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THE EUROPEAN SNOW VOLE (*CHIONOMYS NIVALIS*) IN UKRAINE: A SPECIES IN THE FAR NORTHEAST OF ITS DISTRIBUTION

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The European snow vole (*Chionomys nivalis*) in Ukraine: a species in the far northeast of its distribution. — Zoltán Barkaszi. — The European snow vole is a widespread rodent species of Europe having a highly fragmented range and a number of isolated populations. The species' distribution is mainly restricted to high mountains of Europe and Asia Minor. The European snow vole is represented in the mammal fauna of Ukraine by an isolated population in the subalpine zone of the Carpathians. An extensive survey of all collection samples of the species deposited in zoological museums of Ukraine was conducted, including analysis of 149 available specimens. The paper presents a review of all known records of the species in Ukraine with an updated map of distribution. Morphological features of the local isolated population belonging to the subspecies *C. n. ulpius* is also presented with a focus on external and craniometrical features of adult specimens. The European snow vole is a rather large rodent compared to other vole species of the local fauna. No sex-related variation by linear body dimensions was revealed in adult specimens of the species. Analysis of craniometrical characters and its comparison with that of two other subalpine vole species (*Microtus agrestis* and *Terricola subterraneus*) showed a substantial distinctness of the European snow vole, which might be related to existing niche differentiation between the three vole species supporting stability and low trophic and spatial competition within the subalpine rodent complex. The current state of the local snow vole population along with the specifics of its habitat preferences in the Ukrainian Carpathians are discussed with particular attention on its role in the local subalpine small mammal community as an indicator species. The abundance of the species in the Ukrainian Carpathians is quite high within the species' key habitats. In particular, the European snow vole dominated in samples trapped in all types of plant associations of the Chornohora massif. As an endemic and relict species with a restricted distribution, the European snow vole is protected in Ukraine and listed as vulnerable in the Red Data Book of Ukraine. Current conservation issues are discussed along with possible measures necessary for sustainable development of the Ukrainian snow vole population.

Key words: snow vole, distribution, morphology, habitat selection, species conservation.

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Introduction

The European snow vole (*Chionomys nivalis*) has a fragmented distribution range mostly related to the main mountain systems from the Iberian Peninsula to Turkmenistan and northern Iran (Yannic et al., 2012; Barros et al., 2015). The westernmost records of the species were reported from northwest Portugal (Barros et al., 2015). Despite the fact that *C. nivalis* is usually found in mountain habitats, physiologically the species is not fit for cold environment (Bienkowski, Marszalek, 1974) and depends on mesic microhabitats of rocky biotopes (Luque-Larena et al., 2002) regardless of altitude (Kryštufek, Kovačić, 1989), thus the European snow vole may also occur is lowland rocky habitats (Amori, 1999).

The genus *Chionomys* was considered within the genus *Microtus* for a long time (Wilson, Reeder, 2005). Later it was revealed that *Chionomys* forms a line distinct from *Microtus* by a set of criteria (Nadachowski, 1991; Jaarola et al., 2004). The genus includes three species — *C. nivalis*, *C. gud*, and *C. roberti* — among which the European snow vole has the widest, though highly fragmented, geographic range (Janeau, Aulagnier, 1997; Wilson, Reeder, 2005).

The current distribution of snow voles is related to the features of their evolutionary history. In particular, insular effect of isolated mountain populations and the stenobiontic nature of the species played the main role in the formation of the current phylogenetic structure of all snow vole species

(Bannikova et al., 2013). Several, at times even controversial, views were proposed regarding the ways of evolution of snow voles. Studies of fossils showed that *C. nivalis* appeared simultaneously in Europe and Anatolia in the Middle Pleistocene with subsequent expansion from Europe to Turkey, the Caucasus and Kopet-Dag, while *C. gud* and *C. roberti* appeared in the Caucasus only during the Late Pleistocene (Nadachowski, 1991; Rekovets et al., 2014). The range of both species is still restricted to this region (Janeau, Aulagnier, 1997). Morphological (Kryštufek, 1999) and phylogeographic studies (Castiglia et al., 2009) also supported the hypothesis on the European origin of *C. nivalis*.

However, further research on *Chionomys* phylogeography showed a Caucasian and Near Eastern origin of all three snow vole species with a subsequent westward dispersal of *C. nivalis*. In particular, phylogeographic reconstructions based on both mtDNA and Y-chromosome showed that the easternmost subspecies of *C. nivalis* (*C. n. dementievi*) represents the most ancient lineage within the species, which clearly suggests the eastern origin of the European snow vole (Yannic et al., 2012). Besides, most of the mitochondrial lineages of the European snow vole are related to separate geographic regions and mainly correspond to subspecies designated earlier (Bannikova et al., 2013), the number of which currently is up to 18 (Nadachowski, 1991).

In Ukraine, *C. nivalis* occurs only in the Carpathians (Barkaszi, Zagorodniuk, 2016 a), where it was first recorded in 1932 in the Chornohora (Sagan, 1934). In the Gorgany massif, another key locality of the species in Ukraine, the European snow vole was first recorded only in 1984 on Khomiak Mt in thickets of the creeping pine (Rogatko, 1984). The Ukrainian population represents the most northeastern segment of the species' range. The European snow vole is represented here by the subspecies *C. n. ulpius*, which also occurs in the Romanian Carpathians and from which the Ukrainian population is entirely isolated (Kowalski, 1957; Bannikova et al., 2013). This subspecies is closer to the Alpine subspecies than to *C. n. mirhanreini* of the Tatra Mts, which supports the hypothesis of colonisation of the Carpathians by the snow vole from a southeastern direction (Kowalski, 1957; Dorková et al., 2016).

In Ukraine, the European snow vole is considered a rare endemic species being under protection (Zagorodniuk, Kyseliuk, 2009). Knowledge on this species is fragmentary, thus the aim of the present report is to summarise and clarify the features of distribution and morphology of the European snow vole based on available museum collection data and to address current issues of the species' conservation.

Material and Methods

Study-skins and/or skulls of 149 specimens of the European snow vole deposited in five zoological collections of Ukraine were studied (Fig. 1), including the National Museum of Natural History NAS of Ukraine, Kyiv (NMNH), State Museum of Natural History NAS of Ukraine, Lviv (SMNH), Schmalhausen Institute of Zoology NAS of Ukraine, Kyiv (IZAN), B. Dybowsky Zoological Museum of Ivan Franko National University of Lviv (ZMD), and Zoological Museum of Taras Shevchenko National University of Kyiv (ZMKU).

Features of external morphology were studied on study-skins. Linear body dimensions (L, body length; Ca, tail length; Pl, hindfoot length; Au, auricle length) were taken from the labels of specimens. Additionally, 12 craniometrical characters were studied: CBL, condylobasal length; ZYG, zygomatic width; M13, coronal length of upper molars; BUL, auditory bulla length; CRH, braincase height; CRB, braincase width between ectotympanici; IOR, interorbital constriction width; NAL, nasal bones length; NAB, nasal bones width; ROH, rostral height; FIL, incisive foramina length; and FIB, incisive foramina width. Cranial measurements were taken by calliper with an accuracy of 0.1 mm. Metric data of adult specimens were analysed using tools of MS Excel, Past 3, and Statistica 10. General statistics were calculated (min, minimum value; max, maximum value; mean, mean value; SD, standard deviation; CV, coefficient of variation) and methods of multivariate analysis were applied (principal component analysis, discriminant analysis).

Cartographic data were processed in QGis 3. Drawings were prepared in Corel Draw X7.

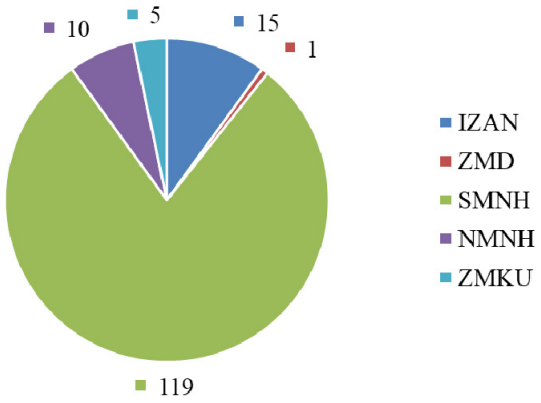

Fig. 1. Number of *C. nivalis* specimens in the studied museum collections.

Рис. 1. Кількість зразків *C. nivalis* у досліджених музейних колекціях.

Results and Discussion

Patterns of distribution

The distribution of the European snow vole in the Ukrainian Carpathians is restricted to the highest elevations. The species' records are known from two large massifs, the Chornohora and Gorgany, where *C. nivalis* was found in associations of the creeping pine (*Pinus mugo*), Carpathian rhododendron (*Rhododendron myrtifolium*), and evergreen sedge (*Carex sempervirens*), as well as in stone fields (Tatarinov, 1956; Korchynsky, 1988; Zagorodniuk, 1993).

Records of the European snow vole are known from nine localities within the Chornohora and Gorgany, in particular from Hoverla Mt, Petros Mt, Baltsatul Mt, Breskul Mt, Menchul-Kvasivskyi Mt, Vaskul Mt, Syniak Mt, Khomiak Mt, and Homul Mt (Fig. 2). Both massifs are located in the southern part of the Ukrainian Carpathians, which is characterised by the highest elevations (~ 1 500–2 061 m). Consequently, the altitudinal zonation of vegetation belts, in particular of krummholz and subalpine meadows (polonyna), here is the most clearly expressed compared to other parts of the Ukrainian Carpathians.

According to Tatarinov (1956), the distribution of the European snow vole in the Carpathians is related exclusively to the presence of krummholz belt and separate types of plant communities and in the Chornohora the species occurs at 1600 to 1950 m asl. However, it is clear now that the European snow vole is a specialised rock-dwelling species (Luque-Larena et al., 2002), and its distribution in the Ukrainian Carpathians restricted to the Chornohora and Gorgany is related to the presence of rocky habitats in these very massifs (Fig. 3).

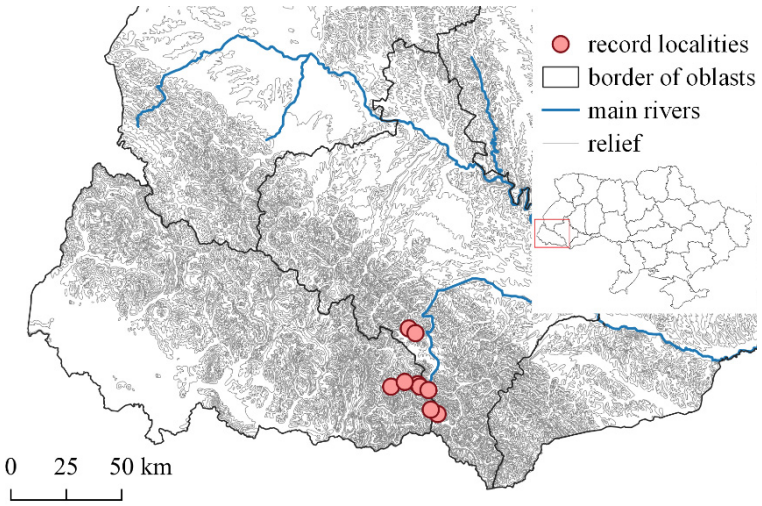

Fig. 2. Record localities of the European snow vole (*C. nivalis*) in Ukraine

Рис. 2. Знахідки полівки сніговой (*C. nivalis*) в Україні

Fig. 3. Subalpine landscape of the Chornohora with stone fields and thickets of *Pinus mugo*, the type habitat of the European snow vole in the Ukrainian Carpathians. Courtesy of Volodymyr Rizun.

Рис. 3. Субальпійський ландшафт Чорногори з кам'янистими розсипами та заростями *Pinus mugo* — типовий біотоп полівки снігової в Українських Карпатах. Фото Володимира Різуна.

The rock-dwelling nature of the European snow vole and its absence in other parts of the Ukrainian Carpathians where the krummholz belt is also present is in full compliance with the revealed pattern of the species' preference of separate characteristics of the environment. Particularly that the European snow vole shows a higher level of association with scree compared to neighbouring, and also available, areas of shrubs (Luque-Larena et al., 2002).

Stone fields are formed under conditions of frosty climate, nival or periglacial (Maruashvilli, 1986). In the Ukrainian Carpathians, stone fields are the most common for the Gorgany massif, where scree may cover up to 100 % of the surface of mountaintops, and up to 75 % of ridges and slopes (Veselova, 2012).

The placement of stone fields in the Gorgany is mainly influenced by lythological and climatic factors. Relict Pleistocene forms of stone fields were also revealed here (Veselova, 2012), which allows suggesting that the snow vole population in this massif is also of relict origin and the loss of its connection with other segments of the species range is a result of postglacial climatic changes.

Features of morphology

The snow vole has clear morphological differences compared to other vole species. The fur colouration of *C. nivalis* in the Ukrainian Carpathians is monochrome, grey with a brownish tint, slightly darker in the upper part of the body.

Compared to other voles of the Ukrainian Carpathians, *C. nivalis* has also relatively larger body dimensions (Table 1). The body length in adults is 110–150 mm, while hindfoot length is up to 25 mm. Males and females are practically identical ($D^2_M = 0.24$, $p = 0.345$) by the four external body characters (Fig. 4), although hindfoot length tends to have higher values in males ($F = 4.26$, $p < 0.05$). The highest loading on PC1 has the body length (0.954), while tale length on PC2 (0.949). PC1 also describes 84 % of the total variance, while PC2 describes 13 %, and PC3 and PC4 describing the rest (2 and 1 %, respectively).

Craniometrical characters (Table 2) were studied on 16 available skulls of adult specimens (most of the museum specimens are represented by study-skins only). Based on craniometrical characters, the European snow vole also differs from other vole species of the local fauna by larger dimensions. In particular, condylobasal length of the skull ranges from 26.2 to 29.3 mm, while the coronal length of upper molars is up to 7.2 mm. Among the 12 characters studied, braincase width (CRB) and height (CRB) are the least variable; a similar pattern was revealed earlier in other voles of the Ukrainian Carpathians (Barkaszi, 2017). Higher coefficients of variation are shown mainly for characters of width of the distal part of the skull (e.g., zygomatic width, width of incisive foramina and of nasal bones). Additionally, relatively high correlations were revealed between M13 and FIL ($r = 0.66$, $p = 0.005$) and M13 and IOR ($r = -0.59$, $p = 0.02$).

Table 1. External metric characters of adult specimens of *C. nivalis* from the Ukrainian Carpathians
Таблиця 1. Екстер'єрні метричні ознаки дорослих особин *C. nivalis* з Українських Карпат

Character	N	Min, mm	Max, mm	Mean, mm	SD	CV, %
All specimens						
L	82	110	150	128	10.94	8.56
Ca	82	52	75	61	5.45	8.90
Pl	82	18	25	21	1.38	6.67
Au	82	14	23	18	1.91	10.92
Males						
L	32	112	148	129	10.44	8.12
Ca	32	43	72	61	6.14	10.10
Pl	32	19	25	21	1.63	7.71
Au	32	15	23	18	1.98	11.28
Females						
L	50	110	150	127	11.33	8.90
Ca	50	46	75	61	5.99	9.83
Pl	50	18	24	20	1.15	5.63
Au	50	14	18	17	1.88	10.79

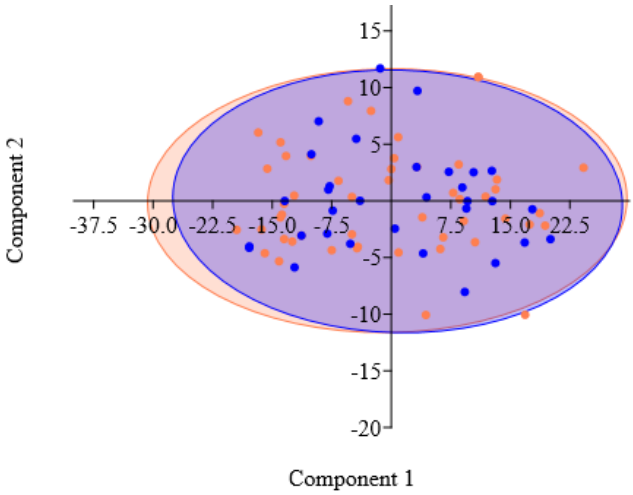

Fig. 4. Distribution of adult male (blue) and female (orange) specimens of *C. nivalis* from the Ukrainian Carpathians in the space of PC1 and PC2 by linear body dimensions.

Рис. 4. Розподіл дорослих самців (синій) і самок (оранжевий) *C. nivalis* з Українських Карпат у просторі ГК1 та ГК2 за лінійними розмірами тіла.

Table 2. Craniometrical characters of adult specimens of *C. nivalis* from the Ukrainian Carpathians
Таблиця 2. Краніометричні ознаки дорослих особин *C. nivalis* з Українських Карпат

Character	N	Min, mm	Max, mm	Mean, mm	SD	CV, %
CBL	8	26.2	29.3	27.7	1.08	3.88
ZYG	14	14.1	16.6	15.3	0.78	5.08
M13	16	6.3	7.2	6.7	0.21	3.12
BUL	16	7.1	8.5	7.8	0.42	5.37
CRH	7	10.5	11.3	10.8	0.27	2.49
CRB	8	13.4	14.1	13.8	0.28	2.03
IOR	16	4.0	4.7	4.4	0.19	4.29
NAL	16	7.3	8.4	8.0	0.31	3.84
NAB	16	3.3	4.1	3.7	0.22	5.85
ROH	16	6.9	7.6	7.2	0.20	2.80
FIL	16	4.7	5.8	5.3	0.24	4.56
FIB	16	1.4	1.7	1.6	0.10	6.19

The European snow vole in the Ukrainian Carpathians is one of the key species of the subalpine rodent complex along with the field vole *M. agrestis* and the European pine vole *T. subterraneus* (Barkaszi, Zagorodniuk, 2016 b). A comparison of these three species based on 8 craniometrical characters[1] (Fig. 5) demonstrated their clear and statistically relevant differentiation ($p \leq 0.01$) by most of the characters (M13, IOR, ROH, FIL, and FIB), which suggests a significant niche divergence and specialisation. The snow vole is tightly associated with rocky habitats, while the field vole and the European pine vole prefer the mosaic of subalpine meadows and krummholz.

The field vole and the European pine vole have practically the same spatial and trophic niche components, although *T. subterraneus* tends to spend more time underground and characterised by a more intense digging activity (Istomin, 1990), which may also explain dimensional differences between the European pine vole and the field vole. In general, all these differences between these species might be related to maintaining stability and low levels of trophic and spatial competition within the subalpine rodent complex existing under conditions of limited environmental resources. These three vole species can be easily identified in museum collections by odontological and craniometrical characters, for which we propose a simple and convenient key (Table 3, Fig. 6).

The three species differ in the morphology of the first lower molar, which have six lobes and five triangles in all species. However, the dentine fields of the fifth (t5) and sixth (t6) triangles are fused in *T. subterraneus* (and in its sibling species *T. tatricus* as well) while separated in *M. agrestis* and *C. nivalis*. The latter differs in the structure of anteroconid complex, which is characterised by rudiments of a seventh lobe and sixth triangle (see the arrow on Fig. 6).

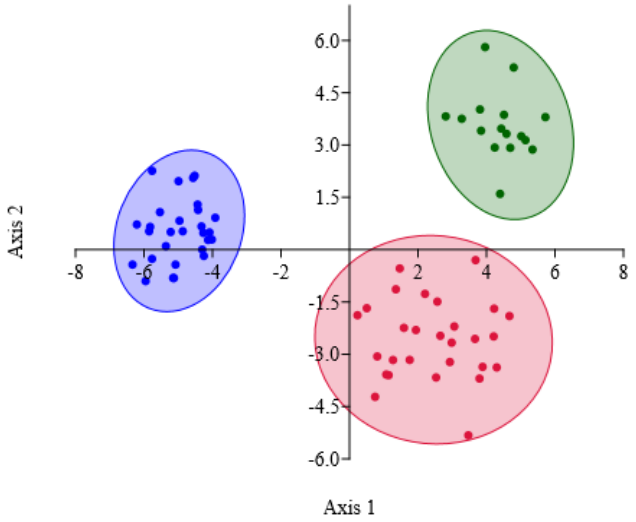

Fig. 5. Distribution of adult specimens of *C. nivalis* (green), *M. agresis* (red) *T. subterraneus* (blue) from the Ukrainian Carpathians in the space of the first and second canonical axes by 8 craniometrical characters.

Рис. 5. Розподіл дорослих особин *C. nivalis* (зелений), *M. agresis* (червоний) та *T. subterraneus* (синій) з Українських Карпат у просторі першої та другої канонічних осей за 8 краніометричними ознаками.

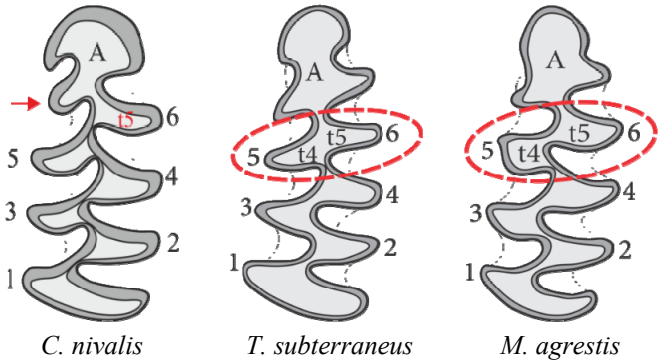

Fig. 6. Morphology of the first lower molar (m1) in subalpine vole species of the Ukrainian Carpathians.

Рис. 6. Морфологія першого нижнього моляра (м1) у субальпійських видів полівок Українських Карпат.

[1] Characters represented the most fully in *C. nivalis* (n = 16, see Table 2) were taken for comparison.

Table 3. Key for identification of subalpine vole species of the Carpathians by craniometrical characters
Таблиця 3. Ключ для ідентифікації субальпійських видів полівок Карпат за краніометричними ознаками

	Characters		Species
1	CRH < 8 mm, CRB < 12 mm, M13 < 6 mm	→	*Terricola subterraneus*
—	CRH > 8 mm, CRB > 12 mm, M13 > 6 mm	→	2
2	CRH < 10.5 mm, IOR < 4 mm	→	*Microtus agrestis*
—	CRH > 10.5 mm, IOR > 4 mm	→	*Chionomys nivalis*

Based on craniometrical characters, the European snow vole, the field vole and the European pine vole can be distinguished by dimensions of the braincase, length of the row of upper molars and width of the interorbital constriction (Table 3).

Population management and conservation

Montane rodents play an important role in high-altitude ecosystems having a direct impact on vegetation and as important prey for carnivores and raptors. Montane populations of voles seem to be remarkably stable compared to those in lowland and arctic regions (Allainé, Yoccoz, 2003).

In the Ukrainian Carpathians, the abundance of the European snow vole within its type habitats is quite high. In particular, the species dominated in trappings in all plant associations of the Chornohora, from 61.5 % in the green alder up to 100 % in the evergreen sedge and in the creeping pine on Hoverla Mt (Rudyshin, 1961). However, the general abundance of the European snow vole in the Ukrainian Carpathians is estimated in 41–91 specimens per ha, which is rather low, and the general portion of the species among small mammals of the Carpathians is 0.1 % or less (Zagorodniuk, Kyseliuk, 2009). Presumably, the species' abundance is largely influenced by its population's insularity, small specific area of habitats occupied by the species, and relatively small population growth (Korchynsky, 1988) due to short period of warm season at high elevations, where the species feeds on green parts of vegetation, occasionally also on insects and their larvae (Rudyshin, 1975). Nonetheless, we can suggest that the snow vole population in the Ukrainian Carpathians is rather stable.

As a relict and endemic species and a specialised rock-dwelling high mountain species of the Ukrainian Carpathians, the European snow vole can be considered as an indicator species of montane communities, as well as a model object for monitoring and evaluation of environmental changes in mountainous region. In Ukraine, *C. nivalis* has a status of vulnerable species (Zagorodniuk, Kyseliuk, 2009), and most of its range is practically located within the area of the Carpathian National Park and Carpathian Biosphere Reserve, where direct anthropogenic influence on the species' population is significantly limited. Among the natural factors that might have an impact of the further state of the snow vole population in the region is the tree line shift. The formation of the current tree line in the Carpathians is tightly related to postglacial vegetation changes and human activity (Klymyshyn et al., 2007 b). The tree line in the Ukrainian Carpathians is lowered by 200–300 m and in most massifs is located at 1 100–1 200 m asl and the natural tree line has remained only in several places in the Chornohora, Marmarosh Mts, Chyvchyny Mts, and Gorgany, reaching the highest elevations of 1 600–1 700 m in the Chornohora (Klymyshyn et al., 2007 *b*). Results of monitoring of vegetation dynamics on the ecotone of the upper forest and subalpine belts showed a considerable upward shift of the tree line after elimination of anthropogenic pressure, especially after providing strict conservation regime (Klymyshyn et al., 2007 *a, b*) leading to contraction of the area of open and semi-open habitats in the subalpine belt.

Currently, effective protection of *C. nivalis* in Ukraine may be achieved under conditions of strict conservation measures in areas of the species' occurrence and by possible formation of ecological corridors between isolated fragments of the local population to increase genetic diversity. Special attention should be paid to the Svydovets massif which connects the Chornohora and Gorgany and where the species also might occur (special studies have not been conducted here). Therefore, conservation of natural habitats of high-altitude massifs, particularly of the Gorgany, Svydovets, and Chornohora, is essential for the European snow vole's protection in the Ukrainian Carpathians.

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