Protected Habitat Management
Guidelines for Latvia

Outcrops and caves

Editor in chief: Ilze Čakare

Authors:

Ilze Čakare (all chapters, where the author has not been indicated),

Agnese Priede (Introduction, Chapters 4, 5.1, 5.2, 6.1),

Juris Jātnieks (Chapters 5.1, 6.4),

Ērika Kļaviņa (Chapter 6.3)

Scientific reviewer: Inese Silamiķele

English translation: SIA "Skrivanek Baltic"

Drawings: Daiga Segliņa

Design layout: Ivs Zenne

Maps: Agnese Priede

Photographs: Ilze Čakare, Andris Bērziņš, Normunds Kukārs, Daiga Segliņa. Photographs (postcards) by unknown authors have also been used from the personal archives of Ilze Čakare and Jānis Šildovskis.

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Outcrops and caves

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Foreword

The bond of humans with nature is eternal. The beauty and diversity of Latvian nature has been affected by ages of interaction between people and the environment. People have no future apart from the surrounding environment, and in the contemporary world the diversity of nature cannot be conserved in isolation from humans by prohibiting any action. Only responsible attitude can make the conservation of semi-natural meadows, sea coast, forests, rivers and lakes possible in the future as well. The rare, the unique and the beautiful can only be preserved by including nature conservation as an indispensable principle in the policies of all sectors of the economy, which includes planning, as well as action.

This book is an important resource for anyone, – either those who have the authority to make decisions and plan the use of land in Latvia, or those who manage their land themselves. The guidelines is a comprehensive source of knowledge and methods applicable in nature conservation, which provides every one of us with an option of sensible and sustainable action while being caring owners, who benefit themselves, their family and nation by maintaining the balance between humans and nature diversity. The choice of future lies with our wisdom, respect and awareness of life.

General Director of the Nature Conservation Agency
Juris Jātnieks

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Contents

Introduction

(A. Priede)

Guidelines for the conservation, management and restoration of protected habitats in Latvia have been developed from 2013 to 2016 under the LIFE+ programme project "National Conservation and Management Programme for Natura 2000 Sites" (LIFE11 NAT/LV/000371) funded by the European Commission and implemented by the Nature Conservation Agency of Latvia. The guidelines provide comprehensive recommendations for the conservation, management and restoration of terrestrial and freshwater habitats of Annex I of Council Directive 92/43/EEC of 21.05.1992 on the conservation of natural habitats and of wild fauna and Flora (the Habitats Directive), in Latvia. The guidelines are one of most important tools to promote the implementation of the Habitats Directive and 2009/147/EC Directive of the European Parliament and of the Council of 30.11.2009 on the conservation of wild birds (Birds Directive) in Latvia. The guidelines include six volumes, each of them devoted to a separate group of habitats: coastal habitats, inland dunes and heaths, lakes and rivers, semi-natural grasslands, mires and springs, outcrops and caves, and forests. This edition provides recommendations for maintaining the nature diversity of rock outcrops and caves.

The guidelines were developed by a leading expert specialised in each group of habitats (coastal habitats, inland dunes and heaths, rivers and lakes, semi-natural grasslands, mires and springs, outcrops and caves, forests) who organised the compilation of the guidelines. The development of the guidelines was an open process; the drafts were available to all interested parties in various development stages – published on the project website, offering the possibility for everybody to participate with suggestions. Six working groups were established as platforms to discuss the development of the guidelines, share opinions and recommendations throughout the process. Representatives of various fields took part in working groups – experts of species and habitat conservation, researchers from scientific institutions, representatives of several governmental and non-governmental organisations – professionals in nature conservation, forestry, agriculture and other industries. In total, 25 workshops were organised during the development of the guidelines – both as working group meetings and excursions to investigate problem situations, and discussions about possible solutions among the representatives of various fields. Meetings with practitioners and researchers both in Latvia and abroad were organised, using the best available experience. This helped to develop the most extensive publication of this type in Latvia yet.

The recommendations provided in the guidelines have been tested in practice in Latvia or geographically similar conditions; their effectiveness has been assessed and recognised as applicable. The project also carried out experimental habitat management and restoration by using less known methods or methods that had not been tested previously in Latvia, to assess their applicability. The experience gained was used in the preparation of the guidelines. Some problem situations lack tested examples in practice not only in Latvia, but also in other geographically similar conditions in the world. So, in the guidelines only the activities for testing have been identified, and - why not in Latvia? Each habitat restoration or management method has been tried somewhere for the first time.

In habitat management, restoration and re-creation, it is not possible to establish one formula valid for all cases. For the restoration of degraded habitats, one should be creative, willing to adapt to existing conditions, experiment and use additional solutions – also such solutions that these guidelines do not offer. Sometimes, even having done everything possible according to the best recommendations and practice, modifications are necessary to correct the mistakes or unexpected deviations from what was planned. Each ecosystem restoration attempt is in a way an experiment, no matter how well planned it is. Its success or failure in the long term can only be affirmed by systematic observations and careful analysis of results, including errors.

The target audience of these guidelines are mainly practitioners (habitat managers) and landowners of areas with significant nature values where active conservation is necessary, as well as those whose duties or work are/is related to improvement of the conservation of natural values.

These persons include public administration and local government employees, and representatives of non-governmental organisations. This edition can be used as a guide for practical action, including both the planning and implementation of restoration.

The guidelines will help in gaining a deeper understanding of ecosystems and developing a harmonised approach to the conservation of nature values in Latvia. Knowledge will improve with time, and techniques and capabilities will change. However these guidelines will remain the most complete summary of nature conservation experience of the last 25 years in Latvia, and they will form the basis for solving nature conservation challenges in the future. The authors hope that this publication will be an important source of inspiration to restore degraded habitats in Latvia.

Part I

Chapter 1. Rock Outcrop Habitat Characterisation

The habitat group of rocky habitats and caves includes outcrops of ancient geological periods. In Latvia, these are mainly outcrops of sedimentary rocks of the Devonian System, exposed by glacial retreat. The total thickness of sedimentary rocks of the Devonian System in Latvia is up to 800 m, and about 80% of it consists of middle and upper Devonian sediments which in many places are covered by a thick layer of later sediments (Stinkule, Stinkulis 2013). The Devonian period lasted for almost 60 million years and ended around 359.2 million years ago. In subsequent periods the land surface of Latvia repeatedly changed until the end of the last glacial period, approximately 10,000 years ago when the last large-scale development of Latvian terrain ended. The current nature landscape base was developed under the influence of the ice sheet and its melting waters (Āboltiņš 2010). Nowadays only a negligible part of sedimentary rocks of the Devonian Period in Latvia is exposed on the ground surface, because most of them are covered by a 10–300 m thick layer of Quaternary sediments.

Of all outcrops, only outcrops of carbonate and sandstone bedrocks are protected in Latvia as protected habitat types or species habitats. Due to their rare occurrence, each, even humblest outcrop of the respective bedrock is considered to be a rare and protected habitat. In Latvia, on rock outcrops (dolomite, dolomitic marlstone, limestone, sandstone concretions and sandstone), three of the European Union (EU) protected habitat types can be found: 8210[1] *Calcareous rocky slopes with chasmophytic vegetation*, 8220 *Siliceous rocky slopes with chasmophytic vegetation* and 8310 *Caves not open to the public*. Bedrock outcrops found along the Baltic Sea coast, such as sandstone outcrops of North Vidzeme coast which are influenced by wave erosion, are identified as habitat type 1230 *Sea cliffs* (Lapinskis 2017), which belong to group of coastal and halophytic habitats.

Rock outcrops can be bare or covered with vegetation dominated by outcrop characteristic mosses, lichens and algae species. Also ferns and few herbaceous plant species can be found. Constant cover of herbaceous and woody species develops only on the top of the outcrop and on the litter if soil has developed there. Outcrops, on top of which soil has developed and forest or grassland plant communities form, are attributed to respective forest or grassland habitats (Rūsiņa (ed.) 2017, *Chapter 10*; Ikauniece (ed.) 2017, *Chapter 15*). Outcrops are characterised by mosaic vegetation, where parts of the outcrop surface are covered with plants and lichens, while other parts are bare. Vegetated patches can vary in size and occupy a proportionally minor or major part of an outcrop. Characteristic vegetation is influenced by the material of outcrop rock, presence or absence of fissures, moisture conditions and exposure. Surrounding habitats play a significant role in outcrop microclimate and stability.

Outcrops at rivers and outcrops with vegetation characteristic for spring discharges (tufa is forming, iron compounds accumulate in sediments) are included in the respective river and mire habitats (Urtāns (ed.) 2017, *Chapter 17*; Priede (ed.) 2017, *Chapter 13*). As the total area of rock outcrops in the country is low and the area of each outcrop is relatively small, outcrops without characteristic vegetation, fragments of rock outcrops and erratic blocks are also included in the respective habitat types. Considering the high significance of rock outcrops in providing the living environment for their characteristic species, habitats partially affected by human activity may also be included in all rock outcrop habitat types. Habitat type 8210 *Calcareous rocky slopes with chasmophytic vegetation* also includes outcrops of dolomite and limestone extraction sites if vegetation characteristic for EU protected habitat types

[1] Code according to habitat types listed in Annex I of the Habitats Directive. These codes added to names of habitat types will be used throughout the book without further specific explanations.

develops on them. Habitat type 8220 *Siliceous rocky slopes with chasmophytic vegetation* also includes outcrops heavily influenced by trampling (excessive walking) of visitors. Habitat type 8310 *Caves not open to the public* in Latvia also includes caves affected by human activity and caves which are created artificially in carbonate or sandstone rocks. Historically they may have been created or enlarged during dolomite or sand extraction, by research excavations, or rock debris may be removed from the cave floor. Many caves are used as tourism objects. Cellars developed in sandstone outcrops have a role that makes them similar to caves of natural origin as habitats, therefore they must be considered as a protected habitat after the cessation of their use as cellars.

Chapter 2. History of Use and Protection of Rock Outcrops in Latvia

2.1. Use of Rock Outcrops and Caves in Different Times

Rock outcrops have long been used as sacred places, with caves playing a special role (Laime 2009a). Impressive names of caves have remained until today, such as Velnala (*Devil's Cave*), Upurala (*Sacrificial Cave*), Jumpravu iezis (*Damsels' Rock*). There are rather few stories and legends about caves and rock outcrops, popularly called cliffs. It may be assumed that up to the 19th–20th century, when nature tourism developed, only the few most popular objects had a significant role in human life. The meaning of the ancient rock inscriptions or petroglyphs is still not fully understood, but we may assume that the role of rock outcrops and caves in our ancestors' lives was greater than we can understand now. Since 1971, when Guntis Eniņš found the first inscriptions in Liv sacrificial caves (Eniņš 1998), such inscriptions are found in 50–60 more places, and their research continues (Grīnbergs 2008; Eniņš 2015). It is concluded that the inscriptions were made over a longer period of time, by returning to the cave several times (Eniņš 1988; Karulis 1997; Laime 2002, 2009a). Direct evidence of the use of caves as religious places was obtained in Liv sacrificial offering caves. Archaeological excavations managed in 1973 by Juris Urtāns show that caves were used for sacrificial offerings from the 14th up to 19th century (Urtāns 1975).

The oldest known inscriptions with year numbers on the walls of sandstone outcrops and in caves date back to the 16th century. However, most of the inscriptions were made in the 19th–20th centuries, when travel to nature objects become popular (Laime 2009a, 2009b; Arājs 2015). Paths, boardwalks, barriers and picnic sites were established in the late 19th century in order to open the view to the most scenic outcrops. Tourism infrastructure was constructed to ensure maximally close access to the object, to climb on it or to enter the cave (Fig. 2.1). The importance of great scenic outcrops is proven by numerous postcards printed in the early 20th century (Fig. 2.2), when tourism was established as a sector of the economy (Laime 2009b).

Fig. 2.1. Scenic outcrops on postcards in the early 20th century. In the picture - outcrop on the bank of the River Mēmele near Bauska. Postcard from the personal archive of I. Čakare.

Fig. 2.3. New scratches on Līču-Laņģu Cliffs after trail construction and increase of tourist numbers in the summer of 2015. Photo: I. Čakare.

Fig. 2.2. Infrastructure in the early 20th century was designed to enable easy viewing of the entire object. Left - railing of boardwalks. Right – bench at the cave's entrance. In the picture – view from Velnala Cave in Sigulda, to the River Gauja. Postcard from the personal archive of I. Čakare.

After World War II, in the 1950s and 1960s, visits to nature objects started to be popular again. Since the establishment of Gauja National Park in 1973, one of the main tasks in the territory was the management of visitor flows in Sigulda and Turaida, with the purpose to prevent trampling of rock outcrops and caves, at the same time developing and maintaining sightseeing points (Rinkuss 1983). The number of visitors in these popular places has always been high. At the end of the 20th century approximately one million visitors per year attended tourist trails in the vicinity of Sigulda. Improvement of tourist trails and the creation of new paths are continued nowadays. The objective of the construction of tourism infrastructure is the regulation of visitor flows and their redirection from sensitive sites. Sometimes, however, this objective is not achieved, and protected habitats are adversely influenced by the establishment of infrastructure. For instance, to prevent trampling, a trail to Līču-Laņģu cliffs was established in 2015. After a few months there was a large influx of tourists and also new scratches on rock walls (Fig. 2.3).

Since ancient times rock outcrops have also been used for practical purposes – for mineral extraction. The extraction of white quartz sand, limestone and dolomite also continues nowadays, but natural outcrops are not being threatened. It was different in the times when most of works were performed manually. Then it was easier to access the deposit in sites where it had already become accessible.

In the early 20th century there were glass factories in Rīga, Kuldīga, Ventspils and in Daugavpils District, and they also used local sand. In the Vidzeme region, sandstone was extracted in quarries and later used for the construction of house foundations (J. D. L. 1912). White Devonian sand was extracted in Riežupe, Vintergrava, Sietiņiezis and Lielā Ellīte complex in Liepa Municipality. Sand was used both industrially for glass production and for household needs – sand was used to spread on floors, to clean wooden bowls, to decorate graves (Lancmanis 1924; Vanags 1939; Eniņš 2004). The contemporary form of caves at the River Riežupe was developed as a result of sand extraction for the production of glass (Znotiņa (ed.) 1997). The demand of households for white sand is over, because the cleaning of wooden bowls and spreading on the floor is no longer topical and industrial mining today does not influence natural outcrops. From the 1970s, outcrops were gradually included in the lists of protected objects and protected nature areas, therefore their economic use nowadays is no longer possible (*see Chapter 2.2*).

In 1912, mineral extraction and processing took second place among the industry sectors of Latvia. Many of the companies were situated outside the cities in the countryside (J. D. L. 1912). Lime kilns were located at Daugava, Abava, Jugla, Ogre rivers and to a lesser extent at the River Gauja because here limestone was deposited close to the ground surface. In Vidzeme quarry not only limestone but also so-called "plieņi" (dolomite blocks used for construction) were produced. It is possible that Zanderu dolomite caves (Fig. 2.4) and Sikspārņu caves were created artificially for the extraction of dolomite which was used for small lime kilns or for construction (Eniņš 2015). In the places where dolomites are exposed in river valleys, the dolomite pieces can also be seen built in the walls of surrounding homesteads (Fig. 2.5). In order to obtain high quality lime, tufa was used. However for local needs it was also recommended to use pieces of dolomite which were then called pebbles. The acquired lime was used as fertiliser, for wall whitening, for mortar in masonry and it was sent to Rīga as a raw material in industry. The extraction of dolomite at the upper Bušleja banks, which could also include the site of Sikspārņu Cave, has been mentioned in Part 2 of the series of publications *Our Tufa Deposits* in 1924 (Rozenšteins, Lancmanis 1924). In the same publication, there is also information on other smaller dolomite quarries in the vicinity of Kārļi: "In Ķempju Incēni (for about a verst (1,066 m)), in Raudzītes and in Akmeņlauži pebbles were extracted, as well as in other surrounding homesteads" (Rozenšteins, Lancmanis

Fig. 2.4. Some researchers believe that caves in carbonate bedrock such as Zanderu caves are created as a result of dolomite mining. Photo: I. Čakare.

Fig. 2.5. Buildings, for whose construction dolomite pieces are used, are often seen in the surroundings of exposed carbonate rocks (Baltiņi farm house in Priekuļi Municipality). Photo: I. Čakare.

Fig. 2.6. Abandoned cellar caves in Līgatne. On the left – fastening wall built of bricks.
Photo: I. Čakare.

1924), which suggests that dolomite mining was widely practised on slopes of ravines, and some contemporary outcrops can actually be artificially created.

Caves were dug in sandstone rocks in order to use them as cellars (Laime 2009a). An especially high number of such cellars were established in sandstone rocks in the vicinity of Mazsalaca and Līgatne (Fig. 2.6). They were used by local people for the storage of vegetables, canned preserves and for other practical needs (Vētra 1956; Eniņš 2004; Hauka 2014). Possibly, caves of natural origin were initially used for cellars, and expanded later. The first cellars in Līgatne could have been dug in around 1770, the last were created in around 1973–1974 (Balodis, *without date*). Since 1973, when Gauja National Park was established, the creation of new cellars has been prohibited there. However, in 2014 in the territory of Gauja National Park a new sandstone cave was found, which was dug during recent years and adapted for long-term living. The cave contains a bed place, the entrance is equipped with a covering screen and the slopes are reinforced (Fig. 2.7).

Sandstone caves in the outcrops have been used as hiding places for people. All cave explorers mention tales, which have been heard or read, about people, who, at different times, were hiding in caves from their pursuers, as well as robbers who hid the stolen treasures in caves (Lancmanis 1924; Eniņš 2004; Laime 2009a).

Fig. 2.7. A cave dug in the early 21st century in the territory of Gauja National Park and used as an overnight place. Photo: I. Čakare.

Legend about the caves of Vintergrava Ravine

Vintergrava ravine is located behind the prison of Cēsis Town. There are two caves on the right bank of the River Gauja, behind the current Gauja Street – a large cave and a small cave. At the time when the Germans invaded our land and wanted to enforce the Christian faith, the neighbourhood of Vintergrava was coated with old, large woods. Residents sought refuge in caves in order to escape Germans. Invaders found the large cave pretty quickly and forced the inhabitants to get christened. The entrance of the small cave was overgrown with vines and people managed to hide from the Germans in this cave for two years. The cave had a second exit in the valley of the River Gauja. It was sometimes used by people to exit, find food and afterwards return to the cave again (1900, 2002. Pēteris Paukšēns Valkas Trikātā, 75 years old; recorded by V. Greble 1953).

Slītere Cave

Next to the Powder Tower in Slītere there is a large cave. In very ancient times, when the forest was not yet there, a camp of pirates was situated near the cave. The sea is not far from there. Pirates used the cave to hide all of their plundered wealth. Not far away, there lived a young man, called Slīters. He had to go and serve in the military for twenty five years. The young man ran away from his recruiters and suddenly disappeared. Plants were bent over the cave entrance and therefore they could not see it. The young man crawled and crawled, and the cave became wider and wider. Finally he found all the treasures of the pirates. He retained the wealth, was able to use the treasures to buy himself freedom from service, built the Powder Tower of Slītere, bought a large ship from Germany and destroyed all the pirates. (2000, 1844. Jūlija Vecmane in Talsu Stende, 59 years old; recorded by V. Strauta 1971).

From: Ancelāne A. (compiler) 1991. Latviešu tautas teikas: izcelšanās teikas, izlase. (*Latvian folk legends: legends of origin, collection.*) Zvaigzne, Rīga, 132–133.

Fig. 2.8. Water that is filtered through the layer of sandstone is also popular nowadays.
Photo: D. Segliņa.

Fig. 2.9. Rūcamavots Spring in Sarkanās klintis (Red Cliffs) is a popular water taking place for people of Cēsis Town.
Photo: I. Čakare.

Devonian rocks in Latvia contain significant reserves of water, which were used in ancient times and are still used (Stinkule, Stinkulis 2013). Legends on the healing properties of some springs coming from the rocks have been told since ancient times. The use of spring water in daily life is still popular (Fig. 2.8). Stairs, boardwalks and chutes are constructed at the most popular springs to make the taking of water easier (Fig. 2.9).

In the cave (*Gūtmanis Cave*) there is a water spring that yields water pure as amber. Our forefathers believed this spring to be sacred and brought flowers to it in a certain season. Even now, older people believe that the water of Gūtmanis cave is sacred, having some healing powers. (T. B. Turaidā, "Vārds" 1901, 69. P, VII, I, 362, 3).

Vella ala (*Devil's Cave*) is located close to Liepasmuiža manor. The bigger cave has a smaller cave starting from its side A spring flows out from the larger cave. The flow of water seems to have washed the sand away, creating this cave. There is another cave close to Liepasmuiža manor, it looks like this one, but is much smaller. The third cave is situated on the opposite side of the River Gauja, and is called Sietiņiezis cliff. These three caves are said to have been the dwelling place of the Devil: he resided sometimes in the first, sometimes in the second and at other times in the third cave. The Devil used to visit the garden of Sietiņš turn into a goat buck and eat cabbages, and there was no form of rescue from this. Then seven priests came together and tried to drive him out. The evil creature was sleeping in the cave on a fireplace hearth. When the priests started to read their prayers in front of the cave, the poor thing ran out of the cliff straight away, and instead of going through the old opening, it escaped by running through the cliff and thus made a new cave entrance. (J. Bankins in Aizkraukle, "Šis un tas" (This and That) III, 1879 p. 59).

From the folklore collection compiled in 15 volumes by Pēteris Šmits "Latviešu pasakas un teikas" (*Latvian Fairy Tales and Legends*) (1925–1937), which is digitised and can be read on the website of the Latvian Folklore collection http://www.lfk.lv.

Some rock outcrops are used for the study of important geological and paleontological issues. The presence of fossils in Devonian rocks in Latvia has already been noted since the 19th century. One of the most significant finds was made in 1994 and thoroughly researched in the early 21st century, when on the banks of the River Ciecere, in sandstones of Ketleri suite, a fossil of an ancient fish *Ventastega curonica* was found (Lukševičs 2016). The research of these outcrops provides a significant contribution to the understanding of species evolution (Ahlberg et al. 2008). The research of fish fossils and plants, especially their spores in Devonian sandy and loamy rocks, as well as the research of the fossil invertebrates in carbonate rocks allows one to determine regional stratographic units that developed during the certain period, to track the particular layer and to establish geological maps (Kuršs 1984). Results of such research are important in geology. For instance, the understanding of nature conditions in the Devonian period can be used to forecast the presence of mineral deposits (Pipira 2015).

While I lived by the River Gauja, I had a possibility to learn about them [fossils] at an early age. Upon careful examination of pebbles below a particular cliff, quite often I found brown flat pieces similar to broken pot pieces. I had never seen pots to be so thin (about 3 mm thick) and covered with tiny bumps sometimes even in the shape of small stars (*Asterolepis ornata* Eichw. – juveniles). I did not understand what these pieces were. When my elder brother entered a secondary school, I got to know from him that they must be parts of armoured plates of placoderm fish.

(Kampe R. 1935. Bruņu zivis Latvijā. Daba un Zinātne Nr. 4. 01.06.1935., 113.

In 1926, botanist Nikolajs Malta wrote that sandstone cliff flora had been sufficiently studied in the period from 1920 to 1926, and further research should focus on ecology (Malta 1926). However, even nowadays it is considered that outcrop flora is not fully explored. For example, in the early 21st century a moss species new to Latvia was discovered on sandstone outcrop near Pēterala in Sigulda (LETA 2015). Every study on rock outcrops and caves has resulted in new knowledge about the flora and fauna in Latvia.

Many outcrops are visually attractive, some of them are displayed in a variety of visual art works. Zvārtes cliff has been depicted on postal stamps three times during different historical periods: during the period of the first free Republic of Latvia in 1924; during the period of the Latvian Soviet Socialist Republic (SSR); in the postal stamp series dedicated to Gauja National Park by the Latvian Nature and Monument Protection Association, together with Ērgļi Cliffs (Fig. 2.10). Three Latvian feature motion pictures were shot at Zvārte Cliff: "Salna pavasarī" (*Spring Frost*) – in 1955 "Latviešu strēlnieka stāsts" (*Latvian Rifleman's Story*) – in 1958, "Agrā rūsa" (*Early Rust*) in 1979 (Eniņš 2015).

Fig. 2.10. Rock outcrops on postal stamps. (1) 1924 (first independent Republic of Latvia) "Pazīsti dzimto zemi! Zvārtas iezis Amatas krastā" (Know your homeland! Zvārte Cliff on the bank of the River Amata). (2) Voluntary deposit collectors' stamps of the Nature and Monument Protection Association of the Latvian SSR. (3) Postal stamps from the series Protected Nature Objects of Latvia by Latvijas Pasts.
Images from private collections of A. Urtāns and I. Čakare.

Icefalls on outcrops are used for ice climbing training in winter. Dzilna Cliff in Gauja National Park used to be popular, but Cabinet Regulations nowadays prohibit such climbing: "moving across rock outcrops, water and icefalls, as well as their use for recreation, sports and other events"[2]. Rock and ice climbing were once popular on outcrops near Bauska Town. This is mentioned as one of the risk factors for the survival of rare fern species. Guntis Eniņš also mentions that the top of Dzilna Cliff is used for meditation (Eniņš 2015).

[2] Section 9.12 of Cabinet Regulation No. 317 of 02 May 2012, Regulation on Individual Protection and Use of the Gauja National Park.

2.2. Brief History of Rock Habitat Research and Protection

Due to their visual appeal, rock outcrops were promoted as tourism attractions from the late 19th century. Several of them became very popular, so soon publications about the necessity for their protection appeared. As the interest in visiting nature objects kept growing in the 20th century, outcrops were made more accessible and observable with a variety of improvements. However, little attention has been paid to the conservation of outcrops as habitats for species. The national park established around Sigulda mainly contributed to the conservation of forests but the beauty of rock outcrops and caves was also promoted and their viewing options were ensured.

In the early 20th century, intensive research of caves as a specific ecosystem was conducted throughout Europe (Romero 2009), and our scientists participated in this research by studying Latvian caves (Lancmanis 1924). A number of popular and scientific reports on nature values and the significance of outcrops and caves were published during the period of first independence (1918–1940) of the Republic of Latvia. In the newspaper for teachers, Zelmārs Lancmanis grouped and described nature monuments including cliffs and caves (Lancmanis 1922a, 1922b, 1922c). Nikolajs Malta published a study on sandstone flora and ecological groups (Malta 1925, 1926, 1940). The publication on moss ecology was based on samples collected on sandstone outcrops along the River Gauja (Apinis, Diogucs 1933). The study on lichen species *Cystocolea ebeneus* (nowadays protected) was published (Skuja, Ore 1933). *Placodermi* class fish in Latvia were described by Reinis Kampe (Kampe 1935). Comprehensive information on nature was also provided in tourist guides (for instance, Ašmanis (1930)).

So already at that time, a lot of information was accumulated about the particular role of outcrops and caves as habitats for species. However, their practical protection, except for in certain cases, was limited to the establishment of tourist trails. Even the protection of outcrops as geological objects was not ensured, although active geological studies had already been carried out and the significance of outcrops was clear.

One of the most important outcrop conservation projects took place in the 1930s, when the bed of the River Amata was altered to protect the Zvārte rock. There was a risk that the flow of Amata River would destroy the rock. In 1938, the newspaper "Brīvā Zeme" (*Indipendent Land*) published a short article "Vai Zvārtes iezis aizies bojā?" (*Will Zvārte Cliff die?*) (M. S. 1938). The article criticised the Cabinet regulations for monument protection in Latvia that were adopted in 1932. On private lands, this legislation only provided for the protection of those nature objects that had archaeological, ethnographic and historical significance. Zvārte Cliff was situated on private land and it did not have status as a protected object. However, thanks to active public interest, large-scale nature transformation works were performed in 1939, with the purpose to protect the attractive landscape related to Zvārte Cliff. In order to protect Zvārte Cliff from erosion, the bed of the River Amata was straightened, resulting in a situation where the river no longer eroded the cliff base (Fig. 2.11, 2.12).

Fig. 2.11. Zvārte Cliff and Amata old riverbed before river straightening. Drawing by D. Segliņa.

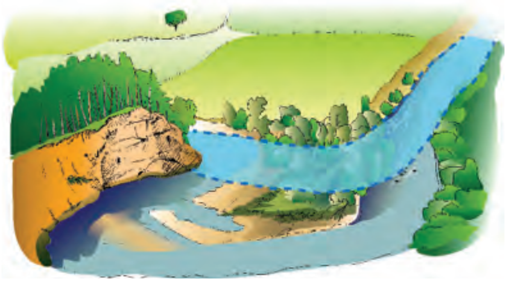

Fig. 2.12. Zvārte Cliff with the River Amata after straightening. River does not erode rock base anymore, and flows past it. Drawing by D. Segliņa.

The rock was protected from collapsing, however, it is not easy to evaluate such measures from the point of view of habitat conservation. The old riverbed gradually clogged; flood waters only removed part of the rock debris while the rest accumulated at the cliff base. The viewpoint on the cliff top was maintained for a long time. Trees and shrubs which started to grow on the scree were at least partially felled, at different times and in different volumes. Nowadays the outcrop of Zvārte Cliff, especially its basal part, is more shaded than it was at the time when the river bed naturally kept it open (Fig., 2.13, 2.14). Until 1939, Zvārte Cliff served as a habitat for sun-loving species, while nowadays such conditions remain only in part of the outcrop. Guntis Eniņš suggested that Zvārte Cliff was exposed just shortly before riverbed transformation in the early 20th century (Eniņš 2015). If so then specific flora and fauna had maybe not yet developed.

Fig. 2.13. Zvārte Cliff before river bed straightening in the 1930s. The River Amata flows along the cliff base and washes away fallen scree. Thus the cliff is kept open and sunlit but the collapse of part of the rock is possible. Postcard from the personal archive of I. Čakare.

Fig. 2.14. Zvārte Cliff in the summer of 2015. River only flows along a small part of the outcrop, the remaining area at the cliff base is floodplain, which gradually overgrows with shrubs and *Alnus incana*. Tree and shrub removal temporarily improved the view to the outcrop, however, it does not ensure the removal of rock debris, which keeps accumulating (landslide on the left side and trees around the centre). Photo: D. Segliņa.

In the Latvian SSR, 84 nature objects were initially registered as protected objects. Most of them were geological monuments, such as river valleys, caves, relief forms. Specially allowed or prohibited economic activities or special conservation measures were not set. This did not provide sufficient protection so it was necessary to change the system. In 1968, the law On Nature Protection of the Latvian SSR was adopted, and several categories of protected objects were defined. The improvement of the list of objects was continued up to mid-1976, when boundaries of all objects included in the list were specified (Melluma 1979). In the list of protected nature monuments in 1977, the 11 geologically most significant rock outcrops and two caves were included (in total, 93 geological and geomorphological objects were listed)[3]. The conservation of outcrops was promoted by the establishment of Gauja National Park in 1973. Since the establishment of the national park, the most popular rock outcrops and caves have been specially protected by establishing extensive tourist infrastructure (Fig. 2.15, 2.16). Geologists, doing research in Gauja National Park, wrote: "Barely a decade, since GNP [Gauja National Park] management delimited the Lielā Ellīte cave complex with a fence. Cliffs gradually overgrow with mosses and lichens, resting from climbers, sliders and autograph writers." (Grāvītis et al. 1985).

Fig. 2.15. Tourism infrastructure at Velnala in Turaida in the 1930s. Postcard from the personal archive of J. Šildovskis.

Fig. 2.16. Tourism infrastructure at Sietiņiezis Cliff near Valmiera. Photo: A. Bērziņš.

[3] Decision No. 241 of the Council of Ministers of the Latvian SSR, Dated 15 April 1977, On The Approval of State Protected Natural Objects in the Territory of the Latvian Soviet Socialist Republic.

During the period of the Latvian SSR, rock outcrops were also protected in other nature areas: in Slītere Nature Reserve, in the complex nature reserves at the Gauja, Venta, Šķervelis, Abava, Ruņupe, Salaca and Daugava rivers, and in Riežupe Nature Park. However, many geological and geomorphological monuments and protected areas that are protected nowadays were not included in this list. The list was supplemented in 1987[4], when 14 rock outcrops and one cave located outside the protected territories were included into the category of geological and geomorphological monuments. Within the borders of protected areas, 66 rock outcrops (10 together with caves) and 11 caves were protected. In total, there were 169 nature monuments in the list (Siliņš 1988), from which 92 objects included outcrop and cave habitats. The protection of geological and geomorphological objects, similarly to nowadays, was focused on the conservation of geological and landscape values. Their protection regime was aimed at the conservation of these objects for the purposes of scientific research and for future generations – as types of stratigraphic sedimentary rock cross-sections, deposits of fossil organism remains, as well as vivid elements of landscape[5]. During the period of the Latvian SSR, nature protection focused mainly on the conservation of fauna and flora within the protected nature areas, and it had a positive impact on rock outcrops and caves located in these areas[6]. In nature reserves, it was forbidden to devastate and destroy valuable natural landscape elements which are important for the conservation of flora and fauna, which comprise the aesthetic value of landscape or are of great scientific or cultural importance. It was also prohibited to disturb the natural peace and silence. Outcrop and cave habitats and localities of rare species outside the protected nature areas were not protected.

At all times, practical protection was mostly planned and organised for the conservation of nature monuments such as geological objects. The largest geomorphological objects were protected but the smallest, humblest outcrops and caves were not properly identified and assessed. However, small outcrops can also be habitats for rare species. Many small outcrops are even richer with rare species than large, scenic cliffs.

At all times, the main method of protection of outcrops and caves was the construction of paths, boardwalks, railings and platforms, to restrict access to the most sensitive sites. In order to preserve the geological value, it is sufficient to prevent trampling and engraving, and to maintain open outcrops. However, for the conservation of habitat, the complete delimitation of visitors may also be needed. This approach was used for the protection of just a few caves (*see Chapter 12.3.3*).

Today, the protection of rock outcrops and caves as habitats is regulated by Cabinet Regulation No. 421 of 5 December 2000 Regulations on the List of Specially Protected Habitats (*see Chapter 6.3*). If the outcrop or cave habitat is located outside the protected area and also if these habitats are located in a protected nature territory but the regulations existing here do not ensure sufficient protection (for example, specific protection measures or more strict restrictions are necessary), a micro-reserve can be established. Here, necessary measures and restrictions are defined by a species and habitat expert. In 2016, this option is still not used[7] (Environmental Protection Agency, *without date*).

Since the time of the first independent Republic of Latvia (1918–1940) to the present day, various scientific and popular publications have shown the special importance of rock outcrops and caves as habitats of rare species (Malta 1925, 1926, 1940, Skuja, Ore 1933; Zirnītis 1935; Āboliņa 1979, 2007; Kušners, Smaļinskis 1994, Liepiņa 1996; Smaļinskis 1997; Opermanis 1999; Pakalne et al. 2007; Piterāns 2007; Šuba, et al. 2008; Rēriha 2013; Vintulis 2013; Āboliņa et al. 2015; LETA 2015; Moisejevs 2015; Vimba 2015). The studies focus mainly on the presence of species and their living conditions, but comprehensive ecological

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[4] Decision No. 107 of the Council of Ministers of the Latvian SSR, Dated 10 April 1987, On Specially Protected Natural Objects in the Territory of the Latvian SSR.

[5] On the Regimes of Specially Protected Nature Objects in the Territory of the Latvian SSR. Annex Part III to Decision No. 107 of the Council of Ministers of the Latvian SSR, On Specially Protected Natural Objects in the Territory of the Latvian SSR.

[6] Decision No. 107 On the Regimes of Specially Protected Nature Objects in the Territory of the Latvian SSR. Annex to Decision No. 107 of the Council of Ministers of the Latvian SSR, On Specially Protected Nature Objects in the Territory of the Latvian SSR.

[7] Cabinet Regulation No. 940 of 18 December 2012 Regulations on Procedures for the Establishment of Micro-reserves and their Management, Conservation, as well as Interpretation of Micro-reserves and the Buffer Zone.

research is still lacking. Also, the classification of rock outcrop vegetation in Latvia has not been created (Rēriha 2013). Plant species related to rock outcrops and which were included in the lists of protected species both in the period of the Latvian SSR and nowadays (for more on the current situation, *see Chapter 6.3*) are: ferns *Asplenium trichomanes*[8], *A. ruta-muraria*, *lichen Cystocoleus ebeneus*, all species of bats *Chiroptera*[9], bird species *Alcedo atthis*. Destruction of the habitats of these species is prohibited. During the period of the current Republic of Latvia (since 1991) the list has been supplemented with moss, lichen and snail species for which outcrop habitats are the only or the most significant living environment.

Chapter 3. Ecosystem Services and Other Values of Rock Outcrops and Caves

The concept of ecosystem services is closely related to the interaction of people with the environment. Ecosystem services are the benefits of ecosystem structures and functions to human welfare, also taking into account the human impact on ecosystems (Burkhard et al. 2012). Ecosystems, their functioning and the provided ecosystem services are threatened by human activities. They are also adversely affected by climate change and the decrease of biological diversity. At the same time, the knowledge of ecosystems and their restoration possibilities is rapidly increasing. The knowledge of services of a particular ecosystem helps to determine the ecological and socio-economic benefits and their amount, allows one to compare them and to make decisions.

Ecosystem services can be classified according to various criteria. Currently the most widely used classification is the international ecosystem services classification *Millennium Ecosystem Assessment* (MEA 2003). Ecosystem services are divided into four major categories: provisioning, cultural, regulating, and supporting services. So far, ecosystem services of rock outcrops and caves have not been professionally evaluated, therefore only the commonly known services are listed below. Rock outcrops are just the visible part of the rock surface. However, the whole of the rock and also the surrounding area, fulfil important functions.

Support services include water, air, nutrient recycling, soil formation and fertility, species habitat – living, breeding, feeding places and migration routes. Rock outcrops provide a specific living environment for algae, lichen and moss species, some of which are found only on outcrops. Animal species are highly capable of adaptation, and no animal species are currently known in Latvia, which could be solely dependent on rock outcrops

[8] Species of Plants, Lichens, and Fungus Protected in the Territory of the Latvian SSR. Annex No. 13 to Decision No. 107 of the Council of Ministers of the Latvian SSR, Dated 10 April 1987, On Specially Protected Nature Objects in the Territory of the Latvian SSR.

[9] List of State Protected Animal Species in the Territory of the Latvian SSR. Annex No. 14 to Decision No. 107 of the Council of Ministers of the Latvian SSR, Dated 10 April 1987, On Specially Protected Nature Objects in the Territory of the Latvian SSR.

alone, though rock outcrops are important living environments for several species. Outcrops of carbonate bedrocks serve as a source of calcium for invertebrates such as snails that require calcium to form their shells. Sandstone rocks are relatively soft and can be easily dug, therefore colonies of *Riparia riparia* are frequently formed in sandstone. *Alcedo atthis* dig burrows in sandstone, as well as *Vulpes vulpes* and other animals. Rock fissures can be used as hiding places. Natural and man-made caves are important hibernation sites for bats. Sometimes *Bubo bubo* uses sandstone "shelves" for nesting; *Troglodytes troglodytes* build their nests in sandstone cavities or between dolomite pieces.

The role of species of rock outcrops and caves in the lives of humans is not studied. It cannot be directly measured or observed. However, it cannot be evaluated as insignificant.

Water from precipitation, filtering through different rock layers in the long term, are purified and enriched with minerals. Spring waters bring the minerals to the surface, thus returning them to biological circulation. Calcium compounds leached from carbonate rocks are particularly important, as they ensure calcium for tufa formation, maintenance of animal shells and growth of calciphilous species. There can be cavities in sandstone rock, filled with water, which serves as an additional source of moisture. Sand volumes in rivers and riverbanks are complemented by sandstone scree. Thereby the conditions necessary for the formation of sandbars and islands are maintained, necessary for a variety of species living or growing in sand.

Regulation and maintenance services or environmental services include climate and flood regulation, as well as water purity. Sandstone layers act as a water filter and purify the rainwater. Outcrops along the river banks restrict the river bed and lateral erosion. Rock outcrops help in maintaining a stable microclimate in river ravines, as they limit the wind and accumulate solar radiation. A constant microclimate all year long is provided in caves, and this affects the nearest vicinity by reducing temperature fluctuations. Springs related to caves and outcrops provide constant air humidity in their vicinity.

Provision services are products that can directly be obtained by society from nature, such as energy (raw materials, water, biofuel, etc.). Rock layers and outcrops can serve as sources of dolomite and sand. Nowadays, people often use spring water for drinking (Fig. 3.1) which discharges at the base of sandstone cliffs and can be either filtered through cracks or accumulated over a long period of time in sandstone cavities. By filtering through the sandstone layer, spring water can become enriched with iron compounds and precipitate as iron oxide (ochre) in contact with air (Fig. 3.2). In ancient times such water was used in yarn dyeing as a mordant; the dried reddish layer was used as a dye.

Cultural services are nonmaterial benefits obtained by a society from nature. It includes both the physical and intellectual interaction of humans with nature (recreation, nature tourism, cultural heritage of natural landscapes, education), as well as the mental, spiritual interaction of humans with nature such as the allocation of a special status for a particular plant, animal or place. Cultural services are the most frequently used group of rock outcrop ecosystem services. The most important services are recreation and leisure services. The aesthetic value of rock out-

Fig. 3.1. Spring at the base of a rock outcrop, equipped for water taking in Slītere National Park. Photo: I. Čakare.

Fig. 3.2. Iron oxide sediments in the spring near Līču-Laņģu Cliffs in Gauja National Park. Photo: I. Čakare.

crops is closely linked with recreation. Nowadays, viewpoints, trails, platforms and boardwalks are established and maintained for the recreation of visitors. Rock outcrops offer a variety of tourism development opportunities. Walks are very popular, both on the top of the rock, with a wide view of the surroundings, and at the rock base to experience the majesty of the exposed rocks. In winter, beautiful icefalls form in places where water flows across rock outcrops. Only a few caves are relatively safe for visitors – caves, where there are no landslides (such as Gūtmanis Vave, Lielā Ellīte complex in Liepa). Despite the dangers, people are increasingly getting involved in speleotourism in Latvia.

Rock outcrops have cultural and historical significance as ancient cult places. For instance, Liv sacrificial offering caves have been known as sites of religious offerings since the 14th century. Some rock outcrops of the River Rauna are objects of modern mysticism. Inscriptions on walls of outcrops preserve the evidence of the development of nature tourism in Latvia.

Rock outcrops are of high scientific value as geological objects. They contain evidence of nature circumstances and life in earlier periods of the Earth's development. By comparing rock outcrops and identifying rock units (stratotypes), the Earth's history is being studied. Rock samples identified in outcrops give the possibility to predict mineral deposit composition in sites where sedimentary rocks of the same type continue underground. Fossils that are significant for the research of life evolution have been found in the rock outcrops of Latvia (*see Chapter 2*).

Chapter 4. Habitat Conservation, Restoration and Management for the Purpose of These Guidelines

(A. Priede, I. Čakare)

Different terms for the activities that focus on the provision of favourable conservation status of a habitat have been used in the guidelines. In the broadest meaning these activities, both passive and active, are called **habitat conservation**. Habitat conservation includes various legal and practical measures: establishment of protected nature areas and micro-reserves, prohibitions and restrictions of various forms, planning of nature protection measures and development, as well as active, targeted restoration, management and establishment of habitats in sites where they have disappeared or are influenced and degraded. So the conservation covers all targeted activities, approaches and techniques – both active and passive, which are focused on the conservation of nature values (Fig. 4.1).

Rock outcrop habitats are determined by geological conditions. This means that rock outcrops are either present or they are absent. Indicators of rock outcrop habitat conservation status include their naturalness, presence of typical species, and diversity. Natural habitats of rock outcrops cannot be recreated, if they disappear (either due to natural causes or due to human activity). While the rock outcrop exists, it also cannot be completely

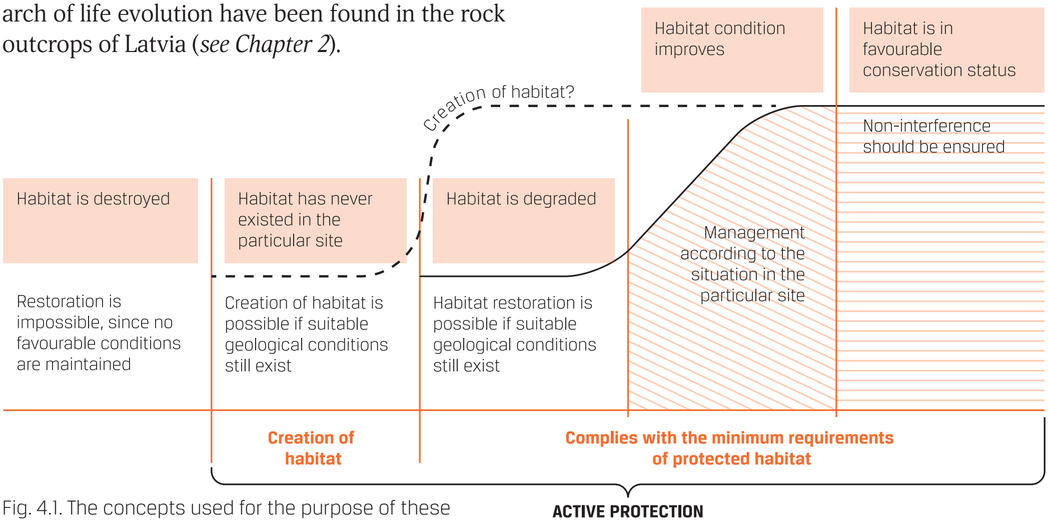

Fig. 4.1. The concepts used for the purpose of these guidelines.

destroyed as a habitat, and only its biological significance can be considerably decreased or completely degraded. In the case of favourable coincidence of circumstances, they can be restored as a result of spontaneous succession or through purposeful action. So the **protection of these habitats is based on the prevention of adverse effects and non-interference.**

Passive conservation plays a major role in the conservation of rock outcrops, which means the limitation of activities that can potentially endanger rock outcrops and related natural processes. Conservation of outcrops can be carried out with the aim of preserving both nature monument and protected habitats and species, as well as aspects of culture and history. Suitable measures include the prohibition or restriction of certain activities, establishment of buffer zones, and others. However, they should not deteriorate the condition of the rock outcrop as a protected habitat. Cases in which it is expected that research of other values such as fossils will have a significant adverse effect on the condition of the outcrop habitat are mentioned in the guidelines but solutions are not provided because the guidelines are intended to define the conditions needed to maintain the best possible quality of protected outcrop habitats.

The conservation status of rock outcrop habitats and associated species can be improved by preventing negative influences; however, they cannot be restored in the same meaning as other types of habitats (such as grasslands or mires).

Rock outcrop and cave habitat **management**, in the meaning of regular maintenance, is only necessary in places where tourist infrastructure has been established and habitat protection must be balanced with visitor safety and comfort. Management of rock outcrops as nature objects is not necessary because non-interference is optimal management for them both as nature monuments and as habitats for species. Typically, management may only be required to maintain visitor infrastructure and a visually attractive landscape. In rare cases, one-time or occasional and irregular management of rock outcrop surroundings may be necessary. For instance, in order to restore the functioning of the stream at the outcrop base and promote the transportation of rock debris.

The dominant attitude in Latvia in recent years is that nature values should be restored in sites which can still be classified as EU protected habitats. In this edition, the understanding of habitat restoration is broadened, to also include conditions and sites which currently do not meet the minimum criteria of a protected habitat, but under targeted actions their conditions can be established or improved enough to increase their biodiversity in the future. For the purpose of these guidelines **habitat creation** is a set of biotechnical measures aimed at the establishment of environmental conditions and structure characteristic for the habitat, and the introduction of characteristic species in a site where the habitat has never existed. Habitat creation is not a goal in itself. However, in the case of some habitat types it may at least partially compensate the consequences of loss of natural rock outcrops, and hence also the loss of EU protected habitat areas.

In order to ensure favourable conservation status for EU protected habitat types in Latvia, there is currently no need for the targeted establishment of new outcrops in sites where they did not exist earlier, which would be possible by outcropping deeper layers of carbonate or sandstone bedrocks. The priority is to ensure adequate protection for existing natural outcrops. However, new outcrops outside their natural localities can develop or be intentionally created in quarries and also on sloping road verges. In some places outcrops and caves have previously been created artificially. This in particular refers to caves that have been expanded, and dolomite outcrops, which in some sites are remnants of earlier dolomite quarries. Nowadays, artificially created Riežupe sand caves and Līgatne cellar caves have become important habitats - winter hibernation sites for bats. It is possible that artificially created rock outcrops can become important species habitats with time, equivalent to natural outcrops in terms of their values of nature. It is highly probable that the targeted creation of habitat suitable for calciphilous species is possible by retaining a dolomite wall after dolomite extraction in a quarry.

Chapter 5. Habitat Conservation and Management Objectives

5.1. Relationship of the Guidelines with the European Union "Nature Directives" and Natura 2000 Network

(J. Jātnieks, A. Priede)

The major nature conservation legislation in the EU is Council Directive 92/43/EEC on the Conservation of Natural Habitats and of Wild Fauna and Plants (hereinafter – the Habitats Directive) and European Parliament and Council Directive 2009/147/EC of 30 November 2009 on the Conservation of Wild Birds (hereinafter – the Birds Directive). Each country has developed national legislation to implement these directives.

The Birds Directive is intended to protect all species of wild birds and their habitats in the EU. The Directive provides for the protection of threatened bird species in the EU, determines the protection of feeding and resting sites most important for migratory birds, particularly emphasising wetlands of international importance. The Directive includes around 450 species. **The Habitats Directive** is intended to promote biodiversity by protecting natural habitats, plant and animal species in the territory of EU Member States. The Habitats Directive defines the necessity of protecting rare, endangered and endemic species, in total approximately 1200 species, in the EU. Annex I to the Directives includes 231 habitat types, out of which 71 are recognised as priority protected habitats at the EU level. Of those, 58 habitat types are found in Latvia, 19 of which are priority protected at the EU level[10].

Due to the intensification of agriculture and forestry, change of land-use practices, urbanisation and many other human influences, many of the natural and particularly semi-natural habitats in the EU and Latvia are in critical condition. The latest assessment about the condition of habitats in every EU member state was carried out in 2013, providing an overview of the years 2006–2012. It is estimated that only 16% of the habitats and 23% of the species included in the Habitats Directive are in favourable conservation status. According to the report (Anon. 2013a), only 13% of the EU habitat types and 28% of species found in Latvia are in favourable conservation status.

The Habitats Directive provides for the implementation of nature conservation in a way that maintains or restores the favourable conservation status of natural and semi-natural habitats, wild flora and fauna[11]. Guidelines proposed in this edition include a set of methods, which facilitates the reaching of favourable conservation status of the EU protected habitats found in Latvia. However, it is only part of the activities related to nature conservation (*see Chapter 4*).

According to the Habitats Directive, one of the ways of how to conserve habitats of Annex I and species of Annex II, is the establishment of protected areas. Together with the areas established in accordance with the Birds Directive, they create the European **protected areas network Natura 2000**. Protected areas are established in accordance with scientific criteria provided in Annex III of the Habitats Directive. When planning and implementing nature conservation measures in accordance with the Habitats Directive, such as developing nature conservation plans, one should take into account the economic, social and cultural requirements, as well as regional and local characteristics.

In Latvia in 2016 there were 333 Natura 2000 sites, seven of them – protected marine areas. In total, terrestrial Natura 2000 sites occupy around 11.5% of the country's territory. Latvia has the third smallest area of protected Natura 2000 territories in the country among the 28 EU Member States (comparison: in ten EU Member States, Natura 2000 territories cover more than 20% of the country).

Natura 2000 sites of Latvia vary from small (up to 1 ha) to more than 90,000 ha, depending on the characteristics of their species and habitats, and their conservation objectives. Many of them are known to the public and are popular natural heritage sites – national parks, nature parks and nature reserves, as well as areas which establish and maintain our agricultural, forest, mire, water and coastal landscapes – a significant part of natural and cultural history heritage.

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[10] Currently three more forest habitat types are being discussed to be included in the list of EU protected habitat types that can be found in Latvia. In this series of guidelines they are already included in Volume 3 – Semi-natural grasslands (Rūsiņa (ed.) 2017), and Volume 6 – Forests (Ikauniece (ed.) 2017).

[11] Favourable conservation status is defined in Article 1 of the Habitats Directive. In Latvia it is adopted by incorporating it in the Law on the Conservation of Species and Habitats (favourable conservation status is defined in Article 7 of the Law).

Article 6 of the Habitats Directive sets the requirements for the conservation and management of Natura 2000 sites. According to this Article, a protection regime appropriate for the conservation of species and habitats must be defined and implemented. It also includes active action in a case when following the non-intervention and caution principles does not ensure conservation of the habitat. These guidelines are a part of the measures defined in Article 6. They offer recommendations for habitat restoration, maintenance and creation in sites where they have been destroyed, taking into account the condition of EU habitats in Latvia and evaluating their conservation possibilities.

5.2. The Objectives of the European Union for the Conservation of Habitats and Species

(A. Priede)

One of the EU biodiversity strategy 2020 objectives requires that by 2020 the Member States should restore at least 15% of the degraded ecosystems in their territories (European Commission 2011). The restoration criteria include the total area of the restored habitats and their conservation status – improvement of living and non-living environmental conditions. Taking into account the degree of ecosystem degradation nowadays in Europe, it is not possible to eliminate all the adverse effects and completely "fix" their consequences. It would be too expensive and technically difficult, sometimes even impossible, especially for habitats such as outcrops and caves, which are determined by geological conditions and processes. Restoration is a condition when a considerable improvement has been reached, at least concerning the main functions, processes and structures of species populations. The reference point is 2006. Then, the first report on the conservation status and areas of habitat types included in Annex I of the Habitats Directive was prepared (Lammerant et al. 2013). Like in other EU Member States, this objective should also be realised in Latvia.

Actually this means that the restoration, management or recreation of any habitat in a specific area at the same time will cause a locally favourable effect (will restore the specific habitat area). However, each restored area will be a piece of mosaic that helps to maintain favourable habitat conservation status in the country as a whole. It is only possible to gain insight on the total situation (desirable or real) by assessing and planning measures at a national level. In this case, the objective is to ensure that the restored habitat area occupies at least 15% of the total area of the particular habitat type by 2020. Rock outcrop habitats cannot be restored in the same sense as many other habitat types, as well as the area of these habitats cannot be increased to a significant degree. In this case, the conservation of the existing rock outcrops is a priority (*see Chapter 4*). Any properly conserved rock outcrop or cave where adverse influences are prevented will at least slightly improve the overall situation or, at least, will not deteriorate it. A complex approach must be followed in the conservation of rock outcrops. Rock outcrops and caves cannot be conserved in isolation from the overall picture – habitat complex. For the conservation of outcrops, the conservation of forests, waters and springs in the widest sense is also important. It can be achieved by measures such as avoiding degrading erosion, prevention of rapid changes in insolation and microclimate, which can cause the extinction of shade loving species, as well as by preventing too intensive tourism load and other adverse influences. Therefore the conservation of rock outcrops and caves must always be viewed in a wider context, taking into account the influencing factors – both natural and man-made.

In order to achieve the biodiversity conservation goal, in 2013, Latvia, like other EU Member States, prepared a *Prioritised Action Framework for Natura 2000* – a- document which defines activities for species and habitat protection, taking into account their degree of risk. This book provides instructions for the conservation of habitats and their related species by carrying out (or in some cases, on the contrary, not carrying out) certain activities.

5.3. Objectives for the Protection and Management of Rock Outcrop Habitats in Latvia

According to the Law on the Conservation of Species and Biotopes the objective of habitat conservation is to provide a set of factors that favourably affects the habitat and its characteristic species and promotes the natural prevalence, structure and functions of the habitat, as well as the survival of characteristic species for a long period of time. Habitat conservation in its range or, in a narrower sense, at a national level, is considered as favourable if its natural range and areas where it can be found are stable or increasing, it has specific structure and functions necessary for the continued existence of the habitat, and it is expected that they will exist in the near future, as well as conservation of the characteristic species is provided.

The objective of rock outcrop and cave conservation is to maintain undisturbed exposed rocks and undisturbed caves with their distinctive regime of moisture and shading, in order to ensure a constant environment for characteristic species of these habitats. Non-interference regime related to rock exposure, collapses, landslides and overgrowth is the priority. Management of rock outcrop habitats can only be considered in areas where excessive erosion of outcrops occurs due to human activities which should be limited, as well as in areas with already established tourism infrastructure where it needs to be adjusted, and visitor flow must be redirected. In rare cases the management of the surrounding habitats may be necessary in order to restore rock debris transportation at the rock base or to remove a particular tree or shrubs from the outcrop, if it endangers nature values important for the habitat.

In the conservation and restoration of rock outcrop and cave habitats the ecosystem approach is important – if the functioning of all ecosystems is ensured, particular EU habitat types will also exist. Favourable conservation status of a rock outcrop or a cave means that the rock outcrop is preserved with its characteristic moisture, and natural processes occur – landslides, rock outcropping, scree transportation; there is permanent cover of characteristic vegetation on at least part of the outcrop, and invasive species are absent. A constant regime of temperature and moisture throughout the year is an especially important indication of favourable conservation status of cave habitats, as well as the presence and vitality of characteristic species. In order to ensure such conditions, the influences of surrounding habitats can be significant. For the maintenance of rock outcrop microclimate and scree transport, a watercourse is important – a spring, a brook, a river, an oxbow or lake with a natural hydrological regime. Insolation and shading conditions of the outcrop and cave, and consequently also the microclimate, depend on the conditions above and below the outcrop. Permanent and stable surrounding habitats are significant. For example, undisturbed deciduous forest above the outcrop provides constant shading in summer, while in winter it allows sunlight to access the outcrop. At the same time, spruce forest ensures shade throughout the year above and around the cave.

Furthermore, wide-scale collapse caused by natural factors is part of the natural process occurring in outcrops and caves and therefore cannot be considered as indicators of an unfavourable status. Rather, it is a natural course of succession. If the natural process of washing away is not influenced and if part of the outcrop remains beneath the collapse, the outcrop can recover itself with time. With the renewal of environmental processes such as sandstone or carbonate rock outcropping, the natural hydrological regime and natural disturbances, as well as the species composition characteristic for habitat, will recover. If the course of natural processes is disturbed, these natural processes can also be imitated. However, there are no experiments and studies on this type of management and therefore attempts to create appropriate conditions can fail. Therefore, non-interference is the best appropriate management type for rock outcrop and cave habitats. If necessary, the habitat for target species such as bats can be improved using special techniques.

As the areas of rock outcrop habitats in the country are small and not all of them are included in protected territories, the following **tasks** have been defined in order to ensure the favourable conservation status of protected rock outcrop and cave habitats of EU significance in Latvia. The results of the implementation of these tasks can be evaluated using certain indicators.

(1) To ensure the conservation of all rock outcrop and cave habitats in the country.

Indicators:

- the total area of the habitat type in the country does not decrease, except under the influence of natural processes (such as collapsing of caves);
- number of habitat localities in the country is not decreasing (with disappearance of locality, the possibilities of conservation of habitat and its characteristic species in the whole region and distribution range also decrease).

(2) To ensure no deterioration of abiotic conditions and improve habitat quality where it is necessary and possible.

Indicators:

- microclimate is optimal for the habitat – humidity, insolation, constant temperature in caves (these may differ for each particular object);
- processes occur with a functional role (transportation of rock debris; small landslides are in balance with lack of disturbances);
- habitat characteristic structure is present (relief, micro-relief, presence of characteristic species, vegetation cover, etc.);
- there is a contact zone with natural or semi-natural habitats which are significant for biodiversity conservation (potential beneficial or neutral impact of the adjacent areas).

(3) To ensure the optimum conservation and management regime for habitat and its characteristic species.

Indicators:

- umbrella species and habitat characteristic species are present;
- rare, endangered, vulnerable species are present in the habitat;
- invasive species are absent in the habitat; atypical expansive species (species indicating degradation) occur in small areas if the habitat is used for tourism.

Rock outcrops and caves are not only protected habitats, they may also have significant cultural and historical, geological, palaeontological or landscape value. Sometimes the requirements for habitat species conservation can contradict other values of rock outcrops, and conflicts may arise during the conservation and research. It is easier to balance the preservation of landscape values because the outcropping of rocks which are also habitats for sun-loving species will not reduce habitat quality, and will also increase the value of the landscape. There are no big conflicts in the conservation of undisturbed processes of rock outcrops and high value geological, palaeontological or cultural sites. However, artificial exposing of rocks or digging up of caves might be necessary for the geological, archaeological and palaeontological research, which means that outcrop vegetation will be damaged and the living environment and natural microclimate will be changed. This is acceptable in particular cases, if localities of rare species or their habitat are not destroyed. Geological research may also conflict with the preservation of unique cultural heritage values (religious sites, petroglyphs), etc. Such permissible exceptions do not apply to rock outcrops and caves where rare and protected species are found. Here, species and habitat protection is the priority.

5.4. Setting of Conservation and Management Objectives in a Specific Area

Rock outcrops are usually geographically isolated as individual objects of various sizes. For example, a particular sandstone outcrop (sometimes it is an outcrop with its own name) may be divided into sections, some of them may be open, others – covered with forest; there may be caves. Part of the wall can be included in tourist routes; sightseeing infrastructure can be established here (boardwalks, trails, barriers, signs). When planning rock outcrop protection, the geographically separable object must be seen in its entirety, not just the exposed part of it, such as a particular cave, without considering the outcrop where it is located, or only one part of the landscape which is the most attractive, without taking into account the part which is covered with scree or surrounded by woodland.

If geographical borders are established for the geological object, the current situation and development of the outcrop can also be evaluated. In order to determine the objective for conservation and management, ecological conditions and their influencing factors must be studied in each part of the object. The especially important factors to examine are characteristic species, indicator species and their condition. This allows one to define a set of ecological conditions, which should be achieved in an ideal situation in a particular location. From the point of view of species and habitat conservation, the aim should always be to create the ideal set of ecological conditions. However, there is a lack of studies on rock outcrop ecological groups, and therefore the main emphasis is being placed on ensuring the optimal conditions for rare and protected species, as well as the conservation of geological objects.

Chapter 6. Preparation for the Conservation and Management of Rock Outcrops and Caves

6.1. Prerequisites of Successful Habitat Restoration and Management

(A. Priede, I. Čakare)

Prior to starting the restoration or management of a habitat, it is most important to define the objective – *what* do we want to achieve with our activity? It requires knowledge about the natural or ideal condition of the habitat, ecological requirements of its species. In addition, the target status should cover both the area and quality of the habitat. In order to determine the status, in each separate case it is necessary to understand the real potential, taking into account the impacts and obstacles. In defining the target status in a particular area one should take into account the conditions that exist in the area and next to it, and the impacts that are long lasting and sometimes not avoidable with our actions. Sometimes only improvement of the status is possible – a sort of compromise that is better than doing nothing. Regarding rock outcrop and cave habitats, it is known which active protection measures are necessary for bat conservation. However, knowledge of other groups of organisms is lacking, therefore the following discussion reviews theoretical aspects of habitat restoration without particular association to outcrop habitats.

Upon setting the objectives to be achieved, various errors are possible if the current situation, causes of degradation, and background conditions are not adequately evaluated. For example, in Western Europe, which has been heavily modified by human action, influenced both by pollution and climate change, even in the Natura 2000 areas we cannot expect the restoration of pristine "wild nature". It is definitely more useful to try to restore a functioning and self-regulating ecosystem instead of a degraded ecosystem, even though it only vaguely resembles the imagined primeval nature condition (Hilderbrand et al. 2005; Thorpe, Stanley 2011).

If the objective is clear, the next step is to figure out how to achieve it – with what actions the idea can be implemented. This requires exploring the situation in detail, research of site conditions, clarification and choice of the potential habitat management techniques, and assessing how suitable they are to the particular situation, taking into account the available resources. At the idea stage it is already necessary to assess the extent to which the objective is achievable, and anticipate the obstacles. This will help to decide whether the investments are commensurate to the expected result. If not, then, most likely, it is better to invest resources where it is more worthwhile.

The biggest disappointment usually happens when one assumes that it is enough to improve the non-living environmental conditions, and the set of characteristic species will establish soon. It can work out in conditions that are little-affected, but the success can be poor when trying to restore habitats in heavily fragmented landscapes. If characteristic species are absent, they can also be introduced artificially. Although the artificial reintroduction of characteristic species nowadays is quite a widely used technique, it can be unsuccessful even if seemingly suitable conditions have been restored or created (Hilderbrand et al. 2005). Reintroduction is most likely unsuccessful because of the lack of a significant component. For example, due to incomplete understanding of the ecological requirements of species, lack of symbiotic relationship or other factors that do not allow species to adjust themselves in the new site, even if they have existed there before. Also, it is not easy to control the spread of "undesirable" species. Most often, undesirable species are invasive species which nowadays are spreading rapidly due to global changes, occupying the ecological niches of local species and creating significant, sometimes even irreversible changes in ecosystems and their functioning. These species usually benefit from changes of the background conditions. In natural ecosystems, there are usually unsuitable conditions for invasive species, and they are not able to survive or at least do not massively reproduce and develop large populations. However, the environment changed by human actions – eutrophication, landscape fragmentation, artificially created migration paths – provides conditions favourable to them. The control of invasive species dispersal is a difficult task, which requires permanent and patient work that may also be unsuccessful if these species are not eradicated and controlled at a national or regional level.

Assuming that ecosystem restoration measures taken in an area have been correct and successful, it cannot be inferred that this is the perfect recipe that works for all similar cases (Hilderbrand et al. 2005). Even if the chosen technique is correct, you may not know whether the outcome will be the same as in another success story. Probably not. We also do not know how the ecosystem "behaves" over a longer period of time after restoration. Only long-term observations can confirm whether the objectives have been achieved and even if not, whether the result can be considered as successful.

In ecosystem restoration one should take into account the background of the modern environment – climate change, pollution, changes in land use which, in turn, are related to human lifestyle changes. For example, the rock outcrop situation was most likely changed in the late 19th century and early 20th century when active travelling around Latvia began, which increased the intensity of disturbances such as trampling, inscriptions on the outcrops; several objects were especially promoted and equipped to be viewed by visitors. As technological industrialisation continued to develop, the influence on the outcrops also increased because of intensive changes of the river and lake hydrological regime.

For example, the flow of the River Salaca was changed from 1924–1929, causing the lowering of the water level in Lake Burtnieks by one metre. There is a wide outcrop situated at the lake shore. After the water level change, lake waves do not reach the outcrop base and do not remove scree, therefore previously exposed wall is now overgrowing with trees and shrubs (Fig. 6.1).

In 2014, trees and shrubs at the outcrop base were removed (Fig. 6.2), but within a few years shoots grew back on the scree, and the outcrop cannot be seen. In the future, the outcrop will overgrow if not maintained regularly (Fig. 6.3). Air pollution is still a topical problem. Additional nutrients are carried by precipitation and atmospheric deposition, that contribute to eutrophication and hence the species composition changes in various ecosystems possibly also including outcrops.

In the management of an ecosystem or, in a narrower sense – habitat – one should always take into account the restrictions: environmental (climate, soil, geological and hydrological conditions, landscape fragmentation and its impact on species populations), economic (financial constraints), social (public, often also funders', opinion). This should already be taken into account during planning of the works – possibly, more money and more time will be needed, and the outcome will not be that successful as expected because of these restraints. However it does not mean giving up all the plans and deciding that it is not worth doing anything. In many cases, it is not possible to restore the degraded ecosystem to the original "perfect" condition. However, the situation can definitely be improved. Good planning and the evaluation of risks urge one to act smarter than without realising these obstacles and, thus, risking making more mistakes.

Fig. 6.1. There is a wide marshy zone between the sandstone outcrops (yellow line in the map) and the open Lake Burtnieks which does not allow lake waves to wash out the outcrop base. Orthophoto map: © Latvian Geospatial Information Agency (2010–2011).

Fig. 6.2. Rock outcrop on the shore of Lake Burtnieks was open in 2014. Photo: D. Kļaviņš, www.panoramio.com.

In these guidelines the guiding principle is the assumption that it is always better to protect and maintain the natural ecosystems (in the narrower sense – habitats) by, wherever possible, eliminating the adverse effect and increased loads, rather than to damage and then try to "fix" them. Restoration of degraded ecosystems is always associated with the risk of failure and high costs, as well as many nature values may be irretrievably damaged by losing rare species, specific conditions, beautiful sceneries and resources necessary for the survival of not only nature, but also humans. Many examples from around the world confirm that the funds invested in restoring a damaged ecosystem are much greater than the benefits derived from ecosystem use. Moreover, the costs increase according to the increase in level of degradation. Thus proper protection of natural ecosystems is most important, and restoration or management is only a tool to "fix" already degraded ecosystems.

6.2. Planning of Habitat Restoration and Management in a Specific Area

From the point of view of species and habitat conservation, management is not needed for rock outcrop habitats. However, in cases when outcrops are significantly modified due to anthropogenic influence such as heavy trampling, which increases slope erosion, and also when visitors are endangered by natural processes – the development of tourism infrastructure is necessary, which directs visitors away from the rock outcrop habitats. The opposite management process that may be necessary includes the dismantling of tourist infrastructure if the outcrop has lost its significance as a tourist attraction, or if the infrastructure significantly worsens the condition of habitat. In some cases improvement of the living environment of certain species is needed, such as bats or mosses.

In order to determine management objectives, detailed research of species and ecological conditions is necessary. First, the borders of a particular geological object must be determined. For example, one rock outcrop object can include sandstone outcrops of various quality, and caves present there. Then the respective types of habitat must be identified. Rock outcrop habitats in Latvia are comparatively rare, therefore, if a forest develops on top of an outcrop as a result of overgrowing, but the conservation of outcrop is still possible and it is also necessary for rare species protection, outcrop protection should be preferred. Before starting works, thorough research and planning work must be carried out including research of outcrops and caves by experts, and a summary and evaluation of expert opinions. For the complete assessment of outcrop importance, a comprehensive study is necessary, which includes opinions of moss, lichen, fern and higher plant experts. It is also desirable to involve algae, invertebrate and bird experts. The opinion of a bat expert is definitely required for cave habitats. Rock outcrops with a cave cannot be treated as separate habitats, and should be seen together. Accordingly, planned actions for cave protection must be evaluated in the context of a rock outcrop. Careful outcrop study is also necessary before taking any action in habitats above the outcrop, next to it and at its base, because habitats of adjacent territories can significantly influence the outcrop.

Information on outcrop history and the development of conditions which might be important in assessing the current situation and for planning and management can be obtained from photos, maps of various times, studies, samples (herbaria and other collections) and publications.

In addition to the examination of species and ecological conditions, it is recommended to clarify the possible geological, paleontological cultural, historical and landscape values of the outcrop habitat in order to understand whether the management will adversely affect other values of the rock outcrops.

If a rock outcrop or a cave has long served as a well-maintained tourist attraction, it is not possible to completely eliminate the impact of visitors. In these cases a compromise between the conservation of habitat and species and the safety and comfort of visitors is necessary. However, little visited sites as well as sites where infrastructure is not properly maintained and where excessive trampling occurs must be closed for visitors, infrastructure must be dismantled, access must be restricted depending on the necessity, and the restoration of natural processes must be allowed.

6.3. Legal Framework

(Ē. Kļaviņa)

6.3.1. Protected Habitat Types and Species

The Cabinet, based on **the Law on the Conservation of Species and Biotopes**[12] has approved the regulations, which include protected habitat types[13] and protected species[14]. Cabinet Regulations include all protected rock outcrop habitat types of EU significance that can be found in Latvia: 8210 *Calcareous rocky slopes with chasmophytic vegetation*, 8220 *Siliceous rocky slopes with chasmophytic vegetation* and 8310 *Caves not open to the public*.

Based on this law, the Cabinet issued regulations with the lists of plant and animal species of EU significance[15], for which protection is needed (lists also include all species of bats which live, feed, reproduce and hibernate in Latvia).

6.3.2. Specially Protected Nature Territories and Micro-reserves

Law "On Specially Protected Nature Territories"[16] defines the basic principles of the nature conservation system. To protect and maintain biodiversity in Latvia, strict nature reserves, national parks, nature reserves, nature parks and other protected nature territories are established. These areas can be divided into functional zones with different approved regimes of protection and management. Micro-reserves are small territories (0.1–30 ha) created to protect habitats or animal, plant, fungus, lichen and algae species. The procedures for micro-reserve establishment, management and conservation are defined by Cabinet Regulation[17]. Borders of protected nature territories and micro-reserves are determined in national regulations and displayed in the public information system – Nature Data Management System OZOLS (http://ozols.daba.gov.lv/). Up to 2017, no micro-reserves for the conservation of rock outcrops and caves have been established.

According to the law "On Specially Protected Nature Territories" **rock outcrops and caves may be defined as geological and geomorphological nature monuments** – specially protected nature territories, which are individual nature formations that have scientific, cultural, historical, aesthetic or ecological value.

Protected nature areas and micro-reserves, which significantly contribute to the maintenance of favourable conservation status of protected habitats or species in the relevant EU biogeographical region, are included in **the network of European protected nature areas Natura 2000**. In these areas the necessary conservation measures are taken to maintain or restore favourable conservation status of protected habitats and species.

Protection and management of specially protected nature territories is regulated by the **General regulations for the protection and use of specially protected nature territories**[18] or their **individual protection and use regulations**. In the territory of a protected geological and geomorphological nature monument[19] no particular measures for habitat management are usually necessary. However, regulations determine various prohibitions – to engrave and to scratch the nature monument and to move it; to make fires in caves and to bring any burning objects that cause smoke or heat. Without written permission from the Nature Conservation Agency it is prohibited to establish public objects of nature tourism and education (such as boardwalks, trails, observation towers) and organise other activities. If protected geological and geomorphological nature monuments are loca-

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12 With the amendments as of 1 January 2016.

13 Cabinet Regulation No. 350 of 20 June 2017, On the List of Specially Protected Habitats.

14 Cabinet Regulation No. 396 of 14 November 2000, Regulations on the list of Specially Protected Species and Specially Protected Species whose Use is Limited.

15 Cabinet Regulation No. 1055 of 15 September 2009, Regulations on the list of those Animal and Plant Species of European Community Significance, for which Protection is Necessary, and the List of those Specimens of Animal Species and Plant Species of the European Community Significance, for the Acquisition of which in the Wild, Conditions for Restricted Use may be Applied.

16 With the amendments as of 11 January 2014.

17 Cabinet Regulation No. 940 of 18 December 2012, On the Procedures for the Establishment of Micro-reserves and their Management, Conservation, as well as Interpretation of Micro-reserves and Buffer Zones.

18 Cabinet Regulation No. 264 of 16 March 2010, General Regulations on the Protection and Use of Specially Protected Nature Territories.

19 These protected objects have been listed in Cabinet Regulation No. 175 of 17 April 2001, On Protected Geological and Geomorphological Nature Monuments.

ted in a protected nature territory or territory of another conservation status such as national park, nature park, nature reserve, and individual protection and use regulations are approved for these territories, these regulations may set stricter or specific provisions for the use and management of rock outcrops and caves.

In order to harmonise the interests of nature conservation, use of nature resources and sustainable development of the region, and to protect nature values of the territory, a **nature protection plan** can be elaborated for protected nature territories[20]. The nature protection plan recommends the measures necessary for the protection and management of nature values.

6.3.3. Coordination of Activities

Many activities for the restoration and management of specially protected habitats and species habitats before implementation **in specially protected nature territories and micro-reserves must be coordinated with the responsible state authorities** (Fig. 6.4). Written permission of the Nature Conservation Agency[21] (responsible institution) is necessary for activities such as deforestation (must also be approved by the State Forest Service) and the construction of nature tourism and educational infrastructure objects for public access, such as trails, observation towers, car parks. A written permit is not required for the removal of shrubs and trees with a stump diameter less than 20 cm outside forest lands, except for restrictions which are defined by the individual protection and use regulations of a particular protected nature territory.

Within the meaning of the Construction Law[22] a building is a physical object which was created by human activities and is linked to a foundation (ground or bed). Thus the majority of infrastructure objects planned with the aim to redirect the flow of tourists and to physically protect habitats, must be performed under Cabinet Regulation[23], which describe the construction process, groups of buildings, required documentation, and other construction-related measures.

WHERE TO FIND INFORMATION AND WHO SHOULD BE CONSULTED ABOUT ANY UNCERTAINTIES?

- **Nature Conservation Agency**: permitted and prohibited activities in protected nature territories and micro-reserves, and other issues of nature conservation: www.daba.gov.lv.
- **State Forest Service**: change in use of forest land, issues of forest management and use: www.vmd.gov.lv.
- **State Environmental Service and its Regional Environmental Boards**: habitat restoration and management outside the protected nature territory and micro-reserves, environmental impact assessment, and other issues: www.vvd.gov.lv.
- **Rural Support Service**: agricultural and forestry support payments and the administration thereof: www.lad.gov.lv.
- **State Inspection for Heritage Protection**: protection of memorial sites of national significance: www.mantojums.lv.
- **Local municipal authorities**: local issues – spatial planning, binding municipal regulations, locally protected nature territories and locally protected cultural heritage objects: contacts on websites of local municipalities

[20] Cabinet Regulation No. 686 of 09 October 2007, Regulations on Drafting the Nature Protection Plans for Specially Protected Nature Territories.

[21] Cabinet Regulation No. 264 of 16 March 2010, General Regulations on the Protection and Use of Specially Protected Nature Territories.

[22] With the amendments as of 1 January 2017.

[23] Cabinet Regulation No. 500 of 19 August 2014, General Construction Regulations.

Is the activity planned in a protected nature territory or a micro-reserve? If it is located in a protected nature territory, what type of functional zone is it?	The State Management System of Nature Data „Ozols" ozols.daba.gov.lv	If the activity will not take place in a protected nature territory or a micro-reserve, consult with the respective Regional Board of the State Environmental Service prior to the activity.
		Individual regulation on protection and use of a protected nature territory defines the permitted, restricted and coordinated activities. **Consult with the Nature Conservation Agency prior to starting the activity.**
		If no individual regulation is applicable, the permitted, restricted and coordinated activities are defined by the general regulation on conservation and use of protected nature territories. **Consult with the Nature Conservation Agency prior to starting the activity.**
Who owns or is in possession of the land?	Clarify this at the local municipal authority or on www.kadastri.lv	If the land owner or possessor agrees with the proposed activity, both parties should harmonise this in writing.
What is the category of land use?	Specified in the land border plan	If the restoration of a protected habitat type or species requires transformation of land into another category (e.g. forest to grassland), it must be coordinated with the responsible authorities. According to the individual or general regulation on protection and use of a protected nature territories, it is necessary to receive a written permit from the Nature Conservation Agency.
What permissions and approvals are required?	Depends on the character of the planned activities	**The actions specified in the general and individual regulations on protection and use of protected nature territory** must be coordinated with the Nature Conservation Agency. **Confirmations for felling in the forest** are issued by the State Forest Service. **Felling of trees outside forests** must be coordinated with the local municipal authority. **Technical regulations** for the cleaning of rivers or rewetting are issued by the State Environmental Service. VSIA ***Zemkopības ministrijas nekustamie īpašumi*** (State Ltd. Real Estate of the Ministry of Agriculture) issues technical regulations for reclaimed land and exploitation protective zones around drainage infrastructure (for construction, afforestation, etc.). **Conditions and permits for building construction** are issued by the Construction Board at the local municipal authority. You can ascertain the compliance of the intention with the spatial plan of the local municipality on the website of the particular municipal authority or by contacting the local municipality.
Are there other restrictions specified in the regulatory enactments?	For instance, protective zones, cultural heritage objects, etc.	It can be verified in the local municipality spatial plan (available on the website of the particular municipal authority) or clarified by contacting the local municipal authority.
Are there any funding options for protection, restoration and management of habitats?	Conditions for receiving agricultural and forestry support, etc.	On the issues of agricultural support (biologically valuable grasslands) one must consult the **Rural Support Service.** Support payments in forestry (refunds for restrictions of forestry activities on Natura 2000 sites) must be consulted at the **Rural Support Service**; in protected nature territories outside the Natura 2000 network – at the **Nature Conservation Agency**. More information is available on the websites of these institutions.

Fig. 6.4. Activities when planning the habitat management.

Forestry activities in forest lands of protected nature territories can be scheduled from 1 August until 15 March, in order not to disturb the animals during the period of breeding, birth and feeding. However, other limitations of terms and activities should also be taken into account, as defined by the individual regulations of conservation and use of a particular protected nature territory.

To avoid lack of time and to be able to carry out works in the appropriate season, requests for permits (if required) must be submitted in a timely manner! If habitat management is planned in protected nature territories or micro-reserves, prior to this the Nature Conservation Agency should always be contacted.

6.3.4. Categories and Types of Land Use

Land use category and land use type are defined for each particular land area. According to the classification of land use types (included in Cabinet Regulation[24]), the category of land use is a set of land use types of similar features. Areas of land use categories and their changes are described in the National Real Estate Cadastre. The State Land service maintains the system of the National Real Estate Cadastre, and it receives actual information from municipalities and the State Forest Service.

According to the Law on Forests[25], forest land is land on which forest grows, as well as land under forest infrastructure objects. According to Cabinet Regulation[26] the State Forest Service is the administrator of the State Forest Register and it maintains up-to-date information on forest inventory, change or exclusion of land categories. Information is removed from the State Forest Register if the area is deforested (its land use type is changed), as based on the administrative deed of the competent institution. By this, the landowner or legal possessor gets rights to change the land use type from forest to the type of land use which is the most appropriate for the conservation of rare species and rare habitat types.

Land use types are displayed (explicated) in particular legal boundaries document or in the respective documents of forest inventory.

To change the land use category in a specially protected nature territory, a written permit must be received from the Nature Conservation Agency.

6.3.5. Habitat Management in Micro-reserves

The establishment of micro-reserves, habitat restoration and management in micro-reserves is regulated by Cabinet Regulation[27]. Micro-reserves can also be established for rock outcrop and cave habitats. These regulations also determine the permitted and prohibited activities. Micro-reserves are managed in accordance with the judgement of a species and habitat expert, indicating the necessary measures for protection and management, such as felling and removal of trees and shrubs, maintenance and restoration of hydrological regime, prevention of unfavourable disturbances, etc.

6.3.6. Habitat Management in Forest

The legal framework that defines forest management is applicable to all forests in Latvia. Different conditions are provided by special laws of protected nature areas, individual protection and use regulations for these territories, or the management regime of micro-reserves.

When restoring specially protected habitats and specially protected species habitats in forest, the activities may only be implemented after land registration in the Land Register. Prior to forestry activities in forest one should receive a tree felling permit from the State Forest Service. Forest trees, the stump diameter of which is less than 12 centimetres, can be felled without a permit.

Nature Protection Requirements in Forest Management[28] define the general nature conservation requirements in forest management,

[24] Cabinet Regulation No. 562 of 21 August 2007, On the Procedures of Land Use Classification and Definition Criteria.

[25] With the amendments as of 1 January 2016.

[26] Cabinet Regulation No. 384 of 21 June 2016, Regulations Regarding Forest Inventory and Information Flow in the State Register of Forest.

[27] Cabinet Regulation No. 940 of 18 December 2012, On the Procedures for the Establishment of Micro-reserves and Their Management, Conservation, as well as Interpretation of Micro-reserves and Buffer Zones.

[28] Cabinet Regulation No. 936 of 18 December 2012, Nature Protection Requirements Regarding Forest Management.

restrictions in protection zones around mires, conditions for the determination and conservation of biologically important forest structure elements.

6.3.7. Deforestation for the Restoration of Habitats and Species Habitats

Protected habitats and protected species habitats in forests are restored in accordance with criteria defined in Cabinet Regulation[29]. The planned activity cannot contradict the spatial plan of the local municipality.

If the restoration of rock outcrop or related habitats requires the removal of trees, deforestation can be performed upon the receipt of a permit issued by the Nature Conservation Agency. The competent authority issues the permit based on the judgment of a certified expert in the field of conservation of species and habitats. When restoring the habitats in forest the applicant should clearly explain the types of planned activities (felling, stump extraction, ditch filling, digging, and other types).

Outcrop habitats which can be restored in forest by using a procedure of deforestation (change of land use type) are outcrops of carbonate bedrocks and sandstone outcrops.

By deforestation, the habitats of protected species related to outcrops can be restored, if these species are included in the List of Specially Protected Species and Specially Protected Species for Limited Use adopted by Cabinet Regulation[30].

If rock habitats are managed in the vicinity of surface water objects, the restrictions defined in the **Protection Zone Law**[31] should be taken into account.

6.3.8. Tree Felling Outside Forest

If the restoration of rock outcrop habitats is planned by felling trees in lands that are not deemed to be forests in the meaning of the Law on Forests, then the felling is performed in compliance with Cabinet Regulation[32]. The appropriate land use type must be registered in the information system of the Real Estate Cadastre.

In such cases a permit is required from the local municipality for the cutting of trees outside forest, except for trees with a stump diameter less than 20 centimetres.

6.4. Cost Estimation

(J. Jātnieks)

These guidelines are developed for use over a long period of time, therefore resources needed for particular works are not specified. Costs should be evaluated separately for each operation or set of works to be performed at a specific place and time.

Cost estimation is one of the most important steps in the preparatory process. Cost varies over time and can rarely be generalised for specific types of works or a set of actions required to improve the habitat condition. The difference in costs can be great for similar works – depending on the geographic location, complexity of works, availability of workers and special equipment, and other factors. The following principles should be used by developers of nature conservation plans, LIFE and other large projects to estimate costs of habitat management and restoration activities for a 2–5 year period, in one large or several Natura 2000 sites.

In small areas (up to 1 ha), as well as in cases when management is regular or parameters are known (for example, tree and shrub cutting), costs can generally be equated to the works performed elsewhere by interviewing the potential workers and agreeing on the total costs of all works. In small areas (up to 1 ha), as well as in cases where management is regular or certain parameters are known (for instance, felling of trees and shrubs), the cost can be generalised by equating it to the works performed elsewhere or interviewing the

[29] Cabinet Regulation No. 325 of 18 June 2013, Regulations Regarding the Restoration of Specially Protected Habitats and Species Habitats in Forest.

[30] Cabinet Regulation No. 396 of 14 November 2000, Regulations on the List of Specially Protected Species and Specially Protected Species Whose Use is Limited.

[31] With the amendments as of 20 June 2016.

[32] Cabinet Regulation No. 309 of 2 May 2012, Regulations on the Felling of Trees Outside Forest.

potential workers, and an agreement can be reached on the total costs of all works.

Key principles to determine reasonable costs of planned actions.

- After surveying the managed site **the most appropriate actions, methods and technical means are selected**. It is advised to divide works into parts, by stages, timing and type of work. For example, hand work, use of particular equipment. In this way, costs can be estimated for each activity separately, and summed costs are more objective. Costs and their efficiency often depend on the season. For example, hydrological regime restoration in wetlands should be carried out in the dry season, otherwise costs can grow unpredictably, but the objective may remain unrealised or the quality may be poor. To be sure that the actions of habitat management and restoration are chosen correctly, species and habitat experts should be involved.
- **Direct costs should be calculated in appropriate units** – man-hours, person-days, cost of equipment per hour, cost of materials per area or volume depending on works (m3, km, kg, t). The number of units required for all the works should be assessed and summed up. Experience shows that mistakes in these calculations are the most common. Therefore it is always advisable to use the experience of similar, already implemented works, such as reports on the projects or specific works, and experience of institutions (Nature Conservation Agency, JSC "Latvian State Forests", Rural Support Service, municipal and non-governmental organisations). Costs of technical works for various habitat restoration and management works over the years are published on the website of the Rural Support Service. Costs of materials and construction works are published annually on the webpage of the Latvian Rural Advisory and Training Centre. Such cost estimates are also available on the webpages of construction companies and the biggest forest management companies. If the set of planned activities consists of various works which are not carried out previously or their pricing is not available, at least three potential contractors should be surveyed. In this case, the result can be faster, however the risk increases that during the works unforeseen costs may arise that can complicate the achievement of the aim.
- **The indirect preparatory costs of habitat management and restoration works** should be assessed – site survey, expert opinions, technical projects, permits and approvals defined in legislation (see Chapter 6.3), including approvals by landowners of adjacent territories or possessors on the transportation of heavy machinery, placing of removed material, and other aspects. This involves both working time, transport and administrative costs, which are often inadequately assessed. For complex work on the projects, especially in the cases when there are several landowners for the managed territory, additional time and resources must be planned (even with a slight reserve) to inform the public and to explain the necessity for the scheduled actions.
- **Regional cost differences in Latvia should be taken into account** and also the availability of work performers in the given region up to 30 km from the planned place of activity. In many cases, especially in remote areas, workers will not be available locally. The costs may rise significantly if the contractors and/or equipment must come from a greater distance. For this reason, specific activities that require special equipment or skills (e.g., dam construction on ditches, topsoil removal) will always be more expensive than simple activities (mowing, cutting of shrubs, etc.). In some areas, finding workers for non-specific tasks can also be difficult. In the case of long-lasting (for several days) works, it is important to take into account accommodation costs in nearby guesthouses. This will reduce employees' travelling time and work will become more efficient.
- **It is recommended to entrust cost assessment to professionals** – managers, managing professionals, practitioners, entrepreneurs – and schedule this job and adequate funding.
- The planning, including financial planning, should also include potential income related to timber obtained in habitat management works. However in practice, a practical application is rarely found for these materials, if the volumes are small, extraction sites are dispersed over a wide and hard-to-reach area. Therefore it should be assumed that the commercialisation of the "byproducts" of habitat restoration measures may not always be economically beneficial and can even cause additional costs.

Chapter 7. Main Methods of Rock Outcrop Protection and Management

For habitats of the rocky habitat group, it is important to ensure natural processes such as rock outcropping under the influence of water and gravity, rock debris (scree) transport from the rock base and cave formation by the action of water. Thus **non-interference with natural processes** as well as the **prevention of adverse influences** are the main management measures which should be ensured for outcrop and cave habitats.

Nevertheless, if scree accumulates in undesirable volumes, the wall overgrows with uncharacteristic moss, lichen, tree and shrub species, and invasive species establish, intervention and active action may be necessary to ensure the optimal conditions. Clear objectives must be set before any outcrop and cave habitat restoration activity – the necessary ecological conditions, the species, and the measures that are necessary to maintain the fauna and flora in the particular site. Emphasising the landscape and ensuring access to visitors for viewing of the outcrop and cave itself is not habitat restoration or protection. Quite the opposite – establishment of tourism infrastructure, uncovering of outcrop and increase of visitor flow without proper research of species and without a clearly defined objective may worsen the habitat condition.

There are several possible options for action which must be used depending on the results of biological and other research of outcrops and the defined objective. More detailed descriptions can be found in chapters on each particular habitat; main methods are summarised in Table 7.1.

Table 7.1. Main methods for the management of rock outcrop habitats.

Measures for the restoration of habitat structure and function		
Problem	**Solutions and conflicts**	**Habitats**
Scree (rock debris) transportation at outcrop base does not occur, scree accumulates	Restoration of natural hydrological regime of springs, creeks, rivers, oxbows or lakes at the outcrop base. Significant influence of water level change must be prevented; natural flood regime and ice drift should not be affected. Sometimes excavation and removal of the scree is efficient – in cases when no active landslide processes occur in the territory of the entire outcrop. Rock fragments of carbonate bedrocks are a protected habitat and should not be transferred.	Stable sandstone outcrops and caves. Carbonate bedrock outcrops, except rock fragments which are a protected habitat themselves.
Undesirable overgrowth of outcrop with trees and shrubs	Felling of trees and shrubs on the outcrop and at its base. Removal of sand and soil debris.	All types of rock outcrops, if an open environment has been characteristic of them for a long time; sites where shading is not desirable.
Drying out of a natural watercourse	Causes of drying out must be found and eliminated. Often, the cause may be far away from the rock outcrop habitat. Sand that has been accumulated on a cave floor can be removed if this can improve the living conditions of protected species.	All rock outcrop habitats in sites where the microclimate is influenced by natural watercourses. In a cave habitat, drying out of a spring can be a result of natural processes, and the decision on the restoration of the watercourse must be taken depending on the needs of species conservation.
Landslides in caves or the collapse of caves	Individual parts of caves and cave entrances can be strengthened. Cave entrance strengthening can decrease the area of outcrop and influence the cave microclimate.	Rock outcrops and caves in outcrops.
Landslides	To uncover the outcrop and to create conditions for habitat characteristic species, the removal of debris material by the water flow must be promoted, if it does not cause other landslides.	Sandstone outcrops and caves.
Eutrophication	There is no research on outcrop eutrophication therefore the problem is difficult to identify. Solutions are complex, depending on the situation in a broad area. First, local influences must be eliminated, such as increased runoff from agricultural land and settlements located above the outcrop.	All rock outcrop habitats.

Table 7.1. Main methods for the management of rock outcrop habitats.

Prevention and Reduction of Visitor Load		
Problem	**Solutions and conflicts**	**Habitats**
Trampling, rock climbing	Development of appropriate infrastructure, which reduces visitor influence and redirects tourists (trails, boardwalks, platforms, information signs, etc.) (in sites with already established but incorrectly planned tourist attraction). Complete closure of the object, its delimitation, if the protected species is significantly influenced by trampling.	All rock outcrop habitats and springs associated with them.
Scratching of inscriptions	Development of appropriate infrastructure in order to prevent inscriptions on the walls (if it is an already managed tourist attraction). Complete closure of the object, its delimitation, if protected species or cultural and historical objects are significantly influenced by inscription engraving.	Sandstone outcrops and caves.
Disturbance (noise, smoke, human presence, etc.)	Development of appropriate infrastructure which prevents disturbance (if it is a tourist attraction). Complete closure or delimitation of object if the protected species is significantly influenced by disturbance (usually in bat hibernation sites).	All rock outcrop habitats, especially caves.
Worn-out tourism infrastructure which encourages trampling and other damage of the rock outcrop	Development of new, appropriate infrastructure, if it is planned to continue to use the site as a tourism object. Complete dismantling and removal of infrastructure, delimitation of the object, if further maintenance of the tourism object is not planned.	All rock outcrop habitats.

Sometimes (but not always) habitat management includes **attempts to establish an outcrop or cave habitat in a site where it did not exist originally**. Establishment of caves has often been successful because artificial sandstone caves and dolomite cavities can serve as habitats for species if there is a cave entrance and a further space of necessary size. However, such activities are not desirable because cave digging destroys part of the outcrop which itself is a protected habitat type and habitat for species. It is also possible to create sandstone wall outcrops in places where they did not exist previously, and preserve exposed walls of carbonate bedrock in abandoned quarries. In this way, quarries can be renaturalised.

If management is necessary for the conservation of rock outcrop nature values, for trampling (excessive walking) prevention and for redirecting of tourist flow, **tourism infrastructure** with elements such as boardwalks, footbridges, barriers, information signs can be established (Fig. 7.1). In any case, the most appropriate infrastructure elements must be chosen which address the problem (Fig. 7.2). The minimum infrastructure, which can be established in areas with a slight visitor load, includes trail signs and information boards. Depending on the need and the available resources, it can be supplemented with path border edging, barriers, boardwalks, footbridges, benches and sightseeing platforms. To prevent trampling, various materials can be used such as wood, boulders, metal grids. It is desirable that constructions do not cover the wall and basal part of the outcrop. Therefore, various lattice-type constructions should be preferred which allow sunlight and precipitation to reach the ground, thus decreasing the influence of constructions on the organisms living on outcrops.

Fig. 7.1. Information board at Sarkanās Klintis (Red Cliffs) near Cēsis, explaining nature values and significance of the outcrop. Tourism load is reduced by educating visitors about the popular recreation and water taking site. Photo: I. Čakare.

Fig. 7.2. Outcrop is partly buried because of active landslides but it is expected that the wall will be uncovered by natural processes. It is also visible that lichen and moss vegetation on the undisturbed part of the outcrop is sparse. It may indicate active landslide processes in all of the outcrop area. In such a case, interference such as scree removal is not desirable because it can promote landslides. Photo: I. Čakare.

Chapter 8. Landscape Ecological Aspects of Rock Outcrop Biodiversity Conservation

Rock outcrop habitats in Latvia are rare, and most of them are located on the banks of the Gauja, Salaca, Venta, Daugava, Abava rivers, and their tributaries. The distribution of outcrops depends on geological conditions. Also rock mechanical properties and differences in various places are important (Anon. 2002) because parts of rock material can be eroded easier than other parts which are harder, and so rock outcrops develop. River banks, especially ravine slopes are often covered with forests that surround outcrops and together with the river and springs create a constant microclimate. Outcrops are unevenly distributed in Latvia and vary in their height and length. In some places they form a belt of many metres along the river, in other sites there are only small outcrop patches in the river valley forest. The living environment on exposed rocks is specific and differs from the environment of surrounding habitats. A common feature for all outcrops is a total or partial lack of soil, which creates living conditions for highly specialised species. The distribution of outcrop characteristic species is limited by the relative isolation of outcrops. Outcrops on river banks are separated by completely different environments – water, forests, grasslands and settlements. Rivers can serve as species distribution corridors from one outcrop to another, however, it is not known to what degree species dispersal is limited by natural isolation.

Latvian outcrops and caves in terms of size cannot resemble the impressive cliffs and caves in other parts of the world. However, our outcrops also host lichen and moss species which are characteristic for only these habitats elsewhere in Europe and worldwide as well. Ecological conditions play a significant role in outcrop species composition (Larsson et al. 1999). In the case of some species, compacted exposed sand, boulders and similar substrates can also fulfil a function that is similar to outcrops (if there is no soil). However, the small number of outcrops and their natural isolation can be a limiting factor in the conservation of rare species. Dispersal of outcrop species may also be limited by differences in ecological conditions of outcrops. Species of a moist, shaded sandstone outcrop cannot find suitable conditions on a neighbouring outcrop if it is dry and exposed to the sun.

Locally, the distribution of outcrop species can be determined by rock heterogeneity, local inclusions, differing processes in different parts of the outcrop, erosion rate and type (Larsson et al. 2000). Moss species diversity is determined by the availability of microhabitats and area of ecotones (Kubešová, Chytrý 2005). Outcrops are considered as a stable environment where changes are determined by microclimate and by rock mineral composition, and the rock itself can act as a buffer against adverse changes in the environment (Kasurinen 2012). However, landslides occur quite often in outcrops in Latvia, and completely change the condition of the rock. This can cause fragmentation and increase the distance between suitable habitats, therefore the conservation of all outcrops is important. It is believed that animal species can spread over much longer distances than lichen, moss and other plant species.

Understanding of the conditions necessary for every organism group and conservation of as many rock outcrops in their natural condition as possible, is the most important task in order to ensure dispersal possibilities for species, and thus their possibilities for preservation. Rock outcrops are an important part of the biological diversity of a larger area, and their conservation must be planned together with the conservation of forests, waters and other habitats (Lindenmayer, Franklin 2002).

Chapter 9. Evaluation of the Success of Protection and Management

Efficiency of management must be evaluated annually, depending on its objectives. If the management objective is the prevention of human-promoted erosion, areas with excessive erosion and trampling must be assessed and compared in relation to undisturbed areas. If the area is managed for species conservation then the abundance and cover of target species must be evaluated, as well as if the establishment of desirable conditions was successful. The initial evaluation before the starting of works is important because it will serve as a reference point for understanding the influence and efficiency of the implemented works. In some cases longer data series are necessary which cannot be obtained shortly before the starting of management. For example, management influence on hibernating bats can only be assessed if a sufficient amount of data is available.

An appropriate monitoring method for each group of species should be used. Vegetation is described in sample plots, the size, number, sampling frequency and other parameters of which depend on the monitoring objective, object size and configuration, and many other conditions which may be so various that we cannot generalise the methods. In all cases, the site must be photographed before and after the management measure, and from the same point of view, which can be marked on site with a peg, a mark on the tree or otherwise. Keep in mind that GPS measurements at the outcrop base may be inaccurate.

Sufficient analysis of the necessary conditions for rock outcrop species is lacking. Algae, lichens and mosses and some invertebrate, bird and bat species depend on particular conditions with a characteristic microclimate, which is defined by humidity, insolation, shading and temperature. The largest body of experience in Latvia is gathered on the evaluation of bat hibernation sites – bat monitoring has been carried out in 80 caves since 1980 (Vintulis 2013). These data can be used for the evaluation of the condition of caves and outcrops with caves.

Success evaluation (monitoring) methods must be elaborated individually for each object or set of objects according to the project.

Part II

Chapter 10. 8210 *calcareous rocky slopes with chasmophytic vegetation*

10.1. Characteristics of Calcareous Outcrops

10.1.1. Brief Description

EU protected habitat type 8210 *Calcareous rocky slopes with chasmophytic vegetation* includes natural outcrops of calcareous bedrock with characteristic vegetation. In Latvia, a dense layer of mosses and lichens has often developed on exposed rocks. Rich vegetation of herbaceous plants which is common on rocky slopes in Atlantic and alpine regions of Europe is not characteristic in Latvia. Some outcrops corresponding to the habitat type description are bare or covered with sparse vegetation. Outcrops of calcareous bedrock in Latvia are relatively small and occur rarely (Fig. 10.1). Therefore this habitat type in Latvia also includes artificially-created non-flooded or temporarily flooded exposed calcareous outcrops.

In areas where exposed rock has remained after the completion of calcareous rock mining, substrate conditions for the characteristic species are similar to naturally exposed rocks. Therefore, all calcareous outcrops regardless of the type of processes as a result of which they were exposed are attributed to this habitat type if there is vegetation characteristic for this habitat type.

Calcareous outcrops can consist of exposed dolomites, dolomite marlstones and limestone, with intermediate layers of clay. Layers of calcareous rock may be exposed at the upper part of sandstone. However, the most significant part in such places is usually occupied by sandstone outcrop which belongs to another protected habitat type – 8220 *Siliceous rocky slopes with chasmophytic vegetation*. In such cases, calcareous outcrop is not separated as an individual habitat type.

Dolomites are found in approximately one third of the Latvian sub-quaternary surface, and it dominates over other calcareous sediments (Stinkule, Stinkulis 2015). However, naturally developed calcareous outcrops are comparatively rarely found in Latvia. They are characteristic for the Daugava river basin as well as for rivers of the southern part of the Lielupe river basin, banks of the Venta and Abava rivers and their tributaries, and the middle part of the River Gauja (Fig. 10.1).

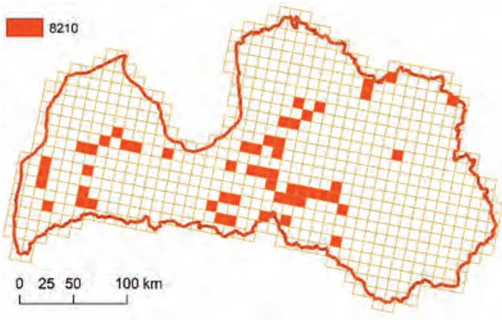

Fig. 10.1. Distribution of habitat type 8210 *Calcareous rocky slopes with chasmophytic vegetation* in Latvia (Anon. 2013a).

Devonian dolomites, which have formed in chemical substitution reactions of calcium carbonate deposits and limestone, have been researched considerably well for the purposes of mineral extraction. Dolomites are pure carbonate rocks located in the central and eastern parts of Latvia, but limestone of similar structure have can be found in the north-east (Stinkule, Stinkulis 2015).

The overall status of the habitat in the country was evaluated as favourable in the Report to the European Commission of 2013 according to Article 17 of the Habitats Directive (Anon. 2013a). The differences in the status of specific calcareous outcrops can vary from excellent to very poor. Habitat occupies approximately 0.2 km^2 in Latvia (Anon. 2013a). No significant changes in the total area of the habitat have been observed since the annual report of 2006 (Anon. 2007).

Calcareous outcrops also have palaeontological, geological, cultural, historical and social value, which, according to public opinion can be more important than the significance of outcrop as a habitat.

Outcrops in the river bed, such as Ventas Rumba waterfall, and parts and fragments of exposed rock that are regularly flooded outside the flood season, are attributed to 3260 *Water courses of plain to montane levels with the* Ranunculion fluitantis *and* Callitricho-batrachion *vegetation*.

10.1.2 Indications of Favourable Conservation Status

Exposed calcareous rock can be considered as a habitat under favourable conservation status if characteristic plant species for calcareous habitats (calciphilous species) can be found on it. The presence of animals characteristic of calcareous habitats (calciphilous species) is considered an additional value of an outcrop. The current level of research of calcareous bedrocks as a substrate allows one to conclude that these outcrops are important for the conservation of some calciphilous mosses and protected fern species. Different communities of species are characteristic for different environmental conditions (dry, sunny and moist, shaded). The exposure and shading of the outcrop is significant. The total cover of vegetation may be low, and species composition is more important for the evaluation of outcrop quality. Also, outcrops where characteristic species occur homogeneously over the entire length of the rock are more significant.

Large proportion of plants with high vitality in a part of the outcrop indicates inappropriate conditions in the rest of the outcrop and can be used for management planning. Fissures, cavities and surface heterogeneity increase the possibilities for vegetation to establish, but, if the surface of the outcrop is highly brittle and unstable, the vegetation will not last long. Calcareous rock slopes typically form walls that are up to 90 degrees steep. Cliff ledges can be found on river banks. The steeper the wall, the greater the significance of micro-relief for the development of vegetation. Lichens can grow on both horizontal and vertical surfaces, but their species composition depends on insolation (Piterāns 1990). Moss species diversity is higher if a spring flows at the foot of the cliff, as well as in partially shaded areas (Āboliņa 1990) (Fig. 10.2, 10.3).

Due to the chemical composition of calcareous bedrock these outcrops are subject to active erosion. They are characterised by wide landslides as dolomite marlstone and loamy dolomite erode, as well as landslides of large monolithic rock debris (scree) of dolomite. Also, scree belongs to habitat type 8210 *Calcareous rocky slopes with chasmophytic vegetation* if characteristic vegetation is found on it.

Fig. 10.2. Dolomite outcrop in Jumpravmuiža. In its upstream (front) part, the outcrop is typical, with average species richness. Further down the stream the activity of ice and flood water prevents the development of characteristic vegetation. Appropriate conditions for moss and fern species that prefer partial shade are ensured by outcrop exposition (north-east), the closeness of the river and the cover of shrubs above it. Photo: I. Čakare.

Fig. 10.3. Dolomite outcrop under the wall of Bauska Castle is dry and sunny because it is facing south. Grassland has developed on the slope and there are no shrubs which would shade the outcrop. Photo: I. Čakare.

Research on calcareous outcrop species is insufficient. To date more attention has been paid to the distribution of rare and protected calciphilous species. Species composition depends on outcrop shading and moisture, wall monolithic structure, presence of fissures, and cardinal direction. Geological data have not been analysed in connection with species distribution on outcrops, but it is known that not all of the calcareous outcrops are rich in calciphilous species (Fig. 10.3). Obviously the chemical and mechanical composition of the outcrop plays a crucial role in species composition formation because many characteristic species are calciphilous.

Vegetation generally consists of mosses. Characteristic species are *Encalypta streptocarpa, Homalothecium lutescens, Pohlia* ssp., *Bryum* ssp., *Tortula* ssp., and *Didymodon* spp. Rare moss species that grow on calcareous outcrops are *Fissidens crassipes, Gymnostomium calcareum* and *Myurella julacea*. Several lichen species have been found: *Polyblastia albida, Thelidium papulare, T. decipiens, Verrucaria marmorea, V. calciseda, Opegrapha rupestris, Aspicilia contorta, Hymenelia prevostii* (Rēriha 2013).

Calcareous outcrops are a habitat of protected fern species such as *Asplenium ruta-muraria* (Fig. 10.4), *A. trichomanes* and *Gymnocarpium robertiana*. *Cystopteris fragilis* is more common and it also grows on sandstone outcrops. In places where loose substrate has accumulated in fissures, *Poa* spp., *Sedum acre* (Fig. 10.5.), and *Hylotelephium maximum* establish. Calcareous outcrops are inhabited by various invertebrates that need base-rich substrate. Millipedes *Diplopoda, Armadillidium* spp., drought loving *Truncatellina cylindrica* and *Trogulus tricarinatus* have been found here (Rēriha 2013).

Fig. 10.5. *Sedum acre*. Photo: I. Čakare.

Mosses *Cratoneuron filicinum* and P*alustriella comuttata* can be found in sites where springs flow over or at the basal part of calcareous rock outcrops. Here mire habitats 7220* *Petrifying springs with tufa formation* (Cratoneurion) (Fig. 10.6.) or 7160 *Fennoscandian mineral-rich springs* and *springfens* can develop. Algae *Hildenbrandia rivularis, Petalonema crustaceum* and *Scytonema julianum* have been found in springs.

Fig. 10.4. *Asplenium ruta-muraria*. Photo: I. Čakare.

Fig. 10.6. Small outcrop is situated at the upper part of the slope, but spring discharge with *Palustriella commutata* at the outcrop base. Photo: I. Čakare.

10.1.3. Important Processes and Structures

10.1.3.1. Erosion

Outcrop erosion is a significant process for a habitat. Intense exposure of rocks continued until the end of the last Ice Age. The principal contemporary processes that occur include the erosion of exposed walls, wearing, and development of local secondary outcrops in the places where soil has developed on outcrops. Calcareous outcrops are characterised by vertical and horizontal fissures (Fig. 10.7). Water in fissures gets frozen and facilitates the disintegration of the exposed rock into pieces. As water enters deeper layers through fissures, loamy and sandy inclusions are mechanically washed out. Roots grow into the soil that accumulates in fissures. Gradually, plant roots widen fissures and consequently contribute to disintegration of the outcrop. The stream of water and ice drift at the outcrop base mechanically grinds the lower part of the outcrop and a cliff ledge develops above the river (Fig. 10.8). The largest pieces that are detached from the wall and fall to the foot of the outcrop remain as a substrate for characteristic species, while their composition may vary depending on the environmental conditions of the new location (shading, moisture and possible mechanical influences of water).

10.1.3.2. Riparian Processes

Riparian processes can contribute to the removal or accumulation of scree (rock debris). The smallest particles are removed more easily, while the largest rock fragments remain. The river bed may change due to a large-scale landslide. Then even tiny particles of the outcrop are not washed away, but accumulate at the base, which may facilitate partial overgrowth of the outcrop with trees and shrubs.

10.1.3.3. Rock Micro-relief

Calcareous outcrops are characterised by surface heterogeneity and a characteristic design of vertical and horizontal cracks, which are determined by rock composition (Fig. 10.9, 10.10, 10.11).

Fig. 10.8. Rock ledge at Jumpravmuiža develops above the river under the influence of ice and water erosion. Photo: I. Čakare.

Fig. 10.7. Structure of calcareous outcrops is characterised by vertical and horizontal cracks. Outcrop in Korkuļi ravine. Photo: A. Priede.

Fig. 10.9. Dolomite outcrop in the valley of the River Pērļupīte, which consists of large, unbound pieces of rock. Photo: I. Čakare.

Fig. 10.10. The outcrop at Jumpravmuiža is rich with irregular fissures and cavities.
Photo: I. Čakare.

Fig. 10.11. Outcrop on the banks of the River Līgatne consists of tightly fitting thin plates, therefore horizontal fissures are not deep. Photo: I. Čakare.

Surface micro-relief may have small cavities or be completely smooth. Fissures and surface heterogeneity increase the possibility of soil accumulation and promote plant introduction. Deeper cracks and caverns can provide a suitable environment for wintering animal species. Outcrops of calcareous bedrock can be located above sandstone rocks. Usually they form a narrow band and supplement the sandstone outcrop with niches, as well as with calcium leachate (Fig. 10.12).

10.1.3.4. Caves

Only a few caves in calcareous rocks are known in Latvia. They have developed in areas where the sandstone layer lies on top of the calcareous substrate. Spaces and caverns have developed underground under the influence of suffusion, and the dolomite layer above the spaces has collapsed. The collapse stopped until a larger plate was able to hold the mass of rock and created the ceiling. In the vicinity of known dolomite caves there are also sites where dolomite was extracted for construction needs, therefore it is possible that at least part of the cave volume has been artificially created or expanded (Fig. 10.13). Rather wide cracks may develop as a result of water and roots, which vertically wash and split the rock from above.

Caves in calcareous bedrocks are important for animal hibernation because there is a constant air temperature and humidity, as well as a large variety of fissures and niches for hiding (*see Chapter 12.1*).

Fig. 10.12. Thin dolomite layer forms above the sandstone outcrop in Māras kambari.
Photo: I. Čakare.

Fig. 10.13. Lielā Sikspārņu Cave (*Big Cave of Bats*) in 2015.
Photo: I. Čakare.

10.1.4. Habitat Dynamics

Calcareous outcrops can gradually overgrow with trees and shrubs that establish into fissures and on scree at the base of the slope (Fig. 10.14). The steeper the slope, the faster a new landslide is encouraged by the weight of vegetation. As the exposed rock overgrows with trees, most frequently with *Tilia cordata, Ulmus glabra, Acer platanoides* and *Alnus incana,* a forest habitat 9180 Tilio-Acerion *forests of slopes, screes and ravines* develops. If a narrow layer of soil accumulates above the outcrop and partly on the slope and if it is not steeper than 45°, a very rare grassland habitat type 6110* *Rupicolous calcareous or basophilic grasslands of the* Alysso-Sedion albican develop, and species characteristic to this habitat type can establish on the outcrop.

Fig. 10.14. Overgrowth of outcrop with deciduous trees and shrubs on the slope of the outcrop near Velnala (*Devil's Cave*) in the Abava Valley. Photo: A. Priede.

10.1.5. Pressures and Threats

10.1.5.1. Slope Processes

Collapses are the main reason for changes in calcareous outcrop conditions. They can be caused by water erosion, processes encouraged by freezing and melting, and gravitation. The process of collapse may be influenced by rock fissures. Human activities can also promote collapses. Walking on the outcrop can initiate the process of sliding of material down the slope, while intensive land cultivation above the outcrop increases water infiltration in fissures.

10.1.5.2. Frequent Water Level Changes

Rock outcrop is affected by the water stream at the base of the outcrop. Outcrops that are situated in floodplain areas of rivers are naturally subject to increased erosion, when the water level rises during spring and autumn floods, as well as during ice drift. Too frequent and pronounced water level changes have a negative impact. Frequent water level changes, which are characteristic for hydroelectric plant operation, reinforce natural erosion processes and prevent the development of characteristic vegetation below the cliff ledge and on the scree. There is almost no research concerning changes of river banks outside the direct construction sites, but the influence of small hydroelectric power plants which divide the river as a unified system is more studied. The insufficient level of knowledge is highlighted by authors of the research project *Significant environmental risk identification in Latvian municipalities for identification of the activities requiring support in the 2014–2020 financial planning period*: "Currently the evaluation of the effect of morphological changes [of river banks] on the ecological status is not sufficient." (Eiroprojekts 2014). Although this study was more focused on the impacts that are directly affecting rivers as a habitat, the issue of the banks has been mentioned there: "the operation of small hydroelectric power plants intensifies erosion processes on the banks, but the eroded material covers natural habitats in downstream sections of the river", and this effect must be rated as significant (Eiroprojekts 2014). In a publication on the impact of three hydroelectric power plants on the hydrological processes in the River Dubna it is concluded that water level fluctuations above and below the dam can cause coastal erosion and collapses (Kirsanovs, Munča 2009, 2010). There are no known protected rock outcrops on the banks of the River Dubna. However, the study confirms the significant role of a modified river hydrological regime on the processes occurring on river banks. Therefore, in accordance with the precautionary principle[33] any case of river damming must be evaluated with the assumption that it may cause serious damage to protected habitats and species, not only in the river, but

[33] Section 3 of the Environmental Protection Law of 16 May 2013.

also on river banks upstream and downstream of the site of action.

Caution is required in all cases where there is a possible impact on the natural hydrological regime of the river. Such impact can be caused by artificially created dams, hydroelectric power plants, structures that accelerate or change the runoff, coastal shore defences, large drainage systems, bridges. For example, the impact of artificial ice breaking on river bank habitats is not studied, however, such research is necessary in rivers where rock outcrop habitats are located in upstream or downstream sites where regular ice breaking works are planned. It is observed that natural ice drift considerably influences the outcrop condition as some of the walls are scratched and eroded. Ice erosion can be desirable for calcareous bedrock habitats, because it creates niches and maintains the outcrop open, as well as undesirable, because it mechanically scrapes off the rare individuals of species.

Fig. 10.15. Landslides are covered with leaves, soil develops and the area of exposed rock decreases. Outcrop on the left bank of the River Raunis. Photo: I. Čakare.

Fig. 10.16. Gap is formed between the spruce roots and cliff, and it is evident that roots have grown in outcrop cracks. Ravine of the River Pērļupīte. Photo: I. Čakare.

10.1.5.3. Overgrowth

If a slope becomes flat due to collapses, or several terrace-like structures are formed, soil starts to accumulate in comparatively flat areas and rock outcrops overgrow with shrubs and trees (Fig. 10.15, 10.16).

Slight overgrowth provides a stable microclimate (smaller daily temperature fluctuations), increased air humidity and moderate shade, which further can have a positive effect on the growth of many moss species. As shade increases, light and drought loving species disappear.

10.1.5.4. Excessive Visitor load

In actively visited sites, trampling (excessive walking) occurs both on the rock outcrop and on the upper and lower slopes of its slope. It is particularly undesirable in places where springs are located on an outcrop slope. Due to trampling, erosion intensifies, characteristic species are destroyed, and open patches without vegetation develop. Visitors turn small rock fragments over and create piles that affect the life of species on them and around them.

10.1.5.5. Rock Climbing

Climbing on calcareous rock outcrop slopes increases surface erosion, which in addition to natural erosion is not desirable. Icefalls develop on outcrops during frost, if a spring flows over them. Icefalls create aesthetically valuable landscapes. Icefall climbing on calcareous outcrops is also not desirable because it can accelerate erosion.

10.1.5.6. Establishment of Cellar Caves

In Gauja National Park in the vicinity of Cēsis, at least two cracks in the dolomite layer have been used as cellars. However, their use was ceased, because the walls of the cracks are unstable and staying in the tunnels is not safe. The establishment of new caves or cellars destroys the part of the outcrop, where the cave has been created.

However, it also creates new hiding and wintering places for animals.

10.1.5.7. Geological and Palaeontological Research

The geological research of exposed Devonian rocks is carried out for scientific purposes. Many of the dolomite rocks of Latvia are comparatively rich in petrified fossils and they keep information on the climatic conditions at the end of the Devonian period. Sample collection for research purposes may destroy part of the outcrop. However, scientists obtain the most important information from quarries where the rock layers can be examined in a larger area and in an unlimited amount compared to eroded outcrops on river banks. Therefore outcrops are little influenced by research. When sampling is planned from a natural outcrop each case must be assessed individually in order to support both research needs and conservation of characteristic species of the outcrop.

10.1.5.8. Mineral Extraction

Calcareous bedrocks are used as mineral resources (Stinkule, Stinkulis 2015). At the time when rock material was mainly extracted manually, naturally exposed rocks on the river banks were used (Fig. 10.17). Since the early 20th century, along with the development of industrialisation, active research and dolomite extraction has been carried out in open quarries, in sites where rocks are not visible on the ground surface. For the protection of a calcareous rock outcrop habitat, natural outcrops on river banks are most significant, and nowadays they are not threatened by mining activities. If the exposed rock is retained in the quarry after mining, it can become a habitat for species typical for calcareous outcrops. Such outcrops can be preserved by taking them into account when developing reclamation plans for post-mining areas.

Fig. 10.17. Small outcrop on the right bank of the River Raunis (right part of the image) was created as a result of dolomite extraction. It is evidenced by a quarry depression, visible entrance site and rampart, (left part of image), left from the former level of the slope. Photo: I. Čakare.

10.1.5.9. Eutrophication

Calcareous outcrop serves mostly as a substrate, or a place where outcrop specific species can establish. Calciphile species are also attracted by the availability of calcium. A pronounced soil layer is not characteristic for bedrock outcrops, and nutrient availability here is very limited, therefore fern, moss and lichen species that are adapted to the specific environment can grow on outcrops. If the concentrations of available nutrients change, the species composition also changes. New species establish which outcompete habitat characteristic species. There can be several causes for such unfavourable change in species composition. River waters may contain elevated concentrations of nitrogen and phosphorus. Increased nutrient supply with flood waters can lead to changes in vegetation in the lower part of the outcrop next to the river and on pits on the river bank. Therefore river water quality is significant for the conservation of outcrop characteristic species. Intensive management of agricultural land above the outcrop can contribute to nutrient rich water runoff and infiltration. Eutrophication is also facilitated by the deposition of airborne nitrogen.

10.1.5.10. Other Undesirable Changes in Species Composition

Potentially unwanted changes in species composition can be caused by acid rain, for instance, sulphur dioxide (SO^2) contributes to environmental acidification. Intensive management of agricultural land, ploughing, excessively intensive grazing and clearcuts up to the slope edge can facilitate soil erosion from agricultural land and subsequent accumulation on the outcrop. To prevent leaching, a buffer zone between the intensively managed site and the top of the slope must be maintained. For a sunny, open outcrop, the distance between intensively managed agricultural land and the outcrop should be at least 5–10 m, and it is advisable to leave this zone as wide as possible. To prevent overgrowing of this belt with shrubs, it must be regularly managed as grassland by mowing (with grass removal) or grazing. If the shading of the outcrop needs to be maintained, the protection belt should be at least as wide as the height of one tree (~ 30 m). To ensure a microclimate that is characteristic for forest, this belt must be as wide as at least two heights of a tree (no less than 50 m). Soil accumulation on the top of the outcrop encourages the introduction and dispersal of invasive (Fig. 10.18) and expansive herbaceous plant species.

Fig. 10.18. Invasive plant species *Heracleum sosnowskyi* on the outcrop on banks of the River Imula.
Photo: A. Priede.

10.1.5.11. Climate Change

It is predicted that in Latvia the number of days with high air temperatures will increase and the number of days with frost will decrease due to climate change. Consequently the vegetation season will lengthen. Data analysis on the period from 1971 to 2010 shows that there are no significant changes in the end dates of the vegetation period. However, the duration of the snow cover, precipitation and temperature regime has changed (Briede 2016). Lower quantities of ice and snow are expected, which will reduce the volume of spring floods. So far, it has been observed that extreme rainfall events (a higher amount of water during a rainfall event) in Latvia have increased. Precipitation has increased in winter, but declined in the summer and autumn period (Apsīte, Bakute 2009). A higher amount of precipitation at one time can contribute to the riverbank slope erosion and to landslides, while a reduced number of frost days will reduce outcrop erosion caused by frost and thawing. An increase in wind strength will particularly influence outcrops in places where trees grow on a rock slope, because of the increased likelihood that wind will knock down the trees, causing collapses. The average rise in air temperature will result in the establishment of warm weather depending species. Leaching of substances from the soil will increase (Kļaviņš 2009). It is possible that more herbaceous plant species will get established on calcareous outcrops, as it has typically occurred in the central and western part of Europe. Broadleaf forest species will establish more intensively, and they could also occupy the outcrops. Climate conditions will be favourable for the development of species-rich vegetation on calcareous outcrops. However, moss species, the locations of which here are on the western or southern border of their range, will be influenced negatively.

10.2. Protection and Management Objectives for Calcareous Outcrop Habitats

All objectives defined for all outcrop and cave habitats are also topical for calcareous bedrock habitats (*see Chapter 5*).

The objective of calcareous outcrop protection and management is ensuring persistence of the outcrop as a habitat for the calciphilous species characteristic for the particular site. In order to reach the objective, the insolation and shade, together with the characteristic moisture, must remain constant for a long time, satisfying the requirements of the complex of species inhabiting the particular outcrop. From the point of view of biological value, it is essential to also maintain natural processes – rock outcropping, collapses, scree and debris at the rock base, scree transport and periodical overgrowth of outcrop. Therefore management can also occur in the surrounding habitat, if it directly influences the conditions on the calcareous rock outcrop. In places where there are protected species, management can be carried out in order to improve the living conditions of these species.

Other conservation and management objectives can be determined for outcrops as habitats of calciphilous species, in order to improve the characteristics of these habitats and, thus, the chances of species survival. The main objective in calcareous outcrop sites which are popular tourist attractions is to reduce the excessive visitor load by balancing the interests of tourism and nature conservation. Outcrops that are significant geological and palaeontological monuments must be preserved for scientific research. Conservation and management in places where calcareous outcrops develop after mining must ensure conditions that enable the establishment of protected habitat characteristic species.

10.3. Protection and Management of Carbonate Bedrock Outcrop Habitats

10.3.1. Knowledge-based Management Recommendations

The experience of calcareous outcrop habitat management in Latvia is insufficient and poorly documented. Knowledge of the effect of various management methods needs to be supplemented with research and monitoring. In sites which are already used as tourist attractions, management measures must be documented and sample plots must be established in order to assess the changes in outcrop vegetation and fauna. It is also necessary to clarify natural processes, their extent and influence on the life of species because there are only a few studies of calcareous bedrock flora and fauna conducted in Latvia to date, and there is no information on outcrop ecology.

Knowledge of the natural processes of outcrops and the role of anthropogenic influences on habitat and their species form the basis for their correct conservation and management.

10.3.2. Non-interference

Erosion of exposed rocks, scree accumulation and washing away are natural processes where no interference is needed. Collapses caused by freezing and thawing, leaching and tree uprooting are the most significant processes of the outcrop. Collapsed material accumulates at the outcrop base in the form of scree. If there is an active watercourse, some debris is carried away. It is expected that natural slope processes will activate the outcropping of the rock in the longer run. The sequential occurrence of natural processes is favourable, since it helps to maintain the characteristic mosaic-like environment on the outcrop. Large-scale collapses can destroy the outcrop; however if they are caused by natural process such as the action of springs, stopping them is not necessary.

If there are no significant changes caused by human activity (such as consequences of excessive visitor load), non-interference is the most appropriate way to preserve the outcrops.

10.3.3. Management of Surrounding Habitats

Felling the forest up to the top edge of the outcrop may promote natural slope processes, therefore at least a 30–50 m or wider unmanaged buffer zone must be left in forest stands above outcrops. In agricultural land above the outcrop at least a 5–10 m wide belt should be preserved, where land management (ploughing, harrowing) does not occur and the grass is grazed or mown and removed. Rapid, artificial water level changes and artificially induced rapid ice drift may reinforce the natural erosion at the outcrop base and cause an unwanted collapse.

10.3.4. Restoration and Imitation of Natural Processes

Depending on the insolation requirements of calcareous species present on the outcrop, the necessity to improve light conditions must be evaluated, if shrubs and trees are established at the outcrop foot or on its wall. For a south-facing outcrop with no shading, the establishment of a tree or shrub belt at the foot of the outcrop must be evaluated. It will at least partially create shade on the outcrop.

The natural hydrological regime in rivers must be preserved. Ensuring a natural flood regime in the areas where rivers are affected by dams is especially important. The operation of hydroelectric power plants must be organised to prevent sharp water level fluctuations. In places where the water flow is stopped at the outcrop base and scree transportation does not occur, the stream must be restored by the removal of fallen trees and beaver dams.

10.3.5. Development of Tourism Infrastructure

To enable visitors to view the calcareous outcrops, tourism infrastructure such as footbridges, paths, boardwalks, platforms and stairs can be constructed on the outcrop and at its base. In addition, recreation infrastructure (tables, benches, car parks, waste bins; less frequently, also toilets) and information boards can be constructed in the vicinity. In order to conserve rock outcrops, delimiting barriers and fences can be built. Properly designed boardwalks, platforms, paths and stairs diminish the trampling effect. It is particularly important to prevent trampling in sites which are rich with springs. Boardwalks consisting of planks that are not tightly fitting but are situated at a distance from each other must be constructed over such sites, in order to enable insolation for the vegetation under the boardwalk. Paths of solid material such as boulders, where the material is placed at footstep distance creating foot-sized patches, are also suitable. The use of dolomite rock fragments for path construction must be first consulted with an expert because sometimes such fragments can be a habitat for rare species, and therefore cannot be used for path construction.

Infrastructure elements must be situated on poles drilled into the ground. Pile driving is not permissible because the vibration may trigger collapses of the outcrop. Information boards should be located close to outcrops, and provide information that outcrops are a rare ecosystem that is sensitive to trampling.

Tourism infrastructure development always influences the outcrop. Therefore it should only be established if visitor load is so high that the consequences of trampling are visible such as trampled patches, and uncontrolled climbing on the cliff wall or trampling of spring discharges (seepages) occurs. Well-organised tourism infrastructure organises visitors, but the fact that it also increases visitor numbers should be kept in mind. It is difficult to determine the moment when tourism infrastructure starts to cause more harm than benefit. Therefore maintenance of the existing well-equipped tourism destinations should be prioritised over the establishment and promotion of new ones.

Improperly designed or poorly maintained trails do not prevent trampling, and can even promote it. Most of the infrastructure at outcrops on river banks is intended for visitors coming from the land side. At the same time, disembarkation sites for boat enthusiasts develop spontaneously. Places where access is limited from the land side can easily be accessed from the river. In sites which are visited by boating tourists the infrastructure must also be established from the side of water, or disembarking must be limited.

If the outcrop has been used earlier as a tourist attraction but is no longer intensively visited, the created infrastructure must be dismantled and the restoration of natural processes must be supported.

10.3.6. Other Types of Construction

When planning river crossings, crossing of calcareous outcrops must be avoided as such outcrops are very rare in Latvia. Upon the reconstruction and maintenance of bridges it must be ensured that outcrop vegetation is not mechanically damaged, because rare species can grow there. It is important to maintain a more favourable level of insolation. During works, one must be cautious in order to prevent rock surface erosion. Pile driving causes vibration and may contribute to collapses. During construction works, the outcrop may be preserved, but the local microclimate may change. In areas where bridge construction will be located above the outcrop, the outcrop will be shaded by the bridge (depending on its height) instead of by riverbank trees and shrubs.

10.3.7. Conservation of Landscape and Cultural Heritage Values

The outcrop can have a role in the surrounding landscape and it can be related to values of cultural heritage. It is recommended to respect such status, however, only to the extent it does not harm the protected nature monuments. In the case of calcareous outcrops, preference must be given to the conservation of geological values and rare and protected species.

10.3.8. Conservation and Research of Palaeontological and Geological Values

Many Devonian dolomites and limestones in Latvia contain a variety of ancient organism fossils. However, material for their in-depth study can be obtained in quarries, thus causing less damage to natural outcrops.

10.3.9. Creation of a Protected Habitat

Considering the wide distribution of dolomite layers, the creation of new habitats is possible during the quarry rehabilitation process (Fig. 10.19). Already during mining, it is recommended to determine sites, where the species rich calcareous outcrops can be created. Priority should be given to places where springs flow over the outcrop or at its base. At the outcrop base, it is recommended to preserve or create a water reservoir that will ensure a constant moisture regime. A moist and partially shaded outcrop will create more opportunities for the establishment of moss species. Therefore, the preservation of forest above the outcrop is also recommended, as well as the establishment of additional shade at its base if grassland is located on the top of the outcrop. The potential for the establishment of species rich communities is higher on outcrops with fissures and micro-niches. Large rock fragments must be preserved at the base of the outcrop.

It is possible that the introduction of target species (calciphilous mosses and lichens) on the outcrop will occur naturally. This process may be slower than on natural rock outcrops on river banks, where the river valley serves as a species migration corridor (Fig. 10.20). If the newly created outcrop is situated farther than 500 m from a high quality natural calcareous outcrop, the introduction of characteristic species from another appropriate location may be required in order to accelerate outcrop colonisation. If outcrop colonisation is successful and species composition indicates appropriate environmental conditions, such outcrops can be used for the expansion of localities for rare species (e.g. *Asplenium* spp.). In order to obtain and transfer species with the purpose to promote outcrop colonisation with rare species and to create new habitats for them, a permit is required from the Nature Conservation Agency. In the donor area, activities should not adversely affect species composition, plant vitality and population viability, and they must be approved by an expert with knowledge on the respective species.

Fig. 10.19. After the end of rock mining, this wall creates a suitable habitat for calcareous outcrop characteristic species. Dārzciems dolomite quarry. Photo: I. Čakare.

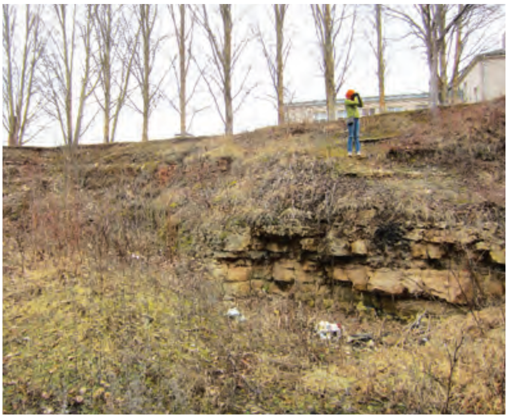

Fig. 10.20. Dolomite outcrop in abandoned quarry in Ape is gradually overgrowing with characteristic species. However, colonisation occurs very slowly. Illegal dumping of household waste in a quarry and the proximity of the town has facilitated the introduction of ruderal species. This outcrop is a protected geological and geomorphological nature monument. Photo: I. Čakare.

10.3.10. Management and Use Unfavourable for Carbonate Bedrock Outcrop Habitats

Climbing on the outcrops has a well-pronounced adverse and eroding effect. It causes increased collapsing of unstable parts of rock. Rock climbing has particularly negative consequences in places where a spring flows over an outcrop. Climbers loosen the stones and damage vegetation that hold back the flow of rain and melting water. This causes increased soil removal from rock fissures.

If infrastructure elements are improperly planned and managed, visitor flow may increase, consequently promoting the erosion of the outcrop. If strengthening walls are constructed on the slope for the maintenance of trails, it may seem convenient to use dolomite pieces available on site. However, this can reduce the area of habitat (Fig. 10.21).

The practice of path marking with paint on the fragments of outcrops or rocks is commonly used in Europe but not recommended in Latvia as the number of calcareous outcrops in Latvia is very low, and they are small. Paint may be toxic for outcrop plants and animals, as well as it can cover them mechanically (Fig. 10.22). If no other solutions are possible, a place where there are no plants and ferns must be selected for signs. Also, paint entering the rock fissures must be avoided. Tourism infrastructure must be maintained in good condition, which not only reduces the risk of accidents, but also correctly directs the visitor load. In sites where boardwalks and platforms have become old and unsafe, and their restoration is not planned, the area must be closed to visitors, and the worn out constructions must be dismantled. Damaged, unusable infrastructure increases the negative impact on the habitat.

Trees growing on slopes or above the outcrop can threaten visitors and therefore they are often felled. To avoid the promotion of erosion, the stumps of felled trees must be preserved.

10.4. Conflicts in Protection and Management of Calcareous Outcrops

As the calcareous outcrop slope overgrows, deciduous forest corresponding to EU protected habitat type 9180 Tilio-Acerion *forests of slopes, screes and ravines* may develop. In sites where characteristic calcareous outcrop species can still be found and it is expected that natural processes will maintain the open surface of exposed rock, the removal of trees and shrubs from the outcrop should be preferred. In these sites, causes that have enabled increased accumulation of soil must be eliminated – such as the disruption of the natural flood regime of the river by beaver dams or other obstacles which do not ensure the necessary slope erosion. Such action can only be permitted in accordance with expert's judgement, which analyses in detail the causes of outcrop overgrowth and gives reasonable predictions regarding the future dynamics of the slope. If there is no sufficient justification, it is recommended to leave the slope to natural succession and not to interfere.

Fig. 10.21. Trail strengthening at Zanderi dolomite caves. Photo: I. Čakare.

Fig. 10.22. Mark on the wall in the vicinity of Zanderi dolomite caves. Photo: I. Čakare.

Chapter 11. 8220 *siliceous rocky slopes with chasmophytic vegetation*

11.1. Characteristics of Sandstone Outcrops

11.1.1. Brief Description

EU protected habitat type 8220 *Siliceous rocky slopes with chasmophytic vegetation* includes siliceous exposed inland rocks with and without vegetation, as well as dolomitised exposed rocks and their fragments (Rēriha 2013). This habitat also includes sandstone concretions, which consists of small, approximately 1 cm, rarely up to 7 cm in diameter round-shaped nodules of calcite crystals that are merged into larger aggregates or bodies.

A key feature for the determination of this habitat type is that these rocks are geologically ancient (in Latvia, mainly belonging to the Devonian system), sedimentary bedrocks formed by sand cemented with particles of clay, iron compounds, dolomite or calcite (Rēriha 2013). Small patches covered with soil on the outcrop surface and at its base, developed by collapses of the outcrop or by scree accumulation are also natural features of the outcrop. Sandstone rocks that are not exposed are not included in this habitat type. Younger layers of laminated sand sediments are visually similar to sandstone rock outcrops. These are not attributed to habitat type 8220 *Siliceous rocky slopes with chasmophytic vegetation*. Sandstone outcrops on the sea coast are included in habitat type 1230 *Vegetated sea cliffs of the Atlantic and Baltic coasts*.

Sandstone rock outcrops are distributed unevenly throughout Latvia. Extensive areas of Devonian sandstone sediments – potential areas of sandstone outcrop distribution – are situated in the northern and north-eastern Vidzeme Region and the northern part of Kurzeme Region; small fragments also occur in the southern part of Kurzeme (Fig. 11.1). Active exposing of sandstone rocks occurred during the last Ice Age in valleys of the Gauja, Abava rivers and their tributaries. In Slītere National Park, Devonian sandstone rocks are exposed on the ancient coast of the Baltic Ice Lake. The composition of sandstone outcrops is determined by the conditions of sediment development during the Devonian period (Segliņš et al. 2013).

Sandstone outcrops with a similar sand grain structure and chemical composition occur in Estonia as well. Many of the sandstone outcrops that occur elsewhere in Europe differ in their hardness, chemical composition and age (Härtel et al. (eds.) 2007).

The overall status of habitat type in Latvia was evaluated as favourable by the Report to the European Commission of 2013 according to Article 17 of the Habitats Directive (Anon. 2013a). The differences in conservation status of individual sandstone outcrops can vary from favourable to bad.

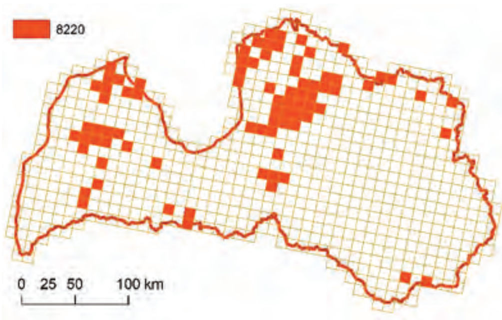

Fig 11.1. Distribution of habitat type 8220 *Siliceous rocky slopes with chasmophytic vegetation* in Latvia (source: Anon. (2013)).

The habitat covers approximately 0.28 km^2 in Latvia (Anon. 2013a). No significant changes in the total area of the habitat have been observed since the annual report of 2006 (Anon. 2007). It is expected that the distribution range of sandstone outcrops will not change in the future, while the total area of outcrops will increase, because only part of the outcrops are mapped to date.

11.1.2. Indications of Favourable Conservation Status

Sandstone outcrop habitat is under favourable conservation status if characteristic species occur on it. A distinct composition of species is characteristic for various environmental conditions (dry, sunny, moist, shaded). Natural slope erosion processes – collapses, scree accumulation and washing – occurs in proportionally small areas. A continuous, long outcrop or a series of closely linked outcrops are more significant than a small outcrop, because in larger areas there are more diverse environmental conditions and more opportunities for characteristic species to persist. This is particularly important if significant disturbances occur. Outcrop height is less significant, but it increases the total area of the exposed rock.

Each outcrop has a distinct cardinal direction, shading, moisture level, surface structure (fissures, niches, cavities) and wall inclination. Geological research indicates that sandstone rocks in Latvia differ in their chemical composition, sand grain size and degree of cementation, as well as by the presence of inclusions such as aleurolitic clay (Stinkulis 1998). Combinations of these factors influence the survival possibilities of various species on the outcrop. If all parameters remain unchanged for long periods of time, a stable living environment is ensured for species which have low competitive abilities, such as moss and lichen species. On a sandstone outcrop under favourable conservation status, algae, moss, lichens, vascular plant and animal species characteristic of the particular shading and moisture conditions can be found (Fig. 11.2). If total vegetation cover on an outcrop does not exceed 50% per 1 m^2, rich lichen flora develops (Moisejevs 2015). Moss cover on a sandstone outcrop varies from 5 to 60%, excluding outcrops without any vegetation (Rēriha 2009).

In terms of biodiversity, outcrops without damage created by people (scratches, trampling), or if they are insignificant or overgrown with characteristic species, are more valuable. It is assumed that old inscriptions have cultural and historical value and they are not considered to be damage. According to the Petroglyphs Centre of Latvia, 1950 is considered to be the dividing line in determining if an inscription is old (Grīnbergs et al. 2008).

11.1.2.1. Characteristic Species

Sandstone outcrops are a significant habitat for algae, mosses and lichens and it is the only or the most significant habitat for many species (Fig. 11.3). Already in 1925, N. Malta published the results of Latvian sandstone flora research, where 120 moss, 77 algae, 36 lichen and five fern species were listed (Malta 1925). A contemporary study of sandstone flora of Gauja National Park found 20 moss species occurring only on sandstone rock outcrops (Pakalne et al. 2007).

Fig. 11.2. Natural undisturbed sandstone outcrop on the bank of a river. Photo: I. Čakare.

Fig. 11.3. *Cystocoleus ebeneus* is a protected lichen species growing only on sandstone outcrops. It forms velvety black patches. Photo: I. Čakare.

In a study on sandstone flora of Slītere National Park and Kaļķupe Valley Nature Park, 116 moss species, including 19 species found predominantly on outcrops, were found (Rēriha 2009). Many mosses and lichens cover a large area of the outcrop, however, their individuals are very small in size (Fig. 11.4). New species are added to the list of outcrop moss and lichen species every year, some of which are new to the flora of Latvia. Inceasing knowledge on lichen species has encouraged the change of understanding of outcrop management, and it is recommended to plan individual measures aimed at the creation of a bare rock surface (Moisejevs 2015).

Fig. 11.4. Sandstone outcrop is covered with lichen and moss species, at water level also with algae. The red colour of bare sandstone is only visible in small patches. Buļi Cliff on the bank of the River Brasla. Photo: I. Čakare.

11.1.2.2. Groups of Environmental Parameters

The ecological conditions of outcrops have been studied insufficiently. Vegetation studies are mostly focused on shading and moisture conditions. Particular measurements of insolation and humidity have not been carried out. Also, the influence of other parameters characterising outcrops have not been studied. Most likely, the most significant factors are outcrop cardinal direction, slope inclination, temperature, degree of rock cementation and the presence of inclusions.

Groups of ecological parameters have been distinguished according to moisture conditions and insolation conditions (Malta 1925, 1926; Āboliņa 2007). Different ecological conditions can occur like a mosaic on a single outcrop, and conditions change both in a vertical and horizontal direction.

Dry, sunny outcrops are typical for valleys of the largest rivers with pronounced floods and ice drift. Outcrops are steep, often with ledges. Scree and litter material does not accumulate at the foot, and the outcrop is not shaded by trees. South-facing outcrops are characterised by being increasingly heated in sunny weather. *Alcedo atthis* and *Riparia riparia* use such outcrops walls for nesting (Fig. 11.5). Vegetation of sunny outcrops is species-poor, mainly dominated by crust lichens of small size. In less open, but also well sunlit locations such as outcrops on shores of oxbows, holes made by plaster bees *Colletidae* or other insects of *Hymenoptera* can be seen. They are later inhibited by other invertebrates such as spiders.

Fig. 11.5. Dauģēni Cliff on the right bank of the River Salaca is a comparatively dry, sunlit outcrop. A colony of *Riparia riparia* inhabits the cliff.
Photo: I. Čakare.

Humid outcrops are the most rich in various species of algae, mosses and lichens (Fig. 11.6). Species composition varies depending on moisture and shading conditions. Typical species are ferns *Polypodium vulgare* and *Cystopteris fragilis*. *Huperzia selago* is also a relatively common species. Typical moss species include *Plagiochila porelloides, Pohlia cruda, Mnium marginatum, Bryoerythrophyllum recurvirostrum, Distichium capillaceum, Bartramia pomiformis*. Typical lichen species of sandstone outcrops are *Cystocoleus ebeneus, Peltigera leucophlebia, Lepraria* spp., *Hypogimnia vittata*.

Fig. 11.6. Moss and lichens grow abundantly on a partially shaded outcrop of Buļi Cliff. At the rock base the River Brasla flows, which provides high humidity.
Photo: I. Čakare.

Fig. 11.7. *Conocephalum* spp. covers a large area of outcrop in the vicinity of water.
Photo: I. Čakare.

Moist outcrops develop in places where springs flow at the base of exposed rock or over it (Fig. 11.7). Vegetation composition mainly consists of moss species characteristic for spring discharges and is influenced by the chemical composition of spring water. Characteristic moss species include, for instance, *Cratoneuron filicinum* and *Conocephalum salebrosum*. Less common species are *C. conicum* together with *Pohlia* spp. and *Fissidens* spp.

Outcrops with protected species of high vitality or with rare species which may indicate particular aspects of environmental quality, are particularly valuable.

Outcrops of sandstone concretions are distinguished into a separate group (Fig. 11.8, 11.9). They consist of calcite crystals that are a suitable substrate for calciphilous species (species loving calcareous substrates). Outcrops of sandstone concretions in Roči Nature Reserve of Gauja National Park are abundantly covered with the protected fern species wall rue *Asplenium ruta-muraria* and are considered outcrops of sandstone concretions of excellent quality.

Fig. 11.8. Unvegetated sandstone concretion in Māras kambari of Abava Valley.
Photo: I. Čakare.

Fig. 11.9. Sandstone concretion overgrown with mosses and *Asplenium ruta-muraria* in Gauja National Park.
Photo: I. Čakare.

In the flora list of vascular plants in Gauja National Park (Limbēna, Čakare 2007), there is also information on other localities of *Asplenium ruta-muraria* and *A. trichomanes*, however, this information on these localities is old and vague. These localities were probably related to thin layers of sandstone concretions above the sandstone outcrops and calcareous outcrops. Nowadays these species are not found in these sites. Calciphilous species can also grow on sandstone outcrops, above which a dolomite layer is situated. Then, calcium rich waters leach from dolomite into the sandstone.

Fig. 11.10. Ice erosion at Dauģēni Cliffs on the left bank of the River Salaca. Photo: I. Čakare.

11.1.3. Important Processes and Structures

11.1.3.1. Erosion

The dynamics of rock outcropping and collapse are important for the habitat. Intensive sandstone rock exposure occurred until the end of the last Ice Age. Nowadays, more common processes are erosion of exposed walls, wearing, creation of local secondary outcrops in places where soil has developed on outcrops. In order to maintain open areas of outcrops, natural erosion is necessary. It can be induced by water activity, freezing and melting processes, collapses caused by trees growing above the outcrop and by gravitation. The influence of water is most pronounced in banks of rivers, where flood water removes scree and washes away the outcrop base. During ice drifts ice also mechanically cuts into the base of the rock outcrop (Fig. 11.10). Similarly, rock outcrops are influenced by floods on the banks of oxbows. The only known outcrop that was maintained bare by the activity of lake waves was the outcrop on the bank of Lake Burtnieks. However, this process has been stopped due to lowering of the water level. The wall of the surrounding outcrop is also influenced by the process of the development of caves formed by the process of suffosion (Fig. 11.11).

It is not possible to define the volume of erosion which is necessary for habitat conservation. Erosion must be sufficient to preserve the characteristic species of the particular outcrop, which means that recently exposed patches that are not covered with soil and are stable, must be available.

Fig. 11.11. New caves are being washed out by springs in Līči-Laņģi Cliff. Photo: I. Čakare.

11.1.3.2. Riparian Processes

Processes occurring in rivers can facilitate scree removal or accumulation (Fig. 11.12, 11.13). As the river transports sandy sediments and deposits them at the outcrop base, scree is not washed away any more. Then, another EU protected habitat 6430 *Hydrophilous tall herb fringe communities of plains and of the montane to alpine levels* can develop. A meandering river changes its location, distance between the sandstone outcrop and the river increases, and the outcrop gradually becomes overgrown with forest. An oxbow forms, and it determines the further condition of the outcrop. A dry oxbow fails to provide scree transportation, and the outcrop gradually overgrows with forest. Oxbow with a constant water level and flood regime helps in keeping the outcrop open.

Fig. 11.12. Overgrowing sandstone outcrop on Dauģēni Cliffs on the bank of the River Salaca. Flood water cannot remove the scree, and the river accumulates additional sediments. Photo: I. Čakare.

Fig. 11.13. Soil gradually accumulates on the most gently sloping part of the wall. Dense cover of moss species characteristic for forest develops, covering the outcrop. Photo: I. Čakare.

11.1.3.3. Micro-relief

Mosaic-like micro-relief is characteristic for rock outcrops. It ensures a large quantity of micro-niches, variable light and moisture conditions. Micro-relief determines the overgrowth of sandstone rock. For instance, mosses initially grow in depressions, because a more stable microclimate is retained here (Fig. 11.14). From these places, colonisation of the outcrop will continue.

Mechanical disturbances, for instance, scratches on the outcrop surface, partially mimic micro-niches (Fig. 11.15). However, their negative influence exceeds the benefit (*see Chapter 11.1.5*).

11.1.3.4. Caves and Cracks

Sandstone rocks are porous, but impermeable layers of clay can occur between sandstone layers. As water flows, the loose sand material above the impermeable layer is washed away and suffosion caves are created (Fig. 11.16). Caves increase the biodiversity of sandstone rock outcrops (for more detail, *see Chapter 12*). As sandstone sediments develop, they are laminated in layers of differing inclination. Material between the layers can easily be washed out, and narrow fissures form (Fig. 11.17). Fissure expansion is facilitated by water infiltration which washes out the filling of fissures and by freezing and thawing processes. Soil

Fig. 11.14. Mosses on the outcrop repeat the pattern of layers and cracks, which is why the wall is covered with lines of various colours. Līči-Laņģi Cliffs. Photo: I. Čakare.

Fig. 11.15. On a smooth outcrop, mosses initially grow in micro-niches, including artificially created niches. Sarkanās Klintis (*Red Cliffs*) near Cēsis. Photo: I. Čakare.

accumulates in fissures, and tree roots may grow there, promoting the outcrop splitting into frag ments. Fissures serve as hiding places and a living environment for various animal species, such as spiders. Niches, fissures and caves increase the quality of the outcrop because a sandstone wall where they are present can be inhabited by more organisms than a smooth solid wall.

11.1.4. Habitat Dynamics

As scree transportation from the outcrop foot decreases or collapse processes become more active, the sandstone outcrop gradually overgrows with forest. If scree contains a great deal of clay, the scree slope is formed flatter and it overgrows faster.

Algae and moss cover can fall off the wall in the form of large mats if the thickness of the moss cover reaches several centimetres (Fig. 11.18). If this does not happen, soil starts to accumulate on a densely covered outcrop. Moss species characteristic for forests as well as dwarf shrubs establish, and trees start to grow (Fig. 11.19). After some time, slope processes can intensify, and the outcrop can be exposed again.

The process of overgrowing with forest is influenced by the chemical composition of the exposed rock, by the quantity of fissures and by outcrop inclination. If the outcrop is only located on the lower or middle part of the slope, it is influenced by natural processes occurring over it. For example, as the soil or clay layer slides down the slope, it can completely cover a small outcrop.

Fig. 11.16. Lībiešu upuralas (*Liv Sacrificial Offering Caves*). Photo: I. Čakare.

Fig. 11.17. Deep fissures in the Sarkanās Klintis (*Red Cliffs*) near Cēsis. Photo: I. Čakare.

Fig. 11.18. Below the cliff ledge, the upper layer or the outcrop is peeling away, and bare sandstone is exposed. Photo: I. Čakare.

Fig. 11.19. Sector of Līči-Laņģi Cliffs where the sandstone wall is almost completely covered with mosses. Patches of forest characteristic species are present on the slope. Photo: I. Čakare.

11.1.5. Pressures and Threats

11.1.5.1. Overgrowth

The main cause of changes in the condition of sandstone rock outcrops is overgrowth of the cliff slope and cliff foot and surrounding habitats with trees and shrubs. This creates light and microclimate changes, which in turn cause changes in species composition.

11.1.5.2. Slope Processes

Sandstone rock outcrops in Latvia are poorly cemented, therefore collapses occur on a regular basis. Collapses in large areas may destroy the wall of the outcrop. Collapses caused by natural conditions (water erosion, processes triggered by freezing and melting, gravitation-induced erosion, etc.) in small areas are desirable and help in keeping rock outcrops open. Anthropogenic activities above the sandstone outcrop, at its base or on the walls can reinforce natural slope processes and cause collapses of undesirable volume. Regular anthropogenic load can cause collapses which are regularly repeated in the same place, thus hindering the development of vegetation characteristic for outcrops.

Collapses create the opportunity for new vegetation to develop on the outcrop, while accumulated sand at the outcrop base covers its wall and reduces the suitable environment for species with low competitive ability.

11.1.5.3. Excessive Visitor Load

In active tourist destinations trampling (excessive walking) is observed on the top of rock outcrops and on their upper and basal parts. Due to trampling, the erosion is intensified, characteristic species disappear, and patches of bare rock develop.

11.1.5.4. Inscriptions

Although historical inscriptions serve as micro-niches and must be preserved as objects of cultural and historical heritage, it is prohibited to create inscriptions on outcrops, for example, in Gauja National Park[34]. If the possibilities for people to visit sandstone outcrops are improved, the number of visitors increases, and people can cause large-scale damage. In this way, perhaps incidentally, rare moss and lichen species are removed from outcrops, and rare species may disappear (Fig. 11.20).

11.1.5.5. Cleaning of Outcrop Surfaces

To preserve historical inscriptions, outcrop surface cleaning of moss and lichen cover may be necessary (Arājs 2015). Most likely, the removed moss or lichen species will perish. Such action allows one to maintain old inscriptions for longer. However, the presence of protected species and conservation priorities should always be assessed.

Without an understanding of geological processes, rock formation and outcropping, and without the knowledge of species, it is likely that actions will be taken that may significantly influence the sensitive vegetation of a sandstone outcrop. Such a situation arose when mystical powers were attributed to outcrops of sandstone concretions in Roči Nature Reserve of Gauja National Park. People were invited to clear outcrops of woodlands and of ground surface (Rotbaha 2002). Outcrops of sandstone concretions are habitats for fern species *Asplenium ruta-muraria*, which is very rare in Latvia and Europe. Also, the surrounding forest corresponds to protected habitat type 9010* *Western Taïga*. “Cleaning” would have caused

Fig. 11.20. Engraving on Līči-Laņģi Cliffs causes mechanical destruction of protected lichen species velvet lichen *Cystocoleus ebeneus*. Photo: I. Čakare.

[34] Section 9.11 of Cabinet Regulation No. 317 of 2 May 2012, Regulations on Individual Protection and Use of the Gauja National Park.

irreparable damage to the particular micropopulation of *Asplenium ruta-muraria* and significantly deteriorate the quality of the rock outcrop.

11.1.5.6. Geological and Palaeontological Research

The geological research of the Devonian sandstone rock outcrops is carried out for scientific purposes. Then, outcrops are mechanically cleaned from vegetation and smoothened (upper layer is removed) in order to perform the required research. This destroys vegetation, causing a disturbance over several years. However, the outcrop later overgrows with characteristic vegetation again.

Some outcrops contain evidence about the life and its development in the Devonian period, when many fish species inhabited the sea and the first vertebrates stepped out on land. Such research involves the excavation of fossil material. Research and sampling affects the outcrop, and habitat is destroyed in the sampling location. Therefore, possible damage must be evaluated before the work.

11.1.5.7. Rock Climbing

Climbing on sandstone outcrop slopes increases surface erosion, and in large areas it is undesirable. Icefalls develop on the outcrops with springs, and these sites are used as training sites for icefall climbing. No known negative impact on plant communities of outcrops has been documented in Latvia. However, sandstone outcrops are insufficiently studied and the optimal ecological conditions for every plant community are not known. Outcrop landslides may destroy the habitat for rare species. Therefore, it is advisable to limit ice climbing on sandstone outcrops. Nowadays, ice climbing is prohibited in the territory of Gauja National Park[35].

11.1.5.8. Construction of Cellar Caves

In the 19th–20th century the construction of cellar caves was common in some areas of Latvia. Cellar caves in Līgatne, which were built in sandstone, are a well-known example. Upon the construction of the cellar cave the wall of the sandstone outcrop is damaged in an area that is equal to the area of the cave entrance. However, an established cave is similar to natural caves in terms of its suitability as a habitat for species. Cave digging is not allowed if this action can worsen the condition of the rock outcrop as a habitat[36]. Such prohibition can also be included in regulations on the individual protection and use of protected nature territories.

11.2. Protection and Management Objectives of Sandstone Outcrop Habitats

The objectives of sandstone outcrop conservation and management must be set based on the main values of the particular outcrop. From the point of view of biodiversity conservation, the priority is the conservation of protected habitat type 8220 *Siliceous rocky slopes with chasmophytic vegetation* in as good a conservation status as possible. However, most often, finding the balance between geological, palaeontological, landscape, nature, cultural and historical heritage values is necessary in such a way that the management of one value does not significantly endanger others.

In undisturbed areas that are just slightly influenced by people the priority is to preserve the sandstone outcrop in its natural condition. This includes maintaining insolation and shading as well as a characteristic moisture regime in order to ensure the conservation of species composition characteristic for the particular sandstone outcrop. From the point of view of the biodiversity conservation it is significant to maintain natural processes such as rock exposure, collapses, scree removal and outcrop overgrowth. Therefore the management of surrounding habitat is also necessary if it directly influences the conditions on the sandstone rock outcrop. In places where protected species are found, management measures should improve their living conditions.

The main management objective in popular tourist destinations is to decrease the adverse influence of visitors by balancing the interests of

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[35] Section 9.12. Cabinet Regulation No. 317 of 2 May 2012, Regulations on Individual Protection and Use of the Gauja National Park.

[36] Section 7 of the Law on the Conservation of Species and Biotopes (with the amendments as of 16 March 2000).

tourism and nature conservation.

For outcrops which are significant geological and palaeontological monuments, their conservation in an unaltered condition for scientific research is also significant. In some sandstone outcrops, the planning of particular measures for the conservation of cultural and historical heritage values such as inscriptions and petroglyphs may be necessary. For the management of outcrops in area with high scenic value, planned management should maintain the view to or from the outcrop.

11.3. Protection and Management of Sandstone Outcrop Habitats

11.3.1. Knowledge-based Management Recommendations

So far, sandstone outcrop management experience in Europe, including Latvia, is limited and poorly documented. Knowledge of the influence of various management methods should be supplemented by management experiments, results monitoring and research. The course and volume of natural processes and their influence on species must also be studied because sandstone outcrop flora and fauna are little studied and information on outcrop ecology is insufficient. For instance, trampling on the rock and in its vicinity can reduce outcrop quality because erosion is promoted. However, there are no measurable criteria of when the tourist infrastructure should definitely be built to ensure the protection of rock. Easy access attracts more visitors, which can increase influence of trampling on an outcrop instead of decreasing it.

Correct management is based on in-depth knowledge of natural processes in outcrops and the role of anthropogenic influence on the habitat and related species.

11.3.2. Non-interference

Rock outcrop erosion, scree accumulation and washing away are natural processes, therefore their cessation would not be desirable. Collapsing of outcrops, caused by freezing, melting and leaching as well as uprooting of trees growing on top of the outcrop is natural. Collapsed material accumulates at the outcrop base. If there is a stream which is active throughout the year or seasonally, scree is carried away. If scree accumulates and is not removed, it overgrows with trees and shrubs which gradually grow over the outcrop, and cover it. In the longer run, rock exposure can be activated by natural slope processes again. The sequential occurrence of natural processes is desirable because it helps to maintain the mosaic-like environment characteristic for the outcrop. Large-scale collapses can destroy the entire outcrop. However, if they are caused by natural processes such as the influence of springs, it is not necessary to eliminate them.

It is best to ensure non-interference if there are no anthropogenic activities (such as excessive visitor load) causing significant changes to the habitat.

11.3.3. Management of Surrounding Habitats

Before the management of surrounding habitats, the potential impact on rock outcrops and their plant communities should be assessed. It is known that marked changes in light and moisture can directly and significantly affect the plant communities of the outcrops. Also, changes in the strength of wind must be taken into account. As a precaution, rapid changes in land use should be avoided.

If woodland is located on the top of a sandstone outcrop, its felling may enhance natural slope processes. Therefore at least 5 m wide belt of unmanaged forests should be preserved along the slope edge. A sufficient number of trees should be preserved to ensure the wind-resistance of mature trees on the slope and on the top of the slope.

If arable land or grasslands are located on the slope above the sandstone outcrop, at least a 5–10 m wide zone must be maintained without land cultivation (ploughing, harrowing). Semi-natural grasslands must be regularly managed. Shrubs and young trees in previously open areas are not desirable because they change the light conditions on the outcrop. Felling of shrubs which are several decades old should be done gradually and in accordance with the requirements of outcrop species to avoid rapid changes in microclimate. Natural river flow regulation for flood prevention and water storage cause rapid changes in water levels and artificially induced ice drifts, and may promote erosion at the basal part of the outcrop enhancing the collapse probability.

11.3.4. Re-instatement and Imitation of Natural Processes

If scree is not actively transported away, it accumulates at the outcrop base and covers it up, thus changing the microclimate and endangering the living environment of habitat-characteristic species including rare and protected ones. In such cases, to protect the habitat for rare species, natural processes can be mimicked. In such cases scree can be removed by excavating and transporting it away. Before these works it is important to assess whether any organisms are using the scree as a living environment (such as amphibians) because this material can be easily used for burrowing in. Removed sand can be pushed or bulldozed in the surrounding with the consideration that removed scree should not deteriorate the condition of other habitats. For example, burying of springs and rare species habitats is not permissible. There is no experience on the result of such activities. Therefore every step must be documented in detail by using photographs and notes in order to record any adverse effects such as excessive trampling and the subsequent destruction of vegetation characteristic for spring discharges.

In sites where stream functioning at the basal part of the outcrop is stopped due to beaver activity or by fallen trees, or another cause, and scree transport does not occur anymore, the stream needs to be restored by the removal of fallen trees and beaver dams.

For the maintenance of conditions necessary for rare and protected species, natural erosion may be imitated by the removal of outcrop vegetation. For example, if vegetation cover exceeds 50% and the growth of particular lichen species is desired, the availability of bare substrate should be increased by promoting erosion in patches. Such activities are not documented to date, and the results will not be visible within a few years, therefore such measures must first be tested in small areas. At the same time, long-term monitoring must be carried out.

11.3.5. Development of Tourism Infrastructure

To provide access and the possibility to view the exposed sandstone rocks and to manage tourist flow, tourism infrastructure such as footbridges, boardwalks, platforms and stairs is constructed. In addition, recreation infrastructure (tables, benches, car parks, waste bins) and information boards, less frequently, toilets are established. To preserve the rock outcrops, barriers and fences are constructed, which limit access to the outcrop. If footbridges, platforms, boardwalks and stairs are correctly planned, they successfully prevent the trampling of outcrops and their surroundings, whereas in cases when the infrastructure is improperly planned, it can have adverse effect (Fig. 11.21, 11.22). (Fig. 11.20).

Fig. 11.21. A boardwalk (before renovation) along Sarkanās klintis (*Red Cliffs*) near Cēsis had become unsafe (it was slippery, plank ends were moving, there were no boundary railings), therefore visitors took the opportunity to walk next to the boardwalk and trampled the basal part of the outcrop. Photo: I. Čakare.

Fig. 11.22. Trail of wooden steps in Līču-Laņģu Cliffs is constructed next to the footbridge. In this way, spring discharge is protected from trampling. However, visitors can easily get to the wall, create inscriptions or otherwise damage it.
Photo: I. Čakare.

To prevent the emergence of new engravings on the outcrop, delimitation should also be created on the outcrop side, and constructions must be placed at least 1.5 m away from the outcrop (Fig. 11.23, 11.24, 11.25). A delimiting barrier that is located too close to the outcrop does not prevent climbing on the rock. Quite the opposite, it can facilitate climbing (Fig. 11.26). A barrier along the top of the outcrop slope leads visitors to the area of interest and limits arbitrary trampling (Fig. 11.27). In the planning of trails, stairs and footbridges, the use of already established paths is not the only solution. For each individual case, the solutions that prevent or at least do not promote damage to the outcrop must be selected. It must be considered that the tourist trail will increase the number of visitors. There are outcrops, which only enthusiasts dared to visit previously. After the construction of the infrastructure, much more people will visit it. People treat things which are difficult to obtain respectfully, but do not appreciate them if they are easily obtainable. Therefore, when making sandstone outcrops easily accessible, increased effort must be paid to prevent people from undesirable actions.

Fig. 11.23. There are no barriers between the trail and rock, and anyone can come and leave inscriptions on the wall. Visitors are partly limited by the fact that the trail lacks surfacing and it is often muddy and unpassable. Unstable scree also prevents visitors from accessing the wall. Sarkanās Klintis near Cēsis. Photo: I. Čakare.

Fig. 11.24. If the tourist trail with boardwalk is located close to the outcrop, the creation of new inscriptions is possible. To prevent it, a minimum distance of 1.5 m from the wall is necessary, and delimiting barriers should also be installed between the outcrop and the trail. Photo: I. Čakare.

Fig. 11.25. Footbridge railings are at a sufficient distance from the rock. However further on the trail is directed along the outcrop. Such stairs will promote the creation of scratches on the outcrop. Līči-Laņģi Cliffs, 2015. Photo: I. Čakare.

Fig. 11.26. Lielā Ellīte in Liepa Municipality (photo taken in 2015). Visitors use the delimiting barrier as a support to climb the less steep slopes of the outcrop, which would be much more difficult to do from the ground. Photo: I. Čakare.

Infrastructure elements must be situated on poles drilled into the ground (Fig. 11.31, 11.32). Pile driving is not permissible because the vibration may trigger landslides of the outcrop. Caution is required when working close to springs, because a new spring discharge may develop, which will wash out the foundations and facilitate landslides at the construction site (Fig. 11.28).

Various constructions are used for the building of footbridges, boardwalks and stairs (Fig. 11.29–11.32). Mainly wooden constructions are used, impregnated for higher durability, and buttresses inserted into the ground are additionally treated against rotting. Since the works are performed in a protected habitat, substances that may cause harm to the environment must be avoided. The use of impregnating substances on materials on site in nature is not recommended.

Fig. 11.31. Stairs and a sightseeing platform at Dauģēni outcrop. Photo: I. Čakare.

Fig. 11.27. The barrier at the top of the slope limits the possibility to walk on the rock. Dauģēni Cliffs. Photo: I. Čakare.

Fig. 11.30. Stairs with metal steps, which will serve for a long time, are constructed in Estonia at Tevaskoje outcrops. Photo: I. Čakare.

Fig. 11.28. Stair strengthening was planned on a sandstone outcrop in Estonia at the River Ahja, but the construction of a stair buttress in a spring discharge site caused a landslide. It indicates that careful investigation of the ground before the construction of infrastructure is an important part in the planning of trails. Photo: I. Čakare.

Fig. 11.29. Wooden plank stairs at Līči-Laņģi Cliffs enable the creation of a complex configuration, because each step is separately fixed with wooden pegs. Wood is a material that wears out rapidly, but each of these steps can be restored separately. However, such steps tend to bend and slide out of place. Photo: I. Čakare.

Fig. 11.32. Footbridge over the spring at Līči-Laņģi Cliffs. Photo: I. Čakare.

The sandstone outcrop itself may not be used as a trail base because the site of the steps and trail is trampled and soon it does not correspond to the criteria of habitat under favourable conservation status (Fig. 11.33).

Fig. 11.33. Path at Sarkanās Klintis (*Red Cliffs*) in Cēsis leads across the outcrop. Steps are established on the outcrop and trampling is apparent, which significantly deteriorates the quality of the outcrop. The photo was taken in July 2016. Photo: I. Čakare.

Fig. 11.34. Information board explaining nature values at Sarkanās Klintis in Cēsis. The photo was taken in June 2016. Photo: I. Čakare.

The establishment of information boards at both ends of the trail and at the key objects is necessary for the conservation of nature values of outcrops. Information boards should contain information that sandstone outcrops are a rare ecosystem sensitive to trampling and other disturbances (Fig. 11.34). It is also necessary to explain the cultural and historical significance of the oldest inscriptions and the harm caused by creating new inscriptions. As part of the entire visitor infrastructure at the outcrop, additional information signs or small information boards must contain warnings not to walk on the outcrop and not to create inscriptions.

The construction of tourism infrastructure always affects the outcrop. Part of the outcrop can be influenced or even destroyed during the construction works. However, the negative impact of tourism infrastructure in the long run occurs if the planning of visitor pressure is incorrect, if solutions selected for construction are unsuccessful, and if the infrastructure is not properly maintained. Therefore infrastructure should only be established if the visitor load is so high that the consequences of trampling are visible, there are heavily trampled areas, and uncontrolled climbing on a cliff wall or trampling of spring discharge areas at the outcrop base occurs. It is positive that well-planned tourist infrastructure organises visitors, but the fact that it also increases the number of visitors must be kept in mind. It is difficult to predict if tourist infrastructure will cause more harm than good, therefore the maintenance of already existing infrastructure objects must be prioritised over the establishment and promotion of new objects. In all cases, the improvement of access to the entire outcrop area is not recommended. If the outcrop is long, parts of it must definitely be preserved intact where the trail leads farther away from the outcrop, or a special place must be constructed where the visitation ends, such as stairs or a viewing platform. Access to small and compact rocks must be organised from one end, while access to the other end is restricted.

Incorrectly designed or poorly maintained trails do not prevent damage to the habitat, and can even promote it. Most of the infrastructure facilities at outcrops on river banks are intended for visitors coming from the land side. At the same time, disembarkation sites for boat enthusiasts develop spontaneously. Places where access is limited from the land side can easily be accessed from the river. In sites visited by boating tourists the infrastructure must also be established from the side of the water, or disembarking must be limited. In these places a barrier must be created on the bank of the river, which obstructs disembarking, or appropriate sightseeing infrastructure must be created and appropriate information must be posted on the side of the river as well.

If the sandstone outcrop has been previously used as a tourist attraction, the created infrastructure must be dismantled and restoration of natural processes must be allowed.

11.3.6. Other Types of Construction

If bridges must be constructed or reconstructed on an outcrop that is situated on the river bank, the increase of erosion during the construction must be prevented. Pile driving is not desirable because it causes vibration and may contribute to landslides. During construction works, the outcrop may be preserved, but the local microclimate may change. In areas where bridge construction will be located above the outcrop, the outcrop will be shaded by the bridge (depending on its height) instead of riverbank trees and shrubs.

11.3.7. Conservation of Landscape and Cultural Heritage Values

There are various opinions regarding the removal of inscriptions on outcrops. Inscriptions, especially the most ancient ones, have cultural and historical significance. In addition, they have fulfilled an ecological micro-niche role for a long time, therefore such places are often important habitats for rare moss or lichen species. Before the removal, the occurrence and rarity of species must be evaluated. Preservation of cultural and historical values should not destroy rare species and sandstone outcrop characteristic species. Such inscriptions can only be removed in accordance with expert judgment that viable populations of all the influenced species will be maintained on the outcrop or in the outcrop complex. Laser scanning and similar methods applied in research do not unfavourably affect the outcrop.

The conservation of the landscape value of outcrops requires the maintenance of an open and visible outcrop. However, for such works it is difficult to predict the long-term impact of management. If trees and shrubs are felled – will it also be possible to maintain an open landscape in the future? If maintenance will not be continued, shrub cover will recover. In such a case, it would be better to leave woody plants intact, and expect old, large trees in the future.

11.3.8. Conservation and Research of Palaeontological and Geological Values

Partial cleaning of the outcrop from vegetation and upper layers can be required for outcrops with significant geological or palaeontological value. Such actions can only be performed in places where the geological values exceed the value of the current value of species. If sandstone layers to be cleaned are buried or are not exposed, but are located sufficiently close to the earth surface, the creation of new sandstone outcrops is possible. After the completion of research, at least some of such recently exposed rocks should be left bare, and the introduction of species must be monitored, in order to gather information on outcrop colonisation.

11.3.9. Climbing on Rock Outcrops

Winter ice climbing training was traditionally held on outcrops of Gauja National Park. However, since 2009, according to the Regulations on Individual Protection and Use of Gauja National Park[37], such activity is prohibited. Ice climbing was also not permitted earlier (M. Mitrevics, pers. com.) due to potential negative impacts (potential collapses). If rock is not covered by ice, climbing on it has an eroding impact. A single instance of climbing can contribute to outcropping of part of the rock. If climbing is repeated several times in the same place, it facilitates the development of a brittle rock outcrop, which is unsuitable for any species.

11.3.10. Management and Use of Sandstone Outcrop Habitats

The best method of sandstone outcrop management is non-interference with natural processes such as overgrowth and outcropping. To prevent the adverse influence of visitors and to maintain particularly important outcrop values, specific management can be scheduled (Tab. 11.1). If tourism infrastructure is incorrectly designed and poorly managed, visitor pressure on habitats and species can

[37] Cabinet Regulation No. 317 of 2 May 2012 Individual Regulation on the Protection and Use of the Gauja National Park.

increase, which in turn, increases outcrop erosion. If the number of visitors is high, if tourist flow is not well organised and information on outcrop values is not provided, the number of scratches and inscriptions can also increase, which endangers many specialist species on the outcrop. Infrastructure development along the entire outcrop length is not desirable and at least some sections must be preserved untouched. The tourist infrastructure must also be well maintained because it reduces the risk of accidents. It is recommended to close access to sites where boardwalks and platforms are worn-out and thus unsafe.

11.4. Conflicts in Protection and Management of Sandstone Outcrops

As the wall of a sandstone outcrop overgrows, deciduous forest, corresponding to habitat type 9180 Tilio-Acerion *forests of slopes, screes and ravines*, or EU protected coniferous forest habitat types 9050 *Fennoscandian herb-rich forests with* Picea abies or 9010* *Western Taïga* can develop. Uncovering of the rock should be preferred if it is expected that further on, the outcrop will be maintained open by natural processes.

Table 11.1. Main management methods, their advantages and disadvantages.

Method	Advantages	Disadvantages	Examples
Establishment of tourism infrastructure (boardwalks, trails, footbridges)	Allows redirecting the visitors from the most vulnerable and most influenced sites.	Infrastructure attracts more visitors. It is not possible to create visually acceptable barriers which cannot be climbed over. Wooden boardwalks and stairs are subject to rotting, they must be replaced relatively frequently. Wooden boardwalks are slippery in winter and in rainy weather, unless they are specially equipped. Collapses can be caused by the construction of boardwalks, trails, stairs.	Infrastructure is established in several protected nature areas, e.g. in Gauja National Park, Salaca Valley Nature Park, Abava Valley Nature Park, etc. In all the these areas, both well designed and unsuccessful technical solutions can be found. Professionals of the Nature Conservation Agency have accumulated the large experience on the selection of trail and boardwalk designs.
Complete delimitation (barriers)	Prevents further erosion in areas with significant visitor pressure.	Should only be used in places which can be effectively delimited from all sides. It is difficult to create a design that limits access and is visually acceptable. Visitors try to circumvent the barriers and damage the infrastructure.	In Gauja National Park, complete delimitation of Zvārte Cliff resulted in successful protection of its top from intensive erosion. However, the solution involved a visually unattractive wire fence which had to be repaired regularly. In Sietiņiezis, wooden fencing was ignored and even promoted outcrop trampling and erosion; similar outcome was experienced at Lielā Ellīte in Liepa.
Uncovering of outcrops	Allows creating new outcrops in sites where their area has considerably decreased as a result of natural succession, and particular species or other values (geological value) of the site are endangered.	Interference with the natural process occurs. Potential threat to biodiversity – habitat suitable to a rare species can be destroyed.	In habitat monitoring of 2011, Pavāri outcrop were described as insignificant and of such a small area that they could not be considered as a protected outcrop habitat any more. The uncovering of the rock increased the outcrop area and habitat characteristic vegetation could recover.
Change of river bed	Allows preserving the outcrop for scenic purposes if the outcrop is being heavily eroded by water.	Adverse influence on spring discharges and on river habitats at the base of the outcrop.	The operation was performed at Zvārte Cliff in Gauja National Park. Currently the basal part of Zvārte cliff overgrows with trees, and the exposed rock must be maintained artificially. Up to now, the outcrop has been preserved.

Chapter 12. 8310 *caves not open to the public*

12.1. Characteristics of the caves not open to the public

12.1.1. Brief Description

EU protected habitat type 8310 *Caves not open to the public* includes caves of natural origin which are at least 3 m long. In Latvia, the distribution of caves is mostly associated with sandstone, and only a few caves are found in dolomite rocks. Most of the caves are located in Vidzeme Region on the banks of the Gauja and Salaca rivers. Some caves are present in Kurzeme Region – in the Zilie kalni in Slītere, on the banks of the River Abava and on the banks of rivers belonging to the Venta river basin (Fig. 12.1). *Foundation Latvian Nature Heritage Fund* has listed 194 caves that conform to the criteria of an EU protected habitat (A. Opmanis, *pers. com.*). The total area of caves in Latvia is negligible – 0.00473 km^2 (Anon. 2013a). No significant changes in the total area of habitat have been observed since the first Latvian report to the European Commission in 2006 on the conservation status of habitats and species (Anon. 2007).

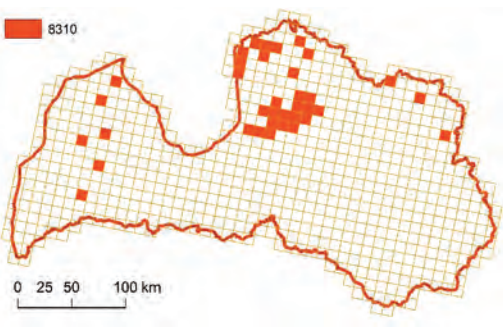

Fig. 12.1. Distribution of habitat type 8310 *Caves not open to the public* in Latvia (source: Anon. 2013a).

Most of the caves in Latvia have formed as a result of suffosion – mechanical removal of matter by the water stream. Brunis Cave near Cēsis is an exceptional case and is considered as a cave of tectonic origin, and was formed under the influence of ground movements (Eniņš 2015). Sinkhole caves form in places where the dolomite layer is located above the sandstone layer. If a space has been washed out in the sandstone layer and later the dolomite layer above it collapses, a cave can be created. It is possible that some fissures and caves in dolomite rocks are of artificial origin – due to dolomite extraction for the needs of surrounding farmsteads.

Suffosion caves similar to those in Latvia are also present in Estonia. In other parts of Europe, cave formation is determined by different processes. In Central Europe, an important process in cave formation is a karst process, and formatted cave systems are much longer than those present in Latvia.

Caves which correspond to this habitat type can be of natural origin, as well as completely or partially man-made. Some caves which are significant for bat conservation, such as Līgatne cellar caves, are not considered as this habitat type because of their artificial origin and it is not possible to establish whether these caves were natural at the beginning. Some of these caves are still used as cellars. The use of cellars has ceased relatively recently – approximately in the middle of the 20th century. However, in terms of biodiversity, cellar caves perform the same function as natural caves. For example, Riežupe Sand Caves were created in the course of sand excavation but they are included in the list of protected cave habitats and are an important bat hibernation place in Kurzeme. Caves most popular for tourists such as Velnala Cave in Sigulda, Kalējala Cave and Lībiešu upuralas (*Liv Sacrificial Offering Caves*), have been intensively visited at different times. At different times they have also at least partially been dug additionally, by clearing sand from the floor in order to allow better access to the cave. However, they are still significant cave habitats. The number of caves in Latvia is comparatively small, and they are a significant living environment for rare species. The factor of non-interference (Anon. 2013b), which is significant elsewhere for caves in Europe, is not that important in Latvian conditions for the determination of the protection status of the cave habitat. Therefore the opinion on cave conservation and management explained in these guidelines is also fully applicable to artificially created cellar caves; after their abandonment they should receive the status of a protected habitat.

The cave can develop or be created in an outcrop, which conforms to the EU protected habitat types 8210 *Calcareous rocky slopes with chasmophytic vegetation* and 8220 *Siliceous rocky slopes with chasmophytic vegetation*. If sandstone outcrops and caves developed in the sandstone are located at the seashore, they belong to the habitat type 1230 *Vegetated sea cliffs of the Atlantic and Baltic coasts*. Life span of the cave in the sea cliff is much shorter, because both outcrops and caves at the sea shore are subject to active coastal erosion.

In 2013, the conservation status of caves in Latvia was assessed as favourable by the Habitats Directive's Article 17 report to the European Commission (Anon. 2013a). However, the conservation status of bat species hibernating in caves was assessed as unfavourable and insufficient. This means that there are caves in poor conservation status which do not provide for the protection of their specific species. There are large differences in the conservation status of particular caves; it can vary from excellent to very poor.

Caves are not only a rare habitat and species habitat, but they also have a significant palaeontological, geological, cultural, historical and social value.

12.1.2. Indications of Favourable Conservation Status

A cave in a favourable conservation status is an undisturbed cave with three insolation zones (euphotic or sunlight zone, disphotic or twilight zone and aphotic or midnight zone) that are suitable for wintering and permanent living for various species (Rēriha 2013). Caves play a significant role in the life of certain species (Kušners, Smaļinskis 1994; Smaļinskis 1997; Vintulis 2013). Winter hibernation of bats *Chiroptera* and many invertebrates, as well as the presence of mosses such as *Schistostega pennata*, lichens *Lepraria* spp. and *Collema* spp. indicate a stable microclimate characterised by slightly variable air temperature and constant humidity. The cave entrance, its size, cardinal directions, and the inclination of the floor, are significant factors which determine the depth of light penetration and air exchange. Caves with a small entrance have constant microclimate, while those with large entrance are more influenced by the external conditions.

Completely undisturbed caves without human-caused damage such as scratches and trampling (or if they are insignificant and already covered with habitat-characteristic plant, lichen and algae species) are more valuable in terms of biodiversity. It is assumed that the inscriptions made in the past are of historical importance and thus they should not be considered as damage. The Petroglyphs Centre of Latvia has considered the year 1950 to be the dividing line for the determination of whether an inscription is old (Grīnbergs et al. 2008).

At a cave entrance, the same moss and lichen species can be found as on the outcrop in which the cave has developed. In the direction away from the entrance, light decreases, species composition changes and becomes poorer. Further from the cave entrance, where it is darker, lower numbers of moss and lichen species are characteristic. In totally dark conditions, only a few specific species of algae may be found.

Caves are an important habitat for moss *Schistostega pennata* (Opmanis 1996), which is a rare and protected species in Latvia. In sandstone caves, sometimes fungi species (Vimba 2015) and *Lathrea squamaria*, a plant without chlorophyll, can also be found. However, caves are not the only habitat for these organisms.

Caves in Latvia are small and are found rarely, therefore there are no species of macroscopic organisms (animals, invertebrates, fungi, lichens and plant), which are adapted to live in caves only and could not occur outside caves, at least there is no records or such species. Nevertheless, two spider species permanently living in caves found – *Nesticus cellulanus* and *Metellina merianae* (Smaļinskis 1997).

The development of caves in Latvia and their colonisation by various organisms has started relatively recently, after the Ice Age, approximately 10,000 years ago. Caves in Latvia are also characterised by relatively active and dynamic processes of washing out and collapsing, therefore highly specialised species are not present here. However, it is possible that such species could be discovered in the group of microscopic organisms such as bacteria, but so far they are poorly studied (Smaļinskis 1997).

Caves provide a significant habitat for several animal species. The most significant role of caves is for bat winter hibernation. All bat species found in Latvia are protected both in Latvia[38] and throughout the EU[39]. All bat species regularly hibernating in Latvia are also found in caves, the most

[38] Cabinet Regulation No. 396 of 14 November 2000, Regulations on the Lists of Specially Protected Species and Specially Protected Species whose use is Limited;

[39] European Council Directive 92/43/EEC of 21 May 1992 on the conservation of natural habitats and of wild fauna and flora.

common species are *Eptesicus nilsonii* and *Plecotus auritus*. Rather common species are also *Myotis daubentoni* and *M. natereri* but *M. dasycneme*, while *M. brandti* and *M. mystacinus* are less common, and *Barbastellus barbastella* is very rarely found in caves. In the guidelines for protecting and managing underground sites for bats (Mitchell-Jones et al. 2007) it is recommended to plan bat conservation in caves in accordance with their abundance. Caves where large numbers of bats hibernate during winter are considered to be more significant. The highest conservation priority should be given to caves where bats are also found outside the hibernation period. These caves must receive priority protection against any interference and must be completely closed to visitors.

Invertebrates that hibernate in caves in large numbers include *Scoliopteryx libatrix*, *Inachis io*, mosquitoes and other insects. The constant microclimate also attracts other invertebrates which use caves as a hiding and feeding place. The most common of them are *Opillones*.

Caves with a water course are used for winter hibernation for vertebrates such as the amphibians *Rana* spp. and *Bufo bufo*. Caves can be used throughout the year by mammals such as *Vulpes vulpes, Meles meles* and *Nyctereutes procyonoides*. Sometimes these animals also expand caves.

12.1.3. Important Processes and Structures

12.1.3.1. Cave Morphology

As an ecosystem, a cave has several important structures that determine the microclimate and species diversity in the cave.

Cave entrance. Significant components that determine the cave microclimate are the shape and size of the entrance in relation to the cave volume, the number of entrances and the configuration of the entrance corridor (Culver, Pipan 2009). For instance, a cave floor that leads down from the entrance hinders the escape of cold air from the cave, while a large entrance increases sunlight and twilight zones and reduces the midnight zone in the cave. Also, the orientation of the entrance to the cardinal direction and prevailing wind are important because they influence the air flow in the cave, as well as temperature and humidity. Any change in the cave entrance either natural or caused by anthropogenic influences can change the suitability of the cave as a habitat for various species.

Cave floor, walls and ceiling. The floor of a sandstone cave consists of sand that falls off or collapses from the ceiling and walls. Water can occupy significant areas in caves with a water course or water body. Caves that are regularly completely flooded are not attributed to a cave habitat. Sandstone cave walls can be either particularly strong, or collapse easily. The resistance of cave walls largely depends on the degree of cementation of the sandstone bedrock. The more durable the cave wall and ceiling in the long term, the higher the chance that the cave will be inhabited by species characteristic for caves. In caves with a variable microclimate micro-niches play a significant role. The sandstone cave ceiling can contain vertical fissures of various lengths – “chimneys”, where warmer air accumulates and the temperature is constant, which is especially favourable for wintering species. Sandstone can be relatively smooth and it may have fissures in the ceiling, cavities in walls and a multi-level floor, which create hiding places for animals. In caves developed in carbonatic rock all cave surfaces – ceiling, walls and floor – consist of dolomite pieces of various sizes with gaps between them, which create large variety of micro-niches. Large-scale collapses of rock pieces cause significant changes in these caves, sometimes completely changing their shape.

Cave length and passageway configuration and the associated light areas determine how deep and what vegetation will develop in the cave, and where and what animals can dwell. Deeper in the cave, microclimate is more constant but the air exchange is slower. The longer the cave, the more diverse the potential proportions of the walls to the ceiling, their slope, cracks, niches, “chimneys”, which determine the accessibility of hiding places and winter hibernation sites and ensure a more homogeneous temperature.

12.1.3.2. Water Influence

Cave formation, volume and entrance size are determined by rock composition. Caves in Latvia have mainly formed as a result of suffosion – washed out by water. So the key factors determining the rate and volume of cave formation are the degree of water supply and rock structure. Constant water flow in the cave, even if it is small and completely absorbed into the sand of the floor, maintains a steady microclimate. Moisture also accumulates in the cave from surface water which seeps through the cave ceiling. Relative humidity in caves can reach 95%. Such caves are characterised by high biodiversity. Caves on the river banks which are regularly flooded at least once a year are less valuable as species habitats because the development of permanent flora and fauna is regularly disturbed.

12.1.3.3. Microclimate

Cave microclimate depends on the size and cardinal directions of a cave and its entrance, entrance shade, entrance corridor configuration, and the humidity in a cave. Air exchange in a cave is influenced by floor inclination, the size of a cave and its entrance, number and configuration of entrances. For example, the cave structure preferred for bat winter hibernation is characterised by a small entrance in relation to cave volume, because it helps to maintain a constant microclimate in the cave (Fig. 12.2). In caves with several entrances such as Peldanga Caves, a strong permanent flow of air can develop which reduces the suitability of these caves for species winter hibernation because a constant temperature and humidity is not maintained. Caves where walls, ceilings and floors are dry, are used for living by a lower number of species than distinctly humid caves. Bat species hibernate in caves where the air temperature remains within the limits from 0 °C to +8 °C and which are relatively humid.

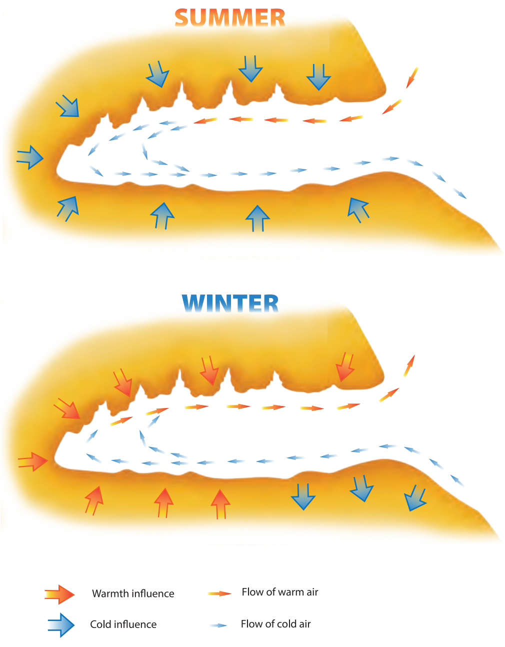

Fig. 12.2. Temperature regime in caves. Drawing by D. Segliņa (according to Mitchell-Jones et al. (2007)).

12.1.4. Habitat Dynamics

Natural development of habitat is significantly influenced by the dynamics of the cave as a geological structure. The watercourse can wash out the cave floor and promote cave wall erosion. If there is surface water infiltration it may increase the ceiling erosion, and the cave will collapse over time (Fig. 12.3). The highest probability of collapsing occurs at the cave entrance, enhanced by surface water runoff. The entrance can collapse and thus reduce or completely close the cave. The empty space in the rock can be preserved and, as time passes, opened again. Sometimes this happens with the help of animals, which dig burrows. In dolomite, water infiltration slowly dissolves rocks, mostly mechanically and to a slower extent chemically, and facilitates the collapse of the cave ceiling. The water stream can also create new caves, but in the early stages they are very unstable and prone to collapse.

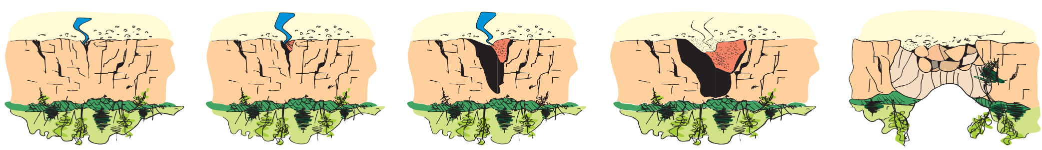

Fig. 12.3. Water washes out a small cave in sandstone, which is gradually expanded as roof fragments keep collapsing. Water infiltration through the ceiling increases but the water flow on the floor is blocked, until the ceiling collapses and the cave ceases to exist. Drawing by D. Segliņa.

Depending on the initial size of the cave as well as wall persistence and microclimate stability, the cave will be gradually inhabited by different organisms. No research on the colonisation of caves has been carried out in Latvia, and there are only individual observations. Already during the first years of cave formation, unless its walls are too brittle, the cave is colonised by algae, small lichens and mosses. Over time, the entire suitable cave surface – usually the entrance walls and ceilings up to the twilight zone – is covered by mosses and lichens, and various invertebrates live among them. As new collapses occur, vegetation cover will develop again, and the composition of moss and lichen species will depend on the species composition of the surrounding rock outcrop. The occurrence of lichen and moss species might depend on the age of the cave and the persistence of its walls. However, such studies have not been carried out. Animal species are mobile, thus as soon as a new niche is available it is filled, so the number of animal species is more influenced both by the size of the cave and by the persistence of its walls and ceiling.

The more organic matter is transported deeper into the cave, the higher the possibility that species living in darkness will also establish. For instance, some fungi grow in caves in total darkness on tree roots which are ingrowing through gaps.

12.1.5. Pressures and Threats

12.1.5.1. Caves – Open Systems

All factors that influence habitats 8210 *Calcareous rocky slopes with chasmophytic vegetation* and 8220 *Siliceous rocky slopes with chasmophytic vegetation*, where caves have been developed are significant to caves as well (*see Chapters 10.1.5, 11.1.5*). A constant microclimate inside the cave is particularly significant for cave habitats. Caves are not closed systems, thus being affected by external factors. They are influenced by incoming air, water, as well as by organisms that enter the cave, move there and exit it. The longest cave system accessible to people in Latvia reaches 150 metres. This is the total length of its underground labyrinth of tunnels; the distance between the cave entrance and the deepest part is smaller. Depending on the size of the entrance, light can penetrate the cave up to 5 m, therefore photosynthesising organisms can also grow up to such a limit. Deeper inside the cave various heterotrophic organisms will be found, which feed on the matter that has been carried into the cave from outside or use the cave as a hiding place and leave it when there is a need. So far it is not known that an environment closed and uninfluenced by the outside world may be established in any cave in Latvia.

12.1.5.2. Cave Locality and Surroundings

The position of the cave in the rock outcrop is significant. If the cave is situated in the lower part of the rock outcrop, the vegetation at the outcrop foot can play a significant role in maintaining the cave microclimate because the cave entrance can be sheltered from the sun and wind by herbaceous or woody plants. The influence of water flowing along the outcrop will also have a greater impact on the cave microclimate if the cave is located in the outcrop base compared to the outcrop middle or upper part where the cave is drier. The surrounding habitat can influence cave insolation and stop wind, thus also regulating the microclimate in the cave. The surrounding habitat determines which animals will live in the cave.

12.1.5.3. Collapses

Sandstone rock outcrops in Latvia are poorly cemented, therefore collapses in sandstone caves occur on a regular basis, but to varying degrees. For caves in calcareous rocks, falling of small rock pieces from the cave ceiling caused by surface water infiltration is characteristic. Large-scale landslides can destroy the cave or block its entrance. Sandstone debris is loose and can easily be washed out by water or dug up by animals. In calcareous caves, fallen pieces remain for a long time in the places where they fell unless people move them elsewhere.

Similarly to habitat type 8220 *Siliceous rocky slopes with chasmophytic vegetation*, also in caves, collapses caused by natural conditions (water erosion, processes triggered by freezing and thawing, gravitation-induced erosion, etc.) in small areas are desirable, as they help to maintain rock outcrops open and prevent cave entrance overgrowth. As the cave entrance collapses, the empty space of the cave can remain underground and a new entrance can develop over time. Large-scale collapses can completely destroy the cave habitat.

Intense anthropogenic pressure in frequently visited caves can facilitate or cause collapses of varying degrees.

12.1.5.4. Human-introduced Cave Wall Erosion

Although Latvian caves are few in number and not big, cave tourism or speleotourism is being promoted in Latvia. Visits to the cave facilitate erosion of the cave walls and ceiling, especially in small caves where it is impossible to move without touching the ceiling or walls. Such mechanically scratched cave walls become smooth, micro-niches disappear and therefore characteristic vegetation cannot develop in sunlight and twilight areas at the entrance. Deeper in the midnight zone, animals attached to the wall are being detached. The cave loses its significance as a valuable habitat. This is especially dangerous for hibernating bats that are attached to the cave wall and can be pulled to the ground and trampled.

12.1.5.5. Air Quality and Temperature Changes Caused by Anthropogenic Influences

Visits to caves can cause damage to bat species which are sensitive to the slightest changes in microclimate during their hibernation period which lasts from October to April. Digging up the cave to enter the cave can excessively expand the entrance and thus change the microclimate, which is unfavourable to the species dwelling in the cave.

Studies conducted in large caves in Europe show that air exhaled by humans in caves contain carbon dioxide (CO_2) that accumulates in caves and can influence the species composition there (Romero 2009). Although such studies have not been carried out in Latvia and the caves here are much smaller, the comparison of cave sizes in Latvia with the size of the human body suggests that the presence of several people in a small cave may cause adverse changes in air quality.

Maintenance of a constant temperature is essential for cave ecosystems, and every visitor can contribute to cave air warming. Constant air temperature – from +4 to +8 °C – with minor fluctuations throughout the year is characteristic for Latvian caves where bats hibernate. Fires, burning of candles and smoking in caves heats the air and pollutes it with hazardous chemical compounds resulting from the combustion process. Since air exchange in a cave is slow, such disturbance can persist for a long time, especially in ceiling cracks. A similarly strong negative impact is left by fires or smoking near the cave entrance and its vicinity, especially if the wind blows smoke towards the cave. Gauja National Park regulations prohibit "fires and bringing any burning objects, including candles, torches, cigarettes that generate smoke or heat, into natural and artificially created dolomite and sandstone caves (except for cellar caves which are still used commercially)"[40].

"The red Devonian sandstone rock of the cave wall is covered in algae, lichens and, in some places, in mosses, as well as sprouts of sporous plants, which are destroyed by fire and smoke with soot. Therefore burning fires in caves is prohibited, damaging of clear water flows and the destruction of old inscriptions is also prohibited."

Written by Kārlis Ašmanis who worked teacher in Cēsis, on Gūtmanis Cave. Published in 1930, journal "Jaunais Zinātnieks" (Young Scientist), Vol. 7, pp. 74.

Although sleeping the night in caves is not directly prohibited, it is prohibited to disturb bats, which are protected species: "In the case of protected species of animals including birds in all stages of their development, the following actions are prohibited: [...] deliberate disturbance (especially during the period of breeding, rearing offspring, feather moulting, winter hibernation and migration) and habitat destruction."[41]

12.1.5.6. Inscriptions on Cave Walls

Similarly to sandstone outcrops, ancient inscriptions are also found in caves, and these should be preserved as cultural and historical heritage. Nowadays new inscriptions on sandstone

[40] Section 9 and 10 of Cabinet Regulation No. 317 of 2 May 2012, Regulations on Individual Protection and Use of Gauja National Park.

[41] Section 11 of the Law on the Conservation of Species and Biotopes (with the amendments as of 16 March 2000).

cliffs and in caves are undesirable. Writing, drawing and etching on all rock outcrops and cave walls is prohibited in the territory of Gauja National Park[42], because such action causes cave and outcrop erosion, can destroy rare species and promote collapses. In Salaca Valley Nature Park[43] this prohibition refers to all geological and geomorphological nature monuments, which also include rock outcrops and caves.

Moss and lichen removal from the historical inscriptions allows one to preserve them for longer, however in such cases the presence and conservation priorities of protected species must always be assessed. For instance, important historical evidence of the beginnings of tourism in Latvia are the inscriptions on the walls of Gūtmanis Cave, which were already engraved in the 16th–17th century. In the early 19th century the inscriptions were even custom-made (Arājs 2015). The walls of this cave and the walls of the sandstone outcrop outside the cave are covered by protected lichen species *Cystocolea ebeneus*, which also covers the inscriptions. The cave is not suitable for bat hibernation, also *Cystocoleus ebeneus* is not endangered at this site and therefore the protection of inscriptions can be prioritised here.

12.1.5.7. Geological, Palaeontological and Archaeological Research

Rock outcrops including caves contain evidence of an ancient era and can be important as research objects. However, such research often includes digging and excavation works in the cave and its surroundings. Digging can preserve a cave as a system, if part of it has been buried or filled with sand sediments. However, cleaning of caves can adversely affect the cave ecosystem that has already stabilised. To date the widest archaeological research has been carried out in Lībiešu upuralas (*Liv Sacrificial Offering Caves*). There are no studies on the impact of research works on the cave species composition. Many caves have been dug out to preserve and measure the collapsed tunnels (Eniņš 2015)

12.2. Protection and Management Objectives of Cave Habitats

The priority is to preserve undisturbed cave habitats with a stable microclimate, ensuring the functioning of natural processes. In caves which are used for bat winter hibernation, conditions for undisturbed bat winter hibernation must be maintained. Such caves offer one of the few opportunities to gather information on the numbers and composition of hibernating bat species, thus assessing the numbers and conservation status of these species in the country.

12.3. Protection and Management of Caves

12.3.1. Knowledge-based Management Recommendations

To ensure the optimum protection regime in each cave as a habitat, which in many cases includes a targeted reduction of anthropogenic pressure, decisions must always be based on the knowledge of conditions and species in the particular site. In some cases the cultural and historical significance of the cave must be evaluated, for instance, if the cave is an ancient religious monument. If the knowledge is insufficient, it is better to be cautious and not encourage an increase in visitor load, which can destroy or degrade potential values.

There are just a few studies on cave habitats in Latvia and their nature values, but they are incomplete. Researchers of the Nature Heritage Fund surveyed many caves in Latvia, drew their plans (DRK, *without date*.), and incidentally also recorded a variety of information about species such as *Schistostega pennata* (Opmanis 1996) and fungi (Vimba 2015). Students of the University of Latvia studied cave flora and fauna in Latvia and Baltic countries (Kušners, Smaļinskis 1994; Smaļinskis 1997) but further studies did not follow. Currently, cave nature values are intensively studied by bat researchers (Pētersons, Vintulis 1998; Šuba et al. 2008; Vintulis 2013). Bats are one of the most important groups of animals that serve as a reason for the protection of caves, but these studies do not include caves where bats do not hibernate, thus information on nature values of such caves is not recorded. Caves have also been

[42] Section 9.11 of Cabinet Regulation No. 317 of 2 May 2012, Regulations on Individual Protection and Use of Gauja National Park.

[43] Cabinet Regulation No. 228 of 10 March 2009, Regulations on Individual Protection and Use of Salacas Ieleja National Park.

studied as cultural and historical monuments and as tourist attractions (Laime 2009; Arājs 2015).

In caves which are traditionally used as tourist attractions and where visitor load cannot be avoided, the establishment of adequate tourist infrastructure in order to reduce the load is necessary (Fig. 4.12). Paths, boardwalks, fences and stairs must be designed to prevent access to the most sensitive values, avoid trampling and also emphasise an interesting object that is not so sensitive. Improperly designed infrastructure increases the visitor load in the cave (Fig. 12.5).

Fig. 12.4. Kalējala Cave. With help of infrastructure elements visitors are redirected from entering the caves. At the cave entrance, delimiting platform is constructed. Cave-like niche can be viewed also from inside, and it is equipped with stairs. Photo: I. Čakare.

Fig. 12.5. Velnala Cave (*Devil's Cave*) in Inčukalns. Boardwalk invites visitors to enter the cave but is not desired in terms of habitat conservation. If boardwalk would be removed, most probably some visitors would avoid entering the cave, whereas the trampling in spring brook would be promoted. Photo: I. Čakare.

12.3.2. Non-interference

Non-interference and natural processes is the optimum solution for the protection of cave habitats. However it can rarely be fully ensured because the information about the locations of caves is widely available on the internet, and natural caves are usually freely accessible. Therefore caves are rather actively used as tourism objects and this status often requires the establishment of tourism infrastructure and the provision of visitor safety. Regular visiting influences natural cave processes such as air exchange, cave dimensions, collapses and overgrowth of the cave entrance. However visitor load can be reduced by restrictive infrastructure elements, thus closing the access to caves, which can be essential for bat conservation.

12.3.3. Cave Management for the Protection of Bats

From the point of view of bat conservation, caves can be divided into four groups, starting with the caves, where no specific visiting limitations are required, and ending with caves that must be fully closed to visitors (Mitchell-Jones et al. 2007):

- caves that are not used by bats;
- caves where bats are rarely found;
- caves where bats occur seasonally in great numbers; in Latvia these are caves where bats hibernate every year;
- caves that are used by bats throughout the year.

Of 194 caves, 82 are included in hibernation monitoring, which is 90% of caves where bats are known to reside (Pētersons, Vintulis 2013). Many of the caves included in the monitoring are caves where bats hibernate every winter. If bats use the cave for hibernation only, caves can be closed for tourists seasonally. However, care must be taken during the tourism season to preserve other undisturbed nature values characteristic for caves. If such caves have not previously been used as tourism objects, tourism should not be developed here.

Only a few caves are significant for bats throughout the year, and these caves must be entirely closed to visitors. At the entrances and in the nearest vicinity of caves most important for bats, bat swarming occurs in late summer and autumn (behaviour which is not fully understood and during which bats fly in and out of the cave and mark the area with droppings and urine, mate, and, possibly, inspect the hibernation sites) (Šuba et al. 2008). Various solutions can be used to close the cave seasonally or fully. A bat expert can help in selecting the best methods of bat conservation in the particular cave. These guidelines list solely some basic ideas of bat protection in caves.

A support wall with grille can be constructed in a cave entrance. Wide continuous masonry can change the microclimate of a cave, because it changes the shape of a cave entrance and influences air exchange. Therefore it is recommended to construct a grille which can be fixed to masonry support (Fig. 12.6). To enable bats to enter the cave, the distance between grille bars and their orientation are significant (Fig. 12.7). Vertical spacing between the bar edges of 150 mm and horizontal spacing of 450–700 mm is considered as optimal (Mitchell-Jones et al. 2007). Be sure to measure the space between the edges of bars and not between their centres, because if large diameter bars are used, the distance between centres will significantly differ from the distance between the edges. Improper bar configuration will hinder bats' entry to and exit from the cave, and may become a cause for cave abandonment. For the purpose of monitoring and research, a lockable entrance should be constructed so that a researcher may enter the cave. The lock should be less durable than the bars. Otherwise, in the case of vandalism, bars will be damaged instead of the lock. This can provoke collapse at the entrance.

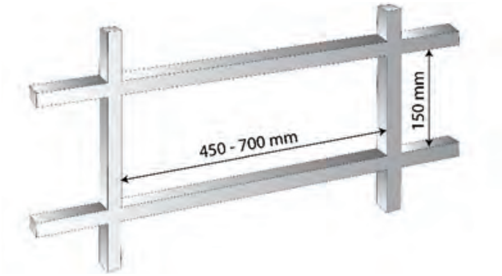

Fig. 12.7. One block of bars; spacing between the bar edges. Drawing by D. Segliņa.

Bars must be positioned vertically and horizontally, and not at other angles, because bats find it much more difficult to pass openings that are inclined. Such an unsuccessful solution can be seen in Līgatne (Fig. 12.8). In order to enable easy access to the cave for bats, this grille should be replaced by a more appropriate one.

Fig. 12.8. Incorrectly constructed bars in Līgatne. Crossbars are inclined, rather than straight. Photo: I. Čakare.

Fig. 12.6. The cave entrance is closed with a grille. On the left, bars are strengthened to support the wall. On the right, they are embedded directly into the wall. The grille has a door with a lock. Drawing by D. Segliņa.

Fig. 12.9. Cīrulīši Cave, a vertical cave (a hole in the ground below which there is a wide cave room), closed with a horizontal wooden grille which is situated too close to the ground, thus making bat entry difficult. Photo: I. Čakare.

Fig 12.10. It is recommended to install an elevated box-type grille above the entrance to Cīrulīši Cave. Drawing by D. Segliņa.

Fig. 12.12. Cave is visible over the low gate and the fencing is easy to step over. Photo: I. Čakare.

For vertical caves, an elevated box-type grille must be created above the ground. The possibility for a researcher to enter the cave must be ensured in this case as well (Fig. 12.9, 12.10).

If several adjacent caves must be closed, or if the cave has several entrances, a fence that is high enough and cannot be easily stepped over must be constructed (Fig. 12.11). If an aesthetically more acceptable solution with a delimiting barrier is used, it must be taken into consideration that some visitors will cross the barrier (Fig. 12.12). Therefore this solution is not suitable for caves where human presence must be completely restricted. In addition to the barriers and bars, information on limitations and undesirable behaviour in the vicinity of the cave must be provided.

Fig. 12.11. Territory of several caves is delimited. Photo: I. Čakare, drawing by D. Segliņa.

12.3.4. Management of Surrounding Habitats

Management of the surrounding habitats must be carried out in the same way as the management of EU protected habitat types 8210 *Calcareous rocky slopes with chasmophytic vegetation* (*see Chapter 10.3*) and 8220 *Siliceous rocky slopes with chasmophytic vegetation* (*see Chapter 11.3*). Removal of trees and shrubs in the close vicinity of caves and outcrops is never desirable in terms of cave or outcrop habitat conservation. In some cases such measures can contribute to the improvement of sceneries for aesthetic purposes in popular tourist destinations because they uncover the view to outcrops and caves. But every such case must be carefully evaluated by considering the expected benefit and losses such as natural, cultural, historical and landscape values. The expected benefits can never be justified if the existence of particular species or other nature values thus become endangered.

Buffer zones are very significant for protection of outcrops and caves. If forest is cleared to the edge of the top of the outcrop, natural slope processes (erosion) can be promoted. Therefore at least a 30–50 m wide unmanaged buffer zone must be preserved in forest stands above the outcrop cliff. In agricultural land, at least a 3–5 m wide protection belt above sandstone outcrops must be maintained where no land cultivation works (ploughing, harrowing) are performed. In this way, increased runoff is prevented.

Rapid, artificial water level changes and artificially induced rapid ice drift may reinforce natural erosion at the outcrop base and lead to undesired collapse which can also affect caves in the outcrop. Therefore the adverse impact of hydroelectric power plants must be prevented. Ice blasting is not recommended in rivers with outcrops.

12.3.5. Re-instatement and Imitation of Natural Processes

If a cave is destroyed, its restoration is not possible. A collapsed cave entrance can be dug out. Creation of a new cave is possible in rock outcrops. However the creation of such a cave will affect the rock outcrop, which will be destroyed at the cave entrance. Collapses of the exposed rock are also possible. Processes in artificially created caves are similar to those in natural caves with similar morphometric characteristics. Therefore, from the point of view of species conservation, artificial caves must be preserved in the same way as caves of natural origin (Fig. 10.13, 10.14).

Fig. 12.13. Long abandoned cellar caves in Līgatne. Only the support wall on the left remains. Entrance doors and their mountings are missing. Photo: I. Čakare.

12.3.6. Development of Tourism Infrastructure

Delimiting barriers and fences may be built to protect caves. Correctly designed boardwalks, platforms, paths and stairs protect the rock from too intense trampling and limit undesirable access to caves. For the complete prevention of access, structures that do not allow people to enter the cave must be constructed. The principles for tourist infrastructure planning are the same as those for sandstone outcrops (*see Chapter 11.3.5*).

Sometimes it is possible to plan trails and board walks in a manner that does not cause visitor interest to little known caves. For the conservation of significant natural values associated with caves it is crucial to avoid the promotion of scantily visited places.

12.3.7. Conservation of Cultural and Historical Heritage

Opinions on the cleaning of inscriptions on rock outcrops, including the inscriptions in caves, differ. Inscriptions, especially the most ancient ones are of cultural and historical significance (Fig. 10.15). At the same time, they

Fig. 12.14. A cave in Velna grava (*Devil's Valley*) which was dug in the early 21st century. Photo: I. Čakare.

Fig. 12.15. Old inscriptions on sandstone outcrop overgrown with mosses and lichens. Photo: I. Čakare.

have long fulfilled an environmental micro-niche role. Often such sites are significant habitats for rare moss, lichen or vascular plant species. The presence and rarity of species must be assessed before cleaning works. Preservation of cultural and historical heritage should not destroy rare species and conditions suitable for them. As a precautionary measure, the cleaning of such inscriptions may only be performed pursuant to expert judgment after the assessment of species occurring on an outcrop and in a cave. Research works by means of laser scanning and similar methods do not influence species on the outcrop; these methods have the least impact.

12.3.8. Conservation and Research of Palaeontological, Geological and Archaeological Values

Cave exploration, which includes rock sampling or excavation, can affect the cave ecosystem both positively, because the space expands or is restored, as well as negatively by altering the constant microclimate, and the works can disturb numerous species. Before rock sampling or excavating, the measurement of the cave must be carried out (passages, their configuration, entrance dimensions, floor inclination, temperature, presence of water); nature values must be identified and vegetation sample plots must be established. The works must be documented for the later assessment and comparison of the impact of sampling on a cave ecosystem. On outcrops with significant geological or palaeontological value, partial cleaning of the wall from vegetation and upper layers may be necessary. Such actions can only be carried out in places with significant geological values, which are more valuable than the present species. If the study results in a structure similar to a cave, it is desired to conserve it after the completion of works, and species establishment monitoring should be initiated.

12.3.9. Management and Use Unfavourable for Cave Habitats

Unsuccessful establishment and inappropriate management of tourism infrastructure objects, as well as careless dissemination of information on caves and their nature values, can result in an increased number of visitors which, in turn, increases the degradation of a cave as a habitat and promotes the collapse of a cave. Erosion can be accelerated, as has already occurred with some of the caves and outcrops, such as the Lielā Ellīte and Peldanga Labyrinth. In bat hibernation caves, disturbance from October to March can cause the death of hibernating bats. The enlargement of natural caves, particularly at their entrance, can change the microclimate.

Cave use for tourism creates additional load, and reduces the cave habitat quality. Candle and torch burning, campfires and smoking in a cave or in its immediate vicinity are not permitted both in bat hibernation caves and also in caves which are popular tourist attractions. Any changes in cave air composition can cause the death of cave species. Sandstone caves in Latvia are not suitable for organised excursions with a large number of visitors and for speleotourism because the number of caves is low, their volume is small and their air composition and microclimate can be easily influenced. If the cave is closed to visitors, improper configuration of bars creates obstacles for bats entering the cave.

There are controversial opinions on digging up caves, although it is quite often used in practice. Less common but equally controversial is the strengthening of cave walls and ceilings.

12.3.10. Comparison of Cave Habitat Management and Conservation Methods

Main methods of cave habitat management and conservation, together with the assessment of their advantages and disadvantages, are compared in Table 12.1.

Table 12.1. Main management methods, their advantages and disadvantages.

Method	Advantages	Disadvantages	Examples
Development of tourism infrastructure (boardwalks, trails, foot-bridges)	Allows redirecting visitors from less sensitive areas to already influenced ones.	Tourism infrastructure attracts more visitors which can significantly accelerate the erosion of cave walls and ceilings, as well as the surrounding outcrop. It is not possible to create visually attractive barriers, which could not be climbed over. Wooden boardwalks and stairs are subject to rotting, they must be replaced relatively frequently. Wooden boardwalks can be slippery in winter and in rainy weather (dangerous for visitors), unless they are specially equipped. Collapses in caves are possible, caused by the construction of boardwalks, trails and stairs.	By the removal of trail which enabled entry to Velnala Cave in Sigulda, the cave was protected from trampling. After that, rare moss *Schistostega pennata* has established in the cave entrance again.
Closing of caves that are significant for bats, either seasonally or throughout the year	Prevents disturbances that could unfavourably affect bats.	Should only be used in places which can be effectively delimited from all sides. Construction of support poles in sandstone rock is difficult – they are dug out, bypassed, circumvented, soft sand under barriers can be dug easily, etc. High costs, because sandstone rock and debris are soft materials therefore fencing can be easily dug out. Delimitation of dolomite caves is complicated because a cave usually has several entrances.	Has not been implemented in natural caves in Latvia.
Cave closure with partial (seasonal) opportunity to visit the cave from May to September (closure during the bat hibernation season)	Undisturbed bat hibernation is ensured.	Should only be used in caves traditionally available to visitors, to limit visits during bat hibernation. Barrier is not insurmountable, limitation of access largely depends on public information efficiency and the integrity of visitors.	An attempt to completely delimit Kalējala Cave failed because visitors broke the fence. Currently, there is partial limitation in Kalējala, and the cave is partially closed during bat hibernation. Relatively successful protection is ensured in Riežupe and in Līgatne cellar caves, where the visiting is only possible if accompanied by a tour guide.
Digging up and deepening of caves	By the proper digging up of caves, additional space is created in the cave; geological and historical research can be carried out.	If the entrance is expanded excessively, the cave microclimate changes and the cave becomes unsuitable for bat hibernation. Visiting options and disturbance intensity increases.	Deepening of caves is a well known method, but its impact on species has not been studied yet. Archaeological research has been carried out in Liv Sacrificial Offering Caves.
Strengthening of cave entrance	Allows slight extending of the lifespan of a cave entrance or the entire cave.	Temporary effect. Complete construction of the cave entrance may positively affect bat hibernation, but several insolation zones in the cave can disappear, causing extinction of vegetation. Partial closure is more desirable because it also ensures air and light exchange.	Strengthening of the cave entrance has retained accessibility to Riežupe Sand Caves; partial strengthening of the cave ceiling has delayed the collapse of Dauģēni Cave.
Collection of municipal waste and fallen trees in the cave and in its vicinity.	Waste in a cave can cause local pollution. The availability of dead wood in the cave and at its entrance can provoke the wish to burn fires at the cave entrance.	None.	Hibernating bat monitoring data show that fires are being burnt at cave entrances. There is no research on the changes in air quality in caves.

12.4. Conflicts in Protection and Management of Cave Habitats

Non-intervention is always the best solution for cave protection. Caves are valuable not only as habitats or suitable environment for numerous species but also as witnesses of geomorphological process. They can also have cultural, historical and spiritual significance. If the digging up, visiting or strengthening of caves is required for cultural, historical or geological research, it must be balanced with the necessities of habitat and species conservation. The time and methods of the works or visits in the cave must be selected so that they have the least impact on cave species (Watson et al. (eds.) 1997).

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Glossary

Abiotic conditions – conditions of the non-living environment, influencing ecosystem structure and function.
Anthropogenic – related to the direct or indirect impact of humankind and its economic activities on nature in general or on its individual components and elements (landscapes, natural resources, habitats, etc.), influenced by human activities. The territory loses its natural characteristics due to extensive anthropogenic load.
Bedrock – here – sedimentary rock – clay, dolomite, limestone, sandstone, gypsum, which were developed in the pre-quaternary period.
Biotechnical measures – active measures to maintain a habitat in a certain condition. Examples of biotechnical measures are cutting of shrubs, mowing and removal of grass. See also: *Habitat management, Habitat restoration and Habitat creation.*
Birds directive – Directive 2009/147/EC of the European Parliament and of the Council of 30 November 2009 on the conservation of wild birds.
Calciphyte – a plant that thrives in carbonate-rich soil.
Carbonate rock – a class of sedimentary rocks composed primarily of carbonate minerals. Typical examples are limestone, dolomite and gypsum.
Collapse – here – sudden separation of a part of a rock from the outcrop which breaks (structure and arrangement (top, bottom) breaks down). Outcrop characteristic vegetation can persist if larger unturned rock fragments remain.
Devononian period – the fourth geological period in the Paleozoic era, spanning approximately 56 million years. It is named after Devon, England, where rocks from this period were first studied. In Latvia, rocks of this period are deposited below the Quaternary (our current period) sediment layer and are exposed mainly in river valleys.
Dolomite – here – a sedimentary rock composed primarily of calcium magnesium carbonate ($CaMg(CO_3)_2$). In Latvia, dolomite covers a significant part of the sub-quaternary surface.
Dolomitic marlstone – dolomitic loam.
Donor area – place where the species specimen or individuals are gathered to transfer (reintroduce) them to a new place, or the place from which these species can disperse naturally to the target area.
Ecosystem – community of living organisms in conjunction with the non-living components of their environment (such as air, water and mineral soil), interacting as a system.
Ecosystem services – various types of ecosystem benefits provided to society.
European Union protected habitat type – habitat type listed in Annex I of the Habitats Directive Annex I of Council Directive 92/43/EEC of 21 May 1992 on the conservation of natural habitats and of wild fauna and flora.
Eutrophication – environmental enrichment with nutrients, caused by natural processes or human activities.
Erosion – here – process when rock outcrop is gradually worn away under the influence of natural factors (wind, water, gravitation, ice) and/or anthropogenic factors (trampling, vibration).
Erratic block – masses of stone which have been transported from their original places by the glacial action, its melting water, or other causes.
Expansive species – species of local origin that are able to quickly spread and dominate over the other species. These species only become expansive in certain circumstances (such as management practice change or cessation, rapid increase of nutrients etc.).
Favourable conservation status – natural range and areas of habitat cover within that range are stable or increasing; the species structure and functions, which are necessary for its long term maintenance, exist and are likely to continue to exist for the foreseeable future; the conservation status of its typical species is favourable.
Fragmentation – here – division of large, continuous landscape into smaller, more isolated remnants. Fragmentation is the opposite of connectivity.
Ground waters – water present beneath the Earth's surface in soil pore spaces and in the fractures of bedrock formations.
Habitat – the concept of habitat in this edition is used according to the Law on the Conservation of Species and Biotopes. A habitat is a land or water area of natural or semi-natural origin, characterised by particular geographical, abiotic and biotic features.
Habitat creation – a set of biotechnical measures aimed at the creation of the environmental conditions and structure (species composition, age structure, etc.) necessary for the habitat, and

their introduction in the place where this habitat type has never existed. This also applies to sites where the habitat has once existed, but the environment has been completely transformed and no signs of the habitat remain.
Habitat management – set of biotechnical measures aimed at maintaining habitats in a favourable conservation status.
Habitat restoration – set of biotechnical measures aimed at the restoration of environmental conditions, vegetation structure (species composition, age structure, etc.) and species in a site where the habitat existed earlier or still exists but under an unfavourable conservation status.
Habitats Directive – Council Directive 92/43/EEC of 21 May 1992 on the conservation of natural habitats and of wild fauna and flora.
Herbaceous plants – annual or perennial plants that have no persistent woody stem above ground.
Invasive species – species that is not native to a specific location and which has a tendency to spread over large areas and outcompete local species. Typically, the spread of invasive species in natural or semi-natural ecosystems is associated with biodiversity decrease, economic loss or human health risks.
Karst process – dissolution of soluble rocks such as limestone, dolomite and gypsum.
Land rehabilitation – the restoration of the initial value of a degraded site in order to prevent threats to environmental quality, human health and life, as well as to facilitate the incorporation of quarry sites, etc. into the landscape.
Landslide – here – detaching of rock outcrop part and its slipping down the exposed rock (material is moving but its position (top, down) is partially retained.
Mineral resources – natural aggregations of minerals and rocks, which are used commercially.
Natura 2000 site — nature protection area included in a network of nature protection areas in the territory of the European Union. The aim of the network is to ensure the long-term survival of Europe's most valuable and threatened species and habitats, listed under both the Birds Directive and the Habitats Directive. See also: Habitats Directive, Birds Directive.
Nutrients – here plant nutrients – chemical elements and compounds required for plant growth and metabolism.
Object – it is used here to emphasise a particular rock outcrop or cave that is distinctive from other similar habitats.
Outcrop – visible exposure of bedrock. Outcrops can be naturally or artificially created.
Outcrop base – basal, lower part of the rock outcrop.
Protected geological and geomorphological nature monument – specially protected nature area – one of the types of protected nature monuments listed in the Law of 2 March 1993 On Specially Protected Nature Territories. Rock outcrops and caves are listed in Cabinet Regulation No. 175 of 17 April 2001 *Regulations on Protected Geological and Geomorphological Nature Monuments.*
Protected habitat – endangered habitat (*see Habitat*), the conservation of which is regulated by national regulations. In Latvia protected habitats are listed in Cabinet Regulation No. 421 of 5 December 2000 Regulations on the List of the Specially Protected Biotopes.
Protected species – endangered species, the conservation of which is regulated by national regulations. In Latvia, protected species are listed in the Regulations of the Cabinet of Ministers of the Republic of Latvia.
Reintroduction – regarding species – returning native species to localities where they are absent but existed previously.
Renaturalisation – type of habitat restoration including restoration of a habitat characteristic environment (abiotic environment, vegetation). Here used similarly as the restoration of bog characteristic environment in the meaning of legislation.
Rock fragment – here – rock pieces of various sizes (fragments of calcareous bedrock and sandstone concretions are the most common, sandstone is less common because it crumbles easily) separated from exposed rock, and characteristic rock outcrop vegetation can still develop on them.
Ruderal plant – plant that grows in waste places, construction sites, abandoned agricultural lands.
Sandstone – sedimentary rock composed of sand-size grains of mineral, rock, or organic material.
Scree – a collection of rock debris (broken rock fragments) at the base of rock outcrops that has accumulated through periodic rockfall from adjacent cliff faces.

Scree accumulation – long-term and increasing accumulation of scree (rock debris) at the base of the rock outcrop, if scree transportation does not occur. Scree partially or completely covers the wall of the outcrop and destroys the vegetation characteristic for the outcrop in the part that has been buried for a long time.
Scree transportation – movement of the weathered rock parts (sand, soil etc.) from one place to the other by the action of wind, ice, water and gravity (mainly by water).
Seepage – moist or wet place where groundwater reaches the earth's surface from an underground aquifer.
Slope processes – here – movement of upper layers of rock outcrop or soil down the slope under the influence of gravitation.
Speleotourism – tourism in caves.
Spring – a natural, concentrated outlet of artesian or ground waters on the land surface or under the ground.
Stratotype – physical location or outcrop of a particular reference exposure of a stratigraphic sequence or stratigraphic boundary.
Succession – ecosystem formation process in which habitat types replace each other, such as dunes transform to grey dunes, which further develop into wooded dunes. Primary succession occurs when there is a new substrate with no existing vegetation, for example, on beach debris or washed away sea cliff. Secondary succession is a process started in sites of preexisting soil and vegetation which is totally or partly destroyed but abiotic conditions and also part of the species (seeds or vegetative propagules) is preserved.
Suffosion – mechanical washing out of tiny rock pieces with the stream of water. Almost all Latvian caves have developed by means of suffosion processes.
Target species – species at which the restoration or management measures (such as habitat management, habitat restoration or creation, reintroduction, etc.) are aimed.
Tectonic cave – cave formed by mass movement of the bedrock. It is believed there is only one cave of tectonic origin in Latvia - Brunis cave in Dambis rock on the bank of the River Amata.
Tufa – a variety of limestone formed when carbonate minerals from solution in ground waters and surface waters precipitate around mosses, herbaceous plants and a variety of plant litter.
Umbrella species – species with large area requirements for which protection of the species offers protection to other species that share the same habitat.
Water level – here – periodically or constantly determined elevation of the free surface of a stream, lake or reservoir.
Vegetation – assemblages of plant species and the ground cover they provide.
Woody plants – trees, shrubs, dwarf shrubs.