetro hermaphroditi-Sphagnetum fusci* on the Shandryaska Mt. (Svydovets massif) are overgrowing by shrubs, that lead to decreasing the part of *Vaccinium oxycoccos*, *Carex pauciflora*, *Empetrum nigrum* subsp. *hermaphroditum* in the habitat. The existence of the upper locus of the *Pedicularis oederi* population between mountains Brebeneskul and Munchel is under threat due to drying of the substrate and negative demographic trends in the population (reduction of the individuals number, habitats area, density, recovery and generation coefficients, etc.).

The transformation of the habitats of rare arctic-alpine plant species in the high mountain part of the Ukrainian Carpathians is due mainly to drying of the substrate, successional processes and increasing of the areas of shrubs and high density plant communities. To conserve habitats that are threatened with extinction due to demutation (*Lloydia serotina* on the Velyki Kizly Mt., *Carex pauciflora* on Shandryaska Mt. (Svydovets) and in the Tsybulnyk valley (Chornohora), *Cerastium alpinum* subsp. *lanatum* on the Rebra Mt.), active conservation measures should be applied to remove more competitive and aggressive species.

Keywords: habitats, climate change, populations, communities, Ukrainian Carpathians, arctic-alpine species

INTRODUCTION

Transformation of natural conditions due to climate changes and anthropogenic impact in the Ukrainian Carpathians led to habitat area reduction and changes in functional organization of many plant species. Most of them are rare, endemics or geographically peripheral. These species are represented mainly by isolated populations that differ in their genetic and ecological structure, are confined to certain types of habitats, which are separated by geographic and biological barriers [22]. Arctic-alpine plants that can serve as model organisms in such researches are particular value for understanding the effects of climate changes for habitats of rare species populations. These species play an important role in the ecosystems of Arctic and sub-Arctic regions and in the mountains of the Northern Hemisphere. Most of the rare arctic-alpine plant species are confined to the high mountain part in the Ukrainian Carpathians, which is represented by the upper limit of the forest, subalpine and alpine belts, and begins on average from an altitude of 1,800 m above sea level. High-altitude forms of relief are characterized by the presence of sharp mountain ridges, glacial cirques and rocky ranges. Chornohora, Svydovets, Marmarosh and Chyvchyny massives are the main high-altitude areas in the Ukrainian Carpathians.

In accordance with the Berne Convention and Habitat Directive, conservation of natural habitats of species is an important mechanism of protecting biodiversity [3, 4]. That is why reservation of subalpine and alpine habitats is the priority task in protection of rare arctic-alpine plant species populations. Today, the concept of habitat in biodiversity conservation programs has been well aprobated in Europe and needs implementation in Ukraine. Changing the conditions of habitats, their insularization are the main cause of losing populations vitality that may lead to their disappearance. Understanding of the changes occurring in natural and anthropogenically modified high-mountain ecosystems under the influence of climatic factors enables us to identify mechanisms of rare species adaptation to environmental conditions, to investigate the strategies of their populations, as well as processes of species formation and evolution in a changeable environment.

The study of the impact of climate change on flora and vegetation of the highlands relates to the upper limit of the alpine zone in Europe and Asia, the dynamics of the upper forest limit during the Holocene, as well as the spread of invasive species to the highland due to current climate warming [1, 2, 26–27, 30]. It was established that climate change in highland ecosystems negatively affects the microphytoclimate of phytocoenosis and self-maintenance of some species populations. In particular, an increase in the temperature of the environment changes the regulation of the temperature regime within the communities of pillow-like shrubs and prostrate shrubs in the Alps [14]. Much less attention has been paid to the study of climate changes on rare plant species habitats within the Carpathian mountain system, in particular within the Ukrainian Carpathians [10, 12–13, 15–16].

The purpose of our work is to analyze changes in highland habitats of rare arctic-alpine plant species of the Ukrainian Carpathians under the influence of climate factors. Our research was aimed on studying the reactions of the highland ecosystems to climate change. Particular attention was paid to rare species habitats on the verge of different

plant communities (successional changes in phytocoenosis and the adaptive reactions of rare species to changeable conditions appear most clearly in the ecotones).

An important step in this work is determining types of habitats – identification and selection of sites which are characterized by presence of appropriate conditions that ensure existence on them of the certain plant species. One of the tasks was to study the effects of climate changes on the parameters and conditions in the habitats, as well as the definition of those who are the first react under transformation. In this context, typification of habitats is a concrete tool for protecting populations, species, communities, etc., and also contributes for implementation the Berne Convention in Ukraine. Also, the definition of rare arctic-alpine plants habitats promotes to creating a reliable basis for the development of an ecological network in Ukraine which is regulated by the Law of Ukraine "About ecological network of Ukraine" and the Law of Ukraine "About the basic principles (strategy) of the state environmental policy of Ukraine for the period till 2020" [17–18].

MATERIALS AND METHODS

The objects of our research are habitats of rare plants species in the high mountain part of the Ukrainian Carpathians, and the subjects of our research are rare arctic-alpine plant species populations.

Habitats were typified in accordance with Annex 1 ("Natural habitat types of community interest whose conservation requires the designation of special areas of conservation") of the Habitats Directive ("Council Directive 92/43/EEC on the conservation of natu-

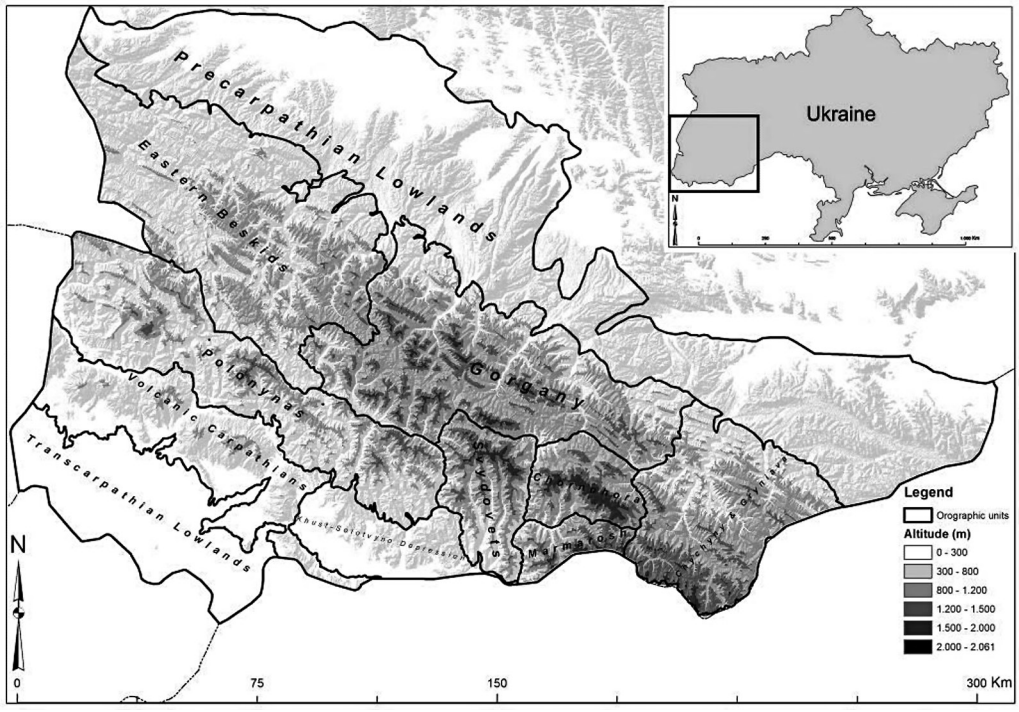

Fig.1. Phytogeographical division of the Ukrainian Carpathians (Novikoff, Hurdu) [25]

Рис.1. Фітогеографічний поділ Українських Карпат (Novikoff, Hurdu) [25]

ral habitats and of wild fauna and flora") [4, 9]. Also, the four-digit numeric codes that were assigned to them in the database of the ecological network "Natura 2000", were filed for habitats. The names of taxa were given in accordance with "The Plant List" [28]. The names of syntaxa were given in accordance with ecological-floristic classification [21].

The investigations were conducted in subalpine and alpine belts of Chornohora, Svydovets, Marmarosh and Chyvchyny massives of the Ukrainian Carpathians (Fig. 1). Permanent research plots and the accounting method on the route were used for obtaining data. Mapping and method of individuals labeling were applied. Geographic location, habitats area, elevation above sea level, slope exposure, humidity, type of substrate, density and number of individuals, coverage, etc. were determined for populations. Considerable attention was paid to demographic aspects, in particular, such parameters as age structure, ontogeny, peculiarities of reproduction, strategies and vitality of individuals [23].

Passive experiments and techniques developed for rare plant species were used in the studies of natural and anthropogenic factors influences [8]. Passive experiments with partial damage to individuals that simulate grazing, trampling, picking and uprooting plants, as well as experiments with point disturbance of grass and soil surface were used for less rare species. Recovery index in populations was calculated as a relation of the number of pregenerative individuals to generative individuals. The coefficient of generative reproduction in populations defined as a ratio of number of generative individuals to adults individuals [29].

RESULTS AND DISSCUSION

Due to climate changes, a significant part of primary plant communities of the Ukrainian Carpathians were transformed, some species and cenosis disappeared, anthropochores spread to high mountain part and formed secondary plant communities [20]. A decrease of area and the disappearance of populations on the periphery of their geographical distribution are observed in many rare plant species. For example, some alpine plants in the Ukrainian Carpathians are located on the north-eastern boundary of their range, while arctic-alpine plant species are vulnerable to climate change on the southern boundaries of their distribution in mountains of temperate latitudes, where reduction of populationa areas, changes in populations structure and dynamics were observed [5, 6–7, 19]. Due to climate warming, establishment of nature protected areas on some territories and decline of farming in the highlands, we observed rising of the upper forest limit, increased of bushlands, shrubs and firm-bunch communities in the subalpine and alpine zones [24].

There are 8 types of habitats in high mountain part of the Ukrainian Carpathians, where rare arctic-alpine plant species exist (Table 1).

Pronounced changes were observed in the parameters of the alpine and boreal heaths (habitat under the number 4060). For example, the populations of *Loiseleuria procumbens* (L.) Loisel. which are forming the phytocoenic center of the community *Loiseleurio-Cetrarietum* (class *Loiseleurio-Vaccinietea*), are subjected to transformation due to climate changes. The area occupied by *Loiseleuria procumbens* population make 80% in the community *Loiseleurio-Cetrarietum* on the south-west slope of the mountain Brebenskul at an altitude of 1950 m above s.l. Subdominant species in the community are *Vaccinium uliginosum* L. (10 %) and *Vaccinium myrtillus* L. (5 %). Assectators are *Carex curvula* All., *Juncus trifidus* L., *Homogyne alpina* (L.) Cass., *Soldanella hungarica*

Table 1. **The main types of rare arctic-alpine plant species habitats in the high mountain part of the Ukrainian Carpathians in accordance with Annex 1 of the "Habitats Directive"**

Таблиця 1. **Основні типи оселищ раритетних аркто-альпійських видів рослин високогір'я Українських Карпат відповідно до Додатку 1 "Оселищної директиви"**

N	Habitats (habitats code in the ecological network database "Natura 2000")	Localities in the high mountain part of the Ukrainian Carpathians	Arctic-alpine plant species that occur in the habitats
1	Alpine and Boreal heaths (4060)	Mountains Brebeneskul, Petros, Munchel, Shpytsi, Pozhyzhevska, a large part of the Ukrainian Carpathians high mountain zone	*Dryas octopetala* L., *Juniperus communis* var. *saxatilis* Pall., *Loiseleuria procumbens* (L.) Loisel., *Salix herbacea* L.
2	Alpine and subalpine calcareous grasslands (6170)	Mountains Chyvchyn, Petros, Shpytsi, Turkul, separate loci in the high mountain part of the Ukrainian Carpathians	*Anemone narcissiflora* L., *Myosotis alpestris* F.W. Schmidt, *Polygonum viviparum* L., *Rhodiola rosea* L., *Selaginella selaginoides* (L.) P. Beauv. ex Schrank et C.F.P.Mart.
3	Active raised bogs (7110)	Tsybulnyk, Pohorilets (Chornohora), Shandryaska Mt. (Svydovets)	*Allium schoenoprasum* L. subsp. *sibiricum* (L.) Čelak., *Carex pauciflora* Lightf., *Empetrum nigrum* subsp. *hermaphroditum* (Hagerup) Böcher
4	Mineral-rich springs and springfens (7160)	Brebeneskul Mt., glacial cirques Munchel, Breskul-Hoverla, Gutyn-Tomnatyk, Rebra-Shpytsi, Pohorilets (Chornohora)	*Carex bicolor* Bellardi ex All., *Epilobium alsinifolium* Vill., *Juncus castaneus* Smith, *Pedicularis oederi* Vahl, *S. stellaris* L. subsp. *alpigena* Temesy
5	Calcareous fens (7210)	Drahobrat Mt. (Svydovets), Rohnieska, Prymaratyk (Chornohora), Chyvchyn Mt.	*Carex pauciflora, Juncus castaneus, Pinguicula alpina* L.
6	Petrifying springs with tufa formation (7220)	Glacial valley Gadzhyna (Chornohora)	*Juncus triglumis* L., *Saxifraga aizoides* L.
7	Siliceous scree of the montane to snow levels (8110)	Mountains Blyznytsia (Svydovets), Velyki Kizly, Shpytsi, glacial cirque Brebeneskul-Munchel, Smotrych (Chornohora)	*Carex fuliginosa* Schkuhr, *Luzula alpino-pilosa* (Chaix) Breistr. subsp. *obscura* S.E. Fröhner, *Oxyria digyna* L., *Potentilla crantzii* (Crantz.) Beck ex Fritsch, *Sedum annuum* L.
8	Calcareous screes of the montane to alpine levels (8120)	Rocks of Blyznytsia Mt. (Svydovets), Shpytsi, Rocks of Turkul Mt., Mountains Pip Ivan, Petros (Chornohora)	*Aster alpinus* L., *Bartsia alpina* L., *Carex rupestris* All., *Cerastium alpinum* L. subsp. *lanatum* (Lam.) Ascherson et Graebner, *Gentiana nivalis* L., *Lloydia serotina* (L.) Reichenb., *Saussurea alpina* (L.) DC., *Saxifraga paniculata* Miller.

Simonk., *Doronicum clusii* (All.) Tausch, *Campanula alpina* Jacq., *Cetraria islandica* (L.) Ach. *Rhododendron myrtifolium* Schott & Kotschy actively invades in the plant community due to climatic changes, that leads to a displacement of *Loiseleuria procumbens* (Fig. 2, *A*). As a result of successional processes, the coverage of the dominant species decreases to 50 %.

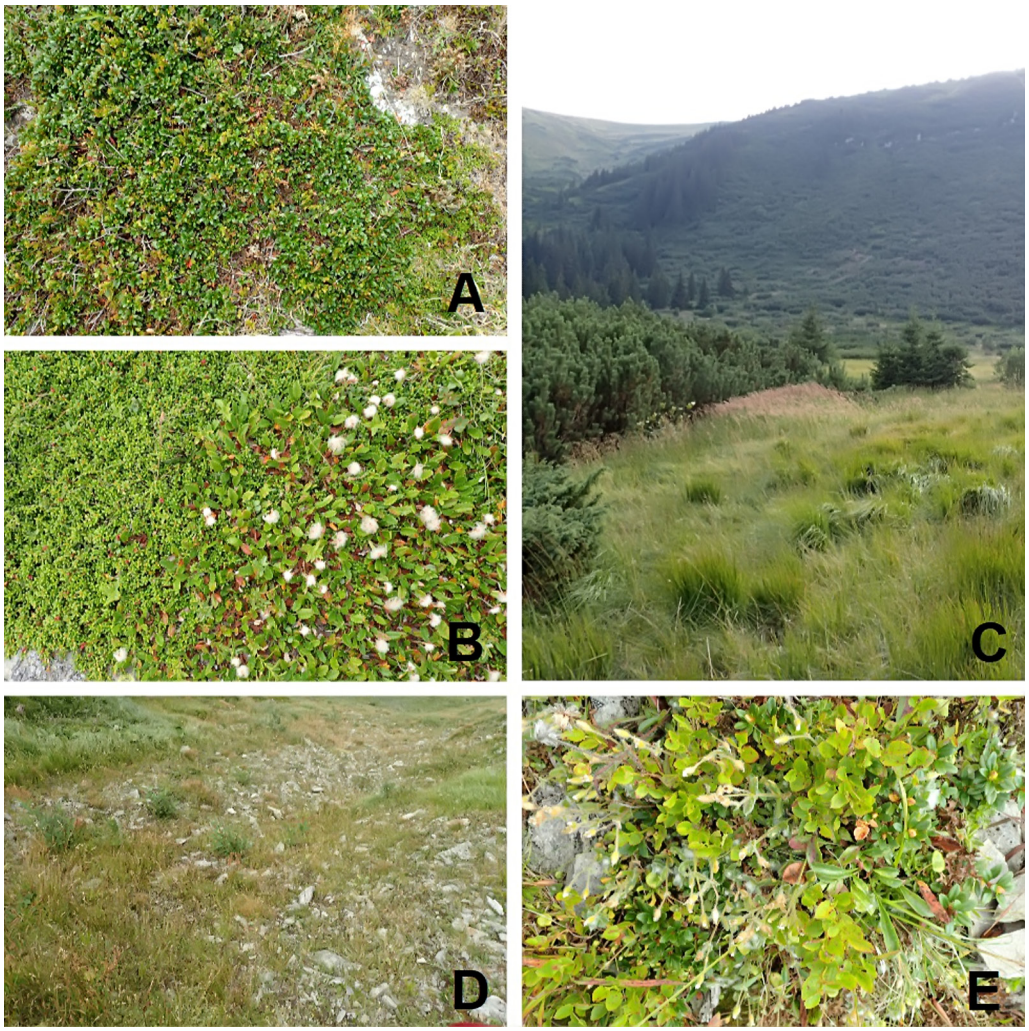

Fig. 2. **A.** *Rhododendron myrtifolium* Schott & Kotschy in the community *Loiseleurio-Cetrarietum* on the Brebeneskul Mt. **B.** *Dryas octopetala* L. and *Loiseleuria procumbens* (L.) Loisel. in the community *Loiseleurio-Vaccinietea.* **C.** Valley Tsybulnyk in Chornohora massif. **D.** Habitat of *Cerastium alpinum* L. subsp. *lanatum* (Lam.) Ascherson et Graebner on the north-eastern slope of Rebra Mt. **E.** Overgrowth of the *Cerastium alpinum* subsp. *lanatum* population with high density and shrub species

Рис. 2. **A.** *Rhododendron myrtifolium* Schott & Kotschy в угрупованні *Loiseleurio-Cetrarietum* на горі Бребенескул. **B.** *Dryas octopetala* L. і *Loiseleuria procumbens* (L.) Loisel. в угрупованні *Loiseleurio-Vaccinietea.* **C.** Урочище Цибульник на Чорногорі. **D.** Оселище *Cerastium alpinum* L. subsp. *lanatum* (Lam.) Ascherson et Graebner на пн.-сх. схилі гори Ребра. **E.** Заростання популяції *Cerastium alpinum* subsp. *lanatum* щільнодернинними та чагарниковими видами

Populations *Loiseleuria procumbens* on the north-eastern slope of Shpytsi Mt. at an altitude of 1890 m above s.l. occur in the next communities: *Empetro-Vaccinietum*, *Cetrario-Vaccinietum* and *Primulo-Caricetum curvulae* (class *Juncetea trifidi*). The role of *Loiseleuria procumbens* in that locations is subdominant. Dominant positions occupy *Vaccinium myrtillus*, *Vaccinium uliginosum* and *Vaccinium vitis-idaea* L., the coverage

of which totals about 70 % and is constantly expanding. The area of *Loiseleuria procumbens* and *Empetrum nigrum* subsp. *hermaphroditum* (Hagerup) Böcher cenopopulations reaches 25 %. Assectators in habitats are: *Pulsatilla alba* Reichenb., *Hieracium alpinum* L., *Campanula alpina*, *Carex curvula*, *Cladonia rangiferina* (L.) Weber ex F.H. Wigg.

Populations *Dryas octopetala* occur on the high mountain part meadow, limestone and sandstone cliffs and have dominant position in the community *Achilleo schurii-Dryadetum* (class *Carici rupestris-Kobresietea ballardii*) and in communities of the class *Loiseleurio-Vaccinietea*. Assectators are the next species: *Carex sempervirens* Vill., *Campanula alpina, Vaccinium myrtillus*, *Vaccinium vitis-ideae*, *Anemone narcissiflora*, *Bartsia alpina*, *Homogyne alpina*, *Sesleria coerulans* Friv.

Population *Dryas octopetala* L. on the north-eastern slope Brebeneskul Mt. at an altitude of 1950 m above s.l. in the community *Loiseleurio-Vaccinietea* covers of 40 % area. Projection of *Loiseleuria procumbens* population is 30 %, but the area of the species in the habitat increases to 40 % due to climate changes (Fig. 2, *B*). Subdominant species in the community are *Rhododendron myrtifolium, Primula minima* L. and *Cetraria islandica*; assectators are the subsequent species – *Campanula alpina*, *Carex curvula*, *Potentilla aurea* L., *Campanula serrata* (Kit. ex Schult.) Hendrych. In general, the *Loiseleuria procumbens* expansion – occupation by populations of free ecological niches (screes, denudation soil surface, tourist paths with moderate anthropogenic impacts) is observed in various communities as a result of climatic changes.

Alpine and subalpine calcareous grasslands (habitat under the number 6170), where rare *Anemone narcissifolia* L. and *Rhodiola rosea* L. occur, are overgrowned by *Juniperus communis* var. *saxatilis* Pall. on the border of the subalpine and alpine belts as a result of climate change. Such processes are well represented on the south-west slopes of the mountains Breskul and Turkul in the Chornohora massif.

Active raised bogs (habitat under the number 7110), Calcareous fens (habitat under the number 7210) and Petrifying springs with tufa formation (habitat under the number 7220) belong to the priority types of habitat in accordance with Annex 1 of the “Habitats Directive” and they are among the first that undergo transformation due to climate change. Habitats are distributed in subalpine belt and in upper forest limits on the well-humidified areas with high levels of organic matter, near springs and along streams. They are formed on neutral and slightly acidic soils. The most threatening factor for these habitats is soils dry out. Drying out of the substrate causes changes in phytocoenotic conditions in the habitat. For example, habitats in the glacial valley Gadzyna in Chornohora massif are overgrowned by shrubs, that may lead to decrease the area of the only Ukrainian population *Saxifraga aizoides* L. [11].

Unique community *Empetro hermaphroditi-Sphagnetum fusci* with *Pinus mugo* Turra on the southern slope of Shandryaska Mt. (Svydovets massif) at an altitude of 1510 m above s.l. undergoes transformation as a result of climatic changes – the part of high density plant species in the grassy layer of the plant community increases and the part of rare species (*Vaccinium oxycoccos* L., *Carex pauciflora* Lightf., *Empetrum nigrum* subsp. *hermaphroditum*) in the habitat decreases. It is worth noting that *Empetrum nigrum* subsp. *hermaphroditum* is resistant to climate change, the species occurs in a wide range of environmental conditions (from bog vegetation to rocky plant community) and have a wide range of tolerance to moisture.

Habitat of the largest population of *Allium schoenoprasum* L. subsp. *sibiricum* (L.) Čelak. in valley Tsybulnyk (north-eastern slope, 1890 m above s.l.) in Chornohora mas-

sif also undergoes transformation as a result of climatic changes (Fig. 2, *C*). The area of the swamp plant community decreases due to the gradual overgrown by *Pinus mugo*, *Alnus viridis* (Chaix.) D.C., *Salix silesiaca* Willd. and *Picea abies* (L.) H.Karst that makes a potential threat to the *Carex pauciflora* population and in general for this habitat. Presently, habitat area of the *Allium schoenoprasum* subsp. *sibiricum* and *Carex pauciflora* populations is above 5,000 m², the density in populations is 15–25 and 60–90 generative individuals per 1 m², respectively.

Mineral-rich springs and springfens (habitat under the number 7160) also undergo transformation due to climate change. Plant community *Eriophoro vaginati-Sphagnetum recurvi*, that occurs in small loci in areas flooded with rainwater and rich in nutrients, is overgrown by shrubs (*Vaccinium myrtillus*, *Vaccinium uliginosum, Vaccinium vitis-idaea* and *Rhododendron myrtifolium*) due to climate warming and drying out of the substrate. Such processes are observed in the community *Eriophoro vaginati-Sphagnetum recurvi* on the south-west slope of Breskul Mt. (1,707 m above s.l.).

The drying of marshes and damp meadows leads to decreasing the scope of some rare arctic-alpine plant species populations, for example, the only Ukrainian population of *Pedicularis oederi* Vahl and populations of *Carex pauciflora*. *Pedicularis oederi* population consists of several locus located on the slopes of the Brebeneskul Mt. on the Chornohora massif. The population is found in the community *Caricetum sempervirentis* (class *Elyno-Seslerietea*) and in open phytocoenosis. The vegetation cover in the community is uneven and diffused. The next species occur in the habitat: *Carex sempervirens*, *Juncus trifidus*, *Festuca airoides* Lam., *Sesleria coerulans*, *Polytrichastrum alpinum* (Hedw.) G.L. Sm., *Cetraria islandica*.

The upper locus of the *Pedicularis oederi* population is located between Brebeneskul and Munchel mountains on the south-west slope at an altitude of 1955 m above s.l. on the mesotrophic meadow. Locus consists of two fragments that are located at a distance of about 20 m from each other. As of 2011 year, the area of the first fragment was 150 m², and the other – 50 m² (Fig. 3, *A*). The number of adult individuals in this habitat was 250 (150 in the first locus and 100 in the second locus), the number of generative individuals was 70 (40 and 30, respectively). The density of generative individuals in the population ranged from 2 to 7 per 1 m², vegetative individuals – 4–6 per 1 m², seedlings – 4–6 per 1 m². The density of individuals ranged from 2 per 1 m² on a dry substrate to 9 per 1 m² – on wet soils, depending on the conditions of the edaphotope. Immature and juvenile individuals, as well as senile and subsenile individuals (up to 10 %) were found in the population. The height of the generative shoots is from 10 to 18 cm, the number of fruits per generative shoots from 8 to 15 pieces, the actual seed yield is an average of 15 seeds per fruit. The coefficient of generative reproduction in the upper loci of population was 30–40 %, the recovery index – within the range of 1.4–1.8.

As of 2017, the upper locus of *Pedicularis oederi* populations has undergone significant transformation due to climate change. The population also suffers by periodic anthropogenic influences as a result of horses grazing. The area of the first and second fragment of upper locus in the population is significantly reduced due to drying out of the habitat. In particular, the area of the first fragment is 90 m² – decreased by 40 %, the area of the second fragment is 35 m² – decreased by 30 %. The number of adult individuals had decreased by 40% and the number of generative individuals – almost by 70 % (Fig. 3, *B*). In particular, the number of adults is 150 (100 in the first fragment and 50 in the second), the number of generative individuals is 20 (15 in the first fragment

and 5 in the second). Proportion of subsenile and senile individuals increases (up to 30 %), density of generative individuals decreases (1–3 per 1 m²) in the population. The coefficient of generative reproduction is 10–15 %, the recovery index – within the range of 1.2–1.5. Taking into account that *Pedicularis oederi* reproduces only via seeds, self-recovery and vitality of populations depends on generative reproduction efficiency and the area of suitable habitats, the further existence of the population in the upper locus would be under threatened if the above negative trends will continue to existing (Fig. 4).

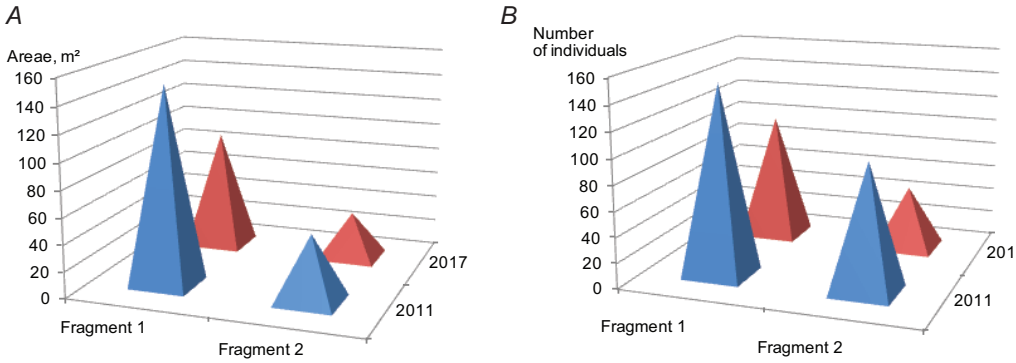

Fig. 3. Changes of features of the upper locus of the *Pedicularis oederi* Vahl population between Brebeneskul and Munchel mountains on Chornohora massif (2011 and 2017). **A.** Changes of area of first and second fragments of the upper locus of the *Pedicularis oederi* population. **B.** Changes of the number of adult individuals in first and second fragments of the upper locus of the *Pedicularis oederi* population

Рис. 3. Зміни особливостей верхнього локусу популяції *Pedicularis oederi* Vahl між горами Бребенескул та Мунчел на Чорногірському масиві (2011 та 2017 роки). **A.** Зміни площі першого та другого фрагментів верхнього локусу популяції *Pedicularis oederi*. **B.** Зміни числа дорослих особин у першому та другому фрагментах верхнього локусу популяції *Pedicularis oederi*

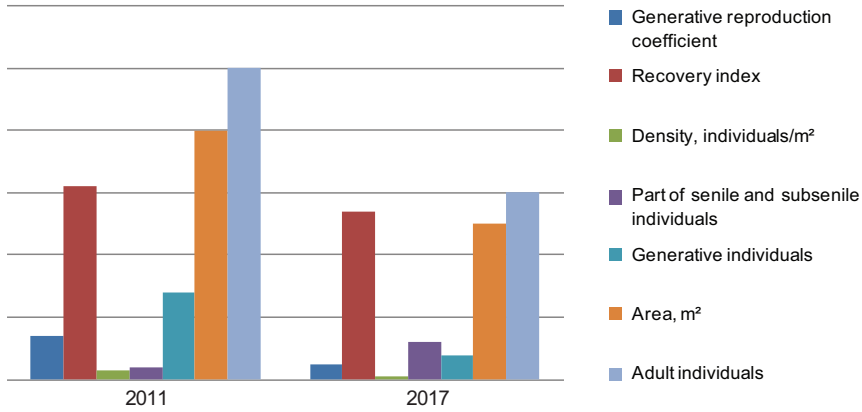

Fig 4. Indicators of the state of the upper locus of the *Pedicularis oederi* Vahl population between mountains Brebeneskul and Munchel on Chornohora massif in 2011 and 2017

Рис. 4. Показники стану верхнього локусу популяції *Pedicularis oederi* Vahl між горами Бребенескул та Мунчел на Чорногірському масиві у 2011 та 2017 роках

Transformation of ecotopes and habitat properties due to climatic changes is threatening to many rare plant species in the subsequent habitats: Siliceous scree of

the montane to snow levels (habitat under the number 8110) and Calcareous and calcshist screes of the montane to alpine levels (habitat under the number 8120). For example, narrow ecological-coenotical amplitude of *Lloydia serotina* (L.) Reichenb. and overgrowing of its ecotopes by *Pinus mugo* and *Alnus viridis* due to rising of upper forest limit, lead to reduction in the number of individuals and narrowing of its habitats, which are not too numerous, on the Velyki Kizly Mt. in Chornohora massif. Population *Lloydia serotina* on the Velyki Kizly Mt. is located on a northwest slope with a steepness of 50–60° at an altitude of 1710 m above s.l. The area of the habitat is 25 m². There are about 30 individuals, of which 15 are generative, in population. The density of individuals is low, caused by the species biology, individuals of which singly populate suitable fragments of the ecotope – rocks cracks and shelves. The actual seed yield is an average of 12 seeds per fruit. Height of generative shoots is 6–9 cm, the length of the leaves is 12–19 cm. A high rate of generative reproduction coefficient (50 %), due to the dominance of generative reproduction, is observed in populations. The low recovery index (0.6) is due to the lack of suitable sites for seeds germination which is caused by overgrown of habitats by shrubs.

The *Lloydia serotina* population is confined to open coenosis and to community *Saxifrago-Festucetum versicoloris*. It is important to control demutation processes in the community to conserve population and if it is necessary to take active protection measures – to remove more competitive and aggressive species.

The expansion of high density and shrub species is observed on screes, in particular, in the habitat of *Cerastium alpinum* L. subsp. *lanatum* (Lam.) Ascherson et Graebner population on the north-eastern slope of Rebra Mt. (Chornohora massif) at an altitude of 1900–1970 m above s.l. Population *Cerastium alpinum* subsp. *lanatum* occurs in the communities *Cetrario-Festucetum airoidis* (class *Junceta trifidi*), *Thymo-Festucetum amethystinae* and in open phytocoenosis. In particular, the coverage of the species in the center of the habitat is 60–70 %, on the edges communities are actively overgrowing by *Juncus trifidus*, *Vaccinium myrtillus* and *Rhododendron myrtifolium*, which reduces the area of the cover of *Cerastium alpinum* subsp. *lanatum* to 30 % (Fig. 2, *E*). The number of individuals of *Juniperus communis* var. *saxatilis*, *Salix silesiaca* and *Picea abies* increases in the habitat (Fig. 2, *D*). These species in recent years are increasingly appearing in ecotops not characteristic of them. With the preservation of this trend, the continued existence of the *Cerastium alpinum* subsp. *lanatum* population in the long run on the Rebra Mt. may be at risk.

In the highland rocky habitats which do not intensively overgrown by shrubs and do not undergo by anthropogenic impacts, effects of climate changes are not so intensive. For example, habitat of *Saussurea alpina* (L.) DC. population on the south-eastern slope of Shpyci Mt. (Chornohora massif) at an altitude of 1840–1860 m above s.l. not undergoes any significant changes during the last 8 years (2010–2017). The population is found on rocky shelves in communities of the union *Oxytropido-Elynion*, in associations *Caricetum sempervirentis* and *Thymo-Festucetum amethystinae* with *Ranunculus thora* L., *Pedicularis verticillata* L., *Saxifraga paniculata* Miller., *Rhodiola rosea* etc. (class *Elyno-Seslerietea*). Total area of the *Saussurea alpina* population is 300 m². The number of adults in the population is about 350, the number of generative individuals – about 80. The density of individuals reaches 15–20 pieces per 1 m². Generative reproduction coefficient varies within 19–23 %, recovery index – within 2.8–3.3.

In the population of *Saussurea alpina* on the north-eastern slopes of Petros Mt. at an altitude of 1820 m above s.l. that grows in rocky communities conditions what is favorable for the species, since 2010 year the number of flowering individuals in the habitat decreases. In 2009, 60 blooming individuals were observed in the population, but in the following years, only 5 blooming individuals were counted. In 2017, 6 individuals of *Saussurea alpina* population were blooming in the habitat. The population is experiencing stressful influences through the trampling (grazing of the sheep is periodically carried out through a habitat during the vegetation season). The question of how much such gaps in flowering of generative individuals are related to anthropogenic pressures, climate changes, or intrapopulation processes require further researches.

CONCLUSIONS

The transformation of the habitats of rare arctic-alpine plant species in the high mountain part of the Ukrainian Carpathians as a result of climatic changes is due mainly to the drying of the substrate, successional processes and the increasing of the areas of shrubs and high density plant communities.

Rhododendron myrtifolium expansions and displacements of *Loiseleuria procumbens* from dominant to subdominant position in the habitat are observed in the community *Loiseleurio-Cetrarietum* on the Brebenskul Mt. Increasing of *Loiseleuria procumbens* projective coverage and occupation by its populations of vacant ecological niches are observed in the habitat of *Dryas octopetala* on the Brebenskul Mt.

Plant community *Eriophoro vaginati-Sphagnetum recurvi* is overgrown by shrubs *Vaccinium myrtillus*, *Vaccinium uliginosum* and *Vaccinium vitis-idaea* on the Breskul Mt. The existence of the upper locus of the *Pedicularis oederi* population between mountains Brebeneskul and Munchel is under threat due to drying of the substrate and the negative demographic trends in the population.

Habitats that have priority status in the “Habitat Directive” are among the first which undergo transformation due to climate change, and therefore require continuous monitoring and development measures for their conservation. To protect habitats that are threatened with extinction due to demutation, active conservation measures should be applied – removing of excess shrub cover (*Lloydia serotina* on the Velyki Kizly Mt., *Carex pauciflora* on Shandryaska Mt. (Svydovets) and in the Tsybulnyk valley (Chornohora), *Cerastium alpinum* subsp. *lanatum* on the Rebra Mt.).

Presently no obvious negative effects of climate changes on the habitats of rare arctic-alpine plant species of the open rocky coenosis are observed.

ACKNOWLEDGMENTS

Publication is based on the research provided by the grant support of the State Fund for Fundamental Research of Ukraine No Ф76/81-2017 from 31.08.2017. Publication is also based on the research provided by the grant support of “The Rufford Foundation” RSG 19611-1.

1. *Alexander J.M., Lembrechts J.J., Cavieres L.A.* et al. Plant invasions into mountains and alpine ecosystems: current status and future challenges. **Alp Botany,** 2016; 126(2): 89–103.
2. *Beniston M., Diaz H.F., Bradley R.S.* Climatic change at high elevation sites: an review **Climatic Change**, 1997; 36: 233–251.

3. **Convention on the Conservation of European Wildlife and Natural Habitats**, 1979; E. T. S. 104 (IEL-MT 979): 70.
4. Council Directive 92/43/EEC of 21 May 1992 on the conservation of natural habitats and of wild fauna and flora. **Official Journal of the European Communities**, 22.07.1992; 206: 7–50.
5. *Didukh J.P.* Ecological aspects of global climate changes: causes, consequences, actions. **Bul. of NAS of Ukraine**, 2009; 2: 34–44. (In Ukrainian).
6. *Erschbamer B., Kiebacher T., Mallaun M., Unterluggauer P.* Short-term signals of climate change along an altitudinal gradient in the South Alps. **Plant Ecol**, 2009; 202: 79–89.
7. *Harald P., Gottfried M., Grabherr G.* Effects of climate change of mountain ecosystems – upward shifting of alpine plants. **World Resource Review**, 1996; 8(3): 382–390.
8. *Holubiev V.N.* To the methodology of ecological and biological researches of rare and endangered plants in natural plant communities. **Bul. of the Nikitsky Bot. Garden**, 1982; (47): 11–16. (In Russian).
9. *Kagalo A., Prots B.* **Habitat concept of biodiversity protection: basic documents of the European Union**. Lviv: ZUKC, 2012. 278 p. (In Ukrainian).
10. *Kobiv Y.* Response of rare alpine plant species to climate change in the Ukrainian Carpathians. **Folia Geobotanica**, 2017; 52(2): 217–226.
11. *Kobiv Y. Saxifraga aizo*ides (*Saxifragaceae*) in Ukraine. **Polish Botanical Journal**, 2016; 61(1): 241–250.
12. *Kobiv Y.Y.* Global climate changes as a threat to the species biodiversity in the high-mountain zone of the Ukrainian Carpathians. **Ukr. Botan. J**, 2009; 66(4): 451–465. (In Ukrainian).
13. *Kobiv Y., Prokopiv A., Helesh M., Borsukevich L.* Distribution, state of populations and habitat characteristics of rare and endangered species of plants in the northern part of Svydovets Mountains (the Ukrainian Carpathians). **Visnyk of Lviv University. Biolog. Ser**, 2009; 49: 63–82. (In Ukrainian).
14. *Körner C.* **Alpine Plant Life: functional plant ecology of high mountain ecosystems. 2nd edition**. Berlin: Springer, 2003. 359 p.
15. *Kyyak V., Shtupun V., Bilonoha V.* Climatic threats to population of rare and endemic plants in upper part of the Ukrainian Carpathians. **Visnyk of Lviv University. Biolog. Ser**, 2016; 74: 104–115 (in Ukrainian).
16. *Kyyak V.H., Bilonoha V.M., Dmytrakh R.I.* et al. Trends in plant population pattern changes under natural and man-induced ecosystem transformation of the high mountain zone in the Ukrainian Carpathians. **Studia Biologica**, 2015; 9(2): 169–180.
17. Law of Ukraine "**About ecological network of Ukraine**": http://zakon3.rada.gov.ua/laws/show/1864-15 (access from 17.01.2018). (In Ukrainian).
18. Law of Ukraine "**About the basic principles (strategy) of the state environmental policy of Ukraine for the period till 2020**": http://zakon2.rada.gov.ua/laws/show/2818-17 (access from 17.01.2018). (In Ukrainian).
19. *Lesica P., McCune B.* Decline of artic–alpine plants at the southern margin of their range following a decade of climatic warming. **Journal of Vegetation Science**, 2004; 15(5): 679–690.
20. *Malinovski A.K.* The cenotaxonomic diversity of the high mountain part of the Ukrainian Carpathians. **Visnyk of Lviv University. Biolog. Ser**, 2002; 31: 126–133. (In Ukrainian).
21. *Malynovski K.A., Kricsfalusy V.V.* **Plant communities of the Ukrainian Carpathian highlands**. Uzhgorod: Carpathian Tower Publishing, 2002. 244 p. (In Ukrainian).
22. *Malinovski K., Tsaryk Y., Zhilyaev G.* et al. **Population structure of rare species of Carpathian flora**. Kyiv: Naukova Dumka, 1998. 176 p. (In Ukrainian).
23. *Markov M.V.* **Population biology of plants (educational-methodical manual)**. Kazan: Publishing House of Kazan University, 1986. 110 p. (In Russian).

24. *Nesteruk Y.Y.* Rare Floristic Diversity of the Chornohora Mts (Ukrainian Eastern Carpathians): History of Research, Current Status, Protection. **Bulletin of the National Museum of Natural History**, 2014; 12: 31–44. (In Ukrainian).
25. *Novikoff A., Hurdu B.-I.* A critical list of endemic vascular plants in the Ukrainian Carpathians. **Contribuţii Botanice. Grădina Botanică "Alexandru Borza"**, 2015. 43–91.
26. *Soudzilovskaia N.A., Elumeeva T.G., Onipchenko V.G.* et. al. Functional traits predict relationship between plant abundance dynamic and long-term climate warming. **PNAS**, 2013; 110(45): 18180–18184.
27. *Theurillat J. P. Guisan A.* Potential impact of climate change on vegetation in the European Alps: a review. **Climatic Change**, 2001; 50: 77–109.
28. The Plant List: http://www.theplantlist.org/ (access from 13.02.2018).
29. *Tsaryk Y., Kyyak V., Dmytrah R.* et al. Generative reproduction of plant populations in the high mountain part of the Ukrainian Carpathians as a sign of their viability. **Visnyk of Lviv University. Biolog. Ser**, 2004; 36: 50–56. (In Ukrainian).
30. *Vincze I., Orbán I., Birks H.* Holocene treeline and timberline changes in the South Carpathians (Romania): Climatic and anthropogenic drivers on the southern slopes of the Retezat Mountains. **The Holocene**, 2017; 27(11): 1613–1630.

ВПЛИВ КЛІМАТИЧНИХ ЗМІН НА ОСЕЛИЩА РАРИТЕТНИХ АРКТО-АЛЬПІЙСЬКИХ ВИДІВ РОСЛИН ВИСОКОГІР'Я УКРАЇНСЬКИХ КАРПАТ

Р. М. Черепанин

Прикарпатський національний університет імені Василя Стефаника
вул. Шевченка, 57, Івано-Франківськ 76018, Україна
e-mail: roman.cherepanyn@gmail.com

Визначено, що у високогір'ї Українських Карпат представлено 8 типів оселищ, до яких приурочені раритетні аркто-альпійські види рослин. Унаслідок кліматичних змін відбувається трансформація умов середовища в альпійських чагарничкових пустищах. В угруповання *Loiseleurio-Cetrarietum* на горі Бребенескул проникає *Rhododendron myrtifolium*, що призводить до витіснення *Loiseleuria procumbens* із домінантної позиції. В угрупованні *Dryas octopetala* на горі Бребенескул спостерігається збільшення проективного покриття *Loiseleuria procumbens* і захоплення популяцією вільних екологічних ніш. Високогірні луки на стику субальпійського й альпійського поясів заростають *Pinus mugo*, *Alnus viridis*, *Juniperus communis* var. *saxatilis*. Площа популяції *Cerastium alpinum* subsp. *lanatum* на горі Ребра зменшується від периферії до центру оселища внаслідок заростання осипищ *Vaccinium myrtillus*, *Vaccinium vitis-idaea*, *Salix silesiaca*, *Juncus trifidus* тощо.

Верхові болота, джерельні та приструмкові трав'яні болота (мочари) одні з перших піддаються трансформації внаслідок змін клімату. Угруповання *Eriophoro vaginati-Sphagnetum recurvi* на горі Брескул та *Empetro hermaphroditi-Sphagnetum fusci* на горі Шандриаська (Свидовецький масив) заростають чагарничками, що призводить до зменшення частки *Vaccinium oxycoccos*, *Carex pauciflora, Empetrum nigrum* subsp. *hermaphroditum* в оселищі. Існування верхнього локусу популяції *Pedicularis oederi* між горами Бребенескул і Мунчел є під загрозою внаслідок висихання субстрату і негативних демографічних тенденцій у популяції (зменшення чисельності особин, площі оселища, щільності, коефіцієнтів відновлення та генерування тощо).

Трансформація оселищ рідкісних аркто-альпійських видів рослин у високогір'ї Українських Карпат зумовлена в основному пересиханням субстрату, сукцесійними процесами та збільшенням площ чагарників, чагарничків і щільнодернинних угруповань. Для збереження оселищ, яким загрожує зникнення внаслідок демутації (*Lloydia serotina* на горі Великі Кізли*, Carex pauciflora* на горі Шандриаська та в урочищі Цибульник*, Cerastium alpinum* subsp. *lanatum* на горі Ребра), потрібно застосовувати заходи активної охорони – вилучати більш конкурентноспроможні й агресивні види.

Ключові слова: оселища, зміни клімату, популяції, угруповання, Українські Карпати, аркто-альпійські види

Одержано: 19.01.2018