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A NEW APPROACH TO THE ASSESSMENT OF CAVE ENVIRONMENTAL CHANGES (AS EXEMPLIFIED BY CAVES IN THE MURADIMOVSKOE USCHELIE NATURAL PARK)

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Abstract

The aim of the research detailed here has been to apply a new approach in assessing cave environmental changes – the so-called Cave Disturbance Index (CDI), relating to relief, water objects, air, vegetation and fauna (as the main geographical components of the cave environment) plus cultural aspects of recent cave use. Indicators coming under each of these categories are considered in detail and a quantitative estimation of total CDI then proposed. Practical application of the CDI method is then demonstrated by reference to caves situated in the Muradimovskoe Uschelie Natural Park (Southern Ural Mountains).

Key words

cave environmental changes • assessment • Cave Disturbance Index (CDI) • Ural Mountains

Introduction

In 2011 the traditional Classic Karst International Karstological School convened in Postojna (Slovenia) was devoted to "Karst Underground Protection". The participants at this international forum (more than 200 from 25 countries of Europe, Asia, South America and Australia) noted how karst caves in the 21st century are increasingly modified by human activity. Re-fitting of natural entrances, deformations of cave sediments, solid dumps, etc. are all resulting in potentially irreversible changes in the environments of caves, which are inherently fragile and vulnerable (Bočić 2011; Cerkvenik 2011; etc.). In the light of these developments,

as well as the work of L.A. North et al. exploring anthropogenic effects on superficial karst, it is expedient and timely to consider a new approach to the qualitative and quantitative assessment of human-induced modifications to the state of caves which will take the form of a Cave Disturbance Index (CDI) based around the five principal categories of relief, water objects, air, vegetation and fauna and cultural aspects. The work on the Index has drawn on numerous expeditions to various different parts of the globe, as well as published information (Pulido-Bosch 1997; Trofimova 1999; Anderson 2006; etc.). The application of the new approach is demonstrated by reference to the caves within the Muradimovskoe Uschelie Natural Park.

Cave Disturbance Index method

The Cave Disturbance Index (CDI) includes the five principal categories of relief, water objects, air, vegetation and fauna (as the main geographical components of the cave environment), plus cultural aspects. The categories considered are characterized in line with the following indicators:

Relief – this category reflects changes in cave relief that include:

a) violations of underground systems:
   - re-fitting of natural cave entrance(s),
   - creation of additional entrance(s) to caves,
   - widening of cavity size to provide for access or construction of additional artificial tunnels;
b) deformations of cave sediments:
   - water/chemical – damage and destruction of speleothems,
   - cave ice – damage and destruction of long standing ice crystals, ice stalactites, stalagmites and ice fields,
   - clastic deposits of fluviolacustrine deposits by geological prospect-holes,
   - organogenic – collection of guano and sampling of osteological material,
   - anthropogenic – archaeological excavations of the cultural layer;
c) the presence of constructions serving visits by tourists and sporting groups:
   - presence of viewing points, tourist trails, ladder transitions and illumination systems,
   - fitting-out of underground bivouacs,
   - presence of garbage holes and dumps for food waste, food packaging, used equipment and carbide.

Water objects – this category indicates anthropogenic changes to the state of cave water objects, involving:

a) contaminations of streams and lakes, as well as percolating waters:
   - chemical – by mineral oil, heavy metals, alkalis, acids and phenols,
   - physical – by radioactive elements, temperature, suspended particles,
   - biological – by pathogenic bacteria;
b) the presence of hydro-technical constructions: inlet and outlet channels, small hydroelectric power stations, dams and flumes.

Atmosphere – this type of cave disturbance has two main characteristics:

a) appearance of the smell of rotting organic material and oil;
b) an increase in the carbonic acid content in cave air (usually after visits by tourist groups).

Vegetation and fauna – this category comprises:

a) violations of the natural microbiological equilibrium in caverns:
   - appearance of phototrophic organisms,
   - appearance of populations of fungi,
   - development of lamp flora (cyanobacteria and algae);
b) violations of the faunal composition: quantitative changes (decreases or full disappearances) of bat colonies, and/or troglobionts.

Cultural aspects – this category is determined by reference to the following man-made features:

a) soot, inscriptions (predominantly by paint) on cave walls and ceilings, as well as recent graffiti;
b) mould which usually forms in the low parts of underground systems after human visits.

All violations of the natural state of caves are graded as: of weak intensity – 1, moderate

– 2 or considerable – 3 points. The points are summed up. A total CDI index of less than 10 points indicates only weak violation of the cave environment by human impact, while Indices from 10 to 25 points point to changes of moderate intensity and those in the range 25-50 to considerable changes. Should the value of the index exceed 50 then the existence of the cave may be regarded as under threat.

Practical approaches to the application of Cave Disturbance Index method

The application of the Cave Disturbance Index method will be presented by reference to the example of caves located in the Muradimovskoe Uschelie Natural Park.

Region of the exploration

The Muradimovskoe Uschelie Natural Park (founded in 1998) is widely known for its amazing beauty. The Park is situated in the Southern Urals, in the valley of the River Bolshoy Ik (a right-bank tributary of the River Ural) (Fig. 1). Orographically, the region researched belongs to the Zalair Plateau (at 520-580 m a.s.l.), and is cut out by the valley of the Bolshoy Ik. The relief in this area is distinguished by the dominance of plane or gently undulating surfaces. The depth of erosion incision varies from 155 to 205 m. Where the geology is concerned, carbonate rocks (mainly limestones) dating from the Upper-Lower Devonian outcrop here. In the western, eastern and southern parts these are overlain by a discontinuous cover of Devonian and Carboniferous terrigenous deposits (Fig. 2, geological conditions shown after Kuznetsov & Shakurov 1988). The climate of the Park is continental. The average annual air temperature is 2.2°C, and average annual less than or equal to 650 mm, approximately 70% of this falling in the warm season. The Park is covered by coniferous and broad-leaved forests, the dominant species being pine and birch.

Figure 1. Area under exploration

Cave environmental changes

More than 40 caves have been discovered in the Muradimovskoe Uschelie Natural Park (most of those known are plotted in Figure 2). The longest is the 2 km Novomuradimovskaya /30/ (here and in the rest of the text the number /X/ corresponds to that shown in Figure 2). This cavern is also the deepest: extending down 108 m. Exotic dripstones are observed in Malaya Labirintovaya /17/, Tsvetochnaya /21/, Volosyanaya /28/, etc., while ice fields are marked in the Bolshaya Labirintovaya /19/ and Ledovaya /24/ caves, Novomuradimovskaya has a stream with small cascades, while bats and pigeons inhabit Bolshaya Labirintovaya, Storozhevaya /16/, etc.

As a consequence of good transport communications, the presence of an accommodation base in the valley of the River Bolshoy Ik, as well as the possibility of caves being visited without special preparation, the underground cavities of the "Muradimovskoe Uschelie" Natural Park are subject to considerable anthropogenic pressure. For example, the number of visits to Novomuradimovskaya by non-organized tourists reach 200 per day in the summer period. That helps explain why the caverns on the Park are characterized by disturbances of their natural state. Garbage is the main problem for underground

Table 1. Cave Disturbance Index of Natural Park "Muradimovskoe uschelie" caves

Name	Relief		Water objects		Air		Vegetation and animal world		Cultural objects		CDI in total
	Description	Grade	Description	Grade	Description	Grade	Description	Grade	Description	Grade	
Staromuradi-movskaya /5/	re-equipped entrance fresh breaks of the rocks	1 3	only the drop, with-out changes	-	without changes	-	mould mush-rooms	1	soot oc-cupies 90% of ceiling and wall's surfaces rubbish (plastic, paper) recent graffiti	3 2 1	11
Golubiny grot /6/	archaeologi-cal prospect-hole on the floor broken stalactites	2 3	only the drop, with-out changes	-	smell of mould	1	mould mush-rooms	1	soot on ceiling and walls rubbish (plastic, food packages, etc.)	1 3	11
Ledovaya /24/	wood ladder "trampled down" ice field	1 1	only the drop, with-out changes	-	without changes	-	without changes	-	rubbish (plastic, broken glass bottles, paper, etc.)	1	3
Novomuradi-movskaya /30/	re-equipped entrance wood and metal lad-ders	1 1	without changes	-	without changes	-	mould mush-rooms	1	rubbish (food and water pack-ages, piles, papers) recent graffiti	2 1	6

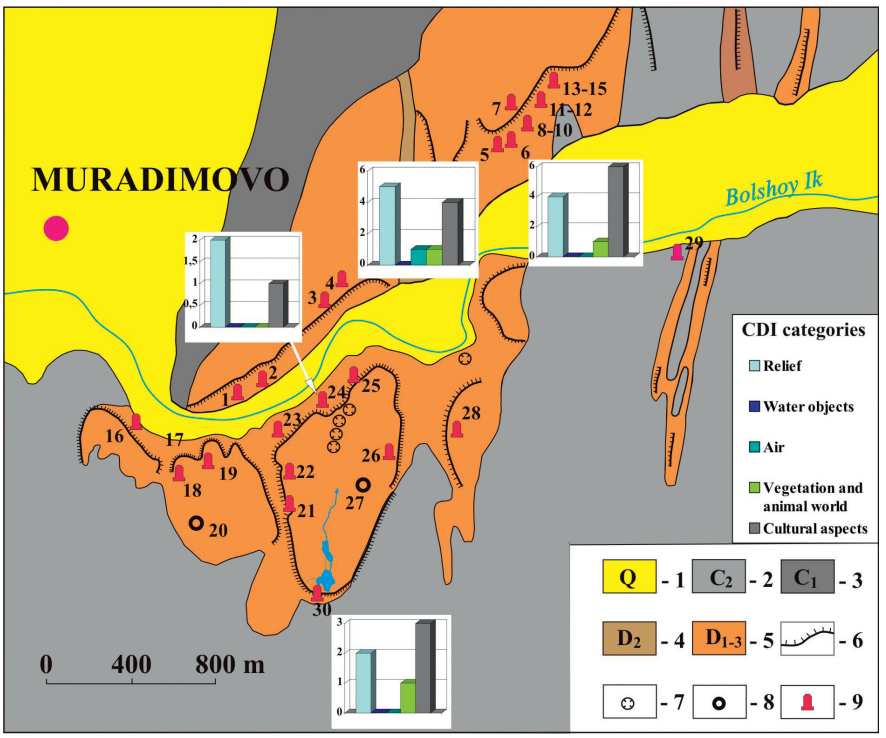

Figure 2. Caves of the Muradimovskoe Uschelie Natural Park

Geological conditions: 1 – alluvial deposits of the Bolshoy Ik Valley, 2-4 – terrigenous rocks, 5 – carbonate rocks (limestones), 6 – erosion scarp, 7 – karstholes, 8 – karst sinkholes, 9 – karst caves: 1 – Detskaya, 2 – Kanionnaya, 3 – Svetlaya, 4 – Al'pinistov, 5 – Golubiny grot, 6 – Staromuradimovskaya, 7 – Muradimovskaya N 3, 8-15 – Muradimovskaya: N 4-11, 16 – Storozhevaya, 17 – Malaya Labirintovaya, 18 – Sharovaya, 19 – Bolshaya Labirintovaya, 20 – Ural speleological section-73, 21 – Tsvetochnaya, 22 – Salavatskaya, 23 – Neozhidannaya, 24 – Ledovaya, 25 – Zashel-Vishel, 26 – Skvoznoy grot, 27 – Proval, 28 – Volosyanaya, 29 – Rifovaya, 30 – Novomuradimovskaya

systems here, being noted (in the form of food and water packages, other plastic, etc.) is practically all of the caverns. Other violations of the ecological state by human activity are revealed in four caves: Staromuradimovskaya /5/, Golubiny grot /6/, Ledovaya /24/ and Novomuradimovskaya /30/. The types of violation and grades thereof in these underground cavities are as described in Table 1 and represented in Figure 2.

As Table 2 and Figure 2 also show, two caves (Ledovaya and Novomuradimovskaya) are characterized by weak violations of the natural state and two (Staromuradimovskaya and Golubiny grot) by moderate-intensity violations. The result of this has been the need for conservation measures for the Park's caves to be taken.

Conclusions

In the course of explorations carried out for the first time the types of changes (violations) to the state of caves were analyzed in detail and generalized, this leading to a proposal for a Cave Disturbance Index, taking account of changes in the principal geographical components of the underground environment, i.e. relief, water objects, air, vegetation and fauna, and cultural aspects of cave use. In line with this new approach, it was demonstrated that the ecological

state of the underground systems in the Muradimovskoe Uschelie Natural Park has been impinged upon by anthropogenic pressure. This makes it necessary to accelerate the process by which caves are granted the status of State Nature Monuments, as well as steps taken to help with the conservation of each cavern. For this reason, it would be desirable if scientific expeditions were organized with a view to recommendations for the conservation of caves in a more natural state being made.

The Cave Disturbance Index thus allows for a determining of the responsibility of human beings in recent times for the future of caverns – unique natural formations created by nature over periods of time extending into the thousands or even millions of years.

Editors' note:
Unless otherwise stated, the sources of tables and figures are the author(s), on the basis of their own research.

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