



OSTEOLOGICAL MATERIAL AND THE POPULATION STATE OF THE SPECKLED GROUND SQUIRREL (*SPERMOPHILUS SUSLICUS*) ON THE PERIPHERY OF THE SPECIES' DISTRIBUTION (BELARUS)

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Abstract

The studies were carried out in 2021 near the village of Yushevichi, Nesvizh Raion, Minsk Oblast (Belarus). The content of pellets of three bird species were analysed: *Buteo buteo*, *Buteo lagopus*, and *Corvus corax*. In total, 129 intact and about 30 destructed pellets were processed. Skeletal elements of five small mammal species belonging to five genera of two orders (Rodentia and Eulipotyphla) were found, including remains of nine speckled ground squirrels. The remains of seven of the nine ground squirrel individuals found in the pellets were found in raven pellets, however, the authors believe that this fact does not yet prove a greater influence of the raven on the local ground squirrel population. The pellets analysis and observations of feeding behaviour of the three bird species prove that the speckled ground squirrel is constantly included in the diet of both diurnal birds of prey (genus *Buteo*) and of atypical predators with a mixed nutrition (raven). Finding of intact skulls of *Spermophilus suslicus* in pellets of the mentioned bird species is unlikely, which is determined by its considerable size. This circumstance does not allow obtaining most of the craniometric characters, but does not prevent the detection of pathomorphological changes. To compare the craniological characters, we used the skulls of dead ground squirrels (n = 5) found in the field near the village of Yushevichi. These individuals had visible injuries (lacerated wounds, etc.) presumably left both by predators and fights between ground squirrels. The most striking pathomorphological changes were revealed: osteoporosis and osteolysis of dental alveoli of the upper and lower jaws and initial osteomyelitis of the cranial vault (in the parietal and frontal bones). We believe that the speckled ground squirrel's conservation status should be raised to at least Category II (according to the system of categories adopted in Belarus) for the following reasons: over the past six years, out of 12 known colonies, only four colonies have survived, two of which are practically unviable; stable for 10 years reduction in the number; and range fragmentation (single localities). According to the IUCN classification, it corresponds to category CR (critically endangered).

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Остеологічний матеріал і стан популяції ховраха крапчастого (*Spermophilus suslicus*) на периферії видового ареалу (Білорусь)

Олександр Саварін, Сергій Шокало

Резюме. Дослідження проведено у 2021 р. поблизу села Юшевичі Несвізьського району Мінської обл. Проаналізовано вміст пелеток трьох видів птахів: *Buteo buteo*, *Buteo lagopus* та *Corvus corax*. Розібрано 129 цілих та близько 30 неповних пелеток. Виявлено кістки скелета п'яти видів дрібних ссавців, що належать до 5 родів з двох рядів (Rodentia та Eulipotyphla), у т.ч. ховрахів крапчастих. Рештки семи із дев'яти виявлених у пелетках особин ховраха випадають на пелетки ворона, попри це, автори вважають, що цей факт ще не доводить більшого впливу ворона на місцеву популяцію ховраха. Аналіз вмісту пелеток та спостереження за кормовою активністю трьох видів птахів свідчать, що ховрах крапчастий входить до основного раціону як денних хижих птахів (рід *Buteo*), так і нетипових хижаків, що мають змішаний тип живлення (ворон). Знахідка цілого черепа *Spermophilus suslicus* у пелетках названих видів птахів малоймовірна, що визначається значними його розмірами. Ця обставина не дозволяє отримати більшість краніометричних характеристик, проте не заважає виявленню патоморфологічних змін. Для порівняння краніологічних характеристик використовували черепи загинувших ховрахів (n = 5), знайдених на полі біля Юшевичі. Ці особи мали видимі пошкодження тіла (рвані рани тощо), що передбачає вплив на їхню елімінацію травм, що отримані в результаті нападів хижаків, а також внаслідок бійок між ховрагами. Виявлено найбільш яскраві патоморфологічні зміни: остеопороз та остеоліз в області коренів зубів на верхній та нижній щелепах, ділянки склепіння черепа (у тім'яній та лобовій частках), що зазнали остеомієліту (у початковій стадії). Вважаємо, що природоохоронний статус ховраха крапчастого має бути підвищений щонайменше до II категорії (за системою категорій, прийнятих в Білорусі) з таких причин: за останні шість років, із 12-ти відомих колоній збереглося тільки чотири, з яких дві нежиттєздатні; стабільне протягом останніх 10 років скорочення чисельності; фрагментарність поширення (поодинокі локалітети). За класифікацією МСОП це відповідає категорії CR (critically endangered).

Ключові слова: Білорусь, *Spermophilus suslicus*, пелетки птахів, хижацтво, кістки, патологія, загроза виживанню.

Introduction

The speckled ground squirrel (*Spermophilus suslicus*) is one of the rare species of the Belarusian mammal fauna; it is included in the Red Data Book (category III of national environmental significance). Whereas only two or three years ago this rodent's colonial settlements were preserved in four administrative districts (Nesvizh, Stolbtsy, Baranovichi, and Kopyl) of Minsk Oblast [Abramchuk *et al.* 2021], at present they are recorded only in Kopyl and Nesvizh raions. The largest colony is on the outskirts of the village of Yushevichi, Nesvizh Raion [Shokalo & Yankevich 2022]. According to the estimates of specialists as of the spring of 2020, the total number of speckled ground squirrels in all known residential colonies of Belarus was about 5000 individuals.

The main unfavourable factors for the speckled ground squirrel colonies in the region are deep land ploughing and the overgrowth of habitats with vegetation due to the lack of cattle grazing on pastures [Shokalo & Yankevich 2022]. To preserve the species' abundance, it is important not only to conduct monitoring observations, but, above all, to identify inhabited areas. It is advisable to do this without removing the animals from their environment (using only dead animals, bird pellets, followed by small mammal craniological characteristics analysis).

Ground squirrels are part of the diet of several predatory mammals (foxes, mustelids, stray dogs and cats) and birds (western marsh and hen harriers, rough-legged buzzards, kestrel, northern goshawk, lesser spotted eagle, black kite, grey heron, and corvids) [Petrovsky 1960; Korepov 2012; Tokarsky 2014; Wojtaszyn *et al.* 2015; Shokalo 2019]. The impact of adverse factors and the elimination of individuals is especially severe in small, isolated colonies.

In the Belarusian theriological literature, there is no information on findings of speckled ground squirrel bones in pellets of birds of prey. The variability of some cranial measurements is indicated in the publications of Obolensky [1927], Mikholap [1956], Petrovsky [1960], and Serzhanin [1961]. Obolensky collected material ($n = 6$) in Slutsk Raion of Minsk Oblast, Mikholap ($n = 160$) in Minsk and Brest oblasts, Serzhanin ($n = 198$) in Nesvizh and Kopyl raions of Minsk Oblast and in Lyakhovichi Raion of Brest Oblast. Petrovsky [1961] examined 814 individuals from various regions of Belarus. His dissertation abstract does not specify the number of measured skulls, while the dissertation text itself gives the average measurements of male ($n = 63$) and female skulls ($n = 79$). Theriological monographs and guides published later in Belarus [for example, Savitsky *et al.* 2005] contain mainly information borrowed from the works of Petrovsky.

The objectives of the work are to assess the prospects of the species' conservation, to give a preliminary assessment of the trophic impact of birds on the speckled ground squirrel settlements, and to describe the skull pathologies identified in individuals that died from unknown causes and in the bone fragments found in pellets.

Materials and Methods

The collection of pellets of three bird species (*Corvus corax*, *Buteo buteo*, and *Buteo lagopus*) was carried out mainly in June 2021 (one pellet in March) near the village of Yushevichi, Nesvizh Raion, Minsk Oblast, Belarus. The study site is an agricultural land used mainly for grazing and haymaking (Fig. 1 *a*). These bird species are common in this area.

Pellets of *B. buteo* were collected under wooden poles set up along the cattle driveways where buzzards prefer to roost (Fig. 1 *b*). The collection of *B. lagopus* pellets was carried out on elevated areas and hillocks where the birds prefer to hunt.

Crow pellets were found in feeding grounds of fledglings on the low-flow canal stop-gate and around it. Adult birds flew with the caught animals to where the nestlings were and fed them. Several pellets were found under a water tower, a favourite place for butchering caught rodents by adult birds (Fig. 1 *c, d*).

In total, 129 intact pellets were analysed: 88 of the common buzzard; 23 of the rough-legged buzzard, 6 of the common and rough-legged buzzards (pellets from both species), and 12 of the crow (and additionally about 30 destructed pellets).

The age of animals found in the pellets was determined according to the pattern of exposed dentin on worn teeth of the upper jaw [Petrovsky 1961; Lobkov 1999].

To compare the craniological characteristics, we used the skulls of dead ground squirrels ($n = 5$, sex not determined) found in the field near the village of Yushevichi (Fig. 2). It is impossible to establish their exact cause of death. However, it should be noted that all of them had visible injuries on the body (lacerations, etc.), which suggests an influence of predators and fights between ground squirrels on their elimination.

Under skull pathologies, we understand morpho-anatomical changes that lead to a decrease in its mechanical strength, disrupt the function of structural elements, can cause pain syndromes, and facilitate the penetration of pathogenic microorganisms. In the pellets, the skull bones were broken to some extent, but this does not prevent the identification of structural parts with signs of pathophysiological processes [Love 2009]. Therefore, various pathology forms and their frequency analysis based on bone remains in the pellets is an effective method in assessing the population viability. This method is of particular importance in the study of rare species, including the speckled ground squirrel.

Results and Discussion

Small mammals in the diet of birds

Bones of five small mammal species belonging to two orders (Rodentia and Eulipotyphla) and five genera were found in the pellets of the common and rough-legged buzzards and raven (Table 1).



Fig. 1. Collecting locality of pellets: field near the village of Yushevichi (a), common buzzard (b) and raven (c, d) with food objects.

Рис. 1. Місце збору пелеток — поле біля с. Юшевичі (a), канюк (b) і ворон (c, d) з кормовими об'єктами.



Fig. 2. Dead individuals of the ground squirrel with varying degrees of injury.

Рис. 2. Мертві особини ховраха з різним ступенем травматизму.

Table 1. The composition and quantitative ratio of food objects of birds

Таблиця 1. Склад і кількісне співвідношення харчових об'єктів птахів

Species	<i>Buteo buteo</i> (n = 88)		<i>Buteo lagopus</i> (n = 23)		<i>Buteo</i> sp. (n = 6)		<i>Corvus corax</i> (n = 12, with crumb)	
	N	%	N	%	N	%	N	%
<i>Microtus arvalis</i>	42	91.30	35	94.59	5	71.43	5	38.46
<i>Apodemus agrarius</i>	3	6.52	1	2.70	1	14.29	–	–
<i>Rattus norvegicus</i>	–	–	–	–	–	–	1	7.69
<i>Spermophilus suslicus</i>	1	2.17	–	–	1	14.29	7	53.85
<i>Talpa europaea</i>	–	–	1	2.70	–	–	–	–

The main food item of the two *Buteo* species was the common vole (>90% of all prey). *Microtus arvalis* and *A. agrarius* are typical meadow–field species. The role of the striped field mouse and the speckled ground squirrel in the diet of these predators is secondary. It is known that buzzards are ecologically plastic and prey on dozens of vertebrate species. Certain prey type dominance in the diet is due to the landscape, hydrological, and phytocoenotic features of the predators' habitat.

It should be noted that in the territory of Ukraine, the speckled ground squirrel is also part of the diet of *B. buteo* (according to Redinov [2012], it is an accidental prey). Our observations suggest that under the conditions of the study site (a field near the village of Yushevichi), the trophic impact of these predators on the ground squirrel population may be higher due to their high abundance.

According to preliminary data, the raven exerts a stronger effect on the ground squirrel number than the *Buteo* species. This is evidenced by the fact that of the nine speckled ground squirrels found in all the pellets, seven were found in raven pellets. Considering the discovery of ground squirrel bones in one crow pellet in March 2021, that is, before the breeding season of these mammals, our assumption seems to be more reasonable. In addition, we observed crows taking small mammals from other carnivorous birds including grey herons, harriers, and rough-legged buzzards. However, the raven, unlike the typical *Buteo* predators, also picks up rodents that died for various reasons. It is possible that this circumstance influenced the preliminary data on the trophic impact of these birds on the local speckled ground squirrel population.

Speckled ground squirrel bones in the pellets

Of the large bone parts in the common and rough-legged buzzard pellets, left lower jaw and fragments of the skull roof of the speckled ground squirrel were found. In the raven pellets, the lower jaws and skull fragments with upper teeth, skull roof parts, forelimb (forearm with a hand) and pelvic bone (Fig. 3, 3–6, respectively) were found. The complete *S. suslicus* skull discovery in the pellets of the named bird species is unlikely due to its significant size (the condylobasal length is about 4 cm or more). This circumstance does not allow obtaining the majority of craniometric characters but does not interfere with the detection of pathomorphological changes.



Fig. 3. Bones in the pellets: (1, 3) lower and upper jaws; (2, 4) cranial vault fragments; (5) forelimb; (6) pelvic bone.

Рис. 3. Кістки в пелетках: (1, 3) нижня та верхня щелепи; (2, 4) фрагменти склепіння; (5) передня кінцівка; (6) тазова кістка.



Fig. 4. Dorsal (a), ventral (b) and lateral (a) views of the skull (adult): (1) condylobasal length; (2) zygomatic width; (3) interorbital width; (4) length of upper diastema; (5) length of upper cheek teeth.

Рис. 4. Дорзальна (a), вентральна (b) та латеральна (c) сторони черепа (доросла особина): (1) конділобазальна довжина; (2) вилична ширина; (3) міжорбітальна ширина; (4) довжина верхньої діастеми; (5) довжина верхнього ряду щічних зубів.

Table 2. Skull measurements of *Spermophilus suslicus* from the territory of Belarus: min–max (mean)

Таблиця 2. Проміри черепа у особин *Spermophilus suslicus* з території Білорусі: min–max (середнє)

Skull measurements	Our data (n = 5)	Obolensky 1927 (n = 6)	Petrovsky 1960 (n = 142)	Serzhanin 1961 (n = 198)
Condylobasal length	39.2–42.7 (41.0)	39.1–41.5 (40.4)	38.3–44.8 (41.4)	38.5–46.1 (–)
Zygomatic width	26.7–27.5 (27.1)	26.0–29.0 (27.0)	25.7–29.9 (27.6)	25.2–30.1 (–)
Interorbital width	8.7–9.7 (9.2)	7.3–8.3 (7.8)	7.6–10.3 (9.1)	–
Length of nasal bones	15.0–16.7 (15.7)	15.0–16.3 (15.7)	13.6–18.7 (15.9)	–
Length of upper diastema	10.8–11.5 (11.2)	9.9–11.5 (10.5)	9.3–12.9 (11.4)	9.8–12.5 (–)
Length of upper cheek teeth	8.7–9.2 (9.0)	8.7–9.9 (9.5)	8.5–10.8 (9.5)	8.3–10.2 (–)

Skull measurements of speckled ground squirrels that died from unknown causes

We measured the condylobasal length, zygomatic and interorbital width (Fig. 4, 1–3, respectively), length of nasal bones, length of upper diastema and upper cheek teeth (Fig. 4, 4–5). For comparison, the same parameters of the speckled ground squirrel given in published works [Obolensky 1927; Petrovsky 1960; Serzhanin 1961] (Table 2) were used.

The table does not include information on the variation of individual craniometric characters of the speckled ground squirrel published by Mikholaп [1956]: in almost all measurements, they coincide with the results presented by Petrovsky [1960] and Serzhanin [1961].

Craniometric parameters obtained by us largely correspond to those presented by other specialists. The upper limit of condylobasal length indicated by Serzhanin [1961] and Mikholaп [1956] requires discussion: 46.1 mm and 48.2 mm, respectively. In a summary based on a study of Europe-

an collections [Kryštufek & Vohralík 2012], the limits of variation of condylobasal length in *S. suslicus* are 36.8–44.2 mm. The monograph by Lobkov [1999] presents data on speckled ground squirrel populations of Odesa Oblast of Ukraine and also does not mention the detection of individuals with unusually large skull measurements. Such a condylobasal length (46.1 mm or more) is possible for individuals of the European ground squirrel (*Spermophilus citellus*), but this species has not inhabited Belarus. In further studies, it is necessary to clarify the maximum condylobasal length in adults currently occurring in the territory of Belarus, which is the periphery of the species range of the speckled ground squirrel.

It should be noted that males have larger skull measurements, especially condylobasal length [Petrovsky 1960]. These sex differences are also characteristic of other geographic populations of the speckled ground squirrel [Lobkov 1999].

The skull measurements of specimens from the territory of Belarus correspond to those in other publications on ground squirrel craniology [Sinitsa *et al.* 2019].

Craniological analysis of speckled ground squirrels caught in the territory of present-day Belarus and kept in the collections of zoological museums in Ukraine is of particular interest [Zagorodniuk *et al.* 2021]. For instance, there are 61 ground squirrel skulls from Belarus in the collection of the National Museum of Natural History, National Academy of Sciences of Ukraine (Kyiv).

Pathologies in the skull and bone fragments from pellets

In the examined material, all bone fragments belong to adults, more than one-year-old individuals. The following most striking pathomorphological changes were revealed:

1. *Osteoporosis* is rarefaction of the bone structure leading to a decrease in its density and mechanical strength. In turn, the bone tissue porous structure facilitates the penetration of pathogenic microorganism. Osteoporosis manifests itself mainly in the dental alveoli of both jaws (Fig. 5). More than 60% of adults were found to have varying degrees of bone tissue damage. This pathology should be classified as diffuse osteoporosis. At high magnification (Fig. 5 c), the spongy substance large-loop pattern is well observed. Osteoporosis is a progressive metabolic bone disease.

2. *Osteolysis* is bone resorption without replacement by another tissue. It is most clearly manifested in dental alveoli of the lower jaw (Fig. 6) as a bone tissue ‘subsidence.’ In some cases (Fig. 6 b), the pathological process covers a significant part of the bone tissue, almost completely exposing the teeth roots. It appears in all individuals.

Osteolysis also happens due to a chronic pathophysiological process. Therefore, in young individuals, it will not have pronounced morpho-anatomical manifestations.

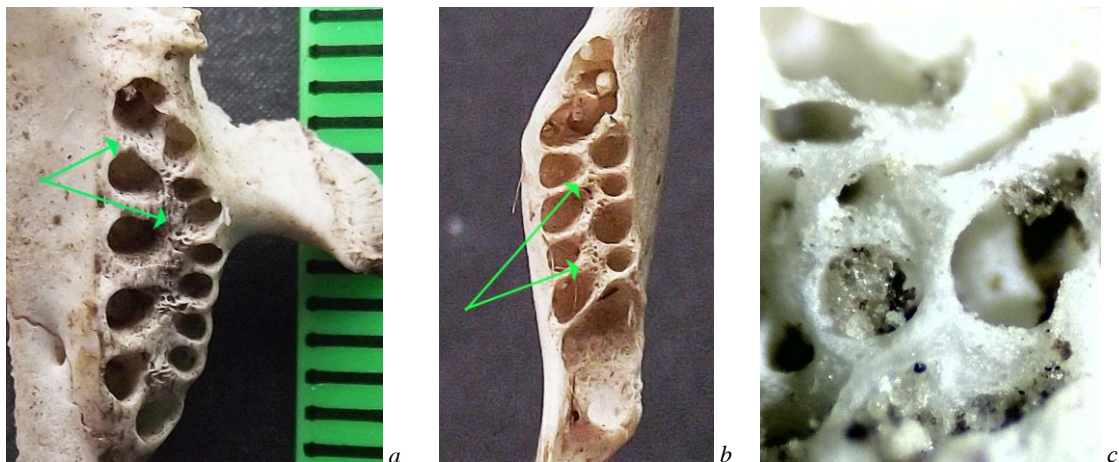


Fig. 5. Osteoporosis in the left upper (a) and left lower jaws (b). Magnification over 200x (c).

Рис. 5. Остеопороз у лівій верхній (a) та лівій нижній щелепах (b). Збільшення більше 200x (c).

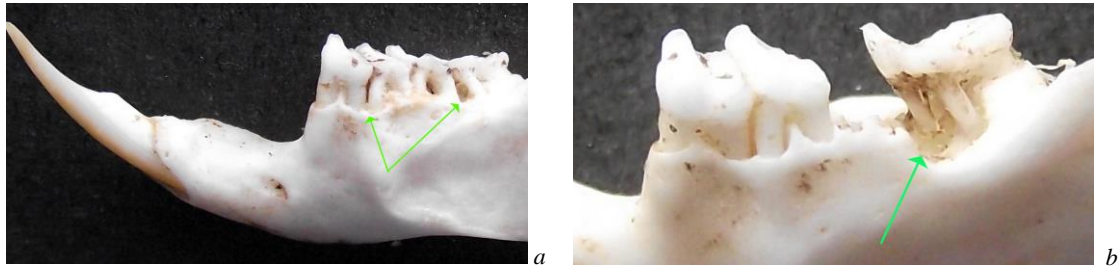


Fig. 6. Osteolysis of dental alveoli of varying degree exposing teeth roots.

Рис. 6. Остеоліз різного ступеня прояву в області коренів зубів.

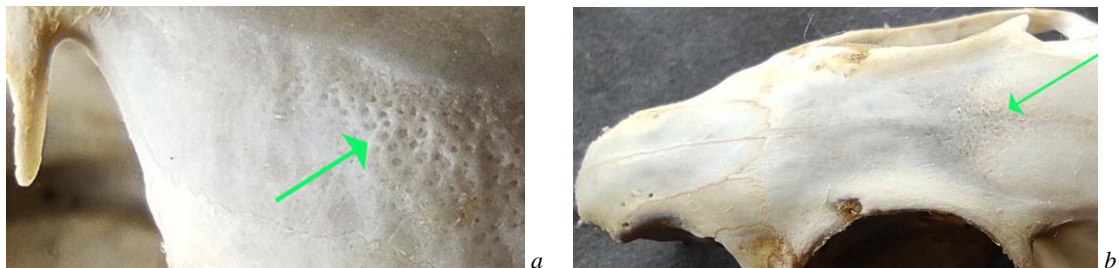


Fig. 7. Areas in the parietal (a) and frontal parts (b) of the cranial vault affected by osteomyelitis.

Рис. 7. Ділянки в тім'яній та лобових частках склепіння черепа, що зазнали остеомієліту.

3. *Cranial vault areas with initial osteomyelitis.* In one out of five skulls, in the parietal and frontal parts, 0.5–0.7 cm long areas with multiple small, rounded depressions were revealed (Fig. 7). In the same skull, a significant part of the facial and cranial sections was thinned ('translucent' bones).

This form of pathology was previously studied by us on a large sample of the northern white-breasted hedgehog from Belarus [Savarin 2015]. Subsequently, the skull areas affected by pathogenic microorganisms expand, forming deep and irregularly shaped recesses with separating fragments.

The revealed pathologies (osteoporosis and osteolysis) were registered in other small mammals as well by different specialists. However, their frequency in review papers, as a rule, is not given [e.g. Jentzsch *et al.* 2020], which is due to the lack of a common point of view among theriologists on the distinction between anomalies and pathologies. In adults and old specimens of the northern white-breasted hedgehog from Belarus, osteolysis is observed in almost 100% of cases, and in more than 80% of muskrats [Savarin 2015].

Other, presumably pathological, changes were also found in the skulls and require a deeper study on a larger sample.

Conclusions

The analysis of pellets and the observation of feeding behaviour of three bird species have revealed that the speckled ground squirrel is a regular part of the diet of both diurnal birds of prey (genus *Buteo*) and atypical predators with a mixed diet (raven). Most of the rodent bone fragments were found in raven pellets. We suggest that this fact does not yet prove a more significant raven impact on the local ground squirrel population.

In the examined material, osteoporosis was detected in 60%, and osteolysis in 100% of cases. Initial osteomyelitis was found in one out of five skulls. The small sample does not allow estimating the actual frequency of certain pathologies in the local speckled ground squirrel population. However, it can be argued that they are caused by a complex of factors, including metabolic disorders (osteoporosis) and infection by pathogenic microorganisms (osteolysis).

The speckled ground squirrel colony preservation in a relatively small, isolated area near the village of Yushevichi, Nesvizh Raion, currently seems to be problematic. The habitats of this species, which is listed in the Red Data Book of Belarus (2015), should be protected.

We suggest that the conservation status of the speckled ground squirrel should be upgraded to at least Category II (according to the system of categories adopted in Belarus) for the following reasons: 1) over the past six years, only 4 of the 12 colonies have survived, of which 2 are practically unviable; 2) stable for 10 years reduction in abundance; and 3) fragmented distribution (single localities). According to the IUCN classification, it corresponds to category CR (critically endangered).

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