Protected Habitat Management Guidelines for Latvia

Mires and springs

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Foreword

The bond between humankind and nature is eternal. The beauty and diversity of Latvian nature has been affected by ages of interaction between people and the environment. The future of people and the surrounding environment are inextricably linked, and in the contemporary world the diversity of nature cannot be conserved in isolation from humans by prohibiting any action. A responsible attitude is necessary to 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, – those who have the authority to make decisions and plan the use of land in Latvia, as well as those who manage their land themselves. The guidelines are a comprehensive source of knowledge and methods that are applicable in nature conservation, providing every one of us with an option of taking sensible and sustainable action while also being caring owners, who benefit themselves, their family and nation by maintaining the balance between humans and nature diversity. The choice of the future lies in our wisdom, respect and awareness of life.

General Director of the Nature Conservation Agency
Juris Jātnieks

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Introduction

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 the conservation, proper management and restoration of mire and spring habitats.

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.

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 wetland habitats in Latvia.

PART I

Chapter 1. Characteristics of Mires and Springs

Mire is an area of land surface which is characterised by persistent or prolonged humidity, specific vegetation and peat formation. Mires develop when precipitation exceeds evaporation. Mire formation is also promoted by undulating relief and clayey, poorly permeable sediments, characteristic in large parts of Latvia (Kalniņa 2008).

Mires in Latvia formed in the post-glacial period both due to the overgrowing of water bodies and land paludification. The intensity of mire development at different times since the glacial retreat has been different. The oldest peat layers accumulated in the Preboreal period about 10,000 years ago, as a result of the overgrowth of shallow lakes or filling up of glaciokarst depressions. Mire development became more intense during the Boreal period in approximately 7,700–9,800 BCE when the climate became warmer, and continued in the Atlantic period when the climate was warm and humid, and thus the rate of dead plant biomass accumulation increased (Kalniņa 2008; Silamiķele 2010). During the period of the Littorina Sea, one of the early development stages of the Baltic Sea, the sea water level was 5–6 m higher than nowadays. The groundwater table in coastal areas rose, promoting paludification. Large mires developed in the Coastal Lowland due to the filling in of wet depressions and the paludification of shallow basins (Kalniņa 2008). Mire development also occurs today – peat continues to accumulate, young mires develop, though in small areas – in relief depressions, by filling in water bodies, and by the paludification of agricultural lands, forests, forest clear-cuts and beaver ponds.

Mires include fens, transition mires and raised bogs, which are at different stages of mire development. Accumulation of organic sediments – peat – is a key process of mire formation, and is characterised by a particular botanical composition in each stage of mire development. In fens, peat composed of reeds, sedge, and wood prevail, whereas in raised bogs it is formed predominantly by sphagnum and cottongrass. Within the course of typical mire development, fen peat sediments are formed first in conditions when the mire is fed by groundwaters and precipitation. Fens gradually transform into raised bogs, receiving the water from precipitation. However, raised bogs can develop on gyttja sediments (in overgrown lakes) or on a wet mineral bottom (paludified terrestrial areas), without the fen development stage (Galeniece 1960). Not all fens turn into raised bogs at the end of their development as mire development is influenced by various factors (climate, run-off, human activities, etc.).

Fens develop in wet areas rich in groundwater and surface water supply. They are characterised by the slightly acidic to alkaline reaction of substrate and water, and they feed mainly from groundwater. These fens usually have a flat or depressional relief, they are being formed in lowlands or terrain depressions. Fens are dominated by brown mosses, sedges and reeds, and these plants are the main peat formers. In alkaline fens, the supply of alkaline groundwater is typical, the substrate is nutrient-poor. Often these fens have developed on carbonate-rich sediments, thus there is a high mineral concentration and alkaline reaction.

With time, peat accumulates and groundwater impact decreases, and fens often turn into transition mires which are fed both by groundwater and precipitation. Gradually the role of groundwater decreases, whereas the precipitation becomes more and more important. In transition mires, plants of both fens and raised bogs can be found – sphagnum mosses, brown mosses, sedges, reeds. After the stage of transition mire, development into a raised bog can follow.

Raised bogs have a dome-shaped (cupola-shaped) or plateau-type relief, formed as a result of peat accumulation. Raised bogs are fed by precipitation, and their substrate is acidic and nutrient-poor. Vegetation is dominated by sphagnum mosses that are the main peat formers. Typical vascular plant species are *Eriophorum vaginatum* and dwarf shrubs – *Calluna vulgaris*, *Ledum palustre*, *Andromeda polifolia*, *Vaccinium uliginosum*, *Oxycoccus* spp. Raised bogs are partially overgrown with pines, and usually the wettest central parts of the bog with the densest peat layer are open (Kalniņa 2008). Raised bogs form the largest mire areas in Latvia, located mainly in the Eastern Latvia Lowland, Northern Vidzeme, and Tīreļi plain of Central Latvia Lowland.

Spring brooks, seepage springs and spring fens are formed in sites where groundwaters and artesian waters well up. Usually they occur on slopes of river valleys, hill slopes, rarely in plains. Depending on the composition of bedrock through which springs are seeping, spring waters can be rich or poor in minerals (calcium carbonate, iron compounds, hydrogen sulphide). Seepage springs are the places of diffuse discharge of spring water that are permanently or seasonally wet depending on the type of water flow. Peat usually does not accumulate on the banks of spring brooks and in seepage springs, especially on slopes, since plant debris is washed away. Spring fens with a site-specific vegetation composition develop in areas where peat accumulates around the flushes. Usually spring mires are small, they have peculiar vegetation that differs from the typical vegetation of both fens and transition mires, and abiotic conditions, characteristic for springs (mineral contents of water, microclimate and others) play a major role.

This edition includes eight types of European Union (EU) protected habitat types:

- 7110* *Active raised bogs*,
- 7120 *Degraded raised bogs still capable of natural regeneration*,
- 7140 *Transition mires and quaking bogs*,
- 7150 *Depressions on peat substrates of* Rhynchosporion,
- 7160 *Fennoscandian mineral-rich springs and springfens*,
- 7210**Calcareous fens with* Cladium mariscus *and species of the* Caricion davallianae,
- 7220* *Petrifying springs with tufa formation* (Cratoneurion),
- 7230 *Alkaline fens.*

These habitat types do not cover all the types of mires in Latvia (for example, acid poor fens); however, the majority of them are protected and also included in the national list of specially protected habitats. The list of specially protected habitats of Latvia approved by the Cabinet of Ministers does not include active raised bogs, the largest proportion of mires in the country, and depressions on peat substrates of *Rhynchosporion.*

Chapter 2. History of Use and Protection of Mires and Springs in Latvia

2.1 Use of Mires and Springs at Different Times

Wetland areas have been inhabited since ancient times, because wetlands, including mires, nearby lakes and rivers, were suitable for fishing and hunting and thus important for human survival. In Latvia, the surrounding of Lake Lubāns in the eastern part of the country was inhibited 5300–3700 years ago, and an amber processing workshop was even located there. Sārnate settlement in western Latvia already existed 3400 years ago. Due to the preservative and anti-microbial properties of peat sediments and anoxic conditions, material evidence regarding the past nature conditions and human activities has survived over centuries and thousands of years, and is available for historical studies.

In the previous centuries, mires were considered to be the least productive areas and hostile to humans, at least from the farmer's perspective. Therefore, the majority of the mires in Latvia survived relatively intact. However at different times mires have been used for the extraction of various resources. In raised bogs, cranberries and other bog berries (cloudberries, bog bilberries) were picked. The bogs were used for peat extraction. Fens were also used for peat cutting, as well as for haymaking and grazing. In some mires, medicinal mud was extracted, whereas springs were sources of drinking and mineral water, including medicinal mineral water and spring sediments (tufa and limonite (bog ore, ochre)). Since ancient times, people have collected medicinal herbs and plants in mires for other purposes (such as food, dye). Many springs have been ancient religious places, where sacrifices were brought to deities; people believed that the spring waters were attributed healing properties (Fig. 2.1). Springs have not lost this role up to the present day.

Human activity of the most ancient pre-industrial age usually created a small, local impact on mires and springs, that can rarely be tracked today. Drainage of mires and transformation into agricultural lands have left the most extensive and significant impact during the last two centuries; many mires were destroyed or transformed into other land use types. Extraction of spring sediments (tufa and bog ore) significantly modified or even destroyed a number of pristine spring habitats.

Mostly, the trace of ancient human activities in mires (gathering of berries and herbs, mowing and grazing, small-scale peat extraction) has almost or totally disappeared. Toponyms such as *Hay fen* are known from several sites in Latvia, and they point to the historical use of these areas. Evidence of grazing in mires is preserved in some folklore materials. Haymaking and grazing in fens and transition mires were mostly practised due to a lack of more productive meadows and pastures. Gradually, people cultivated and drained more productive areas suitable for agriculture, and left those which were moist and difficult to manage. Thus, in around the second half of the 20th century this practice had declined significantly; at the end of the 20th century nearly all mown and grazed fens were abandoned.

A more significant human impact on mires began in around the 18th century along with ditch digging and peat extraction, and it significantly increased during the 20th century. Initially, mires were drained to get land suitable for forestry and agriculture. The efficiency and impact on mire ecosystems of hand-dug ditches was relatively insignificant; draining attempts often ended without a result, or work was only successful after repeated efforts (Draviņš 2006).

Where have you been pasturing, herdswoman?
The cows have not eaten to satiety.
Have you been pasturing
Near the marsh?
(Recorded in Krustpils)

Eat, little heifer, marsh grass,
Do not drink marsh water:
I will give you drink
From the spring dale.
(Recorded in Tirza)

Goad, herdsmen, where you are goading,
But do not goad in the mire;
Snakes are lying in the mire,
Rolling their green eyes.
(Recorded in Sarkaņi)

Leave the hay, leave the hay,
Go and harvest clover!
My horse is no longer eating
The bad mire hay.
(Recorded in Sece)

Eat, cows, mire grass,
Do not drink mire water:
Devil's children have soiled it
With their hairy feet.
(Recorded in Nītaure)

People cut hay in the mire,
Waiting for me to go and rake;
I with my brothers
Was rolling by the river.
(Recorded in Kandava)

Fig. 2.1. Offerings at Bolēnu Holy Spring. This is an ancient cult spring to which gifts are still brought today. Photo: A. Priede.

Fig. 2.2. Peat extraction site abandoned in the mid-20th century, the north eastern border of Great Ķemeri Mire (Ķemeri National Park). Photo: A. Priede.

Fig. 2.3. Today, peat milling technique for peat extraction dominates. Partially cut-away peat milling field in Aizkraukle Bog. Photo: A. Priede.

Up to the first half of the 20th century, peat was dug by hand, and the impact on mires was local. The first peat cutting machines in Latvia were introduced in the mid-19th century (Šnore 2013). However, only from the beginning of the 20th century did they gradually become more widely used for peat cutting. Compared to the methods used later, these types of peat extraction resulted in relatively local effects on mires and their hydrological regime (Fig. 2.2). From the 1950 to 1960s the peat milling method prevailed in Latvia (Nusbaums 2013b; Šnore 2013). In the first half of the 20th century, especially in the 1920–1930s, peat extraction volumes increased. Peat became more popular and more widely applied – as fuel, litter and growing media in agriculture (Nusbaums 2013b). In the 1930s peat extraction companies were established, and the amount of extracted peat increased. Farmers were urged to extract peat and use it in agriculture and heating. Peat extraction was widely promoted in the press and special propaganda events (so-called *Peat Days*) in rural regions of Latvia. Although at this time hand work was still widely used, peat digging was gradually mechanised. Peat extraction on its largest scale started in the second half of the 20th century. Mainly, the peat milling method was used (Fig. 2.3), resulting in the significant degradation of numerous mires.

In Latvia other sediments related to mire and spring ecosystems may also be found: tufa – calcareous spring sediments, including barrage tufa, a well-cemented, plant-constructed calcareous sediment type (Fig. 2.4), and limonite (bog ore, ochre,

Fig. 2.4. Barrage tufa – a well-cemented, plant-constructed spring sediment. Photo: A. Priede.

Fig. 2.6. Iron compound sediments in Dāvid's Springs (Dāvida avoti) in Gauja National Park. Photo: A. Priede.

Fig. 2.5. A barn wall built of tufa and limestone pieces in an old farming house near Matkule Village in western Latvia. The rocks are taken from Imula River valley where tufa forms from carbonate-rich springs. Extracting tufa for different usages has depleted most of Ķauķu Hill (Ķauķu kalns, also called Kursas Staburags) that once had a large deposit of tufa. Photo: A. Priede.

Fig. 2.7. Bārbele sulphurous spring – the oldest resort in Latvia, where sulphurous water has been used in therapy. In photo: the spring in 2015. Photo: A. Priede.

earth pigment). Tufa was used for soil liming and in producing various goods. For instance, after World War I, Riga Portland cement factory produced dental cleaning powder and cement using tufa as raw material, and Bušlejas factory near Cēsis also used locally extracted tufa in producing dental cleaning powder (Rozenšteins, Lancmanis 1924). Tufa was also utilised for chalk production and for ceiling and wall whitewash (Anon. 2004b). In the first half of the 20th century, barrage tufa was used in building construction and interiors (Fig. 2.5). In some regions of Latvia it was also used for the construction of buildings in farmsteads, design objects, grave monuments, decoration of buildings (both interiors and façades). In the middle and second half of the 20th century, barrage tufa was popular as a decorative element in rock gardens. Nowadays, the extraction of tufa has almost been ceased. The remaining resources are insignificant (Anon. 2004b), and their extraction is limited by restrictions aimed at nature conservation.

Iron compounds deposited in mires and springs (Fig. 2.6) have already been used since ancient times. Iron extraction was carried out on a wider scale in the time of the Duchy of Courland, in the 16th to 18th century (Juškevičs 1931; Draviņš 2000). Many toponyms in Latvia remind us of these activities (for example, Dzelzāmurs (*Iron hammer*), Dzelzciems (*Iron village*), Uguņciems (*Fire village*)). Later, bog ore was used in ink production on both an industrial scale and in households. It was also used for gas fuel refinement (Mellis 1939; Draviņš 2000).

Mineral water is another important resource associated with mires and springs. Many springs are used for drinking water extraction. They are often equipped with tubes, sheds, stairs, and other elements. Many springs are also ancient religious (cult) and healing places. Significant resources are sulphurous mineral waters and mud that occur in the surroundings of Ķemeri, Baldone, Zuši, Kandava and Bārbele towns (Fig. 2.7). Many springs in Latvia have already been used in therapy since ancient times, especially at the end of the 19th century and during the 20th century when several health resorts developed. Most widely, these resources have been used in Ķemeri (nowadays – part of Jūrmala City). Although nowadays the use of spring resources has declined, mud is still being extracted in Sloka Bog near Ķemeri and the surroundings of Baldone. Sulphurous mineral waters from Ķemeri, Zuši and other sites are still used. Although many springs are significant as peculiar geological objects, not all of them comply with the EU protected habitat identification criteria (Ikauniece 2013; Rēriha 2013). Many springs do not represent specific habitat conditions (soil, moisture, etc.) and do not host specific spring species.

Raised bogs, especially those rich in heather *Calluna vulgaris*, are widely used as bee pastures. *Calluna vulgaris* is rich in nectar, the heather honey has a specific taste and smell. Raised bogs with pools and lakes, lagoon lakes with fens and reed beds are traditionally used for bird hunting.

Another type of mire usage is nature tourism. Over the past two decades, it has been attracting more and more interest. This type of nature tourism started a long time ago, and the interest is still growing. Some springs have also been popular visitor destinations since ancient times. Since the end of the 20th century, the establishment of nature trails, equipped with wooden boardwalks, information boards, viewing towers, car parks, began in several bogs in Latvia. Trails and the extraordinary scenery attract a large number of visitors to raised bogs, which were difficult to access before the establishment of the infrastructure elements.

2.2 Brief History of Mire and Spring Protection

In ancient times, springs and their surroundings were preserved mainly due to people's attitudes rather than statutory restrictions. The careful attitude was caused by the understanding about the sacral and medical role of springs as well as by a traditional attitude towards nature, and not because of the formal protection status of species and habitat types. Springs were considered to be protected and retained. At the same time, mires, especially bogs, were considered as useless areas, hostile to humans, and therefore destroyable. Thus drainage and transformation to "more useful" land use types would provide profits in the form of extracted peat, with converted areas further involved in economic circulation. Mires drew little attention as nature objects to be worth preserving.

In the first half of the 20th century, a few mire and spring areas were officially declared as protected nature objects due to the presence of rare plant species or other reasons, but not for the conservation of mire ecosystems and their functions. Although in the second half of the 20th century quite a large number of bogs were recognised as valuable in terms of nature protection, during the entire 20th century mire conservation was understood only as a passive, prohibiting action in order to preserve a particular species or resource instead of habitats or ecosystems as a whole.

Fig. 2.8. Alkaline fen near Šlītere in north western Latvia in the 1930s. Photo from the archive of Kurzeme Regional administration, Nature Conservation Agency.

In the 1920s so-called protected forests were created in order to preserve sulphurous springs in the surroundings of Kandava, Ķemeri and Baldone (Anon. 1923). Čužu Mire in the surroundings of Kandava, established as one of the earliest protected nature areas in Latvia, has been under state protection since 1924 (initially, the protected area was called "Kandava sulphurous spring forest"), sheltering the sulphurous springs and the only locality of a rare plant species *Pentaphylloides fruticosa* in Latvia. In 1923, Šlītere Nature Monument was founded covering 1,100 hectares (Anon. 1923) (Fig. 2.8). This area included the slope forests and alkaline fens in which any further economic activities were forbidden. In 1957, one of the earliest nature reserves – Ķemeri Strict Nature Reserve – was established including several raised bogs and fens. However the reserve only existed "on paper" and just for a short time (abolished in 1961 (Veinbergs 1967) or in 1965 (Strazds, Ķuze 2006)). In spite of the official status of strict nature reserve, the actual nature protection was ineffective – peat was continuously extracted, deforestation and ditch digging continued (Galeniece, Cukermans 1958). Later, the conservation of mires in the surroundings of Ķemeri was partially provided by the Ķemeri sanitary protection zone (Galenieks, Krauklis 1995).

Mire conservation was also ensured by Gauja National Park (established in 1973), Slītere Strict Nature Reserve (established in 1979) and Teiči Strict Nature Reserve (established in 1982), where mires were already influenced by human activities before the establishment of these reserves, but further drainage of mires was ceased.

In 1977, with Decision No. 241 of the Council of Ministers of the Latvian Soviet Socialist Republic (SSR), the number of protected areas significantly increased, and 14 mire reserves were established in Latvia. Drainage, peat extraction, afforestation, and other economic activities were prohibited there. Their establishment was inspired by the activities of the International Mire Conservation Group "TELMA", in which the researchers from the Soviet Union were also involved. During this period 62 restricted areas for protecting wild cranberry resources in mires were also established. Their aim was to maintain the genetic resources of wild native cranberries and control their use (Melluma 1979). According to the ideology of that time, in the 1950–1960s scientists actively studied the nature resources that could be useful in contributing to the stagnating economy, including non-wood forest resources. For example within this frame, in 1953–1954, the researcher E. Pētersons studied wild cranberry

resources and stated that the average yield can reach around 177 kg/ha, the maximum – 600 kg/ha (Vimba 1981). Too intense cranberry picking was stated as a problem. Therefore, in 1969 a decision was issued by the Latvian SSR Council of Ministers: "Time-limits for the collection of wild berries and nuts". This prohibited cranberry picking till a certain date which was determined every year, according to the climatic conditions (usually, the picking of berries could begin in the middle or the second half of September). This restriction often turned out to be ineffective and contributed directly to people's desire to pick cranberries before the determined date, or provoked a massive flow of people in the first allowed day, and caused excessive pressure on the ground vegetation and cranberries.

Since the first half of the 20th century, the protection of springs in Latvia has already been ensured by the nature monument status granted to many springs. This form of protection has been kept until today. Nowadays many springs, including those with nature monument status, are enclosed in the larger protected nature territories.

Today, the majority of the protected nature territories and some of the micro-reserves are incorporated in the Natura 2000 network[1]. Micro-

[1] *See Chapter 6.3.2.*

Fig. 2.9. Peat dam on the ditch in Vasenieki Mire, in 2016 – almost ten years after its construction. Photo: A. Priede.

Fig. 2.10. A recently built peat dam on the ditch in Rožu Bog in 2013. Photo: A. Priede.

Fig. 2.11. Rewetted cut-away peat milling field in Ķemeri National Park. Within several years, the bare, dry peat has overgrown with mire vegetation, including sphagnum mosses – the main peat-formers in the raised bogs. The photo was taken in 2016. Photo: A. Priede.

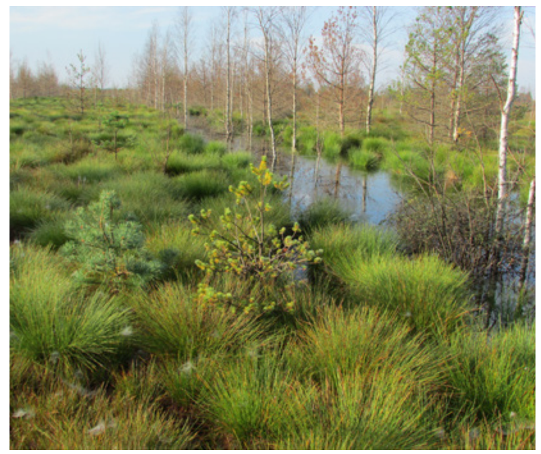

Fig. 2.12. Rewetting of the former peat milling fields by blocking ditches and raising the water level in Lielsala Mire in northern Kurzeme. The photo was taken in 2014. Nearly 20 years after the re-establishment of wetland the area is dominated by *Eriophorum vaginatum*. *Sphagnum* spp. and other mosses are still almost absent. Photo: A. Priede.

Fig. 2.13. In 2013, a dense pine stand was felled in Raganu Mire (Ķemeri National Park), also the dense dwarf shrub cover was mown and removed. The photo was taken in 2015, two years after restoration activities. Photo: A. Priede.

Fig. 2.14. Rewetted bog in the "Ādaži" Protected Landscape Area. In raising the water level a water flow regulator was built. The photo was taken in 2014, around two years after restoration. Photo: A. Priede.

Fig. 2.15. Recently, restoration of alkaline fen habitat by clearing the shrubs and mowing of herbaceous vegetation has taken place in several locations in Ķemeri National Park. In the photo – haymaking in *Cladium mariscus* fen near Lake Kaņieris in 2015. Photo: A. Priede.

Fig. 2.16. Restored spring fen in Gauja National Park. In 2013, trees and shrubs were cleared and removed. Before restoration, the fen was heavily overgrown with reeds that were mown and the biomass removed. Photo: A. Priede.

reserves[2] are being established to protect both mire habitats and related species. Nowadays, most of the protected mires have been included in strict nature reserves, nature reserves, or strict nature reserve zones or nature reserve zones of protected nature territories. Laws and regulations are prohibiting activities that may adversely affect mire and spring habitats or endanger the species present there.

Nowadays the protection of mires is also partially ensured by mire protective belts, prohibiting certain activities near mires and springs. The purpose of the mire protective zone (20–100 and more metres depending on the mire area) is to preserve the biodiversity and stabilise the hydrological regime in the contact zone between the forest or agricultural land and mire, therefore numerous potentially unfavourable activities are prohibited there.

Nowadays, there is an increasing interest in cranberry collection, causing too much pressure on the mire vegetation. Therefore, in order to protect the mires as cranberry sites, some municipality councils have prohibited the picking of cranberries before a set date in mid-September, thus resuming the tradition of the early cranberry picking prohibition that was suspended in the post-Soviet period.

[2] *See Chapter 6.3.2.*

In the 1990s, along with the increasing communication among the researchers and nature conservation practitioners from the former Soviet countries, including Latvia, and Western countries, new ideas were also presented in mire conservation, encouraging the first restoration attempts. This was the beginning of active, not only passive, mire protection. In Latvia since the end of the 1990s, considerable experience has been accumulated concerning mire restoration. So far most of the habitat restoration work had been focused on the restoration of raised bogs. Whereas fen, transition mire and spring habitats have only been restored and managed in a few cases covering small areas.

First restoration works of a raised bog hydrological regime were carried out in 1997 in Teiči Bog by constructing wooden dams on the ditches to prevent the drainage impact on the bog ecosystem (Bergmanis et al. 2002; Bergmanis 2013). In the next years, the construction of dams on ditches was carried out on a larger scale both in Teiči Bog and in Lubāna Wetland (Bergmanis 2013). In 2006, the first peat dams were built in Cena Mire (Nusbaums 2008) and in Great Ķemeri Mire (Ķuze, Priede 2008). Later, peat dams were built in several other bogs – Vasenieki Bog (Fig. 2.9), Klāņi Mire, in 2012 and 2013 also in Melnais Lake Mire, Aizkraukle Bog, Aklais Bog and Rožu Bog (Fig. 2.10). In 2012, the first trial of filling up of ditches was carried out in bog woodlands in Smiltene surrounding (northern Latvia) and in 2015 in Gauja National Park. In 2017, similar filling up of ditches is planned in Ķemeri National Park. In 2006, for the first time, targeted habitat restoration of the cut-away peatland was carried out: water level was restored in a post-harvesting area on the margin of Great Ķemeri Mire (Ķuze, Priede 2008) (Fig. 2.11). Mire renaturalisation has been carried out in the part of the cut-away peatland in Lielsala Mire in the Stikli Mire complex (north-western Latvia) (Fig. 2.12) (Cupruns et al. 2013). In 2007 in Janīši-Daina Mire, in 2013 in Raganu Mire (Fig. 2.13), in 2015 and 2016 in Skali Mire, and in 2015 in Dūmiņi Mire, pine felling in raised bogs was carried out, though mostly in small areas, up to a few hectares in size. Large-scale tree felling in bogs was carried out in the "Ādaži" Protected Landscape Area, on the same time restoring the hydrological regime (constructing dams and water flow regulators), thus restoring open mire landscapes (Fig. 2.14).

When rewetting the bogs, the nearby transition mires are also often affected, thus improving the overall ecosystem conditions. Only in a few cases (for example, in Pēterezers interdune depression in Slītere National Park and in Veseta floodplain mire) did the restoration activities include the removal of excessive cover of trees and shrubs.

So far the largest restoration works in alkaline fen habitats were carried out in Čužu Mire in Abava valley (since 2006). Trees and shrubs were removed in nearly the entire area, the young shoots that developed after shrub clearing were repeatedly removed, thus restoring the open fen. Between 2005 and 2015, alkaline fens were restored by felling trees and mowing the herbaceous vegetation in Ķemeri National Park (Fig. 2.15), in 2013 – in Slītere National Park. Felling of trees, clearing of shrubs and mowing of young shoots and young trees was also continuously carried out in a calcareous spring fen on the slope of Abava valley near Sabile.

So far in Latvia, mineral-rich springs and spring fens around mineral-rich spring flushes have been rarely sufficiently protected and restored as habitats. The majority of activities targeted at spring protection have been performed in popular spring areas to diminish the visitor pressure by constructing some infrastructure elements (plankways, stairs, platforms, etc.) Similarly, in some spring areas which are popular tourist attractions, waste is being regularly collected. In order to prevent unfavourable hydrological change, beaver dams have been periodically destroyed in a few sites, however the problem is widespread and the activities carried out are insufficient. Restoration of spring habitats and species diversity has been performed very rarely, thus Latvia still has little experience in this field. One of the few examples is the restoration of spring mire vegetation in a small area in Gauja National Park in 2013–2015 (Fig. 2.16).

Chapter 3. Mire and Spring Ecosystem Services

Ecosystem services can be grouped and classified according to various criteria, however, the Common International Classification of Ecosystem Services (Millennium Ecosystem Assessment) (MEA 2003) takes an increasingly important role. This classification provides the division of all the ecosystem services into four main categories: basic services, regulatory and maintenance services, provision services, and cultural services.

Essential ecosystem services are so-called **basic services** – assurance of water, air and substance circulation, soil formation, habitats for species – living, breeding, foraging places, migration pathways. The value of the basic services is difficult or even impossible to measure and convert in terms of money. For example, it is actually impossible to objectively measure how much the species that inhabit the mire cost. A species itself is a value, regardless of how we perceive it, how we use it and whether we think it is valuable or not.

Mires and springs are important not only in order to preserve biodiversity. Their role in nature is diverse. Undisturbed and slightly affected mires have the highest value in terms of ecosystem services. The more affected and degraded the mire is, the more it loses its natural role or even becomes the cause of environmental problems (Bonn et al. 2014). This can best be characterised by the role of mires in the carbon cycle. Intact mires are carbon sinks, thus contributing to diminishing the release of greenhouse gases into the atmosphere, whereas degraded mires, especially those affected by peat extraction, become emission sources.

Mire and spring ecosystems have a great role in the **regulation and maintenance of environmental services**. Mires have a regulatory role in climate and water circulation – intact mires participate in the regulation of climate and water circulation, thus they have an important role both in nature and in the human-made world. For example, floodplains and fens participate in flood regulation by accumulating a substantial part of the "excess" water during spring flood periods, as well as acting as natural pollution filters (Cusell et al. 2014; Bonn et al. 2014). In mires, due to dead plant decomposition and peat accumulation, huge quantities of carbon are accumulated, bound by plants from the atmosphere. On a global scale, approximately one third of the Earth's atmospheric carbon is accumulated in wetlands (Joosten, Clarke 2002) which is equivalent to the entire terrestrial plant biomass on Earth, and contains about twice as much carbon as the Earth's forest ecosystems (Parish et al. 2008).

Therefore, nowadays more and more attention is paid to the impact of mire draining and peat extraction. In degraded, drained mires, dry peat decomposes and loses its carbon and water accumulation capacity. For this reason such mires are considered as important emission sources of carbon dioxide – a greenhouse gas (Bonn et al. 2014) (Fig. 3.1). Intact mires accumulate carbon, whereas drained and otherwise degraded mires – on the contrary – release carbon, in this way increasing the excessive amount of carbon dioxide CO_2 in the atmosphere, encouraging climate change. For example, it has been calculated that in the wetlands of the EU Natura 2000 protected area network, around 9.6 billion tonnes of carbon are accumulated, which is equivalent to 35 billion tonnes of carbon dioxide. Translated into monetary terms, it would be 600–1,130 billion EUR (2010 estimate) (Anon. 2013b). By restoring wetland ecosystems, it is possible to increase the volume of accumulated carbon dioxide, thus "withdrawing" it from the atmosphere and reducing the impact on climate change. It is most important to preserve and restore the natural functions of mires which helps to keep mire ecosystems and the associated biodiversity alive.

Subsurface waters (both groundwaters and artesian waters), including those discharging on the Earth's surface as springs, are of great importance in the biogeochemical cycle. They are related to surface waters and affect their quality. This means that groundwater is associated with many wetland types, thus in order to preserve wetlands and their regulatory role in nature, it is important to ensure a good quality of groundwater (Klöve et al. 2011). Springs have an important role in maintaining the microclimate, especially in forests (Lārmanis u. c. 2000) where the proximity of springs causes constant humidity and coolness; spring water enriches the soil with minerals (lime, iron and sulphurous compounds, etc.), which is important for the existence of many specialist species.

The society can receive **provision services or resources** of ecosystems directly from nature, including in the form of materials and energy (berries, mushrooms, raw materials, food, water, bioenergy, etc.). Mires are an important source of various materials. Intact or slightly influenced mires are the main producers of peat, which, depending on the peat type and characteristics, is a material with a broad range of applications, including the production of materials with high added value (Krūmiņš et al. 2013). Peat is a natural resource that recovers very

Fig. 3.1. Degraded mires, especially abandoned cut-away peatlands, release carbon dioxide causing a greenhouse effect and contributing to climate change. Photo: A. Priede.

Fig. 3.2. Springs are important resources of drinking water and mineral waters. Photo: A. Priede.

slowly, its restoration is only possible in wet conditions favourable for mire development. Therefore, the statement that peat is a renewable resource is only true if mires are preserved and every effort is made to restore the post-harvested peatlands so that they again become functioning ecosystems, as well as to prevent the decrease of mire areas.

Groundwater is one of the most important resources to ensure the existence of mankind, including springs, which are an important drinking water resource (Fig. 3.2). Mires and springs are related to the formation of medicinal mineral waters, especially sulphurous mineral waters, which up to present day have been successfully used in medicine, rehabilitation, the production of medicines and cosmetics. Mud and spring sediments formed in mires and springs (tufa, limonite) have already been used for human needs for a long time.

Raised bogs are picking places of cranberries, bog bilberries and cloudberries (Fig. 3.4–3.6). In Latvia, the picking of berries, especially cranberries, is not only a popular leisure activity, but also a significant economic benefit, and provides additional employment and income opportunities to many people. Drained mires are not suitable for cranberry growth, thus they lose their significance as a berry picking site. State-owned intact and slightly affected mires as berry picking sites are a "gift of nature" for anyone willing to pick berries. However to restore a degraded bog to a condition where it is suitable for cranberries, one has to invest large resources, and it also requires a long time.

In many cut-away peatlands, the establishment of cranberry plantations is one of the potential after-use options. Cranberry plantations give a higher yield than natural mires and it is an important form of land use after peat extraction, but it requires long-term work and relatively large financial investment.

Fens, especially on the lakeshores, are abundant with reeds, less often with *Cladium mariscus* stands, which can be used for thatching (for more about use of *Cladium mariscus – see Chapter 14.1.5.4*) (Fig. 3.3) and other purposes.

Many mire and some spring plants, for example, *Calluna vulgaris*, *Ledum palustre*, *Comarum palustre* (Fig. 3.7), *Menyanthes trifoliata*, *Sphagnum* spp., *Cardamine amara* (Fig. 3.8), can be used in medicine and are traditionally collected for a variety of other purposes. The properties and use of these plants in medicine, cosmetics, the food industry and elsewhere is not yet fully explored. Any species of mire and spring habitats holds irreplaceable genetic information. Genetic diversity provided by the wild populations is important for the sustainability of populations; they can serve people through the significant unexplored potential of food, medicine and other resources.

Calluna vulgaris, which is often found in raised bogs, is an important nectar plant; thus raised bogs are often used as bee pastures. Bee products – honey, pollen, bee bread, wax and others – have long been important for both food and other uses (in medicine, cosmetics, etc.). Bee products harvested in undisturbed nature areas have an added value as eco-products.

Traditionally, fens and transition mires were used for grazing, haymaking and litter gathering (Gustiņa 2015). Nowadays, grass and hay as a resource has largely lost its economic importance, however, this resource can still be used for other purposes as well, e.g. as fuel.

The most important timber resources are concentrated in the forests, but in small amounts they

Fig. 3.3. Reeds can be used for thatching, as insulating material or as fuel. Photo: A. Priede.

Fig. 3.4. Bog cranberry *Oxycoccus palustris* – one of the most important mire resources in Latvia. Photo: A. Priede.

Fig. 3.5. Bilberry *Vaccinium uliginosum*. Photo: A. Priede.

Fig. 3.6. Cloudberry *Rubus chamaemorus*. Photo: A. Priede.

Fig. 3.7. *Comarum palustre* – valuable medicinal plant. Photo: A. Priede.

Fig. 3.8. *Cardamine amara* – wild edible plant, delicious and rich in vitamins. Photo: A. Priede.

are attainable in mires, especially in drained mires where there is typically an increased amount of wood in comparison to intact mires. Nowadays, wood resources of mires can be used as a byproduct (firewood, wood chips) when restoring bogs and fens and removing the tree and shrub cover.

Cultural services are intangible benefits which the society receives from nature. The benefits are the physical, intellectual and mental interaction of a human being with nature (recreation, nature tourism, cultural heritage, education). This ecosystem service category includes the inherent cognitive value of mires and springs – both scientific and educational. Mire development is a process which provides an insight into other natural processes and phenomena such as soil development, vegetation and animal diversity, ecological interactions in nature. Mire research can provide important conclusions about the biogeochemical cycles, including the human impact on the environment. For example, peat accumulates chemical elements and compounds which have come at different times since the beginning of mire development, both from the atmosphere by deposition and precipitation, and the surface (De Vleeschouwer et al. 2010; Silamiķele et al. 2013). Thus, mires and mire-related organisms are important as indicators of environmental change, which shows on a much broader scale, not only locally, changes in the environment, such as pollution and its dynamics over time.

Mires are a kind of nature "archive" that provide a possibility to reconstruct and compare the concentration of chemical elements of different times, including atmospheric pollution by analysing peat layers of different ages, and perhaps detect the sources. By studying peat layers one can reconstruct the timing and impact of various natural disasters, such as volcanic eruptions. Volcanic eruptions can be traced in peat deposits in regions even far from the event site, including also in the Baltic region, since the ashes can be carried thousands of miles away with air mass transfer. In anoxic conditions in deeper mire peat layers, "witnesses" of the past are naturally preserved, allowing the reconstruction of a much longer history than it would be possible using, for example, handwritten sour-

Fig. 3.9. In recent decades, a variety of mire boardwalks have been constructed in Latvia; some of them have become a destination for hundreds and thousands of visitors, confirming the great importance of mires as a recreational place. Photo: A. Priede.

Fig. 3.10. Exploration of a mire can be an exciting experience in different seasons and in different ways – hiking, explorative activities or nature watching. Photo: A. Priede.

ces or human activity traces. In peat layers, pollen from ancient times remains almost unaffected. It helps to reconstruct flora and fauna, characteristic for a particular region in earlier periods. Also, past evidence of a larger size can be found in bogs – perfectly preserved mummified animal and human remains and various material traces of history – human settlements, warfare, economic activity. With mire drainage, these preserved values are usually destroyed, thus already losing them forever before being aware of them.

In Latvia, the traditional use of mire and associated cultural heritage is under-explored, e.g. what the haymaking and grazing tradition was in mires, how the mire resources were used (plants, animals, minerals, water), how people adapted and co-existed with mires. Mires have also preserved evidence about the use of mires in earlier centuries – ancient roads, peat extraction places, peat drying sheds, etc. (Ikauniece (ed.) 2011). This insufficiently studied heritage is not only interesting for research, but also keeps useful and usable knowledge for the future.

Folklore stores many tales, songs and beliefs about mires, and they keep the ancient beliefs about the origin of mires as well as their names and characteristics. Many mires have already been physically destroyed, surviving only in legends and tales.

Mires as peculiar, specific nature landscapes also have high aesthetic value, which is linked to recreation, nature exploration, source of inspiration and mental healing, and in recent decades they are becoming more and more popular, especially among urbanised populations (Fig. 3.9, 3.10). Many springs are significant as brilliant scenic tourism objects that serve both for nature and culture-historical (springs – ancient worship sites) exploration.

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

In the guidelines we have used different terms for the activities that focus on the provision of a favourable conservation status of habitat. In the broadest meaning these activities – both passive and active – should be called **habitat conservation.** Habitat conservation in the widest sense includes various actions – both the establishment of protected nature territories and micro-reserves, various forms of certain prohibitions and restrictions, control, nature conservation measures and planning (the guidelines do not include those aspects), as well as active, targeted restoration, management or re-creation of habitats in places where they have been degraded or destroyed. More and more often the term "conservation" is used as an alternative term for habitat "protection". In these guidelines both terms have been used as synonyms. So protection and conservation cover all targeted activities, approaches and techniques – both active and passive – which are focused on the conservation of nature values (Fig. 4.1).

In these guidelines **habitat restoration** is considered as set of biotechnical measures aimed at restoring the environmental conditions, structure and typical species composition in the place where the habitat has once existed or still exists, but is in a poor conservation status. In mires, restoration for the purpose of these guidelines includes, for example, rewetting, filling up or blocking of ditches and felling of trees, which have established due to artificial draining. Restoration is considered as on-off action (in contrary to management, which means re-current actions).

In Latvia in recent years the approach has dominated that the nature values should be restored in the sites that are still classified as protected habitats of EU importance. But not always should restoration or management be planned only in an area currently recognised as an EU habitat. In this edition the scope has been expanded to also include conditions and sites that do not currently (no longer) meet the minimum criteria of the protected habitat, but with determined action the conditions can be created or improved. For the purpose of these guidelines **habitat creation** is a set of biotechnical measures aimed at the creation of environmental conditions, structure necessary for the habitat and implementation of the species inherent to the conditions in a place where the habitat has never existed or been completely destroyed. Creation of new valuable habitats is not an end in itself, but in some cases it can at least partially compensate mire degradation and hence the consequences of the shrinking of the EU protected habitat area. Creation of mire habitat refers to post-harvested peatlands and other post-mining areas where the spontaneous recovery or creation of mire habitat is possible. According to the terms used in the regulatory enactments of Latvia, habitat creation in mineral and peat extraction sites corresponds with the term "**renaturalisation**". In order to recognise a mire to be created or renewed as a protected habitat, all the minimum quality criteria should be defined for all EU habitats (Auniņš (ed.) 2013; Auniņa 2016a).

Habitat management in recent years has been considered as activities in a very broad sense including both passive and active action, and also a non-interference regime. In this edition the understanding of the management notion has been narrowed. It is a set of biotechnical measures aimed at maintaining the habitat in a favourable conservation status, or **maintenance**. Management for the purpose of these guidelines includes re-current activities such as mowing and haymaking, removal of shoots of cleared shrubs, grazing, and other.

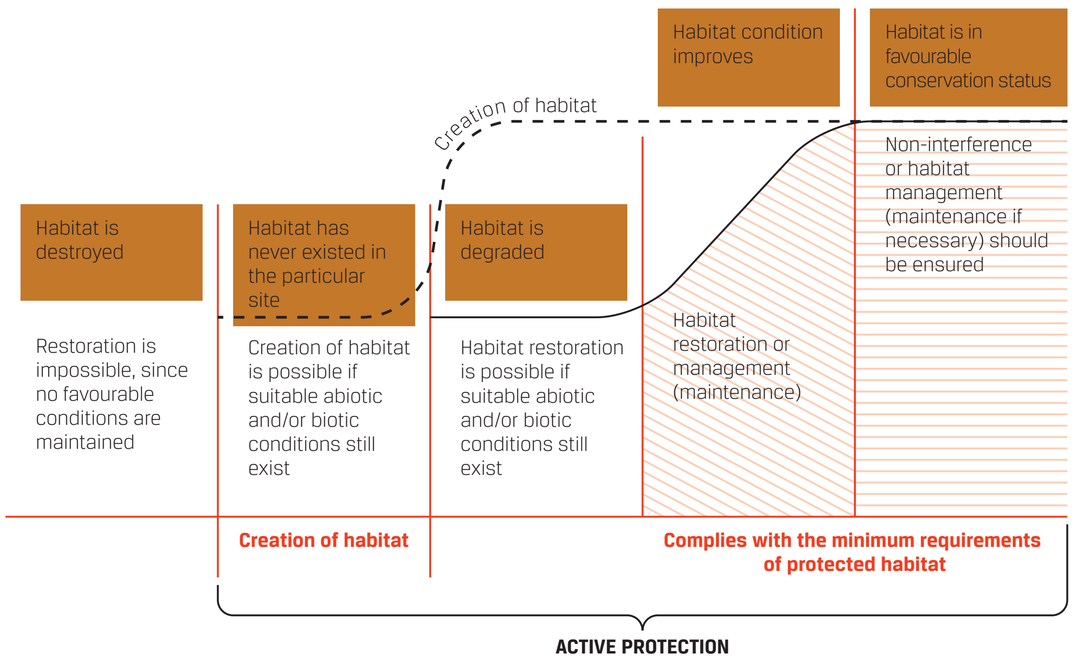

Fig. 4.1. The concepts used for the purpose of these guidelines.

Chapter 5. Common 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 of 21 May 1992, on the conservation of natural habitats and of wild fauna and flora (hereinafter – the Habitats Directive), and Directive 2009/147/EC of the European Parliament and of the Council of 30 November 2009, on the conservation of wild birds (hereinafter – the Birds Directive). Each country has developed national regulatory enactments for the implementation of the "nature 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, protects feeding and resting sites most important for migratory birds, particularly highlighting wetlands of international importance. The Directive includes around 450 species. **The Habitats Directive** is intended to promote the biodiversity by protecting natural habitats, wildlife and plant species within the territory of the EU Member States. The Habitats Directive defines the necessity of protecting rare, endangered and endemic species, in total approximately 1200 species, in the EU. The Directive includes 231 habitat types, out of which 71 are recognised as priority protected at the EU level. In Latvia one can find 58 habitat types referred to in Annex I of the Habitats Directive, out of which 19 are protected as a matter of priority at the EU level[3].

Due to the intensification of agriculture and forestry, change of land-use, urbanisation and other human influences, many of the natural and semi-natural habitat types in the EU, including Latvia, are in an unfavourable conservation status. The latest assessment about the situation of habitats was carried out in 2013, providing an overview of the years 2006-2012. In 2013 in the EU it was estimated that only 16% of habitat types are in favourable conservation status and only 23% of the species included in the Habitats Directive are in favourable conservation status. According to the report (Anon. 2013), in Latvia only 13% of the EU habitat types found in the country and 28% of species are in favourable conservation status.

[3] 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).

The Habitats Directive provides for the implementation of nature conservation in a way so as to maintain or restore the favourable conservation status of natural and semi-natural habitats, animal and plant species[4]. In this edition the proposed guidelines include a set of techniques and methods to facilitate the consummation of favourable conservation status of the EU protected habitats found in Latvia. However, it is only a part of the activities encompassed by nature conservation (*see Chapter 4*).

According to the Habitats Directive, one of the ways of how to preserve the habitats of Annex I and species of Annex II is the designation of protected areas. Together with the areas established in accordance with the Birds Directive, they create the **network of protected areas Natura 2000**. Designation of protected areas is based on the scientific criteria provided for in Annex III of the Habitats Directive. However, upon the planning and implementation of nature conservation measures in accordance with the Habitats Directive, for example, developing site management 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 pro rate the third smallest area of protected nature territories in the country out of 28 EU Member States (in ten EU Member States, Natura 2000 territories occupy >20% of the country).

Natura 2000 sites of Latvia are both small (up to 1 ha) and also may reach more than 90,000 ha, depending on the species requirements or habitat features and conservation objectives. The area of Natura 2000 sites in Latvia varies from 100 to 1,000 ha on average. Many of them are known as popular nature and cultural history heritage sites – national parks, nature parks, protected landscape areas, as well as areas, which are established to preserve the relatively intact ecosystems and nature diversity related to low-intensity management – nature reserves and strict nature reserves.

Article 6 of the Habitats Directive sets out the requirements for the conservation and management of Natura 2000 areas. Article 6 provides that the protection regime corresponding with the habitat and species conservation requirements should be set and appropriate measures should be applied. It also includes actions preventing degradation and an adverse effect on species and preventing their deterioration, if a particular species or habitat conservation cannot be ensured with the provision of non-interference and the precautionary principle. These guidelines are a part of the measures set out in Article 6 and offer recommendations for habitat restoration, maintenance and recreation in sites where they have been destroyed, taking into account the condition of the EU habitats in Latvia and evaluating the real conservation opportunities.

[4] A favourable conservation status has been defined in Article 1 of the Habitats Directive which has been taken over in Latvia by incorporating it into the Law on the Conservation of Species and Biotopes (favourable conservation status is defined in Article 7 of the Law).

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

One of the objectives defined in the EU Biodiversity Strategy 2020 requires that by 2020 the Member States should restore at least 15% of the degraded ecosystems in their territories (European Commission 2011). The restoration result is not only the total area of the restored habitats, but also the improvement of biotic and abiotic environmental conditions. Taking into account the degree of ecosystem modification in Europe today, it is not possible to eliminate all the adverse effects and completely "fix" its consequences. It would be too expensive and technically difficult, sometimes even impossible. "Restored" is a condition when a considerable improvement has been reached, at least the main functions, processes, structures, species populations and suitable conditions for them have recovered or recovery has at least been initiated. The reference point is the year 2006 – the year in which 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).

Any habitat restoration in a specific area at the same time causes a favourable local effect (will restore the specific habitat area). At the same time, each restored area is a mosaic piece that helps to maintain favourable habitat conservation status at the national and EU scale. It is possible to gain an insight into the overall situation (desirable or real) by assessing and planning the action at a national level. Ideally, in the overall picture the priority areas should be selected by taking into account the principles of landscape ecological planning. But even if we act at a local level and do not take in the overall picture, any restored or properly managed habitat area will improve the overall situation slightly.

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 provides for the action on how to preserve species and habitats, taking into account the threats and problems related to their conservation. This guideline book provides instructions on restoring and managing the habitats and related species by performing (or in some cases – on the contrary – using non-interference regime) certain activities.

5.3 Objectives of Mire and Spring Conservation, Restoration and Management in Latvia

According to the Law on the Conservation of Species and Biotopes, **the objective** of habitat conservation is to provide a set of such factors that favourably affect the habitat and its characteristic species and promote preservation of the natural distribution, structure and functions of the habitat, as well as the survival of the characteristic species in the long term. The conservation status of a natural or semi-natural habitat will be taken as favourable when its natural range and cover within that range are stable or increasing, and the specific structure and functions which are necessary for its long-term persistence exist and are likely to continue to exist for the foreseeable future, and the conservation status of its typical species is favourable.

In the protection, restoration and management of mire and spring habitats the ecosystem approach is important – by providing the functioning of the entire ecosystem, separate EU habitat types will also exist. Favourable conservation status of mire and spring habitats means to preserve and restore the specific abiotic conditions which, in turn, supports the ecosystem functions (peat accumulation, carbon sequestration, water accumulation, and filter functions, circulation of substances and energy, climate, including microclimate, regulation) and their sustainable existence, which is the most important precondition for the existence of the habitat-related species.

This means to preserve, restore or create abiotic environmental conditions typical for the ecosystem – hydrological regime, soil, ecological disturbances, if any are required for the existence of habitat and related species, thus – also to preserve, restore or create suitable conditions for the characteristic species, including target species. In unsuitable conditions the existence of these species or return is not possible. Thus, the restoration of mire and spring habitats should always be carried out in a coordinated way – if the action is directed towards the conservation of a species or group of species, then suitable conditions should be provided first. In semi-natural habitats re-current action is required to maintain these conditions.

For the provision of favourable conservation status for the EU protected mire and spring habitats in Latvia the following **tasks** have been set, which can be evaluated using specific features.

(1) To stop the decline of mire and spring habitat areas.

Indications:

- the total area of the habitat in the country does not decrease (reference point: the total habitat area in Latvia and Natura 2000 sites in 2006),
- the number of habitat locations in the country does not decrease. With the area shrinking or complete degradation of the location the conservation potential of the habitat and characteristic species reduces throughout the region, including decreases its distribution range.

(2) To ensure that the abiotic conditions do not worsen, and to improve the habitat quality where it is necessary and possible.

Indications:

- optimum hydrological conditions for the long-term existence of the habitat,
- the ecosystem functions (peat and water accumulation, carbon sequestration, filter functions, climate regulation),
- specific structure of the habitat (relief, micro-relief, presence of characteristic species, their cover, etc.),
- contact area with natural or semi-natural habitats significant for biodiversity conservation (potential impacts from the adjacent areas).

(3) To ensure appropriate conservation of the particular habitat and related species.

Indications:

- umbrella species and habitat characteristic species are present in the particular habitat type throughout the country,
- rare, endangered, vulnerable (protected) species are present; in suitable conditions they can be found throughout the country,
- there are no species indicating degradation (expansive and invasive non-native species or their proportion is negligible).

5.4 Setting Conservation and Management Objectives in a Specific Area

When setting restoration or management objectives in a specific area it is important to thoroughly investigate it before planning and implementing any actions. The causes and factors influencing habitat degradation or recovery must be understood.

In order to set realistic objectives, there are two options.

(1) **Reconstruction of the "perfect" situation**. It means restoring the historical habitat area so that it can be considered as a habitat in favourable conservation status, thus also restoring the ecosystem functions. Such an objective can be set if reliable detailed information is available on the exact habitat area, the conditions and composition of species in the past. However this is only possible if there are no irreversibly or severely degraded conditions that make restoration of the habitat and its functions impossible.

In mires, restoration of the "perfect" situation is possible if the hydrological and other changes (conversion into agricultural areas, peat extraction) have not affected the mire to the extent where the characteristic species have disappeared or if the mire has not entirely transformed into a forest. Restoration of the "perfect" situation is possible by implementing rewetting and biotechnical measures, such as felling of trees, clearing of shrubs, mowing, grazing, in some cases also reducing the nutrient amount in the topsoil or upper layer of peat (removal of topsoil or peat surface).

Restoration of the "perfect" situation is only possible if the mire is perceived as a complex system, including restoration of a larger territory confined not only by the edge of the mire, but also including the adjacent forests, grasslands, water courses, and water bodies if they are hydrologically related to the target area.

(2) **Restoration compromise**. Realising that for some reasons restoration of the "perfect" situation is not possible, restoration of a part of the former mire area and its species complex, though incomplete, and partial prevention of the drainage impact is sometimes possible. For example, it is not possible to fully restore "intact conditions" in post-harvested peatlands or in heavily drained mires converted into agricultural areas, afforested peatlands or peatlands spontaneously overgrown with forest. A significant obstacle in restoring the species complex characteristic for the habitat can be fragmentation and local extinction of the habitat-related species, and disruption of the biogeochemical cycle. There are also cases when the ecosystem is irreversibly degraded and restoration is no longer possible or the funds to be invested are not adequate for the predicted result.

Mostly only partial restoration of the habitat is possible, i.e. it is not possible to restore all the features of the original ecosystem. Thus, it is better to focus on specific targets that should be precisely defined. Sometimes the priority objectives should be established between several possibly conflicting objectives (for example, restoration of the particular vegetation type, different groups of organisms or certain species, conservation of geological monuments, and cultural heritage). When the targets are defined, appropriate methods should be chosen to implement them (*see Chapter 7*) and the results should be assessed (*see Chapter 9*).

Chapter 6. Preparing for the Restoration and Management of Mire and Spring Habitats

6.1 Prerequisites of Successful Habitat Restoration and Management

It is not easy to plan ecosystem restoration or – in a narrower sense – habitat restoration. Each site is different with specific geographical conditions that are difficult to generalise. In many areas the socio-economic conditions are influencing both habitat conservation status and its conservation and restoration options, therefore this cannot be ignored.

Prior to starting to restore a habitat, the most important thing is to define the objective – *what* do we want to achieve? It requires knowledge about the desirable condition of the habitat, ecological requirements of the target species. In addition, the target status should cover both the area and quality of the habitat. In order to determine the status, in each individual case it is necessary to understand the potential outcome, 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 its surroundings, and the impacts that are long lasting and sometimes cannot be averted by implementing the restoration actions. Sometimes only slight improvement of the conservation status is possible – a sort of compromise that is better than doing nothing.

Upon setting the objective to be achieved, various mistakes are sometimes made as the current situation, causes of degradation and background conditions are not adequately assessed. For example, in Europe, which has been largely modified by human activities causing land use changes and affected by pollution and climate change, even in the Natura 2000 areas we cannot expect the recovery of intact "wild nature". Nevertheless, it is surely worth trying to restore a functioning and self-regulating ecosystem instead of a degraded ecosystem, even though it only vaguely resembles what we perceive a wild nature condition to be (Hilderbrand et al. 2005; Thorpe, Stanley 2011).

If the objective is clear, the next step is to figure out *how* to achieve it – the actions that should be carried out to implement our idea. This requires detailed exploration of the situation, surveying the site conditions, clarifying and choosing the potential habitat restoration and management techniques and assessing how suitable they are for the particular situation, moreover, taking into account the available resources. At an early stage we already need to be able to assess the extent to which the objective is achievable, and anticipate the obstacles. This will help to decide whether the investment complies with the expected outcome. If not, then, most likely, it is better to invest the energy and resources where it is more worthwhile.

The biggest disappointment usually happens when one assumes that it is enough to restore the abiotic conditions for the set of characteristic species to propagate soon. It can work in slightly altered habitats, but the success can be poor when trying to restore habitats in heavily fragmented landscapes. Due to the lack of the target species the species are sometimes introduced artificially. Although the (re)introduction of the target species nowadays is quite a widely used technique, it can be unsuccessful even when seemingly suitable conditions have been restored or created (Hilderbrand et al. 2005). Most often it happens because of the lack of a vital component, for example, the ecological requirements of the species are not completely understood, e.g. symbiotic relationship or other factors that do not allow species to adapt to the new site, even in their historical localities where they have since become extinct.

Also, it is not easy to control the spread of un-

Table 6.1. The basic information required for planning.

The geographical conditions, impacts on the area in the past and the present
The character of the area (terrain, geological and hydrological conditions, soil, etc.). The role of the particular area as a part of a broader habitat complex. The former coverage of the habitat type (cartographic and other materials of different times). Management in the past, whether it has been suitable for the conservation of the habitat or, on the contrary, unsuitable (mostly unpublished data, sometimes the information is stored in the memories of local residents). The past impacts in the particular area and hydrologically related surroundings (drainage, land use and its changes). The current impacts and threats to the habitat.
Species and habitats
Typical common species, rare species. Changes in habitat and species distribution and factors affecting it, causes of the changes. Threats to the species. Mapping of the area to be restored/managed and, depending on the extent of the potential impact, also mapping of the nearby habitats and species may be necessary.

desirable species, e.g. invasive non-natives that due to global change are spreading rapidly, taking the ecological niches of native species and creating significant, sometimes even irreversible changes in ecosystems and their functions. These species usually benefit from changes of the environment. In natural ecosystems, the conditions are mostly unsuitable for them, and they are not able to survive or at least do not form stable populations, while human-caused environmental changes, e.g. eutrophication, landscape fragmentation, artificially created migration paths, create conditions favourable to them. The spread of invasive non-native species and their control is a difficult task, which always requires permanent and patient work that may also be unsuccessful if nothing is done at a national or regional level.

Assuming that we have acted in an appropriate way when restoring the ecosystem in some area, and the result is successful, we cannot be sure that this is the perfect recipe that works in all similar cases (Hilderbrand et al. 2005). Even if the chosen technique fits well, 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 attest to whether we have reached the goal and even if not, whether the result can be considered as successful.

In ecosystem restoration one should take into account the contemporary impacts on the environment – climate change, pollution, changes in land use which, in turn, are related to changes in human lifestyle. For example, the European mires in the second half of the 20th century have been affected not only by drainage, but also by climate change and air pollution-caused eutrophication, which is likely to promote the tree encroachment in mires and decrease the proportion of open areas. Latvia is still considered a relatively little affected country, but this assumption can be misleading. One should take into account this background in restoration when setting the goals.

In the restoration of an ecosystem or, in a narrower sense, – habitats – one should always take into account the potential restrictions: environmental (climate, soils, geological and hydrological conditions, landscape fragmentation and its impact on species populations), economic (financial constraints), social (public, often also the funders' opinions). They should already be taken into consideration in the planning stage – possibly more money investments, more time and less success can be expected. However it does not mean giving up all the plans and accepting that it is not worth doing anything. Even if in many cases the degraded ecosystems are not able to recover to the original "perfect" condition, it is usually possible to improve their conservation status. Proper planning and assessment of risks urge one to act smarter than without realising these obstacles, thus risking making more mistakes.

In these recommendations the guiding principle is the assumption that it is always better to preserve intact natural ecosystems (in the narrower sense – habitats) through, wherever possible, timely elimination of the negative impacts, than to damage them and then try to "fix" them. Restoration of degraded ecosystems is always associated with a risk of failure and high costs, as well as many nature values may be irretrievably damaged, losing rare species, specific conditions, beautiful sceneries and resources necessary for the survival of not only nature, but also humans. Countless examples from around the world confirm that the economic benefits that have not been obtained while saving the natural ecosystems, are less than the investments required afterwards to restore them. Moreover, the costs increase according to the increase in level of degradation. Thus, the proper protection of natural ecosystems is always most important, and restoration is to only be used as a tool to "fix" already degraded ecosystems.
A different approach should be used for the restoration of semi-natural habitats (traditionally managed habitats, for example, formerly mown and grazed fens). In these habitats the complex of characteristic species has been established during long-term interaction with moderate human impact, therefore for their maintenance it is necessary to continue or re-establish moderate interaction between humans and nature.

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

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

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

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

[9] Cabinet Regulation No. 153 of 21 February 2006, On the List of Priority Species and Habitats of the European Union Encountered in Latvia (priority habitats and species marked with an asterisk *).

[10] With the amendments as of 11 January 2014.

6.2 Planning of Habitat Restoration and Management in a Specific Area

When starting to plan restoration or re-establish regular management in a specific area, one should try to answer the following questions (Pakalne 2013):

- what are the expected limitations (legal, administrative, technical, etc.)?
- what is the estimated result of habitat restoration or management?
- what may the side-effects in the restoration process be (preferable, undesirable)?
- how soon can the objectives be achieved?
- what can the impact outside the area to be restored be?
- what are the costs (including planning, inventories, etc. costs)?

Although in the planning stage it is rarely possible to answer these questions, careful feasibility studies can play a vital role in the implementation of the plan. The main aspects to be considered are summarised in Table 6.1.

In the planning stage all the available information should be used though it is quite often scant without specific feasibility studies. Possible data sources include the following:

- monitoring data;
- cartographic material of different times, orthophoto images;
- all available published and unpublished sources;
- memories of the local residents and experts (the site history);
- photos taken at different times;
- all other available information.

If no useful information can be found, or it is incomplete or outdated, additional exploration is required – inventories of the area, mapping of habitat and species (in large areas remote sensing can be effective), detailed topography exploration, etc. Restoration of mire habitats and its planning require comprehensive knowledge, so usually both experts of species and habitat conservation and other professionals (hydrologist, geologist, etc.) should be involved, preferably professionals with prior experience in mire restoration.

6.3. Legal Framework

(Ē. Kļaviņa)

6.3.1 Protected Habitats and Species

The Cabinet, based on **the Law on the Conservation of Species and Biotopes**[5] has approved the Regulations, which define the types of protected habitats[6] and species[7]. The list of protected habitats in Latvia is not identical to the list in Annex I of the Habitats Directive[8]; the so-called EU protected habitats (*see Chapter 1*). The list of nationally protected habitats does not include raised bogs, however, it includes the *Myrica gale* community and fens with *Juncus subnodulosus* that are not in the list of Annex I of the Habitats Directive.

The Cabinet Regulation includes the list of EU priority habitats[9]. The following protected mire habitats are marked as a priority: 7110* *Active raised bogs*; 7210* *Calcareous fens with* Cladium mariscus and species of the Caricion davallianae, and 7220* *Petrifying springs with tufa formation.*

6.3.2 Protected Nature Territories and Micro-reserves

Law "On Specially Protected Nature Territories" defines the basic principles of the nationally pro-

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

- **Nature Conservation Agency:** permitted and prohibited activities in protected nature areas 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 areas and locally protected cultural heritage objects: contacts on websites of local municipalities.

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 areas. **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. 6.1. Activities upon planning of habitat management.

tected system of nature territories. To preserve the nature diversity of Latvia, strict nature reserves, nature reserves, national parks, nature parks and other types of protected nature territories have been created. These territories can be divided into functional zones with different protection and management regimes. Micro-reserves[11] are small areas (0.1–30 ha) created for the protection of habitats or animal, plant, fungus, lichen, and algae species. The procedures for designation and managements of micro-reserves are defined by Cabinet Regulation[12]. The boundaries of protected nature territories and micro-reserves, and functional zones of protected territories are laid down in the regulatory enactments and depicted in the public information system – the State Management System of Nature Data "Ozols" (http://ozols.daba.gov.lv/).

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

Conservation and management of protected nature territories are regulated by the **General regulation on the protection and use of protected nature territories**[13] or **the individual regulations for their protection and use**. In order to harmonise the interests of nature conservation, use of nature resources and development interests of the region within the protected territory, **a site management plan**[14] can be developed. The site management plan recommends the actions required for the protection and management of the nature values in the area.

National parks and strict nature reserves have special laws and related individual regulations for their protection and use and have higher priority in the legal framework.

6.3.3 Coordination of Activities

Prior to restoration and management the activities targeted at protected habitats and species **in protected nature territories and micro-reserves must be coordinated with the responsible public authorities** (Fig. 6.1). Before starting the activities all the necessary information should be gathered and in the case of any uncertainties, the responsible authorities should be consulted. According to the General regulations for the protection and use of specially protected nature territories, a written permit of the responsible institution, the Nature Conservation Agency, is required when performing, for example, rewetting for the areas adjacent to water courses and water bodies, construction of hydro-technical buildings and establishment of drainage system, its reconstruction or renovation, restoration of protected habitats and species habitats (prescribed burning of heaths, reeds, forest ground cover and litter, deforestation, change of land category, establishment of public nature tourism infrastructure (e.g. trails, viewing towers, car parks).

For the purpose of the **Construction Law**[15] a building is a physical object which has resulted from human activities and is linked to the ground (land surface). Thus, the majority of infrastructure objects planned with the aim to redirect the flow of tourists and to diminish the pressure on habitat, are enforceable under Cabinet Regulation[16], which describes the construction process, required documentation, and other construction-related measures. Drainage system (engineering structure) of one owner should be classified as a group I object with a simpler construction procedure. When planning the construction of small-scale infrastructure or cleaning of an overgrown ditch, the local building authority in the local municipality, which according to the legal framework defines tasks to be carried out before the implementation of these activities, should be notfied of the planned activities.

In order to carry out extensive and voluminous works in habitat restoration, for example, filling up of drainage ditches and constructing of dams, a construction permit is required. In the building

[11] Law on the Conservation of Species and Biotopes (with the amendments as of 1 January 2016.

[12] 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 Zone.

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

[14] The site management plan, content and procedures for drafting are provided for in Cabinet Regulation No. 686 of 9 October 2007, On the Content of and Procedure Regarding the Elaboration of the Nature Protection Plan for Specially Protected Nature Territory.

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

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

authority, when submitting the construction conception, the applicant will be informed from which institutions additional technical regulations or special regulations should be received (public and municipal institutions shall issue them within 20 days), the initial impact assessment should be carried out (State Environmental Service), afterwards, probably, also the environmental impact assessment procedure (*see Chapter 6.3.5*), the building design should be developed and other necessary activities performed.

Forestry activities in the forest of protected nature territories can be scheduled from 1 August until 15 March, in order not to disturb the wild animals during the period of mating and breeding. Other limitations on terms and activities should also be taken into account as defined by the individual regulations for the protection and use of a protected nature territory.

Outside the forest, a written permit is not required for grass mowing, clearing of shrubs and felling of trees with a stump diameter less than 20 cm, except where the restrictions are defined in the individual regulations for the protection and use of protected nature territories.

In order to keep to the schedule so that works can be carried out in the appropriate season, requests for permits (if required) must be submitted on time. If habitat restoration is planned in a protected nature territory or micro-reserve, the Nature Conservation Agency should be contacted prior to this.

6.3.4 Categories and Types of Land Use

Any area of land contains a specific category of land use and purpose of use. According to the classification of land use types[17], the category of land use is a set of land use types of similar features. There are eight categories of land use, among them: agricultural land (arable lands, meadows, pastures); water land (land under water – rivers, springs, water drains); forest; shrubs; mires; other land (glades, flooded plains, forest clearings, etc.). The changes in the area of land use categories are depicted in the National Real Estate Cadastre. The State Land Service maintains the Real Estate Cadastre Information System for which the local municipalities and the State Forest Service shall provide up-to-date information.

For the purpose of the **Law on Forests**[18], forest land is land covered by forest, land under forest infrastructure facilities, as well as adjacent paludified forest clearings, marshes and glades. According to Cabinet Regulation[19], the State Forest Service is the administrator of the State Forest Register and keeps up-to-date information on forest lands, inventory data, change or exclusion of land categories. The information shall be excluded from the State Forest Register if the area is deforested on the basis of the administrative deed of the competent institution allowing the land owner or legal possessor to restore a protected habitat or a habitat of a protected species in the forest, thus changing the type of land use. **Types of forest lands** in forest management and conformity with the **type of land use** included in the regulation clarify the ascription of the types of land use if it is planned to restore or manage habitats or habitats of species. The types of land use are depicted (explicated) in certain document determining legal boundaries of land or respective forest inventory documents.

In order to change the category of land use in a protected nature territory, a written permit shall be received from the National Conservation Agency. After coordinating with the National Conservation Agency, the category of land use can be changed in order to restore the protected habitats and protected species habitats, for example, restoring an open fen in a place overgrown with forest.

6.3.5 Environmental Impact Assessment

Preparation required for the restoration and management of habitats and species habitats includes not only careful planning, but also the initial impact assessment carried out according to the regulatory enactments. In many cases, prior to habitat restoration one should carry out expertise, coordinate activities, elaborate building design, and receive permits. It is necessary to access whether the proposed activity will result in any adverse changes that may significantly affect human health and safety, landscape, cultural and natural heritage, as well as

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

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

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

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

other habitats or species. The Law **"On Environmental Impact Assessment"**[20] is applicable to the activities that meet specific criteria, according to which the impact of the intended activity[21] on the environment can be assessed, especially if it is realised in protected nature territories, micro-reserves, wetlands of international importance, the Baltic Sea and Gulf of Riga coastal protection zone, surface water body protection zones, and can affect protected species, their habitats and protected habitats.

The Law provides for an assessment of the intended activity; **initial impact assessment** is required for activities that may significantly affect the Natura 2000 area. The initial impact assessment is performed by the State Environmental Service. Activities that require an initial impact assessment are defined by the Law[22].

An initial impact assessment is required for a change of category of use of agricultural land (> 50 ha); construction of new drainage and irrigation systems (if land area > 100 ha); reconstruction of the existing drainage or irrigation systems (if land area > 500 ha); afforestation and deforestation (if land area > 50 ha). When planning the habitat restoration activities in forest or mires, which are related to the change of the hydrological regime and the implementation of which may result in major changes, an initial impact assessment should be performed.

If it is stated in the initial impact assessment that the activity may significantly affect a protected nature territory of European importance (Natura 2000), then the assessment of the impact on the Natura 2000 site is performed in accordance with the procedure provided for by Cabinet Regulation[23].

If in accordance with the initial impact assessment, habitat restoration requires the procedure of environmental impact assessment (for example, restoration of mire habitat related to a substantial change of hydrological regime and possible impact on the adjacent areas), the State Environmental Service sends the prepared statement to the responsible authority to give an opinion on the relevance or irrelevance of the environmental impact assessment. One should recognise that the decision will take at least 130 days, which will be spent on the preparation of the programme, and statement of the environmental impact (additional time should be considered for the preparation of the report on the environmental impact assessment).

If, in accordance with the results of the initial impact assessment the intended activity does not require an environmental impact assessment, the State Environmental Service issues the technical regulations for each specific intended activity in conformity with Cabinet Regulation[24].

6.3.6 Rewetting

In order to modify the hydrological regime, the procedures are applied as defined in the Cabinet Regulation of the Amelioration Cadastre[25]. It determines that the drainage system, regardless of its ownership and status, shall be registered in the Amelioration Cadastre, and the State Limited Liability Company (SLLC), "Immovable Properties of the Ministry of Agriculture" is the administrator of the cadastre system. If disruption of the amelioration system or part of it is planned, the cadastral data should be updated. The land owner or legal possessor must submit the application to the regional board of SLLC "Immovable Properties of the Ministry of Agriculture", adding the inventory case of the amelioration system and the statement of the technical examination prepared in accordance with the regulatory enactments on the construction of amelioration systems and hydro-technical buildings.

If it is proposed to disrupt the operation of the drainage system or its part in protected nature territories in order to ensure the favourable conservation status of protected species, protected habitats or EU priority habitats, then the planned activity should be additionally coordinated with the Nature Conservation Agency.

6.3.7 Restoration and Management of Mire Habitats in Forest

To a large extent the legal framework regulating the activities in forest can also be referred to mires where habitat restoration may require the felling of

[21] Intended activity – implementation of a project, construction, extraction or use of natural resources, influencing of areas and landscapes not affected or little transformed by human activities, as well as other activities, the performance or result of which may significantly affect the environment.

[22] Law on Environmental Impact Assessment, with the amendments as of 1 January 2017, Annex 2.

[23] Cabinet Regulation No. 300 of 19 April 2011, On the Assessment of Impact in a Specially Protected Nature Territory (Natura 2000).

[24] Cabinet Regulation No. 30 of 27 January 2015, Procedures by which the State Environmental Service Shall Issue Technical Regulations for the Intended Activity.

[25] Cabinet Regulation No. 623 of 13 July 2010, Regulation Regarding the Land Amelioration Cadastre.

trees. The main information source for mire areas is the State Forest Register and the registered type of land use. If the area of interest is registered as a forest, then one should act according to the regulatory enactments relating to forest. If the area is classified as mire, the felling of trees is defined by the regulations on the felling of trees outside forest (also forest lands) (*see Chapter 6.4.8, 6.4.9*).

When restoring protected habitats and protected species habitats in forest, the activities can only take place after land registration in the Land Register. The Law on Forests defines that for all state-owned forests and other forest properties, the area of which is larger than 10,000 ha, forest management plans must be elaborated. Such plans should also be elaborated in the national parks (with the exception of Rāzna National Park) for the management of the existing forests, regardless of the land area (excluding the neutral zones of protection). Prior to the forestry activities in forest one should receive a permit for the felling of trees from the State Forest Service.

Nature Protection Requirements in Forest Management[26] define the general nature conservation requirements in forest management, limitations in protection zones around mires, provisions for the definition and conservation of biologically important forest structure elements and limits operating activities during the animal breeding season from 1 April to 30 June. In the restricted economic activity zone of the Baltic Sea and the Gulf of Riga the restrictions are in force from 1 April to 30 September. The regulation also defines the need to protect a variety of elements important for forest biological diversity (forest stands in mire islets, geological objects, springs, and other).

In protected nature territories and micro-reserves these regulations are applied if they are not in contradiction with the regulatory enactments regulating the conservation and use of protected nature territories and micro-reserves. Prohibition of complete deforestation in mire protection zones and mineral islands in mires and prohibition of selective felling is referred to in the regulations in protection zones along mires and in buffer zones of micro-reserves.

6.3.8 Deforestation for the Restoration of Mire Habitats and Mire Species Habitats

Protected habitats and protected species habitats in forests can be restored in accordance with the criteria defined in Cabinet Regulation[27]. The planned activity cannot contradict with the spatial plan of the local municipality.

If restoration of a mire habitat or mire species habitat requires the removal of trees, deforestation can be performed upon the receipt of a permit issued by the competent authority (Nature Conservation Agency). The Nature Conservation Agency issues the permit based on the opinion of the certified species and habitat expert. To carry out deforestation for the restoration of a protected habitat or species habitat, one should have a valid forest inventory of the respective area in accordance with the regulatory enactments on forest inventory and flow of information of the State Forest Register. When restoring the habitats in forest the applicant of the activity should clearly divide the planned activity types (felling of trees, pulling out of stumps, filling up of ditches, digging of soil or other types).

The Regulation provides that deforestation must meet at least one of the four criteria. One of them – in the area there should be species or characteristics of any of the protected habitats. This means that currently the area may not meet the criteria of the protected habitat, however, its characteristic features (for example, peat layer which is sufficient for the restoration of a mire's characteristic moisture conditions; at least some of the species typical for mire or spring habitats can be found) allow one to assume that the protected habitat can be restored.

The following types of protected mire habitats can be restored in forest by deforestation:

- petrifying springs with tufa formation,
- alkaline fens,
- alkaline fens with *Cladium mariscus*,
- transition mires and quaking bogs.

However, according to this Regulation it is not possible to carry out deforestation in order to restore the raised bog and mineral-rich spring habitats (including spring fens). In such cases deforestation can be carried out for the restoration of some protected species or species habitat typical for the habitats listed in the Cabinet Regulation[28].

[26] Cabinet Regulation No. 936 of 18 December 2012, On Nature Protection Requirements in Forest Management.

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

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

[29] Cabinet Regulation No. 309 of 2 May 2012, On Felling of Trees Outside Forest.

6.3.9 Tree Felling Outside Forest

If the restoration of mire habitat is planned by felling trees in lands that are not a forest according to the Law on Forests (for the purpose of the Law on Forests, all mires are forest lands, however, their land use type is not a forest), then it is carried out in accordance with the Cabinet Regulation on the felling of trees outside forest[29]. The appropriate land use type must be registered in the National Real Estate Cadastre Information System. In such cases the permit of a local municipality is required for the felling of trees outside forest.

6.3.10 Habitat Restoration and Management in Micro-reserves

Creation of micro-reserves, restoration and management of micro-reserves are regulated by Cabinet Regulation[30], according to which the State Forest Service approves micro-reserves in forest lands (including mires) outside the nature reserves and national parks, where the establishment of micro-reserves is approved by the Nature Conservation Agency. The boundaries of micro-reserves are defined in the decisions on the establishment of micro-reserves as well as in the public information system – the State Management System of Nature Data "Ozols" (http://ozols.daba.gov.lv/).

Micro-reserves are managed in compliance with the procedures provided for in the regulatory enactments in order to ensure favourable conservation status for the species or habitats for which the micro-reserves have been established. Micro-reserves are managed in compliance with the opinion of the certified species and habitat expert. In the expert statement, the necessary protection or management measures are listed, such as removal of reeds, prescribed burning, felling or mowing and removal of trees, shrubs and dwarf shrubs, rewetting, as well as other activities that the expert has specified in the statement. In micro-reserves, the expert opinion is not necessary for the removal of grass.

6.3.11 After-use of Post-harvested Peatlands

The procedure for the after-use (recultivation[31]) of post-harvested peatlands is provided for by Cabinet Regulation[32], in which the major after-use options of peat extraction sites are listed: renaturalisation (restoration of mire-specific environment), preparation of areas for agriculture (for example, berry or willow plantations), preparation of areas for forestry, creation of water bodies, recreation, and other. The regulation does not provide methodical guidance for after-use. The after-use plan provided for in the licence for mineral resources extraction can be modified and approved by the building authority of the local municipality.

6.3.12 (Re)introduction of Native Species

Most probably, the reintroduction of native species is not and in the near future can hardly be widely applied in the restoration of biodiversity in Latvia. However it could be implemented along with some other activities, for example, when renaturalising post-harvested peatlands (*see Chapter 6.4.11*). Reintroduction of species characteristic for bogs may speed up the recovery of the ecosystem.

The concept of "reintroduction of species" is defined by the Law on the Conservation of Species and Biotopes where it has been interpreted as "re-population of extinct species". However the Law does not specify whether the term includes only protected species or any wild species. The Law defines the cases in which the obtaining of protected species is allowed. This activity requires the decision from the Nature Conservation Agency. The procedure for issuing a reintroduction permit is determined by Cabinet Regulation[33]. In order to obtain the permit a detailed argument is required, as well as public discussions.

6.3.13 Eradication of Invasive Species

In order to maintain and restore habitats in a favourable conservation status, invasive non-native plant species should be eradicated. In order to comply with the necessary safety precautions and avoid potential risks, **the Plant Protection Law**[34] and the related Cabinet Regulations[35,36] must be followed.

[30] 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.

[31] The term "recultivation" is used in Cabinet Regulation No. 570 of 21 August 2012, On the Procedure Regarding the Extraction of Mineral Resources.

[32] Cabinet Regulation No. 570 of 21 August 2012, On the Procedure Regarding Extraction of Mineral Resources.

[33] Cabinet Regulation No. 1165 of 21 December 2010, Procedures for Issuing Permits for Acquiring Individuals of Non-Game Species, for Introducing Wild Species Uncharacteristic to the Nature of Latvia (Introduction), and Restoring Populations of Species in the Nature (Reintroduction).

The Law provides that in Latvia it is prohibited to cultivate plant species included on the list of invasive plants. The land owner or possessor is obliged to eradicate the invasive plant species, if they occur on their land.

Cabinet Regulation[37] mentions *Heracleum sosnowskyi* as the only "official" invasive plant species. The control of other invasive plant species is not covered by any legal framework. On the other hand, their control is also not restricted by any regulatory enactment. The methods for control of *Heracleum sosnowskyi* are defined in Regulation[38].

Cabinet Regulation provides for the requirements for the use and storage of herbicides[39], liabilities and rights of professional users and operators of herbicides, procedures for the issuing of permits for the spraying of herbicides and other measures to control invasive species. In addition other normative enactments should be taken into account that may restrict the use of the products, especially in protected nature territories (for example, in some protected nature territories individual regulations on protection and use are in force) or protection zones (Protection Zone Law).

6.3.14 Prescribed Burning

Prescribed burning is hardly ever a suitable method for the restoration of mire habitat, but in exceptional cases it can be applied. Prescribed burning can be performed for the restoration of protected habitats or species habitats in protected nature territories, micro-reserves and outside the afore-mentioned areas in conformity with the provisions set out in Cabinet Regulation[40]. If in the proposed restoration area, the inventories or monitoring data prove that the features of a protected habitat or a protected species has gone extinct due to deforestation or change of other environmental conditions, prescribed burning can be performed (if appropriate). In order to control the burning of litter, reed beds, heaths, and forest, a written permit of the Nature Conservation Agency is required. Outside the protected nature territories and micro-reserves the permit is issued by the State Forest Service (if deforestation is not planned). Prior to burning the authority responsible for fire safety should be informed in writing.

6.4 Cost Estimation

(J. Jātnieks)

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 work or a set of actions required for the improvement of habitat condition. The difference in costs can be great for similar works – depending on the location, complexity of works, executors, availability of special equipment, and other factors. These guidelines are to be used over a longer period of time, thus we do not offer exact costs for all types of works – only the indicative costs are given (see Annex). Thus, we recommend assessing the costs for each individual action or for a set of activities at a particular place and time.

The following principles should be used by the developers of nature conservation plans, LIFE and other large projects to estimate the costs of habitat management and restoration activities.

In small areas (up to 1 ha), as well as in cases where management is regular or certain parameters are well known (for example, annual mowing, grazing, excavating or filling up of ditches of certain size), costs can generally be equated to the works performed elsewhere or by interviewing the potential executors and agreeing on the total cost of all of the works.

Key principles to determine the reasonable costs of planned actions.

- After a detailed survey of the proposed restoration site, **the most appropriate actions, methods and technical means are chosen.** It is advised to divide works into parts, by stages, timing and type of work. For example, hand work, use of particular equipment. Costs and their efficiency often depend on the season, for example, the major field work for rewetting mires should be carried out in the dry season, otherwise the costs can grow unpredictably, but the objective may remain unrealised or the quality may be poor. To be sure that appropriate habitat management and restoration methods are selected, a species and habitat expert should be involved.
- **Direct costs should be calculated in appropriate units** – in man-hours, person-days, cost of equipment per hour, cost of materials per area or volume depending on works (m^3, km, kg, t). The number of units required for all the works should be assessed and summed up. Practical experience shows that these calculation errors are the most common, thus it is always advisable to use both the experience of similar, already implemented works, such as reports on the projects, specific works, and the experience of institutions (Nature Conservation Agency, JSC "Latvijas Valsts meži", Rural Support Service, municipalities) and non-governmental organisations. Costs of technical works for many types of 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 also annually published on the webpage of the Latvian Rural Advisory and Training Centre. Such cost estimates are also often available on the webpages of construction companies and the biggest forest management companies. If the set of planned activities consists of various works which have not been carried out previously or their pricing is not available, at least three potential executors can 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 should be assessed: site surveys, expertise, technical design, permits and agreements referred to in the regulatory enactments (see Chapter 6.3). It involves working time, transport and administrative costs, which are often inadequately assessed. The time and means to inform the public and explain the necessary steps must be scheduled in complex work projects.
- The regional cost differences in Latvia should be taken into account and also the availability of the executors in the given region up to 30 km from the target area. The costs may rise significantly if the executors and/or equipment must come from a greater distance. For this reason, the 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, clearing of shrubs, mulching of the topsoil and stumps).
- It is desirable to entrust cost assessment to professionals – managers, practitioners, entrepreneurs, – and schedule this job and the adequate funding.

In the planning stage, including financial planning, potential income should also be foreseen related to wood and other biomass (hay, reed), upper layer of peat and other materials obtained during the habitat restoration and management. Ideally, they can at least partially be used on site (for example, for the construction of dams in rewetting of a mire) or brought out of the area and used somewhere else (such as wood chips or wood, reeds and sedges for roof thatching, biomass for animal fodder, cogeneration or as a material for hay transfer to introduce certain target species in habitat restoration areas), peat – for composting or gardening. However in practice, these materials rarely find a practical application, if the volumes are small, extraction sites are dispersed in a wide and hard-to-reach area, as well as high quality of the material cannot always be guaranteed. Therefore it should be considered that the use of habitat restoration byproducts may not always be economically beneficial and their utilisation may require additional cost.

The Annex shows the indicative costs for various types of works referred to in this edition. The costs have been studied in the form of surveys (project implementers, managers, practitioners, public price lists) and are approximate – applied to the period from 2010 to 2015. Costs vary and in each case are determined by the factors mentioned above.

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34 With the amendments as of 26 November 2016.

35 Cabinet Regulation No. 468 of 30 June 2008, List of Invasive Alien Plant Species.

36 Cabinet Regulation No. 559 of 14 July 2008, Regulation Regarding Restricting the Spread of the Invasive Alien Plant Species – *Heracleum sosnowskyi*.

37 Cabinet Regulation No. 468 of 30 June 2008, List of Invasive Alien Plant Species.

38 Cabinet Regulation No. 559 of 14 July 2008, Regulation Regarding Restricting the Spread of the Invasive Alien Plant Species – *Heracleum sosnowskyi*.

39 Cabinet Regulation No. 950 of 13 December 2011, Regulations Regarding the Use of Plant Protection Products.

40 Cabinet Regulation No. 325 of 18 June 2013, On Restoration of Specially Protected Habitats and Specially Protected Species Habitats in Forest.

Chapter 7. Main Methods of Mire and Spring Habitat Restoration and Management

Generalised mire, spring and seepage spring habitat restoration and management methods that focus on solving of specific issues are summarised in Table 7.1. Methods have been described in detail in Subchapter 3 in each chapter on the particular habitat types. For more on the influencing factors and risks important for each EU protected mire and spring habitat types – see Subchapter 1.5 in the particular habitat chapters.

Table 7.1. Overview on the methods of mire and spring habitat restoration and management.

Restoration of habitat function		
Problem	**Solutions**	**Habitat types**
Construction of drainage ditches, flood protecting dams, subsurface drainage systems, etc., renovation of drainage systems in the area hydrologically related to mire or spring habitats, lowering of water table (for example, mining, adjustment of lake water level)	Prevention of activities that can lower the water table in the mire or affect the natural subsurface water flows.	All types of natural and semi-natural mire and spring habitats.
Functioning of drainage systems (ditches, drainage channels, flood protecting dams, etc.) causing enhanced decomposition of peat and increased vulnerability to fires	Ditch blocking, filling up of ditches or their parts, destruction of berms along ditches, construction of terraces for maintenance of the water table on slope mires, waterproofing membranes. Includes preparatory works before the change of water table – preparation of surface (smoothing, establishing of terraces in mires on slopes, removal of artificial constructions that modify the water level, removal of highly decomposed upper peat layer, etc.).	All types of natural and semi-natural mire and spring habitats; post-harvested peatlands.
Pollution of surface water	Preclusion of pollution by preventing certain activities. Elimination of pollution source, prevention of agricultural pollution or reduction of its level in the whole catchment basin, treatment of sediments in water courses or water bodies.	Lakeshore quaking bogs, transition mires and fens in river and lake floodplains.
Pollution of groundwater	Identification and elimination of the pollution source. Prevent the pollution sources by avoiding certain activities.	Spring habitats, fens.
Eutrophication in heavily drained fens	Elimination of external eutrophication sources (air deposition, inflow of polluted (eutrophic) waters) (actions at a regional scale). Removal of topsoil/ highly decomposed, drained upper layer of peat before rewetting.	Heavily drained fens (agricultural land, areas overgrown with forest).

Table 7.1 continued

Restoration of habitat function		
Problem	**Solutions**	**Habitat types**
Elevated water table and/or paludification due to beaver activity (too high water level)	Demolition of beaver dams, insertion of pipes below the dams, control of beaver population (hunting, traps).	Spring habitats, fens, transition mires.
(trees, shrubs, dwarf shrubs) in drained mires; increased transpiration reinforces the drainage effect	Removal of tree and shrub cover. Rewetting (creation of inappropriate conditions for increased expansion of woody species).	All types of natural and semi-natural mire habitats, especially heavily degraded mires, including post-harvested peatlands.
Restoration and improvement of habitat structure		
Problem	**Solutions**	**Habitat types**
Woody species encroachment	Removal of trees and shrubs, ring-barking (girdling) of trees, milling of tree stumps, suppressing of shoots after tree and shrub removal and young trees by mowing, grazing, cutting and weeding.	All types of natural and semi-natural mire and spring habitats.
Spread of expansive plant species and decrease of species richness due to drainage or cessation of traditional management	Reintroducing of traditional management (mowing, low intensity grazing). Prescribed burning (in exceptional cases after careful analysis of the benefits and disadvantages). Removal of tussocks of *Molinia caerulea*. Fragmentation of reed stands.	Fens, spring fens.
Spread and dominance of invasive non-native plant species	Rewetting, removal of invasive woody species, extraction of their roots, herbicide injections, mowing, weeding, cutting, digging of roots, herbicide injections, etc.	All types of natural and semi-natural mire and spring habitats; post-harvested peatlands.
Lack of micro-niches causing a decline in species diversity	Substrate disturbance (removal of topsoil/upper layer of peat, small-scale dig-ups, creation of small ponds, etc.), thus creating suitable micro-niches for various plant and animal species.	All types of natural and semi-natural mire and spring habitats; post-harvested peatlands.

Restoration of habitat-specific species population		
Problem	**Solutions**	**Habitat types**
Degradation or local extinction of habitat-specific plant communities	Activities aimed at restoring and improving the natural habitat structure. (Re)introduction of target species: planting, sowing of mire plants, planting of species-rich turf, species-rich hay transfer, preparing appropriate conditions prior to this.	Mostly post-harvested peatlands; in some cases – other mire and spring habitats.
Local extinction of rare, endangered species, specialist species	Restoring conditions suitable for the particular target species (restoring or maintaining the habitat in favourable conservation status). (Re)introduction of the target species.	All types of natural and semi-natural mire and spring habitats.

Table 7.1 continued

Local extinction of typical animal species or population depletion	Creating or restoring the conditions suitable for the particular target species – for bird breeding (artificial islands, artificial nests, perching poles, shallow waters (for wading birds), fragmentation of reed stands, etc.).	Mostly post-harvested peatlands; in some cases – other mire and spring habitats.
Isolation of species populations in fragmented landscapes	Creation of migration corridors at different levels (landscape level, local level – for example, fragmentation of monospecific reed beds, restoration or creation of habitat patchiness in overgrown areas, appropriate management of (potentially) species-rich road verges and other "surrogate habitats", restoration and management of semi-natural habitats in the surroundings).	All types of natural and semi-natural mire and spring habitats, especially alkaline fens.
Prevention and reduction of visitor pressure		
Problem	**Solutions**	**Habitat types**
Adverse, degrading effect on the ecosystem and the inhabiting species related to the visitor pressure (trampling, waste, undesirable disturbances – noise, physical presence, aesthetic damage, etc.)	Planning and creating paths, plank-ways, platforms, delimiting and redirecting barriers in mires and around springs. Creation of distracting infrastructure (redirecting the major visitor pressure to similar, but less sensitive areas). Distributing educational information (information boards, educational playgrounds, educational lessons, guided excursions, etc.).	All types of natural and semi-natural mire and spring habitats, especially spring habitats.

Chapter 8. Landscape Ecological Aspects in Mire Conservation and Management Planning

8.1 Characteristics of Mire and Spring Landscapes

Landscape can be perceived both as the visual image of nature and as an ecological, complex system that results from the interaction of nature and humans. In the planning of mire ecosystem conservation and in practical habitat management it is preferable to use the approach of landscape ecology. It is based on the definition of the American researchers Forman and Godron (Forman, Godron 1986) and states that the landscape is "a heterogeneous land area composed of a cluster of interacting ecosystems that is repeated in similar form throughout". In this sense, the landscape is perceived as a mutual interaction of various elements that include the movement of energy, materials and species.

Mires are a part of the landscape created by natural processes, although they have often been significantly affected by humans, especially during the last two centuries. Mires form landscapes with specific vegetation, moisture and soil formation processes (Silamiķele 2010). They are characteristic with peculiar terrain, hydrological and microclimatic conditions, and vegetation – an environment providing ecological niches for many specialist species.

In natural conditions mires, especially spring habitats, are often relatively isolated from each other due to specific geological conditions and terrain (Kapfer 2012). In most cases, mires develop in terrain depressions or in the place of overgrown water bodies, whereas spring habitats are formed around subsurface water discharges. So these habitats and their species also form a kind of "island" less or more isolated by the surrounding landscape. "Islands" are isolated by distinctive terrain, bedrock, moisture, and other conditions – unsuitable for the mire and spring species and communities. Without the human impact, mires in the landscape mosaic are relatively stable – bogs in particular may survive nearly unchanged for hundreds and even thousands of years.

In fens the terrain is flat, or they are located in depressions. In fens, sedges and brown mosses dominate. In natural conditions the fens are open, treeless or covered with a sparse pine and deciduous tree layer, or low shrubs. In wet depressions and around groundwater discharges, reeds are often present, or the depressions are wet and marshy, with low vegetation and open water.

In transition mires, which are the next development stage of mires following the fen stage, both the features of fens and raised bogs are characteristic. In intact and slightly modified conditions transition

Fig. 8.1. Slightly transformed wooded landscape in the river valley with formerly traditionally managed fen and meadow patches, and small oxbow lakes in Slocene valley in Ķemeri National Park. Orthophoto map: © Latvian Geospatial Information Agency, 2005–2008.

Fig. 8.2. Severely modified, highly fragmented landscape in the surroundings of Olaine – the former raised bog (today transformed into abandoned cut-away peat milling fields, intensive agricultural lands, roads and residential areas, straightened watercourses). Orthophoto map: © Latvian Geospatial Information Agency, 2005–2008.

Fig. 8.3. Mosaics of alkaline fens, reed beds and islets in Lake Kaņieris in 2009. Photo: A. Priede.

Fig. 8.4. Peat milling fields in Drabiņu Bog in 2009. Photo: A. Priede.

mires are open, treeless, sometimes very wet, with sparse tree and shrub cover or reed stands. Depending on various factors (mire development stage, geological conditions, etc.) they can be dominated by sedges or reeds, there can be open water pools or quaking bogs with sphagnum cover.

Raised bogs form a peculiar landscape, they usually have a dome-shaped surface – one or more cupolas that form a specific terrain characteristic only for this type of mire. The bog landscape has specific micro-relief characteristics with hummock and pool, hummock and ridge, or ridge and hollow complexes. On the slopes of the cupola that is particularly characteristic in large bogs, slow sliding of peat takes place resulting in peat fractures, and thus creating a peculiar mosaic of bog pools. Large bogs have a so-called lagg zone – a very wet open water belt between the ombrotrophic bog and mineral soils of the surrounding landscape (Howie, Tromp-van Meerveld 2011). The central parts of large raised bogs can be open with tiny pine cover representing characteristic crooked forms, however, the majority of the raised bogs in Latvia are entirely covered with sparse, low pines (Silamiķele 2015).

During the last two centuries, the natural mire landscapes in many places of Latvia have been significantly altered by human activities – mainly drainage and peat extraction, and so completely intact mire landscapes, especially fen landscapes, became rare during the 20th century.

8.2 The Role of the Landscape Pattern in the Conservation of Mire-related Species

Diversity of species typical for a particular region cannot be achieved by protecting, restoring and managing only the protected areas and habitats within them. Biodiversity at the level of species and populations is largely determined by the structure of the landscape, its mosaic (patchiness) and the diversity and character of its elements. Biodiversity is affected by the structure of the natural landscape, by the degree of landscape modification, the density and character of dispersal corridors, and the degree of isolation of species localities and communities. The species composition and its typicality for the particular habitat type, as well as the diversity of characteristic species is an essential indicator of habitat quality. Thus, for successful mire conservation and management it is important to cover not only the local, but also the landscape aspects.

Connectivity of species localities is important in the conservation of many populations and is predominantly determined by the structure of landscape. Species have different environmental requirements, therefore their spreading patterns and capability are also very different. For example, birds and large mammals can move over long distances, whereas plants and invertebrates can often only move a few metres within a year, which means that a fundamental reason for the rarity of numerous species is their low dispersal ability. For a species population to survive, it is present in the largest continous area with suitable conditions possible. If the suitable area decreases or its properties change towards unsuitable as regards the particular species, the prospects of species survival decline. Thus, in small, isolated mire and spring patches the species diversity is usually lower than in large complexes of mires and springs. In small mire and spring habitats the long-term survival chance of the characteristic species, especially, rare, threatened, species, is lower than in large habitat complexes.

Due to land use change, drainage, urbanisation and other human-made modifications the number and areas of mires have decreased, and they have become more and more isolated (Middleton et al. 2006). Isolation of mire habitats and their species has been promoted by the transformation of the hydrological network (straightening of rivers, digging of ditches) which is important in the spread of many species (Fig. 8.1, 8.2). Upon the decrease of the areas of suitable habitats, the chance of survival of the species populations and their breeding decrease, causing deterioration at a genetic level and increasing the risk of local extinction (Middleton et al. 2006).

Watercourses and river valleys serve as natural dispersal corridors of species, ensuring connectivity among populations. Fens in natural or slightly altered conditions are quite often connected with raised bogs, wet forests and wet grasslands or are located in river valleys or lake depressions where they become seasonally flooded. Raised bogs are usually isolated due to natural causes. The fragmentation is of lower importance in complexes consisting of several raised bogs, especially in large inter-connected bogs.

In the modern landscape, the natural dispersal corridors of species are often modified or eliminated. Therefore in the dispersal of mire species, human-made corridors also have a certain role, e.g. road verges and ditches along the roads may serve as a shelter and dispersal pathways for alkaline fen plant species. Though roadside conditions may be similar to natural and/or semi-natural habitats, they are not as valuable as intact alkaline fens due to the lack of numerous components of the ecosystem. Nevertheless, they may be significant in ensuring the connectivity between the populations in the increasingly fragmented contemporary landscape.

Decreasing of the fragmentation effects can be performed in many ways, for example, by breaking down the barriers by removing the trees and shrubs between several overgrown mire patches. This would help to preserve, for example, rare invertebrate species with limited dispersal ability. The dispersal ability of the snails residing in the soil and litter is low, they can only move over short distances (from several centimetres to some metres) (Juřičkova et al. 2008), therefore, when planning habitat restoration, it is very important to try to reduce the habitat fragmentation (Knop et al. 2010) by connecting the isolated fen patches. The fragmentation effect can also be diminished by mowing the roadsides with alkaline fen and grassland plant species and communities, which would promote their spread across the landscape.

8.3 Actions for Mire and Spring Conservation at a Landscape Scale

When planning the restoration of habitats and species, it is important to take into account the context of the landscape that also usually affects the results of restoration. For example, when restoring the hydrological regime in an area rich in mires it is expected that the characteristic species will soon establish, if appropriate conditions exist. But when restoring suitable conditions in an area poor in mires, where intensive agriculture or other types of human-altered landscape prevail, it may be the case that the desirable species will not establish themselves and their (re)introduction may be necessary. The mire ecosystem with its characteristic species and communities can be restored more successfully in regions where natural or slightly altered mires have been preserved, as well as little modified natural ecosystems predominate in the surrounding area (Fig. 8.3). Mire restoration is more intricate in areas where they are completely destroyed, and the surrounding landscape has been substantially modified (Fig. 8.4). The expected success of restoration is also affected by the degree of landscape modification – the smaller it is, the sooner the target conditions and species will establish.

When choosing the priority mire areas to be restored, it is important to take the regional aspect into account. Restoration of mires, also heavily degraded, is of higher importance in regions poor in mires than in mire-rich regions or regions where they are still in good condition. Each restored mire is a stepping stone connecting habitats and species populations. Therefore, the more stepping stones, the better prospects for the survival of species and their genetic diversity. Thus, in Latvia, the highest priority for mire restoration should be given to Zemgale region (Central Latvia), which is characteristic with the lowest proportion of mires as many of them have been heavily affected by peat extraction, often completely destroying the mire. Therefore in Zemgale, when planning the after-use of extracted peatlands, it is important to bear in mind that the restoration of mires should be the priority among the after-use options. Similar priorities should also be defined for different types of mire habitats by assessing their incidence and regional distribution.

When restoring the mire habitats, whenever possible, the entire habitat complex should be included in the restoration plan, which, in the case of mires (also wet forests and grasslands), is often a hydrologically joint system. For example, when planning the habitat restoration on lakeshores with a mosaic of reed beds, fens and wet meadows, the best solution would be to plan and restore the conditions for not only a single habitat type or a single patch of the habitat, or an individual species, but to cover the whole complex whenever possible. Restoration of the habitats in a holistic way would help to maintain the populations of numerous species by improving their survival and spreading capabilities.

In biodiversity conservation, so-called secondary habitats also play a significant role. For example, a large proportion of the alkaline fen plant species and related insects are also present in calcareous grasslands (habitat types 6410 *Meadows on calcareous, peaty or clayey-silt-laden soils*, 6210* *Semi-natural dry grasslands and scrubland facies on calcareous substrates* (Festuco-Brometalia)). This means: the better the conservation status of the calcareous grasslands, the bigger the chance to preserve the alkaline fens and related species, and vice versa. Similarly, human-made habitats (e.g. road verges, roadside ditches) also have a significant role as secondary habitats. If they are mown on a regular basis, thus being species-rich and diverse, they often serve as shelters and dispersal corridors for the species of alkaline fens and grasslands. In contrast, overgrowing of the ditches with shrubs and tall herbs reduces the chance of species survival not only locally, but also regionally, as the habitats and populations become more and more isolated.

Chapter 9. Evaluation of the Success of Management and Restoration

9.1 Purpose of the Evaluation

When restoring and managing the habitats, it is important to evaluate the results, including success and failure. Evaluation of the results means systematic recording of the changes (monitoring), or at least a comparison of the situation before and after restoration. A reliable result can only be obtained if the changes are recorded systematically, following certain principles and on a regular basis. The monitoring results should be able to answer whether the restoration has reached the initial target and the extent, or what the reasons are for why the target has not been reached. The assessment of the outcome is also necessary to improve the management performance; if the target has not been reached, one should understand why and take the necessary steps to improve the result and eliminate the failure. For example, if the dams failed to raise the water table in a drained mire, additional dams should probably be built in the right places in order to achieve the proposed objective – rewetting the degraded wetland ecosystem.

Indicators of habitat restoration efficiency depend on the objective and specific habitat. In the assessment of restoration efficiency in mire restoration and management two types of observations are used most: **changes of vegetation** and **water table fluctuations**. Vegetation monitoring is a relatively simple and cheap way of assessing the character of changes, thus it is considered to be the minimum amount of monitoring. Ideally, vegetation monitoring is supplemented with water level monitoring. Mire restoration and the creation of favourable conditions for wetland species can be seen also by the changes in fauna – for example, dragonflies, benthic organisms, and birds can be used as indicators. Evaluation should be carried out according to the methods used in scientific practice that allow comparison of the results with the results of monitoring or research carried out somewhere else. In many cases, useful, valuable additional information on habitat changes is provided by **systematically collected photos**.

In order to assess the restoration or management outcome and to transfer the obtained experience to other restoration sites, one should carry out well-planned monitoring, implemented with the help of an expert. The monitoring will provide reliable results if the vegetation and other parameters are recorded in both the habitat, which has remained unrestored (control), and in the restored area. If the control conditions cannot be ensured, the initial

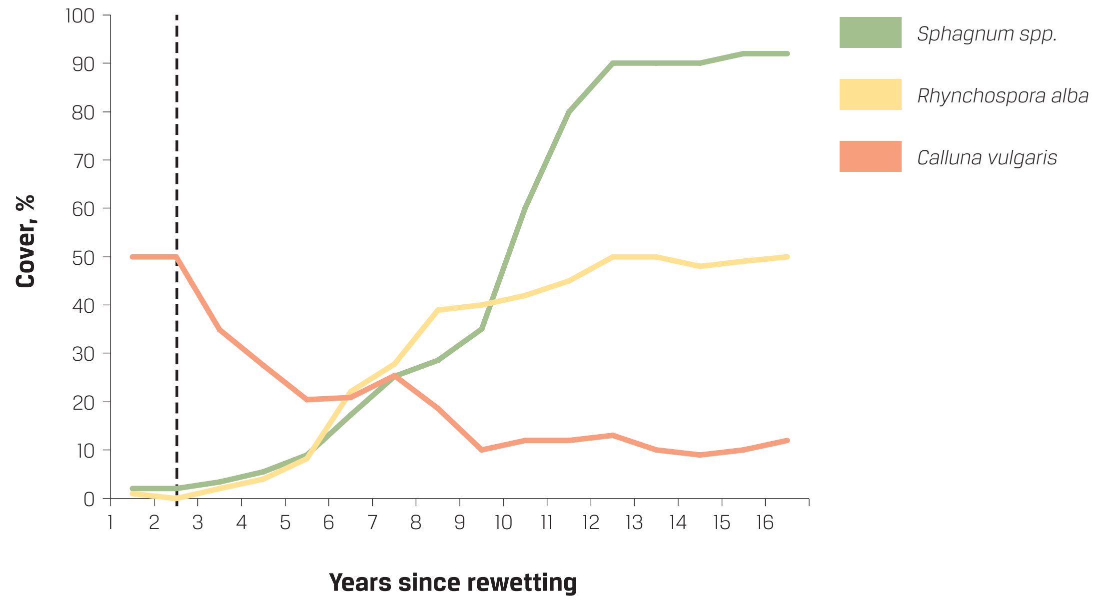

Fig. 9.1. The changes of the cover of plants in a drained mire after rewetting (ditch blocking time – the black, dashed line).

Table 9.1. Plants indicating changes in mire habitats.

Raised bogs and transition mires (EU habitat types 7110*, 7120, 7140)		**Alkaline fens (EU habitat types 7210*, 7230)**	
Indicators of successful mire restoration	**Indicators of unsuccessful mire restoration**	**Indicators of successful mire restoration**	**Indicators of unsuccessful mire restoration**
Frequent, dominating: *Rhynchospora alba, Oxycoccus palustris, Carex rostrata, Sphagnum* spp.	**Commonly present:** *Dicranum* spp., *Pleurozium schreberi, Campylopus introflexus, Cladina* spp. and *Cladonia* spp. **Dominating or with large cover:** *Calluna vulgaris Empetrum nigrum, Ledum palustre, Vaccinium uliginosum*, other dwarf shrubs.	**Commonly present:** *Campylium stellatum, Drepanocladus* spp., *Scorpidium scorpioides, Calliergonella cuspidata, Preissia quadrata, Fissidens adianthoides, Juncus articulatus, Sesleria caerulea, Calamagrostis canescens, Primula farinosa, Pinguicula vulgaris.* **Frequent, dominating:** sedges belonging to Carex flava family (*Carex flava, C. lepidocarpa, C. scandinavica*, etc.), *C. davalliana, C. lasiocarpa, Schoenus ferrugineus, Cladium mariscus.*	**Commonly present:** *Campylopus introflexus, Cladina spp. and Cladonia* spp. **Dominating or with large cover:** *Molinia caerulea* (dominates), *Festuca ovina, Agrostis canina*, ruderal tall-herbs (*Urtica dioica, Rubus idaeus, Epilobium hirsutum*, etc.), macrophytes of eutrophic water species (*Typha* spp., *Lemna* spp.).
Neutral species (poor indicators)*		**Neutral species (poor indicators)***	
Eriophorum vaginatum, Eriophorum polystachion, Phragmites australis, Trichophorum alpinum, Phragmites australis.		*Phragmites australis, Juncus effusus, J. conglomeratus, Eriophorum polystachion.*	

* Simple interpretation; these indicator species (their presence, cover) cannot be used without an in-depth analysis.

(pre-restoration) conditions should be documented. The performed works should be thoroughly documented – when, what and how it was done, including the annual or periodic re-current works, if the habitat restoration or management is not a one-off action. For example, if mowing has taken place, then it must be documented in which years, what dates, by which technique and the area (marking the configuration of the managed area on the map). Various external factors and processes affecting the specific area should also be recorded (e.g. beaver activity, trampling, grazing intensity, etc.). It is advisable to record them in previously developed data forms and store the data in the database allowing one to analyse the changes over the years.

In evaluating the success it is advisable to attract experienced professionals able to choose and apply the most appropriate monitoring methods, able to identify the species, analyse the environmental factors and their dynamics, etc. However under the conditions of limited funding, hiring of the best experts is not always possible or the monitoring cannot be funded for a longer period of time. In such cases a simplified indicator system can be used, which can also partially be implemented by non-professionals by learning the plant species present in the territory, methods of how to assess their cover and how to observe and record other changes (e.g. water level measurements). The most important thing is to do it systematically and in good faith. In case of doubt, professionals should be consulted.

9.2 Vegetation Monitoring

In vegetation monitoring, the most commonly used method is the recording of plant species present in the sample plots and evaluation of their cover. Sample plots of a certain size are marked with poles or in other ways to ensure that exactly the same location is found in the subsequent years. Additionally, the geographical coordinates of the plots (centres, corners or otherwise) must be recorded. No universal

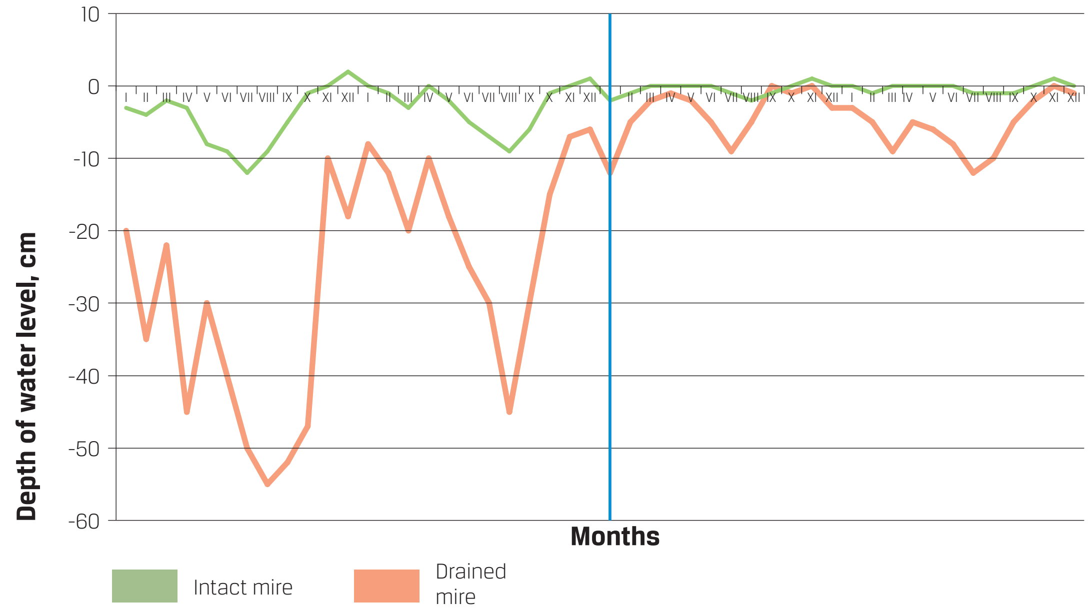

Fig. 9.2. Changes of the water table before and after rewetting in an intact and drained mire. Blue line – time of blocking the drainage system.

monitoring method can be advised that is applicable in all situations. Therefore, in each case the situation should be assessed on site and a decision made as to where and how the monitoring sampling plots should be established.

Before the establishment of the monitoring sampling plots, it is important to take into account several considerations:

- how diverse is the vegetation in the specific area when beginning the monitoring?
- which monitoring method will be chosen – how much time and resources will be needed for monitoring each time, and is it affordable?
- does the selected number and size of sample plots reflect the character and diversity of the particular area and the character of changes – will they be representative and reliable enough, including for statistical analysis of the data?

It may be the case that in the first year of monitoring, a large number of sample plots are set because the researcher has a great interest and plenty of time at that moment. However due to a lack of time and enthusiasm in the coming years they may not be followed up. On the other hand, a too small number of sample plots will not reflect the character of the area and the pace of changes. A small number of sample plots may also cause difficulties in applying statistical data analysis to get a reliable result.

A too large sample plot will include too much diversity for proper evaluation (micro-relief, moisture conditions, etc.) and it will be difficult or even impossible to determine the actual factors influencing the changes (Lawesson (ed.) et al. 2000). On the other hand, a too small sample plot may cover only part of the structure of a micro-relief, for example, in a mire – only part of a hummock, thus incompletely reflecting the nature of the vegetation. For example, a typical plant in bogs and post-harvested peatlands with residual acidic peat is the tussock-forming cottongrass *Eriophorum vaginatum*; a single plant can

Fig. 9.3. A bore-hole for monitoring of water level in Veseta floodplain mire. Photo: A. Priede.

Fig. 9.4. Post-harvested area in the north-western edge of Ķemeri Mire in 2007. Photo: J. Ķuze.

Fig. 9.5. The same place in 2010. Photo: A. Priede.

cover more than 1 m², which means that the whole sample plot will be smaller than the single plant. If small sample plots are established, it is more likely that not all of them will include species characteristic for the area, thus in order to reflect the actual diversity of the area, a larger number of sample plots will be necessary than in the case if the sample plot is larger. In contrast, describing of a larger sample plot is labour-consuming and takes more time.

The positioning of the sample plots can be accidental, in transects or other.

Since the monitoring should be started before rewetting, it is advisable to establish more sample plots than actually needed, because some of them can become flooded and inaccessible (if special plank-ways are not installed). In rewetting areas, prior to establishing the sample plot, the specialists responsible for hydrological modifications should be consulted, and the technical project should be considered to understand which parts of the area may become inaccessible because of the raised water level.

The indicators of the success in habitat restoration and maintenance are chosen depending on the type of works, restoration targets, as well as available funding, time and human resources. Some common plant species are given here (Table 9.1) which, based on practical experience when monitoring the mires in Latvia, can be used as indicators reflecting the nature of the changes in raised bogs and alkaline fens. The presence of species indicating degradation does not always mean that the mire is degraded. Additionally, the cover and frequency of the particular species should always be assessed. Usually the best indicators are the species characteristic for the particular plant community (habitat) and so-called umbrella species (Auniņš (ed.) 2013). The species composition in spring habitats are highly variable, thus general indicators are not offered, also due to a lack of knowledge and detailed studies.

The cover of several plant species characteristic for specific conditions can be used as indicators of the changes (example in Fig. 9.1).

9.3 Hydrological Monitoring

Water level is an indicator that is widely used in assessing the recovery of the mire. It is one of the basic indicators in determining whether rewetting of the mire is successful. Usually the water table increases in successfully rewetted sites, and water table fluctuations become less pronounced (Fig. 9.2). This means that the conditions are becoming appropriate for the recovery of mire vegetation and establishment of other mire communities. Sometimes the rise of the water table may also have an adverse undesirable effect, such as elevated water table due to a beaver dam in a fen or spring fen that may cause extinction of the typical species and communities.

Usually for the monitoring of the hydrological regime several bore-holes (profiles) are made that are located perpendicular to the ditches. The distance between the holes may be constant (Indriksons 2008), or may increase along with increasing distan-

Fig. 9.6. The same place in 2014. Photo: A. Priede.

ce from the ditch (Dēliņa, Ģederts 2013). However similarly to the vegetation monitoring, it is not possible to provide universal recommendations applicable for all the cases as regards the placement of monitoring bore-holes and their number – it is determined by the specific hydrological and topographical conditions of each site.

Usually plastic pipes are inserted in the holes and covered with a lid (Fig. 9.3). Monitoring must be regular – preferably once a week or at least 1–2 times a month. The water level can be measured with a tape measure, fitted with a float from the top of the well until the water level (Indriksons 2008). Automatic water level controller can be used as well, which gives a more accurate overview of the changes over time.

In order to assess the changes and interpret them correctly, water level observations should be linked not only with rewetting, but also with precipitation, transpiration and their monthly and annual distribution. Persistent rain or a high precipitation level causes the rise of the water table both in intact and drained mires, thus these conditions must be considered when interpreting the monitoring data.

9.4 Photographing

In regular monitoring of the site, photos should be taken from the same point every time. It is recommended to do it at the same period of vegetation development. It is important to select representative photo points so that the documented changes can be attributed to the entire territory. This can be done most successfully by establishing a photo point (preferably more than one) – for example, a thick wooden pole dug into the ground, marking the shooting direction with a colour or otherwise. Each time the picture should be taken from this point from the same angle. To gain an accurate understanding of the changes, one should take pictures of the place before restoration and in different years after restoration or management. In the examples in Fig. 9.4–9.6 one can assess the changes in vegetation cover through the years. Such photos do not allow the changes of the composition of species or cover of particular species to be assessed (which is often important in analysing the changes in the habitat), but give an idea of the general changes in the area that are difficult to evaluate without a large number of vegetation sampling plots.

9.5 Other Indicators

Perhaps the best indicator characterising successful restoration of a mire ecosystem is peat formation. If the restoration has resulted in the development of mire vegetation, especially habitat-specific mosses (in most cases – sphagnum mosses), within several decades the accumulation of peat may be expected. Peat accumulation proves that the mire ecosystem and its functions have been successfully restored and the target plant species and communities have established.

PART II

Chapter 10. 7110* *Active raised bogs* and 7120 *Degraded raised bogs still capable of natural regeneration*

10.1 Characteristics of Raised Bogs

10.1.1 Brief Description

Raised bogs (EU habitat type 7110* *Active raised bogs*) are rain-fed bogs that receive water and nutrients with precipitation. In raised bogs, the environment is acidic and poor in nutrients. The vegetation is composed mainly of sphagnum mosses, as well as perennial plants – dwarf shrubs and plants belonging to the sedge family (*Eriophorum* spp., sedges). Sphagnum mosses in raised bogs are the main peat formers. In intact bogs the largest part of the bog peat formation is active, but it can be interrupted for some time due to natural factors, such as fire or lengthy periods of drought (Auniņa 2013a).

Habitat type 7110* *Active raised bogs* (Fig. 10.1) occurs fairly often throughout the territory of Latvia, mainly in lowlands and plains. The largest number of bogs and also the bogs with the largest area are found in the East-Latvian Lowland, northern part of the Central Latvian Lowland, and Tīreļu Plain (Auniņa 2013a).

Habitat type 7120 *Degraded raised bogs still capable of natural regeneration* are raised bogs where the natural hydrological regime has been altered or which have been partially used for peat extraction, however, in which it is still possible to prevent the drainage influence, and the formation of peat can resume within 30 years. Thus, degraded bogs where the vegetation is still composed of plant species typical for the raised bogs after the changes in the hydrological regime (drainage, peat extraction) are classified as this habitat type (Auniņa 2013b). This habitat type does not include abandoned extracted peatlands dominated by bare peat, or the territories have been intentionally afforested or have afforested themselves, or converted into agricultural lands. Peat extraction areas where the indications of raised bogs still prevail or have recovered (abandoned block-cutting peatlands filled up with water, minor peat cutting areas if bog vegetation has recovered, rewetted peat milling fields, where bog vegetation has developed) are considered as this type of habitat (Auniņa 2016b).

Fig. 10.1. Teiči Bog, the largest bog in Latvia. Photo: A. Priede.

10.2. Intact raised bog with bog pools (Great Ķemeri Mire). Photo: A. Priede.

In Latvia, three variants of the habitat 7120 *Degraded raised bogs still capable of natural regeneration* have been distinguished (Auniņa 2016b).

Variant 1: raised bogs or their parts heavily affected by drainage (Fig. 10.3). Such bogs or bog parts can be with tree cover or open. Trees have a large annual increment and pointed crowns. In such bogs or bog parts there is no acrotelm; the hummock micro-relief prevails. Usually there is an excessive dwarf shrub cover, abundance of mosses typical for dry coniferous forests, no or minor sphagnum cover. Decomposition and compaction of peat can be observed.

Variant 2: extracted block-cutting bogs, where the peat has been harvested by hand or mechanised cutting. Usually these areas are typical with a very uneven terrain consisting of successive so-called "trenches" (peat extraction pits) and rises, usually overgrown by trees (Fig. 10.4). Commonly the trees have a large annual increment and pointed crowns. There is no acrotelm.

Fig. 10.3. Raised bog habitat heavily affected by drainage in Lake Melnais Bog. Photo: A. Priede.

Variant 3: rewetted peat milling fields where the drainage system does not function anymore and the water level has risen reaching the surface of peat or the peat surface may be seasonally covered with shallow water. Vegetation is dominated by sphagnum mosses, and the species of raised bog and transition mire depressions are present (Fig. 10.5).

Fig. 10.4. An old peat block-cutting area in Great Ķemeri Mire abandoned in the 1960s. Over the last decade after raising the water table, the bog vegetation recovers successfully. A quaking blanket of sphagnum mosses and cotton grass has developed. Photo: A. Priede.

Distribution of the habitat type 7120 *Degraded raised bogs still capable of natural regeneration* is similar to the habitat type 7110* *Active raised bogs* (Fig. 10.6, 10.7) as they usually occur in the same area. The total area of the habitat 7110* *Active raised bogs* in 2013 was estimated as approximately 266,200 ha or 4.1% of the country's territory, whereas the cover of 7120 *Degraded raised bogs still capable of natural regeneration* was estimated as 31,700 ha or 0.5% of the national territory (Anon. 2013).

Fig. 10.5. An abandoned peat milling field in Ķemeri National Park abandoned in the 1980s. The water table was raised in 2006, thus favouring the recovery of bog vegetation. The photo is taken in 2016. Photo: A. Priede.

In the raised bogs of Latvia both habitat types are mostly present, distinguished by the degree of degradation. In the parts of bog affected by drainage, the habitat usually complies with 7120 *Degraded raised bogs still capable of natural regeneration*, whereas in less affected or intact parts it is considered as 7110* *Active raised bogs*. Knowledge on the distribution and the total cover of these habitat types in the country is still insufficient.

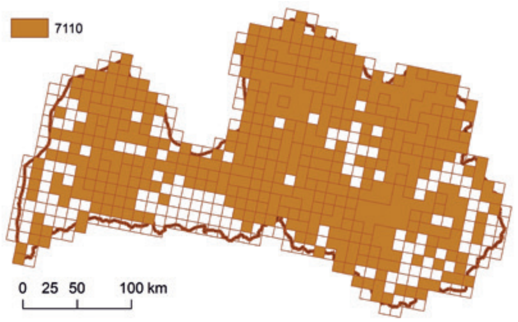

Fig. 10.6. Distribution of habitat type 7110* *Active raised bogs* in Latvia (source: Anon. 2013a).

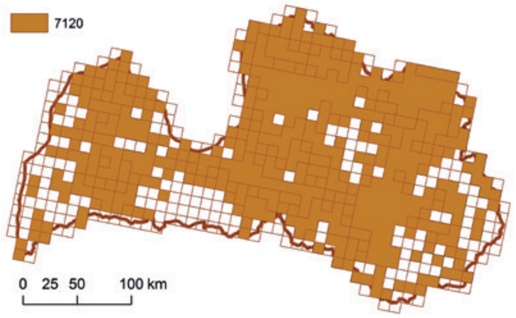

Fig. 10.7. Distribution of habitat type 7120 *Degraded raised bogs still capable of natural regeneration* in Latvia (source: Anon. 2013a).

In these guidelines the further text applies to raised bogs as an ecosystem, which includes both types of EU protected habitats – 7110* *Active raised bogs* and 7120 *Degraded raised bogs still capable of natural regeneration*, as their origin and functions are similar and they are classified as different habitat types just because of the human-caused degradation.

10.1.2 Important Processes and Structures

Raised bogs have developed over several thousands of years as a result of paludification of the mineral ground or overgrowing of lakes. The depth of the peat layer in some bogs in Latvia may reach ten and more metres. Raised bogs are usually dome-shaped with one or several cupolas. Rarely, raised bogs have developed in valleys and on slopes.

In intact raised bogs, the conditions are constantly wet. The water level is high, in the wet season reaching the surface of peat, but generally it naturally slightly fluctuates depending on the amount of precipitation. Large fluctuations usually indicate a drainage impact. The environment is acidic (pH 3–4.5) and poor in nutrients available to plants (phosphorus and nitrogen compounds, macro-elements). The nutrients reach the bog with precipitation and atmospheric deposition.

Intact and slightly affected raised bogs are open, with or without a sparse tree and shrub cover, mainly composed of Scots pine *Pinus sylvestris*. However, a bog can also be overgrown with pines because of natural reasons, for example, on the margins of the bog and on the ridges with drier substrate. The extent and intensity of tree encroachment in bogs is also related to the depth of peat layer, structural diversity of the bog, and the total bog area.

The diversity of micro-relief structures varies in large bogs and smaller bogs. In large raised bogs (several hundreds to thousands of hectares) usually bog pools, bog hollows, hummocks and ridges, and a lagg zone can be found, whereas in smaller bogs only a few structural elements occur (Auniņa 2013a). In small bogs the bog pools are usually absent, and they are often more or less overgrown with trees.

On the Latvian scale there are differences in bog structure and species composition between western Latvia and other regions. In the raised bogs of western Latvia the micro-relief is mainly formed by the complexes of mud-bottom hollows and low ridges, however, there are often few or no bog pools. In raised bogs of eastern and northern Latvia the hummocks are usually higher, they often form ridges. In the bogs of western Latvia, the complexes of hummocks and hollows almost never form a regular pattern (it can be seen in the orthophoto images), but the ridge-hollow-pool complexes in the raised bogs in the rest of Latvia often form regular concentric arcs (in cupola bogs) or are located circularly (in valley or slope bogs) (Auniņa 2013a). On cupola slopes of the largest intact raised bogs, active formation of bog micro-relief takes place – there are mud-bottoms, the arrangement of which may change dynamically over the years.

In degraded raised bogs, typical signs of drainage are peat compaction (particularly typical in areas bordering peat milling fields and on the edges of large ditches), including dropping of the water level in bog pools and hollows, loss of open water surface in bog pools, extinction of sphagnum mosses, which are being replaced by dense stands of dwarf shrubs. Under heavy drainage, the mosses typical for dry coniferous forests (e.g. *Pleurozium schreberi*, *Hylocomium splendens*) are spreading, rapid overgrowing with *Pinus sylvestris* and *Betula* spp. takes place, especially in the vicinity of ditches (Fig. 10.8). In severely drained bogs, the degradation and collapse of hummocks may be observed.

Fig. 10.8. Degraded part of Buļļi Bog affected by drainage – sphagnum mosses have disappeared in the vicinity of the ditch, and the ditch edge is occupied by fast-growing *Pinus sylvestris* and *Betula* spp., a dense layer of dwarf shrubs has formed. Photo: A. Priede.

10.1.3 Succession

For most time of their existence, raised bogs in Latvia have evolved naturally, without human intervention, but the course of their formation has been influenced by climate fluctuations. Many bogs in Latvia started to develop in the Early Holocene (8,000–10,000 years ago), though the formation of some bogs began earlier (for example, development of Teiči Bog started in the Late Dryas period 10,800–10,200 years ago) (Silamiķele 2010). However, the majority of bogs started to develop during the Subboreal period (4,500–4,700 years ago) (Markots u. c. 1989). In drier periods, especially at the end of the Subboreal period, approximately 2,500 years ago, mires fully or partially overgrew with forest (Zunde 1999).

Development of mires in the post-glacial era mainly occurred according to two scenarios – by paludification of soil and overgrowing and filling up of lakes. Formation of mires in lowlands and the coastal zone began mostly by the paludification of wet depressions in which fens with sedge, reed and moss vegetation developed. Over several thousand years they transformed into transition mires and later into raised bogs.

In uplands, the formation of mires occurred mostly by the overgrowing of lakes. As lake sediments accumulated, the volume and depth of lakes decreased. At the same time, gradual overgrowing from the shores took place. Over time the surface of the lake overgrew with a quaking mat that, as a result of peat accumulation, formed the dome-shaped surface typical for raised bogs.

Young mires are also being formed today by the paludification of depressions, succession of beaver ponds, and overgrowing of lakes. The contemporary land use with extensive land drainage and cultivation hinders the paludification process and limits it to small areas only. Development up to the raised bog stage may take several thousands of years and in some cases may not ever be reached.

10.1.4 Indications of Favourable Conservation Status

In raised bogs with favourable conservation status, the hydrological conditions are not modified by human activity, acrotelm (the active surface of the bog) is present, and peat accumulation takes place. Peat has a high water-storage capacity, thus in an intact raised bog there is no explicit water level fluctuation. The bog waters are acidic (pH 3–4.5), the environment is poor in plant nutrients. No significant modifications and impacts are caused by human activity (drainage, peat extraction, intense trampling, etc.).

An intact or slightly altered bog is usually open or with small tree and shrub cover, or tree cover is present only on ridges of hummocks, in mineral soil islets, and shores of bog lakes. Rapid overgrowing with trees does not occur (trees in the bog are slow-growing, in recent decades there are no signs of rapid overgrowing of the bog). In intact and slightly affected raised bogs, bog pools are usually typical; however, these are more characteristic for large bogs.

Sphagnum mosses, the main formers of peat, prevail in the ground vegetation. Plant species characteristic for raised bogs are frequent, of them the most common are *Eriophorum vaginatum*, on hummocks – *Calluna vulgaris* and other dwarf shrubs. Conditions are favourable for the existence of so-called umbrella species, and they can be found in the bog: vascular plants – *Rhynchospora alba, Scheuchzeria palustris, Carex limosa*, sphagnum mosses – *Sphagnum cuspidatum* (Fig. 10.9), *Sph. tenellum, Sph. majus, Sph. balticum, Sph. angustifolium*, birds – *Tringa glareola* (Fig. 10.10), *Pluvialis apricaria, Numenius phaeopus* (Auniņa 2013a).

7120 *Degraded raised bogs still capable of natural regeneration* is the only type of EU protected habitat in Latvia, the reduction of area of which is acceptable – in cases when the conservation status is being improved and it turns into another EU protected habitat type – 7110* *Active raised bogs* or 91D0* *Bog woodland*.

Fig. 10.9. *Sphagnum cuspidatum* is a common species in raised bog pools. Photo: A. Priede.

Fig. 10.10. In large intact and slightly affected bogs *Tringa glareola* can often be observed sitting on the tops of small pines. In Latvia, they breed only in raised bogs. Photo: A. Priede.

10.1.5 Pressures and Threats

10.1.5.1 Drainage and peat extraction

Drainage is the main cause of raised bog degradation in Latvia. Drainage has affected raised bogs in Latvia since the 18th century. Raised bogs have been drained in order to improve the forest growing conditions on bog margins, although in Latvia such bogs have not ever been extensively drained in vast areas for forestry purposes, as it happened, for example, in Finland and Sweden (Vasander et al. 2003). The conditions of raised bogs in Latvia were considered unsuitable for silvicultural purposes (Zālītis u. c. 2013).

Raised bogs in Latvia have also been drained for peat extraction. Thus the water level was lowered, and seasonal water level fluctuations increased (Indriksons 2008; Ruseckas, Grigaliūnas 2008). In the parts of bogs significantly affected by drainage, especially in the vicinity of ditches, the formerly open areas are occupied by trees (Dyderski et al. 2015). Penetration of tree roots in the catotelm, the inactive layer of bog peat, enhances the decomposition of deeper peat layers, thus promoting bog degradation. Due to drainage, sphagnum mosses (the major peat formers) disappear or their cover decreases, they are being replaced by dwarf shrubs. Consequently, this increases the risk of fire. Decrease of the open bog areas has an adverse effect on typical bird species of raised bogs, especially *Tringa glareola* and *Pluvialis apricaria*.

Drainage causes changes in the micro-relief – peat compaction along the ditches, dropping of the water level in bog pools and lakes. Severe hydrological modifications, usually related to peat extraction, may discontinue the peat accumulation process. Both moisture level and light conditions are changing, promoting the changes in species composition typical for raised bogs and the extinction of characteristic species. Expansion of trees, especially birches, favours the drainage effect on bog by increased evaporation through tree leaves.

The impact zone of ditches and significance of the impact cannot be generalised. The significance of the impact is determined by the hydrogeological conditions of each bog and the type of ditch (depth, whether the ditch reaches the mineral ground, length of use, clogging). The impact zone of ditches can be assessed over a longer time by assessing the changes in vegetation and by regular water level monitoring at various distances from the ditch. Water level monitoring in most cases suggest that significant draining of peat surface under the impact of the ditch occurs only a few metres away from the ditch (Mioduszewski et al. 2013; Lindsay et al. 2014). Nusbaums (2008) states that optimal draining of a bog is possible if the distance between the ditches is not less than 20 m; if the distance is greater, draining is less effective. The best example of effective, bog-degrading draining is a bog prepared for peat milling, where the drainage ditches have been dug after every 20 metres.

Ditches reaching the mineral ground usually have a drainage effect on larger areas than those dug in peat. Mioduszewski et al. (2013) suggest that the impact zone, using the depth of the water level as an indicator, could reach 30–60 metres. A similar estimate on the impact zone of drainage ditches, based on vegetation data, is observed in Aizkraukle Bog (Latvia) in the buffer zone around the peat milling fields (Priede 2014).

Observations in various bogs suggest that the water level monitoring does not show the actual impact of the ditch – it can cause larger impacts than indicated by water level monitoring (Lindsay et al. 2014; Priede 2014). One reason is the combined effect of both ditches and transpiration (Mioduszewski et al. 2013; Lindsay et al. 2014). In drained bogs, the peat-forming plants (mainly sphagnum mosses) are being replaced by woody plants with a deeper root system, causing changes in water circulation. The establishment of trees, especially deciduous trees, also reduces the amount of precipitation reaching the bog surface, some of the precipitation which could feed the bog remains in foliage of trees, thus making the bog drier (Bragg 2002; Lindsay et al. 2014). The impact zone of older ditches functioning for at least two to three decades in the raised bog can almost always be determined visually by the vegetation. Usually the impact zone extends as far as the variations in the vegetation may be observed: in the drainage-affected part of the bog the dwarf shrubs dominate, bog overgrows with fast-growing pines and birches (Fig. 10.11). Further away from the ditches these signs gradually disappear, and the vegetation of intact raised bogs prevail (Priede 2014). The distance from the ditch, considered as the impact zone, can vary from some metres near recently dug, shallow ditches up to 100 or even more hundreds of metres near functioning ditches dug a long time ago (Lindsay et al. 2014; Priede 2014). In cases when the network of ditches criss-cross the entire bog, their impact zones can overlap, and the summed drainage impact can be remarkable, though the impact of each ditch is hard to distinguish. A functioning ditch may drain the bog for years, but due to the long-term its actual impact can only be assessed after several decades.

If only water table measurements are used for the assessment of drainage impact, this can give false information on the actual impacts of ditches. The raised bog consists of the acrotelm, the active bog surface, formed by *Sphagnum* mosses and other plants, and of catotelm, the inactive layer, consisting of the dead, decomposed plants (peat). Drainage affects both bog layers in different ways. The high water storage capacity of catotelm allows it to store a large volume of water accumulated in peat, also in the vicinity of a ditch, however, the water storage capacity of the acrotelm is much smaller, and the drainage influence of a ditch may affect a much wider area – dozens or even hundreds of metres (Lindsay et al. 2014) (Fig. 10.12). Thus, the impact of ditches on the acrotelm is significant – upon draining of the active surface of bog, conditions unsuitable for the typical bog plant species gradually develop, especially for sphagnum mosses. In the vicinity of ditches, peat forming sphagnum mosses disappear, and gradually the local impact of ditches may expand to a relatively broad zone around the ditch.

In general, the impact of ditches on the catotelm is slow and indirect. Near the ditch, water is forced out of the peat layer due to the pressure of the upper peat layer and, under the impact of the force of gravity, forms spring-like discharges on the slopes of the ditch. Over time the dry compressed peat no longer saturated with water causes pressure on the lower layers of peat, which causes further peat compaction (Lindsay et al. 2014). This process causes peat compaction, which can be observed along larger ditches. It is observed that explicit compaction of peat occurs within an area of 20–30 m wide along the ditch (Fig. 10.13). The impact zone is determined by ditch depth, its efficiency and other factors. Drainage also increases the depth of freezing of the peat layer (Nusbaums 2008), which in turn can lead to peat erosion, observed in the zone of peat compaction.

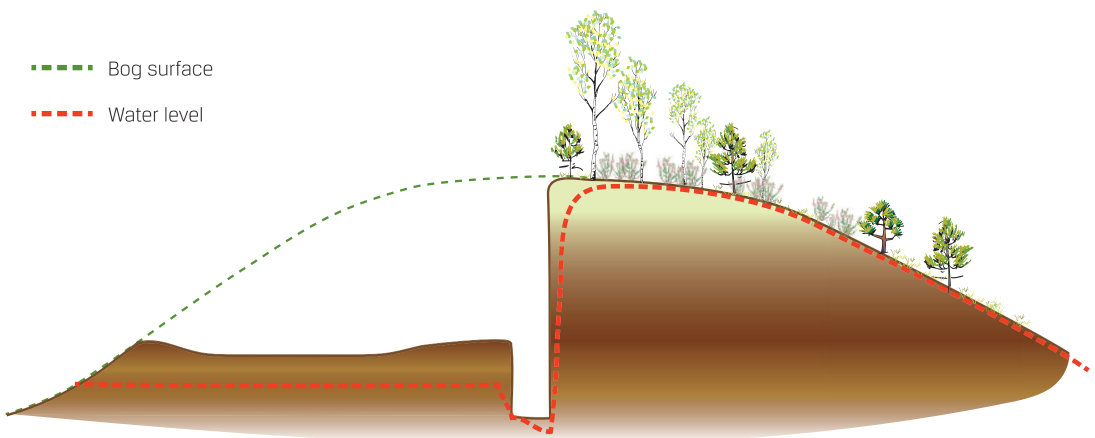

Fig. 10.11. Impact of peat extraction and related ditches around the peat extraction site on the water level in raised bog. On the left – peat extraction site, on the right – a raised bog not directly affected by peat extraction. Drawing: D. Segliņa (according to Mioduszewski et al. 2013).

Fig. 10.12. A sunken depression in raised bog approximately 90 m from the ditch surrounding the peat extraction site in Great Ķemeri Mire. Photo: A. Priede.

Fig. 10.13. A ditch surrounding the peat milling fields in Aizkraukle Bog. In the vicinity of the ditch, dropping of the water table, peat layer compaction, dense woodland with dwarf shrubs in the ground cover can be observed. Photo: A. Priede.

In the 19th century and the first half of the 20th century peat was extracted in relatively small volumes in Latvia. In 1920, peat was extracted in 324 bogs manually or using simple equipment (Nusbaums 2013b; Šnore 2013). In the 1920s–1930s, several peat extraction companies were established, thus significantly increasing the extracted amount. Although in this period manual peat cutting was still widely used, peat extraction was gradually mechanised.

Along with the peat milling method introduced at the end of the 1940s, technical capabilities improved and the need for peat rose, and consequently the affected bog areas also significantly increased. In the 1960s the milling became the most widely applied method in peat extraction (Nusbaums 2013b). This approach required deep draining, thus significantly affecting the bog ecosystems.

The impact of peat extraction on bog is both direct and indirect. The direct impact is removal of the peat layer. The indirect impact is drainage of the area proposed for extraction and its surroundings. Peat extraction fields are always enclosed by a surrounding major ditch, while local draining is performed by smaller drainage ditches crossing the peat fields. Additionally, a subsoil drainage system is established. Thus, the ditches, depending on natural water flow directions, inevitably create a draining impact on the adjacent mire habitats – peat compaction, increased tree establishment and related accelerated transpiration, and degradation of ground vegetation.

Peat cutting widely applied up to the mid-20th century caused a less significant impact on the bog hydrological regime than the later used peat milling. In peat cutting recommendations published in the 1940s (Delvigs 1943), several approaches were advised, which would both ease the peat cutting work and, from today's perspective, cause minor drainage impacts on the bog. In order to reduce the impact of frost so that peat cutting could be resumed in early spring, in autumn after the digging works, it was advised to block the ditches connected to block-cutting "trenches", which meant that during the winter the peat cutting pit and its surroundings remained wet. The upper layer of peat unsuitable for burning or other purposes was thrown into the dug peat holes and smoothed (Delvigs 1943), which, upon filling up of the pits with water, meant good prospects of bog vegetation recovery.

The acidic water rich in humic substances and peat particles brought out by ditches from bogs, especially from peat milling fields, may become a substantial environmental problem, if it enters the surface waters, for example, mesotrophic lakes. Such waters impair water turbidity and change the physical and chemical properties of water (Nusbaums 2008; Urtāns (ed.) 2017, *Chapter 12.1.6.5*), thus affecting the aquatic ecosystem.

Bogs and their hydrological regime are also affected by road construction. In some places roads have been built over the bogs, although such situations are rare in Latvia. Sometimes the ancient routes crossing the bogs do not exist anymore and are not passable as roads, but can still be detected by rows of trees (Ikauniece (red.) 2011). The road dams can obstruct the water flows, enhancing paludification on one side of the road and the formation of drier conditions and subsequent overgrowing with forest on the other side.

10.1.5.2 Fires

Most likely, fire in raised bogs in the pre-industrial era was rare. However, it was a natural disturbance (Zoltai et al. 1998). According to peat sediment studies in raised bogs of Northern Europe, the frequency of burning in bogs increased in the dry, warm Holocene period 7,000– 10,000 years ago. Fires in intact and little affected raised bogs are rare and are almost only possible in dry summers (Zoltai et al. 1998; Sillasoo et al. 2011), also in the climatic conditions of Latvia.

Nowadays the origin of fire in bogs is almost always related to human activity. Risk of burning particularly increases in drained bogs that can be burnt on a regular basis, especially near human settlements. Most of the plant species and vegetation of raised bogs in general, as well as animal species, are not adapted to regular burning (Auniņa 2013a). The impact of burning may differ depending on its intensity, frequency, as well as on water level and other factors. In burnt bogs, the dominance of species tolerant to burning and changes of substrate moisture is characteristic. The tree and shrub stand can be totally destroyed. After burning, *Calluna vulgaris*, *Eriophorum vaginatum*, and *Polytrichum* spp. can establish and dominate for several decades (Sillasoo et al. 2011; Namatēva 2012). *Calluna vulgaris* has a significant role in fire spreading – it easily catches fire, which can then spread rapidly in the dwarf shrub layer, especially if it is dense (Sillasoo et al. 2011). In the after-fire succession it has an important role in the recovery of sphagnum cover by creating a suitable microclimate. After burning, the raised bogs are usually invaded by birches (Galenieks 1935). Sometimes, if a deep peat layer has burnt, the bog returns to the earlier succession stage, thus in the burnt places vegetation typical for a transitional mire can develop (Namatēva 2012). If the bog returns to the transition mire stage due to intense burning, recovery of the hummock micro-relief typical for raised bog may take up to 350 years (Sillasoo et al. 2011). After burning, the hummock micro-relief and the related species are replaced by the hollow species (Sillasoo et al. 2011). This means that the bog surface becomes wetter. Due to repeated and intensive burning of raised bogs including peat layer incineration, vegetation similar to wet heaths can develop. In Latvia large areas of burnt raised bogs similar to wet heaths can be found in the "Ādaži" Protected Landscape Area. Under the impact of drainage and long-term grazing in bogs, vast areas of wet heaths have developed in Great Britain (Anon. 2011; see also Laime (ed.) 2017, *Chapter 17*).

10.1.5.3 Beaver activity

Eurasian beaver *Castor fiber* is not a characteristic species for raised bogs and is rare there, however its presence and activities here have been facilitated by humans by creating ditches. Ditches create conditions suitable for beavers by promoting the establishment of deciduous trees – an important component in a beaver's diet. Berms along the ditches are suitable for burrow digging, and ditches provide a method of moving around the area (Pilāts 2013). Most often, beaver dams are located on drainage ditches on bog margins, rarely – on smaller ditches in post-harvested bogs. Absence of beavers in the central parts of bogs is explained by the limited availability of food.

Beaver activity when creating dams on ditches and raising the water table cannot be considered as undesirable for raised bog habitats, as they reduce water run-off from the bog and may even restore the optimal water level in drained bogs (Pilāts 2013). Water level increase caused by beavers can lead to the dieback of forest stands on bog margins. Although this may destroy the forest, from the point of view of biodiversity, beavers increase the volume of dead wood, creating micro-habitats for other animal species, for example, insects that inhabit the dead wood and woodpeckers, which feed on these insects. Thus, beaver-caused impacts cannot be judged as solely "desirable" or "undesirable".

10.1.5.4 Eutrophication

Intact raised bogs are poor in plant nutrients – phosphorus and nitrogen (Ellenberg 1988), so they are one of the most sensitive ecosystems to nitrogen increase (Bobbink, Roelofs 1995). Raised bogs receive nutrients and water from precipitation, and they

are especially sensitive to air pollution, including nitrogen compounds dissolved in the precipitation water or atmospheric deposition in the form of dust. Dust deposition is also increased by intense agriculture in the surroundings of bogs, as soil particles are transported by wind (van der Linden, van Geel 2006).

Increased nitrogen concentration has an adverse effect on the growing of sphagnum mosses and it promotes the development of vascular plants (Rydin, Jeglum 2013). Sphagnum species typical for raised bogs are particularly sensitive to nutrient increase (Anon. 2000). Bog research in Western Europe suggests that the increase in concentration of nitrogen ions several times over causes the extinction of sphagnum mosses or replacement of sphagnum by nitrophilous species (Franzén 2006; van der Linden, van Geel 2006). In highly eutrophic conditions sphagnum mosses are replaced by nitrophilous moss species, graminoids, or cottongrasses *Eriophorum* spp. Under the impact of increased nitrogen concentration the survival and reproduction ability of insectivorous sundews *Drosera* spp. decreases.

In the acidic environment in raised bogs, the decomposition of organic substances is slow, and this promotes peat accumulation (Anon. 2000). High levels of nitrogen cause faster growing of plants and accelerate the decomposition of dead plants (Anon. 2000). Consequently, the proportion of dead biomass composed of various organism groups changes as well as the decomposition rate. Vascular plants decompose faster than sphagnum mosses. Thus, eutrophication also changes the properties of peat and its botanical composition.

It is estimated that the nitrogen threshold in raised bogs could be from 5 to 10 kg/ha per year (Bobbink, Roelofs 1995). Studies in Sweden show that peat decomposition in the last decades has sped up by more than four times. Also, more intense decomposition was found in the bog peat surface than in the lower layers, probably facilitated by eutrophication (Franzén 2006). In this way raised bogs turn from carbon sinks into carbon sources (Aerts et al. 1992; Franzén 2006).

In Latvia, significant nitrogen loads in precipitation have not been found, and most probably the current nitrogen concentration does not cause an undesirable impact on raised bogs or such effects have not been detected. However, so far the bogs of Latvia have not been well studied in this aspect.

Peat extraction sites are sources of eutrophication themselves. Nutrients are washed out through ditches, thus they can reach water courses and water bodies, causing their eutrophication.

10.1.5.5 Changes in substrate pH

Raised bogs may be affected by change in substrate pH (Ellenberg 1988), as it happened, for example, in Estonia during the second half of the 20th century due to atmospheric deposition – pollution with sulphur dioxide and other chemical compounds from industrial plants. Increase of soil pH causes changes in vegetation composition – extinction of some sphagnum species and establishment of plants typical for nutrient-rich soils (Paal et al. 2009).

Probably, atmospheric deposition may have also affected raised bogs of Latvia, especially in the 1980s. However, since this has not been studied, the degree of impact is unknown. Most likely, the impacts are minor, and consequences are not as explicit as in Estonia and perhaps some other countries in Europe.

10.1.5.6 Climate change

Climate conditions play the key role in the development of mires. Climatic conditions may be more or less favourable to mires at different periods of their development. Raised bogs are fed by atmospheric precipitation, thus their development and persistence are directly related to the amount of precipitation and evaporation.

In Europe mires are considered as the habitat group most affected by climate change (Anon. 2012). Mires are influenced both by changes in air temperature and in the amount of precipitation, moreover, changes in mire ecosystems are facilitated by the combination of these factors with the impact of nitrogen deposition (Rydin, Jeglum 2013). In Northern

Fig. 10.14. *Betula nana*, a boreal plant species, which is rare and protected in Latvia. It may disappear due to global warming. Photo: A. Priede.

Fig. 10.15. The shore of the bog pool in the raised bog in Great Ķemeri Mire heavily affected by trampling (2008). In such places the natural vegetation can recover, however, it takes several years. Photo: A. Priede.

Fig. 10.16. Trampling on the shores of a popular bog pool in a raised bog. In such places vegetation recovers relatively quickly after the cessation of regular trampling. Photo: A. Priede.

Europe there is a tendency for an increase in the average annual rainfall (Anon. 2011), which creates favourable conditions for mire development. However, the rise of the average air temperature may cause increased evaporation from the mire surface, promoting their desiccation. Higher average temperature facilitates the faster decomposition of dead plants, decreasing peat accumulation (Silamiķele 2010) and enhancing carbon dioxide release in the atmosphere (van der Linden, van Geel 2006).

Significant changes in raised bogs can also be induced by prolongation of the active vegetation period and decrease of rainfall in summer and autumn. Consequently, drought or moisture deficit periods in a bog may become longer, thus enhancing the growth of trees and transformation of a bog into a forest. Longer periods of drought also increase the probability of wildfires (Rydin, Jeglum 2013). Longer droughts and the changes of the seasonal distribution of the amount of annual precipitation also facilitate changes of the bog vegetation (Robroek 2007), but the species of raised bogs usually have low adaptive capacity.

The average temperature rise may also promote the shift of the southern range borders of some boreal species towards the north (Harrison et al. 2006). In Latvia it means that in the long-term perspective, climate change with increased average temperatures and shifts in precipitation seasonality may cause the extinction of some boreal bog species, e.g. *Betula nana* (Fig. 10.14).

The role of recent climate change and tendencies in raised bog ecosystems is not yet clearly understood. Undoubtedly, during the last two centuries the main cause of bog ecosystem degradation has been human activity – drainage and peat extraction, in many cases also human-promoted eutrophication. However, climate change is the most significant factor in the long-term dynamics of the bog ecosystems, and the consequences of bog changes affected by the climate in the long term cannot be eliminated with the local management actions.

10.1.5.7 Excessive visitor load

Intact and slightly affected raised bogs are often rich cranberry sites, thus in the picking season there is a large number of visitors that, in turn, causes trampling of the ground vegetation (Fig. 10.15). A similar effect is caused by swimming in the bog lakes in areas with a large number of visitors, e.g. in bogs with popular nature trails (Fig. 10.16). In this way the vulnerable ground vegetation of the bog is being mechanically damaged. However such an impact can be considered as temporary – the moss cover can usually recover naturally within a year, in heavily trampled places – within several years, if the impact is not continuous. The degrading impact is also caused by the use of cranberry harvest equipment by pulling out cranberry stems that are slowly recovering.

Aesthetic degradation is caused by the waste left by the berry-pickers, which deteriorates the bog scenery and can sometimes injure wild animals.

Prior to the restoration and management of bog habitat, it is important to understand the current condition of the habitat, main problems, their causes and the desired result. This means a careful inventory and identification of all potential obstacles. Only then can appropriate methods be chosen, knowing their advantages and disadvantages. If the target cannot be achieved, alternatives should be evaluated.
There is no universal recipe for bog restoration. Due to geographical differences, a detailed site assessment should be carried out in each case and only then should the most appropriate restoration techniques be chosen.
In bog rewetting a careful inventory and modelling should be carried out to already avoid mistakes in the planning stage, otherwise the habitat restoration may not achieve the goal or may be of low efficiency.

10.2 Restoration objectives in raised bogs

See the common objectives for all mire habitats (*Chapter 5.3*).

10.3 Restoration of Raised Bogs

10.3.1 Restoration of Raised Bog Habitats for the Purpose of the Guidelines

For the purpose of the guidelines, habitat restoration shall refer both to slightly degraded areas where the indications typical for both types of the EU protected raised bog habitats can still be found, i.e. meet the minimum criteria (Auniņa 2013a, 2013b), and highly degraded areas where it is possible to restore or create the conditions characteristic for raised bogs by achieving the restoration of structures and species composition typical for the raised bogs. In Latvia, there are also deteriorated bogs where it is impossible to restore the bog habitats, e.g. bogs converted into arable land or grassland.

These guidelines also include heavily degraded but potentially restorable raised bogs, e.g. post-harvested peatlands where, although not always, it is possible to restore bog ecosystem function and species composition, but in a long time also the characteristics of the EU-protected habitat.

Prior to the restoration and management of bog habitat, it is important to understand the current condition of the habitat, main problems, their

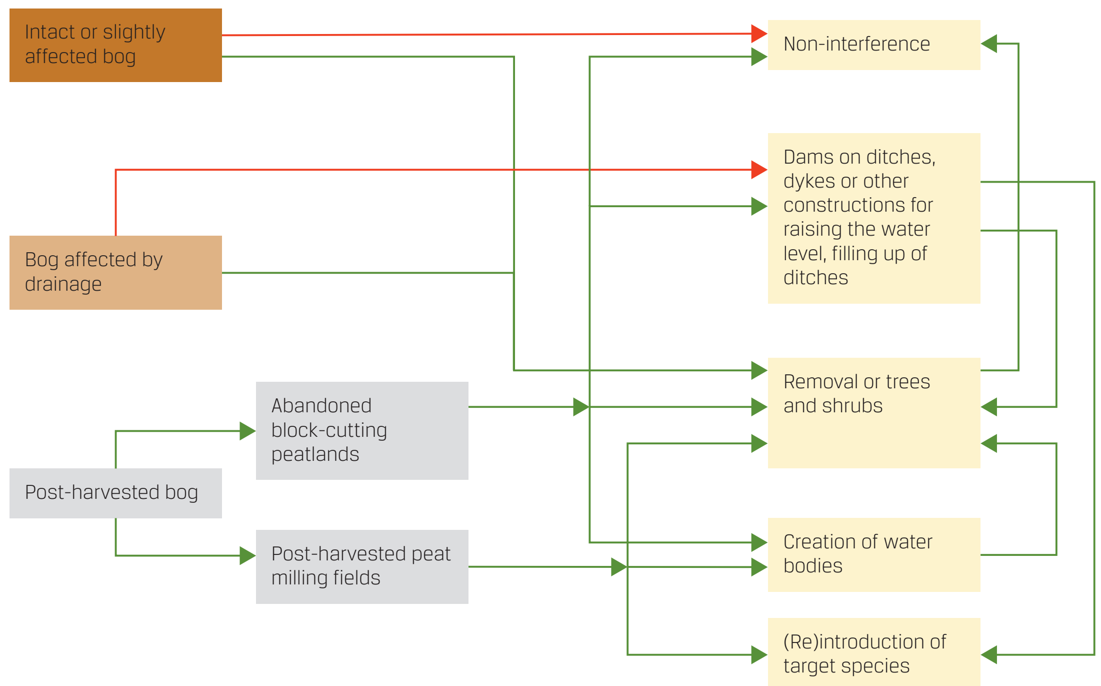

Fig. 10.17. Selection of appropriate raised bog habitat restoration techniques in various situations. Red arrows show the most common solutions, dashed arrows – alternative solutions that may improve the result or that are only applicable if necessary in the particular area after careful evaluation.

Fig. 10.18. Raised bog after approximately 15 years after extensive fire (Great Ķemeri Mire in 2015). Habitat restoration is not necessary here, natural processes should take place. Photo: A. Priede.

Fig. 10.19. Sloka Bog has been affected by fires several times. The dense cover of *Calluna vulgaris*, large proportion of birches and dead wood indicate the effects of fire. However, the main cause of the frequent burning is drainage, which has severely affected the bog. Photo: A. Priede.

causes and the desired result. This means a careful inventory and identification of all potential obstacles. Only then can appropriate methods be chosen, knowing their advantages and disadvantages. If the target cannot be achieved, alternatives should be evaluated.

There is no universal recipe for bog restoration. Due to geographical differences, a detailed site assessment should be carried out in each case and only then should the most appropriate restoration techniques be chosen.

In bog rewetting a careful inventory and modelling should be carried out to already avoid mistakes in the planning stage, otherwise the habitat restoration may not achieve the goal or may be of low efficiency.

In each situation an initial assessment of the situation is necessary, understanding the problems and adopting appropriate realistic solutions (Fig. 10.17). Each attempt to restore habitats should aim for the ideal, best solution, however, if it is not possible, the best alternatives should be chosen.

10.3.2 Non-interference

In intact or slightly affected raised bogs without functioning drainage ditches, the non-interference is the best method for their protection. Habitat restoration is not necessary in areas without undesired impacts. Raised bogs can be adversely affected by activities or processes in the adjacent areas, for example, digging of new drainage ditches or renovating of old ditches in forests in the vicinity of bogs. Such activities causing an adverse effect on bog habitat are not permissible.

When deciding on the necessity of habitat restoration, a careful assessment of the current condition and impacts is necessary. In intact bogs without ditches or with non-functioning ditches (for example, under the impact of beaver activity or completely overgrown) rewetting or any other measures are not necessary. In undrained or slightly drained raised bogs overgrown with trees, perhaps due to climate change or natural succession, it is possible to improve the habitat structure or create conditions more suitable for birds by felling the trees, however, there are contradictory opinions on whether this helps in preserving an open bog in the long term. Most probably, this would be of low efficiency.

> Prior to any restoration, the current habitat condition and potentially negative effects must be assessed comprehensively. Such assessment should lie on the basis of the decision on whether to restore the bog habitat or not. A single feature may not be taken out of context as this can lead to a wrong decision. The best solution is the development of a detailed restoration programme for the particular bog, including inventories, risk analysis and the choice of the best solutions based on the assessment of alternatives.

Sometimes in ditches, usually in drainage-affected forests adjacent to bog, a high water level is maintained by beavers. In such cases, beaver dams should be preserved. Beaver dams on ditches at least partially restore the water level in drained bogs, therefore, from the point of view of bog conservation, they play a positive role. Sometimes beaver activities provide good results and do not cost anything. If neighbouring forests or agricultural lands become wetter due to water level rise caused by beaver activity and therefore it should be limited, it is considered as a compromise with economic interests, rather than a desirable activity aimed at restoring and preserving the bog habitats.

Natural processes are a priority in small raised bogs that overgrow when reaching a certain succession stage, without the impact of drainage. Exceptions are areas in which the maintenance of small open bogs is necessary to preserve habitats of particular species, e.g. *Tetrao tetrix* populations. It shall be decided upon assessing the situation as a whole (*see Chapter 4*).

Wildfires, depending on the intensity of burning, may cause significant changes in both vegetation and the peat formation process (*see Chapter 1.5.3*). However, no interference is necessary in intact and slightly affected bogs after fires (Fig. 10.18). Prior to any activities it is important to correctly assess the burning impacts and not misinterpret them as drainage impact, as well as to understand the interaction of both impacts in the specific situation. However, in bogs that have burnt several times in a relatively short period, the main cause of burning should be assessed – almost always the fires are promoted by drainage creating favourable conditions for burning. In this case, the vegetation structure established after the burning should not be "improved", however, it must be estimated whether it is possible to eliminate the drainage impact (Fig. 10.19). Rewetting can prevent the increased burning risk in heavily drained bogs.

10.3.3 Rewetting

10.3.3.1 Basic principles of rewetting

Rewetting is carried out to create hydrological conditions optimal for the bog ecosystem by raising and stabilising the water level, as well as to prevent explicit seasonal water level fluctuations caused by drainage. Water level in the bog is optimal when the catotelm is saturated with water, and the water level in wet seasons reaches the peat surface.

> **Bog lakes and the potential impact of rewetting**
> *A. V. Urtāns*
>
> There are two groups of dystrophic lakes – lakes of primary (relict lakes) and secondary origin. Primary lakes are the remains of ancient lakes. Their connection with the mineral ground still persists. Lakes of secondary origin or bog pools have formed in the cracks in the peat layer by tension or peat being sunk by gravity. Secondary lakes do not have a connection with the mineral ground, and they feed only from precipitation. The origin of both lakes can be defined after geological studies – there is gyttja (sapropel) in the deposits of the lakes of primary origin, they have a specific zooplankton community and a certain abundance of species found in the zooplankton.
> Peat layer compaction and sinking are characteristic for the shores of both primary and secondary lakes. Evaporation is more intense from an open water surface than from a sphagnum-covered bog surface, thus the water losses from the lakes are greater. Lakeshores are drained naturally, so the rainwater saturated with oxygen (aerobic) flows in the upper layers of peat. This causes oxidation of the organic substances and promotes peat compaction and sinking. Rewetting of such oxidised peat causes transformation of the oxidised organic carbon compounds into the form of dissolved organic carbon. When the dissolved organic carbon reaches the lake, the bacteria activity is facilitated. The bacteria split the macro-molecular humic substances, and the phosphorus and nitrogen compounds adsorbed thereon partially dissolve in the water.
> Released phosphoric and nitrogen compounds are nutrients that promote the transformation of dystrophic lake into diseutrophic condition, i.e. it causes lake habitat degradation. Thus deliberate blocking of the outflowing ditches and raising of the water level in the lake are a significant interference and deteriorate the lake ecosystem.
> Raising of water level and maintenance of an elevated water level is acceptable in bog lakes of secondary origin with quaking shores. This would promote the development of sphagnum on the lakeshore and prevent peat sinking, oxidising and compression.

To restore the bog hydrological conditions, it must be ensured that most of the water received from the precipitation remains, and its rapid outflow through the drainage ditches, thus degrading the

Prior to rewetting, the binding regulatory enactments should be carefully studied, including permitted and prohibited activities in particular areas, and the agreements and permits that are required to perform the restoration works. It takes quite a long time (up to two years) until all the necessary permits and consents are received. For dam construction, the permission of the local building authority in the local municipality is required. In protected nature territories the activity must be coordinated with the Nature Conservation Agency. In some cases, the environmental impact assessment procedure can be applied (*see Chapter 6.3*).

ecosystem, must be avoided. The hydrological regime can be restored by blocking the ditches – both by constructing dams and filling up ditches or their parts, and other actions.

Ditches are of various sizes, and they perform a draining function with different efficiency. Larger ditches usually cause a draining effect in a wider area. But smaller ditches can also have just as important a draining role. Sometimes, partly overgrown ditches can also ensure drainage. Also, the density of the ditch network is important. A local draining

Fig. 10.20. It is recommended to use peat for the filling up of ditches, taken from the bog surface by excavator, forming shallow depressions. It can be expected that they will overgrow with bog vegetation within a few years. Photo from from the bog restoration site in Finland. Photo: I. Lazda.

effect is caused by deep logging tracks, which act in a similar way to ditches. Whether the ditches reach the mineral ground layer or are dug only in peat is important. Ditches that are dug in the mineral ground, especially in sand deposits, can have an effect on a relatively wide area (Rehell et al. 2014), while the impact zone of the ditches dug only in the peat layer is smaller.

It is important to conduct a thorough inventory, modelling and planning. It is recommended to involve a hydrogeologist, hydrologist, species and habitat expert. The density of the ditch network and their role in drainage must be assessed; ditches in which the water flow should be blocked and best methods for doing this, should be selected. The topographical situation and run-off directions should be studied. The optimal methods and costs must be evaluated. Most importantly, it is necessary to set a realistic goal taking into account the risks and potential failures.

Fig. 10.21. Recently filled up ditch in Gulbjusala Bog (Gauja National Park) in 2015. Photo: A. Priede.

Fig. 10.22. The ditch in bog woodland in southern Finland filled up several years ago – entirely overgrown with bog vegetation. Photo: A. Priede.

More on the experience of filling up of ditches: Vestarinen et al. (2014).
In Latvia, the ditches have been filled up in the surroundings of Smiltene (JSC "Latvian State Forests" in 2012), as well as within the LIFE+ project "Forest habitat restoration within Gauja National Park" (FOR-REST) in 2015 and "Restoring the hydrological regime of Ķemeri National Park" (HYDROPLAN) (restoration activities are planned in 2017).

Bog rewetting should not impair the condition of hydrologically related habitats, particularly the surface waters, for example, by causing pollution with excess nutrients, sedimentation, erosion in lakeshores, inflow of dystrophic waters, and water level rise in lakes. Such impacts can modify the physical and chemical parameters of water and thus also alter the entire lake ecosystem. It is particularly important to assess the risks related to mesotrophic, nutrient-poor lakes, if such are characteristic in the surroundings (Urtāns (ed.) 2017, *Chapter 12*).

Various methods of rewetting, their advantages and disadvantages are compared in Table 10.1.

10.3.3.2 Filling up of ditches

The filling up of ditches (Fig. 10.20–10.22) is usually the most effective rewetting solution, as this completely prevents the drainage impact. However, due to technical reasons, filling up of ditches is not always possible. Filling up of ditches is also usually more expensive than the construction of dams. However, if possible, it is always recommended to be used as the best alternative, because it eliminates the draining function of the ditch permanently.

In many cases, prior to the filling up of ditches, trees on the berms must be removed. Although their transportation may be problematic or impossible, felled trees cannot be used for the filling up of diches and covered with peat, since the water continues to flow through the spaces between trees under the peat.

When filling up a ditch, the creation of linear ditch-like depressions parallel to the ditches must be avoided, as they can create a draining effect. The peat layer along the ditches can be compacted and the peat can be highly decomposed, thus the ditch margins should also be filled up in order to prevent water flowing parallel to the filled ditch (Vestarinen et al. 2014).

More on the experience of filling up of ditches: Vestarinen et al. (2014).

Possible mistakes and failures

There is a risk of filling up of natural water courses (natural water courses straightened a long time ago cannot always be well distinguished from ditches). Therefore careful pre-inventories and understanding of the natural run-off from the bog is essential. It is important because flooding large forest or agricultural areas in the vicinity of the bog must be avoided if this is not planned in the project. The main ditches may not be filled up if this can adversely affect the hydrologically related areas.

Filling up of ditches should not rise the water level in the surrounding lakes (ditches flowing into and out of the lakes can be confused with natural water courses), changing their ecological condition.

To avoid the formation of spontaneous new streams running parallel to the filled ditch, especially

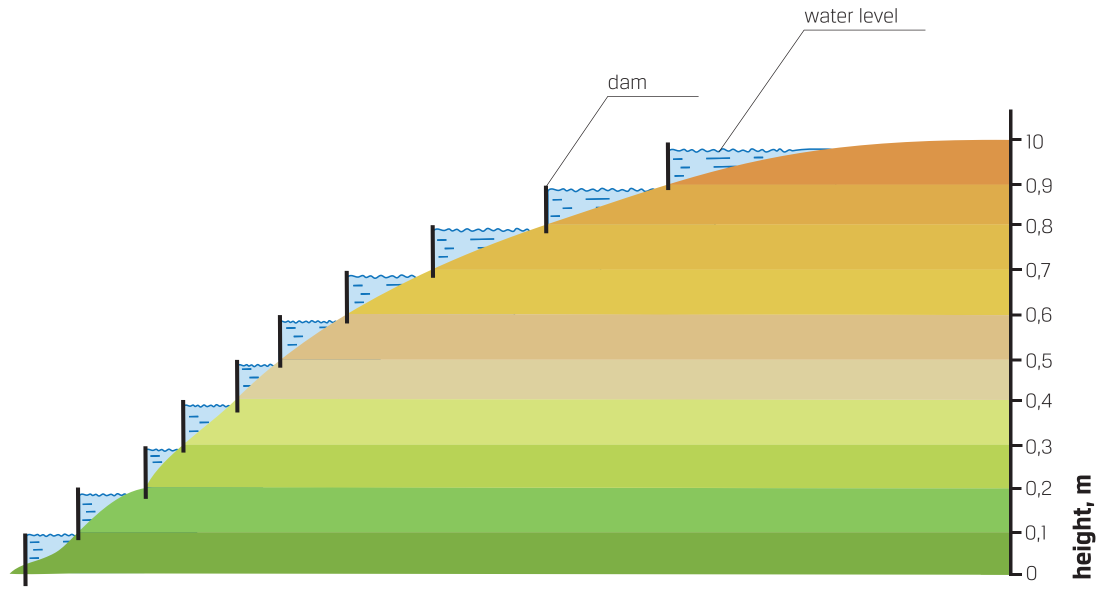

Fig. 10.23. Dam placement on the cupola slope of the raised bog (ideally, one dam on each 0.1 m of slope inclination). Drawing: D. Segliņa.

on the flat slopes, sometimes additional dams should be created perpendicular to the ditch (Vestarinen et al. 2014). *See also Chapter 3.3.5.*

10.3.3.3 Dam construction on ditches

The aim of dam construction on ditches is to restore the conditions favourable for the particular habitat type by stabilising the water level and limiting its fluctuations that increase due to drainage. Construction of dams on ditches in bogs is a well approbated and widely applied method in the world. This method has also been used in many raised bogs in Latvia.

Prior to restoring the hydrological regime it is very important to carry out a comprehensive inventory and planning, especially levelling. Establishing of digital terrain models is recommended to enable modelling of the results of water level changes (Rydin, Jeglum 2013). Data obtained by LiDAR laser scanners can be used to make the model prior to rewetting, especially in large areas. In Latvia, the LiDAR data for the preparation of 3D terrain models have been successfully used in the restoration of several bogs (LIFE+ projects "Restoring the hydrological regime of Ķemeri National Park", LIFE10 NAT/LV/000160 (HYDROPLAN) and "Forest habitat restoration within Gauja National Park", LIFE10 NAT/LV/000159 (FOR-REST).

The location of dams should be chosen not only considering the bog slope inclination, but also assessing the accessibility options and possibilities to transport materials for dam construction. In the sites chosen for dam construction, the draining effect of the ditch to both sides should also be assessed, hence also the dam width. Dam width should be

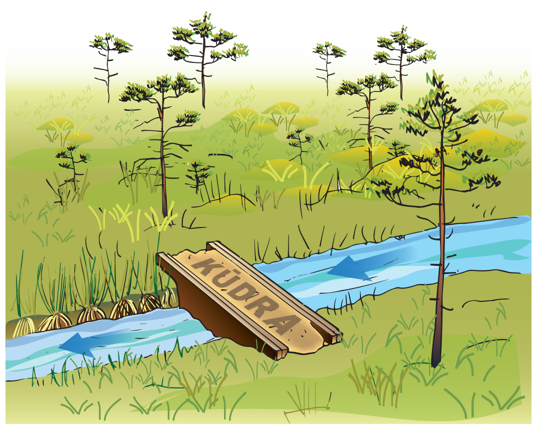

Fig. 10.24. Board dam packed with compacted peat. Drawing: D. Segliņa.

Fig. 10.25. Dam in Teiči Bog, constructed of timber (logs) obtained on site (built in 2003). A few years after the installation, the dam is already overgrown with bog plants. Photo: J. Ķuze.

Fig. 10.26. Hand built wooden dam, built around 1997, after a longer time completely overgrown with *Sphagnum* spp. and *Eriophorum vaginatum*. Teiči Bog, the photo is taken in 2013. Photo: M. Priedēna.

Fig. 10.27. Wooden dam in Soomaa Bog in Estonia consists of two rows of logs driven perpendicularly to the ditch, filled with peat. Surface is strengthened with boards, but the upstream of the dam is isolated with durable plastic film. Photo: S. Ikauniece.

Fig. 10.28. Log dam packed with *Sphagnum* spp., Rāksala in Teiči Bog in 2004. Photo: J. Jātnieks.

Fig. 10.29. Wooden dam of logs, upstream of the dam packed with peat, Viru Bog in Estonia. Photo: A. Priede.

Fig. 10.30. Wooden dam filled with peat in a bog in Estonia. Photo: S. Ikauniece.

planned approximately so as to cover the ditch and its direct impact zone to the point where peat is no longer sunk (for large ditches – around 15 m) (Nusbaums 2008).

The surface of raised bogs is dome-shaped, thus the number of dams in raised bogs must be larger than that in fens. The location and number of dams on the ditches depends on the bog slope inclination. The bigger the inclination, the more dams are needed to achieve the desired water level. Ideally, dams on ditches should be located after every 0.1 m of slope inclination, the minimum – after every 0.5 m of slope inclination (Nusbaums 2008) (Fig. 10.23). A higher number of dams will ensure a higher rewetting efficiency.

The essential things to be taken into account when planning dam construction:

- dams must serve for a long time, thus they must be efficient and durable;
- the dam must ensure a water level rise in the entire impact zone of the ditch;

> To fell trees necessary for the construction of dams, an agreement issued by the State Forest Service is required, if the average diameter of the stump exceeds 12 cm. Like other documents, it must be prepared well in advance, prior to the implementation of works. *See Chapter 6.3.*

- the dam must not be eroded (water can erode the dam, flowing over it or around the edges), so correct placement, appropriate width, and a sufficiently durable construction which is able to withstand the water pressure, must be chosen;
- the dam will not function if the water filtrates through the dam or through the mineral ground under the dam (Nusbaums 2008).

10.3.3.4 Types of dams

Choice of dam type is determined both by the available material on site, material sustainability and efficiency, as well as the transportation options and costs. The shorter the time the material serves, the sooner you will need to restore the dam, and this is related to additional costs. Therefore, it is usually best to use as sustainable materials as possible and materials obtainable on the site. These are also the cheapest, for example, trees felled on site or peat from the bog surface near ditches.

Dams, especially in the first years after their construction, as long as they are not overgrown with permanent vegetation and have proven their persistence, should be regularly monitored and, if necessary, repaired.

Wooden dams are built manually, usually in places that are difficult to access by excavators. In Western and Northern European countries, for the construction of such dams, different materials are used – logs of the trees felled on site (in Latvia this method was used, for example, in Teiči Bog and Lubāns Wetland), as well as plywood, boards or planks that are less durable and serve for a shorter period. Hydro-isolating materials are used in addition (waterproof sheeting, waterproof membranes), sphagnum mosses, turf or sacks filled with peat or sphagnum to secure against the water flow through dams. If boards, planks or plywood are used (usually for the

In Latvia, great experience in wooden dam construction has been obtained in raised bogs of eastern Latvia (Teiči Bog, Lubāns Wetland). For more – see Bergmanis u. c. (2002) and Bergmanis (2013).
Long-term experience on bog restoration has been gained in Finland (Similä et al. (ed.) (2014), http://julkaisut.metsa.fi/julkaisut/show/1733.

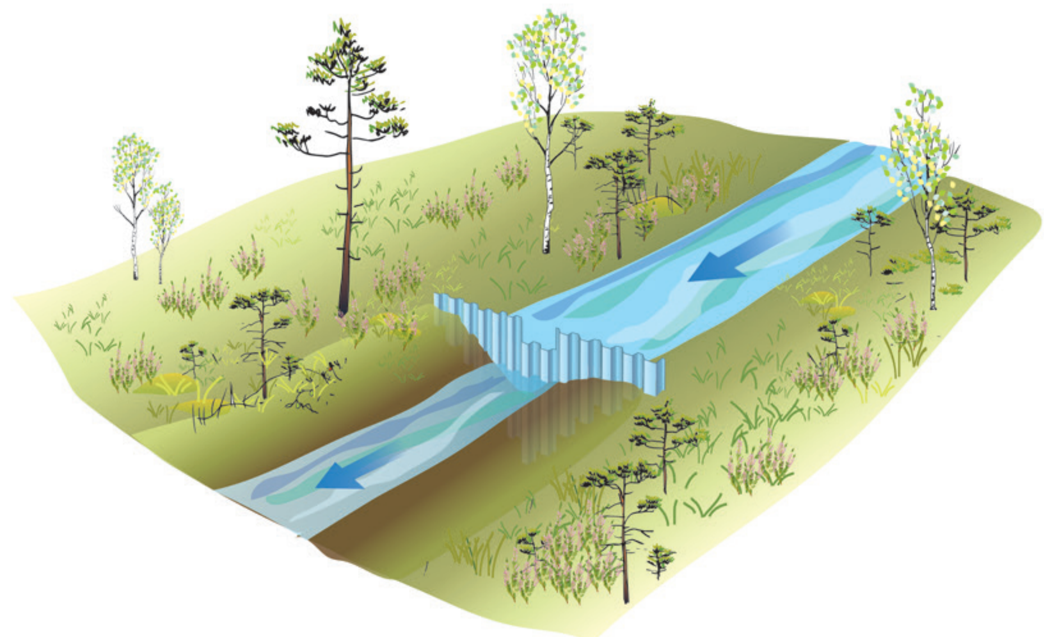

Fig. 10.31. A plastic piling dam. Drawing: D. Segliņa.

Fig. 10.32. A plastic piling dam in extracted peatland in Žuvintas Biosphere Reserve in Lithuania. Photo: M. Pakalne.

Fig. 10.33. A plastic piling dam built over a wide ditch in Kamanos Strict Nature Reserve in Lithuania. Photo: S. Ikauniece.

Fig. 10.34. A plastic dam masked with moss cover to encourage its faster overgrowing and integration in the surroundings. Kamanos Strict Nature Reserve in Lithuania. Photo: S. Ikauniece.

Fig. 10.35. A plastic piling dam masked with fallen logs and branches in Kamanos Strict Nature Reserve in Lithuania. Photo: S. Ikauniece.

blocking of small, shallow ditches), then several (at least two) layers of the material are established by deeply driving boards across the dam, and filling and packing peat between the boards (Vestarinen et al. 2014) (Fig. 10.24).

To maintain the desired water level, a spillway is established in the upper part of the wooden dam by sawing an approximately 1–1.5 m wide opening which is not too deep. The spillway must be wide enough not to avoid water flow obstruction, dam edge erosion and water flowing through the bottom of the dam (Bergmanis 2005). It is recommended to strengthen the dam bottom with peat (by creating a peat layer at the upstream part of the dam). Strengthening with branches, stones and sacks filled with peat is also recommended (Vestarinen et al. 2014). Different types of wooden dams – Fig. 10.25–10.30.

To fell trees necessary for the construction of dams, an agreement issued by the State Forest Service is required, if the average diameter of the stump exceeds 12 cm. Like other documents, it must be prepared well in advance, prior to the implementation of works. *See Chapter 6.3.*

Possible mistakes and failures

If sufficient waterproofing under the lower log or board is not ensured, water gradually erodes the ground and flows under the dam. In such cases the dam is not functioning, and it cannot be restored.

If log or board dams are constructed and natural packing material (sphagnum, turf) is used, the dam sinks within 2–3 years and water starts flowing through it. In such a case, the waterproofing layer must be restored or plastic sheeting or other long-lasting artificial waterproofing materials must be used.

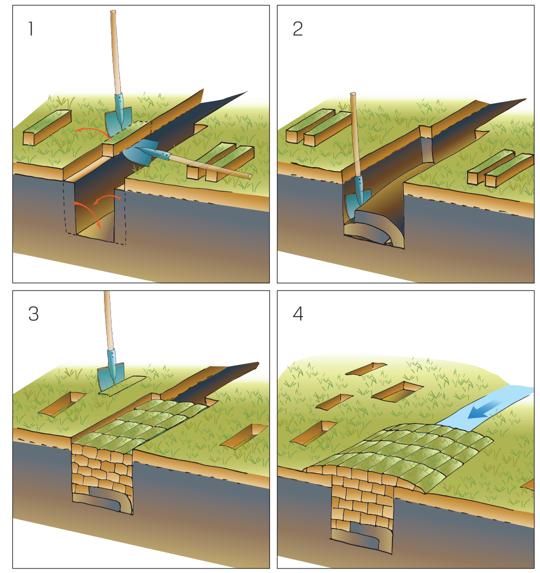

Fig. 10.36. The course manual construction of a peat dam. Such dams are suitable for small, narrow ditches where access with an excavator is difficult or impossible. Drawing: D. Segliņa (according to Anon. 2014a).

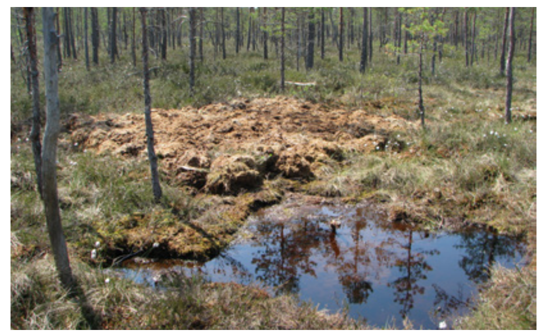

Fig. 10.37. Hand-built peat dam in Aklais Bog (in 2013). Peat has been dug out from the bog surface near the dam. Photo: A. Priede.

Fig. 10.38. Manually built peat dam in 2013 in Aizkraukle Bog on a small, almost overgrown ditch. The edges of the dam are reinforced with wooden piles. Photo: A. Priede.

Fig. 10.39. Recently installed peat dam, built with an excavator in Rožu Bog. The dam surface is higher than the bog surface, taking into account the compaction of peat. Photo: A. Priede.

Fig. 10.40. Construction of a peat dam with an excavator in Great Ķemeri Mire in 2006. First, trees along the ditch, which can interfere with excavator movement were felled. Then, a peat dam several metres wide was built by obtaining peat from the adjacent area, thus creating small ponds. Photo: J. Ķuze.

Fig. 10.41. A peat dam built with an excavator in Rožu Bog (in 2013). Photo: A. Priede.

Fig. 10.42. For the construction of the dam in Lake Melnais Bog, the peat was obtained from the bog surface near the dam, creating a shallow pond. The photo was taken a year after the installation of the dam. It is expected that in the longer term the depression will overgrow with quaking bog vegetation. Photo: A. Priede.

Wrongly chosen distances between dams cause the dam to dry out, decompose or erode, thus creating unforeseen repair costs.

The spillway can be too narrow, resulting in water flowing through not only the spillway, but also over the dam edges, thus eroding it. If such failure is found, the spillway must be sawn wider and slightly deeper, and the eroded edges of the dam must be repaired by strengthening it with logs or boards (Bergmanis 2005).

The dams must be sufficiently durable so that they are not washed away in precipitation-rich seasons or in spring when the surface run-off increases due to snow melting.

Dams of plastic and other artificial materials (Fig. 10.31–10.35). Most often, plastic piling dams (cor-

rugated walls) of different sizes are used in the same way as wooden dams. The main advantage of plastic materials is their durability and persistence. They are widely used in several European countries, for example, in Great Britain (Anon. 2014b), also in Lithuania. In Latvia they have not been used so far.

Peat dams. Peat dams are one of the most effective and cheapest methods for the rewetting of bogs. Peat dams can be built both manually (on small, narrow ditches) and using an excavator.

Manually, peat dams can be built on small ditches in sites which are difficult to access with an excavator and where only a few dams are necessary, thus the amount of work is relatively small (Fig. 10.36–10.38). It is advisable to perform the works in a low water period (usually from August to October), taking into account the conditions of the current year.

In the dam construction site, the layer with highly decomposed peat on the ditch edges is dug off. Layers of decomposed peat from the ditch margins are compacted into the ditch, gradually filling it up. Material is taken both from the edges of the emerging dam and the bog surface along the ditch. The dam must be higher that the ditch edges and compacted as much as possible, since the peat will sink over time. Lastly it is advisable to cover the dam with turf of living vegetation from the bog surface, thus stabilising the dam and enhancing its integration in the bog landscape.

When constructing peat dams with an excavator (Fig. 10.39, 10.40), peat must be well compacted, taking into account the gradual sinking of peat over time. Therefore, the initial height of the dam must be at least 0.5 m higher than the expected water level in the ditch (Ķuze, Priede 2008; Nusbaums 2008).

Principles of peat dam construction and the order of works are described in detail by Nusbaums (2008). Extensive experience has been obtained in Finland, which is also described in the guidelines (Vestarinen et al. 2014).

Usually the peat for dam construction is taken from the ditch edge. It is recommended to use peat from ditch edges upstream of the dam by widening the ditch and making a dam slope with the same inclination as that one of the ditch (Nusbaums 2008). It is not advisable to use peat from the ditch berms as it is heavily mineralised and has low water storage capacity. The use of berm peat makes the dams less persistent, they are easier to erode, and peat is difficult to compact.

Peat can be taken by creating small ponds near the new dam (Ķuze, Priede 2008), however one should take into account that the ponds will remain open for several decades and locally they will perform a draining function. A better alternative is the creation of shallow, artificial depressions of a larger area or obtaining peat from the bog surface. Shallow pits will overgrow earlier and become incorporated in the surrounding landscape (Fig. 10.41, 10.42).

To reduce the risk of washing out of the dam, a spillway tube can be inserted in its upper part (or on the edges) prior to the placement of the upper peat layer (Nusbaums 2008) (Fig. 10.44).

To stimulate the dam surface overgrowing with bog plants, it is recommended to use acrotelm with fragments of plant propagules for covering the upper

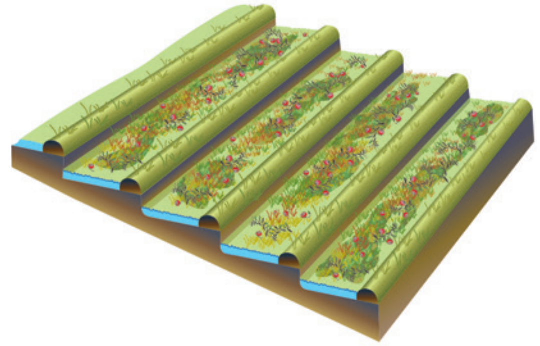

Fig. 10.43. Scheme of terraces. Drawing: D. Segliņa, according to Wheeler et al. (2002).

Fig. 10.44. Peat dyke (large dam) in Great Ķemeri Mire. The purpose of the dam is to keep the water level high in the extracted peatland upstream of the dam. To adjust the water level, a pipe is built in. Photo: A. Liepa.

layer of the dam. This would also stabilise the dam and decrease the risk of washout.

To prevent beaver damage (burrows) (if beavers are observed in the particular area), which can cause lowering of the water level upstream from the dam, the edges of the peat dams can be strengthened with metal sieves.

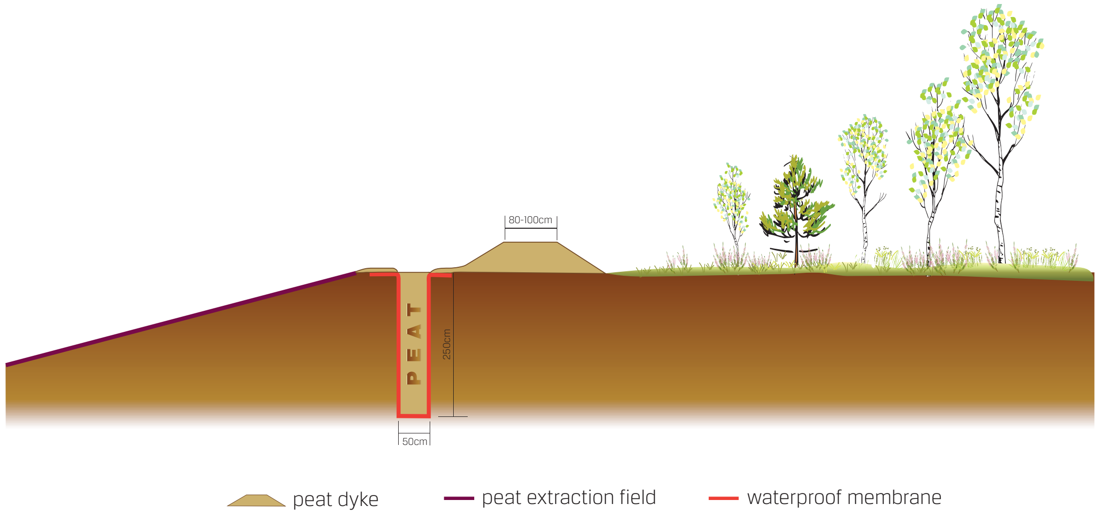

Fig. 10.45. Scheme of waterproofing wall. Drawing: D. Segliņa, according to Pakalnis et al. (2009), Jarašius et al. (2013).

Fig. 10.46. Waterproofing wall made from plastic sheeting, covered by the peat dyke along the outer edge of extracted peatland in Aukštumala Bog in Lithuania. Photo: M. Pakalne.

Fig. 10.47. A recently dug ditch in Aizkraukle Bog along the edge of the newly planned peat milling field and along the edge of the intact bog. To diminish the undesirable impact on the bog, the waterproofing membrane should be installed parallel to the ditch in the early stage of draining, prior to significant reduction of the water table in the planned peat extraction site. Photo: A. Priede.

Table 10.1. Comparison of various rewetting methods.

Method	Advantages	Disadvantages
Complete filling up of ditches	Drainage impact is completely eliminated. One-time action ensuring the complete elimination of ditch impact. Long-time monitoring and repair are not necessary.	Sometimes difficult to implement if the ditch does not have a berm and the ditch margins are overgrown with forest. On bog cupola slopes, secondary water flows can develop along the former ditch; then, additional costs are necessary for the establishment of perpendicular dykes to prevent this. Relatively high costs.
Wooden (log) dams	Natural material. Low material costs, if built from the timber obtained on site (additional costs, if plastic sheeting, geotextiles or other artificial materials are used). No transportation costs if materials are obtained on site. Relatively long-lasting. If correctly constructed, repair is not necessary. Such dams fit well into the bog landscape, and sometimes after several years are hardly noticeable.	In comparison with peat dams, greater water permeability is possible (requires proper compacting and isolation). Manual work with great work and time investment. Great investment of human resources - relatively high labour costs. Fairly high risk that dams are not waterproof; then repair or reconstruction is necessary.
Wooden (boards, plywood) dams	Natural material. Compared to the log dams, less labour investment. Relatively low material costs.	In comparison with the peat dams, greater water permeability is possible (requires compaction and waterproofing). Large investment of human resources – relatively high labour costs. Additional costs due to material preparation/processing and transportation. Materials should be transported into the bog (can be difficult to deliver to dam site where there are no roads). Relatively low durability; wooden materials decay, and then they must be replaced (repaired, resulting additional costs in the long term).
Plastic dams or dams of other artificial material	Long-lasting – repair is usually not necessary; low maintenance costs in the long term.	Relatively high material costs. Artificial material, does not fit into the natural landscape. If built just by manual work, requires relatively great investment of human resources and time. More efficient, if an excavator is used (in sites where it is possible to access); it improves the quality of dams, and the work can be done quicker. Materials should be brought into the bog (difficult to deliver to the dam site, where there are no roads).
Peat dams (built by hand)	Long-lasting. If constructed correctly, repair is not necessary in the coming years. Can be used in places which cannot be accessed with an excavator. Relatively low costs if used just for a few dams. Fits well in the landscape, overgrows with vegetation in a relatively short period.	Can only be used for narrow ditches. Relatively great investment of time and human resources. On ditches with a steep gradient the dams can be easily eroded if peat is not compressed enough or the dams are not properly built.
Peat dams (built with an excavator)	Long-lasting. If constructed correctly, repair is not needed in the coming years. The most cost-efficient solution in the case of a large amount of works. Fit well in the landscape; overgrow with vegetation in a relatively short time (especially if peat is obtained from the surface of the bog).	Cannot be used in areas, which cannot be accessed with an excavator. To ensure accessibility for the excavator, it is necessary to fell the trees near the ditches. It means additional costs, but it also benefits the bog restoration – the tree stand established due to drainage must be removed. If dams can be damaged by beavers, they should be strengthened with sieves. Can be washed out (if not built properly). Moderately high costs.

Possible mistakes and failures

- If the ditch base is dug into the mineral ground, water infiltration below the dam can occur, especially if peat used for constructing of the dam is not well compacted.
- If the peat used for dam construction is not well compacted, it can be washed out, especially in ditches with a large gradient and water flow, and if ditches are built by hand when peat cannot be compacted as efficiently as with an excavator.
- Ditch establishment should not raise the water level in surrounding lakes, especially in primary (relict) lakes with firm shores (mistakes are also possible if lake inflowing and outflowing ditches are not distinguished from natural water courses), thus changing their ecological condition (Urtāns (ed.) 2017, *Chapter 15.3.2*).

10.3.3.5 Creation of dykes

Creation of dykes can be an important restoration measure in bogs on slopes, where it is not always possible to achieve the rise of the water level by only ditch blocking. Terraces are established by creating dykes (low-lying walls, similar to large dams) perpendicularly to ditches to create an even water level. For the creation of dykes both peat (Fig. 10.44) and mineral soil can be used, depending on the characteristics of the site (Kozulin et al. 2010; Vestarinen et al. 2014). Dykes are also used in the post-harvested peatlands on slopes (Fig. 10.43). *See also Chapter 10.3.8.5.*

Fig. 10.48. Raised bog affected by drainage in the surroundings of Sārnate. Drainage has caused overgrowth with forest. By deforesting and filling up or blocking the ditches, restoration of the raised bog habitat is possible. Photo: A. Priede.

Fig. 10.49. Raised bog cleared from trees, simultaneously restoring the water level by blocking the ditches with peat dams. Soomaa Bog in Estonia in 2016. Photo: S. Ikauniece.

Fig. 10.50. Bog restoration site in Ādaži military training area (photo taken in 2014), where the water level is raised significantly. Trees were not removed and fall down gradually. Photo: A. Priede.

10.3.3.6 Waterproofing walls

Waterproofing walls are established along the outer edges of peat extraction sites (mainly peat milling fields) to reduce the drainage impact on the bog intact part. This solution was used, for example, in Aukštumala Bog in Lithuania (Jarašius et al. 2015), where in a length of about 1 km along the peat milling fields, up to a 3 m deep, narrow ditch was dug, lined with waterproofing membrane (plastic sheeting), filled up with peat. On the intact bog side, a peat dike was constructed parallel to the ditch (Fig. 10.45–10.46). However, the hydrological monitoring shows that the water level is still inadequate for a bog, although some improvements in the bog hydrological regime can be observed (Jarašius et al. 2013; Jarašius et al. 2015). The efficiency of waterproofing walls could be higher, if they are created at the same time when digging the first drainage ditches in the

Prior to bog habitat restoration, one must ascertain the land use type of the area (if it is a forest land and it is planned to restore a habitat, which is not a forest, a deforestation permit of the responsible authority is required). According to national regulations in 2016, deforestation in raised bogs was not permissible in bog habitat restoration as it is not considered a nationally protected habitat type. However deforestation for certain protected bog species (e.g. birds) could be performed. When planning deforestation, one must find out in what period the forestry activities are permitted and what the limitations are. Forestry activities in protected nature territories are usually not allowed during the bird breeding season from 15 March to 31 July. In micro-reserves and their buffer zones, specific regulations defining the permitted and prohibited activities must be followed. For example, some bird species for which those micro-reserves are established, start their breeding in February – in this case specific requirements of species conservation must be followed.

peat extraction fields, i.e. before the ditches have drained the adjacent intact bog (Fig. 10.47).

10.3.4 Removal of trees and shrubs

Trees and shrubs in raised bogs are removed to restore ecosystem functions and structure. Deforestation reduces transpiration through the foliage, diminishing the drainage effect and helps to restore an open bog (Fig. 10.48–10.49). Bog hydrological regime and expansion of trees are mutually related, therefore a comprehensive approach is necessary in bog restoration, and actions should be planned sequentially. If a significant rise of water level is expected when blocking or filling up ditches and the tree cover is not dense, one should already understand in the planning process whether the felling of trees is necessary and useful. Removal of trees improves the rewetting result and promotes faster recovery of the bog ecosystem, however it may cause additional costs. If the volume is large, the removal of trees can generate income that can be invested in bog habitat restoration. Depending on the site conditions, several alternatives should be considered.

Fig. 10.51. In an intact bog trees grow slowly – pines usually have rounded tops, curved branches. In the photo – Great Ķemeri Mire. Photo: A. Priede.

Fig. 10.52. The growing conditions improve under the drainage impact, thus the trees grow faster. Pines in drained bogs usually have pointed crowns and large increment (large distance between the branch whorls). In the photo – Raganu Mire. Photo: A. Priede.

When planning tree removal in a raised bog, several aspects must be taken into account. If there are no drainage ditches and there is no information (from old maps or other sources) that there has been any, and the growth increment of trees is low, than most probably tree establishment is a natural process or promoted by climate change, or other external factors which cannot be eliminated locally. Enhanced overgrowth with birches may also be enhanced by burning. If bog burning occurred in summer, when the bog is dry, but there is no drainage impact or it is insignificant, then the expansion of birches can be considered as a relatively short-term succession stage.

Tree invasion in bogs is also promoted by climate change or natural climate fluctuations, thus in the long run it is not possible to prevent overgrowing by removing the trees. If the establishment of trees is promoted by eutrophication caused by airborne deposition, removal of trees will have a temporary effect. The real causes of short-term changes are usually difficult to determine without thorough research.

Prior to bog habitat restoration, one must ascertain the land use type of the area (if it is a forest land and it is planned to restore a habitat, which is not a forest, a deforestation permit of the responsible authority is required). According to national regulations in 2016, deforestation in raised bogs was not permissible in bog habitat restoration as it is not considered a nationally protected habitat type. However deforestation for certain protected bog species (e.g. birds) could be performed. When planning deforestation, one must find out in what period the forestry activities are permitted and what the limitations are. Forestry activities in protected nature territories are usually not allowed during the bird breeding season from 15 March to 31 July. In micro-reserves and their buffer zones, specific regulations defining the permitted and prohibited activities must be followed. For example, some bird species for which those micro-reserves are established, start their breeding in February – in this case specific requirements of species conservation must be followed.

Felling of trees in raised bogs in Latvia is still a rare practice. It was carried out in 2007 in Janišu-Dainas Bog in a 4.1 ha area (Reihmanis (ed.) 2011), in 2013 in Raganu Mire – in a 0.5 ha area (felling residues were collected and burnt on site). In Skalu Bog, trees were felled twice – in 2015 in a 5 ha area (trees were left dispersed), and in 2016 in a 10 ha area (tree tops were gathered and burnt, trunks were left dispersed) (M. Kalniņš, *pers. com.*). In 2015 in Dūmiņu Bog – in a 28 ha area (felled trees were collected and burnt on site (H. Hofmanis, *pers. com.*)). In 2017, the largest clearance of trees in a heavily drained bog so far is planned within a LIFE project HYDROPLAN (LIFE10 NAT/LV/000160) in Ķemeri National Park.

Restoration of an open bog is difficult in areas which are severely drained and thus overgrown with forest, or in sites that are afforested and have lost the features of a raised bog. In Latvia there is almost no experience in restoring such heavily degraded bog areas, however the experience elsewhere in Europe, for example, the results of the LIFE project "Restoration of raised bogs in Denmark with new methods" (RERABOG) in Denmark (Risager 2009), shows that bog recovery after clearing the tree layer is slow. Most likely, the slow regeneration is also affected by the high landscape fragmentation that hinders the establishment of target species.

In Latvia, the highest priority in restoration should be given to slightly affected bogs, in which the structures and complex of typical bog species are still present. Such bogs are relatively easy to restore with the high probability of a good outcome. Along the edges of drained bogs overgrown with forest, an alternative could also be the stabilisation of the water level without the removal of trees and maintaining the area as bog woodland.

When felling the trees, it is advisable to preserve only the old pines. Usually they can be identified by a rounded top and curved branches (Fig. 10.51–10.52). The annual growth ring pattern of the old bog pines is a kind of "nature museum" storing records of the climate and moisture changes over a long period of time, which may be caused both by natural and human-made factors (*see Chapter 15.3.7.1*). However, an open, wet bog is more valuable for the conservation of the typical bog species, thus there is no reason to leave too many trees when planning the restoration activities. Pines in the bog are important for insects, such as dragonflies, and birds. However, it is enough to preserve some old pines for this purpose.

Trees can also be removed without rewetting, creating areas suitable for the breeding of bog birds (*Tringa glareola*, *Pluvialis apricaria*). In such cases, the best option is to collect all the felled trees. If it is not possible, felled trees including their crowns, must be carefully delimbed and left dispersed. It is important that delimbed branches and parts of the trees do not form a layer of felling residues which limits the ability of ground-breeding birds to view the surroundings. The necessity to remove the felled trees or leave them in the bog is sometimes an ambiguous issue, as it has several aspects. When considering the possibilities to restore an open bog and habitats suitable for bog birds, the best option is to remove the felled trees. However, to reduce carbon emissions, the best option would be to leave felled trees in the bog where the organic material is "stored" in the peat, and not released into the atmosphere.

The results of bog restoration in Ireland and Great Britain (Anderson 2010) show that bog vegetation recovery in sites where felled trees have been left on the ground is slower due to shading. Whereas, when felled trees are left on the ground, the transpiration from the bog surface is lower, thus reducing the water level fluctuations, especially during the summer drought period. Leaving the trees on the ground may also delay the establishment of young trees, if the water level has not yet stabilised after rewetting (which usually happens over a period of years) (Anderson 2010). The branches lie on the ground and while decaying, serve as shelter for the better establishment of sphagnum mosses.

It is essential to plan the sequence of works. First, trees must be felled, and afterwards the activities related to rewetting can be performed. Trees must be removed from the bog in winter when the ground is frozen – it is important not only for practical reasons, but also to prevent damage of the bog ground, to avoid the creation of deep tracks which can later act similarly to drainage ditches. Felled trees may also be used in the construction of log dams on ditches and log roads to ensure the movement of the excavator across swampy ground.

10.3.5 Control of Shoot Regrowth and Young Trees

It is important to construct dams or fill up the ditches as soon as possible after tree removal, otherwise rapid establishment of young trees and sprout regrowth can be expected. Water level stabilisation usually takes several years, thus during the first years the young shoots of felled birches can grow intensively. However, if several years after the rewetting and removal of trees, there are many young trees and a dense cover of young shoots, it is most likely a sign of unsuccessful restoration. If optimal moisture conditions are achieved, then the capability of trees to survive is low and a dense tree stand cannot establish. If rewetting is successful, but the young trees and shoots spread rapidly during the first year, they will most likely die off as the water level rises. Similarly to in intact bogs, the survival of trees may only be expected on micro-relief elevations.

In cases of unsuccessful rewetting (optimum water level is not restored and drainage-caused water fluctuations not prevented), recently established trees and shoots can be cut or weeded out. However, this will have a temporary effect. The only long-term solution is elimination of the technical mistakes in rewetting.

10.3.6. Removal of Trees and Shrubs without Rewetting

Removal of trees and shrubs in the bog without rewetting is only worthwhile if a typical species pool has persisted but rewetting is not possible (for example, excessive drainage has been carried out in the surrounding area having an effect on the bog, and local actions will not ensure success; it was not possible to reach an agreement with landowners, etc.). Removal of trees can be carried out in bogs that are recently invaded by trees, but where there is no significant drainage impact. This will help to maintain an open bog landscape, mainly as a habitat for birds. Tree removal will also decrease transpiration, creating more humid conditions. However, if the excessive establishment of trees results from natural succession or climate change, and there is no drainage impact or it cannot be prevented by rewetting, tree removal will only provide a short-term effect, but the functions of a bog ecosystem will not recover.

10.3.7 Removal of Dwarf Shrubs

In raised bogs affected by drainage, dense stands of dwarf shrubs, especially *Calluna vulgaris*, are common. Therefore the dominance of dwarf shrubs can be used as one of indicators of drainage impact. In such bogs the most important action is rewetting, i.e. restoration of ecosystem functions rather than management of structural elements. To achieve a "proper" cover of dwarf shrubs in the raised bog, the most appropriate action is to restore the water level, thus making the conditions unsuitable for the dominance of dwarf shrubs (Ķuze, Priede 2008; Priede 2013). In Latvia, bogs have not been used for mowing or grazing, as it happens, for example, in the British Isles.

Heath management experience shows that mowing promotes vegetative regeneration of *Calluna vulgaris* (Laime (ed.) 2017, *Chapters 17, 18*), thus the mowing could result in the development of vigorous, dense *C. vulgaris* stands. Thus mowing or grazing of dwarf shrubs in drained raised bogs is not efficient in improving the conservation status of the bog habitat and it will most likely have a temporary effect.

10.3.8 Renaturalisation of Post-harvested Peatlands

10.3.8.1 Justification of necessity

According to the regulatory enactments in Latvia (Cabinet Regulation of 21 August, 2012, No. 570, on

Fig. 10.53. An abandoned peat milling field in Cena Mire abandoned approximately 25 years ago. Due to substrate dryness, establishment of bog vegetation is not possible. Only a few highly tolerant species have established. Area gradually turns into sparse birch-pine woodland. Photo: A. Priede.

Fig. 10.54. Successful recovery in an abandoned peat milling field in Estonia. Within approximately 20 years, vegetation similar to transition mire dominated by sedges and sphagnum mosses has developed. Photo: A. Priede.

the procedure of mineral deposit extraction), after-use options of peat extraction sites are defined: renaturalisation (restoration of the mire-specific environment), agriculture (for example, berry or biomass plantations), forestry, water bodies, recreation, and others.

Peat extraction decreases the bog area – both locally, directly decreasing the area of the particular bog and creating a deteriorating impact on the adjacent wetland areas, and at the national scale. In areas directly affected by peat extraction, the EU protected bog habitats 7110* *Active raised bogs* and 7120 *Degraded raised bogs still capable of natural regeneration* are completely destroyed. However, there is a chance after peat extraction to restore the bog functions and habitat structure. The aim is not to achieve complete recovery of the intact raised bog, since it is not possible, at least not in a relatively short period; the aim is to improve a significantly degraded ecosystem by restoring its functions.

Renaturalisation of bogs is the only option allowing restoration of the areas used for peat extraction, at least partially, thus compensating the nature values lost due to gaining economic benefits. For this reason bog renaturalisation should be considered as a priority among the after-use options in extracted peatlands, especially in regions with few bogs and in areas neighbouring with protected nature territories. Renaturalisation is the best way not only from the point of view of partial compensation of the post-harvested peatland area, but it also reduces other undesirable effects – reduces carbon dioxide emissions, eliminates or at least substantially reduces the fire risk of dry peat fields, as well as reduces the risk of invasive plant species spreading.

Bogs, in which peat has been extracted using a block-cutting method, or post-harvested milling fields where the bog vegetation has recovered, can be classified as habitat type 7120 *Degraded raised bogs still capable of natural regeneration* (Auniņa 2013b, 2016). The other areas of post-harvested bogs cannot be interpreted as the habitat type 7120 *Degraded raised bogs still capable of natural regeneration*, such as dry milling fields dominated by bare or sparsely vegetated peat, peat fields without mire vegetation or dominated by nitrophilous vegetation, agricultural crops, etc. as well as cut-over bogs, where the mineral ground layer has been reached, thus the conditions are not suitable for raised bog recovery. However, even in such severely degraded bogs it is worth trying to improve the situation as long as the abiotic conditions are suitable for the recovery of bog or other type of wetland.

Peat milling usually takes at least two to three decades, however, during this period the knowledge about the best solutions and possibilities in Latvia may change. The recommendations provided in this edition are considered as current, based on the latest knowledge and recent research of extracted peatlands. This book provides an insight into two after-use options – restoration of the bog ecosystem and creation of water bodies. Other options have not

been analysed, such as afforestation or establishment of agricultural lands, as they do not promote the recovery of natural or semi-natural self-sustaining, functioning ecosystems.

10.3.8.2 Can post-harvested peatlands self-regenerate?

Mire habitats in post-harvested peatlands can self-regenerate without targeted actions (e.g. planting, hay transfer, sowing seeds of target species, etc.) if the water level rises due to ditch blocking, beaver activity or cessation of pumping out the water. Such examples in Latvia can mainly be observed in long abandoned peat block-cutting areas which are flooded. In such cases, the lowest elevations, so-called "trenches" – block-cut peatlands, have overgrown with bog characteristic vegetation (sphagnum mosses, plants of sedge family, etc.). Successful recovery of vegetation in abandoned peat milling fields is less common – the establishment of wetland vegetation is hindered by a functioning drainage system (Fig. 10.53). If the ditches and sub-soil drains in the peat milling fields are blocked, the outcome may be similar to purposefully rewetted milling fields – it can lead to successful recovery of the wetland ecosystem (Fig. 10.54), although this does not always mean that the "new habitat" will comply with any of the EU protected habitat types.

10.3.8.3 Planning of renaturalisation

The choice of after-use options in post-harvested peatland depends on several factors: hydrogeological and topographical conditions, the surrounding landscape and the intensity of land use, the opinion of the land owner or manager, etc. In post-harvested peatland, if there is a residual peat layer and presence of mire-characteristic species, and the area is not entirely overgrown with forest or transformed into another land use type, restoration of bog-specific conditions, processes, and vegetation is still possible. In some cases, a better and more realistic solution is the creation of water bodies, which can also be areas important for nature diversity.

When planning the after-use of post-harvested peatland, it should be foreseen, which peatland sections will be exploited and abandoned earlier – these areas will require restoration or other rehabilitation measures sooner than others. Renaturalisation always includes construction works, i.e. installation of hydro-technical buildings for which, according to the national regulatory enactments, a technical design must be developed (Šnore 2013).

In post-harvested peatlands, the catotelm is uncovered – the "dead" peat layer with characteristics different from the acrotelm or the "living" bog surface (e.g. water accumulation capacity). Most probably, the conditions that can be restored in post-harvested peatland with a residual acidic bog peat layer will more resemble fens or transition mires than bogs in terms of water chemistry and nutrient availability. As a result, the vegetation in the early succession stages will be, most probably, dominated by species of poor fens and transition mires. Many of the raised bog plants can also establish and survive in such conditions that differ from the environment of typical bog. However, it is not correct to assume that the restoration of raised bog is possible in extracted peatlands. Restoration of the *raised* bog, not only restoration of the bog vegetation, but also the cupola, micro-relief, functions and processes, is not possible there or may only be achieved within several hundreds or even thousands of years.

When planning renaturalisation, several issues must be assessed that might have a crucial role both in practical implementation and the expected outcome.

Peat extraction technique. The peat extraction technique that has been applied in the particular site determines both the degree of anthropogenic impacts and the success of restoration or natural recovery. Generally, two methods – block-cutting and peat milling are used. The block-cutting method creates a relatively local impact on the hydrological regime of the bog, while peat milling, which has prevailed since the mid-20th century, causes vast drainage impacts (*see Chapter 10.1.5*).

Water level and its fluctuations. In most cases, the water level in peat milling areas is low, sometimes even >0.5–1 m below the peat surface, and it has great seasonal fluctuations. In summer, the peat surface becomes very dry and during the day it may heat up a lot. Large homogeneous, heavily drained areas are also subjected to wind and frost erosion (Campbell et al. 2002). In such conditions only some plant species tolerant to a wide range of ecological conditions can survive, thus the bog vegetation does not recover within a longer period of time. According to practical experience, the establishment of sphagnum mosses is only possible in sites where the water level is at the same level as the peat surface or, when seasonally fluctuating, does not fall lower than ~ 0.3 m below the peat surface (Konvalinková et al. 2011).

Landscape context. The total area and configuration of the peatland to be restored, as well as the landscape pattern (forests, agricultural lands, natural wind barriers, etc. in the surroundings) affect the microclimate and the potential wind erosion. Microclimate will significantly affect the success of bog vegetation establishment. The more micro-niches, shelters, depressions present in the area, the better the success; moreover, the diversity of micro-niches will also ensure a greater diversity of species. Due to the lack of micro-niches it is difficult to achieve good restoration results in large, homogeneous areas, which are exposed to wind erosion, greater evaporation, lack of shade – factors that increase severe temperature fluctuations in summer. The peat surface is dark, thus in summer it heats up, substantially hindering the establishment and survival of plants. Freezing and thawing in winter, which are more typical in large, open areas, cause peat surface deformations, decreasing the success of vegetation stabilisation.

Upon planning the renaturalisation, both the post-harvested peatland area and the area in the process of extraction must be evaluated together. The larger the continuous peat extraction area, the greater the fragmentation effect – the viable plant propagules have to travel over larger distances to reach the potential sites of establishment. Therefore extracted peatlands located next to intact mires or surrounded by other mires have a higher recovery potential because the donor areas rich in seeds and spores are closer. In cases when the area to be restored is surrounded by other types of habitats (e.g. dry forests or arable lands), the potential for mire recovery is considerably lower, and the recovery may be much slower.

Type of drainage during peat extraction. During peat extraction, the area is drained both by open ditches and by sub-soil drainage. Additionally, the excessive volume of water may be pumped out. After the cessation of peat extraction, areas drained with ditches and sub-soil drainage might be suitable for mire restoration (if it is possible to raise the water level up to the peat surface). In areas where water has been regularly pumped out, the best solution after peat extraction would probably be the creation of a water body. The creation of water bodies is usually also the most suitable type of after-use in bogs which have developed by overgrowing of lakes (Šnore 2013).

Terrain peculiarities of the area (topography). Shallow water areas and wet peat can only be created on flat terrain. On sloping peatlands, restoration of the hydrological regime without changing the surface is not possible. In Canada and Western European countries, in such cases the construction of dykes is recommended (*see Chapter 10.3.3.5*). If it is not possible due to technical or financial limitations, another type of after-use should be chosen.

Properties of the residual peat layer. The residual peat type (fen peat, bog peat, transitional type) determines the vegetation composition of the mire to be restored. The physical and chemical parameters of the residual peat layer – pH, conductivity, degree of peat decomposition, and others – influence the expected composition of the vegetation. Peat type and pH can be used as simple indicators, which are easy to determine. The result can also be significantly affected by, for example, the bioavailable phosphorus content and other factors.

Establishment of bog plants and sphagnum mosses can be expected if the residual peat is acidic (pH 3–5). In post-harvested peatlands, although the pH is usually higher than in an intact raised bog, the conditions are still suitable for the majority of raised bog species.

In slightly acidic to neutral (pH > 5–7) peat, bog species are not able to establish. In such cases, vegetation of poor fens will develop, most likely, sedge, rush and reed vegetation. Rarely, if the bottom of the bog is rich in carbonates and water pH is slightly acidic to neutral (pH > 5.5), the vegetation of alkaline fens can establish (*see Chapter 15.3.13.5*). Such environment is not suitable for typical bog species (*Sphagnum* spp., *Oxycoccus* spp., *Eriophorum vaginatum*, etc.), or their cover will be insignificant. In such

Fig. 10.55. Bog vegetation cannot recover in peat pits ("trenches") which are dry. The severely drained, partially block-cut bog has overgrown with forest, the upper layer of peat has decomposed. In this situation, restoration of the bog is almost impossible. Sloka Bog. Photo: A. Priede.

Fig. 10.56. Successful renaturalisation in a former block-cutting area in Great Ķemeri Mire several years after the rise in water level. Depressions ("trenches") have overgrown with a sphagnum blanket, quaking bog vegetation has developed. Many trees have died off within several years, opening gaps in the formerly closed forest cover. Photo: A. Priede.

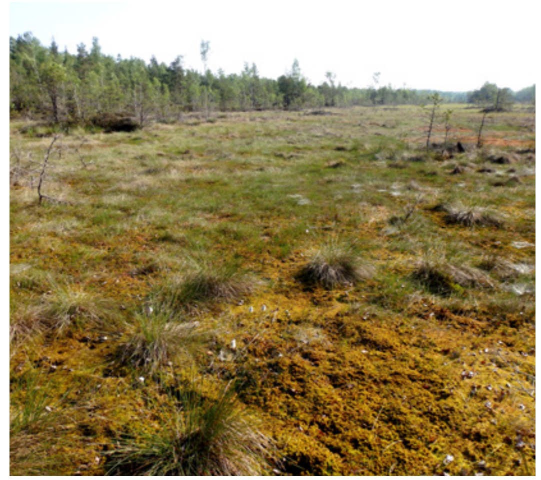

Fig. 10.57. The former block-cutting peatland in Medema Bog, where peat extraction was ceased in the 1950s. Nowadays the vegetation largely resembles an intact bog and it is dominated by sphagnum mosses and cottongrasses. Landscape is patchy with drier island-like rises. Photo: L. Grīnberga.

cases, small-sedges (*Carex flava* group, *C. flacca*, *C. panicea*) usually prevail, while wetter places are dominated by *Phragmites australis*.

Understanding the features of the residual peat is of particular importance, when it is planned to promote vegetation recovery by sowing or planting wetland species. Introducing the species unsuitable for the growing conditions would most probably fail.

Depth of the residual peat layer. In Latvia, in the second half of the 20th century, the minimum peat layer thickness to be left was considered 0.3 m, although nowadays the regulatory enactments do not specify this. However, since the bottom of the bog is usually uneven, the residual peat layer thickness can vary a lot. The thinner the layer, the greater the impact of the groundwater, and it is more difficult to achieve successful establishment of the desired bog or fen vegetation. Sites with a shallow residual peat layer and sufficiently high water level, most likely, will be occupied by reeds. In sites with a thicker residual peat layer, the physical and chemical properties of waters are determined mainly by the chemical composition of precipitation.

If the peat layer has been extracted to the bottom, especially, if sandy deposits lying beneath the peat are uncovered, this can substantially decrease the water holding capacity. In such cases, if the sand bottom has been exposed in a larger area, it is recommended to cover the areas with severely decomposed peat prior to increasing the water level, as this would improve the water holding capacity

Fig. 10.58. In a peat milling field abandoned more than 20 years ago, the highly decomposed peat surface was removed and in wet depressions Sphagnum mosses were piled up, from where it can spread further. Photo: A. Priede.

(Quinty, Rochefort 2003).

Properties of mineral ground. The type of mineral ground and its water permeability has an important role in water retention. If ditches reach the mineral ground, as it usually occurs in peat extraction sites, raising of the water level may be difficult to predict or even be unsuccessful (Rehell et al. 2014). On permeable grounds (sand, gravel), the surface water runs away through the bottom of the ditch. On a poorly permeable bottom (clay, limestone, dolomite), water level restoration can be successful. Prior to selecting the after-use methods in a particular post-harvested peatland, it is recommended to determine the properties of the mineral ground and its water holding capacity, and to test the possibility to raise the water level in a smaller section of peatland. If the hydrological restoration test fails, it is better to

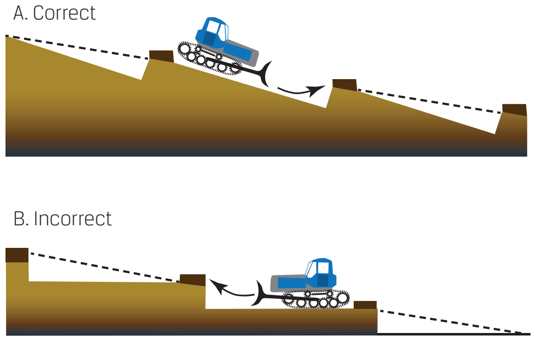

Fig. 10.59. Preparation of peat surface – creation of terraces and dykes. Drawing: D. Segliņa, according to Quinty, Rochefort (2003).

Fig. 10.60. A dyke built of peat in a post-harvested peatland on slope. The photo is taken in a restored post-harvested peatland in Germany. Photo: K. Lapiņš.

choose another type of after-use (Nusbaums 2013a).

The result is also affected by bedrock properties – mainly the composition of mineral substances in groundwater and how close it is located to the "new surface" of the extracted peatland. If the mineral ground is carbonate-rich, groundwaters will be calcareous, creating conditions suitable for the development of alkaline fens.

In peatlands which have developed after the overgrowing of lakes, gyttja (sapropel) layers are quite common. Gyttja is poorly permeable permeable, however able to hold water, that to some extent can compensate peat layer desiccation during

Fig. 10.61. In Great Ķemeri Mire in the former peat extraction site, the road has been used as a dam in order to increase the water level, by raising its surface. The water level is regulated by a culvert. In the photo – the dam during construction works in 2006; the culvert has just been installed, so the water level has not yet risen. Photo: A. Liepa.

periods of drought (Malloy 2013). The presence of gyttja layers on the bottom of the peatland may most likely promote the restoration of hydrological conditions optimal for bog.

When was peat extraction ceased (finished) and what is the present success of vegetation recovery? This criterion refers to those post-harvested peat extraction sites where no restoration measures have been carried out after the cessation of peat extraction. In sites where mire vegetation is recovering itself or moisture conditions are optimal for its recovery, active intervention is not necessary (Nusbaums 2013a). Prior to the planning of works, a site assessment is always necessary, considering the target to be achieved (open bog areas, habitats suitable for particular species, etc.), and, depending on the target, one can plan specific actions – such as hydrological restoration, removal of trees, and other.

The best option is to carry out the restoration measures immediately after the cessation of peat extraction. The longer the area is abandoned, the more the peat changes its properties. In turn, when the peat gets decomposed, its water accumulation capacity significantly decreases (Konvalinková et al. 2011).

10.3.8.4 Renaturalisation of block-cutting post-harvested peatlands

Block-cutting in peat extraction does not require

Fig. 10.62. Diverse micro-relief allows the establishment of plants characteristic both for a wet and drier environment. As a result, a diverse vegetation mosaic can develop. In the photo – peat milling fields in Salaspils Bog, abandoned in the 1990s. Drainage ditches criss-crossing the area do not function anymore, thus the peat milling fields gradually overgrow with bog plants. Photo: L. Grīnberga.

Fig. 10.63. Uneven micro-relief approximately 50 years after the abandonment of the block-cutting peat extraction area in Labais Bog. The small elevations are overgrown with *Pinus sylvestris* and *Calluna vulgaris*, in depressions there are *Rhynchospora alba*, *Sphagnum cuspidatum* and *Warnstorfia* spp. In periodically flooded depressions, rare species *Lycopodiella inundata* can be found on bare peat patches. Photo: A. Priede.

drainage of large areas, so usually the peat quarries ("trenches") have filled up with water, overgrown with a sphagnum blanket, reeds and other wetland plants, while the ridges between the "trenches" have overgrown with trees and dwarf shrubs. In such areas non-interference is the best option. If "trenches" are dry (Fig. 10.54), then it must be assessed whether the water level can be increased – whether the area is drained by ditches, and whether they can be blocked by raising the water level, thus ensuring bog-specific hydrological conditions (Fig. 10.56). Sometimes the conditions suitable for bog species have gradually recovered themselves after the cessation of peat extraction (Fig. 10.57).

10.3.8.5 Renaturalisation of peat milling fields

Surface preparation. The first step in the renaturalisation of a harvested peatland is the preparation of surface. Accurate topographic measurement (levelling) is important in order to properly plan the result of rise in water level. In recent years, surface models obtained with remote sensing are also used for this purpose (Rydin, Jeglum 2013).

If the peat surface has been dry for a long time, the upper layer of peat decomposes, and its water accumulation capacity significantly decreases. Thus the best option is to restore the post-harvested peatlands as soon as possible after peat extraction, while the properties of the upper level of peat have not changed. Prior to rewetting, surface levelling must be performed. If the peat fields have been abandoned for more than 10–20 years, prior to rewetting it is recommended to remove at least a 10–20 cm layer (Fig. 10.58) and smooth the peat surface.

In overgrown areas, first, trees and shrubs must be removed so that it does not interfere with the movement of equipment, does not increase the evaporation from the bog surface and does not hinder the vegetation recovery after rewetting (Rochefort, Lode 2006). Afterwards, the peat surface must be removed (if renaturalisation is not performed immediately after the cessation of peat extraction). It can be used in dam construction or filling up of ditches.

Obtaining of the desired water level in the entire target area without the surface transformation is only possible in flat areas. If the bog is located on a slope, water level retention can be achieved by the construction of dykes (Fig. 10.59) (*see Chapter 10.3.3.5*). The dykes can be built both from the mineral soil and peat (Fig. 10.60–10.61). It is important that the surfaces of the terraces between the dykes are flat, rather than sloping (Quinty, Rochefort 2003) (Fig. 10.59), otherwise it will not be possible to achieve raising of the water level in the entire area. The dykes must be durable enough not to get washed away. In the upper part of the dams, similarly to peat dams, a spillway is established (with a tube or fixed channel) regulating the water level so that it would not be too high, as well as to prevent washouts.

The location of dams, depending on the slope inclination, can be both parallel and grid-like, and, it is recommended to encourage their overgrowth with mire vegetation for their strengthening (for example, by using turf).

Diversification of the micro-relief. A homogenous environment hinders the formation of species diversity due to a lack of ecological niches and makes the established plants vulnerable to drought and frost, therefore they have a low survival rate. Thus in large homogeneous peat milling areas, prior to rewetting it is useful to carry out the diversification of the micro-relief – this will create various ecological niches for species (Price et al. 2002; Konvalinková (ed.) 2011) (Fig. 10.62, 10.63). The type and the amount of works must be planned for each site individually, since this will be influenced both by the characteristics of the particular peatland (flat or uneven, thickness of the residual peat layer), sediments on the mire base and its properties. In sites where the creation of water bodies is planned, prior to raising the water level it is advisable to create islets suitable for bird nesting (Šnore 2013) (Fig. 10.64).

If the layer of residual peat is thin, the creation of depressions may uncover water-permeable ground, thus reducing the water holding capacity. If there is such a risk, the priority is water level stabilisation and preserving the water holding capacity, rather than the diversification of micro-relief. It is advisable to cover the mineral ground with a peat layer prior to raising the water level, which could increase the water holding capacity. It is recommended first to test this method in a small area before the covering of large areas with peat (Quinty, Rochefort 2003).

Water level rise and blocking of drainage system. The next step is the blocking of drainage systems and raising of water level up to the peat surface or the creation of open shallow water areas. Water level can be raised similarly to in drained peatlands – by blocking or filling up the ditches. The number of dams to be installed depends on the slope inclination of the ditches (*see Chapter 10.3.2*). Usually, if the rise in water level is achieved in the entire target area, smaller drainage ditches within the peat fields clog and overgrow themselves in a relatively short period.

Usually, rewetting is not successful in large peat extraction areas, where renaturalisation has been planned in a separate, already harvested sector, while peat harvesting is still in process in other sectors; therefore drainage ditches, sub-soil drainage and pumping systems are still functioning. It is rarely possible to isolate the abandoned fields from the active peat extraction fields. In such cases, the water level can only be increased partially, by rewetting at least the topographically lowest parts, however, complete blocking of the drainage system can only be performed after peat extraction in the entire area. In the meantime, which may take a decade or more, the dry peat fields will partially overgrow with trees. By raising the water level, trees will gradually die off, and the removal of trees is not usually necessary.

In order to restore the mire vegetation, conditions where the water level is approximately on the same level as the peat surface are optimal. In seasons with high precipitation the area can be covered with shallow water. Sphagnum mosses can tolerate conditions where the water level in the summer season does not drop more than 0.3 to 0.4 m below the peat surface (Schouwenaars 1988; Konvalinková (ed.) 2011). Plants of bogs and transition mires, including sphagnum mosses, can only be introduced in places with an acidic, nutrient-poor environment.

If there are larger areas where water is deeper than 0.5–1 m, wave action prevents the formation of a sphagnum blanket. If the mineral ground is uncovered in the bottom of the water body and the water body is influenced by groundwaters, then due to the alkalinity and high concentration of dissolved minerals, the establishment of species typical for bogs and dystrophic waters cannot be expected. In such deeper water bodies, reeds and other water plants will most likely occupy the area (*see Chapter 10.3.8.6*).

Introduction of wetland plants. Introduction (planting, sowing, hay transfer) of bog plants accelerates the recovery of mire vegetation, thus also the peat accumulation process. However, introduction of the target plant species can only be performed when the preparatory works have been carried out, i.e. the conditions are suitable for the target species – the surface of the harvested peatland has been properly prepared and the water level is raised.

When planning renaturalisation, the following must be considered:

Is the introduction of wetland plants necessary and useful in the particular area? For faster recovery of a mire ecosystem, the introduction of target species is advisable. In Latvia, most probably it is not a priority, because the characteristic species will establish themselves in favourable conditions. However, one must take into account: the larger the continuous area of renaturalisation, the slower the recovery of mire vegetation. In large areas the introduction of mire plants is recommended and will hasten the achievement of the desired result.

What are the properties of the residual peat, i.e. which plant species are suitable for the conditions of the specific site? In acidic and slightly acidic sphagnum or transition mire type peat, the most important aspect is to achieve the formation of sphagnum cover. However, in a harvested peatland with a residual layer of slightly acidic to neutral, or alkaline transitional type peat, sphagnum mosses will most probably not establish due to unsuitable conditions. In such bogs sphagnum mosses, will perhaps establish later, when the successfully restored wetland has gone through the development stage of fen and transition mire.

The selection of plant species. Plant material should be chosen depending on the peculiarities of the residual peat layer in the area to be renaturalised. If the residual peat layer is dominated by acidic sphagnum peat, bog species must be chosen. If the residual peat layer is dominated by fen peat, then depending on the acidity, plant species of fens are more suitable (so the result of the peatland restoration will not be bog vegetation). In slightly acidic fen conditions suitable species are tall sedges (*Carex rostrata*, *C. lasiocarpa*), *Phragmites australis*, *Eriophorum* spp., *Juncus* spp. (*Juncus effusus, J. conglomeratus*). In alkaline fen conditions, small-sedges are suitable (species of *Carex flava* group), *Carex elata*, *Trichophorum alpinum, Cladium mariscus*, *Schoenus ferrugineus* (the last two species are rare and protected in Latvia) – *see Chapter 15.3.13*. When choosing the donor areas, it is advisable to take into account the dominant species, and the further sorting by species when gathering is not necessary.

Sphagnum mosses. In an acidic bog environment so-called peat-forming sphagnum mosses can be found. In the recommendations developed in Canada (Quinty, Rochefort 2003), so-called peat and hummock forming species having greater biomass have been recommended as the most suitable for planting: *Sphagnum magellanicum*, *Sph. fuscum*, *Sph. palustre*, *Sph. squarrosum*, *Sph. fallax*. *Shp. cuspidata* is a typical pioneer species colonising rewetted peat milling fields, however this species does not form the bog-specific hummock micro-relief, rather prepares the environment for the sphagnum species of later succession phases.

Herbaceous species. More suitable species for the restoration of bog vegetation are those that establish in the harvested peatlands themselves and that are frequently met in the intact raised bogs and transition mires: *Eriophorum vaginatum*, *E. polystachion*, *Rhynchospora alba*, *Carex rostrata*.

Species unsuitable for peatland restoration. It is not advisable to collect the plant material on long-term drained bog edges. Usually the drained bog margins are overgrown with fast-growing pines, while the ground vegetation is dominated by dwarf shrubs (*Ledum palustre*, *Calluna vulgaris*, etc.) and mosses typical for dry coniferous forests – *Pleurozium schreberi, Dicranum* spp., *Hylocomium splendens*, etc. Due to drainage, sphagnum mosses are absent. Species of drained bogs represent drier conditions, thus they are not the target species and are not suitable for transplanting into the restorable peatlands, as their survival ability in wet growing conditions is low.

Where and how to collect the material? When collecting the material for transplanting, one should not damage the donor area by destroying the vegetation, especially, if rare and protected plants or animals are present there. There will be an impact in any case, however it must not lead to adverse unfavourable, irreversible damage. Collecting the material by hand from the bog or bog woodland, overgrown ditches or similar sites does not usually create deteriorating effect.

In Latvia, the most realistic way of obtaining the replantable material is from the surface layer, which is removed in active peat extraction sites. Sphagnum mosses can also be obtained from the overgrown ditches on the edges of peat extraction sites, when cleaning of the drainage system is performed. Collection of material and transplantation can be carried out within the same bog area or the material can be transported to other areas. The difference will be in the costs, which increases when the distance between the donor area and target area is larger. Bog areas drained a long time ago and overgrown with forest, where sphagnum cover is absent in the ground cover, are not suitable for collecting the transplantable material. This also refers to areas proposed for peat extraction, if they are drained for a long time, thus the bog species suitable for renaturalisation have disappeared. Sometimes the sphagnum mosses and other bog plants have only been preserved in ditches.

The amount of the plant material to be collected is defined both by the size of donor area, and size of area to be renaturalised. So far the best results in restoring the harvested peat milling fields have been achieved in Canada. According to the methodology developed there (Quinty, Rochefort 2003), the ratio

> Renaturalisation of post-harvested peatlands by applying the Canadian method has been used in Estonia in several bogs with different success: in Hara Bog in an area of 102.8 ha, in Viru Bog (37 ha), in Rannu (41 ha), in Maasika (5 ha) and in Tässi Bog. For more on the Canadian method: see Quinty, Rochefort (2003).

of the area of the collection site to the area of the site to be restored is suggested as 1:10 to 1:12. So, the material collected from 0.1 ha in the donor site will be sufficient for approximately 1 ha of the area to be restored. In about the same proportion, material has also been collected and spread on the peat fields in the renaturalisation experiments in post-harvested bogs in Estonia, resulting in successful recovery of bog vegetation (Karofeld et al. 2015).

The plant material is collected from the bog surface in a mechanised way or by hand –depending on the aim, required amount and the amount that can be collected in the donor area without damaging it. For example, if the material is collected in an area where peat extraction is planned, plant material can num fragments are sensitive to surface wetness, because they are not able to accumulate water as larger sphagnum clusters do. The sphagnum cover can only establish if there are suitable hydrological conditions and the replanted plant material does not dry out.

One of the methods of replanting bog vegetation is the planting of turf. The turf from the donor area is cut or torn into approximately $1\ m^2$ large and 10 cm thick pieces and transported to the area to be recultivated (Silvana 2009). The larger the turf, the greater the probability of survival (Robroek 2007). An advantage of such method is the presence of micro-organisms and invertebrates that arrive in the restoration area together with the turf.

If peat milling field drainage ditches are shallow, without a significant impact on peatland, it is not planned to fill them up, and the water level reaches the peat surface, reintroduction of sphagnum turf or turf containing cotton-grasses (*Eriophorum vaginatum*, *E. polystachion*) or sedges (for example, *Carex rostrata*) is recommended. This will reduce evaporation from the open water and peat surface and decrease the ditch functions, accelerating their overgrowing.

Turf can be spread by hand, for example, by loading sphagnum in the truck and evenly spreading it with a pitchfork. In small areas hand work may be used, however, one should take into account that turf is wet and heavy. It can be moved in sacks or buckets, but a relatively large investment of human resources is necessary. If it is possible to achieve a relatively rapid rise of the water level by blocking ditches or ceasing water pumping, sphagnum turf must be spread prior to rewetting. If turf fragments lie on a dry peat surface for a longer time, its survival capacity decreases. In sites where the water level seasonally drops below the peat surface, hummock-forming sphagnum species, such as *Sphag-*

be collected (removed and piled) in a mechanised way by using the same types of machines as in peat extraction. However, in intact and slightly affected bogs such an approach is not advisable, and the material must be collected more carefully.

Methods of introducing bog plants. To hasten the recovery of bog vegetation, including sphagnum, two methods are used: (1) planting of turf, (2) spreading of sphagnum and other bog plant fragments. The advantages and disadvantages of both methods are compared in Table 10.2.

Planting of turf. Sphagnum mosses are able to spread from small fragments, however the efficiency of fragment dissemination depends on the moisture content of the surface and other properties. Sphag-

Fig. 10.64 A restored cut-over peatland filled up with water in the surroundings of Oulu in Finland. Islets are suitable for bird breeding, shrubs are periodically removed, preserving open habitats for birds. Photo: A. Priede.

Fig. 10.65 A water body in Labais Bog, processed with the block-cutting method. A mosaic of open water, reed beds and submerged water plant vegetation is suitable for various bird and insect species. Photo: A. Priede.

num magellanicum and *Sph. fuscum* (larger, greater water accumulation capacity) have a greater chance of survival than pioneer species, e.g. *Sph. cuspidatum* (Robroek 2007).

Dispersal of sphagnum fragments. In favourable conditions, sphagnum mosses are able to start growing from small, 1–3 cm long fragments, thus, in order to reduce the volume of the material to be collected, one can disseminate shredded fragments of sphagnum mosses and other bog plants. Such method has been shown to be effective in Canada (Quinty, Rochefort 2003), and has also been tested in some European countries, such as Denmark and Estonia (Risager 2009; Karofeld et al. 2015). The dispersal of sphagnum fragments, especially in larger areas, is efficient by using agricultural equipment designated for the spreading of manure. It simultaneously shreds and evenly spreads the sphagnum material.

After dispersing, the sphagnum material is threatened by desiccation (due to low water level and wind) and frost erosion. Thus survival can be significantly increased by creating "shelters", which diminish the temperature fluctuations. The authors of the method adopted in Canada recommend the use of straw. The sphagnum layer is covered with a thin straw layer immediately after the spreading of sphagnum fragments. In post-harvested peatlands partially overgrown with trees and shrubs the solution for improving the survival of replanted sphagnum could be the removal of trees prior to the rise of water level by leaving the branches on site. Felling residues would partially replace the sphagnum "shelters", protecting them from drying out. Similarly the branches of the felled trees and mown dwarf shrubs could be used from the recently prepared peat milling fields. Application of branches instead of straw has not been tested yet, thus it is recommended to test it prior to implementation in larger areas.

Ideally, the plant fragments are spread on moist peat shortly after the rise of the water level. However, if plant material is dispersed by machines, movement over the peat field can be difficult due to ground wetness. Therefore sphagnum should be spread prior to the increase of the water level, and the water table must be raised as soon as possible after the spreading of plants. To diminish the drying out of mosses and plant roots and to increase their survival capacity, it is better to spread the materia in autumn. Mosses grow throughout the frostless and snowless period – this will ensure that some of the fragments are already stabilised by the next vegetation season.

10.3.8.6 Creation of water bodies

Creation of water bodies is one of the after-use options of harvested peatlands suitable for the areas that are extracted with the block-cutting method or by extracting a deep peat layer with water pumping.

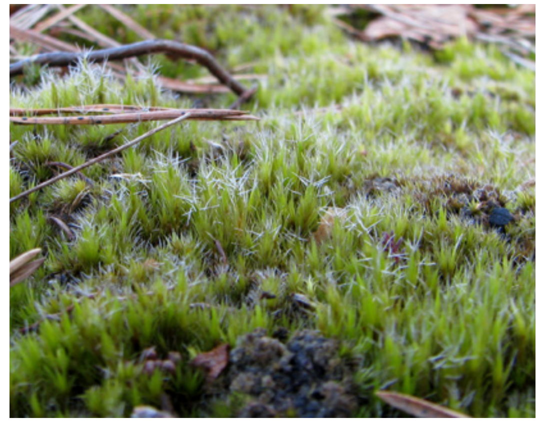

Fig. 10.66. *Campylopus introflexus.* Photo: A. Priede.

Fig. 10.67. *Aronia prunifolia.* Photo: A. Priede.

Possibly, the creation of water bodies is the most suitable after-use option for post-harvested peatlands that have formed by overgrowing of the lake (Picken 2006; Šnore 2013). When water pumping is ceased, such areas fill up with water.

Water bodies (Fig. 10.64–10.65) are also a suitable after-use option in areas where the peat layer has been extracted to the mineral ground. In such cases, the water body is predominantly fed by groundwaters and have a high mineral content, high pH and chemical properties that are not characteristic for dystrophic bog waters (Kļaviņš et al. 2011). However, peat extraction reaching the mineral ground was practised a relatively long time ago, in around the mid-20th century. During the last decades at least a 0.3 m deep peat layer has usually been preserved. On average, it is even deeper, commonly around 0.5–0.6 m, as the bottom below the peat deposits is uneven (Šnore 2013).

If water bodies are deeper than 0.5–1 m on average and occupy areas of several hectares, the recovery of bog vegetation cannot be expected. If the

Table 10.2. Overview of renaturalisation methods in post-harvested peatlands.

Method	Advantages	Disadvantages
Planting of sphagnum turf	Greater chances of sphagnum survival and other bog plants than by spreading of shredded plants. The chance of plant survival is relatively high, as the root system is not severely damaged. Turf contains micro-organisms, which are introduced along with the turf, thus contributing to the recovery of the wetland ecosystem.	High investment of work (dispersion must mostly be carried out by hand). It is not possible to cover the surface evenly, thus the cover is fragmentary; part of the turf can desiccate and perish.
Dispersal of sphagnum fragments	In comparison with turf, the material is easier to collect (can be collected and shredded in a mechanical way). Equipment for manure spreading can be used, no specialised equipment is necessary.	Sphagnum fragments are more sensitive to drying out than turf (drying out is reduced by covering with straw). Lower chances of survival than by planting of turf.

waters have contact with the mineral ground, thus having a high mineral content, the conditions are unsuitable for sphagnum mosses. Development of sphagnum blankets is also impossible in dystrophic waters, if the water body is large and deep – the establishment of sphagnum is hindered by wave activity.

If it is decided that a water body is the most suitable after-use option for the particular site, it is useful prior to raising the water level to remove the residual peat layer, otherwise it can emerge later (Šnore 2013). The largest areas of water bodies in post-harvested peatlands in Latvia are found in Seda Mire. In the 1980s, it was planned to establish agricultural lands in these post-harvested areas. The peat surface was ploughed up and, possibly, fertilised, thus the peat layer decomposed (Kļaviņš et al. 2011). Later on, after failing to create the agricultural areas, the pits were filled up with water.

Due to the uneven bottom below the peatland, it is never possible to extract the whole peat layer to the mineral ground, which would be the optimal solution for the creation of water bodies (Šnore 2013). The post-harvested areas, like in Seda, can be ploughed, mixing the residual peat layer with the mineral ground (Anon. 2006) and leaving it for several years, thus causing relatively quick peat decomposition. In such case, the emerging of peat up to the surface of water will happen to a much less extent than by filling up the water body immediately.

Water bodies in post-harvested areas may become suitable as a breeding, foraging and resting place for birds, also during migration, as well as important habitats for insects, especially dragonflies (Anon. 2006). To create the conditions suitable for birds, diversification of the micro-relief is highly desirable prior to elevating the water level. Usually this includes the creation of islets, as well as shallow water and transitional zones. Thus more diverse aquatic vegetation can develop, which can serve as a hiding, breeding and feeding place for various animal species.

In later succession stages, regular removal of shrubs on the islets and banks of water bodies is recommended (important for the ground-nesting birds), as well as fragmentation of the reed beds is necessary (crucial for the diversification of habitats for birds breeding in reed beds). Mowing of reeds can also be economically beneficial, as reeds can be used for heating, thatching or other purposes.

More on the renaturalisation of harvested peatlands: Priede A., Silamiķele I. 2015. Recommendations for the renaturalisation of harvested peatlands. Institute of Biology, University of Latvia, Salaspils, www.lu.lv/latvijaspurvi (in Latvian only).

10.3.9 Eradication of Invasive Plant Species

In slightly affected and intact raised bogs, there is acidic, nutrient-poor substrate and moist conditions, so their susceptibility to non-native plant invasion is low. In raised bogs affected by drainage, especially in heavily degraded bogs, the risk of invasive species establishment increases. Raised bogs are usually located far away from the donor areas of the invasive plant species – residential areas, allotments, etc., which also reduces the risk of invasive plant species. However, susceptibility to invasive species is mostly reduced by the naturalness of the bog (Chytrý et al. 2008).

In Latvia, in raised bogs affected by drainage and peat extraction, invasive species have been found. In drained post-harvested peatlands, the non-native moss species ***Campylopus introflexus*** (Fig. 10.66) has widely spread. It has been found in nearly all extracted, abandoned peatlands both on acidic and slightly alkaline substrates, however only on dry peat (Priede, Mežaka 2016a). It spreads by fragments and spores. Spreading is promoted by peat transportation, movement of peat extraction machines, visitors (spores and fragments attach to the soles of footwear, clothes, vehicles), spores are carried by the wind over large distances. In some places on the edges of drained, extracted peatlands ***Aronia prunifolia*** (Fig. 10.67) and ***A. melanocarpa*** have spread. Both species are dispersed by birds (birds eat the fruits, seeds are carried to other areas through the gastrointestinal tract). Occasionally, other invasive species can also be found on drained peat on bog edges.

To prevent drained and post-harvested peatlands becoming donor areas for the further spread of invasive plant species into natural or semi-natural habitats (for example, *Campylopus introflexus* may establish from peatlands into dune habitats), unsuitable conditions must be created by restoring the mire-specific hydrological conditions. It is the most effective way of limiting these species in peatlands. Other techniques (e.g. removal of *Aronia* spp. shrubs, tearing out of *Campylopus introflexus* turf, spraying the herbicides) are ineffective or even cause unwanted side effects. Such methods do not eliminate the basic problem – degradation of peatlands, which is the primary cause of establishment of these species in mires. Use of herbicides should be avoided, as this may cause a much more significant adverse effect on the mire ecosystem than the presence of the invasive species.

10.3.10 Creation of Tourism Infrastructure in Raised Bogs

When planning new tourist destinations in bogs or restoring the existing tourism infrastructure, the side effects of the nature trail should be carefully assessed, and also the impact of the increased number of visitors on the protected or sensitive species and their habitats. The undesirable side effects might be excessive trampling, which may occur despite the infrastructure elements; there is also increased risk of picking and digging out of rare plants, unwanted disturbance to birds or other animals breeding or resting in the bog.

If it is decided that the trail or tourist attraction will be established, several aspects must be taken into account.

- The purpose of the creation of a place of interest for the public – what to show to visitors, what to hold back to avoid the unnecessary popularisation of rare species and subsequent picking, digging out, trampling, or disturbance. The trail route and the information on the information boards or elsewhere must be carefully planned and coordinated. The aim is not to hide the information on species and habitats in the area, but to present it to visitors in a way so as not to cause unwanted risk, especially, if there are rare, sensitive species.
- The trail route. If it does not contradict species and habitat conservation or other considerations, it is advisable to make not only intact bogs, but also bog restoration sites available to the public, using appropriate methods (information signs, information, infrastructure) to explain why the area was restored, what techniques were used and what the results and benefits are. It is also necessary to explain the causes and consequences of ecosystem degradation.
- The material that will be used for the trails. The trail in the bog must not cause hydrological changes and damage the ground vegetation, or cause increased risk of eutrophication and establishment of invasive and atypical plant species.
- It must be kept in mind that in Natura 2000 sites, the priority is the conservation of habitats and species, rather than the maintenance of a place of interest and tourism. Thus if an impact unfavourable to the habitat is observed and it turns out that the visitor flow cannot be regulated with the existing infrastructure, additional infrastructure elements must be constructed (for example, barriers, platforms) or the object must be closed. In some cases, the visitor pressure can be limited with seasonal restrictions (in significant bird nesting or animal breeding places) or with visits only accompanied by a guide.

It is better and more meaningful to inform the visitors of nature trails about the bog as an ecosystem, its functions, its role in nature and typical species, rather than to draw attention to rare species by encouraging them to look for them.

10.3.11 Inappropriate Management and Use of Raised Bog Habitats

Management and use unfavourable to the raised bog include the following:

- all activities that might cause the dropping of the water level (digging of new ditches, cleaning of old ditches) in the bog and the hydrologically related area;
- demolition of beaver dams on ditches on the bog edges;
- movement of any vehicles in the bog, especially during the frost-free season, except for the activities required for planned and coordinated restoration;
- construction of poorly planned tourism infrastructure elements that may cause damage to the habitat or species (increases the visitor load – promotes trampling, disturbs the animals, especially if the infrastructure affects breeding and mating areas);
- both prescribed and uncontrolled burning;
- berry picking by using rakes, especially, if the berries are picked in large amounts (stems are pulled out, their recovery is slow, the ground cover is damaged);
- leaving of any waste in the bog.

10.4 Conservation and Management Conflicts in Raised Bogs

Apparent conflicts between conservation and management are caused by situations when it is not clear enough what is more important to preserve and what to restore – a raised bog or a bog woodland, as both of them are protected habitat types. Usually such contradictions arise on the edges of the raised bogs affected by drainage and where difficulties in habitat interpretation (bog vs. bog woodland) arise. In such cases, it is important to assess both the naturalness of the hydrological regime (whether the area has been affected by drainage and to what extent). Other indicators are the annual tree increment (whether they have grown slowly – characteristic for natural bog conditions, or trees with a "normal" increment characteristic for drained soils), and the ground cover (whether the species composition is characteristic for the bog or drainage effects can be observed – great proportion of dwarf shrubs, low occurrence of sphagnum, dominance of mosses typical for dry forests, etc.). Depending on the assessment, it must be decided whether the priority is the natural process – gradual overgrowing of raised bog with forest (if there are no signs of drainage) or restoration of an open bog (if overgrowing with forest has occurred due to drainage, and it is still possible to achieve bog-specific hydrological conditions). One can also make a decision to restore the hydrological regime by filling up or blocking the ditches, but to preserve the tree stand, thus restoring the conditions of bog woodland.

To decide on the restoration of bog or bog woodland, the long-term perspective must always be taken into account. Even if it is possible to improve the structure of the bog habitat by removing trees, it must be clear whether the effect will be sustainable and whether it is worth doing. Most likely, natural succession is the priority in small, overgrown bogs that have reached the development stage where they naturally turn into a forest. Nevertheless, it would also be wrong to make a general statement that the restoration of small bogs is not necessary. Sometimes, restoration of an open landscape is important even in relatively small bog patches, in order to preserve the conditions suitable for particular species, for example, for *Tetrao tetrix*.

In the restoration of raised bogs, conflicts between nature conservation and economic interests often arise, e.g. in cases when woodland should be removed, as it is overgrown due to the drainage impact, and the hydrological regime suitable for a bog ecosystem should be restored. It may also be the case that the trees, if left on site, die off due to the raised water level. Thus, both objectives – a healthy bog ecosystem and an economically valuable forest stand – cannot be achieved at the same time. After dich blocking or filling up, the transpiration can also make the hydrological restoration less efficient. Therefore, if nature conservation is the priority in the particular area, the main task should be the restoration of the bog ecosystem functions. In assessing such situations objectively, the evaluation of woodland age must be carried out, which usually provides the answer as to whether the forest has formed naturally or after bog drainage.

Similar management conflicts may also arise concerning beaver activity on the edges of bogs. Beaver dams are often beneficial for the bog habitat as they block the drainage ditches. However, the raised water level can adversely affect the adjacent forest stands. Conflicts may also arise if commercial areas (forests, agricultural lands, settlements) are located close to the bog outside the protected nature territory, and therefore ditch management and cleaning is necessary. Conflicts may also be caused by understanding what constitutes a valuable landscape, its elements (mires, forest stands, old trees, etc.), and the necessity to preserve them. Whenever possible, a compromise must be sought, and the arguments must be based on detailed studies of the particular case.

Also, various nature conservation methods may have conflicting aspects. For example, trees must be

felled to create an open bog landscape. They be removed, burnt or left on site. If felled trees are left on the ground, they hinder the visibility for birds, so there is a higher probability that target species will not return to such a place. If felled trees are gathered and burnt, used in firewood or wood chips, carbon accumulated in the wood is released into the atmosphere. So there is no single perfect solution – it must be sought depending on the target. However, most likely, if trees cannot be removed and the habitat does not become suitable for birds of the open bog, there is no use in the felling of trees – living trees have a higher efficiency in carbon sequestration.

In some cases, restoration of the bog ecosystem may create unfavourable conditions for a protected species that is not typical for a raised bog. This refers to species which have established due to drainage or can tolerate large water level fluctuations, e.g. club-mosses *Lycopodium annotinum*, *L. clavatum*, and *Huperzia selago*. Increase of water level, i.e. recovery of the bog ecosystem, causes local extinction of these species. However, in this case, the priority is the raised bog ecosystem, rather than protected species atypical for the habitat, which also are relatively common throughout the country. Similarly, a rise in water level can affect a very rare lichen species *Cladonia incrassata*, which rarely occurs in extracted and/or post-harvested bogs (Āboliņa et al. 2015; Priede, Mežaka 2016b). Rapid water level changes can also cause the local extinction of other rare plant species, for example, *Trichophorum cespitosum* and *Myrica gale*, especially in post-harvested peatlands. In such cases, the priorities are determined by assessing the rarity of the species and their typicality for the raised bog. In post-harvested peatlands, the restoration of the functioning ecosystem with appropriate living conditions for typical species in the long term is more important than preserving a human-created secondary habitat for rare, probably, occasional species.

There is no universal recommendation for solving conflict situations and contradictory cases. In each situation the conditions of the particular site must be carefully assessed and the actions must be planned according to the conservation priorities at the national or regional scale. It must always be assessed whether the benefit is comparable to the investment. Therefore the decision must be taken after assessing all aspects (*see Chapter* 4).

Chapter 11. 7140 *Transition mires and quaking bogs*

11.1 Characteristics of Transition Mires and Quaking Bogs

11.1.1 Brief Description

Habitat type 7140 *Transition mires and bog pools* includes peat-forming plant communities developed on the surface of oligotrophic to mesotrophic waters, with the characteristics intermediate between soligenous and ombrogenous types. Vegetation is formed by swaying swards, floating carpets or quaking mires formed by medium-sized or small sedges, associated with *Sphagnum* spp. and/or brown mosses (European Commission 2013).

Transition mires and quaking bogs usually occur on lakeshores and in the complexes of raised bogs. They can cover large areas of overgrown lakes, and relatively small areas on the edges of raised bogs, near bog islets and terrain depressions. In the boreal region, minerotrophic mires, which are not a part of the larger mire complex, are also included in this habitat type, as well as mires with *Carex rostrata* stands in the quaking bogs on the lakeshores (Auniņa 2013c). Transition mires may also develop in humid dune slacks (Laime (ed.) 2017, *Chapter 16.3.2*).

In Latvia, **two variants** of this habitat type have been distinguished (Auniņa 2013c, 2016c).

Variant 1: transition mires on the edges of raised bogs, at the mineral soil islets in bogs or in terrain depressions. This type of transition mire is poor to moderately rich in species with a well-pronounced moss cover with dominance of *Sphagnum* spp. (Fig. 11.2).

Variant 2: limnogenous mires, including quaking bogs. Vegetation characteristic both to fens and mires, which has developed by the overgrowing of lakes (Fig. 11.3) is typical for this type of transition mire.

11.1.2 Important Processes and Structures

Transition mires and quaking bogs are a transitional succession stage between a fen and a raised bog, when upon increasing the peat layer, the mire feeds both from the groundwaters and precipitation. Along with the mire succession and accumulation of the peat layer, the role of precipitation increases.

In intact transition mires and quaking bogs, there are constantly wet conditions with slight water level fluctuations, sometimes with the presence of surface waters, especially in seasons rich in precipitation. The environment is usually acidic to neutral (pH 4.5–5.5). Peat accumulation takes place, and the mire development is in process – usually the ecosystem gradually turns into a raised bog.

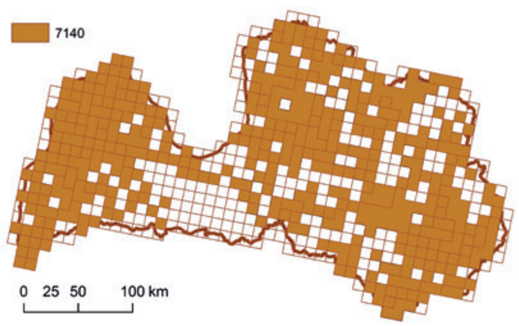

Fig. 11.1. Distribution of the habitat type 7140 *Transition mires and quaking bogs* in Latvia (source: Anon. 2013a).

Fig. 11.2. Habitat variant 1 – transition mire habitat in Raganu Mire. Photo: A. Priede.

Fig. 11.3. Habitat variant 2 – a quaking bog on the shores of Lake Aklais near Klapkalnciems. Photo: A. Priede.

The micro-relief can be both flat (the mire surface is wet, with open water pools, depressions or bare peat patches) and with hummocks. In natural conditions with an undisturbed hydrological regime, transition mires and quaking bogs are open, with a sparse tree or shrub layer (Auniņa 2013c). Overgrowing with trees and shrubs can take place on the edges of the mire, which are usually drier. Trees, if present, have a low increment and are low, often with curved shapes and rounded crowns.

11.1.3 Succession

Transition mires develop after the paludification of terrestrial areas, or in terrain depressions with fens upon the accumulation of peat. Quaking bogs develop when the lakes are overgrowing with floating mats composed of mire plants, e.g. *Comarum palustre, Menyanthes trifoliata, Calla palustris.* The roots and stems of these plants are hollow, so they hold on the water surface. Sphagnum mosses, brown mosses and other smaller plants establish on the floating mats. Overgrowing of the water surface is typical for deep, small water bodies with steep banks, where severe wave action does not happen.

Although the process is slow, young transition mires are also developing nowadays, for example, in beaver ponds and terrain depressions that after the fen stage gradually turn into transition mires. The development of quaking bogs occurs in the same way on lakeshores. However, the mire does not always go through all the development stages of a fen to a raised bog. Small transition mires, especially in small depressions, may overgrow with forest without the stage of a raised bog.

In most cases tree encroachment in transition mires is enhanced by drainage. However, transformation into forest may also occur in small mire patches without drainage, for example, in small terrain depressions. Establishment of trees is also promoted by natural climate fluctuations – in years with low rainfall, especially if the dry years follow each other in a row, more trees can establish. They may perish in the following years.

11.1.4 Indications of Favourable Conservation Status

In intact transition mires and quaking bogs, a high water level with slight annual fluctuations is typical. The substrate is usually acidic to slightly alkaline, with low nitrogen and phosphorus content.

The plant communities of transition mires and quaking bogs represent both communities of nutrient-poor (Fig. 11.4) and nutrient-rich (Fig. 11.5) conditions. Vegetation composition and species diversity is predominantly defined by the physical and

Fig. 11.4. Species-poor transition mire in the terrain depression in the "Tumes meži" Nature Reserve. Photo: A. Priede.

Fig. 11.5. Species-rich transition mire in "Pelcīšu purvs" Nature Reserve. Photo: A. Priede.

Fig. 11.6. A gyttja extraction site in an overgrown lake (Lake Spīgu). Orthophoto map at the scale 1: 5000 © Latvian Geospatial Information Agency (2007–2008).

chemical properties of substrate, i.e. the nutrient availability. Species-poor vegetation dominated by sphagnum mosses and one or a few *Carex* species can be found on the bog margins with a nutrient-poor, acidic environment. In transition mires with nutrient-rich groundwater inflow, plant species composition may be diverse and rich.

Local site conditions and the stage of mire development largely affect the vegetation composition. Absence of a particular species does not necessarily mean an unfavourable conservation status. Nearly always the vegetation is dominated by sphagnum mosses and/or brown mosses. In transition mires in the raised bog margins and at the mineral islets in bogs, the vegetation is species-poor or medium rich in species, with a well-pronounced dominance of sphagnum. In transition mires and quaking bogs that have developed by the overgrowing of lakes, the vegetation may be more diverse (depending on the type of the lake) – plant species of both fens and transition mires may be present. Characteristic vascular plant species are *Carex elata*, *C. chordorrhiza*, *C. pseudacorus*, *Thelypteris palustris*, *Pedicularis palustris*, *Eriophorum gracile*, *Galium trifidum*; in quaking bogs along the shores – *Cicuta virosa*; in depressions with open water – *Utricularia intermedia*; mosses – *Cinclidium stygium*, *Scorpidium revolvens*, *Hamatocaulis vernicosus*, *Calliergonella cuspidata*, *Calliergon cordifolium*, *C. giganteum*, *Sphagnum subsecundum*, *Sph. contortum*, *Helodium blandowii* (Auniņa 2013c). In a transition mire or quaking bog in a favourable conservation status at least some of the afore-mentioned characteristic species can be found.

In Latvia, transition mires and quaking bogs are almost the only suitable habitat for several rare, protected plant species: *Hammarbya paludosa*, *Malaxis monophyllos*, *Saxifraga hirculus*, *Carex heleonastes*, *Hamatocaulis vernicosus*, *H. lapponicus*, *Calliergon richardsonii*. Transition mires and quaking bogs are also a significant habitat for other rare species, e.g. *Liparis loeselii*, *Dactylorhiza incarnata*, *D. maculata*, *D. russowii*, *Salix myrtilloides*, *Meesia triquetra*, *Scapania irrigua*, *Sphagnum obtusum* (Auniņa 2013, 2016c).

Expansive plant species (for example, *Phragmites australis*) or dwarf shrubs do not dominate over large areas and do not form homogeneous stands.

11.1.5 Pressures and Threats

11.1.5.1 Hydrological regime modification

Drainage, also related to peat extraction, is the main cause of degradation of transition mires in Latvia. To a lesser extent it has affected quaking bogs on the lake shores. Drainage contributes to the degradation of the typical vegetation and transformation of mires into forest. Over time, drainage ditches, if not maintained gradually, fill up and their impact decreases, thus the conditions in the mire may also improve. Renovation of ditches in the adjacent, hydrologically related areas will have a deteriorating impact.

Lowering of the lake water level may significantly affect the areas of quaking bogs – both unfavourably and favourably. The unfavourable impact is related to decreasing mire cover and promoting the formation of drier growing conditions as the water level drops. The favourable conditions are created by increased shallow water areas on the lakeshores that gradually turn into a quaking bog, if the water level remains low for a long time. The water level in lakes can be both lowered by establishing drainage ditches, and increased by blocking the ditches (due to habitat restoration or beaver activity).

Road construction and the related establishment of road dams and embankments, draining of roads by digging ditches, and other impacts related to road construction and maintenance, have also affected transition mires in Latvia. Sometimes such activities have caused an adverse effect on the hydrological regime of mire, making the conditions drier and promoting tree encroachment.

11.1.5.2 Extraction of peat and gyttja

Degradation of transition mires is promoted by peat extraction, which is related to development of a drainage system (*see Chapter 10.1.5.1*). Quaking bogs, developed in overgrown lakes, may also be affected by gyttja (sapropel) extraction, which nowadays causes minor impacts due to small extraction volumes in Latvia (Fig. 10.6).

11.1.5.3 Eutrophication

Intact transition mires and quaking bogs are poor in plant nutrients. Therefore, eutrophication is one of the reasons for such mire habitat degradation. Mires receive extra nutrients mainly with precipitation water and air depositions, as well as due to lake pollution. Nutrient level in the mire can also be affected by increased surface run-off, for example, from the adjacent farmlands and forest clear-cuts (Apsīte 1999).

Eutrophication accelerates the peat decomposition rate. It also promotes the establishment of species atypical for the particular habitat type, both mosses and vascular plants, whereas the typical species, including rare and protected ones, may disappear due to the changes in nutrient amount and related changes in plant communities. A similar impact can be caused by carbonate-rich atmospheric deposition and precipitation, which increase the substrate pH. A similar effect, caused by industrial pollution in the Soviet period in the second half of the 20th century has been observed in some Estonian mires, where the establishment of calciphilous plant species atypical for acidic mires was observed (Paal et al. 2009). In Latvia, the impact of eutrophication in transition mires and quaking bogs has not been studied; however, most likely, it is considered to be of minor importance.

11.1.5.4 Beaver activity

The impact of beaver activity on the habitat and its species is not clearly favourable or unfavourable, therefore it should be evaluated in each individual case. Beaver activity may affect transition mires and quaking bogs, if it is related to drainage ditches which serve for beavers as a migration corridor and living space (Pilāts 2013). In most European countries, beaver activity is not topical as an essential factor affecting mire habitats, since the beaver populations are small. In Latvia, beaver activity has caused significant water level increase in some places, leading to substantial changes in vegetation. Constantly increased water level may transform the site into monodominant reed beds. Beaver-caused rise in water level may cause the local extinction of some rare plant species, for example, *Saxifraga hirculus* or *Liparis loeselii*. In Latvia, a decline of *Liparis loeselii* population due to increased water level has been observed in the transition mires on the shores of Lake Pūrica, Linezers Mire (Anon. 2013) and in the surroundings of Ovīši (Roze et al. 2013).

However, beaver activity can also have a positive impact on drained mires by blocking the ditches and raising the water level, thus restoring the moisture optimal for the existence of mire and its species, as well as decreasing the shrub cover and maintaining an open mire.

11.1.5.5 Impact of wild large mammals

Wild large herbivores (elk, deer) reduce the proportion of shrubs and maintain low vegetation by browsing the young deciduous trees and shrubs, and by decreasing the proportion of recently established pines. However, one cannot rely on large wild herbivores to maintain the open mire landscape in sites where such management is necessary. The browsing intensity is also related to other factors (number of animals per area, disturbances affecting animals, etc.).

Animal trails in mire serve as suitable substrate for low, light demanding species of early succession stages, for example, *Liparis loeselii*; such ecological niches are particularly important in overgrowing mires. Animal trails also promote the spread of certain plant species. Usually, there is at least a little open water in the trails, which plant propagules can use to spread to areas with suitable growing conditions. For example, it is important for *Liparis loeselii* (Roze et al. 2013).

Sometimes the ground vegetation and upper peat layer may be damaged by wild boar, although

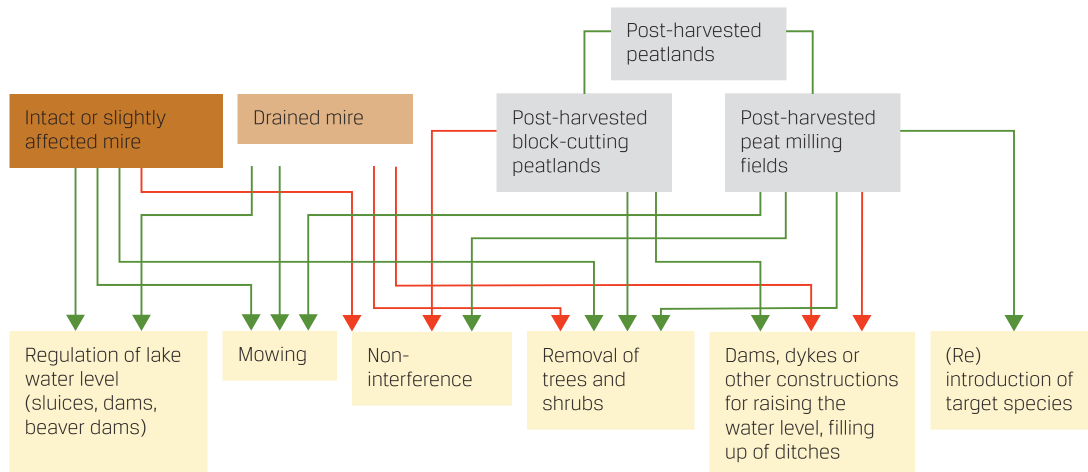

Fig. 11.7. Selection of appropriate restoration techniques for transition mire and quaking bog habitats in various situations. The red arrow depicts the most usual solutions, the dashed arrows – alternative solutions that may improve the result or are only applicable if necessary in the particular area after careful inventories.

this is more typical for drier areas and hardly affects marshy sites. Large numbers of wild boar may promote the decrease of some rare orchid species populations if the animals regularly eat the tubers.

11.1.5.6 Logging

In Latvia, some forest clear-cuts are bordering with the transition mire and quaking bog habitats (Anon. 2013), but their impact must not be unequivocally assessed as unfavourable. Removal of trees, especially after clear-felling, changes the mire microclimate, thus temporarily promoting desiccation of the surface. At the same time, removal of the tree stand significantly reduces the transpiration rate, promoting paludification, thus making the substrate wetter and improving the mire conditions.

However, clear-cuts cause increased surface run-off and draining through the ditches, as well as increased wash-out of phosphorus and mineral substances from soil (Nieminen 2003). Thus, depending on the topography of the particular site, the soil properties, presence of ditches and other factors, the clear-cuts may contribute to the eutrophication of the mire.

11.1.5.7 Climate change

Climate conditions have had the most important role in the development of mires. Climate conditions at different stages of mire development have been less or more favourable. In Europe, mires are considered to be the habitat group most affected by

Fig. 11.8. Intact transition mire on the shore of a small forest lake in the terrain depression in the "Pinku ezers" Nature Reserve. All of the area gradually overgrows with forest, trees are old, with low increment, and the tree stand is sparse. Habitat is suitable for species of both transition mires and bog woodlands. In such cases, no interference is necessary. Photo: A. Priede.

Fig. 11.9. In transition mires, reed beds and tree groups can occasionally be present, however they are not considered to be a sign of mire degradation. In such cases, reed cutting or tree removal is not necessary, if there are no drainage ditches in the mire or on its margins. To preserve the habitat and species, intervention in intact mires is almost never necessary. Photo: A. Priede.

Fig. 11.10. Naturally overgrowing small transition mire in the terrain depression in the surroundings of Tukums. Photo: A. Priede.

climate change (Anon. 2012). In Northern Europe, a tendency can be observed that the average amount of precipitation is increasing (Anon. 2011), creating favourable conditions for mire development. However, together with the rise of average temperature, increased transpiration from the mire surface can be expected, promoting their desiccation. Moreover, a higher average temperature would facilitate faster decomposition of the dead organic material, decreasing the peat accumulation (Silamiķele 2010), as well as enhancing the release of carbon dioxide in the atmosphere (van der Linden, van Geel 2006). Major changes in the raised bogs and related habitat complexes, including transition mires and quaking bogs, may also be caused by the prolongation of the active vegetation period and decrease of precipitation in the summer and autumn. This means that longer periods of drought or water deficit may be expected in mires. That may promote the encroachment of trees, as well as increased fire risk.

The impact of the recent climate change in the mire ecosystems is not yet clearly understood. However, although during the last two centuries the main role in the transformation of mires has been human activity – drainage and peat extraction, human-driven climate change is also one of the most significant factors in the long term. The changes in mire ecosystems influenced by the climate in the long term cannot be eliminated with targeted management measures. In Latvia, the observations show that many transition mires in a natural condition or slightly affected by drainage are being invaded by pines during the last two to three decades, which is possibly driven by climate change.

11.1.5.8 Excessive visitor load

Transition mires and quaking bogs can be rich in cranberries, so during the picking season there are many visitors causing trampling. The fragile mire ground vegetation is getting mechanically damaged. However, such an impact can be considered as temporary – the moss layer can recover itself within a year or more, heavily trampled places – within a few years. The degrading impact is caused by the use of berry-picking rakes by pulling out cranberry shrubs that are slowly recovering. Aesthetic degradation is caused by the waste left by the berry-pickers that may sometimes injure wild animals.

11.2 Restoration Objectives of Transition Mires and Quaking Bogs

See the common objectives for all mire habitats (*Chapter 5.3*).

11.3 Restoration of Transition Mires and Quaking Bogs

11.3.1. Restoration of Transition Mires and Quaking Bogs for the Purpose of the Guidelines

For the purpose of the guidelines, habitat restoration refers both to areas where the features characteristic for transition mires and quaking bogs are met, and to areas where they do not exist anymore, but it is possible to restore or create mire-specific conditions and ecosystem functions. Therefore, in the guidelines the completely degraded raised bogs considered as potentially restorable have also been included – post-harvested peatlands in which, though not always, it is possible to restore a transition mire habitat and the related species composition. These considerations are also applicable to transition mires in humid dune slacks (EU habitat type *2190 Humid dune slacks* (Laime (ed.) 2017, *Chapter 16*).

Various action models depending on the initial situation are indicated in Fig. 11.7. For details on planning: *see Chapter 6*.

> Prior to the resumption of habitat restoration it is important to understand the current condition, the main problems and their causes, and to set a realistic objective. This means a careful inventory of the current situation and identification of all potential obstacles. Only then can appropriate methods be chosen, recognising both their advantages and disadvantages. If the objective cannot be reached, alternatives should be assessed.

11.3.2 Non-interference

In intact transition mires and quaking bogs the most important aspect is to preserve the natural water level in the area and in the related hydrological system – in a raised bog (if the transition mire is located in a raised bog massif), lake (if the transition mire or quaking bog is located on the lakeshore) or in the surrounding bog woodlands.

One should not strive for restoration of the mire habitat in the current succession stage, even it does

Fig. 11.11. A former bog lake, once heavily affected by drainage and rewetted about 10 years ago, in Great Ķemeri Mire near a former peat extraction site. After raising the water level, quaking bog developed in the site of the former bog lake. Open water is overgrowing with sphagnum and sedge mats. Removal of trees in such conditions is not necessary – they wither and fall down within a few years. Photo: A. Priede.

not correspond with our idea of a "perfect" transition mire or quaking bog. The priority is natural processes if the mire has not been unfavourably affected by drainage or other human-caused alterations (Fig. 11.8-11.9).

If there are no rare species that are exclusively related to the conditions characteristic for a transition mire, as well as there are no drainage impacts, and overgrowing of the mire is considered to be a natural succession – transformation into bog woodland, the best scenario is most likely a natural process. But in this case, the conservation objectives of particular Natura 2000 sites must be revised, since over a longer time the areas that have been established in order to protect open mires, naturally transform into bog woodlands.

11.3.3 Rewetting

If transition mires and quaking bogs are part of a larger wetland – a raised bog or a complex of mires, lakes and bog woodlands, the drainage impact cannot be solved locally, referring only to a separate habitat patch. In such cases, the problem must be dealt with in a comprehensive way – the water level must be restored in the entire hydrological system (in the raised bog, if the transition mire is part of the raised bog complex, or in the lake, if the transition mire or quaking bog are located on the lakeshore). In transition mires and quaking bogs on lakeshores, prior to restoring the water level in the lake, the potential impact must be assessed in the entire lake ecosystem. It is essential to understand, how it will affect lake ecological quality. Achieving the level optimal for the transition mires on the shore must not impair the lake ecosystem and water quality.

The most widely used rewetting method in raised bog complexes is ditch blocking and filling, sometimes supplemented with the removal of trees. Removal of excessive tree cover in drained mires both decreases the transpiration rate and restores open mire areas. For more on rewetting methods *see Chapter 10.3.3.*

11.3.4 Maintenance and Control of Beaver Dams

Sometimes in drained mires, the water level optimal for a mire is maintained by beavers. In such a case, beaver dams should be preserved, and it is not desirable to tear them down, if they do not create permanent stagnant ponds in the mire or adjacent forests.

If adjacent forests or agricultural lands are flooded due to the rise in water level caused by beavers, but the optimal water level in the mire is ensured

Fig. 11.12. During the last decades the transition mire habitat in Kalēju Mire has overgrown with pines, although the drainage impacts are uncertain. In order to improve the hydrology of the mire and preserve an open mire habitat, removal of all pines established during the last decades is necessary. Photo: A. Priede.

Fig. 11.13. To restore and preserve the Veseta floodplain mire and its species richness, removal of trees and shrubs is necessary, as well as regular, annual mowing of reeds. Photo: A. Priede.

Fig. 11.14. In Latvia, transition mires are almost the only suitable habitat for *Saxifraga hirculus*, a rare plant species. Photo: I. Čakare.

in this way, a reduction of beaver population might be necessary (hunting, insertion of tubes under the dams (efficient methods), and regular demolition of dams (less efficient, as beavers soon renew their dams). However, it should be regarded as a compromise with economic interests (forestry, agriculture), rather than a desirable action that preserves transition mire habitats.

11.3.5 Removal of Trees and Shrubs

Removal of trees and shrubs is required mainly to improve the habitat structure – to restore open mire for typical and/or rare species if there are signs of degradation. Tree and shrub encroachment in transition mires may be both a consequence of mire degradation, i.e. drainage, and a natural process, as the mire reaches the development stage when it naturally becomes drier and more suitable for the growth of trees (Fig. 11.12–11.13). Therefore, when planning restoration of a mire habitat, it must be clear whether and to what extent drainage has promoted overgrowing of the mire.

If mires are overgrown with trees of the same age, this indicates that tree invasion has been caused by drainage. In such mires, pines do not have curved forms and rounded tops (so-called bog pines) or branches covered with lichens (for spruces) as in intact mires. In mires affected by drainage, for the purpose of habitat restoration both the drainage impact must be prevented (by blocking or filling

Fig. 11.17. By weeding and cutting, one person can efficiently remove recently established pines over quite a large area within a few hours. Sloka Mire in Ķemeri National Park before the cutting and weeding of young pines in 2013. Photo: A. Priede.

Fig. 11.15. In the autumn of 2012, shrubs were removed in a 4 ha area of transition mire in Pēterezers inter-dune depression in Slītere National Park. The photo was taken in April 2013. Photo: A. Priede.

Fig. 11.18. The same place after the removal of the young, fast growing pines (in 2014 the pines have been cut and pulled out in an area of 0.5 ha). In wet conditions, the result is rather persistent – in 2016 (photo) only a few trees were established. Photo: A. Priede.

Fig. 11.16. The same place in August 2016 – around 2 m tall shoots have occupied the area. Photo: A. Priede.

up of ditches), and the tree cover developed due to drainage must be removed.

In cases when rewetting is planned and a significant rise in water level is expected, the formation of quaking bogs with floating sphagnum mats or shallow water areas will take place. Trees and shrubs may die off within several years (Fig. 11.11), therefore tree removal prior to rewetting is only necessary in sites where they form dense stands.

Removal of trees in those transition mires affected by drainage without rewetting has a short-term effect. That does not improve the mire functions significantly, thus does not help the mire to be preserved in the long term. Although the habitat structure can be improved in this way, it only produces a "cosmetic" effect. Removal of deciduous trees and shrubs (birches, black alders, alder buckthorns) in drained sites may promote the formation of dense cover of young shoots that due to the changes of light conditions may create more unfavourable conditions for mire species than before felling. Therefore, in such situations only a comprehensive approach is applicable – rewetting along with improving the habitat structure (removal of trees, shrubs, sometimes also ground cover vegetation).

Fig. 11.19. Mowing should be considered if reeds are dominating over large areas. However, if there are small reed patches, it is most likely a part of a natural mire structure, and intervention is not necessary. In the photo – transition mire in Riesta-Džūkstes Bog. Photo: A. Priede.

Prior to restoring the mire habitats, if tree removal is planned, the category of land use must be clarified. In a forest land, a deforestation permit issued by the responsible authority is required to restore a protected non-forest habitat. Deforestation of the areas overgrown with forests in order to restore open habitats is regulated by Cabinet Regulation No. 325 of 6 June, 2013, on the restoration of protected habitats and protected species habitats in forest. On non-forest land there are no shrub clearing limitations, but the felling of trees with a stump diameter exceeding 20 cm must be coordinated with the local municipality.
It must be clarified at what period tree and shrub felling is allowed. Felling in protected nature territories is usually not allowed during the bird breeding season from 15 March to 31 July. In micro-reserves and their buffer zones, the Regulation for the protection and management of micro-reserves[41] should also be complied with, since some bird species already start breeding in February. In this case the characteristics of the particular area and requirements of species conservation must be followed.
Prior to any restoration and management activities in protected nature territories and micro-reserves it is always advisable to contact the Nature Conservation Agency and clarify whether the proposed action needs official agreements or permits.

When restoring the mire habitats, it is advisable to remove all the trees with large increment and other characteristics for fast growing. Only the oldest trees can be preserved, however, also the number of those is subordinated to the major objective – restoration of open mire. When selecting the trees to be felled, it is advisable to preserve old pines *Pinus sylvestris*, old spruces *Picea abies* and junipers *Juniperus communis* (such can sometimes be found in species-rich transition mires).

Removal of trees and shrubs must be performed in winter in frost conditions or, if it is not possible, in the second half of the summer after the bird breeding season and in autumn (not earlier than in August).

The felled trees and shrubs must be collected. It is best if they can be transported from the area when the land is frozen. If this is not possible, trees and shrubs can be burnt on site, creating piles for burning so that the impact on the ground cover affects as small an area as possible. In wet conditions, burning is only possible on drier elevations.

[41] Cabinet Regulation No. 940 of 18 December 2012, Regulations on the Procedures for the Establishment and Management of Micro-reserves, Protection Thereof, as well as the Determination of Micro-reserves and Buffer Zones Thereof.

When deciduous trees (*Betula* spp., *Alnus glutinosa*, *Frangula alnus*) are removed, soon vigorous re-sprouting from stumps can be expected (Fig. 11 *Betula* spp., *Alnus glutinosa*.15, 11.16). Therefore, when planning the habitat restoration, re-current mowing of young shoots must be planned for several years in a row. It is advisable to remove bigger deciduous trees (*Betula* spp., *Alnus glutinosa*) so that the stumps remain as low as possible. Later, to promote rapid decaying of stumps, they may be cross-notched.

In sites where restoration included both deforestation and rewetting, but an intense re-growth of deciduous tree shoots occurs, this usually indicates a failure in hydrological restoration. In such cases, the basic problem must be solved, searching for and eliminating technical mistakes in rewetting.

The proportion of recently established young pines, which usually invade recently deforested areas, can be reduced by weeding out or cutting the young trees (Fig. 11.17–11.18). These methods do not even require a brush-cutter or motor-saw and any special skills. Volunteers can be involved in such habitat management. Pruners and shears may be used, and shears with long handles are recommended. Although this method is relatively time consuming, in small areas it is more efficient for the removal of young trees than, for example, the use of a brush-cutter, which is often complicated because of tussocks. Usually due to the complicated micro-terrain (hummocks) the shrubs are cut too high. The wet conditions also encumber moving around. Young trees (especially conifers, which do not develop stump shoots) should be cut off below the lowest branch whorl, which ensures that lateral branches do not form and the trees cannot regenerate.

Fig. 11.20. Sphagnum mats in abandoned block-cutting peatlands filled up with water in Great Ķemeri Mire. The water level is suitable for the recovery of mire vegetation. Photo: A. Priede.

Fig. 11.21. Rewetted post-harvested peat milling field in Great Ķemeri Mire. Approximately ten years after the rise of water level, vegetation typical for transition mires with *Sphagnum* spp., *Rhynchospora alba* and other plants of sedge family has developed. Photo: A. Priede.

11.3.6 Mowing

In the past, in many regions of Latvia there was a shortage of hay meadows and pastures, especially in coastal areas, therefore transition mires and quaking bogs were used for haymaking and grazing (Zīrnīte 2011). However, nowadays it could be difficult to implement mowing in marshy and hard-to-reach areas due to the lack of economic justification (sedges and other vascular plants in mires have low nutritional value, the areas are not accessible for mechanised mowing, etc.). In those transition mires, which are natural or slightly affected by human-caused alterations, mowing also does not usually have ecological justification, as they can also persist without human intervention. Thus, mowing as a restoration method of transition mires can only be necessary in some cases as a part of habitat restoration complemented with hydrological restoration and tree and shrub removal. Usually re-current mowing is not necessary – when restoring the optimal water level, the composition of species characteristic for the habitat will spontaneously recover.

Sometimes reed invasion can be observed in the transition mires – most likely, reed beds establish at groundwater discharge sites or sometimes their spread may be caused by drainage-caused enhanced peat decomposition. Usually the reeds in transition mires should not be limited, and management is rarely necessary to reduce their proportion (Fig. 11.19). Reed mowing may be necessary in localities of rare plant species in order to improve their growing conditions. The usefulness of such action should be assessed in each individual case. If mowing is applied, it must be a re-current, rather than one-time activity. The mown reeds must always be removed from the area.

When planning mowing in transition mires, one must take into account difficult working conditions due to ground wetness. Often the areas are difficult to access and due to ground wetness it is difficult to collect the hay. Mowing is only possible with manual work (with a brush-cutter or scythe). Movement of tractors or other machines in the mire in the frost-free season may cause serious damage to ground vegetation.

11.3.7 Grazing

In some regions of Latvia, transition mires and quaking bogs were traditionally used for haymaking, and sometimes also grazed, for example, in the inter-dune depressions in North Kurzeme (Zirnīte 2011). However, this has not been a traditional management throughout Latvia; most probably, grazing was only a commonly applied practice in regions with poor soils and a lack of agricultural land suitable for pastures. Grazing in marshy places also presents a threat to grazing animals as they can get stuck, thus there is no reason to believe that such areas were specially designated as suitable for grazing or grazed on a regular basis. Grazing took place by roaming across large areas and also by grazing small mire patches in the terrain depressions.

Grazing may help to decrease the re-sprouting of the removed shrubs and the density and vigour of reeds, although it does not always guarantee the desirable result in decreasing the reed cover. A study in Switzerland showed that the proportion of reeds in the partly overgrown transition mire did not significantly decrease within three years, while the amount of nutrients increased, soil pH increased, as well as the cover of mire plant species decreased, being replaced by pasture species (Küchler et al. 2009). Moreover, the mire was significantly trampled causing the extinction of mire-specific species and subsequent changes in species composition.

Overall, grazing is not considered to be a suitable management in transition mires and quaking bogs, mostly there is also neither the ecological nor economic need to establish pastures in these habitats.

11.3.8 Habitat Restoration in Post-harvested Peatlands

Post-harvested peatlands, especially abandoned block-cutting peatlands, with a well-distinguished terrain of "trenches" and rises, and abandoned block-cutting areas that have filled up with water, have a high restorability potential. By rewetting such areas, i.e. blocking the drainage ditches or filling them up completely, sphagnum blankets and mire plant vegetation can be restored. If the re-establishment of vegetation is successful, the mire functions (accumulation of water and carbon, accumulation of peat) recover over time.

In "trenches" filled up with water, no action is usually necessary, except water level restoration of the optimal level for the recovery of mire vegetation – the depressions overgrow with sphagnum mats and plants of the sedge family (*Eriophorum* spp., *Carex* spp.). When rewetting the post-harvested peat milling fields, initially vegetation similar to that of a transition mire develops. Later, it transforms into a mosaic of raised bog and transition mire communities, which is also related to the formation of a bog-specific micro-terrain (if water is not too deep and water bodies are not formed). Gradually, sphagnum hummocks and wet depressions develop. Over a longer time, which usually takes several decades, peat accumulation begins (Fig. 11.20).

When restoring the water level, development of vegetation characteristic for transition mires can be expected in post-harvested peatlands, where the residual peat layer is composed of slightly to moderately decomposed peat and the water pH is acidic to slightly acidic (pH ~ 3–5.5) (Fig. 11.21). On a well decomposed, rewetted fen peat in the residual peat layer the mire will undergo the succession stage of fens; reed stands will most probably develop. Establishment of vegetation typical for transition mires or bogs can take several decades or even hundreds of years.

The necessity to promote vegetation development by (re)introducing mire species largely depends on the situation in the particular site (landscape pattern, propagule sources in the surroundings, etc.), as well as financial resources available.

For more on the renaturalisation of extracted peatlands *see Chapter 10.3.8 and 15.3.13*.

11.3.9 Tourism Infrastructure in Transition Mires and Quaking Bogs

Tourist trails and other visitor attractions in transition mires and quaking bogs are rarely created, because their construction is encumbered by natural conditions – how marshy and difficult to access the area is. However, if such infrastructure is planned, then the same principles must be applied as in raised bogs (*see Chapter 10.3.10*).

11.3.10 Inappropriate Management and Use of Transition Mires and Quaking Bogs

Management and use unfavourable to the habitat include the following:

- any activities that might cause a drop in water level (digging of new ditches, renovating of existing ditches in a mire and its hydrologically related area);
- demolition of beaver dams;
- felling of trees, clearing of shrubs and mowing or shredding of herbaceous vegetation without the removal of biomass; felling residues and mown herbaceous plants left on site;
- movement of vehicles (including restoration activities) in a mire in the frostless period;
- establishment of tourism infrastructure which might threaten the habitat or related species (trampling, risk of species local extinction, disturbance, etc.);
- feeding of wild animals;
- inflow of eutrophic waters through ditches, from the lake or surface run-off from the adjacent forest clear-cuts or agricultural lands.

11.4 Conservation and Management Conflicts in Transition Mires and Quaking Bogs

In the restoration of transition mires and quaking bogs, conflicts may arise with regard to forest management, as well as due to different opinions of the society. Rise in water level in drained mires, both caused by human action or by beaver activity, is favourable to the habitat as the mire function can gradually recover. However, a rise in water level, especially if it is rapid and occurs in heavily drained mires, may cause trees to die and complete or partial destruction of the woodland, which, in the eyes of local community or other interested parties, is sometimes judged as "destruction of nature".

Management conflicts may also be caused by a clash of economic interests and nature conservation – for example, necessity to destroy or to preserve beaver dams on the forest ditches bordering mire areas, especially when the neighbouring forests are located outside the protected nature territory. From the point of view of mire conservation, maintenance of the beaver dams would be favourable; however the raised water level might initiate the dying of trees, thus causing economic losses. When looking for the right solution, both the conservation objectives for the particular protected nature territory and the rarity and conservation status of the specific habitat type at the national scale must be taken into account and, whenever possible, a compromise with the economic interests, especially concerning the local community, must be sought.

Rewetting sometimes may cause the local extinction of some protected plant species, which might be present in drained mires, but typically grow in other habitats (for example, *Lycopodium* spp.). Most probably, this might happen in post-harvested peatlands. However, in this case, the priority is the restoration of conditions characteristic for the mire ecosystem and its functions, rather than preserving protected species atypical for the mires, which are actually indicators of mire degradation.

Chapter 12. 7150 *Depressions on peat substrates of* Rhynchosporion

12.1 Characteristics of the Habitat Type

12.1.1 Brief Description

The habitat (hereinafter – the *Rhynchosporion* community) is formed by pioneer plant communities on wet exposed peat or sand substrate with *Rhynchospora alba, Drosera* spp. and *Lycopodiella inundata* in raised bogs, in seep- or frost-eroded areas of wet heaths, raised bogs, transitional mires and fens, as well as in the fluctuation zone of shallow waters poor in nutrients with sandy and/or slightly peaty substrate. These communities are similar, and closely related to those of shallow bog hollows and of transition mires (European Commission 2013).

This habitat type is a part of a mire or wet heath complex and cannot exist independently from it. These include bare peat patches in the raised bogs on the slope of the cupola, where the active formation of bog micro-relief structures occurs. The main precondition for existence of the habitat is active geological processes in which the characteristic plant community may develop. In wet heaths this habitat type is related to disturbances (excessive vehicle use, burning, grazing).

The habitat type is rare in Latvia (Fig. 12.1), almost only in the largest intact and slightly affected mires where the active accumulation of peat takes place (Fig. 12.2, 12.3). According to approximate estimates, in the raised bogs the areas where this habitat type may develop cover around 1870 ha or 0.03% of the country's area (Anon. 2013a), but the total area of wet bare peat and sand patches with this pioneer community most likely take up only a few hectares throughout the country (Auniņa 2013d). In small areas the habitat can be found in transitional mires and fens, as well as in heaths. Knowledge on the distribution and total cover of this habitat type in the country is still insufficient.

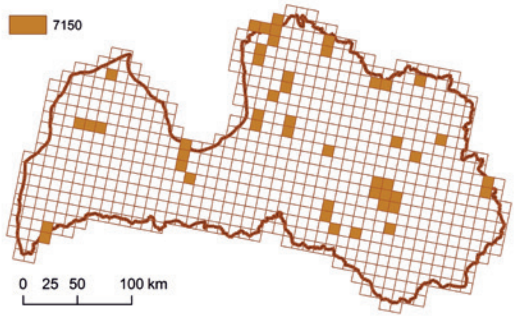

Fig. 12.1. Distribution of the habitat type 7150 *Depressions on peat substrates of* Rhynchosporion in Latvia (source: Anon. 2013a).

In Latvia, **two variants** of the habitat type have been distinguished.

Variant 1: the typical variant; can be found on wet, shallow exposed peat in transitional mires or on bare wet sand in heaths. It can probably also be found in sandy, open lakeshores and humid dune slacks (Fig. 12.1.1.2, 12.1.1.4).

Variant 2: raised bog hollows (Fig. 12.3).

Fig. 12.2. Habitat type 7150 *Depressions on peat substrates of* Rhynchosporion in a fen in Zaļais Mire. Photo: A. Priede.

Fig. 12.3. Habitat type 7150 *Depressions on peat substrates of* Rhynchosporion on a raised bog cupola slope in Great Ķemeri Mire. Photo: A. Priede.

Fig. 12.4. The substrate suitable for the plant community characteristic for habitat 7150 *Depressions on peat substrates of* Rhynchosporion on the shore of a mesotrophic lake. In the photo – Lake Mazuikas near Ādaži. Photo: A. Priede.

Fig. 12.5. Pioneer community characteristic for the habitat type 7150 *Depressions on peat substrates of* Rhynchosporion in Labais Bog. Habitat characteristic species are present: *Lycopodiella inundata, Drosera* spp., *Rhynchospora alba*. Plant community has developed in a post-harvested peatland on wet sand with a tiny peat layer. Photo: A. Priede.

The plant community can also develop in post-harvested peatlands on wet peat or sandy substrate and in abandoned sand and gravel quarries (Fig. 12.5). In such cases, the plant community in Latvia is not considered as the habitat type 7150 *Depressions on peat substrates of* Rhynchosporion. However, the abiotic conditions (substrate, moisture) are similar both in natural and artificially created habitats, thus also human-made habitats with the particular conditions can be very important in the conservation of certain rare species, for example, *Lycopodiella inundata*. Such pioneer communities in small areas covering a few square centimetres to a few square decimetres, if occurring on the shores of mesotrophic lakes (Fig. 12.4), according to the current approach, are considered as a part of the habitat type 3130 *Oligotrophic to mesotrophic standing waters with vegetation of the* Littorelletea uniflorae *and/or of the* Isoëto–Nanojuncetea (Auniņa 2016d).

12.1.2 Important Processes and Structures

The *Rhynchosporion* community characteristic for habitat 7150 is dynamic. It depends on disturbances; therefore the transformation of a particular vegetation type also means the disappearance of this habitat. In intact mires and wet heaths, the dynamic conditions are created by the cracking and sliding of peat caused by gravity and frost erosion. In mires affected by drainage, the active processes in the body of peatland may cease, causing the disappearance of bare peat cracks in the mire surface and overgrowing of the pioneer plant communities.

In Latvia, the heaths depend on human-made disturbances caused by vehicles, grazing, fires, and other factors. Thus, the *Rhynchosporion* community (habitat type 7150) can only persist if its substrate is less or more regularly disturbed, which creates bare substrate, as it happens, for example, in Ādaži military training area, where heaths are regularly influenced by military training activities. Similarly, the existence of the habitat on the shores of oligotrophic to mesotrophic lakes depends on moderate disturbances (e.g. wave action, moderate trampling).

12.1.3 Succession

As mentioned above, the formation and existence of the *Rhynchosporion* community characteristic for habitat type 7150 depend on disturbances. It can establish both after a single disturbance – characteristic plant community develops and then gradually disappears due to overgrowing as it transforms into another vegetation type. Repeated disturbances re-initiate the formation of a partially overgrown pioneer community, occasionally returning to the pioneer stage. To preserve this habitat and its characteristic species in the long term it is necessary to ensure the existence and formation of similar niches in the larger complex of habitats (mire, heath, etc.).

After disturbance, *Rhynchosporion* community exists for about ten years (Stallegger 2008) during which it gradually becomes colonised by perennial vascular plants and mosses (Fig. 12.6-12.8): *Sphagnum* spp., *Polytrichum* spp., *Calluna vulgaris*, *Rhynchospora alba*, *Eriophorum* spp. (in raised bogs), plant species of heaths (*Molinia caerulea*, *Calluna vulgaris*, etc.), *Phragmites australis*, *Calamagrostis epigeios*, and other.

12.1.4 Indications of Favourable Conservation Status

Ideally, a *Rhynchosporion* community should form inclusions in a larger mire of a heath complex. Typically, the habitat type is characteristic with sparse vegetation dominated by low pioneer plant species and a large proportion of wet, bare peaty or sandy substrate. The moss cover is insignificant, closed vegetation of moss, perennial herbaceous plants and shrubs is not characteristic. The bare substrate patches are dynamic, spatially they can change through the years; however, in general the habitat area does not significantly reduce.

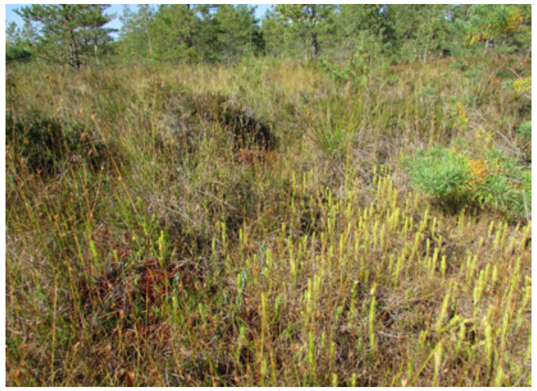

Fig. 12.6. A wet depression in a raised bog with *Lycopodiella inundata* (Aizkraukle Mire). In the course of natural succession, a bare peat patch has almost overgrown with closed vegetation. The moss layer indicates that the micro-niche will soon become unsuitable for the pioneer species *Lycopodiella inundata*. Photo: A. Priede.

In raised bogs, transitional mires and fens, the occurrence of *Rhynchosporion* community indicates active mire formation processes and active mire development. In intact and slightly affected mires, the most significant precondition for existence of the habitat are natural disturbances – sliding of peat, peat cracks, frost erosion, dynamic formation of wet depressions with exposed peat.

In semi-natural and artificially created habitats affected by disturbances (heaths, post-mining areas, post-harvested peatlands), the occurrence of the *Rhynchosporion* community is determined by the nature and intensity of the disturbance. For the existence of particular conditions and related plant community, moderate, regular (at least once in a few years) disturbances are necessary. Due to disturbances, bare substrate is created in wet depressions, and closed continuous vegetation cannot develop. For the existence of this particular habitat type, a constantly wet, periodically flooded peat or sandy substrate is required. Usually the substrate pH varies from acidic to slightly acidic (pH 3.5–5.5). *Rhynchosporion* community does not develop in alkaline conditions (Stallegger 2008). Substrate is poor in nutrients, which slows down the overgrowing with tall herbaceous plants. The plant pioneer community consists of disturbance-dependant species with low competitive ability.

Fig. 12.7. An overgrown wet depression on bare peat with *Drosera* spp. in Ķemeri National Park. Plant community has developed on a gas pipeline track that is maintained by periodic removal of shrubs and mulching of the topsoil. After a longer period without disturbance, the open patches become colonised by *Calluna vulgaris, Molinia caerulea* and shrubs. Photo: A. Priede.

Fig. 12.8. Wet depression in a former military training area has abundantly overgrown with *Polytrichum commune* due to a lack of re-current disturbances. Photo: A. Priede.

Occurrence of the habitat type 7150 *Depressions on peat substrates of* Rhynchosporion in raised bogs, transitional mires, fens, and heaths increase the structural diversity of the habitat complex. The habitat, including the secondary pioneer communities in quarries and post-harvested peatlands, is a refuge for disturbance-dependant plant species which are unable to grow almost anywhere else. Nowadays, such growing conditions are very rare, thus the chances for survival and spread of some of these species are decreasing.

Typical species in the habitat are vascular plants *Rhynchospora alba, Drosera anglica, D. intermedia, Lycopodiella inundata, Cladopodiella fluitans, Gymnocolea inflata* (Auniņa 2013d). In transitional mires the sparse vegetation of wet depressions is composed mainly of *Rhynchospora alba* and *Drosera intermedia*, rarely with the presence of *Lycopodiella inundata*. In wet heaths, *Radiola linoides, Lycopodiella inundata, Juncus alpino-articulatus, Carex nigra, Molinia caerulea* can be found (Auniņa 2016d). The bare, wet substrate provides a suitable environment for invertebrate species related to mires and wet depressions (Stallegger 2008), e.g. *Mecostethus grossus* (Spuņģis 2014).

12.1.5 Pressures and Threats

12.1.5.1 Interspecific competition

Disappearance of habitat type 7150 *Depressions on peat substrates of* Rhynchosporion in a particular area is a natural and inevitable process, since it is a succession stage with vegetation mainly composed of disturbance-dependant species. These species have low competitive ability – when appropriate ecological niches disappear, they gradually become suppressed by dwarf shrubs, mosses, sedges, rushes, grasses and shrubs. Absence of periodic disturbances of the substrate causes natural transformation of the habitat into other vegetation types. As a result, the characteristic plant community disappears due to interspecific competition.

12.1.5.2 Hydrological regime modification and peat extraction

Hydrological regime modification in habitat complexes with 7150 *Depressions on peat substrates of* Rhynchosporion are mainly caused by drainage that may affect both mires and wet heaths. In mires, significant changes can also be caused by peat extraction that cannot be assessed unequivocally in the context of habitat type 7150. On the one hand, drainage related to peat extraction causes an adverse effect on the mire ecosystem, interrupting peat accumulation (*see Chapter 12.1.3*). On the other hand, peat extraction may create suitable conditions for the habitat because wet bare peat or sandy substrate is being created (Auniņa 2013d). Conditions favourable for development of the *Rhynchosporion* community have been promoted by the traditional block-cutting method in peat extraction (Stallegger 2008). However, the impact of peat extraction by destroying and at the same time creating suitable substrate for habitat development is not comparable in the categories "favourable" and "unfavourable". Effective draining can cease the active processes of intact mire. However, it is not possible to estimate how large areas will be suitable for the *Rhynchosporion* community after peat extraction and whether it will establish there. The formation of the secondary habitat is rather a result of coincidence, even in a situation where suitable conditions are available.

12.1.5.3 Eutrophication

The *Rhynchosporion* community is specific in terms of growing conditions – it can only be formed in nutrient-poor, acidic conditions (Anon. 2002; Stallegger 2008). If nutrient levels increase, or if the substrate becomes neutral to alkaline, extinction of the specific plant community can be expected.

Eutrophication is a natural process including the decomposition of litter and accumulation of nutrients. However, eutrophication and turnover of

Fig. 12.9. A recently created wet depression in the heath in Ādaži military firing ground, where the sod has been removed and a shallow water body with sandy substrate and nutrient-poor waters developed. Within a few years after the disturbance, a pioneer community with *Drosera* spp., *Lycopodiella inundata* and other species characteristic for habitat type 7150 may develop. Photo: A. Priede.

Fig. 12.10. A partially overgrown wet depression in the heath in Ādaži military training area – shrubs were removed and re-grown shoots regularly cut, thus maintaining the open landscape. Driving with military vehicles has created bare soil patches suitable for the pioneer communities. Photo: A. Priede.

species may be significantly hastened by the inflow of waters rich in nitrogen or phosphorus, including precipitation and atmospheric deposition. In Latvia there are no studies about the impact of such pollution on mires and habitat type 7150, however, it is most likely negligible.

12.1.5.4 Establishment of invasive non-native plant species

Fig. 12.11. Removal of sod in the heath in small patches in Ādaži military training area. In wetter places, the conditions are suitable for the pioneer communities with *Drosera* spp., *Lycopodiella inundata* and other species characteristic for habitat 7150 may develop. Photo: A. Priede.

In the conditions suitable for the *Rhynchosporion* community in heaths and artificially created habitats, several invasive species (for example, *Campylopus introflexus, Aronia* spp.) may establish. However, they are rare and do not dominate in the plant community. The invasive species may outcompete and displace the native plant species. However, in intact and slightly affected mires the establishment of invasive species is unlikely due to unsuitable conditions..

12.1.5.5 Other affecting factors

In general, habitat type 7150 *Depressions on peat substrates of* Rhynchosporion is affected by all the factors significant for other mire habitat types (*see Chapter 10.1.5*).

This habitat type can also be directly destroyed by significant disturbances of ground vegetation and substrate. If the disturbance is short term and moderate (for example, excessive vehicle use, sod damage or removal, topsoil mulching may have a positive impact, because it causes the disturbance necessary for the persistence of the particular habitat type. Habitat can be destroyed completely by activities such as burying it under construction debris and nutrient-rich soil, building of roads, etc., that completely change the conditions of the abiotic environment, making it unsuitable for the specialist

Fig. 12.12. Suitable conditions for *Lycopodiella inundata* and *Drosera* spp. – a post-harvested block-cutting peatland abandoned a long time ago in Labais Bog. Over time, as the bare peat overgrows with vegetation, the pioneer communities disappear. Conditions suitable for pioneer species might be created by removing the sod patches, thus opening micro-niches with wet bare peat or sand substrate. Photo: A. Priede.

Fig. 12.13. Pioneer community with *Lycopodiella inundata* and *Drosera rotundifolia* in an abandoned sand quarry in Ķemeri National Park. In the course of natural succession, perennial grasses and shrubs establish. The pioneer community may be preserved by re-current cutting of shrubs and loosening the substrate sand or removing the substrate upper layer. Photo: A. Priede.

Fig. 12.14. An abandoned sand quarry abandoned in Ķemeri National Park. In order to restore the pioneer community of habitat type 7150 (still there, though suppressed by perennial vegetation), a disturbance must be created and the sedge and reed vegetation removed. Photo: A. Priede.

species.

12.2 Restoration and Management Objective for the Habitat Conservation

See the common objectives for all mire habitats (*Chapter 5.3*).

A specific objective of habitat type 7150 *Depressions on peat substrates of* Rhynchosporion conservation, restoration and management is to create and maintain the conditions suitable for specialist species and disturbance-dependant plant communities – an acidic bare, wet peaty or sandy substrate, ensuring the continuity of natural disturbances in natural habitats (bogs, fens, transitional mires), at the same time preserving the natural hydrological regime. In semi-natural and human-made habitats (heaths, post-harvested peatlands, post-mining areas and elsewhere) it is necessary to ensure suitable moisture and substrate properties as well as to create periodic disturbances.

12.3 Habitat conservation and restoration

12.3.1 Habitat restoration for the Purpose of the Guidelines

The most appropriate management types for the habitat type 7150 *Depressions on peat substrates of* Rhynchosporion are determined by the habitat origin in the particular place. Prior to choosing the suitable management type, the habitat groups must be distinguished: natural bogs, fens and transitional mires, in which the existence of pioneer communities is defined by natural disturbances (including humid dune slacks with mire vegetation), semi-natural habitats – heaths, in which the conditions suitable for the pioneer communities are created by anthropogenic disturbances (Stallegger 2008), and human-made habitats – mainly post-harvested peatlands and sand or gravel quarries. In intact mires, the existence of *Rhynchosporion* community and the typical conditions can be ensured by preserving the mire ecosystem functions, whereas in heaths, post-harvested peatlands and quarries the community depends on the disturbances, mainly on anthropogenic disturbances.

These guidelines provide an insight into the appropriate management types for the habitat. However, they should almost always be implemented in a comprehensive way. The pioneer communities and pioneer species can be best preserved by ensuring a favourable conservation status for the entire mire or heath by applying appropriate management, or by creating and/or maintaining moderate disturbances in a post-harvested peatland or quarry area.

12.3.2 Mire Conservation and Restoration of Ecosystem Functions

For the conservation of habitat type 7150 *Depressions on peat substrates of* Rhynchosporion, it is most important to preserve an undisturbed or slightly affected hydrological regime, eliminating unfavourable impacts. In drained mires the existence of habitat type 7150 and the recovery of the natural disturbance dynamics is promoted by the restoration activities of raised bog habitats (*see Chapter 10.3*). It is crucial to ensure natural processes in mires, rather than invest efforts in achieving static localities of *Rhynchosporion* community, which, taking into account the dynamic character of this habitat type, is actually impossible. This means that most of the attention should be paid to ensuring the process, rather than the area of a habitat or plant community.

12.3.3 Heath Management

The conditions favourable for the pioneer communities are ensured by regular heath management (removal of shrubs and trees, mowing, grazing), and regular disturbances caused by military training activities (as a large proportion of dry heath in Latvia is located in a military training area). Such disturbances create bare substrate patches and decrease the competition with perennial vascular plants, dwarf shrubs and mosses. The conditions favourable for habitat type 7150 are ensured by heterogeneity of the habitat and the presence of various micro-niches. An important precondition is the presence of wet, periodically flooded, bare peat or sand patches. Such patches can be formed both in places that are driven on (unpaved roads in sandy areas and heaths), in military training areas (Fig. 12.9, 12.10), and in places trampled by grazing animals. Suitable conditions can also be created intentionally, for example, by sod cutting (Fig. 12.11).

Creation and management of the conditions suitable for habitat type 7150 in heaths is always a complex action that should be planned together with other heath restoration and management works (Laime (ed.) 2017, *Chapters 17 and 18*).

Grazing management in heaths is also recommended, in this way maintaining not only the heath habitat, but also promoting the development of bare wet soil patches created by trampling and intense grazing. However, grazing does not guarantee the development of conditions suitable for habitat type 7150 and establishment of the *Rhynchosporion* community, since grazing animals may cause too heavy trampling pressure and eutrophication. These side effects are difficult to limit and sometimes this may cause an adverse effect – disappearance of habitat 7150 (Stallegger 2008).

12.3.4 Eradication of Invasive Non-native Plant Species

Eradication of invasive non-native plant species must be carried out as soon as possible in the entire habitat complex. Mechanical eradication (felling, mowing, turf removal) is labour-consuming, expensive, and often not efficient. Rewetting (*see Chapter 10.3.3*) can provide better results by making the conditions unsuitable for the invasive species, but biotechnical measures must only be performed as an additional measure and in cases when it is not possible otherwise.

12.3.5 Creation of the *Rhynchosporion* Community in Human-made Conditions

Creation of the conditions suitable for the habitat type 7150 in abandoned peat extraction sites and quarries can promote the development of *Rhynchosporion* community, however, it does not guarantee this. In such cases, suitable conditions mean appropriate moisture level, low nutrient availability, low substrate pH, as well as the presence of the characteristic plant propagules (seeds, spores) in the surroundings of a particular area or rich soil seed and spore bank. Seeds and spores of many disturbance-dependant species can be preserved for a long time while "waiting" for suitable conditions (Anon. 2004).

In Latvia, post-harvested peatlands are one of the most suitable habitats for the development of *Rhynchosporion* community typical for habitat type 7150; however, an important prerequisite is a wet peat or sand surface or uneven mosaic-type moisture conditions with wet depressions and drier elevations (Fig. 12.12). The most suitable conditions for this pioneer community are gently sloping depressions where the peat layer reaches the sand sediment, which is constantly wet or seasonally covered with shallow water.

For the renaturalisation of post-harvested peatlands, the approaches described in *Chapter 10.3.8* are used. In any case, the renaturalisation target in post-harvested peatlands is the creation of the conditions optimal for the mire, while the plant community typical for habitat type 7150 in favourable conditions may occupy suitable micro-niches – depressions with wet peaty or sandy substrate. In restored post-harvested peatlands, where continuous vegetation cover has developed resembling the vegetation of raised bog hollows (*Sphagnum* spp., *Rhynchospora alba*, etc.), the establishment of plant communities characteristic for habitat type 7150 would be promoted by the removal of sod in small patches (Stallegger 2008). Sod must be removed, ideally – taken away from the area or stacked in compact piles. The sod "bricks" can also be used for ditch dams, if it is planned to build such.

Sometimes natural disturbances in such places occur due to frost erosion (frost cracks, frost heaving) that hampers the development of vegetation. The cracks may be suitable for the establishment of pioneer plant communities.

Although abandoned sand and gravel quarries can be a perfect environment for the pioneer communities typical for habitat type 7150, the particular plant community is rare. In quarries, suitable conditions for the plant community may be found on flat, wet shores of water bodies, small island-like elevations in ponds, flat and wet depressions (Fig. 12.13, 12.14). Water bodies with steep shores, dry areas and steep slopes, as well as the areas with perennial vegetation are unsuitable.

In quarry areas with the pioneer communities with *Lycopodiella inundata*, *Drosera* spp. and other species of habitat type 7150, active management is necessary. In overgrowing places, removal of shrubs and trees (cutting, rot extraction), mowing of perennial grass vegetation and periodic loosening of the substrate in wet depressions and on the shores of the flat depressions are necessary. Solely clearing of shrubs will not help in preserving the pioneer communities, since they need an open substrate. Loosening (a forest plough applicable in the preparation of soil in forest clear-cuts can be used) must only be performed in places suitable for the pioneer communities of the habitat type 7150 – in wet depressions and on the gentle-sloping shores of ponds, and not in the entire area of the extracted quarry (Řehounková, Řehounek 2011).

Abandoned sand and gravel quarries with diverse micro-relief, shallow ponds and sparse vegetation also provide a suitable habitat for rare animal species, for example, natterjack toad *Bufo calamita* (specific recommendations – see the species conservation plan: Bērziņš (2008)), newts *Triturus* spp., dragonflies *Odonata*. The measures taken (diversification of the micro-terrain, creation of gentle-sloping shores, etc.) to improve the conditions for amphibians and insects may also be favourable to the development of the pioneer communities. Therefore, the rehabilitation of post-mining areas should be planned in a comprehensive way. Wet depressions in sand and gravel quarries may also be a significant habitat of *Liparis loeselii*.

Restoration and improvement of the conditions characteristic for the pioneer communities of habitat type 7150 on the shores of oligotrophic to mesotrophic lakes must be performed together with the measures for improving the structure of the lakeshore vegetation. It may be mowing and pulling out the perennial vegetation, loosening of substrate and the removal of the accumulated organic sediments (Urtāns (ed.) 2017, *Chapter 12.3*). In Latvia, such method was applied in the protected landscape area "Ādaži" (Auniņa (ed.) 2014), however, its impact on the pioneer community with *Lycopodiella inundata* on the lakeshore is not known.

12.3.6 Inappropriate Management and Use of the *Rhynchosporion* community

The following actions are unfavourable for the conservation of the particular habitat type:

- mire drainage;
- intense grazing and related heavy trampling;
- too intense use of heaths (frequent destruction of the ground cover);
- afforestation;
- mowing or shredding without the removal of biomass;
- destruction of pioneer communities and their characteristic substrate by covering them with waste, debris, nutrient-rich soil and other artificial materials.

12.4 Conservation and Management Conflicts

Restoration and management of larger habitat complexes (mires, heaths, habitats of anthropogenic origin) may sometimes locally destroy the specific pioneer community and the conditions suitable for it. Pioneer community may be also temporarily destroyed by the actions directed at its conservation – loosening of substrate, excessive use of vehicles, sod cutting, and raising of the water level. However, the priority is to ensure the long-term persistence of the particular habitat in the long term, and the only way is the creation and maintenance of the suitable conditions. Therefore, the disturbances must be planned so that they do not affect or destroy all localities of the characteristic species at the same time, allowing their dispersal to other areas with suitable conditions.

Chapter 13. 7160 *Fennoscandian mineral-rich springs* and *springfens* and 7220* *Petrifying springs with tufa formations* (Cratoneurion)

13.1 Characteristics of Spring Habitats

13.1.1 Brief Description

Habitat type ***7160 Fennoscandian mineral-rich springs and springfens*** includes spring brooks, seepage springs and spring fens with a constant supply of subsurface waters. The water in springs is cold and has a constant temperature, is rich in minerals and, due to the rapid water movement, rich in oxygen. In the spring discharge sites, a pond or a creek with spring-specific vegetation may develop. In spring fens, the water filtrates through the ground in a disperse way; over time the peat accumulates and spring-specific vegetation develops. Since the water discharges from deeper layers of the ground, its temperature is constant, therefore the springs often do not freeze even in cold winters. The invertebrate fauna is specific for springs, and flora is rich in northern species (European Commission 2013; Ikauniece 2013).

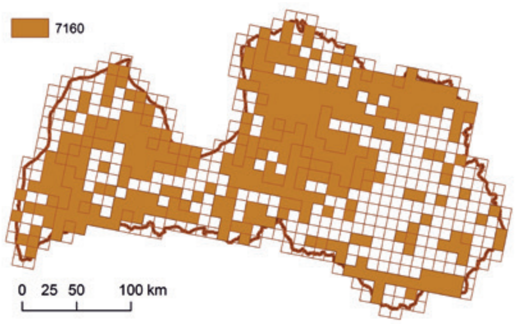

Fig. 13.1. Distribution of the habitat type 7160 *Fennoscandian mineral-rich springs and springfens* in Latvia (source: Anon. 2013a).

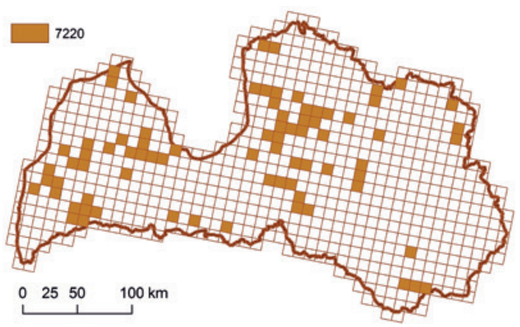

Fig. 13.2. Distribution of the habitat type 7220* *Petrifying springs with tufa formation* (Cratoneurion) in Latvia (source: Anon. 2013a).

Mineral-rich springs and spring fens are quite rare throughout Latvia. They may be found mainly on the slopes in river valleys, e.g. in valleys and side-ravines, also on the hill slopes where the underground water discharges (Fig. 13.1). In flat terrain, the springs discharge in depressions where they may promote paludification and the development of fens (Ikauniece 2013). In Latvia, the total area of this habitat type takes up around 240 ha (Anon. 2013a). Mineral-rich springs are often ancient religious sites and water taking places, also outstanding scenic places with historical importance that at the same time are also popular tourist destinations.

In Latvia, **three variants** of the habitat type have been distinguished (Ikauniece 2013; Ikauniece, Auniņa 2016).

Variant 1: seepage springs (filtration springs) – usually located in a forest with more or less explicit tree and shrub layer. Often several subsurface water (most often, the groundwater) seeps are located close to each other. Usually seeps do not create creeks, and only wet soil patches, with spring-specific vegetation are visible (Fig. 13.3).

Variant 2: spring creeks with rapidly running water; the mineral composition of water is highly variable; there are few habitat-specific plant species. There is almost no peat accumulation since the flow of water washes away the dead plant parts (Fig. 13.4).

Fig. 13.3. Variant 1 – a seepage spring on the shore of Lake Sāruma. Photo: A. Priede.

Variant 3: spring fens – fens fed by spring waters, usually located on flat terrain, on gentle slopes or in relief depressions. The soil is constantly waterlogged, thus there is an active paludification process with peat accumulation. Usually wet, sparsely vegetated patches interchange with species-rich spring-specific vegetation (Fig. 13.5).

Habitat type 7220* ***Petrifying springs with tufa formation* (Cratoneurion)** are springs with carbonate-rich waters flowing through the underground layers consisting of carbonate sediments (limestone, dolomite). Such springs actively form tufa sediments (lime tufa, barrage tufa). The vegetation is dominated by mosses (plant community *Cratoneurion commutati*). In Latvia, this habitat type includes both active springs (Fig. 13.6), tufa outcrops where the sediment formation has ceased, and tufa sediments, which are exposed in old tufa extraction sites (Rēriha 2013) (Fig. 13.7).

Petrifying springs with tufa formation can rarely be found throughout the territory of Latvia, most often in the river valleys and their side-ravines, rarely on the slopes of hills and rises of ancient shores and at their basal part (Fig. 13.2). In Latvia, the total cover of this habitat type is around 52 ha (Anon. 2013a). Several petrifying springs and seepage springs with tufa formation have a significant scenic importance, for example, an outstanding tufa outcrop was developed in Daugavas Staburags – once the largest tufa-forming spring in Latvia, which was destroyed in the 1960s, when the Pļaviņas hydro-power plant was constructed and the water level in the River Daugava was significantly raised, thus flooding the nature monument. Other examples of tufa-forming springs are Raunas Staburags and Kursas Staburags. An outstanding scenic site is also Līvānu-Jaunzemju tufa outcrop, though it is affected by human activities (Fig. 13.7).

If spring waters with different mineral contents are discharging in the same locality, the spring discharges may sometimes bear the features of both habitat types (7150 and 7220*). Good examples are Dāvid's Mills Springs in Gauja National Park, where there are high concentrations of both iron and calcium in spring waters, or springs in Raganu Mire in Ķemeri National Park where springs are forming ponds with high sulphur and calcium content.

Currently knowledge on the distribution and the total cover in the country is still insufficient and has to be made more precise.

Spring habitats may occur in forests, agricultural lands and mires. From the perspective of EU habitat classification, they may overlap with other protected habitat types (forests, grasslands, mires, rock outcrops). However, not all the mineral-rich or tufa-forming spring discharges comply with the EU habitat types. The spring discharges may not meet the protected habitat criteria in sites without spring-specific vegetation and/or sites without spring sediments. Also severely modified springs, e.g. equipped with tubes and/or covered with artificial materials (*see Chapter 13.1.5.8*), and springs discharging on the bottom of water bodies (lakes, rivers, ditches, canals) cannot be classified as protected habitats.

13.1.2 Important Processes and Structures

The most important precondition for the formation and existence of spring habitats is spring activity. Therefore, spring activity and its protection, including measures to prevent unfavourable impacts, are the priority in the conservation of the spring habitats. When the spring runs dry, the dynamic process of habitat formation disappears as well, and only the sediment formed by the spring remains. The spring-related vegetation may temporarily survive; however, soon the characteristic species disappear upon the change of the conditions.

7160 *Fennoscandian mineral-rich springs and springfens*: the formation and existence of the habitat is ensured by the outflow of mineral-rich waters on the earth surface (most commonly rich in iron, less frequently – with sulphurous compounds or other mineral substances). Spring waters usually have low calcium content, waters are slightly acidic to alkaline. If the mineral concentration is high, iron or sulphurous sediments are deposited around the spring.

The most important precondition for the existence of the habitat type **7220* *Petrifying springs with tufa formation*** is spring activity and the formation of tufa. Usually calcium carbonate petrifies in the form of small particles by sticking around the dead plant debris and/or forming solid calcareous rock. If a spring has a small capacity, the calcareous deposits may accumulate under the soil surface as loose sediments. In Latvia, tufa sediment petrifies on steep slopes, in flat depressions and wet depressions (Pudovskis 1944). Depending on the location in the terrain, the type of tufa deposits may also differ (well-cemented on steep slopes, moderately to slightly cemented, loose on slopes and depressions). When the spring runs dry, the spring sediments may still serve as a suitable habitat for various calciphilous plant species and the fauna related to a calcareous environment. Cessation of water flow in the spring (due to natural factors or anthropogenic impacts) also causes the cessation of tufa formation and changes the entire environment around the spring, especially micro-climate related to the spring activity (constant high air humidity and low air temperature), which is important for numerous spring-related species and communities.

The water temperature in springs is constantly low and changes little depending on the air temperature (Kapfer et al. 2012). In winters, if the air temperature does not drop extremely low, the springs do not freeze. Usually the soil around the spring is constantly wet; in depressions and on gentle slopes fen peat is formed (usually it does not form on steep slopes where it is being washed away). Spring discharges with low outflow capacity – the seepage (filtration) springs – form wet soil patches without a visible water flow (Ikauniece 2013), and in summers with low precipitation they can dry up.

Species composition in spring habitats is determined by many factors; moreover, the habitat may be located both in a forest and an open landscape (mire, grassland). Habitat structure and species composition vary depending on the character of the site (mineral contents of water, sediment type, surrounding habitats, location on the terrain, etc.), processes and suitability of the site conditions to the particular species.

13.1.3 Succession

If springs are not affected by humans, their development is only influenced by natural processes. Most of the springs are discharging on the slopes and side-ravines of river valleys, thus they are influenced by slope erosion. Sometimes the development of side-ravines might be initiated by the spring activity. Landslides may affect the spring vegetation; however, such disturbances are natural and cannot be considered as deteriorating. On steeper slopes, peat sediments do not usually accumulate, since sediment is eroded under the impact of gravity. In "cliffs" formed by springs petrifying tufa (habitat 7220*), the pieces of tufa may break off under the impact of gravity, but the spring sediments continue to accumulate.

On flat terrain around the seepage springs, fen peat develops. In the constantly wet conditions, paludification of the soil occurs, therefore spring fens can persist for a long time as open mire landscape. The succession of open spring fen vegetation is similar to that of fens, traditionally managed as meadows or pastures. In early succession stages, small-sedge vegetation prevails. With time, tall sedges and reeds establish, whereas in the later succession stages the areas overgrow with forest. During the overgrowing process the species of open seepage springs and fens are replaced by forest species. Since the areas with springs are unsuitable for most economic activities, the spring habitats can mostly be found in forests where the habitat development is determined by forest dynamics, which in turn is affected both by natural and human-caused disturbances.

As the spring dries up, which may happen naturally or, most commonly, due to human activity (lowering the groundwater table, affecting the subsurface water flows or destroying the springs due to the extraction of tufa or other mineral resources), the spring-specific species complex may survive for some time. However, in the long term, spring habitats and the characteristic species cannot persist without the active flow of spring water. As the springs dry up, the petrifying spring with tufa formation habitat remains as a dry calcareous substrate that may be an important habitat as a substrate for species of dry calcareous habitats. If no management is applied, overgrowing with forest can be expected.

13.1.4 Indications of Favourable Conservation Status

Springs gather water from a relatively large area. There are both groundwater springs and artesian springs. Groundwater springs are fed from waters that accumulate in the upper layers from a few to several tens of metres deep in quaternary deposits. Such springs usually have weak flow, and the flow volume is affected by precipitation. They sometimes form diffuse seeps and do not always form spring brooks. Artesian permanent springs discharge waters from deeper layers (artesian waters) with at least one impermeable rock layer above it. Such springs usually have a constant water flow. The water temperature is relatively little affected by changes in the air temperature.

Spring habitats in favourable conservation status are characterised by undisturbed, unpolluted water flow. Groundwater springs that discharge water from unconfined layers are more exposed to pollution risk than artesian springs. Thus, the groundwater springs can be easily affected by human activities influencing the groundwater table and quality. For petrifying springs with tufa formation, the tufa formation is an essential feature of favourable conservation status (except for the outcrops and exposed tufa grounds, which are classified as habitat type 7220* in Latvia, too).

In spring habitats, natural, undisturbed flow of water is the key feature in determining the conservation status. The habitat structure and species composition, as they are highly variable, cannot be sufficiently defined to be used as an indicator of the conservation status of the habitat. Spring discharges can be found in forests, agricultural lands and mires, and their location in the terrain varies a lot. Various spring sediments can be formed, and the water flow may have a different character and discharge capacity. Considering the variety of spring types, it is not possible to generalise the desirable habitat structure and species composition. It is important that the habitat structure, including terrain, micro-relief, the flow character and vegetation have developed in a natural way, without significant human-caused modifications. In spring habitats in a favourable conservation status, invasive non-native and expansive native plant species are absent or, at least, do not dominate. No other signs of eutrophication or mechanical damage may be observed in springs and their nearest surroundings. The exception is traditional management in fens around the springs, which does not modify the spring flow and does not cause degradation of the soil around the springs.

The vegetation in spring habitats may be very diverse and influenced by location in terrain, spring capacity, water chemical composition, and many other factors. Due to natural causes the plant communities and their spatial distribution at a local scale may significantly differ, thus the composition of plant communities specific only to particular spring habitats cannot really be defined.

7160 ***Fennoscandian mineral-rich springs and springfens***. The composition of typical species can vary a lot depending on the spring location and site conditions. The following moss species are the so-called umbrella species characterising the habitat type in Latvia: *Trichocolea tomentella*, *Marchantia polymorpha*, *Philonotis* spp., *Cratoneuron filicinum*, *Scorpidium cossonii*, *S. revolvens*, *Calliergonella cuspidata*, *Calliergon giganteum*, *Campylium stellatum*, *Marchantia polymorpha*, *Paludella squarrosa*, *Sphagnum teres*, *Sph. warnstorfii*, *Hamatocaulis vernicosus*, *Plagiomnium undulatum*, *P. elatum*, *P. ellipticum*, *Brachytecium rivulare*, *Hylocomium umbratum*.

The vascular plant species composition varies depending on site conditions. Several rare and protected vascular plant species are strongly related to this habitat type: *Montia fontana*, *Equisetum telmateia*, *Stellaria crassifolia*, *Saxifraga hirculus*, *Ligularia sibirica*, *Dactylorhiza fuchsii*, *D. maculata* (Ikauniece 2013). Their presence increases the value of the habitat in the particular site. The species typically occurring in this habitat type are *Carex remota*, *C. appropinquata*, *Sagina nodosa*, *Cardamine amara*, *Chrysosplenium alternifolium*, *Cirsium oleraceum*, *Crepis paludosa*, *Myosotis palustris*, *Veronica beccabunga*.

This habitat type is also characterised by the presence of certain invertebrate fauna in the soil: *Carychium minimum*, *C. tridentatum*, *Cochlicopa lubrica*, *Vallonia costata*, *V. pulchella*, *Euconulus fulvus*, *E. alderi*, *Punctum pygmaeum*, *Vertigo substriata*, *V. angustior*, *V. antivertigo*, *V. pusilla*, *V. pygmaea*, *Nesovitrea hammonis*, *Pupilla muscorum* (Ikauniece, Auniņa 2016).

7220* ***Petrifying springs with tufa formation***. The so-called umbrella species that characterise the quality of the habitat are mosses *Palustriella commutata* and *Philonotis calcarea*, and vascular plants – *Pinguicula vulgaris*, *Primula farinosa*, *Carex ornithopoda*, *Dactylorhiza* spp. However, numerous other plant species are characteristic for this habitat type, e.g. moss species – *Scorpidium cossonii*, *Preissia quadrata*, *Cratoneuron filicinum*, *Plagiomnium elatum*, *P. ellipticum*, *P. undulatum*, *Pellia endiviifolia*, *Bryum pseudotriquetrum*; lichens – *Verrucaria* and *Thelidium* family species; vascular plants – *Carex appropinquata*, *C. flacca*, *C. hostiana*, *C. paniculata*, *Caltha palustris*, *Cardamine pratensis*, *C. amara*, *Equisetum palustre*, *Cirsium oleraceum*, *Crepis paludosa*, *Myosotis palustris*, *Stellaria nemorea*, *Veronica beccabunga*.

For several species, petrifying springs with tufa formation is the only or almost only suitable habitat, e.g. for moss species *Palustriella decipiens*, *Eucladium verticillatum*, *Gymnostomum aeruginosum*, and *Seligeria pusilla* (Rēriha 2013; Rēriha, Auniņa 2016).

However, the specific fauna of springs, especially of habitat 7160 *Fennoscandian mineral-rich springs and springfens*, has been little studied in Latvia. Alkaline fens around the springs that have formed on tufa sediments host several rare snail species – *Vertigo genesii*, *V. geyeri*, *V. angustoior*. Also *Aporrectodea rosea*, *Pedicia rivosa*, in water – *Gammarus* spp. can be found here (Rēriha 2013; Rēriha, Auniņa 2016). In forest seepage springs the snail species *Acicula polita* may be found (Suško 1997).

13.1.5 Pressures and Threats

13.1.5.1 Hydrological modifications

The groundwater flows and hence also the spring activity may be unfavourably affected by the drop in water table caused by the digging of drainage ditches and ponds, mining activities, excessive water extraction or other hydrological modifications. The impact of human activity on artesian water flows is less likely, because it is protected by impermeable rock layers, however, it may be affected by mining and water extraction.

13.1.5.2 Mineral extraction

In Latvia, tufa has been extracted and used for different purposes for a long time. Well-cemented tufa has been used in building construction and as a decorative material in façades and memorial monuments. Poorly-cemented and loose tufa sediments have been used for soil liming and other purposes, such as the production of tooth cleaning powder (Rozenšteins, Lancmanis 1924; Pudovskis 1944). In the second half of the 20th century, well-cemented tufa was also widely used for decorative purposes in gardening and landscape designing.

In many petrifying springs tufa has been extracted, thus decreasing the sediment volume, sometimes also causing drying up of the spring and destruction of the habitat. However, sediment extraction, although it has a deteriorating effect, does not always damage the water flow and tufa formation. However, such activities can destroy the habitat-specific vegetation and cause the local extinction of rare species.

Extraction of tufa has occurred in many places in Latvia. One of the largest tufa deposits in Latvia may be found in Kazugrava ravine near Cēsis, which has been used for tufa mining for a long time. Already in 1924 there was a call to preserve this nature monument from over-exploitation (Rozenšteins, Lancmanis 1924).

"In total, in the whole inventory according to our rather incomplete data, one could estimate 27,000 m^3 extracted and 230,000 m^3 still unutilised tufa sediments. In any case, this is one of our most prominent resources of tufa, as regards both volume, and conditions of origin, and other geological peculiarities (ancient bed, delta cone, swallow holes, dolomite) and features (dales, waterfalls, residual tufa wall) of the surroundings. The locals already have an idea of building summer cottages, which is quite possible due to the proximity of Cēsis Town (approximately 2.65 miles). The Monuments' Board should take measures to ensure the protection of the remains of the tufa deposits and some parts of the delta cone to preserve them for researchers as a rare and glorious nature monument, and for the enjoyment of future generations" (Rozenšteins, Lancmanis 1924).

13.1.5.3 Slope processes

Slope processes are natural, especially on steeper slopes, and they also affect spring habitats. Slope processes result in landslides and the development of ravines. However, the instability of slopes may also be encouraged by human activity, for example, intense cultivation of land (ploughing) and clear-cuts near the slope edges. Due to landslide and erosion processes, a spring may be temporarily buried, due to which the typical vegetation may be destroyed, and the spring may change its stream bed. At buried springs, over time the typical vegetation recovers spontaneously.

13.1.5.4 Logging

Forests with spring discharges have been relatively little affected by forestry operations, thus the features characteristic for natural forests have developed and natural processes prevail (Suško 1997; Kapfer et al. 2012). The constant flow of water and sheltering impact of forest creates a relatively constant micro-climate with low fluctuations in the air temperature and shady conditions suitable for numerous spring-related species. Springs with high contents of calcium in the water provide an environment for calciphilous plant species and snails for which the calcium is essential for developing the shell (Lārmanis u. c. 2006). The constant, specific micro-climate around springs is especially important for mosses, as many of them depend on a permanent micro-climate around the springs (Suško 1997). Drying up of springs causes local extinction of habitat-specific mosses, mostly due to microclimate changes.

Forestry operations, depending on their intensity, may significantly modify the habitat-specific conditions and cause changes in the spring vegetation due to alterations in light availability and soil damage, which in turn changes the evapotranspiration rates. On one hand, logging operations, particularly clear-felling, in the surroundings of springs have an undesirable impact as they cause drastic changes in the micro-climate and light conditions, thus enhancing the risk of local extinction of habitat-specific and rare species. On the other hand, the observations in the sites with the habitat type 7220* *Petrifying springs with tufa formation* suggest that the removal of trees probably promotes the precipitation of tufa as the amount of water accumulated in the soil increases due to lower evapotranspiration. Additionally, the enhanced insolation promotes the growth of mosses and thus also the precipitation of calcium carbonate particles on mosses and plant litter. The improved insolation in sites where trees are removed, usually cause the establishment of light-demanding herbaceous species. This may result in alteration of the tufa structure as its development is strongly related to the living and dead plant material specific for the particular site (Pentecost 2005).

Thus, the impact of logging on the habitat cannot unequivocally be considered as favourable or unfavourable, since the different forest and non-forest conditions promote the development of a different species complex. Reasonable assessment of the impact of tree felling is only possible upon comprehensive studies on the parameters of a specific location, such as age of the forest, forest structure, and species diversity and their ecological requirements and influencing factors, presence of structures of old-growth forests. If the forest is not old, nearly-natural, and logging would improve the spring habitat quality, then felling of trees and/or removal of shrubs is acceptable. The logging method is also crucial – seepage springs and spring brooks in a forest may be significantly damaged or even destroyed by the use of heavy forest vehicles, while manual felling of individual trees can cause minor alterations in the habitat.

Fig. 13.8. Beaver activity caused a rise in water level and dying of trees around the spring. Over time, when the trees fall down, such sites are usually invaded by reeds, while the spring habitat and the specific vegetation are in most cases irreversibly destroyed. In the photo – the spring on a slope in the surroundings of Rakši in Gauja National Park. Photo: A. Priede.

Fig. 13.9. Beaver pond on the slope of a side-ravine in Gauja National Park near Rakši. In this case, the beaver pond affects a small area, since the slope is quite steep. Photo: A. Priede.

13.1.5.5 Groundwater and surface water pollution

Groundwater springs that are fed by waters in unconfined layers can easily be polluted by organic and non-organic substances, including pesticides from agricultural lands, municipal wastewaters and pollution from other sources. There is less risk of pollution for springs that accumulate the waters from confined layers, covered with at least one impermeable bedrock layer. Pollution in the spring waters causes spreading of the pollution to surface water bodies – rivers and lakes.

13.1.5.6 Rise in water level and beaver activity

Spring habitats may be unfavourably affected by a constantly raised water level that may be caused both by human-made hydrological modifications (e.g. artificial ponds, dams) and beaver ponds. In permanent flooding conditions, the spring flow may persist for some time, however, as the other conditions in the habitat completely change, the spring-specific species composition disappears. If flooding has been for a short time only, the recovery of the spring and its specific conditions may be expected, though it can take a long time. In long-term flooding the spring habitat may be irreversibly degraded, although the artesian spring discharges may persist.

Beaver activity affecting spring habitats cannot be unequivocally assessed as negative, since the degree of impact is also determined by their placement in the terrain. Beaver ponds create an unfavourable impact on springs on a flat terrain (Fig. 13.8). If the spring discharges on a slope, beaver activity most often does not affect the spring habitat or affects only a small area by creating "terrace" ponds (Fig. 13.9). Since the beaver feeds predominantly on deciduous trees, shrubs and their stem shoots, beaver activity sometimes helps to maintain open spring fens by decreasing the overgrowth with shrubs.

The spring activity may also be affected by the rewetting of drained fens and grasslands. In such restoration areas, if springs are present, the potential impacts of raising the water level must be assessed prior to rewetting. There are no universal recommendations; each situation must be assessed by involving experienced experts.

13.1.5.7 Mowing and grazing

Long-term persistence of open spring habitats and the presence of species characteristic for open spring fens indicate that the particular sites might have been once used for haymaking or grazing. Many of the spring fen species are adapted or even depend on low to moderate intensity disturbances, such as mowing and grazing. However, due to difficult conditions of terrain, substrate wetness, low nutritional value of the grass and other factors these areas are abandoned nowadays. Due to a lack of moderate disturbances, in many places fens are gradually overgrowing with forest, and the diversity of the species related to the open spring habitats is declining.

Mowing creates a moderate intensity disturbance and some trampling impact, which is usually of minor importance. Mowing is efficient in decreasing the dominance of expansive plants (most often *Phragmites australis*) and promoting the development of species-rich vegetation; in most cases it helps in maintaining open spring fens.

Grazing in spring fens may have a significant trampling impact on ground vegetation, causing soil compaction, creating bare soil patches, and mechanically destroying the plant and moss cover on the ground. Grazing also causes significant additional inputs of nutrients in the spring waters and soil, and further along the catchment basin – also potentially in larger water courses. Most likely, grazing in the long term is unfavourable to spring habitats; it can even cause the local extinction of some species. However, in the long term it also helps for spring fens to remain open. Due to the delayed effect, the highest species richness in formerly grazed sites may develop some years after the abandonment of pasture grounds, when the intense impact has been ceased and overgrowing with forest has not yet started.

13.1.5.8 Human-made constructions

Various constructions – curbs, pipes, wooden boardwalks, etc. – that are installed at popular water taking sites create an impact of different intensity on springs and spring habitats. Complete transformation of spring discharges (concrete constructions, pipes, sheds and other constructions) may destroy the spring habitat. However, in most cases these constructions do not have a relevant long-term impact on the spring flow and spring habitats. By removing the human-made constructions, in quite a short time the natural vegetation may recover, if such has been there before and the terrain or the brook has not been significantly modified. However, in each case other functions of the spring must be taken into account when planning the restoration of the habitat. For example, the spring may be an important water source for the local residents or popular as a water taking site even on a national scale, or it can be an ancient religious site or tourist destination. Therefore the restoration of the natural habitat in each spring area is not always the best and only solution. All other aspects must be taken into account and a compromise must be sought.

Fig. 13.10. *Heracleum sosnowskyi* established on tufa sediments in Kursas Staburags (Kauķa kalns) in the River Imula valley. Photo: A. Priede.

13.1.5.9 Trampling

Trampling of the ground vegetation typically occurs in popular, frequently visited springs and their surroundings. Intense trampling damages the vegetation, especially the moss cover, causes soil compaction and eutrophication that, in turn, promotes the establishment of ruderal, expansive native or invasive non-native plant species. In habitat type 7220* *Petrifying springs with tufa formation*, trampling also causes mechanical damage of the fragile barrage tufa sediments.

In pastures, heavy trampling is caused by livestock, especially cattle, which are completely degrading the spring vegetation (*see Chapters 13.3.6 and 13.3.7*). Trampling is also caused by wild large mammals as their trails often cross the spring areas; however, this should be considered a natural disturbance of minor importance, and due to the small scale they do not cause a significant impact, rather they increase the diversity of micro-niches. Broader and more significant impacts may be caused by wild boar, especially if they establish and regularly visit so-called "mud baths" in springs.

13.1.5.10 Invasive plant species

The establishment of invasive non-native plant species causes undesirable changes in the vegetation structure, especially by the establishment of tall herbs with high competitive ability such as *Heracleum sosnowskyi* (Fig. 13.10) and *Impatiens glandulifera*. *Impatiens parviflora* may be found in spring habitats fairly often, which often takes the dominant role in the vegetation. Some other invasive species may rarely be present in spring habitats, e.g. *Solidago canadensis* and *Petasites hybridus* (sometimes planted near springs as ornamental plants). The establishment of these species changes the light conditions by creating shade, therefore the dense moss cover characteristic for springs decreases or disappears. Ground stability may then decrease, thus increasing the instability of soil and encouraging landslides on slopes, especially in the autumn-spring season when there is higher rainfall.

The vicinity of running spring water also increases the risk that seeds and root fragments of invasive plants may be carried to other areas downstream, and contributes to the spread of invasive species over a larger area.

13.1.5.11 Debris and municipal waste

Burying of spring discharges and spring habitats under construction and other waste can irreversibly destroy the habitat. Municipal waste, if not in a large quantity, or if it does not cause chemical or organic pollution, mainly causes aesthetic damage rather than an impact on the habitat quality or habitat-related species; however, it may injure wild animals and humans, especially, if the spring is a popular water taking site.

13.2 Restoration and Management Objectives in the Conservation of Spring Habitats

See the common objectives for all mire and spring habitats (*Chapter 5.3*).

In the conservation of spring habitats it is highly important to prevent impacts that may unfavourably affect the subsurface water flows or water quality, or that may cause other unfavourable impacts on springs. The potential impact not only at a local scale, but throughout the entire impact zone must be taken into account as the springs receive waters from a wider area.

13.3 Restoration and Management of Spring Habitats

13.3.1 Basic Principles of Spring Habitat Restoration and Management

Spring habitats are never isolated from the surroundings as they are affected by both natural and human-caused impacts in the adjacent areas. Therefore in the protection of springs and spring habitats the impacts in the groundwater catchment area and the adjacent habitats must always be taken into account. Above all, in spring habitats it is important to ensure natural processes and prevent undesirable human-caused impacts, e.g. pollution, over-exploitation, trampling. The exception is traditionally managed spring fens, which are very rare in Latvia and in which, in order to preserve the characteristic and rare species, open habitats must be maintained by removing shrubs and mowing or, in some cases, by low intensity grazing. Over a longer period of time, spring fens gradually transform into woodlands, which, though harbouring different plant communities, may also be rich in species and thus important for biodiversity. Since many springs have been important as water extraction sites or ancient religious sites for centuries, or they are popular tourist destinations, thus experiencing continuous human-caused impacts, the other functions of springs cannot be ignored when planning the protection and restoration of these habitats.

Prior to habitat restoration and management, it is important to understand the current condition of the habitat, main problems and their causes, and define the desirable habitat condition. It can be both restoration of natural process, which ensures the preservation of certain species and conditions or restoration of a particular complex of species or particular species that depends on moderate disturbance. *See also Chapters 5.3 and 5.4.*

Often, spring discharges in Latvia are located in a complex of rock outcrops and caves. For more on these habitat types and their management, see Čakare (ed.) (2017).

13.3.2 Non-interference

In spring habitats it is important to preserve not only natural plant or animal communities, but also the functionality of the ecosystem. This means also preserving the quality of the subsurface waters in the aquifers of both groundwaters and artesian waters, and the entire water catchment area. The spring can also be affected by activities that take place not only in the vicinity of the spring discharge, but also further away – agriculture, forestry, mineral extraction, industrial pollution. It is not possible to generalise the area, in which these activities might affect the spring and thus also the quality of spring waters and the habitat. It is determined by the placement of the groundwater and artesian water aquifers, the properties of soil and soil bedrock, terrain and other factors. The groundwater accumulation zone is usually smaller than that of the artesian waters, therefore the potential undesirable impacts may affect a smaller area. However, the groundwaters are located at a shallower depth than artesian waters, thus it is more sensitive to pollution as it is not protected by impervious rock layers. To protect the spring from pollution, it would be advisable to establish a protective zone of at least 30 to 50 or more metres around the spring discharge (Dēliņa 2015) – not only around the water-taking places and geological and geomorphological protected monuments, as it is currently provided for by the regulatory enactments of the Republic of Latvia[42], but also around any significant and otherwise valuable springs, especially if they form a spring habitat with the characteristic vegetation and spring sediments. The water catchment area where specific activities should be limited (use of pesticides, drainage, etc.), can only be determined in each separate case on the basis of a survey and cannot be generalised.

Non-interference regime by preventing potentially unfavourable impacts is usually the best option for spring habitats. Above all, undesirable impacts that may unfavourably affect the subsurface water flows both locally and in the larger area must be prevented. Thus it is not always enough to prohibit the activities within the protected nature territories and micro-reserves. In order to ensure the preservation of springs and spring habitats, the protection regime must be implemented in a wider zone around the springs.

Non-interference regime is the best solution for preserving the characteristic flora and fauna in spring habitats which are not influenced by human activities such as forestry and agriculture, including mowing and grazing. From the perspective of protecting spring ecosystems and related species, in sites little affected by humans, no "aesthetic improvement" or "cleaning" works, such as removal of decaying trees or felling of living trees, are necessary. Only in some cases is it necessary to eliminate some of the deteriorating impacts, for example, beaver activity, "mud baths" of wild boar (in both cases the most effective solution is to limit the number of animals in the area) or excessive visitor pressure by creating the appropriate infrastructure elements (boardwalks, platforms, barriers, etc.).

Natural processes are also the best option for significantly modified spring habitats, if the springs are still active. Then, it should be ensured that undisturbed natural processes may take place in the future, and the environment is not being polluted or otherwise altered (burying with waste, pollution of groundwaters, etc.) anymore. If the spring is still active, than the recovery of spring habitat characteristic vegetation structure and species composition occurs in a natural way, although it may take many years or even decades.

One must always be careful when planning to popularise undisturbed or slightly affected, less known springs as tourist destinations, because the visitors, in most cases, create a deteriorating effect on the fragile spring habitats, even in cases when appropriate infrastructure elements are constructed. The best way would be to only disseminate information on the well-known spring sites as tourist destinations, which should then be equipped with appropriate infrastructure elements. The natural and nearly-natural spring sites should be "hidden" by avoiding disseminating any information on them and ensuring only the basic infrastructure elements in sites which are only visited by a small number of people.

13.3.3 Rewetting

If the spring flow has ceased, usually due to human activity, it cannot be restored, thus the only solution is the prevention of impacts unfavourable to springs. The water flows and spring habitats are unfavourably affected by the constantly raised water level caused both by human-made alterations (e.g. artificial ponds) and beaver ponds. In the conditions of constantly raised water level, the spring activity may last for some time, however, as the other conditions change, the species composition characteristic for the spring habitats disappears. In cases when the water level in the vicinity of springs and spring fens has risen due to beaver activity, or if it might rise in the near future (for example, beaver dams and gnawed trees are observed in the neighbouring ditches), the beaver dams must be demolished as soon as possible and the beaver population should be limited by hunting. Beaver dams must be destroyed on a regular basis. As the dams are usually established again, tubes can be inserted below the dams so that beavers cannot restore the high water level. In sites where the beaver-caused raising of the water level has affected the spring for a short time, it is usually possible to restore the spring flow and spring habitat with the characteristic vegetation.

Sometimes rise of water table may affect the springs and spring habitats when rewetting other habitats, e.g. fens, bogs, forests, semi-natural grasslands. Therefore prior to any restoration measures this aspect should be carefully assessed so that rewetting of other habitats does not cause an adverse effect on the groundwater flow, creating an unfavourable impact on the spring, the surrounding habitat and related species.

[42] Cabinet Regulation of 20 January, 2004, No. 43, On the Methodology for Determining the Protection Zones Around the Water-Taking Places, and Cabinet Regulation of 16 March, 2010, No. 264, On the Protection and Use of Protected Nature Territories.

Fig. 13.11. The natural spring habitat in a popular cult place and water extraction site is destroyed by building around a stone wall, wooden fence and a shed. Removal of constructions might not provide the desired result if the spring is still frequently visited by a large number of people and there would be increased trampling effect. In the photo – Leju Sacred Spring in Rucava. Photo: A. Priede.

Fig. 13.12. Simple infrastructure elements – stairs and wooden footbridge at the popular spring – cult place and water taking site (Doru (Galtene) Sacred Spring). Photo: A. Priede.

Fig. 13.13. An example of simple infrastructure elements for the management of the surroundings at Kulšēnu Spring. Although non-native ornamental plants have been planned near the spring, these are not invasive species, and, by regularly mowing, their spread is not expected. Photo: A. Priede.

Fig. 13.14. Effects of trampling at a spring near Kandava – a popular water taking site. The spring is equipped with simple infrastructure elements – a tube and a plank. However, the heavily trampled ground and presence of ruderal species suggest that access to the spring should be limited, for example, by installing barriers or closing the road to prevent access by vehicles. Photo: A. Priede.

13.3.4 Human-made Constructions and Tourism Infrastructure

Sometimes spring habitats suffer from excessive visitor impacts or are completely modified by equipment created to "improve" the spring for water taking. This can deteriorate the spring environment, making it completely unsuitable for the habitat-related species. If the habitat conservation aims to prevent unfavourable human-caused impacts (*see Chapters 13.1.5.9 and 13.3.2*) and restore a natural habitat by removing constructions around the spring (boardwalks, masonries, tubes), and if the spring flow has not been significantly modified, then recovery of the spring vegetation can be achieved in a relatively

Fig. 13.15. Sometimes springs are diligently "cleaned up" by removing the dead wood and modifying the spring discharge in a "more correct" way. Such "restoration" activities do not have any benefits for the spring ecosystem, even worse – removal of dead wood destroys numerous micro-habitats for spring-related specialist species (especially mosses, snails and other invertebrates). In sites similar to that in the photo, no intervention and "leaning up" is necessary. Photo: A. Priede.

short time. These constructions must be removed as carefully as possible without damaging the natural flow of springs and spring sediments.

However, the removal of the artificial constructions alone does not usually decrease the visitor pressure on those springs which are popular tourist destinations. It may even cause an adverse effect by increasing the trampling impact. Therefore, if the spring is visited frequently (e.g. popular cult and water taking sites), a compromise is the construction and maintenance of boardwalks, platforms, and other infrastructure elements. There is no use in removing the constructions, if the spring habitat has been significantly altered and chances to restore the habitat are low (Fig. 13.11). However, in many cases, in sites with moderate visitor pressure it is possible to achieve a good result with little investments (Fig. 13.12, 13.13). In many cases, wooden plank-ways, stairs, platforms and railings are not necessary – well-planned, smart placement of several elements is often enough. For example, in seepage springs, flat stones (for example, dolomite pieces) can be placed within stepping distance and/or a small wooden or log footbridge can be placed over the spring brook.

It is important that the infrastructure is regularly repaired and changed in case of wear. Otherwise, if the plank-ways are broken, the visitors will search for other access ways, spontaneously increasing trampling. Generally, in the spring habitats, in the planning and creation of tourism trails and other places of interests, the same principles should be

Fig. 13.16. An overgrowing spring fen in a forest glade in Ķemeri National Park, formerly used as a forest meadow. Restoration of an open spring fen is still possible. When restoring open spring fens in overgrown sites, it should be taken into account that repeated shrub cutting will be necessary in the forthcoming years. Photo: A. Priede

It is important to realise that spring habitats and related species, especially those occurring in old-growth forests, do not need human-made "improvements". Thus the opening of little-visited and natural springs to tourists, popularisation, and increase in the number of visitors are never recommended. It can contribute to the degradation of those vulnerable habitats or even the local extinction of some species.

used as in raised bogs and other mires (*see Chapter 10.3.10*).

For the preserving of the spring habitat and related species, the popularisation of little-known

Fig. 13.17. Result of selective tree removal around the tufa-forming spring in a recently overgrown forest glade on the slope of the Abava valley. Removal of trees improved the light conditions causing the rapid spread of tall herbs (tall sedges, *Cirsium oleraceum, Eupatorium cannabinum*, etc.). Vegetation gradually stabilises, and low calciphilous sedges and mosses typical for tufa-forming springs recover. Photo: A. Priede.

Fig. 13.18. Spring fen with sedge tussocks gradually overgrowing with forest. To preserve the open habitat with tussocks, from time to time (once every 10 years or more) removal of shrubs and trees is necessary. In the photo – Dāvid's Mills springs in Gauja National Park in 2013. Photo: A. Priede.

springs is undesirable. Dissemination of information may significantly increase the interest about the destination; this will cause increased number of visitors, thus degrading the site. Therefore, popularisation of such potential tourism objects and the establishment of tourism infrastructure must be planned in accordance with both nature conservation and tourism development plans, keeping in mind that these habitats are vulnerable. Once the information on the site is spread, it can become difficult or even impossible to prevent an unwanted large number of visitors. In cases when due to excessive visitor pressure the spring habitat has been affected by heavy trampling and other undesirable effects, the access to the site should be limited or closed (with information signs, barriers, piles of branches, etc.) (Fig. 13.14). In some cases, the visitor pressure may be reduced by transferring the tourists to other, less sensitive places of interest by offering alternative sites for visiting (information boards, road signs, media, etc.). Although it is not always efficient, as people often know the way themselves and do not always respect the limitations, the visiting intensity can be controlled by creating limiting and distracting barriers that redirect the visitors to the adjacent areas or do not allow entry to the object.

However, the people's habits are difficult to control, therefore it is better to prevent unwanted excessive visitor pressure by smart planning of the tourist destinations and not distributing sensitive information, which may cause a potential threat to habitats and species.

13.3.5 Removal of Trees and Shrubs

13.3.5.1 Springs in forests

In forests with spring discharges, the management is usually non-interference regardless of whether it is an old-growth forest with indications of woodland key habitat (Ek et al. 2002) or a relatively young stand hardly having features of a natural woodland. If the forest can be classified as a woodland key habitat, then in order to preserve the habitat or improve its conservation status, felling of trees or removal of dead, decaying wood is not necessary as they provide valuable micro-niches for numerous species, including specialist species and rare species (Fig. 13.15).

Felling of trees and shrubs may be necessary if, upon planning the habitat restoration, it is decided that the priority is a species or community characteristic for open spring habitats, which is still present in the particular place, but may disappear due to overgrowing with forest (Fig. 13.16). Removal of trees and shrubs is acceptable if features of natural, old-growth forests – structures and species, especially rare species – cannot be found in the particular site (Fig. 13.17).

The area where felling is necessary may already be naturally overgrown with forest and included in the forest land category in accordance with the State Forest Register. According to the national legislation in Latvia, deforestation in spring habitats

Fig. 13.19. Due to abandonment, the previously managed spring fen near Kandava (Kuršu hill fort) is dominated by expansive plants (reeds, tall sedges) and shrubs. Since the spring ecosystem still functions, restoration of an open fen is possible. Photo: A. Priede.

Fig. 13.20. Shredding of the biomass several times a year has promoted eutrophication of the spring fen on a slope in Kandava. Eutrophication causes the expansion of high, nutrient-demanding plant species, which start to dominate in the vegetation. Rare plant species e.g. *Primula farinosa* disappear. Photo: A. Priede.

can be performed, if open spring fen species are still present in the area and their habitat is likely restorable (Fig. 13.18), especially if there are rare, protected species.

Felled trees and shrubs must be removed from the area in a way that does not severely damage the ground vegetation and spring deposits. It must nearly always be done manually. Heavy machines damage the ground vegetation and spring deposits and also create deep tracks that later function as drainage ditches. If the volume of felled trees and shrubs is not large, they can be burnt on site. The fireplaces can be located on stumps of shrubs, in such a way partially burning the roots, thus decreasing their re-growth. Practical experience shows that fireplaces completely overgrow with site-specific plants within a few years.

When removing trees and shrubs, it is advisable to leave at least several snags and dead trees if there are such in the area, or at least preserve their lower parts at a height of a couple of metres. They will serve as a habitat for insects and snails. Also, it is recommended to leave decaying fallen trees of greater dimension, especially if they are overgrown by mosses.

In sites with little cover of trees, ring-barking (girdling) of deciduous trees (birches, black alders) might be more efficient than felling. In this way, slow withering of trees can be achieved, thus significantly reducing shoot re-growth (*see Chapter 15.3.7*).

> Prior to the felling of trees in an overgrown spring fen, the required permits must be received in accordance with the procedure provided for in Cabinet Regulation No. 325 of 18 August, 2013, on the restoration of protected habitats and protected species habitats in forest. Currently the regulation does not provide for the restoration of habitat type 7160 Fennoscandian mineral-rich springs and springfens in forest. However, the necessity for deforestation might be justified with the restoration of the habitats of rare species of open spring habitats, if such are present in the particular place.

13.3.5.2 Controlling re-growth of shoots

After clearing the woody species, vigorous stump shoots usually regrow, thus the habitat cannot be considered as restored after a one-off action. To maintain the area open, mowing of shoots will be necessary in the next years. Mowing once a year at least in the first 2–3 years after restoration is the minimum amount of work to be invested. Perhaps later the frequency of shoot removal can be diminished, for instance, once in every five years, which could be sufficient in wet, undrained sites. However, there is no universal solution – each site must be assessed individually, planning actions according to the particular situation.

Bigger deciduous trees should be felled so that the stumps remain as low as possible. To suppress stump shoots, it is advisable to cross-notch the stumps to promote the establishment of saprophytic fungi and consequently the decaying of stumps. For more on controlling the shoots, *see Chapter 15.3.7.6*.

13.3.6 Mowing

In spring fens which were mown or grazed in the past, some protected light-demanding plant species (e.g. *Saxifraga hirculus*, *Dactylorhiza* spp. in mineral-rich spring fens, *Primula farinosa* and *Pinguicula vulgaris* – on tufa sediments) may be present. They are vulnerable to changes in light availability and usually disappear along with overgrowing of the fen. Usually in succession in abandoned fens which were mown or grazed in the past, small-sedge vegetation, rich in brown mosses, is replaced with tall herb (e.g. *Urtica dioica*, *Epilobium hirsutum*) and tall sedge stands (*Carex acutiformis*, *C. elata*), and *Phragmites australis*. Later the fen is occupied by shrubs (most commonly willows) and transforms into forest (Fig. 13.19).

Mowing helps to control the expansion of tall herbs, prevents overgrowing with shrubs and enhances the conditions suitable for fen-specific species. However, the expansive tall vegetation can only be suppressed by mowing several years in a row, in the first years more frequently, preferably every year, afterwards – once every couple of years if mowing every year is not possible. If the habitat is heavily overgrown with tall herbs and/or *Phragmites australis*, in the first 2–3 years it is recommended to mow twice a year, gathering the mown grass.

> In the vicinity of springs and spring fens, **herbicides** cannot be applied for the abatement of shoots, since it may cause significant damage to the flora and fauna. The pollution can easily spread in groundwaters, streams and water bodies, accumulate in food chains and harm both biodiversity and human health.

Phragmites australis can be most effectively limited by mowing in June or July (Asaed et al. 2006; Fogl et al. 2014), as later nutrients accumulate in the roots, thus the removal of the surface biomass does not help to diminish the reed dominance. However, not all of the studies prove the efficiency of mid-summer mowing (Güsewell et al. 2000) – the effectiveness is also influenced by site conditions, and mowing may not promote, at least not within a few years, the decrease of reed abundance. The effectiveness of mowing may also be affected by the climatic conditions. Possibly, mowing provides better results in years with low rainfall when the reeds use the nutrients stored in the roots, however in wet years mowing does not cause substantial changes in reed dominance. The density of reeds may also be influenced by spring frost, when the young shoots may become weaker, however, their number is higher (Güsewell et al. 2000). Mowing of reeds in shallow water or areas with a fluctuating water level is usually efficient – a large proportion of them die off when the water level rises and the water gets into the stubble.

Grass should be mown as low as possible (up to 10 cm). Mown grass must always be removed. Leaving it on site, including shredding, promotes eutrophication, therefore it is not recommended. Moreover, the mown grass left on the site creates a mulch-like layer (Fig. 13.20) that decreases the availability of light to the ground and promotes the extinction of habitat-specific mosses and small plants.

If for some specific reason mowing is necessary several times a year (for example, spring habitats in urban areas, where mowing is mainly done for landscaping), mowing should not be more frequent than twice a year, and the grass must always be removed. Otherwise, species diversity decreases, and a few highly competitive species may take the dominating role in the vegetation.

Traditional haymaking in species-rich fens helps to disseminate seeds of target species. Therefore this method is preferable in comparison to the gathering of fresh biomass. On the contrary, in sites dominated by expansive plants (in most cases – abandoned, formerly managed spring fens) it is better to collect the biomass right after mowing, which will diminish the seed dissemination potential, thus preventing the spread of unwanted species.

In spring habitats, mowing and gathering of biomass must only be performed manually using a scythe or a brush-cutter, since the ground vegetation of spring fens is highly vulnerable to trampling, therefore using a tractor or other equipment may cause significant damage. Small and light mowers (e.g. pedestrian-driven mowing machines) may also be used.

13.3.7 Grazing

The impact of grazing in spring habitats has been little studied, and the opinions on its applicability in spring fen management are contradictory. On the one hand, moderate disturbance related to grazing create micro-niches which can ensure greater species diversity, e.g. sward of various heights, trampled bare ground. On the other hand, too intense grazing may damage the soil, ground vegetation and soil fauna, especially if cattle are used. Moreover, grazing increases the nutrient content in soil with dung, especially if animals are fed additionally with hay brought from highly productive grasslands (McDonald et al. 1998; Clément, Proctor 2009). Supplemental fodder may also be a source of undesirable plant species, especially nitrophilous species, which may establish in the area. However, it is important to understand the difference between the impact of grazing of little intensity or seasonal grazing, and the impact of intense grazing, which may significantly differ.

In Latvia, some spring fens have been grazed in the past, e.g. Čužu Mire (Salmiņa (ed.) 2005; Auniņa (ed.) 2014), although the history of this practice is poorly documented. So far in Latvia there are no studies proving the favourable impact of grazing to open spring habitats. Also, the recommendations and experience of other countries are contradictory. In different habitat restoration projects in Europe, grazing has been recommended as an appropriate measure for spring habitat management (for example, Kinnekulle – LIFE02 NAT/S/008484 (LIFE Kinnekulle, *without date*), RARE NATURE – LIFE11 NAT/DK/894 (LIFE RARE NATURE *without date*), REFLOW – LIFE07 NAT/DK/000100 (LIFE REFLOW 2011)), however, most often it is not clear what the reason for choosing the certain type of management was. At the same time, some studies and observations suggest that grazing might have a degrading impact on spring habitats, especially in habitat 7220* *Petrifying springs with tufa formation* (McDonald et al. 1998; JNCC 2007; Clément, Proctor 2009).

Taking into account the contradictory opinions of the grazing impact on spring habitats, it is not reasonable to recommend it as a suitable management measure, at least not without long-term studies on its impacts. Due to the vulnerable ground in springs it may create too intense trampling causing damage to the spring vegetation and rare species, promote spreading of nitrophilous plant species (e.g. *Urtica dioica*) and species typical for pastures (e.g. *Juncus* spp.), enhance the erosion risk on slopes and deteriorate spring sediments, particularly tufa sediments.

However, grazing may be appropriate in some exceptional cases. If the spring habitat is adjacent to a larger pasture, where animals stay throughout the year or which are also grazed during the winter, grazing in the spring fen may be an efficient method in decreasing the proportion of shrubs and expansive species when grazed during the winter in frost conditions. To avoid excessive trampling pressure and regulate the intensity of grazing, access to certain parts of the pasture ground can be controlled with fencing (locking access to certain parts of the pasture by using electric fencing). Regulated pasturing can be effective in recently restored spring fens where the trees are removed and re-sprouting may be expected. In such cases, grazing can be efficient in suppressing the young shoots after the clearance of shrubs.

Spring discharges in pastures should be protected from over-trampling by using fencing or mobile electric fencing. To prevent their overgrowing with tall herbs and shrubs, the grass in spring surroundings must be mown and grass removed once per vegetation season.

13.3.8 Eradication of Invasive Plant Species

In Latvia, the spread of several invasive non-native plant species has been observed in spring habitats (Table 13.1). In comparison to native plant species, the invasive species are highly competitive. Due to their size, their almost monospecific stands create shading, thus making the conditions unsuitable for the majority of habitat-specific species. In sites shaded by invasive species, there is almost no turf or the ground is covered with a few shade-tolerant moss species. This increases the soil erosion risk and slope instability.

Spring habitats in river valleys are particularly vulnerable to non-native plant invasion as the propagules (seeds, root fragments) are often spreading with floating water. In riparian systems, including spring habitats, efficiency in the control of invasive plants may only be achieved if the management is applied in the entire invaded area both upstream and downstream of the target area. Additionally, the eradication measures must be applied repeatedly and on a regular basis. **The invasive plants must be eradicated as soon as possible after their establishment by pulling out, digging out and removing the biomass and propagules from the site. Later when vigorous stands are established, eradication might become complicated or even impossible and require a longer time**.

In the effective control of invasive plants, prevention of their establishment in spring habits is of particular importance. Therefore, ornamentals, which are invasive or potentially invasive, should never be planted in the vicinity of spring habitats as they might spread and cause unfavourable impacts on the natural habitats and related native species. Any garden waste containing potentially invasive plant material (weeds, plant fragments of ornamentals) should not ever be disposed in the vicinity of springs!

In the vicinity of springs, **herbicides cannot be used** in order to eradicate invasive non-native plant species, as they may cause significant damage to the native flora and fauna, including rare species. The toxic compounds may spread via the flowing water into larger water bodies, thus posing risks not only to ecosystems, but also to human health.

Table 13.1. Invasive non-native plant species commonly found in spring habitats and the methods of their eradication.

Species	Method of eradication
Heracleum sosnowskyi  Photo: A. Priede. Perennial monocarpic plant (flowers and sets seeds once during the lifetime, then dies). Spreads by seeds and vegetatively by basal roots and root fragments.	In spring habitats, the most efficient way is **digging out** individual plants in spring (from April to the beginning of May). Roots must be cut with a shovel as deep as possible. In order to prevent re-growth, the dug and pulled out roots must be removed from the site. Removed roots can be dried (contact with fresh soil must be avoided), composted or burnt. Additionally, to prevent rapid re-growth from the soil seed bank, the dug up soil can be covered with black plastic sheeting at least for one vegetation season or treated with glyphosate (can only be applied at a safe distance from water bodies). **Mowing** is not efficient. Even if applied several times a year, it does not ensure the extinction of *Heracleum sosnowskyi*. **Removal of inflorescence** during flowering (before seed ripening) is more effective than mowing, ensuring a reduction of the number of germinable seeds in the soil bank. However, this method is only suitable for small invaded areas. In any case, **flowering and ripening of seeds should not be allowed!** In springs, dense stands can be **covered with black plastic sheeting** for several months during the vegetation season, securing it firmly on the edges. **Grazing** is an efficient method (especially, sheep grazing). **Spraying with herbicides** is most efficient if it is performed in the springtime when the seeds are germinating and the diameter of the rosettes of the second-year hogweeds reach ~20 cm. However, in efficient control of *Heracleum sosnowskyi* **a single method does not usually work, and combined methods are usually necessary**. More: The methods are suggested by the Integrated Growing School and the State Plant Protection Service (Gulbis (red.) 2013; VAAD, *without date*).
Impatiens glandulifera  Photo: A. Priede. Annual plant that can reach the height of 2–3 metres. Seeds are dispersed by a special mechanism – when mature and dry, the fruits split open explosively if touched, flinging the seeds a considerable distance from the parent plant. Lower stems often develop adventitious roots – when the stem is cut, in favourable moist conditions it may root again and continue growing and producing seeds.	The plant can be rather efficiently controlled by **mowing**; however, the biology of this species must be taken into account. Stems of plants mown in early summer (end of May, June) are capable of generating secondary shoots, which can flower and produce seeds in the same vegetation season. Therefore it is important to mow so that the residual stubble height is as low as possible. If mowing is applied in late summer when plants are flowering and ripening the seeds, the efficiency is low, especially if the biomass is not removed from the site. One must also be careful when removing biomass as it contains plenty of viable seeds. Removal and transporting of plant biomass mown late in summer may cause the establishment of the plant in other areas. **Weeding** is an effective measure, especially in small areas. Weeding must be carried out 2–3 times during the vegetation season (from May to September), since the decrease of shading will enhance the germination of the seeds of the soil seed bank. Establishment of other plant species (natural competitors) can be stimulated by sowing a grassland or mire species mixture (only native, habitat-related species can be used). In spring habitats, small stands of *Impatiens glandulifera* can be **covered with black plastic sheeting** for several months (during the vegetation season), securing it firmly at the edges.
Impatiens parviflora  Photo: A. Priede. Annual plant. Spreads in the same way as *Impatiens glandulifera*.	Eradication of this species is unrealistic, since it is very common in different habitat types in Latvia, most frequently in mesic and wet forests. Locally, in order to eradicate the plant, it can be mown close to the ground shortly before flowering so that the seeds do not ripen. However, in the next years re-establishment of the species can be expected from the adjacent areas. In general, any method is not sufficiently effective, since the species is widespread and has a highly efficient seed dispersal mechanism (*see Impatiens glandulifera*).

Table 13.1 continued

Species	Method of eradication
Solidago canadensis  Foto: A. Priede. Perennial plant. Spreads with seeds (pappi, wind-dispersed) and root fragments.	Plants can be efficiently eradicated by **mowing several times a year** (at least twice – in June before flowering and in September). In early invasion phases, eradication may take a shorter time, in monospecific stands – several years. By mowing for several years in a row, the plants will become weaker and weaker, and gradually will be outcompeted by other species, which are more tolerant to mowing. Establishment of other plant species (natural competitors) can be stimulated by sowing of a grassland or mire species mixture (only native, habitat-related species can be used). In spring habitats, small stands of *Solidago canadensis* can be **covered with black plastic sheeting** for several months (during the vegetation season), securing it firmly at the edges.
Petasites hybridus  Foto: J. Jātnieks. Perennial plant with a vigorous root system. In Latvia, it only spreads vegetatively. Sometimes it has been planted near springs and in wet soils as an ornamental, often resulting in large monospecific stands.	An efficient eradication method is **repeated digging out and pulling of the roots** (especially in small invaded patches). Afterwards they must be removed from the site so that the plants do not establish from the viable root fragments. Establishment of other plant species (natural competitors) can be stimulated by sowing of a grassland or mire species mixture (only native, habitat-related species can be used). In spring habitats, the stands can be **covered with black plastic sheeting** for several months (during the vegetation season), securing it firmly at the edges.
Invasive woody species *Amelanchier spicata*, *Aronia* spp., *Spiraea* spp. *Sorbaria sorbifolia*, *Acer negundo*	**Cutting and removal is of low efficiency** due to rapid re-sprouting. It should be repeated for a long time and must be done frequently to suppress the re-growth. **Pulling out and digging out of roots** is more efficient than mowing; however, the plants are also able to regenerate from tiny root fragments remaining in the soil, therefore most probably this must be repeated several times. **Cutting and covering the stumps with black plastic sheeting** is quite efficient if the sheeting is kept for at least one vegetation season. However, covering with the sheeting is only possible in non-wooded areas or only in the early stages of the invasion when the invaded area is still relatively small. **Treatment of leaves with herbicides** (most commonly glyphosate) is quite an efficient method, however, due to the high risk of pollution in the spring ecosystem and harm to the spring-related flora and fauna, especially invertebrates, this method should not be used. **Treatment of stumps with herbicides** (most commonly glyphosate) or **injections in the stumps** can be used as a fairly efficient method; however, herbicides cannot be used close to the springs due to the abovementioned reasons (high pollution risk).

Fig. 13.22. Restored open spring fen (7160 *Fennoscandian mineral-rich springs and springfens*) after the removal of trees and mowing two years in a row. Photo: A. Priede.

13.3.9 Controlling the Number of Wild Animals and Supplemental Feeding

Control of wild animal populations refers to a larger area, and it is implemented by hunting. In terms of preserving spring habitats, the number of animals in the surroundings must only be limited in the case if significant, regular disturbances of wild boar ("mud baths") or beaver caused elevation of water level occurs. Feeding places attract animals and cause heavy trampling and soil eutrophication along with the establishment of ruderal and/or invasive plant species. Sometimes it may completely destroy the spring habitat. Therefore the establishment of game animal feeding sites in the vicinity of spring habitats is not permissible. If feeding sites are already established, they must be removed immediately.

13.3.10 Specific Activities for the Conservation of Rare Plant Species

So far in Latvia, relatively few activities have been aimed at the conservation of rare plant species typical for spring habitats and fens. One example is Čužu Mire near Kandava, the only locality of *Pentaphylloides fruticosa* in Latvia, where the calcareous fen-grassland-like habitat on tufa deposits was restored in the beginning of the 21st century. In the 1940s, *Pinguicula alpina* was introduced in Raunas Staburags, a scenic tufa deposit in northern Latvia, from Daugavas Staburags, the only natural locality of this species and formerly the largest tufa outcrop in the country, which was flooded when establishing a hydroelectric power station on the River Daugava in

Fig. 13.23. A small tufa extraction site in the Abava valley, abandoned in around the mid-20th century. Springs have dried out a long time ago, but a layer of tufa sediment is preserved. Right now the conditions are more suitable for species of dry calcareous grasslands than tufa-forming springs or spring fens. Under continuous grazing and/or mowing, the development of a dry grassland habitat is possible over time. Natural succession leads to overgrowing with forest, therefore the removal of shrubs and regular mowing or grazing is necessary. Photo: A. Priede.

Fig. 13.24. An old tufa quarry in Čužu Mire, abandoned in around the mid-20th century. Springs have dried out a long time ago. Shallow ponds have formed in the old pits, where the rain water has accumulated. The shallow ponds are suitable for amphibians (e.g. *Triturus cristatus*), stoneworts *Chara* spp. On shores, *Primula farinosa* and other calciphilous plant species can be found. Photo: A. Priede.

the 1960s. The artificially established population in Raunas Staburags persisted for some time, however, nowadays it has disappeared, most probably due to trampling on the Rauna tufa outcrop (Vimba 2004), which is a popular tourist destination.

In Latvia, several very rare plant species are found in spring habitats, e.g. *Saussurea esthonica*,

Fig. 13.25. Ponds in old tufa extraction pits. Although such sites are not considered as protected habitats, they can be suitable for aquatic species of alkaline waters, e.g. stoneworts *Chara* spp. Stoneworts often establish abundant stands, which should be preserved as a valuable feeding ground and shelter for numerous aquatic organisms. Photo: A. Priede.

Fig. 13.26. A recently developed spring on the slope in the abandoned dolomite quarry in the surroundings of Plostmuiža (Kaļķis). There are several spring discharges on the slope, and gradually the vegetation typical for alkaline fens develops. Photo: A. Priede.

Ligularia sibirica, Swertia perennis. In order to preserve their localities, active management measures are often necessary. Management of the species localities (improvement of the conditions in the habitats of these species, creation of suitable ecological micro-niches, re-introduction of the species in the wild, reduction of the genetic depletion of the populations) and/or creating conditions suitable for the particular species require research-based specific knowledge. Such projects can only be implemented along with *in situ* and *ex situ* scientific studies, and

Fig. 13.27. In a tufa extraction site abandoned a long time ago near Lake Sāruma, a spring fen is recovering. Vegetation diversity in the fen is still low; a few species such as *Carex paniculata* and *Phragmites australis* prevail. Overall the vegetation is characteristic to spring habitats. Photo: A. Priede.

the actions should be carefully documented and monitored. Activities with protected species require a written permit of the responsible authority, which is the Nature Conservation Agency (*see Chapter 6.3.12*).

13.3.11 Removal of Waste and Dead Wood

All waste of anthropogenic origin must be removed from springs both to improve the habitat quality and the aesthetic value of the site.

Sometimes dead wood fallen into the springs is considered as waste that degrades the spring and therefore it should be removed. From an ecological point of view, in undisturbed natural springs the removal of dead wood is not necessary as it provides diverse micro-habitats for different organisms, especially mosses and invertebrates (*see Chapter 13.3.5.1*). The removal of decaying wood may sometimes cause the local extinction of rare species. Removal of dead wood may only be necessary in exceptional cases, e.g. after extensive windthrow, when some of the recently fallen trees may be removed (this could be especially topical for springs which are popular tourist destinations). In such cases, older decaying trees should be preserved, because they serve as a substrate for various species. However, before taking measures, it is advisable to attract an expert who will help to find the balance between the need for "management" and conservation of natural values.

13.3.12 Examples of Spring Habitat Restoration and Management in Latvia

In Latvia, there are few examples of targeted spring habitat and species restoration. Restoration of spring habitats has mainly been performed due to other reasons (logging, landscape management for aesthetic purposes, management of popular tourist destinations).

Rakši spring fen in Gauja National Park. In 2013–2015, restoration and maintenance of the spring fen in an area of 0.6 ha has been carried out by removing trees and shrubs, followed by mowing once a year three years in a row, and gathering the mown grass (Fig. 13.21, 13.22). Since the site is difficult to access and it is not possible to access it by any vehicles, it was not possible to remove the mown grass, and it was piled on the forest margin.

Some management actions (removal of trees and shrubs, mowing) have been carried out in the spring in Čužu Mire and Drubazu spring fen in the Abava valley (*see Chapter 15.3.14*).

13.3.13 Restoration of Severely Deteriorated Spring Habitats

The existence and restoration potential of spring habitats depend on the active water flows and functioning of springs. In Latvia, tufa outcrops without spring activity are also classified as the habitat type 7220* *Petrifying spring with tufa formation* (Rēriha 2013). Such sediment deposits are significant in preserving the geological information and habitats of specific moss flora. However, if the springs have dried out, it is no longer possible to restore the habitat with its functions and processes.

Springs in tufa extraction sites have often already dried out before mining activities. In Latvia, such extraction sites are usually small and have operated till the mid-20th century or earlier, later being abandoned. In such cases, active water flow cannot be restored, however, over time in such areas the secondary post-mining habitats may be suitable for numerous rare and/or specialist species (Fig. 13.23, 13.24). In many cases, if the pits are still characteristic with calcareous substrate, it is worth applying some management measures, e.g. removal of shrubs and mowing of grass, to enhance the species diversity instead of tree encroachment. When tufa extraction pits fill up with water, the recently created ponds may host amphibians, benthic organisms and they are particularly suitable for stoneworts *Chara* spp. (Fig. 13.25), as long as they provide nutrient-poor, clear water conditions.

Fig. 13.28. Spontaneous recovery of the spring habitat after removal of a beaver dam. Photo: A. Priede.

In abandoned tufa extraction areas with still active spring discharging, spring habitats are able to recover naturally, although they might be significantly damaged. Although rarely, spring habitats with the characteristic vegetation structure and species composition may also develop in recently created human-made areas, for example, in quarries of carbonate rocks (Fig. 13.26, 13.27).

If a spring habitat is **buried under construction debris or other artificial material**, the material must be completely removed as soon as possible and the place should be left to natural processes. If the spring flow has not been significantly affected, the recovery of spring habitat is possible within a longer period of time. However, it is an essential habitat-degrading impact, and recovery might take many years or even decades.

Springs may be significantly affected by **pond and ditch excavation**. The impact may vary greatly – depending on the character of the subsurface water flow, location of the pond or ditch and other factors. For example, excavation of pond on the slope terrace may cause the depletion of the spring at the foot of the slope, although it does not affect the spring directly. Thus, prior to the excavation of ponds in the vicinity of springs, a careful assessment is always necessary before action, coordinating it with the responsible authorities.

Ponds, which accumulate the spring waters, may be different in terms of species diversity. Usually this is determined by the fact of how natural the development of the pond has been after its excavation. If the flora and fauna of the pond have developed in a natural way, they may be a suitable habitat for, for example, stoneworts (in alkaline waters). On the pond edges, tufa sediment can be exposed, which may serve as substrate for calciphilous plant species. However, if a similar pond and its surroundings have been significantly altered, for example, by creating a lawn and planting ornamental non-native plants, its role in the conservation of species diversity is small. Filling up of artificial ponds and restoration of the former terrain and spring flow might be difficult or even impossible.

Overall, so far in Latvia and in Europe there is little experience in restoring severely deteriorated spring habitats.

13.3.14 Inappropriate Management and Use of Spring Habitats

Management and use unfavourable to the spring habitats includes:

- all activities that may unfavourably affect the spring flows (changes in the subsurface water flows, decrease or increase of groundwater table, drainage);
- raising of water level (including beaver dams, which can cause flooding of the spring);
- clear-cuts in forests around springs and spring fens;
- logging followed by moving the harvesting equipment over the springs and spring fens (causing soil compaction, creating deep tracks);
- afforestation of spring fens;
- excavation of ponds in areas where it affects the springs and the flow of subsurface waters;
- burning of plant litter and dry reeds around springs and in spring fens;
- grazing, especially intense grazing as it causes heavy trampling;
- topsoil and shrub root mulching after the removal of trees and shrubs (except for small areas where it does not damage the entire habitat);
- game animal feeding in spring habitats and their surroundings;
- establishment of tourism infrastructure if it increases visitor pressure on a spring habitat;
- introduction of non-native ornamental plants near springs (especially when potentially invasive species are used);
- placement of garden waste in the vicinity of springs (the risk of spread of invasive and ruderal species, eutrophication);
- filling up of springs or dumping of waste, debris or other materials in the spring habitats or in the close vicinity of springs;
- any kind of organic or inorganic pollution (manure, pesticides).

13.4 Conservation and Management Conflicts in Spring Habitats

In plains and terrain depressions the spring habitat might be affected by beaver activity. This is of particular importance in Latvia, where the beaver population is large. Sometimes they completely change the conditions by establishing dams and raising the water level. The raised water may cover the spring discharges and their surroundings. On the one hand, beaver ponds and their vicinity are valuable habitats suitable for various species, especially woodpeckers and different invertebrates related to dead wood. Beaver ponds are also important as structural elements, increasing the diversity of forest landscape (Lārmanis u. c. 2000). On the other hand, due to beaver-caused raising of the water level spring habitats can be destroyed or at least degraded for a long time. Sometimes the spring habitats may recover after removing the beaver dams and lowering the water level, but these are most probably exceptional cases (example of successful recovery – Fig. 13.28).

It is not possible to preserve a spring habitat and beaver pond at the same time, therefore in each case it is necessary to understand the priorities. The frequency of both habitat types and distribution and conservation status of the habitat-related species at the country scale must be taken into account. Other properties of the particular site must also be carefully assessed, e.g. chemical composition of the spring water (how common or rare such springs are), geological and scenic value of the particular spring, etc. In Latvia, the priority will almost always be the necessity to preserve and restore the spring habitats as they can be found rarely in comparison to much more widespread beaver ponds.

Chapter 14. 7210* *Calcareous fens with* Cladium mariscus *and species of the Caricion davallianae*

14.1 Characteristics of *Cladium mariscus* Fens

14.1.1 Brief Description

The habitat is composed of *Cladium mariscus* stands in the emergent-plant zones of lakes, extensively managed wet meadows and fens in contact with the *Caricion davallianae* community or the species of *Phragmition communis* community (European Commission 2013). This habitat type is determined by the presence of a single dominating species – *Cladium mariscus*, thus the occurrence of the habitat and its conservation status are closely related to the ecological requirements of this species.

In Latvia, *Cladium mariscus* stands can be found on lakeshores and in shallow lakes (Fig. 14.1), in calcareous fens, around calcareous springs (Fig. 14.2), very rarely – in wet meadows and in post-harvested peatlands. *Cladium mariscus* stands are very rare (Fig. 14.3). The largest habitat cover has been found in Coastal Lowland along the Gulf of Riga and south-western Latvia. The habitat is very rare in eastern Latvia. The total area occupied by this habitat type in Latvia takes up around 220 ha or 0.003% of the territory of Latvia (Anon. 2013a). In Latvia, the distribution of *Cladium mariscus* is limited by climatic conditions (low temperature in winter and relatively long periods of frost), thus in Latvia it is mainly found in coastal areas (Salmiņa 2004).

Fig. 14.1. *Cladium mariscus* stands in shallow water on dolomite ground in Lake Kaņieris. Photo: A. Priede.

Fig. 14.2. *Cladium mariscus* fen with calcareous spring discharges in Raganu Mire. Photo: A. Priede.

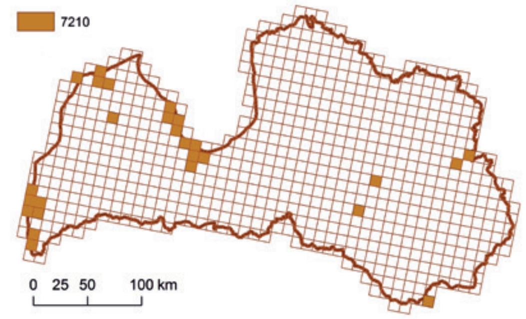

Fig. 14.3. Distribution of habitat type 7210* *Calcareous fens with* Cladium mariscus *and species of the* Caricion davallianae in Latvia (source: Anon. 2013a).

Cladium mariscus, the umbrella species of this habitat type, is a rare species in Latvia and thus – protected. Waterlogged alkaline substrates are rare in Latvia; they host numerous specialist species almost only characteristic to calcareous fens (rare plants, snails, insects, spiders). *Cladium mariscus* stands also provide habitat for a globally endangered bird species *Acrocephalus paludicola* (Poulin et al. 2010; Keišs 2013; Grzywaczewski et al. 2014).

14.1.2 Important Processes and Structures

Cladium mariscus stands occur in stagnant, shallow water. It grows best at a water table that is between 15 cm below ground and 40 cm above (Conway 1942; Brink, Achigan-Dako 2012). In *Cladium mariscus* stands around springs, the most significant process is spring activity, which ensures the calcareous environment. Waters suitable for this species are poor in nutrients (especially phosphorus), alkaline (although in same cases it also occurs in a slightly acidic environment), and rich in calcium (Ellenberg

1988). *Cladium mariscus* stands are almost always open, without a closed tree and shrub cover. Usually *Cladium mariscus* forms monospecific stands with the presence of few other plant species. The *Cladium mariscus* community around the spring discharges may be mosaic-like – mixed with other plant communities, commonly with species of *Caricion davallianae*. In undisturbed sites, a great amount of plant litter is present, the layer is thick, formed by dead plant leaves and stems from previous years if the grass has not been mown regularly, grazed or recently burnt.

14.1.3 Succession

In Europe, *Cladium mariscus* reached its maximum distribution in the post-glacial period, when alkaline, nutrient-poor aquatic habitats – shallow lakes and wet depressions – were frequently found (Hafste 1965). It is a relict species from the Atlantic period. In some places, the localities of *Cladium mariscus* may remain relatively unchanged, even for several thousands of years (Pokorny et al. 2010). Due to the accumulation of organic substances and the overgrowing of lakes, the number of habitats suitable for *Cladium mariscus* in the post-glacial period has decreased; therefore the species has become rare. In the lakes of Latvia *Cladium mariscus* has only survived in narrow zones between the open lake and the quaking bogs and fens of the lakeshores (with few exceptions when it grows throughout the shallow coastal lakes). Upon the process of the lake overgrowing, it may disappear (Salmiņa 2004). Presence of *Cladium mariscus* stands indicate a certain stage of mire development, but, as the fen develops into a transitional mire or raised bog, and peat is accumulating, which also means changes in the substrate pH, the conditions become unsuitable, and this species is gradually outcompeted by other plants (Pokorny et al. 2010).

Fig. 14.4. Undisturbed *Cladium mariscus* fen, gradually overgrowing with forest. Photo: A. Priede.

Fig. 14.5. Natural drop of the water level in Lake Engure during the summer drought period. The eastern shore of Lake Engure in 2013. Photo: A. Priede.

Cladium mariscus, the dominating species in this habitat, is a strong competitor with a vigorous root system that in favourable conditions forms continuous almost monospecific stands, mainly spreading vegetatively. The stands of *Cladium mariscus* are little affected by temporary irregular disturbances, for example, burning, mowing, or temporary alterations of water level (Pokorny et al. 2010). In favourable conditions *Cladium mariscus* stands form a relatively stable plant community (Sádlo 2000).

In a temperate climate, in permanently waterlogged substrates and shallow waters suitable for *Cladium mariscus*, trees cannot establish (except for drier rises), at least they cannot create a closed canopy and thus do not compete with *Cladium mariscus* (Conway 1942). After drainage, *Cladium mariscus* and other calciphilous plant species disappear, and the formerly open fens are invaded by woody species (Conway 1942). Therefore, in the conservation of *Cladium mariscus* and *Cladium mariscus* fens, the priority is the prevention of hydrological alterations. Though the observations suggest that within a longer period of time *Cladium mariscus* stands may also gradually overgrow with trees without the drainage impact, the vegetation structure, moisture conditions and other features characteristic for this particular habitat type may survive for a long time (Fig. 14.4).

Gradual overgrowing with forest may also be promoted by natural long-term fluctuations of rainfall, especially periods of drought, which last for several years. Such a tendency has been observed in northern Italy (LIFE Friuli Fens, *without date*).

Fig. 14.6. *Cladium mariscus* stands in post-harvested peatland with alkaline sulphurous spring discharges abandoned in the 1950 to 1960s (Labais Bog in the Ķemeri National Park). Photo: A. Priede.

14.1.4 Indications of Favourable Conservation Status

In habitat in favourable conservation status, the substrate is waterlogged throughout the year. The water level can seasonally fluctuate, however without exceeding the ecological tolerance boundaries of *Cladium mariscus*. *Cladium mariscus* tolerates water level fluctuations from 15 cm below the soil surface to 40 cm above the soil (Conway 1942; Rodwell (ed.) 1998; Brink, Achigan-Dako 2012). The substrate is alkaline and nutrient-poor (Ellenberg 1988), although some authors suggest that *Cladium mariscus* is relatively tolerant to the substrate pH (pH 4.5–8.6) (Brink, Achigan-Dako 2012). The alkaline substrate is formed by carbonate-rich bedrocks, high concentration of mussel shells in the substrate, or the presence of alkaline spring discharges (Auniņa 2013). In a favourable conservation status, there are no artificial modifications of water level.

The quality of the habitat is characterised by the proportion of generative shoots of *Cladium mariscus*, the total cover of *Cladium mariscus* and the cover of other vascular plants (Auniņa 2013). *Cladium mariscus* is the dominant species in suitable ecological niches, e.g. lakeshores with shallow water, alkaline fens with small-sedge vegetation, quaking bogs and depressions fed by alkaline groundwaters. Therefore, the *Cladium mariscus* community may be in various stages of development. In younger stands the vegetation may be mosaic-like, whereas in the later succession stage a well-pronounced dominance of *Cladium mariscus* is characteristic. In suitable conditions *Cladium mariscus* fens are treeless or with little tree and shrub cover.

In the entire habitat area, species characteristic for alkaline fens may be found: vascular plants – *Cladium mariscus* (dominant species), *Carex elata*, *C. lasiocarpa*, *Schoenus ferrugineus*, *Utricularia* spp., mosses – *Scorpidium scorpioides*, *Campyllium stellatum*, *Scorpidium cossonii*, stoneworts – *Chara aspera*, *C. globularis*, *C. tomentosa* (Auniņa 2013e). In some patches calciphilous low-sedge vegetation prevails (*Caricinion davallianae*) as well as calciphilous brown mosses. *Phragmites australis* can be present.

14.1.5 Pressures and Threats

14.1.5.1 Drainage

In Europe, drainage has been the main reason for the decrease of *Cladium mariscus* fens (Conway 1942; Rowell 1986). *Cladium mariscus* tolerates short-term periods of drought, but the optimal growing conditions are in shallow water up to approximately 40 cm depth (Conway 1942; Rowell 1986; Buczek 2005). The calciphilous fen plant species have adapted slight natural water level fluctuations. Drainage causes unsuitable conditions for alkaline fen species characteristic for the habitat, and reduces their competitive ability and vitality. Due to drainage *Cladium mariscus* does not flower, its vitality decreases, which leads to the replacement of *Cladium mariscus* by plants of drier soils. Moreover, drainage causes the decomposition of peat, thus the amount of the nutrients available to the plants in the substrate increases, leading to eutrophication, which in turn causes expansion of a few strong competitors, commonly *Molinia caerulea* or *Phragmites australis* (Wheeler 1984). In the further course of succession, the drained areas overgrow with woody plants, for which the substrate would otherwise be too wet. However, similar consequences can also be caused by natural reasons – decreased amount of precipitation for several years in a row may also lead to lowering of the water level and changes in the fen vegetation.

14.1.5.2 Modifications in the water level of lakes

Since the largest areas of *Cladium mariscus* stands in Latvia can be found on the lakeshores and in littoral zones, *Cladium mariscus* and its habitat may also be significantly affected by the changes in the lake water level. Rise in the water level may also promote the extinction of *Cladium mariscus* – if the water level has dropped below the optimum, local extinction of *Cladium mariscus* has been observed, and it is replaced by reeds (Buczek 2005). Lowering of the water level causes a similar effect to drainage (*see Chapter 1.5.1*).

In Latvia, the water level changes have affected

Cladium mariscus stands in at least two lakes – Lake Engure and Lake Kaņieris. The level of Lake Engure was already lowered in the 19th century by 1.5–2 m, uncovering a large lake bed with carbonate-rich substrate (Laiviņš u. c. 2012). Moist to wet depressions have formed there, which nowadays are occupied by the vegetation of alkaline fens, including *Cladium mariscus* stands. The water level has also been changed several times in Lake Kaņieris. There, a slight lowering of the water level has affected *Cladium mariscus* stands in the lake, in its littoral zone and on the shores in the beginning of the 21st century. Significant degradation of the *Cladium mariscus* stands has not been observed; however, the lowering of the water level most likely promotes the establishment of graminoids and sedges of drier habitats. Dropping of the water level also decreases the vitality of *Cladium mariscus* – in drier conditions it does not flower anymore, but in the long term the *Cladium mariscus* stands get invaded by trees. Natural seasonal water level fluctuations in the lake do not significantly affect *Cladium mariscus* (Fig. 14.5).

14.1.5.3 Peat extraction and change of land use type

In Latvia, *Cladium mariscus* stands are occasionally found in post-harvested peatlands in alkaline, nutrient-poor shallow waters (Fig. 14.6). But it is not known, whether *Cladium mariscus* in these particular areas was present before peat extraction or has established afterwards. In some cases, the conditions suitable for *Cladium mariscus* fens have formed just after peat extraction. Thus, the impact of peat extraction cannot always be assessed unambiguously. It can destroy *Cladium mariscus* habitat, but sometimes the post-harvesting peatlands provide suitable conditions for this habitat type. However, peat extraction and the provision of favourable conditions to the habitat after peat extraction do not necessarily ensure the formation of *Cladium mariscus* stands. The habitat type is affected not only by locally favourable conditions (waterlogged peat substrate and/or shallow waters, calcareous substrate or calcareous spring discharges), but also the proximity of *Cladium mariscus* donor areas (Rowell 1986).

In Latvia, the data on drained *Cladium mariscus* fens converted into other land use types due to peat extraction or otherwise are missing. Nowadays, the extent of such impacts cannot be assessed reliably.

14.1.5.4 Mowing and grazing

In some European countries *Cladium mariscus* has been mown and used for thatching (in Great Britain, Sweden) and other purposes, for example, as a heat insulation material and as a packaging material. Wet clay bricks were covered with the hay of *Cladium mariscus* while drying; in England *Cladium mariscus* was also used as kindling (Rowell 1986; Regnell et al. 1995; Krogulec 2012) and, possibly, also for other purposes. In Sweden, in some regions during periods when there has been a shortage of hay, *Cladium mariscus* has also been temporarily used as fodder, although in general it is recognised as an unsuitable fodder plant that may even harm animals and cause injuries (Rowell 1986). Mowing of *Cladium mariscus* below the water level causes the dieback of the shoots due to a lack of oxygen (Conway 1937). Thus on waterlogged soils and in areas with great natural fluctuations of the water level, mowing can decrease the proportion of *Cladium mariscus*.

In Great Britain, where *Cladium mariscus* has been traditionally mown for thatching, mowing has usually taken place in the first half of summer once in every 3–5 years, which was considered as a suitable method of re-growing the thatching material (Rodwell (ed.) 1998). A similar mowing regime is also being implemented nowadays (Anon. 2015). Mowing once every 3–5 years has apparently been favourable to *Cladium mariscus* fens, promoting diversification of the plant species composition. Other traditional mowing times are also described, for example, Rowell (1986) mentions that in the first half of the 20th century *Cladium mariscus* was mown for thatching in winter. However it must be noted that in Great Britain the climate is mild, often with snowless conditions in winter that allows mowing in winter as well, which would hardly be possible in more continental regions.

In Latvia, *Cladium mariscus* has most likely not been traditionally mown or otherwise used, or it has been done rarely, although there is fragmentary information that in some areas *Cladium mariscus* has been used as fodder (Keišs 2013). Most probably, it is related to the rare occurrence of the species and the availability of other materials for fodder, heating or other everyday needs that are easier to obtain (e.g. reeds, wood). In the areas where *Cladium mariscus* can be found, similar to other "mire grasses" (sedges), it was traditionally considered to be unsuitable for fodder. In some areas (Pape, Engure), *Cladium mariscus* has probably been mown for hay (Keišs 2013) and used for bedding.

Nowadays in Latvia, *Cladium mariscus* stands are not mown and grazed for any economic purposes. Only in a few small patches near Lake Kaņieris has mowing taken place along with management of alkaline fens.

Mowing and grazing in *Cladium mariscus* fens create micro-niches for other plant species and increase the species diversity (Meredith 1985). In turn, if not mown, the plant community becomes more homogenous with lower species diversity, the vegetation structure changes and plant species with weak competitive ability disappear, for example, *Liparis loeselii* (Roze et al. 2014).

All in all, this habitat can exist without human interference, and it does not depend on regular disturbances, however moderate use of the habitat for economic purposes has caused an impact that, possibly, has promoted the diversification of the vegetation composition.

Fig. 14.7. Recently excavated ditch in an alkaline fen with *Cladium mariscus* on the shore of Lake Kaņieris in 2014. Here, the only habitat-favourable activity is the elimination of this impact by filling up the ditch immediately. In this case, the berm can be used for filling up the ditch. Most probably, alkaline fen vegetation will recover within a few years after filling up the ditches. Photo: A. Priede.

14.1.5.5 Fires

Cladium mariscus stands, especially terrestrial stands that are relatively dry, moreover if drained, may easily catch fire, because *Cladium mariscus* creates a large amount of litter when its leaves die off. No data suggest that burning would have been deliberately used in the management of *Cladium mariscus* stands in Latvia. However, uncontrolled burning in some places has affected *Cladium mariscus* stands, for example, fires have occurred in Apšuciems Fen, fragmentarily on the shores of Lake Kaņieris and in Raganu Mire, possibly, also in other areas. In Latvia, so far there are no studies on the impact of burning on *Cladium mariscus*, its habitat and habitat-related species.

There are contradictory opinions concerning the impact of burning on *Cladium mariscus* stands – it has been assessed both as favourable and deteriorating. For example, it has been indicated that *Cladium mariscus* is little affected by short-term irregular disturbances, including burning, mowing or short-term drop in the water level (Pokorny et al. 2010). Most probably fires have helped to maintain open fens, preventing the establishment of shrubs (LIFE Friuli Fens, *without date*). Burning in *Cladium mariscus* stands has been documented in Poland, noting its positive impact on the passerine bird fauna, including the globally endangered *Acrocephalus paludicola*, for whom the layer of plant litter characteristic for *Cladium mariscus* fens create favourable breeding conditions. However, if the litter layer becomes too thick, breeding conditions become unsuitable. Thus, burning might be a useful method for the removal of the excessive amount of litter (Krogulec 2012).

Studies on the impact of burning on *Cladium mariscus*, especially in the case of burning repeated within a short period of time, suggest that the vitality of *Cladium mariscus* decreases due to fire. If both lowering of the water level and burning have taken place, the shoots of *Cladium mariscus* are more likely to gradually die off and are replaced by graminoids, mainly by *Molinia caerulea* (Buczek 2005). Burning, especially if it has not been traditionally used in the management of fens, also has an unfavourable impact on the rare, protected *Vertigo* spp., which occurs in alkaline fens, and most probably also on other invertebrate species (Cameron et al. 2003; Kileen 2003; Anon. 2009) dwelling in the ground cover or in the dry layer of the litter and therefore die in the case of fire.

14.1.5.6 Beaver activity

Beaver dams and ponds may have both a favourable and unfavourable impact on the habitat. The water level maintained by beaver dams may help to recover the optimal water level in drained fens without special restoration measures. However, the beaver dams may cause a risk when the water level is raised too high, that, in turn, may promote the local extinction of *Cladium mariscus* and habitat-related calciphilous species, and the establishment of continuous reed cover instead of the former alkaline fen vegetation.

In some cases, beaver activity on a micro-scale may diversify the vegetation structure in the fen, if beavers create small ditches functioning in a similar

Fig. 14.8. Rapid shrub encroachment indicates lowering of the fen water table and conditions unfavourable to *Cladium mariscus* stands. In such case, rewetting is a priority, but the habitat structure can be improved by the removal of shrubs. Photo: A. Priede.

Fig. 14.9. The shapes of pines suggest that the trees are old and slowly-grown, thus mire-specific, and are natural elements of the mire. In such a situation, the removal of trees is not usually necessary. Photo: A. Priede.

way to the trails trodden by large wild herbivores, and serving as dispersal paths for the spread of calciphilous, light-demanding plant species, e.g. *Liparis loeselii*, *Primula farinosa*, and *Pinguicula vulgaris*.

14.1.5.7 Eutrophication

Eutrophication (i.e. enrichment with nitrogen, phosphorus, potassium) is widely regarded as an important cause of changes in fen vegetation resulting in a decline of species richness. Eutrophication in fens may result from excessive nutrient inflow from ditches, surface runoff from agricultural lands, or airborne nitrogen deposition. Eutrophication may also be caused by natural succession when the fen overgrows with forest. In fens influenced by eutrophication, the biomass increases, while the species diversity decreases (Laiviņš u. c. 2012). Since nutrient-poor substrate and waters are essential for the persistence of *Cladium mariscus* and other calciphilous plant species typical for alkaline fens, the availability of an excessive amount of nutrients promotes the local extinction of these species, and the establishment of species characteristic for nutrient-rich waters, for example, *Phragmites australis* and *Typha* spp. (especially in lake littoral zones) (Wheeler 1984).

14.1.5.8 Climate change

Since the distribution of *Cladium mariscus* is limited by low temperatures and frost, this species may be used as a climate change indicator (Conway 1942; Pokorny et al. 2010). Warming of the climate may promote the establishment of *Cladium mariscus* in new sites with suitable growing conditions. If the temperature increases and rainfall decreases due to climate change, this may enhance the peat decomposition, including peat in *Cladium mariscus* fens, leading to increased fen eutrophication. This, in turn, may cause the invasion of nitrophilous, highly competitive plant species and gradual overgrowing with forest. In Latvia, such a tendency has not been observed, however this topic has not been studied yet.

14.2 Restoration and Management Objectives in the Conservation of *Cladium mariscus* Fens

See the common objectives for all mire habitats (*Chapter 5.3*).

114.3 Restoration and Management of *Cladium mariscus* Fens

14.3.1 Restoration of *Cladium mariscus* Fens for the Purpose of the Guidelines

For the purpose of these guidelines, habitat restoration and management should be referred both to areas with the characteristic features of *Cladium mariscus* fens, and areas where it is possible to restore or create the conditions, vegetation structure, and species composition characteristic for this habitat type. Therefore, the guidelines also include mineral extraction sites as potential target areas, where, in some cases, the establishment of *Cladium mariscus* stands and the habitat-specific species composition

Fig. 14.10. Mowing in fens should almost always be performed with a brush-cutter. In the conditions typical in fens in Latvia, mowing with tractor equipment is almost never possible due to wet, marshy conditions and difficult access. In the photo – mowing of shoots after shrub clearing two years ago. Photo: A. Priede.

Fig. 14.11. *Cladium mariscus* is gradually replacing *Schoenus ferrugineus* in an alkaline fen near Lake Engure. Photo: A. Priede.

can be encouraged. The recommendations should also be applied to humid dune slacks, since *Cladium mariscus* stands can be found here (*see also* Laime (ed.) 2017, *Chapter 16*).

14.3.2 Non-interference

In undisturbed sites with optimal hydrological conditions, where *Cladium mariscus* stands are vigorous and vital, no special management measures are necessary. In such cases, only potential threats (e.g. drainage, lowering of water level, frequent fires, inputs of nutrient-rich waters, etc.) must be prevented.

14.3.3 Ensuring the Optimal Water Level in Lakes

Cladium mariscus stands on the lakeshores may be unfavourably affected by changes in the lake water level, due to which the groundwater table in lakeshore fens may drop. It is particularly important in lakes that are regulated by a sluice. The water level may also drop when restoring drainage systems in lake surroundings, removing beaver dams, or due to other reasons, e.g. mining. Prior to restoring or regulating the water level favourable to *Cladium mariscus* stands, a comprehensive assessment of the potential impacts on the habitat and related species should be performed. The expected impact on the adjacent areas must also be taken into account, as the changes in water level may affect the neighbouring agricultural and forest lands.

In lakes, shallow water conditions are optimal for *Cladium mariscus* (*see Chapter 14.1.4*). With increasing water depth, *Cladium mariscus* may die off and may be replaced by *Phragmites australis*.

14.3.4 Rewetting

Cladium mariscus is vulnerable to drainage – it may disappear due to drainage and other hydrological modifications, which lower the water level. In Latvia, there are no *Cladium mariscus* stands with a direct and explicit long-term unfavourable impact on ditches. If such has occurred, then *Cladium mariscus* has already disappeared, the conditions have changed insomuch as the habitat cannot be classified as the protected habitat type anymore.

Above all, it is important to prevent hydrological alterations, which may unfavourably affect *Cladium mariscus* fens. However, in the case when the draina-

Fig. 14.12. Thick layer of litter in *Cladium mariscus* stands creates unfavourable conditions for small plants and decreases the richness of invertebrates in comparison to other alkaline fens. Photo: A. Priede.

Fig. 14.13. Mowing with removal of mown biomass decreases the abundance of *Cladium mariscus* within a few years. This improves the conditions suitable for light-demanding, small plant species and mosses. *Cladium mariscus* shoots in the next spring after mowing are threatened by frost, which may reduce its cover. Photo: A. Priede.

Fig. 14.14. The only known example of *Cladium mariscus* fen mowing in recent decades on the shores of Lake Kaņieris in an area of 0.5 ha in 2015 and 2016. *Cladium mariscus* stand was mown with a brush-cutter, hay was collected with rakes by gathering it into heaps and burning it afterwards. Photo: A. Priede.

ge ditches are dug (in Latvia, this would be an illegal action, as all *Cladium mariscus* fens are included in protected nature territories with a more or less strict protection regime), the excavated ditches must be filled up as soon as possible (Fig. 14.7).

In *Cladium mariscus* fens that are drained by older ditches, which due to some reason cannot be filled up completely, blocking of ditches by dams is advisable, following the same principles as in raised bogs and alkaline fens (*see Chapter 10.3.3 and 15.3.3*). This can most likely be applied to ditches on the marginal zone of fens, where the drainage impact has caused the expansion of species of drier habitats, most commonly – *Molinia caerulea*, and the invasion of woody species.

If beaver activity has caused unfavourable changes by raising the water level above the optimum, the beaver dams must be removed and the beaver population controlled by hunting. Beavers, though they often create suitable conditions for mire habitats and species, cannot be relied upon as "habitat managers", as the impact may be both favourable (restores the optimal water level) and unfavourable (creates ponds and paludified areas, due to which *Cladium mariscus* may disappear). Constantly increased water level in beaver ponds and their surroundings causes organic matter accumulation and eutrophication, resulting in the disappearance of *Cladium mariscus*.

Fig. 14.15. Over recent decades, management has only affected *Cladium mariscus* fens in small areas. Since 2005, in a few small alkaline fens, including *Cladium mariscus* stands, shrubs were repeatedly cleared on the shores of Lake Kaņieris and in Raganu Mire. In the site on the photo – mowing and collection of hay in *Cladium mariscus* fen on the shore of Lake Kaņieris in 2015. Photo: A. Priede.

14.3.5 Removal of Trees and Shrubs

Intense shrub encroachment in the *Cladium mariscus* fens indicates the impact of ditches or on lowering the water level in lakes (Fig. 14.8). Thus it is most important to eliminate the basic problem – to restore the water level suitable for alkaline fen communities. In such cases, the felling of trees and clearing of shrubs can only improve the habitat structure, but due to drainage the vitality of *Cladium mariscus* de-

According to national legislation acts, prior to the removal of trees in *Cladium mariscus* fens, the type of land use in a document of the legal boundaries must be clarified. If it is a forest land, a deforestation permit is required by the responsible authority if deforestation is planned to performe to restore a protected non-forest habitat). More on the procedure: *see Chapter 6.3*.
In some areas, forestry operations, including deforestation of overgrown fens aimed at restoring protected habitats, are limited. Therefore, the limitations, e.g. time limitations must be clarified in each case. In protected nature territories, forestry operations are usually prohibited in the bird breeding period from 15 March to 31 July. In micro-reserves and their buffer zones the regulations should be complied with regulating the protection of micro-reserves, since some bird species for whom the micro-reserves have been created, already start breeding in February; in this case specific area features and requirements of species conservation must be followed.

creases, habitat-specific species disappear, and habitat degradation continues.

Trees may also be present in intact *Cladium mariscus* fens (Fig. 14.9), however, in such cases they never form dense stands and usually represent the shapes typical for constantly waterlogged soils; commonly these are so-called "bog pines" with crooked trunks and branches (*see Chapter 15.3.7.1*). Usually they occur on drier elevations. In undisturbed fens, trees are natural elements of the landscape, and their removal is not necessary (Fig. 14.9).

Felling residues must be collected and removed from the area or burnt in piles on site. For more on the removal of trees and shrubs, *see Chapter 15.3.7*.

Burning of the felled shrubs on the spot in *Cladium mariscus* stands is related to a high fire risk due to the thick layer of plant litter. Thus burning on site is not advisable, and burning must not be performed in dry, windy conditions. If felling residues cannot be burnt outside *Cladium mariscus* stands, then burning on the spot must be limited by prior burning of a "fire safety circle" around them.

14.3.6 Control of Shoot Re-growth and Young Trees

In wet areas, it is expected that shoot regrowth will not be as intense as in drier sites, e.g. drained fens and fen meadows. Also the thick layer of litter, typical for *Cladium mariscus* stands, limits the establishment of young trees. However, if it is decided to restore open, treeless fen, one must recognise that there will be many stumps generating a dense layer of shoots in the next years. Consequently, the felling of trees and shrubs in heavily-overgrown places must be repeated over a number of years (Fig. 14.10).

In grasslands, re-sprouting can be successfully suppressed by mulching. In exceptional cases, this can be applied in fens. However, in most cases mulching in alkaline fens is not suitable due to the undesirable side-effects, especially concerning soil fauna and ground vegetation. In Latvia, mulching has not been used in *Cladium mariscus* fens, therefore its impact on this habitat is not known. On very wet soils, mulching is not possible due to difficult conditions and, most likely, also not necessary. On very wet soils, this method may only be used in certain cases, for example, for the treatment of formerly heavily overgrown, relatively dry recently cleared forest edges.

Deciduous trees must be cut as low as possible. To promote rapid decaying of stumps, they may be cross-notched.

To get rid of young pines, which often establish in enhanced light conditions after clearing shrubs, weeding is the simplest method. The same can be done with young deciduous trees. In small areas with few young trees, they can be manually cut near the root collar using hand tools (e.g. pruning shears) once per year or once in several years.

Use of herbicides to control the emerged young

Fig. 14.16. *Cladium mariscus* patches in pasture on the eastern shore of Lake Engure in a dry summer, when the water level has dropped below the average. Cattle tread the muddy, uncovered lake bottom, but do not graze *Cladium mariscus*. Photo: A. Priede.

shoots is not permissible due to the high risk of groundwater and surface water pollution. The application of herbicides also poses risks to invertebrates living in the soil and ground cover.

14.3.7 Mowing

Prior to the planning of mowing, it should be understood whether it is necessary or not in the particular situation. If the management is aimed at preserving the typical vegetation structure and the site is not affected by drainage or other hydrological modifications, most probably no management, including mowing, is necessary. Mowing increases the competitive ability of other plant species, decreasing the proportion of *Cladium mariscus*, increases the bare soil proportion, thus opening gaps suitable for seed germination (Meredith 1985). Therefore, *Cladium mariscus* mowing is applicable in alkaline fens with small-sedge vegetation where both habitat types (7210* *Calcareous fens with* Cladium mariscus *and species of the* Caricion davallianae and 7230 *Alkaline fens*) can be found (Fig. 14.11). In such areas *Cladium mariscus*, a species with a tendency to form monospecific stands, with time takes over areas occupied by lower plants, mainly small-sedges. In such fens in Latvia with mixed *Cladium mariscus* and small-sedge vegetation, the priority is the conservation of small-sedge alkaline fens, as they are rare and threatened. Thus the control of *Cladium mariscus* is acceptable.

Mowing creates micro-niches for other plants, including rare calciphilous plant species, which are rare or absent in natural *Cladium mariscus* stands as they are almost monospecific and characteristic with a thick layer of plant litter. The presence of other plants, including mosses, creates environmental conditions more suitable for a higher diversity of invertebrates, especially snails. Their population density is higher in alkaline fens with *Schoenus ferrugineus* than in the almost monospecific *Cladium mariscus* fens (Spuņģis 2014).

However, mowing can only cause vegetation diversification in drier sites, whereas in shallow water *Cladium mariscus* can only be replaced by a few emergent or submerged aquatic plants.

In a temperate climate, including Latvia, mowing in autumn or winter may cause frost damage to *Cladium mariscus* shoots (Fig. 14.12–14.13). Mowing below the water surface may promote dying off of the *Cladium mariscus* shoots (Rowell 1986; Krogulec 2012). The observations in Latvia also suggest a similar impact of frost (Fig. 14.12–14.13).

Mowing should be carried out in the summer (from July to August) using a brush-cutter or a scythe. Practically, this is possible in small fens, as well as in areas where *Cladium mariscus* occurs in a mosaic with alkaline fen vegetation. Tractors of light construction or light pedestrian-driven mowers can

Fig. 14.17. The layer of litter in *Cladium mariscus* stand in optimal moisture conditions without any disturbance. Photo: A. Priede.

Fig. 14.18. The layer of litter in *Cladium mariscus* stand in optimal moisture conditions soon after the burning. Photo: A. Priede.

Fig. 14.19. The layer of litter in a *Cladium mariscus* stand in optimal moisture conditions two years after burning. Photo: A. Priede.

Table 14.1. Comparison of management methods of *Cladium mariscus* fens.

Method	Advantages	Disadvantages
Mowing	Reduces the dominance of *Cladium mariscus* in areas where it occurs in small-sedge alkaline fens outcompeting other plant species. Increases the diversity of micro-niches for flora and fauna. Fairly effectively reduces the re-sprouting of felled shrubs and eradicates young, recently established trees.	In small areas it can only be carried out by manual work (high costs, difficult working conditions). In large areas, specialised machines should be used (caterpillars or double or triple tyre tractors). The specialised machines are not available everywhere or must be bought for the particular purpose (high costs). Gathering of the mown biomass is necessary (additional costs), but the biomass does not have a practical usage.
Low intensity grazing	A relatively cheap method (can be used in larger grassland and fen complexes). A sustainable solution that ensures maintenance of species-richness and reduction of re-sprouting after clearing. Promotes development of vegetation mosaics with higher diversity of micro-niches than in monodominant *Cladium mariscus* stands.	Animals do not browse *Cladium mariscus* or graze it unwillingly (only the young shoots); the sharp leaves may cause injuries. Most probably, untouched patches of *Cladium mariscus* will remain even in heavily grazed areas. Low nutritional value, therefore supplemental feeding is necessary that, in turn, creates a risk of establishment of undesirable species. Trampling unfavourably affects soil fauna and grass-dwelling invertebrates, especially snails. Construction of fencing creates additional costs. Constant surveillance of animals is necessary.
Prescribed burning in spring or in late autumn or winter	Cheap method. Effectively suppresses shrubs and reduces the amount of litter for several years. If burning is not carried out frequently and done in the appropriate period (in late autumn or winter), the impact on the composition of the plant species is not significant.	Fire risk to adjacent areas. Wrong timing of burning endangers birds, amphibians and reptiles. Burning in areas affected by drainage promotes spread of expansive plant species *Molinia caerulea*. In burnt areas, the young shoots of *Cladium mariscus*, especially if burnt in autumn, may be damaged by frost, thus the proportion of *Cladium mariscus* may decrease.

be used, similar to those used for reed cutting in winters on ice. It is preferable if the mowing equipment gathers and sheaves the mown material immediately (similarly to reed mowing and collecting for thatching, which is practised on some lakes in Latvia). The alternative is mowing with a brush-cutter and collecting by a rake which is more labour-consuming (Fig. 14.14, 14.15).

If mowing must be carried out in terrestrial areas not covered by water, dominated by *Phragmites australis* and *Cladium mariscus*, where manual mowing is not possible, it is advisable to use double or triple wheeled tractors or caterpillars, thus minimising damage to soil and vegetation. Mowing should be performed at a height of 7–10 cm, and the mown grass must always be collected and removed. Low mowing promotes the die off of *Cladium mariscus* (water gets into the tissues posing a greater risk of frost damage). Higher mowing decreases the cover of shrubs but does not significantly change the composition of herbaceous vegetation.

In larger *Phragmites australis* and *Cladium mariscus* complexes, mowing may be performed using vehicle that shred the mown grass, gather it in a container and transport it away, or collect it in sheaves that are easy to gather afterwards. Overly careful collection of litter is not necessary, as this most likely has an unfavourable impact on fauna dwelling in the ground cover, especially snails. Gathering of

Fig. 14.20. The conditions suitable for *Cladium mariscus* stands on the shore of an abandoned dolomite quarry in Līkumciems. Photo: A. Priede.

litter also enhances the establishment and survival of wooden species. If litter removal is necessary to restore an alkaline fen overgrown with *Cladium mariscus* (habitat type 7230 *Alkaline fens*), then mowing of *Cladium* should not be performed in the entire area and not every year. Practical management examples show that after the gathering of mown biomass and litter by hand using a rake, a lot of the litter is still left on site, thus not posing a risk to fauna dwelling in the litter and mosses.

Studies on the impacts of mowing in Poland suggest that mowers, even if equipped with wide tracks, cause an unfavourable impact on the ground vegetation and the soil fauna as they reduce the microtopographical variations (Kotowski et al. 2013). On wet, swampy soils the use of tractors creates deep tracks which function similarly to drainage ditches. To some extent, the tracks filled with water create favourable niches for some bird species, however in general they have an unfavourable impact on the hydrological regime (Krogulec 2012).

In deeper waters, floating mowers can be used. In Latvia, such equipment is used for lake and river management. When using floating machines, the mown material is difficult to gather. But its removal is important in order to prevent rapid eutrophication and consequent changes in vegetation. However, in Latvia there are no known sites with *Cladium mariscus* stands in deep water where mowing is necessary.

In Latvia, the experience concerning the frequency and impact of *Cladium mariscus* mowing on species diversity is insufficient. Examples from Great Britain where *Cladium mariscus* is still used for thatching show that mowing once every 3–5 years is optimal for preserving the typical vegetation structure and composition. More frequent mowing may promote the decrease of *Cladium mariscus* cover.

The mown biomass of *Cladium mariscus* fens may be used as insulation material, fibres, thatching and/or kindling. The biomass removed in the second half of summer, when it contains seeds, could be used in alkaline fen restoration in post-harvested peatlands and/or the rehabilitation of carbonate rock post-mining areas if the abiotic conditions are suitable and recovery is possible. Freshly mown grass (green hay) should be transported to the target territory as soon as possible after mowing to avoid shedding of seeds before the plants are transferred.

Such establishment of *Cladium mariscus* stands may most likely only be promoted in post-harvested peatlands with residual alkaline fen peat that are located in coastal areas, because the climate there is mild (*see Chapter 14.3.10*).

14.3.8 Grazing

In literature, different and contradictory information can be found about grazing in *Cladium mariscus* fens and use in fodder in European countries (*see Chapter 14.1.5.4*). For example, Conway (1942) mentioned that in Great Britain, *Cladium mariscus* has never been used as fodder, while Rowell (1986) noted that cattle graze the young *Cladium mariscus* shoots. In some countries, e.g. Sweden, *Cladium mariscus* has been used in cases when better fodder was not available.

Overall, *Cladium mariscus* is not suitable as a fodder plant, and its sharp leaves may cause injuries, thus the animals do not eat them or eat them unwillingly. In Latvia, this plant has most likely not been used for this purpose due to its low nutritional value and sharpness, and similarly to some other tall sedges, has also been considered as unsuitable for fodder. Nowadays the *Cladium mariscus* habitats are only grazed in small areas in "Lake Engure" Nature Park in the pastures on the eastern shore of Lake Engure (Fig. 14.16). In the past, alkaline fens were most probably maintained open by grazing, which decreased the proportion of *Cladium mariscus* and created the patchy structure of vegetation.

To maintain open fens, nowadays, alkaline fens can be extensively grazed, decreasing the dominance of *Cladium mariscus* if it is found in particular area, and thus increasing the species diversity. In this way, micro-niches (animal paths, intensively browsed patches) suitable for smaller light-demanding calciphilous plant species are created. Low-intensity grazing may be an efficient measure to control overgrowing with shrubs in large fen areas, which enclose a complex of different habitat types. However the establishment of pastures in nearly monospecific *Cladium mariscus* stands is not ecologically justified. Most likely, it is also impossible due to practical reasons (swampy ground, low nutritional value and sharpness of *Cladium mariscus* leaves). Supplemental feeding, which would be necessary for animal welfare in such areas, should not be implemented due to the risk of the introduction of unwanted, ruderal and/or invasive non-native species. In wetland complexes with *Cladium mariscus* stands, if grazing is chosen as a management method, sheep and goats are not suitable. It is better to use horses or cattle that can also access the swampy sections of the fen and browse the shrubs and reeds, thus decreasing their expansion.

14.3.9 Prescribed Burning

In some places in Latvia, *Cladium mariscus* stands have been affected by fires, however it is not known whether burning has been knowingly used as a management method in this habitat type. As far as it is known, the fires have been unintentional and uncontrolled.

In Poland, burning has been advised as an appropriate method to preserve and restore the habitats of *Acrocephalus paludicola* and other birds residing in wet sedge meadows and wetlands, particularly passerine bird species. Prescribed burning helps to maintain the area open by damaging the shrubs and decreasing their cover. This example shows that burning significantly reduces the height of the vegetation and the amount of litter, which recovers to the former amount within several years (Grzywaczewsk et al. 2014). Observations in burnt *Cladium mariscus* fens in Latvia suggest that fires, if not frequent, do not cause significant changes in species composition. The most visible change is a reduction of litter layer, which recovers within several years (Fig. 14.17–14.19).

Thus prescribed burning, if outside the bird breeding season (from the beginning of March to August), has a positive role in preserving the habitats significant for birds and can be used in management of the habitat. In order to avoid undesirable effects on the birds, it should not be performed every year, which would also cause damage to vegetation and change its typical structure. The fire return interval, though it has not been tested in the long term, could be once in every 5–10 years.

The impact of rare fires on vegetation structure and composition in undrained, intact fens is most likely insignificant. Burning probably creates a favourable impact on the light-demanding, small plants, which are otherwise limited by the thick layer of litter characteristic for *Cladium mariscus* stands. In turn, in places affected by the lowering of the water level, frequent burning promotes the establishment of the vegetation characteristic for grasslands, especially *Molinia caerulea* (Buczek 2005). Burning has an unfavourable effect on snail fauna dwelling in the soil and ground vegetation (Cameron et al. 2003). The knowledge of the influence of fire on the insect and spider fauna, including burning in the winter period, is insufficient. However, the impact is probably not significant if the burning is not frequent.

Fig. 14.21. *Cladium mariscus* stand in the ditch in a meadow in Ķemeri National Park. Photo: A. Priede.

14.3.10 Comparison of Different Management Methods

The management methods of *Cladium mariscus* stands are compared in Table 14.1.

14.3.11 (Re)creation of *Cladium mariscus* Fens in Severely Deteriorated Areas

In Latvia, there is no information about *Cladium mariscus* fens, which have been transformed into agricultural lands or afforested. Thus, the re-creation of completely destroyed habitats is not necessary.

Sometimes carbonate-rich post-mining areas are suitable for creating new habitats for the development of alkaline fens, including *Cladium mariscus* fens. Peat and tufa quarries that are filled up with water may be suitable for *Cladium mariscus*, if the water is nutrient-poor and alkaline. In some cases, *Cladium mariscus* establishes spontaneously, especially in the vicinity of donor areas. In post-harvested peatlands, the conditions are suitable if the residual peat layer is thin and the bedrock is alkaline or the substrate is carbonate-rich due to spring discharges (Fig. 14.6). Suitable conditions for *Cladium mariscus* may also be found in post-mining areas with carbonate rocks – limestone, dolomite or carbonate-rich sand and gravel quarries (Fig. 14.20). Usually such conditions are characteristic with open or sparsely vegetated calcareous waterlogged substrate or shallow water areas. The mosaic of deeper and shallower ponds, wet depressions and elevations creates suitable habitats not only for *Cladium mariscus*, but also for numerous rare plants, waterfowl and wading birds, dragonflies, benthic organisms, etc.

Establishment of *Cladium mariscus* in post-mining areas may be promoted or hastened by transferring of the *Cladium mariscus* hay containing generative shoots with viable seeds or turf with viable shoots to appropriate places. It is possible in regions where post-mining areas are located not far from the natural habitats of *Cladium mariscus* – thus, most likely, these areas are suitable for *Cladium mariscus* in a climatic sense as well.

Principles of promoting the development of alkaline fen vegetation in post-mining areas is described in the guidelines of habitat type 7230 *Alkaline fens* (*see Chapter 15.3.13*). Prior to such experimental management, experienced experts must be involved as well as the activities must be coordinated with responsible authorities (*see Chapter 6.3*), since the habitat type 7210* *Calcareous fens with* Cladium mariscus *and species of the* Caricion davallianae is also a protected habitat in Latvia, moreover, it is inhabited by numerous protected species. Such activities must be performed wisely, without creating significant impact on the donor area.

The examples of restoring of the EU habitat type 7210* *Calcareous fens with Cladium mariscus and species of the Caricion davallianae* by using different methods (ditch infilling, felling of trees, clearing of shrubs, creating of micro-niches for rare species, introduction of rare species) are available on the website of the project "Conservation and restoration of calcareous fens in Friuli", LIFE06NAT/IT/000060 (in northern Italy), www.lifefriulifens.it.

14.3.12 Establishment and Maintenance of Tourism Infrastructure

When creating tourism infrastructure (trails, boardwalks, footbridges, viewing platforms and towers) in areas where the habitat type 7210* *Calcareous fens with* Cladium mariscus *and species of the* Caricion davallianae can be found, the same principles should be used as described in *Chapter 10.3.10*.

The most appropriate infrastructure type in *Cladium mariscus* fens are boardwalks constructed of wood or other materials because they do not cause hydrological changes in the fen. Mowing of *Cladium mariscus* on the sides of the boardwalks is acceptable as it does not cause threats to the species and the habitat, and probably even promotes the development of micro-niches for small, light-demanding plant species, such as *Primula farinosa*, *Pinguicula vulgaris*, *Liparis loeselii*.

14.3.13 Inappropriate Management and Use of *Cladium mariscus* Fens

Management and use unfavourable to the habitat includes the following:

- all activities that may modify the groundwater table or water level in lakes with *Cladium mariscus* stands (excavation of new ditches, cleaning of the existing ditches in the fen and the adjacent areas, beaver ponds, etc.);
- demolition of beaver dams on ditches, where they maintain an optimal water level;
- water pollution (nitrogen, phosphorus, potassium compounds), which leads to eutrophication – use of any fertiliser within the habitat areas and in its vicinity, or excessive use of fertilisers in the hydrologically related areas;
- shredding of mown grass and leaving on site;
- mulching and ploughing;
- high intensity grazing and related trampling;
- movement of heavy vehicles across the fen during the frost-free period, including mowers which create deep tracks and other damage to the ground;
- use of herbicides to control shrub stem shoots and expansive or invasive non-native plants;
- burning of ground vegetation and litter (except for prescribed burning in exceptional cases coordinated with the responsible authorities);
- establishment of tourism infrastructure that causes undesirable impacts on the habitat and related species (increased trampling, damage or disturbance to rare species, etc.);
- supplemental feeding of wild game (promotes eutrophication and establishment of ruderal, expansive and invasive non-native plant species);
- afforestation;
- any damage to the topsoil and vegetation (removal of topsoil, bulldozing of area, construction building), except for activities aimed at habitat restoration or management that are well planned and coordinated with the responsible authorities, for example, diversification of the micro-niches (for small sized light-demanding species) or removal of nutrient-rich topsoil.

14.4 Conservation and Management Conflicts in *Cladium mariscus* Fens

In some cases, especially in Coastal Lowland (e.g. the shores of Lake Engure and Lake Kaņieris), both habitat types – 7210* *Calcareous fens with* Cladium mariscus *and species of* Caricion davallianae and 7230 *Alkaline fens* – can be found in a mosaic. In some areas the expansion of *Cladium mariscus* in alkaline small-sedge fens can be observed, thus one protected habitat type transforms into another in the course of succession.

To answer the question of which habitat type (i.e. vegetation type) is the priority in this case, their distribution, total cover and threats should be taken into account (the latest available data, e.g. the latest national report of Article 17 of the Habitats Directive). In Latvia, the habitat type 7230 *Alkaline fens* is critically endangered, thus its conservation is, most probably, a higher priority than *Cladium mariscus* stands. Therefore, management, e.g. mowing aimed at restoring the habitat type 7230 *Alkaline fens*, if performed in the mosaic-type fens with both habitat types, should not be considered as deteriorating for *Cladium mariscus* stands if the management activities result in the development of small-sedge communities. If the *Cladium mariscus* hay is regularly collected together with the litter, the conditions will improve for small, light-demanding plants, however the young tree seedlings may benefit and their survival prospects may increase. Moreover, hay collection may have an adverse effect on soil and grass-dwelling invertebrate fauna. Some of the tiny invertebrates dwelling in the litter, especially snails and including some rare species, can be removed together with litter. Similar impacts, both positive and negative, can be caused by grazing. Additionally, grazing creates a trampling impact and mechanically damages the soil fauna.

Prescribed burning could occasionally be an effective and inexpensive method for reducing the proportion of shrubs and helping to maintain open fens and suitable conditions for numerous fen plant species and the typical vegetation. Occasional burning also has little impact on the vitality of *Cladium mariscus*. However, if the wrong timing is chosen (burning in spring and summer), it endangers the bird and soil fauna.

If *Cladium mariscus* is found in ditches (Fig. 14.21) that drain an alkaline fen or a wet meadow, the priority is the rewetting of fen or meadow if necessary rather than preserving a small size *Cladium mariscus* patch, which may be destroyed when filling up or blocking the ditch. Exceptions might be in the cases when it is the only species locality in the region. Therefore, all aspects should always be taken into account to choose the restoration and management methods wisely and to choose the priorities reasonably.

Chapter 15. 7230 *Alkaline fens*

15.1 Characteristics of Alkaline Fens

15.1.1 Brief Description

Alkaline fens have developed on calcareous soils permanently waterlogged under the process of paludification or on the lakeshores with a calcareous water supply, rarely – on slopes with waterlogged, calcareous soils formed on spring sediments. The vegetation is species-rich, dominated by small-sedges and brown mosses. The depth of the peat layer may reach several metres, although in young fens it can be very thin. Alkaline fens often belong to a wetland complex, thus they neighbour or partly overlap with wet calcareous semi-natural grasslands (*Molinion*), tall sedge communities (*Magnocaricion elatae*), reed beds (*Phragmition australis*) and some other plant communities typical for wet depressions. The plant communities of alkaline fens in Latvia are *Caricion davallianae, Caricion lasiocarpae, Sphagno warnstorfiani–Tomenthypnion* (Auniņa 2013f; European Commission 2013).

Mainly due to the rare occurrence of suitable conditions, alkaline fens are rare. In Latvia, alkaline fens may be found mainly in the western part of the country, especially in the Coastal Lowland. The largest areas can be found in the surroundings of Liepāja, in the coastal areas from Ventspils to Kolka, as well as in eastern Kurzeme, in Ķemeri National Park, and in the surroundings of Lake Engure. In small areas, the habitat can be found in western Zemgale and western Vidzeme (Fig. 15.1). Alkaline fens are among the rarest EU protected habitat types in Latvia, and only take up around 900 ha or 0.01% of the country (Anon. 2013a). Currently knowledge on the distribution and the total area of alkaline fens in the country is still insufficient and must be specified.

In Latvia, there are **two variants** of this habitat type (Auniņa 2013f, 2016e).

Variant 1: alkaline fens with spring discharges (Fig. 15.2). Usually they are located on the slope or at the basal part of the slope, and occupy a small (up to several hectares) area. In tufa petrification areas and in a narrow zone along the spring brooks, spring-characteristic moss species can be found, most commonly *Cratoneuron filicinum*, *Palustriella commutata*, and *Philonotis calcarea*. Species-rich plant communities are characteristic.

Variant 2: alkaline fens in plains (Fig. 15.3). They have formed in wet terrain depressions of different origin and may occupy an area of several tens or even hundreds of hectares. The plant communities are species-poor to species-rich, dominated by calciphilous species.

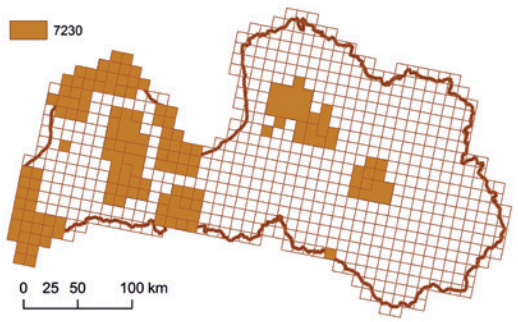

Fig. 15.1. Distribution of the habitat type 7230 *Alkaline fens* in Latvia (source: Anon. 2013a).

Fig. 15.2. Variant 1 – an alkaline fen with tufa-forming springs. The calciphilous fen plant communities can be found in a narrow belt along the spring brooks. In the photo – "Diļļu Meadows" Nature Reserve. Photo: A. Priede.

Fig. 15.3. Variant 2 – an alkaline fen in the Slocene floodplain. The plant community is formed by several sedge species, dominated by *Carex buxbaumii, C. elata, Eriophorum polystachion*. The species composition is poorer than in Variant 1. Photo: A. Priede.

15.1.2 Important Processes and Structures

Alkaline fens have formed in terrain depressions, on calcareous sediments formed by springs in the plains or on slopes, or on the lakeshores. Such fens feed mainly from the groundwaters, flowing surface waters and springs. Alkaline fen vegetation can very rarely be found in raised bog complexes around alkaline spring discharges.

The most important precondition for the formation of alkaline fen vegetation is the presence of carbonate-rich waters, or carbonate-rich bedrock close to the soil surface, constant supply of carbonate-rich groundwater, or high concentration of mollusc shells in the upper layer of sediments. The substrate is waterlogged peat, usually with a high mineral content. The groundwater table may seasonally fluctuate, which is mainly affected by the changes in the surface run-off (amount of precipitation), however the groundwater table in intact fens is relatively stable. Large groundwater table fluctuations usually result from drainage.

Alkaline fens usually have a several metre thick peat layer, however this habitat type, if the aforementioned typical abiotic conditions and species complex are characteristic, also includes geologically young fens, where the peat layer has started to develop relatively recently, therefore it is thin. The peat in the alkaline fens is rich in calcium, alkaline (pH > 6), and poor in nutrients (nitrogen, phosphorus) (Auniņa 2013f).

Intact and slightly disturbed alkaline fens with no or little drainage impact are open, treeless or with a sparse tree and shrub stand, while the sections affected by drainage overgrow with trees and shrubs. In small fens and in fens with a shallow peat layer, gradual tree encroachment is usually faster than in large fens or fens with a deeper peat layer even without drainage, and should be considered a result of natural succession.

In many European countries, including Latvia, many alkaline fens, similarly to species-rich grasslands, are considered as semi-natural habitats affected by the long-term interaction between natural processes and human activity by mowing and/or grazing, as well as by partial drainage (Wassen, Joosten 1996; van Diggelen et al. 2006; Auniņa 2013f). Thus, semi-natural fens are often regarded as fen meadows (Klimkowska et al. 2010b).

15.1.3 Succession

In Latvia, the full development cycle of mires starts with a stage of a minerotrophic mire or fen, and ends with the formation of an ombrotrophic mire or bog. However, not all mires pass through all the development stages. Sometimes, due to natural factors, for example, due to drier climate periods or prolonged seasonal droughts, mires overgrow with forest. Nowadays, the degradation of mires and rapid overgrowing with forest has been promoted by drainage, most likely also by climate change.

In small intact fens or fens slightly affected by drainage, overgrowing with forest usually takes less time than in large intact fens. The progress of overgrowing is also most likely determined by the thickness of the peat layer. Under natural conditions, large homogeneous areas of fens can remain open without management for thousands of years, however small fens can overgrow with forest within some hundreds of years or even decades. The development of a fen is also influenced by other factors, for example, placement in the terrain and presence of spring discharges. In Latvia, alkaline fens have sometimes formed on carbonate-rich spring sediments, also on slopes. In such conditions the succession of fens into raised bog is not expected.

The development of fen also has several stages in which different plant species and communities replace each other. For example, in some areas the small-sedge (e.g. *Schoenus ferrugineus*-dominated community) or tall sedge (e.g. *Carex lasiocarpa* and/or *Carex elata*-dominated communities) vegetation characteristic in the alkaline fens, is gradually replaced by *Cladium mariscus*. In this case, within the perspective of EU habitat classification, the habitat type 7230 *Alkaline fens* naturally transforms into habitat type 7210* *Calcareous fens with* Cladium mariscus *and species of the* Caricion davallianae.

15.1.4 Indications of Favourable Conservation Status

Alkaline fens in a favourable conservation status are characterised by permanently waterlogged substrate, which in most cases is peat (in exceptional cases in young fens the peat layer is absent or very thin), the substrate is alkaline, poor in nutrients (nitrogen, phosphorus, potassium). There is not impact of drainage.

A fen is treeless or with little tree and shrub cover, rapid overgrowing with trees does not occur. Trees in the fen have grown slowly and many of them are old – mainly *Pinus sylvestris*, rarely

Fig. 15.4. Alkaline fen with *Schoenus ferrugineus*. Photo: A. Priede.

Fig. 15.5. Alkaline fen with *C. lasiocarpa* and *Myrica gale*. Photo: A. Priede.

Fig. 15.6. *Liparis loeselii*, plant species characteristic for alkaline fens. It is an orchid, which is hard to notice because of its small size (up to 20 cm high). It is included in the list of species of Annex II of the Habitats Directive and is protected throughout the EU. Photo: A. Priede.

Fig. 15.7. *Saussurea esthonica*, a very rare plant species throughout Europe, grows in alkaline fens. The species is included in Annex II of the Habitats Directive. In Latvia it can only be found in two localities. Its conservation in the future depends on appropriate protection and management measures. Photo: A. Priede.

Juniperus communis, *Picea abies*, *Alnus glutinosa* and *Betula pubescens*. No explicit dominance of expansive plants (*Molinia caerulea*, *Phragmites australis*) can be observed. Vegetation is dominated by sedges and low herbs, the vegetation structure is diverse.

In the fen, specialist species of alkaline fens, calcareous spring habitats and *Molinion* grasslands prevail. The vegetation is species-rich, often with a large proportion of rare species (for more detailed information – see Auniņa (2016e)). Species composition in Latvia is affected by the geographical location of the fen – alkaline fens in eastern and central Latvia differ from those in western Latvia. However, in all cases, small-sedge species (*Schoenus ferrugineus* (Fig. 15.4), *Carex davalliana, C. panicea*) and/or some tall sedge species (*C. elata*, *C. lasiocarpa* (Fig. 15.5), *C. buxbaumii*) dominate. Small, light-demanding plants, such as *Primula farinosa* and *Pinguicula vulgaris*, and mosses – most commonly *Scorpidium revolvens*, *S. cossonii*, *Campyllium stellatum*, and *Scorpidium scorpioides* can be found.

Alkaline fens are a significant habitat for many rare plant species, for example, *Liparis loeselii* (Fig. 15.6), *Saussurea esthonica* (Fig. 15.7), and several species of *Dactylorhiza* genus, mosses *Leiocolea rutheana*, *Preissia quadrata*, and *Moerkia hibernica*. Rare snail species can also be found: *Vertigo genesii*, *V. geyeri*, *V. angustior* (Auniņa 2013f). Their presence increases the importance of the fen in terms of the conservation of species diversity, however they are rare, therefore their absence does not necessarily indicate unfavourable conservation status of the habitat.

Fig. 15.8. An alkaline fen, drained in the mid-20th century, nowadays completely overgrown with forest. The western part of Zvejnieku Mire in Ķemeri National Park. Photo: A. Priede.

15.1.5 Pressures and Threats

15.1.5.1 Drainage

The most important impact with a deteriorating effect is drainage, which causes lowering of the groundwater table. Lowering of the groundwater table in fens can occur due to excavation of ditches (Fig. 15.9), modification of the water level in lakes (if alkaline fens are located on the lakeshores), and/or drying up of springs. Due to drainage, the peat decomposition rate of peat increases, thus the nutrients (mainly phosphorus) are released and become available for plants. Substrate becomes suitable for expansive, nutrient-demanding species, which may become dominant, in most cases *Molinia caerulea*. The growing conditions become drier and thus more suitable for woody species. A drained fen can overgrow with forest within several decades (Fig. 15.8).

Due to drainage, both the moisture and light conditions change, promoting changes of the alkaline fen-typical species composition and extinction of the characteristic plant species, which are replaced by expansive species and species of drier conditions. Over a longer time, open mire overgrows with forest. The establishment of trees, especially deciduous trees and mainly birches, significantly increases the transpiration rate, thus enhancing the drainage effect.

Sometimes the ditches get clogged over time and only drain the area partially (Fig. 15.10), however they still continue functioning for several decades.

Fig. 15.9. A ditch in Strēļu Mire, which is severely deteriorated by drainage and peat extraction. Due to drainage of the fens, the peat decomposition is enhanced and the mire vegetation, its structure and composition are degraded. Drained fens overgrow with forest more intensively than intact ones. Drainage arrests the ecosystem functions of the fen (accumulation of peat and water, sequestration of carbon). Photo: A. Priede.

Fig. 15.10. An old drainage ditch in the fen near Bigauņciems. Sometimes, as in this case, after a longer time the drainage ditches do not function anymore or function only partially, thus they do not cause significant deteriorating impacts on the fen ecosystem functions and vegetation. Photo: A. Priede.

Today, in mires in protected nature territories and micro-reserves, with the exception of unauthorised activities, new ditches are not dug and the old ditches are not repaired. However, an unfavourable impact on the alkaline fens is sometimes created by the digging of new ditches in the adjacent areas, which may have an adverse effect on the fen habitat.

A similar unfavourable impact on alkaline fens is also caused by artificial lowering or raising of the lake water level. The water level of lakes fluctuates naturally, also affecting the alkaline fens on its shores. To some extent, plant species occurring in alkaline fens have adapted to water level fluctuations within the range of approximately 25 cm (Gailīte 2012). Nevertheless, a prolonged drought or prolonged rise in water level reduces their vitality. The diverse vegetation is replaced by expansive species. When the conditions become constantly drier, *Molinia caerulea* (Fig. 15.11) may take the dominant role in the vegetation, while the typical calciphilous moss and vascular plant species, as well as rare snail species found in such habitats gradually disappear. At a constantly increased water level, the vegetation can be overwhelmed by reeds.

Regulation of the lake water levels can also affect alkaline fens, promoting the development of new fens. In Latvia, such fens are found near Lake Engure and Lake Kaņieris. In Lake Engure, the water level was lowered in 1842, uncovering the lake bottom, which is nowadays overgrown with calciphilous fen vegetation (Laiviņš u. c. 2012). Similarly, alkaline fens developed on the bottom of Lake Kaņieris, where the water level was lowered in the first half of the 20th century, and mosaic-type vegetation composed of fens and reed beds developed (Galeniece, Cukermans 1985). In Lake Kaņieris in 1965, the water level had been raised again (Strazds, Ķuze 2006), thus reducing the areas of young alkaline fens.

Fig. 15.11. *Molinia caerulea*, a common species in alkaline fens. Its well-pronounced dominance in fens indicates drainage and/or a burning impact. Photo: A. Priede.

Fig. 15.12. Abandoned peat quarry, filled with water, near Lake Sloka. Photo: A. Priede.

15.1.5.2 Peat extraction and change of land use types

In previous centuries many alkaline fens were affected by peat extraction. In Latvia, the exact areas affected by peat extraction in alkaline fens are not known. In most cases the peat was extracted manually, thus affecting relatively small patches. However, some alkaline fens were also harvested in larger areas, both by block-cutting and peat milling, for example, Praviņu Mire and Ķirba Mire. Due to peat extraction several alkaline fens are permanently destroyed and nowadays are transformed into other land use types. Some post-harvested fen peat block-cutting areas have filled up with water, and nowadays form a mosaic of ponds and reed beds (Fig. 15.12). Alkaline fens have also been drained and transformed into agricultural lands or forests, however the information on their area is insufficient.

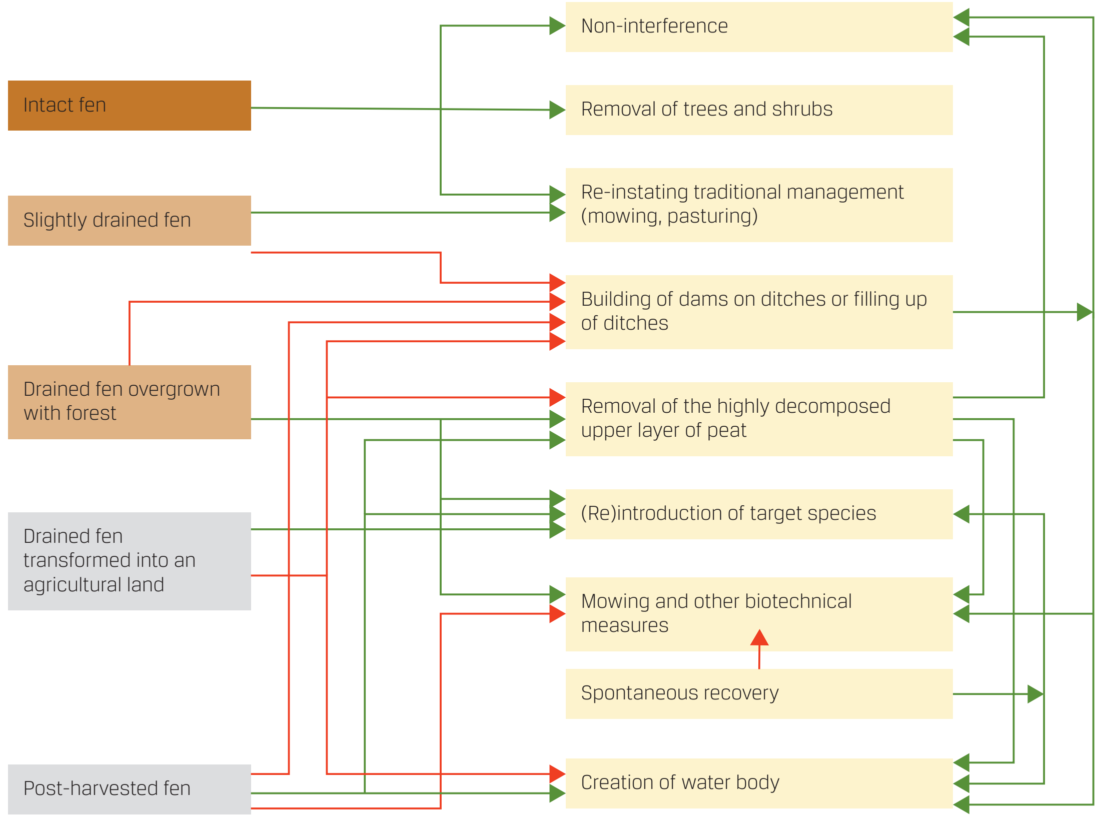

Fig. 15.13. Selection of appropriate restoration methods for alkaline fen habitats in various situations. The red arrows depict the most commonly applied solutions, the dashed arrows – alternative solutions that may improve the result or that can only be applied if necessary, in specific cases, after careful inventories.

15.1.5.3 Drying up of springs

Drying up of springs may be the reason for degradation in spring-fed alkaline fens. Springs may dry up due to both natural and anthropogenic factors (*see Chapter 13.1.5*).

15.1.5.4 Mowing and grazing

Until the mid-20th century, in Latvia the area of meadows and pastures was insufficient to fulfil the needs for hay and fodder. Therefore many fens, including alkaline fens, were used as hay meadows and pastures. To improve the productivity of grass, many fens were partly drained using shallow manually dug ditches. In this way, numerous fens were converted into grasslands (most commonly – *Molinion* grasslands). Haymaking and grazing therein was often difficult due to marshiness. In some European countries, fens were mown for bedding or for fodder (Šefferová Stanová et al. 2008). As the economically profitable and productive grasslands were cultivated and the socio-economic situation changed, mowing and grazing in fens gradually ceased in the 20th century.

Plant species diversity of alkaline fens affected by mowing and grazing, similarly to semi-natural grasslands, has formed under the long-term moderate impact of humans and animals. Due to this, many fens have survived treeless until nowadays. Today, mowing and grazing in fens has almost ceased. In addition to drainage, abandonment is among the major reasons for fen overgrowing and decline of species diversity.

Similarly to semi-natural grasslands, too frequent mowing (several times a year), as well as shredding the mown grass and leaving it on the ground cause a negative impact on vegetation diversity and related plant and animal species. Topsoil mulching causes litter accumulation and eutrophication. Litter accumulation alters the light conditions, which leads

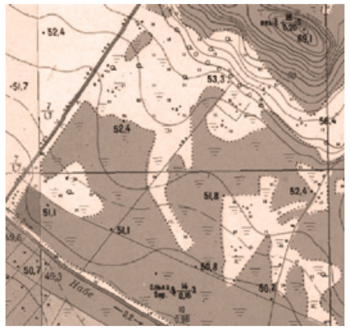

Fig. 15.14 Soviet military topographic map (1940s – 1960s).

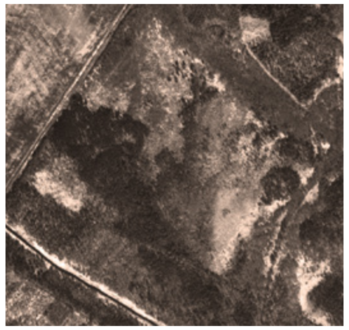

Fig. 15.14B. Orthophoto map (mid-1990s).

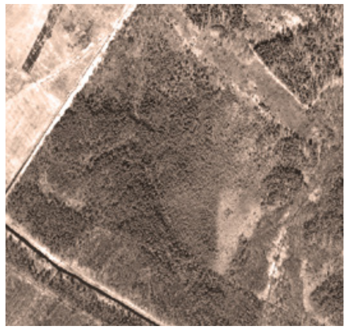

Fig. 15.14C. Orthophoto map (2008).

Fig. 15.14. Changes in the fen area in Elle Mire. The formerly open fen has overgrown with forest during the second half of the 20th century, most probably due to drainage. The largest drainage ditches still function, also draining the surrounding agricultural lands, whereas the small ditches have completely overgrown. In this and similar cases, a decision on the necessity of restoration can only be taken after a field survey. Prior to any actions, we should assess the biological value of the forest established in place of previously open fen and compare it to fen which could be restored by felling and other measures. Orthophoto image: © Latvian Geospatial Information Agency (1994–1995, 2013–2014).

to the local extinction of light-demanding vascular plant species, increase of the proportion of expansive plant species, and changes of moss species composition. Overall, eutrophication is among the most important factors leading to the degradation of fens.

In the past, traditional mowing with a scythe and use of horse vehicles affected the soil structure insignificantly. Hay transportation promoted the spread of the characteristic plant species. The use of tractors on peaty, waterlogged peat substrates creates deep tracks, damages the vegetation, thus changing its structure and mechanically destroys the invertebrates (mainly snails) dwelling in the upper layer of the soil, in mosses and litter.

Although the grazing practice in fens in Latvia is not well documented, at least a few examples show that grazing has been of low intensity. Most likely, the fens were grazed as part of larger areas where the animals were roaming across forests and other less productive pasture grounds as it happened, for example, near Lake Engure till approximately the 1980s (Rūsiņa u. c. 2013). In this way the fens have remained open, without overgrowing of trees and reeds (Laiviņš u. c. 2012; Rūsiņa u. c. 2013).

Low to moderate intensity grazing in alkaline fens mainly has a positive impact, for example, the diversity of micro-niches increases as well as the availability of light to small, light-demanding plant species (*Primula farinosa, Pinguicula vulgaris, Liparis loeselii, Carex scandinavica*, etc.). Grazing is effective in decreasing the amount of litter and control of shrubs and root suckers. Too intense grazing has an unfavourable impact by trampling the soil and causing damage to soil fauna (Cameron et al. 2003; Šefferová Stanová et al. 2008).

15.1.5.5 Beaver activity

Beavers can affect alkaline fens both favourably (blocking the drainage ditches and maintaining the optimal water level, thereby reducing or eliminating the impact of drainage) and unfavourably (creating a constantly high water level that may result in the formation of monodominant reed beds, thereby causing the disappearance of species characteristic to alkaline fens). Eutrophication of the standing waters in beaver ponds may cause irreversible changes unfavourable to the habitat. In most cases, the impact of beaver activities on alkaline fens is unfavourable or even destroys the habitat.

15.1.5.6 Impact of large wild mammals

Establishment of young trees in fens is to some extent limited by wild large herbivores (elk, deer), however one cannot fully rely on wild animals as "habitat managers". In some cases, they contribute to the maintenance of open landscapes (forest meadows, fens), however this is influenced both by the number of animals in the particular area, and food availability in the surrounding area.

Fens are often criss-crossed by animal trails. Animal trails in fens serve as suitable niches for small light-demanding plant species, particularly species of the early succession stages, e.g. *Liparis loeselii* (Roze et al. 2014), *Primula farinosa*, and *Pinguicula*

vulgaris. This is of particular importance in fens heavily overgrown with reeds and shrubs. Animal trails also promote the dispersal of certain plant species – in the trails there are usually open water "puddles", thus the plant propagules can spread by the trails until they reach suitable growing conditions, e.g. this spreading pathway is important for the rare, protected orchid species *Liparis loeselii* (Roze et al. 2013).

Sometimes in alkaline fens, so-called "mud baths" are created by wild boar. They also search for orchid tubers and although it does not have that much impact on the habitat as a whole, it does impact local populations of individual plant species.

15.1.5.7 Eutrophication

Natural eutrophication in fens is a result of succession, when the habitat is overgrowing and gradually transforming into a forest. During the course of succession, the biomass increases and the diversity of species decreases (Laiviņš u. c. 2012). In nutrient-poor, intact alkaline fens this process is very slow.

Eutrophication caused by human activities is among the most deteriorating factors of alkaline fens in Europe, especially in regions with intensive agriculture. It is caused by fertilisers (phosphorus, nitrogen, potassium). Nutrients can be brought to fens both with waters (run-off from agricultural lands) and with atmospheric deposition (McBride et al. 2011; Lamers et al. 2014). Eutrophication can significantly hinder the successful restoration of alkaline fens as too high nutrient availability completely changes the substrate conditions making it unsuitable for undisturbed fen species.

In alkaline fens in Latvia, the impact of intensive agriculture and atmospheric deposition is not considered a significant threat. Rarely, eutrophication of alkaline fens in floodplains could be caused by the inflow of streams rich in phosphorus and nitrogen compounds during spring floods. However, the accumulation of nutrients in alkaline fens also results from natural succession, as the organic matter gets decomposed. In the past, when many fens were grazed and mown, large volumes of biomass were removed. The accumulation of nutrients is also caused by the seasonal defoliation of deciduous trees and accumulation of litter. Usually eutrophication in alkaline fens results in the dominance of a few expansive plant species, most commonly *Molinia caerulea*, *Phragmites australis*, *Typha* spp., and *Glyceria maxima*, species with large biomass, which create large amounts of litter.

Fig. 15.15. A wooden dam made of planks in a rich fen in Germany. Photo: M. Priedēna.

Fig. 15.16. A dam made of a corrugated plastic wall in a rich fen in Lithuania. Photo: G. Eriņš.

15.1.5.8 Climate change

Climatic conditions with more or less favourable periods have played the most important role in the development of mires. In Europe, mires are considered to be among the most vulnerable habitat types, which might suffer due to current climate change

(Anon. 2012). In Northern Europe, the mean annual precipitation is increasing (Anon. 2011), creating favourable conditions for mire development. However, together with the rise of average temperature, increased evapotranspiration from the mire surface can be expected, promoting their desiccation. An increased average temperature would facilitate faster decomposition of the dead plant parts, decreasing the rate of peat accumulation (Silamiķele 2010), as well as enhancing the release of carbon dioxide into the atmosphere (van der Linden, van Geel 2006). Significant changes in mires may also be caused by the prolonged active vegetation period and reduction of precipitation in summer and autumn. Most probably, this will result in longer periods of drought and deficiency of moisture leading to the establishment of trees and overgrowth of mires with forest, as well as increased vulnerability to fires.

15.1.5.9 Invasive plant species

Invasive non-native plant species in alkaline fens in Latvia have rarely been found, and so far they have never been found there as dominating species. Generally, undisturbed alkaline fens are not susceptible to invasion by non-native species, however, similarly to expansive native plant species, the presence of invasive species indicates unfavourable impacts, most commonly, drainage.

Invasive plant species rarely found in alkaline fens in Latvia are woody plants *Aronia prunifolia*, *A. melanocarpa*, *Amelanchier spicata*, *Ligustrum vulgare*, and herbs *Solidago canadensis*, *Heracleum sosnowskyi*, and *Impatiens glandulifera*. In many post-harvested peatlands the invasive moss species *Campylopus introflexus* has been recorded.

15.2 Restoration and Management Objectives in the Conservation of Alkaline Fens

See the common objectives for all mire habitats (*Chapter 5.3*).

15.3 Restoration or Management of Alkaline Fens

15.3.1 Restoration of alkaline fens for the purpose of the guidelines

Restoration of alkaline fen habitats for the purpose of these guidelines means to restore and manage not only the areas where the habitat is already in a favourable condition or complies with at least the minimum criteria of this habitat type (Auniņa 2013f), but also the sites where it has been degraded or completely destroyed, however still with the capability of recovering. The least favourable sites include drained fens transformed into grasslands, post-harvested peatlands, and tufa extraction sites. So far in Latvia, little experience has been gained in the restoration and management of alkaline fen habitats. The recent restoration and management activities have mainly been related to the improvement of vegetation structure (clearing of trees and shrubs, mowing). In Latvia there is no experience in the targeted creation of alkaline fen habitats on "new substrates" in post-mining areas, thus the experience and examples given in this book are taken from sites, which have spontaneously recovered in the course of natural succession. The majority of the recommendations provided in these guidelines are taken from experiences in other countries, scientific studies, and observations in Latvia.

Prior to the restoration and management of alkaline fens, it is important to assess the current condition of the habitat, the main problems, their causes and to define the desired result. This can be done with a careful pre-inventory and identification of all potential obstacles. Only then can the appropriate methods be chosen, being aware of both their advantages and disadvantages. If the perfect condition cannot be achieved, alternatives should be evaluated and chosen (Fig. 15.13).

Fig. 15.17. A small boulder threshold in the stream, built to raise the water table in a fen in Brandenburg, Germany. Photo: A. Priede.

Sometimes due to irreversible changes in landscape settings, hydrology, soil and trophic conditions, the full restoration of alkaline fens is nearly impossible. However, if improvement of the ecosystem functions and species diversity is possible, restoration of semi-natural grasslands (most commonly the EU habitat type 6410 *Molinia meadows on calcareous, peaty or clayey-silt-laden soils*) is one of the alternative targets (Klimkowska et al. 2010b).

The recommendations provided for in the guidelines are also applicable to inter-dune slacks where alkaline fens have developed (Laime (ed.) 2017, *Chapter 16*).

15.3.2 Non-interference

In intact alkaline fens with no or an insignificant drainage impact, active management is almost never needed. In such areas it is important to ensure a non-interference regime and to prevent impacts unfavourable to fen habitat (*see Chapter 15.3.7*).

However, in some situations, the choice between non-intervention and active management is not unequivocal. For example, it is not always possible to determine the role of old ditches. They can be completely overgrown without any impact and they can still function, causing degradation of the habitat (an example is given in Fig. 15.14).

15.3.3 Rewetting

15.3.3.1 Basic principles of rewetting

Rewetting aims to restore the optimal water level in a fen as close as possible to the natural condition, which would be suitable for the recovery or persistence of the fen species complex. Although there is no strict definition of what the "optimal water level" is in an alkaline fen, we can consider that it is a condition, when the peat layer is saturated with water. The water level may fluctuate and drop slightly in seasons with low rainfall, however, in wet seasons the water level should reach the peat surface or be slightly above it.

Fig. 15.18. A beaver dam with a small pond established on a drainage ditch in a post-harvested fen. The raised water level creates favourable conditions for the recovery of mire vegetation. Sometimes, beaver activity in drained peatlands provides good results and it does not cost anything. Photo: L. Grīnberga.

Preparatory actions are an important step in rewetting, and they should include a careful field survey prior to choosing the most appropriate method. Experienced experts (a hydrologist or hydrogeologist, expert(s) on species and habitats) should be involved. The pre-restoration inventory should focus not only on habitats and species in the area, but also on the ditch network. It is important to understand the role of each ditch in the draining of a particular site, including their relation to the surroundings outside the target area. Local geological conditions and natural runoff directions should be carefully assessed. It is always useful to study the historical materials as far as it is possible (maps and other sources), e.g. historical area of fen, time of ditch excavation, etc.). This would help to set a realistic goal, taking into account the potential limitations and failures, and to achieve the best possible result in the particular situation. When setting targets to be reached in rewetting, it is not possible to generalise the situations as they can vary from site to site.

The drainage ditches are of different sizes, and they perform the draining function with different levels of efficiency; for example, larger ditches with visible water flow usually have a draining effect in an area wider than small size ditches. The density of the ditch network is also important. Draining is sometimes effectively performed by partly overgrown and clogged ditches. Sometimes the ditches have had a deteriorating effect a long time ago, but nowadays they are completely overgrown, while the drainage outcome (tree encroachment, degradation of ground vegetation) remains. A local draining impact can also be caused by deep tracks created by vehicles, as they function in a similar way to ditches.

The most commonly applied rewetting methods are the construction of dams on the ditches, and filling up of the ditches. Some other measures could be taken or supplement those abovementioned, e.g. construction of dykes, sluice systems, etc.

Fig. 15.19. The radial growth increment of a pine grown in an intact mire. Slowly growing "bog pines" in undisturbed and slightly drained mires have narrow annual growth rings. Photo: A. Priede.

Fig. 15.20. The annual growth rings of a pine from a drained mire are wider than those of intact mires. The variations in ring widths suggest changes in the hydrological conditions – most probably, the change from a small annual increment to a large one indicates the time of establishing drainage or perhaps a change in climate. Photo: A. Priede.

Prior to rewetting the legal requirements and potential limitations should be analysed, as well as the permitted and prohibited activities in the particular area, and the consents and permits required to perform the necessary actions (*see Chapter 6.3*).

There is not a universal recipe for rewetting of an alkaline fen. Therefore, it is always important to carry out careful planning to eliminate the potential failures, otherwise the habitat restoration may not achieve the goal or may be less efficient than expected. The best solution is the development of a detailed mire restoration plan, including detailed field inventory, risk analysis and alternatives of the methods to be applied. Such plans have been developed, for example, within the LIFE+ projects recently implemented in Latvia: "Forest habitat restoration within Gauja National Park" (FOR-REST, LIFE10 NAT/LV/000159) and "Restoring the hydrological regime of Ķemeri National Park" (HYDROPLAN, LIFE10 NAT/LV/000160).

Fig. 15.21. Old pines in an intact fen – characterised by curved shapes and rounded tops. Photo: A. Priede.

Fig. 15.22. Rapidly grown pines in a drained mire. They usually have pointed tops, upwards directed branches and large distances between the branch whorls. Photo: A. Priede.

Fig. 15.23. An alkaline fen on the shore of Lake Engure, partly overgrown with birches. The majority of birches are old and curved, which indicates their slow growth. The shapes of trees, their density (sparse cover), the vegetation composition (dominance of typical alkaline fen species), and absence of drainage ditches suggest that intervention by removing the trees is most probably not necessary. Photo: A. Priede.

Fig. 15.24. An alkaline fen overgrown with young birches and buckthorns on the shore of Lake Kaņieris. The density of the shrub stand, their rapid growth and the composition of ground vegetation (large proportion of *Molinia caerulea*) suggest that the overgrowing has taken place due to alteration of the water level. In this case, to maintain open mire, the removal of shrubs and re-current mowing of shoots is necessary. Photo: A. Priede.

Fig. 15.25. Due to overgrowing with shrubs, alkaline fen species are almost absent in the ground vegetation, though some patches have survived in the shaded conditions. Since the moisture conditions are still suitable for the recovery of an open fen and the fen plant species, it is worth removing the tree cover and applying regular management measures (mowing or grazing). Photo: A. Priede.

Fig. 15.26. In fens overgrown a long time ago, the recovery of open mire is only possible if the conditions characteristic for the mire are re-created and maintained. To restore an open alkaline fen in such areas, the tree layer should be cleared and mowing and/or low intensity grazing introduced. Reintroduction of the target species may be necessary. Photo: A. Priede.

15.3.3.1 Filling up of ditches

Filling up of ditches is the most efficient, though relatively expensive method of drainage elimination. Usually it is more efficient than dams (*see Chapter 15.3.3.2*) as it eliminates the drainage effects, and there is no need for regular control of dams and repair of damage, especially of wooden dams (*see Chapter 10.3.3*). Ditches can be filled up completely or partially (some sections). The selection of method is determined both by the specific conditions of the area (e.g. availability of material to fill up the ditches, most commonly the berm) and available funding. For more on the filling up of ditches *see Chapter 10.3.3.2*.

Fig. 15.27. *Lonicera caerulea* ssp. *pallasii* – a rare woody species characteristic for alkaline fens. Photo: A. Priede.

Fig. 15.28. *Myrica gale* – rather common species in alkaline fens of the Coastal Lowland in Latvia, though extremely rare in the rest of the country. Photo: A. Priede.

15.3.3.2 Construction of dams on ditches

Construction of dams on drainage ditches in mires is a well-known method, however so far it is more often used in raised bogs than in fens. In Latvia, dams have been built in many raised bogs, however up to now there have not been any trials to block the drainage system in alkaline fens. For more on the dams, *see Chapter 10.3.3*.

Different materials can be used for the building of dams – wooden dams (Fig. 15.15) made of the logs of the trees cut on site, planks, plywood, often supplemented with waterproof or slightly permeable materials (plastic membranes, sphagnum mosses), plastic dams (corrugated walls) (Fig. 15.16), and other materials.

In most cases, the surface of alkaline fens, except for the spring-fed fens on slopes, is flat or depressional. Therefore, in comparison to the dome-shaped raised bogs, a smaller number of dams are necessary to raise the water level (Nusbaums 2008). It must be ensured that when raising the water level, acidic, dystrophic waters do not enter the alkaline fen as this may completely change the environment, which would transform the growing conditions making them unsuitable for alkaline fen species (Rehell et al. 2014).

The dams must be as durable as possible so that no repair, at least no frequent repair, is needed. It is important that the dams are impermeable and efficient in blocking the water flow. When building the dams, it is important to check during the first years whether the dams are eroded or washed out, thus becoming incapable of maintaining the desired water level upstream from the dam. If the rise in water level upstream of the dam after building it is not sufficient, a mistake was most probably made in their construction, or the dams are located in inappropriate places.

When planning the location of dams on ditches, the type of ditch must also be considered. The fact of whether the bottom of the ditches reaches the mineral ground or it is excavated in the peat layer is important. The ditches that have been excavated in the mineral ground, especially in the highly permeable sand sediments, can cause an impact on relatively wide surroundings (Rehell et al. 2014). Ditches that have been excavated in the peat layer have an impact on a smaller area than those dug in the mineral ground. If the mineral ground is exposed in the ditch bottom, water seeping below the dams can be expected, and then the raising of the groundwater table upstream of the dam will be unsuccessful. In such cases, the outcome of ditch blocking is difficult to predict. Groundwater table may rise in a larger area than planned, or it may only rise gradually over several years (Rehell et al. 2014). Therefore, rewetting can be more successful in areas where ditches are excavated in the peat layer, not reaching the mineral ground. In fens it is usually better to fill up and block the ditches gradually over several years, constantly monitoring the outcome and applying corrective measures if necessary.

Prior to dam construction, trees along the ditches must be removed. Trees along the ditches are always a result of drainage, so there is no need to preserve them in terms of mire restoration. In sites where it is planned to use an excavator or other machines, access should be ensured, and usually the use of heavy vehicles is not possible without the re-

For more about the different types of dams, their advantages and disadvantages *see Chapter 10.3.3.4*.
Extensive experience in mire restoration has been accumulated in Finland: Similä et al. (ed.) (2014), http://julkaisut.metsa.fi/julkaisut/show/1733.

moval of trees (Vestarinen et al. 2014).

When filling up the ditches or building the dams, there are often no berms along the ditches so that the peat for infilling or building dams must be taken from the surface of the surrounding area. It can be taken from the surface from a larger area around the ditch or in a concentrated way from a small patch. It is important not to dig up peat in a continuous mass parallel to the ditch to be infilled, since this would function as a new ditch (Vestarinen et al. 2014). When taking the peat from the surface, shallow depressions with water or small ponds are created that are later suitable for plant pioneer communities, amphibians, benthic invertebrates, and in some cases they can also attract birds. Diversification of the micro-relief in intact fens is not usually necessary, however, these artificial depressions in fen restoration areas have a favourable impact on species diversity.

15.3.3.3. Stone weirs, thresholds and sluices on the watercourses

In the drained floodplain fens the groundwater table can be raised by building stone weirs, thresholds or sluices on the straightened streams (Fig. 15.17). The simplest solution is the establishment of thresholds. The complexity of construction depends on the ground composition and permeability. In permeable soils (sand, gravel), under the threshold, a waterproof “shield” is most likely necessary.

The disadvantage of sluices is that they sometimes require guarding so that they are not damaged intentionally, which in turn means additional costs. Additional costs may also arise due to the provision of automatic regulation of the sluices and electricity supply. Thresholds and sluices to raise the water table are also used in the restoration of grassland habitats – *see also* Rūsiņa (ed.) 2017, *Chapter 21.6.8*.

15.3.4 Ensuring the Optimal Water Level in Lakes

Alkaline fens on lakeshores can be unfavourably affected by lake water level changes. Lowering of the water level may occur in lakes that are regulated with a sluice. In cases when the water level is lowered for a longer time, the surrounding ecosystems can adapt to the new hydrological situation. Therefore prior to restoring a water level favourable to alkaline fens, a comprehensive assessment of the overall situation must be carried out taking into account the following aspects – how the rise in water level may affect other habitats and related species, and the adjacent agricultural lands, forests, human settlements. This is of particular importance in sites outside protected nature areas or close to the borders of protected nature areas.

Table 15.1. Advantages and disadvantages of various timings of tree and shrub removal.

Method	Advantages	Disadvantages
Felling of trees and clearing of shrubs in late autumn and winter (from October to the end of February) in frost conditions	Work performance is easier after the growing season, especially in frost conditions. No disturbance to birds (no actions during the breeding season). No trampling during the non-frost season when the ground and soil fauna is vulnerable to disturbances.	Difficult work conditions if there is a lot of snow and/or if the mire is very wet in autumn. If there is a thick layer of snow during felling, residual stumps may be too high and encumber further management.
Felling of trees and clearing of shrubs in late summer and autumn (August to November)	Less intense re-sprouting of deciduous trees can be expected in the next year. No disturbance to birds (no actions during the breeding season).	Trampling of the ground cover, including causing of an adverse impact on the soil and grass-dwelling invertebrates.
Felling of trees and clearing of shrubs in spring-summer (April to August)	Felling of trees and shrubs in spring does not have any advantage from either an ecological or practical point of view.	If deciduous trees are felled in spring, their shoots regrow more intensively than if felled in autumn. Adverse impact on breeding birds, causing a disturbance or destroying the nests.

If due to any reason the lake level is lowered to an extent that causes degradation of an alkaline fen, e.g. overgrowing by shrubs, extinction of typical plant species, expansion of *Molinia caerulea*, etc., then the only way to prevent the further deterioration of fen habitat is restoration of the previous water level, additionally restoring the habitat by the felling of trees and shrubs.

15.3.5 Prevention of Unfavourable Effects on Springs

In spring-fed alkaline fens, it is essential to prevent the activities that may change the spring capacity or lower the groundwater table, thereby increasing the risk of drying up of springs. In the case of the spring drying up, the changes in the fen habitat are irreversible, and the habitat cannot be restored (*see Chapter 13.3.3*).

15.3.6 Maintenance and Control of Beaver Dams

Beaver dams can cause significant changes to the water level in streams, ditches and stagnant waters in the hydrologically related areas adjacent to the fen. A permanently raised water level due to beaver activity can create an unfavourable impact on an alkaline fen and lead to its transformation into a monodominant reed bed or eutrophic ponds. Rarely, the impact of beaver dams on a fen can be favourable, for example, in drained mires, by maintaining an elevated water level in ditches (Fig. 15.18).

In most cases, the beaver population can be limited by hunting and re-current demolition of the beaver dams. The installation of tubes under the dams is effective, decreasing the beavers' eagerness to repair the dam. The end of the tube upstream of the dam must be at least 1.5 m long, otherwise the

Fig. 15.29. The contact zone of an alkaline fen and forest. Though the area is heavily overgrown, calciphilous fen species can still be found in the ground vegetation. By clearing trees and shrubs, as well as after mowing the herbaceous layer several years in a row, an open fen can be successfully restored, achieving the return of the target species. Photo: A. Priede.

Fig. 15.30. A recently cleared heavily overgrown forest edge bordering an open fen. The uneven micro-relief with hummocks dominated by mosses and the wetness of substrate suggest that the vegetation characteristic for an alkaline fen may recover within several years. The removal of trees decreases the evapotranspiration, thus the substrate wetness leads to the reduced establishment of young trees and suppresses the regrowth of shoots. However, the recovery of an open fen is only possible if shoots are regularly removed. Photo: A. Priede.

Fig. 15.31. *Rhytidiadelphus triquetrus*. Photo: A. Priede

Fig. 15.32. *Dicranum polysetum*. Photo: A. Priede

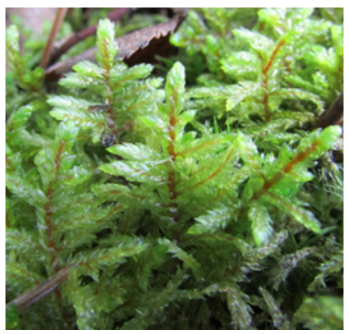

Fig. 15.33. *Pleurozium schreberi*. Photo: A. Priede

beaver can block it. Downstream of the dam the tube may be shorter.

15.3.7 Removal of Trees and Shrubs

15.3.7.1 Is the removal of trees and shrubs really necessary?

Rapid overgrowing of trees and shrubs in alkaline fens indicates the impact of drainage. In partly drained fens, some wetter patches, mostly lower depressions, usually remain treeless (Laiviņš u. c. 2012), whereas the fen margins and the vicinity of ditches are often densely covered by trees. Overgrowing promotes further fen degradation because there is increased evapotranspiration, which intensifies the drainage impact. Removal of trees and shrubs helps not only to increase the open fen area and to improve the light conditions in the ground cover, but it also reduces the loss of water evaporated through the tree leaves. After removing the trees, similarly to the forest clear-cuts, the substrate may become wetter, and the conditions in the fen habitat should more or less improve.

The stages of overgrowing can be well detected in the orthophoto images taken in different years. The time of establishing the drainage system can usually be determined on the annual growth rings of the trees – after the excavation of ditches, the growth of the trees increases rapidly, especially near the ditches (Fig. 15.19, 15.20). The pattern of the growth rings of the old pines in fens keeps records of the changes in substrate wetness, which in turn has been caused by climate change and/or human-caused alterations in the hydrological regime.

The old, slowly grown "bog pines" can usually be identified by rounded tops and curved branches (Fig. 15.21). In contrast, rapidly grown trees influenced by drainage are characterised by a large distance between the branch whorls and pointed crowns (Fig. 15.22). However, in a mire it cannot always be visually estimated. It can be verified by felling some trees typical for the area and counting the annual growth rings, or obtaining samples of the growth rings with an increment borer from at least some typical trees. Similarly, the approximate age and growth history can be detected for other species (birches, black alder).

When planning the restoration of alkaline fens, it must first be assessed whether the clearing of trees and shrubs is necessary. Trees and shrubs may also be present in intact fens, therefore in every situation we should assess whether they are "natural" or established after drainage. Many situations can be

Fig. 15.34. A recently ring-barked birch. Photo: A. Priede.

Fig. 15.35. A birch some years after ring-barking – the tree has gradually died without developing stem shoots. Photo: A. Priede.

confusing, however, every area must be assessed individually, and it is not possible to provide universal recommendations. In Fig. 15.23–15.26 some examples suggest the way of how to assess the necessity of tree felling and removal of shrubs.

Clearing of trees and shrubs can provide good results in the restoration of alkaline fens, if a fen is not completely overgrown and if alkaline fen plant species are still present in the ground vegetation. Since drainage is the main reason for the establishment of dense tree and shrub stands, in the long term fen recovery is not possible without blocking the drainage system. Removal of trees will also reduce the evapotranspiration rate, thus diminishing the loss of water.

It is advisable to remove all the deciduous trees, thus creating an open area. In the first year after cutting, intense re-sprouting may be expected, sometimes the young shoots form dense stands which are even denser than before clearing the trees and shrubs. Removal of woody species must always be planned as a re-current action, otherwise tree cutting is useless, especially in drained fens. Old coniferous trees, especially pines and junipers – individual trees or clusters – should be preserved as they can be important micro-habitats for numerous invertebrate species, especially beetles. In areas with lots of junipers with low vitality, only the viable and healthy individuals must be preserved. In Latvia, alkaline fens are among the few habitat types suitable for the rare woody species *Lonicera caerulea* ssp. *pallasii* (Fig. 15.27), thus it is advisable to preserve some vigorous shrubs, while old shrubs with low vitality can be removed. Usually they recover from stump shoots, developing young, vital shrubs.

In alkaline fens in the coastal areas in western Latvia, *Myrica gale* (Fig. 15.28) is rather common, while being almost absent in the rest of the country. Usually it forms dense stands in alkaline fens, fen meadows and overgrown, abandoned *Molinion* meadows. Since *Myrica gale* is included in the protected species list in Latvia, management of its localities has always been challenging. In some site management plans and recommendations it is advised not to cut *Myrica gale* in order to preserve it, i.e., to apply selective mowing. However, when restoring the fen, the preservation of all *Myrica gale* stands and restoring species-rich vegetation at the same time is not possible as the open fen and *Myrica gale* stands are actually different succession stages of the same vegetation type. Recent management examples in Ķemeri National Park suggest that *Myrica gale* successfully recovers after mowing. In old stands the shrub vitality decreases, as well as the diversity of other plants declines due to the dominance of *Myrica gale*. If mowing is planned in a fen, it is advisable to also mow *Myrica gale* stands and only preserve a few stands with vigorous plants, thus ensuring the patchiness that is important for the diversity of vegetation and insects.

In the drained alkaline fens overgrown with forest, it must be additionally assessed whether rewetting is necessary, and if it is feasible. If possible, the activities must be planned and performed together and sequentially: first the trees must be removed and then, as soon as possible, actions targeted at rewetting must be performed. However, there may be situations when the ditches are overgrown, and the fen has naturally become wetter, and transformed into a swamp forest or bog woodland during the course of succession (an example is given in Fig. 15.14). In such situations a decision must be based on the priorities at a national scale. Since alkaline fen is a very rare habitat throughout the country and not common in the entire region, the priority will most likely be the restoration of open fens.

Legal requirements

When planning tree felling and shrub cutting, first the binding regulatory enactments, permitted and prohibited activities in the particular area, as well as agreements and permits that are required to perform the works, must be studied. Prior to the felling of trees in alkaline fen habitats, the below mentioned issues must be taken into account.

- Find out what the land use type is in the State Forest Register.

In forest lands, a permit of the responsible authority is required for deforestation aimed at restoring protected non-forest habitats.

- Find out when it is allowed to perform the forestry activities, including the felling of trees and shrubs to restore fens, and removal of timber. Forestry activities in protected nature territories are usually not allowed during the bird breeding season from 15 March to 31 July. In micro-reserves and their buffer zones, regulations defining the protection regime in the micro-reserves should be followed. For some species, the breeding season starts earlier, therefore the requirements of each micro-reserve might vary according to the needs of the species for which the micro-reserve has been established. *See also Chapter 6.3.*

15.3.7.2 Methods of tree felling and shrub cutting in alkaline fens

In alkaline fens, the most appropriate method of felling involves using chainsaws and brushcutters, firstly as they cause almost no undesirable side-effects (e.g. no tracks created by heavy vehicles, no severe damage to the ground), and, secondly, due to difficult work conditions, which in most cases do not allow the use of any machinery. Manual work is overall more "habitat-friendly".

15.3.7.3 Optimal time for tree and shrub removal

When planning the felling time, various factors must be taken into account: efficiency (for deciduous trees – intensity of shoot development), potential impact on the ground cover, potential impact on other groups of organisms (especially birds during the breeding season), as well as practical considerations (Table 15.1). Development of shoots is usually less intense if trees are felled in the second half of summer (August), when it is also acceptable in relation to the bird breeding period.

15.3.7.4 Determining the area to be cleared

Prior to the felling of trees and clearing of shrubs in heavily overgrown areas, the borders of the area to be cleared must be set. The transitional zones between the fen and forest are often gradual, and the habitat types merge into each other. However, when planning tree felling for fen restoration, the borders must be marked. By cutting a part of the forest edge, the open fen cannot usually be restored if the moisture conditions in this zone are not characteristic for fen.

The approximate borders of the fen to be restored should be first identified on maps and aerial images of different periods and then in the field. To assess the restorability of fen, it is important to evaluate the composition of the ground vegetation. The character of the micro-relief and presence of typical calciphilous fen species, especially brown mosses, indicate whether the recovery of fen can be expected (Fig. 15.29, 15.30). If growth conditions on the forest edges are too dry for most of the fen species, the micro-relief is formed by *Molinia caerulea* tussocks, and mosses of dry coniferous forests dominate, e.g. *Rhytidiadelphus triquetrus* (Fig. 15.31), *Dicranum* spp. (Fig. 15.32), *Pleurozium schreberi* (Fig. 15.33), then the recovery of fen vegetation may not be expected due to too dry substrate. In such sites, intense development of shoots will occur after felling.

Table 15.2. Some indicators that can be used when assessing the necessity for mowing.

Is mowing necessary?	
Most probably, mowing is necessary	**Most probably, mowing is not necessary**
• The ground is not very wet and swampy. • The fen is young, with a thin peat layer. • There are drainage ditches in the fen or nearby. • The groundwater table has well-pronounced fluctuations; in summer the fen is dry. • There is a dense shrub cover and plenty of young trees; the woody species have rapidly established within a short time. • There is a great proportion of expansive species (abundant Molinia caerulea, forming tall tussocks). • Thick litter layer, formed mainly by *Molinia caerulea*. • Abundant rapidly spreading reeds suppressing smaller light-demanding plants. • The area was traditionally managed by mowing or grazing.	• The fen is very wet and swampy, part of the area may be covered with water in seasons with high rainfall. • The area is treeless or the tree cover is sparse, dominated by old, crooked trees. • Rapid overgrowing with shrubs does not take place, or there are few shrubs. • Few expansive species (*Molinia caerulea, Phragmites australis*), they can be found in the fen, but not as dominating species. • No explicit layer of litter, formed by *Molinia caerulea*. • The fen has never been mown or grazed or it has been done a very long time ago, no signs of mowing or grazing have survived until nowadays.

Fig. 15.36. An intact alkaline fen with dominance of *Phragmites australis* (Niedrulieķņa Fen in Ķemeri National Park). Reed stands develop in the course of natural succession. To reestablish species-richer communities, the removal of shrubs and trees and re-current mowing is necessary. Photo: A. Priede.

Fig. 15.37. An intact alkaline fen where mowing or other type of human interference is not necessary (Zaļais Mire in Ķemeri National Park). Photo: A. Priede.

Fig. 15.38. An alkaline fen on the shore of Lake Engure that was traditionally grazed or mown. Over recent decades, mowing and grazing was ceased leading to overgrowing with shrubs and expansion of reeds. Establishment of forest communities might be expected within a few decades. In this and similar situations, in order to preserve an open fen, both the removal of shrubs and re-current mowing are necessary. Photo: A. Priede.

Fig. 15.39. An alkaline fen with a small proportion of reeds. Common reed *Phragmites australis* is not always a "wrong" species in alkaline fens. The proportion of reeds, the changes of cover over the years and the possible reasons for their expansion must be taken into account. If their abundance does not change over a long time, mowing is most probably not necessary. On the contrary, if the proportion of reeds increases, mowing is most likely needed to maintain the species diversity. Photo: A. Priede.

15.3.7.5 Gathering of the felled trees and shrubs

The felled trees and shrubs must be collected to prevent the accumulation of extra nutrients in the substrate. If logs and shrubs are not gathered, they can significantly encumber further management of the restored fen. It is best to remove the cut material out of the area and, for example, use it for woodchips or firewood. If any machines should be brought into the mire, it must be done in winter in frost conditions to avoid damage to the ground and not create deep tracks that may further function as drainage ditches.

In cases when the amount of wood is small or the wood material cannot be removed from the area due to difficult access, the felled trees and shrubs can be gathered in piles and burnt on site. The shrubs cut in winter must be collected immediately after cutting so that they do not remain frozen until spring. The burning sites must not be located on the protected plant stands or in the most species-rich habitat patches. This is of particular importance in small fens. It is best to burn the material closer to the edges of the fen, which is usually of lower quality in terms of habitat representativity. The number of burning places should be as low as possible so that the burning affects as small an area as possible. Burning places can be located on the stumps of cut shrubs, especially willows, to reduce re-sprouting. Burning of felling residues usually creates a short-term impact, fire places completely overgrow within several years, without significantly affecting the habitat. Some smaller piles of felling residues can be left on forest edges, where they will serve as shelters and hibernation places for amphibians, small mammals and invertebrates.

It is desirable to leave some large size snags (standing dead trees and trunks), as well as coarse woody debris that serve as a micro-habitat for mosses, fungi, insects and snails, sometimes as a feeding habitat for woodpeckers. Usually there are very few large size dead trees in alkaline fens, so they do not encumber the further management of the habitat.

15.3.7.6 Removal of shoots and advance growth

After felling deciduous trees and shrubs, stump shoots appear in the following years. To reduce regrowth, practitioners advise felling in late summer and autumn at the end of the vegetation season (end of August, September) and to follow the moon phases, selecting the third quarter. If trees are cut in spring, their shoots grow more intensively.

Re-current mowing of shoots. The growth intensity of shoots usually reduces within 2–3 years after first removal. However, in order to have good results re-current removal of the shoots and advance growth is always necessary in the cleared areas, if regular mowing does not take place there.

Promotion of stump decay. It is advisable to fell larger deciduous trees (birches, black alders) so that the stump remains as low as possible and does not encumber management in the forthcoming years. To promote its faster decay by saprophytic fungi, the stump should be cross-notched or drilled in several places.

Fig. 15.40. Tussocks of *Molinia caerulea* and stumps of felled trees encumber mowing. Photo: A. Priede.

Mulching of topsoil and stumps (*see Chapter 15.3.8.*) is an effective measure for the restoring of heavily overgrown drained fens and fen meadows to prevent rapid re-growth of shoots. It cannot be used in very wet areas (deep tracks, damaged soil and ground vegetation). In some cases it can be applied in frost conditions in slightly drained fens. Mulching cannot be used as a regular management method, especially in areas where rare snail species are present in the substrate, except for some heavily overgrown patches. It means that selective mulching may be applied in some patches with stumps of felled trees and shrubs, perhaps also patches heavily overgrown with reeds, whereas the patches with species-rich typical vegetation should be left untouched (*see Chapter 15.3.8.4*).

Ring-barking (girdling) of deciduous trees. Ring-barking of deciduous trees is used in the restoration of various habitats as an alternative for felling, usually in areas without a dense cover of trees (if there are not many trees or they are felled selectively). Ring-barking can be carried out with an axe, drawknife or motor saw by removing a strip of bark from around the entire circumference of the tree trunk. The strip should be at least 20–30 cm wide and 2–3 cm deep, but practically it depends on the size of the tree (Fig. 15.34, 15.35). In this way slow withering of the tree can be achieved, shoots do not develop or their density is reduced. The dead tree can be removed after several years or the dead wood can be left on site. It is better to perform ring-barking in spring during the time of sap circulation. Ring-barking in autumn has a lower efficiency and more intense development of young shoots may be expected. There is no need to ring-bark the coniferous trees, as it is sometimes done in forests to increase the volume of dead wood and related species diversity. In mires, ring-barking should solely be used as a measure to prevent the development of young shoots.

Grazing. Shoots developed after the removal of shrubs are efficiently reduced by grazing (especially by horses and goats). To avoid too intense trampling (*see also Chapter 13.3.7*), which would damage the ground vegetation and soil fauna, only seasonal pasturing should be performed – the animals should be brought to the area during the autumn-winter period, if the topsoil is frozen (*see Chapter 15.3.9*).

Covering with mulch or black plastic sheeting. To reduce the re-growth of woody plants after cutting, covering of stumps with mulch (straw or hay) can be performed. In Latvia there is no such experience, however such attempts have been made, for example, in Switzerland (Suter et al. 2006). Stumps of the cut shrubs should be covered with black plastic sheeting or mulch in spring (April, May), kept throughout the summer, and removed afterwards. The applied mulch must also be gathered, otherwise

Fig. 15.41. A crawler tractor equipped with a mulcher. Photo: A. Liepa.

Fig. 15.42. Topsoil mulched in winter after the removal of a dense shrub cover in fen meadow. In Ķemeri National Park, this method has proved its efficiency in suppressing stump shoots and reeds. Photo: A. Liepa.

Fig. 15.43. The tussock micro-relief in an area treated with a mulcher (on the left) and left without mulching (on the right). Mulching is effective in decreasing the proportion of *Molinia caerulea* tussocks in larger areas, making mowing easier. Photo: A. Priede.

Fig. 15.44. A fen meadow half a year after mulching. First, the trees and shrubs were removed (by brush-cutter and motor saw) and gathered by hand. In the following winter, mulching was performed. Photo: A. Priede.

it adversely increases the amount of nutrients in the soil. If the plastic sheeting is used, it must always be fixed at the edges, taking into account the possible damage by wild animals. However, the method can only be used in the places where shrub clusters have been cut. It cannot be used in cases if a large homogenous area has been cleared.

Weeding and cutting the young trees. This method has been widely used, also by involving volunteers. The method is simple and can be implemented without a brush-cutter or a motor saw. Various types of pruning shears may be used, but the work efficiency is higher with pruning shears with long handles. Although the method is relatively time consuming, it is more efficient in destroying the young trees than, for example, the use of a brush-cutter. Use of a brush-cutter in alkaline fens is often complicated because of tussocks, due to which the shrubs are usually cut too high above the root collar. Similarly to weeding, young trees (especially conifers, which do not develop shoots) can be cut below the lowest branch whorl that ensures that lateral branches do not develop. The cut and pulled out trees must be gathered and burnt.

Use of herbicides in alkaline fens is not advisable, especially close to water bodies, due to the high

Fig. 15.45. Triple-wheeled tractor can be used for mowing in wet meadows and alkaline fens overgrown with reeds. The photo is taken in a heavily overgrown floodplain meadow in Latvia with similar conditions as in overgrown fens. Photo: A. Liepa.

risk of pollution, endangering the invertebrate fauna and also destroying other vegetation, including rare plant species. The studies on the use of glyphosate-containing herbicides (Roundup) in alkaline fens after the clearing of shrubs has proven that its efficiency in the eradication of the young woody shoots is not much higher than re-current mowing 2–3 times during the vegetation season 2–3 years in a row. In a study in the fens in Poland (Klimkowska et al. 2010) it has been proven that the use of Roundup (applying the herbicide on leaves of shoots) is efficient, when combined with mowing, while only use of Roundup does not provide the desired result. Since there are no convincing arguments for the significant advantage of herbicide use over mowing of shoots, the herbicides may only be used in exceptional cases, for example, when treating the stumps of individual deciduous trees or injecting the herbicides into the trunk, thus achieving gradual withering of trees without developing shoots.

15.3.8 Mowing, Removal of Tussocks, and Mulching

15.3.8.1 Is mowing always necessary in alkaline fens?

Mowing in the fen helps reduce the proportion of expansive plant species, improves the light conditions in the ground cover, increases the proportion of habitat-specific species and the presence of rare species, as well as reduces the establishment of trees and shrubs. In intact fens mowing is usually not necessary as they can persist without human intervention. Mowing is rather a measure to restore or improve the vegetation structure in drained fens or preserve a specific species composition, for example, rare plant species. Actually it is an attempt to keep the fen in a certain development stage related to a specific species composition. During their development, mires go through different succession stages, also ones that are "wrong" from the point of view of a "perfectly" preserved habitat in terms of the habitat identification manuals; for example, when reeds prevail in the vegetation or when the fen has naturally transformed into forest. Therefore, we cannot select a universal management method, which would suit all alkaline fens. Mowing is a useful management method, however it is not required in all mires, even if they are dominated by reeds.

Usually in fens, if the clearing of shrubs is necessary to restore an open area, mowing should also be performed, and vice versa. Re-current management, in most cases mowing, is usually required in so-called fen meadows – in fens moderately drained a long time ago and traditionally used for haymaking. Due to the extensive human impact, species-rich communities, which depend on regular management, have developed.

When assessing the necessity to eradicate the expansive species in the particular fen area, their presence and role should not be misunderstood. The most frequent expansive plant species – *Molinia caerulea* and *Phragmites australis* – are typical species of alkaline fens, and they should not be completely eradicated. Each specific situation must be thoroughly analysed taking into account the causes and the consequences. The dominance of *Molinia caerulea* may be linked with human-caused alteration in the hydrological regime, whereas the dominance of *Phragmites australis* – with beaver activity as the fen becomes wetter. However, as they are common native species in alkaline fens, we should not generalise and misinterpret these species. In each case we should decide whether they can be considered to be expansive in the particular area and whether their control is necessary.

Similarly to semi-natural grasslands, re-current mowing in alkaline fens increases the plant species diversity. This also has a favourable impact on the insect species that are inter-related to plant diversity and in many cases depend on certain plant species. For example, the rarely found *Euphydryas aurinia* feeds only on *Succissa pratensis* in Latvia, thus if due to the overgrowing of the fen or meadow *Succissa pratensis* disappears, then *Euphydryas aurinia* will also vanish.

The basic features and some examples that allow one to define whether mowing is necessary, have been summarised in Table 15.2 and Fig. 15.36–15.39, however the decisions must always be made by taking into account the specific character of the particular area, its management history, current conservation status, etc.

15.3.8.2 Practical considerations when planning mowing

When planning the works, the difficult mowing conditions (tall tussocks, dense layer of plant litter) a greater investment of time and energy is always necessary than in the management of, for example, a wet meadow. In Latvia, most alkaline fens cannot be accessed by roads, or, if the roads have once been there, they are overgrown and are not usable for vehicles. When reinstating regular management in formerly mown fens, the first task is the provision of access. It is necessary in order to collect the felled trees and hay from the management area, and transport heavy tools. In order to build or renovate the access roads, coordination with several owners of the neighbouring lands and the responsible authorities is usually necessary. Also, felling of trees and gathering of the fallen trees, as well as the improvement of the road surface need coordination and agreement among several land owners or responsible authorities. Moreover, the renovation of access roads should not impair the hydrological conditions of the fens and/or other wetland habitats.

15.3.8.3 Is the removal of tussocks necessary?

Tussocks form a mire-specific micro-relief, thus they should not be considered as "wrong" in alkaline fens. They usually occur in traditionally managed, slightly drained fen meadows, which have been abandoned for a long time. In alkaline fens, tussocks are most commonly formed by *Molinia caerulea*, rarely – *C. elata* or other sedge and graminoid species. A great proportion of *Molinia caerulea* forming tall tussocks indicates the degradation of the fen – most commonly, the impact of drainage, long-term abandonment and unfavourable impact of burning (Jacquelyn et al. 2005).

The tussocks increase the diversity of micro-niches (Truus et al. 2008; Edgar et al. 2010), which is of particular importance for small, highly specialised organisms – mosses, soil and grass-dwelling invertebrates, and reptiles. The tussocks are not a problem themselves, however, their abundance might encumber mowing (Fig. 15.40; *see Chapter 15.3.8.4*), especially in sites, which due to difficult work conditions should be mown manually. Tussocks should not be removed in all cases and throughout the area to be restored. Reduction of the tussocks is necessary to the extent where they no longer significantly hamper mowing.

Fig. 15.46. The amount of fresh aboveground biomass in a 25 m² sample plot in an overgrowing fen after long-term abandonment. Photo: A. Priede.

Fig. 15.47. Raked litter and fresh biomass in an overgrowing fen after long-term abandonment. A large amount of litter is left on the ground, and complete gathering by raking is practically impossible. Photo: A. Priede.

Fig. 15.48. Gathering of hay in an alkaline fen at Lake Kaņieris in July 2015. Photo: I. Lazda.

Removal of tussocks slightly lowers the mire surface, resulting in wetter substrate conditions. Various methods for reducing the proportion of tussocks and height practised so far cannot be assessed unequivocally. Some methods are not very efficient, too labour consuming or have a degrading impact on the ground vegetation and the soil fauna. Thus prior to the restoration of the habitat, the following aspects must be assessed.

- Do tussocks significantly encumber mowing? If it is planned to use a tractor, the proportion and height of the tussocks will probably decrease if mown several years in a row, and special measures are not necessary.
- Are there rare snail species and/or other invertebrates in the topsoil and layer of litter and mosses? An expert must be involved in the assessment of soil fauna. In sites where rare invertebrate species are found, topsoil mulching can have a deteriorating effect, therefore it should not be performed.

Fig. 15.49. Burning of the mown biomass (hay, branches) is not the best option, however, if the removal of hay is not possible, burning is one of the solutions. Precautionary measures must always be taken to prevent uncontrolled fires. Photo: A. Priede.

15.3.8.4 Mulching

Mulching of topsoil and stumps of shrubs and trees (Fig. 15.41, 15.42) should only be used in restoring heavily overgrown fen meadows with lots of tall tussocks if it is decided to remove them. Mulching is an efficient method in smoothing the land surface to make it suited to regular mowing or pasturing, which helps to suppress the regrowth of cleared shrubs and reeds. In alkaline fens this method cannot be

Table 15.3. Comparison of various mowing methods.

Method	Advantages	Disadvantages
Manual mowing, gathering of hay and removal from the area **The most appropriate method!**	Ensures the dissemination of seeds of typical fen plant species. Improves the light conditions, which is of particular importance for small, light-demanding plant species. Prevents eutrophication due to the accumulation of biomass. Creates small-scale substrate disturbances, suitable for the germination and survival of small light-demanding pioneer plant species (small-sedges, *Primula farinosa, Pinguicula vulgaris, Liparis loeselii*, etc.). Gathering of the dry hay leaves the smallest impact on the grass-dwelling invertebrates and soil fauna.	High costs. Large investment of time and labour. Removal of hay from the area may be practically difficult or even impossible (no access roads, marshy ground).
Selective mowing and/or selective gathering (in selected patches)	In patches where the mown grass or hay is gathered and removed, the conditions for enhanced vegetation diversity are created (the biomass forming the litter is removed, eutrophication effect reduces, the light conditions improve). Greater chance for the small invertebrates to escape, especially the snails residing in the litter (mowing and gathering of hay does not affect all of the area at once).	In the patches where the fresh biomass or hay is not gathered, the amount of litter increases, eutrophication occurs, and the light conditions deteriorate. In the unmown and/or ungathered sections of the fen, the vegetation diversity declines, also causing simplification of grass-dwelling and soil fauna.

Table 15.3 continued

Gathering of the grass immediately after mowing	The amount of nutrients decrease. Small-scale substrate disturbances (bare peat patches) are created, suitable for the pioneer species (small-sedges, *Primula farinosa, Pinguicula vulgaris*, etc.). In the long term, mowing with hay collection is the only way to ensure species diversity in alkaline fens affected by drainage.	By gathering fresh biomass, especially if mown early or in midsummer, the seeds cannot be disseminated. Along with the fresh biomass, a large number of protected invertebrate individuals may be gathered and destroyed. Usually there is no practical application of the mown biomass as it has low nutritional value. Grass transportation may be practically difficult or impossible (lack of access roads, marshy conditions).
Shredding of the mown grass and immediate gathering of shredded biomass in a container	The biomass is gathered, thus reducing eutrophication.	Although caterpillars or wide-wheeled or tracked tractors cause less damage to the ground than "common" tractors, they still damage the ground, cause compaction of peat and cause a threat to the invertebrate fauna in the soil and ground vegetation. Adjustment and transportation of the equipment is necessary, which creates high costs.
Gathering of fresh biomass and hay in piles and leaving on site	The biomass is gathered, in this way reducing the eutrophication. Removal of biomass improves the light conditions in most of the area.	Eutrophication is reduced only partially (the biomass is not removed from the area). Piles remain for several years; the ground cover vegetation beneath the gathered piles is degraded.
Gathering of hay in piles and burning	The biomass is gathered, in this way reducing the eutrophication. Removal of biomass improves the light conditions.	Additional work investment (burning is time consuming when supervised). Fire can spread into the neighbouring areas.
Mowing without biomass removal **Unsuitable method!**	Lower costs than for mowing with gathering.	There is no ecological justification as to why this method should be used, it does not significantly improve the habitat condition, if at all, or has a short-term effect.
Shredding of the mown grass, leaving it on site **Unsuitable method!**	Mowing with a shredder helps to preserve an open fen, reducing shrub encroachment.	Shredding of the biomass enhances the eutrophication, contributing to degradation of ground vegetation.
Selective mowing of the expansive plant species	Lower costs (smaller area to be mown than mowing the entire area).	he effectiveness may be low. Lack of management in the rest of the areas causes their gradual overgrowing, even though the habitat quality in the selectively mown patches improves.

used regularly, since it has a degrading impact on the vegetation and soil fauna as well as has a deteriorating effect on soil structure. This method will most likely only be required in fen meadows that are slightly affected by drainage, not in undrained fens.

Mulching should not be applied in areas where rare snail species and other rare soil invertebrates can be found. However, if mowing cannot be introduced because of tussocks, mulching can only be performed in the most overgrown patches, e.g. on the patches where large willow clusters have been removed. In such areas, some patches and interconnected "islands" with the richest vegetation should be preserved.

Mulching is subsequently performed after the felling of trees and shrubs as it helps to reduce the intensity of shoot regrowth. Most commonly, mowing and haymaking is not possible before tussock removal or is encumbered (Fig. 15.43). After mulching, a thick layer of chipped grass and litter is sometimes left on the soil surface that, if not immediately removed, has already partially decayed in the next year. Preferably it should be removed right after mulching, otherwise it contributes to soil eutrophication.

Mulching should be performed in late autumn or winter (November–February) – preferably, in frost conditions without snow cover – both because it is easier for the machines to move on the wet ground, and it reduces the potential unfavourable impact on plant and animal species. Although in such a way the conditions of further management can be improved, the mulching diminishes the diversity of the micro-niches (Fig. 15.44), which host a large number of species.

15.3.8.5 Manual removal of tussocks

Removal of the *Molinia caerulea* tussocks with a shovel or other hand tools is of low efficiency and practically difficult to implement, especially in large areas. If there are few tussocks and the area to be restored is small, then the reduction of tussocks is possible by raking when gathering the hay, which is the simplest and cheapest method with the least undesirable impact on the soil fauna. *Molinia caerulea* tussocks, especially in abandoned fen meadows and drained fens, are "loose", thus raking is rather efficient.

In Estonia, experimental cutting of *Molinia caerulea* tussocks with a brush-cutter has been carried out in a small area. Locally, this helped to reduce the proportion of *Molinia caerulea*, as well as created favourable conditions for brown mosses, *Carex davalliana* and *Schoenus ferrugineus*, species typical for alkaline fens. It was concluded that this method is effective in controlling *Molinia caerulea*, and the re-establishment of species-rich fen vegetation is only possible if the water level is high or has been raised (Truus et al. 2013).

All the manual methods of tussock reduction are time-consuming and require great investment of hand work, thus they can solely be applied in small areas. These methods are less efficient in the removal of tussock-forming tall sedges as they are dense and firm.

15.3.8.6 Mowing methods

Movement of vehicles in a fen, including mowing equipment, damages the ground and can have an adverse effect on soil fauna by mechanically destroying them, therefore using tractors or similar vehicles in mowing should only be used in exceptional cases. Due to practical reasons (limited access, marshiness of the ground), mowing with a tractor in alkaline fens in Latvia is only possible in a few areas. In most cases, **manual mowing is preferable, using a brush-cutter or scythe.** In some countries, pedestrian-driven mowers are also used (Šefferová Stanová et al. 2008), which have not been used in Latvia in fen management up to now, however in some cases might be applicable.

Fig. 15.50. Grazing in overgrown alkaline fens and fen meadows on the shore of Lake Engure. Prior to establishing a pasture, shrubs have been cleared and a fence constructed. Photo: A. Priede.

In some European countries, for the mowing of fens and wet grasslands, **specially equipped double and triple-wheeled tractors and tracked mowers** are also used to reduce the impact on the soil, by mowing and immediately gathering the biomass in the container. In Latvia, so far there is little experience in this type of fen management. So far it has rarely been applied in wet grasslands. The impacts caused by this type of machinery can only be assessed by long-term monitoring (Fig. 15.45).

Although the impacts caused by specially equipped mowing machinery are not studied in Latvia yet, this approach does not seem to be suitable for the majority of the alkaline fens of Latvia. Usually the alkaline fens in Latvia are small, marshy, and inaccessible due to a lack of roads. According to expert opinion, the use of such machinery might cause a negative impact on the snail fauna by mechanically destroying them. In Latvia, there are few large continuous alkaline fens for the adjustment of such equipment to be rational, except for in some areas, e.g. it might be applicable in the heavily overgrown lakeshore fens near Lake Engure. As suggested by the experience of Poland (Biebrza fens), a significant disadvantage of such equipment is the degradation of micro-terrain heterogeneity. This type of mowing flattens the surface and makes it more homogenous, which may result in reduced survival of species (Kotowski et al. 2013), both plants and invertebrates, related to the tussocks.

Fig. 15.51. An alkaline fen in late autumn approximately a month after an accidental fire. In the front – a square-shaped sample plot where the grass was mown and both the hay and the litter were gathered in the last two years. The grass in the sample plot did not catch fire due to the absence of litter. This example shows that frequently managed fens with no thick litter layer and diverse vegetation, is resistant to burning. Photo: A. Priede.

15.3.8.7 Optimal mowing height

In the literature there are almost no references on the optimal mowing height in alkaline fens. Based on practical experience (for example, small-scale experimental mowing within the LIFE+ project NAT-PROGRAMME, LIFE11 NAT/LV/000371), the optimal and practically possible mowing height in an alkaline fen with lots of tussocks is around 5 centimetres. It is difficult to cut the grass lower due to tussocks, and it is also not necessary. In the case of higher mowing, tall stubble remains, a large proportion of the biomass is left on site, thus reducing the mowing efficiency and increasing the amount of litter, further contributing to eutrophication.

15.3.8.8 Mowing frequency

In the first years of heavily overgrown alkaline fen restoration, the biomass is large and there is a lot of litter, therefore mowing should be performed every year at least three years in a row. Afterwards, it is not necessary to mow every year, especially in areas, which were not used for haymaking in the past. Only those parts of the mire where the expansive species prevail (*Molinia caerulea*, *Phragmites australis*) must be mown more frequently. In the past, in most of the fens, which were used for haymaking, mowing was also not possible every year due to excessive wetness. Nowadays if annual mowing is not possible, the acceptable compromise for intact and slightly drained alkaline fens would be mowing once in every 3–5 years, which would help to reduce the proportion of expansive plant species and to suppress the shrubs. In drained fens and fen meadows mowing should be more frequent than in intact or slightly drained areas.

15.3.8.9 Optimal mowing time

Re-current mowing is one of the ways to reduce the dominance of the expansive plant species (most commonly *Molinia caerulea* and *Phragmites australis*) in alkaline fens. In controlling the dominance of *Molinia caerulea*, a successful result depends both on choosing the appropriate time and the frequency of mowing. It should be mown during the flowering time, preferably from July to the first half of August. In successful management hay gathering is important (Taylor et al. 2001). Frequent mowing, even three times a year without hay collection, may not help to decrease the *Molinia caerulea* cover, even if the proportion of *Molinia caerulea* and the vegetation height are reduced in this way (Anderson et al. 2006).

The proportion and competitiveness of *Phragmites australis* can be reduced most efficiently by mowing in summer – in June or July (Asaed et al. 2006; Fogl et al. 2014). At the end of the summer and in autumn the nutrients are accumulated in roots, thus removal of the aboveground biomass does not change the vigour of *Phragmites australis* significantly. However, not all of the studies attest to the effectiveness of mid-summer mowing (Güsewell et al. 2000). The effectiveness is also influenced by the conditions of a particular area, and mowing may not always promote, at least not within few years, the decline of reed density and vitality. Effectiveness of mowing may also be significantly affected by the climatic conditions – perhaps mowing provides better results in dry years when the reeds use the nutrient reserves accumulated in the roots, however in wet years there are not substantial changes. The density of reeds may also be influenced by spring frosts – shoots become weaker after freezing, but at the same time their number increases (Güsewell et al. 2000). Mowing provides better results in wet areas and areas covered with shallow water, when the reeds are mown as low as possible in order for the stubble to be flooded when the water level rises. For more on the limitation of *Phragmites australis*, see Rūsiņa (ed.) 2017, *Annex 3.*

The observations in the alkaline fens of Latvia also suggest that, at least within a few years, both the proportion of reeds and effectiveness of mowing would most likely be more influenced by the rainfall in the first half of the vegetation season, than the timing of mowing.

In areas where the expansive species have dominated in the vegetation for a long time, moreover, where the fen is drained and the upper peat layer is well decomposed due to drainage, mowing may not be efficient as a restoration measure. In such cases, topsoil removal or grazing could potentially be applicable measures.

15.3.8.10 Collection of hay

To reduce the amount of excess nutrients in the substrate and to improve the light conditions, the hay must be removed after mowing. In drained alkaline fens with dominance of *Molinia caerulea*, aboveground parts of plants form a large volume of biomass and thus also a thick layer of litter can be accumulated. Alkaline fens are naturally poor in nutrients, therefore gathering of the mown biomass is especially important. However, litter also has a certain role in the maintenance of an open fen, it diversifies the vegetation structure, serves as a shelter and hiding place for numerous invertebrate species, e.g. for snails, where the litter helps them to survive during the frost and drought periods (Campbell et al. 2003). However a huge amount of litter negatively affects the diversity of the plant species (Clément, Proctor 2009) as it decreases the light availability and decreases the seed germination. Therefore the mown grass or hay must always be gathered after mowing.

The mown grass or hay can be gathered both manually in the traditional way by rakes, and in a mechanised way – if movement with a tractor is acceptable in the particular fen, and it is practically possible. However, it is always better to use traditional methods, which are less destructive to the habitat and related species.

Too careful gathering of the mown grass and the litter in the entire area of the fen may cause an unfavourable impact on the invertebrates, especially on snail fauna. However, if the fen overgrows with a forest, the conditions will become unsuitable for the rare snails and other invertebrate species anyway. Therefore, a compromise would be leaving unmown and ungathered patches, or not mowing the entire area every year. Practical experience shows that in fens with lots of tall tussocks and wet ground it is not possible to remove all the litter manually by rakes (Fig. 15.46, 15.47), thus most likely the outcome will be a compromise as regards the diversity of both plants and animals. Gathering of hay (Fig. 15.48) instead of removing fresh biomass would be better, as this allows dissemination of seeds and decreases the mortality of grass-dwelling fauna.

In conditions of difficult access (tall tussocks, no access roads), removal of hay from the area may be hampered. Therefore, in exceptional cases the hay can be gathered in piles and burnt (Fig. 15.49). It is related to increased fire risk, therefore precautionary measures should be taken (burning should not be done during the dry season, it must be ensured that the fire cannot damage the adjacent areas, etc.). Fire must not be left unsupervised, since this may cause uncontrolled fires. The piles must be burnt before they become wet in the autumn rains.

Gathering of hay and litter is beneficial for the diversity of herbaceous vegetation, but at the same time it increases the establishment and survival of woody plants (Laiviņš u. c. 2012). Thus hay gathering, though improving the habitat quality, may also promote the overgrowing of fen with trees. This can only be prevented by regular mowing.

Table 15.3 provides an overview on various mowing methods.

15.3.9 Grazing

Grazing (Fig. 15.50) is one of the traditional ways of alkaline fen use in Latvia (Laiviņš u. c. 2012; Rūsiņa u. c. 2013). Nowadays, grazing in alkaline fens has almost ceased. Grazing should be considered as the first option over any other form of management in areas where fen has been grazed in the past but grazing has stopped for some reason; in areas where there is no history of mowing and where it is possible to introduce grazing to a fen site to inhibit succession; and in areas where the selective removal of vegetation has been identified as the most appropriate form of management (McBride et al. 2011). In areas where the past management was grazing, species have adapted to this management type.

In Latvia, the history of use of particular fen areas is almost never known and the management has been ceased a long time ago, therefore it is often impossible to imitate the past management. Due to practical considerations, it is not always possible to establish a pasture in any place, even if it is the best solution from the point of view of biodiversity conservation. It must be taken into account that somebody should look after the animals, in remote areas they are endangered by wild predators, the pasture ground and fences must be maintained and regularly repaired.

The opinions on grazing as a type of management in alkaline fens differ: it is considered both as optimal solution (McBride et al. 2011), and suboptimal – only applicable in cases when the fen can-

Fig. 15.52. Abandoned grassland on fen peat substrate – a severely modified alkaline fen in a drained floodplain. Due to drainage the upper peat layer is well decomposed. The high proportion of ruderal nitrophilous species (*Urtica dioica, Arctium* spp., *Cirsium* spp.) indicates that there is an excessive amount of nutrients due to peat decomposition, and the area has not been managed for a longer period of time. Restoration of the fen is most likely only possible by removing the well-decomposed topsoil and then raising the groundwater table, or restoring the natural flooding regime. Photo: A. Priede.

Fig. 15.53. A rich fen in drained soils where the water level is raised by beavers. Within a few years the vegetation typical for eutrophic shallow waters has developed, dominated by *Typha latifolia*. Similar conditions may arise when rewetting drained, well-decomposed alkaline fens. Photo: A. Priede.

not be mown for some reason (Šefferová Stanová et al. 2008). Grazing in spring fens and alkaline fens with spring flushes can also be judged both as acceptable and inappropriate management (*see Chapter 13.3.7*) as it causes trampling, which is difficult to control. Grazing in fens is usually interpreted as favourable from the point of view of preserving/restoring the vegetation diversity and bird fauna, whereas from the point of view of the conservation of other organisms (e.g. invertebrates, reptiles), grazing is more destructive than beneficial.

Grazing is selective; gradual removal of plant biomass creates micro-niches and is generally favourable to the species diversity, enhances the light availability on the ground cover and helps to remove litter. Grazing is effective in reducing the proportion of expansive species, especially reeds when animals are pastured in spring. It is a good solution in cases when there is no need for the hay and its removal is not economically justified.

Low to moderate intensity grazing causes a favourable impact on plant species diversity and vegetation structure, it enhances the light availability on the ground cover and helps to remove the litter, young trees and shoots of shrubs, and sometimes also larger shrubs. However trampling by grazing animals, especially in intensively grazed areas, causes soil compaction and mechanical damage of ground cover. Creation of micro-niches related to trampling and ground damage is desirable to a certain extent as it diversifies the environment for plants and ground-dwelling invertebrates (Boschi, Baur 2007), whereas too intense trampling is destructive. Long-term intensive trampling has an unfavourable impact on the soil fauna, including very rare species, for example, *Vertigo* spp. (Campbell et al. 2003).

Ideally, if grazing is selected as an appropriate management method in alkaline fens, seasonal grazing should be introduced. To diminish the trampling pressure, grazing animals should only be brought to the pasture in late autumn and winter in frost conditions by using electric fencing or a rotational grazing system, sections of which can be temporarily closed or opened. It means that only hardy breeds (cattle, horses) can be used which can withstand the cold weather. In some countries, mobile herds are brought in for a certain season in seasonal pastures, but the rest of the year they are pastured elsewhere. Grazing in late autumn and winter is advisable to suppress re-sprouting from stumps where the trees have recently been removed. Usually horses and cattle willingly eat young woody shoots and young trees during the winter.

In fens, if they are not very marshy and wet, the most suitable pasture stock is horses and cattle, preferably the hardy breeds, e.g. *Konik Polski* horses, *Heck* cattle, *Highlander* cattle, etc. Horses and cattle effectively reduce the proportion of shrubs and the expansive species (*Phragmites australis*, *Molinia caerulea*). Sheep browse the grass close to the

ground, which in the long term causes the extinction of various plant species. Sheep are not suitable in wet pastures, since they are highly susceptible to diseases and parasites. Sheep are also not suitable for heavily overgrown places with tall grass and lots of shrubs.

The number of animals per hectare should not exceed 0.9 livestock units. However it is better to choose a lower density and to pasture the animals only seasonally, not throughout the year, thus diminishing the potential trampling and overgrazing.

From a practical point of view, year-round grazing may not be possible because fens in autumn and spring can be partially flooded. Such areas can only be grazed during the frost season and/or during the drier summer months. Generally, grazing is not a suitable type of management in very wet, marshy areas and areas, which are rich in spring discharges and/or periodically flooded. Also areas with no or limited access to water (drinking places) are not suitable for establishing pastures (McBride et al. 2011).

15.3.10 Prescribed Burning

Burning in alkaline fens is considered to be an unsuitable method, since it promotes the spread of expansive species *Molinia caerulea* (Taylor et al. 2001; Clément, Proctor 2009) and negatively affects the invertebrates in the soil and the ground vegetation (Cameron et al. 2003; McBride et al. 2011). After burning the fen can be invaded by birches. However burning, if it is not regular and frequent, also has a favourable impact in heavily overgrown mires – part of the thick litter layer is burned, and the proportion and vitality of shrubs are decreased. In well-managed fens, burning is most likely much less significant if compared to degraded, overgrown mires (Fig. 15.51).

The timing of prescribed burning is important. Prescribed burning as a type of management in alkaline fens may only be used in exceptional cases as a measure to remove the thick layer of litter. Burning in fens should only be applied in snowless frost conditions in winter (such may also not occur every year), when it causes the least negative impact. Winter burning only affects the layer of litter, shrubs and young trees. After the litter has burnt, fen becomes even less susceptible to fires. Burning must not take place in the summer drought period, since the upper layer of peat may also ignite and it can cause continuous smouldering, which is difficult to extinguish. Burning in the summer drought period, especially in drained fens, causes damage to invertebrate fauna; expansion of *Molinia caerulea* can also be expected.

Fig. 15.54. Peat milling field abandoned approximately 20–25 years ago with residual alkaline fen peat. The substrate is too dry for the recovery of fen vegetation. In summer, the peat surface heats up, in winter it is affected by frost erosion, hindering the development of vegetation. Such conditions are prefect for the spread of invasive moss species *Campylopus introflexus*, which now covers large areas. Photo: A. Priede.

Fig. 15.55. Fen peat quarry, abandoned a long time ago, filled up with water. The recovery of alkaline fen vegetation is not possible, however, the ponds are a suitable habitat for stoneworts, amphibians, potentially also for waterfowl. Photo: A. Priede.

When implementing prescribed burning, the fire safety rules must be strictly followed, in order not to threaten human life and health, neighbouring land properties and biodiversity that is not related to fire disturbance. *See also Chapter 6.3.14.*

Prescribed burning can only be used in the case where there are no other effective possibilities to reduce the litter layer in heavily overgrown mires. It cannot be used in places where rare snail species of

Fig. 15.56. Spontaneous recovery of calciphilous plant communities in an extracted peatland on wet fen peat approximately 60 years after the cessation of peat extraction. Photo: A. Priede.

Vertigo genus can be found, it is also most probably not applicable in sites with rare plant species. Prescribed burning should always be combined with other management measures – clearing of shrubs, recurrent mowing or light grazing in the next years after burning.

15.3.11 Eradication of Invasive Plant Species

Invasive plant species in intact and slightly altered alkaline fens can almost never be found, and the risk of establishment thereof due to unsuitable conditions is low. The invasive plant species may become a problem in drained and otherwise negatively affected mires, for example, in post-harvested peatlands.

The methods of invasive plant species control are described in *Chapter 13.3.8*. However, the most effective and sustainable way is rewetting, making the conditions unsuitable for their spread. In particular, it refers to moss species *Campylopus introflexus*, the spores and small fragments of which spread by wind and, supposedly, also by wild animals, thus any kind of eradication (turf removal, herbicides) is not sufficiently efficient.

It is most effective to eradicate the invasive plants in the early invasion stage, which is both more efficient and cheaper, for example, to pull out the first invasive plants after their establishment as soon as possible before they have established large stands that are difficult to eliminate.

Herbicides cannot be used in fens, as well as in the localities of rare plant species and on the shores of water courses and water bodies. The use of herbicides creates a high pollution risk, threatens water ecosystems, especially the invertebrate fauna, and further along the food chain – other organisms as well.

15.3.12 Measures Aimed at the Conservation of Target Species

In alkaline fens, numerous rare species and species are found, which occur exclusively in alkaline fens and are only able to survive in such conditions and therefore are endangered. Their return into the area is possible, if suitable conditions are restored or created. However, the target species will not always

Fig. 15.57. An old peat quarry with residual fen peat filled up with water near Jaunsāti. The recovery of the alkaline fen vegetation does not take place, because the water is too deep. However the pond with alkaline water is a suitable habitat for stoneworts, amphibians, and dragonflies. Photo: A. Priede.

Fig. 15.58. An old small peat extraction site on the edge of an alkaline fen filled up with water in Platene Mire. On the margins of the peat excavation pits, the alkaline fen vegetation is spontaneously recovering. Photo: A. Priede.

return by themselves – if all the individuals have disappeared, no seeds have remained in the soil seed bank and/or there are no other species localities in the surroundings, reintroduction activities may be necessary. This is also important for the species with limited dispersal ability – they cannot move over long distances, even if suitable habitats are available in the surroundings.

For the introduction or reintroduction of the target species, firstly, development of a scientifically based plan is required. In Latvia this is a national species conservation plan approved by the public authority or specific actions proposed for a particular site in the nature conservation plan. For more on the formal process, *see Chapter 6.3.12*.

In Latvia, there is little experience as regards the (re)introduction of target species in sites where they probably never existed earlier, or there is no reliable evidence that they have ever been found in the particular area. Many species are rare due to natural reasons, thus any introduction or reintroduction of rare species is controversial, and first of all, scientific studies and well-argued justification is necessary.

Above all, (re)establishment of target species is related to the creation of suitable conditions. The habitat and micro-niches required for the species may be created by rewetting, mowing and other management measures. The target conditions depend on the ecological requirements of the particular species (Mälson 2008). For small, light-demanding plants that are weak competitors (*Primula farinosa*, *Pinguicula vulgaris*, *Liparis loeselii*, etc.), suitable conditions can be created by re-current mowing or creating small substrate disturbances, for example, cutting out pieces of turf. The creation of "corridors" by mowing will also help those species to spread within the fen area (Roze et al. 2015). The diversity of amphibians is increased by creating small, shallow depressions that are filled with water. Such depressions can be created along with the building of ditch dams, in order to obtain the material required for dams. Thus, in restoring the habitat the same equipment, which is used for blocking or infilling the drainage ditches, can be used for multiple benefits.

When the suitable conditions are available (restored), the next step is the transfer of the target species. It can be done in many ways, which depends on the species. For plants it can be planting of seedlings, dissemination of seeds, hay transfer, etc. Small invertebrates, e.g. snails *Vertigo* spp. can be successfully (re)introduced by transferring the turf from the fens that are rich in those species (Cameron et al. 2003). As this cannot be done without developing a plan, special knowledge and qualification, as well as permits issued by the responsible authority, the details are not provided here.

Fig. 15.59. *Carex lepidocarpa* and *Juncus articulatus*. Photo: A. Priede.

(Re)introduction of target species is especially important when restoring heavily degraded fens – deforesting and/or rewetting heavily drained fens, as well as restoring wetland ecosystems in post-harvested peatlands. In such cases, (re)introduction is most probably necessary to promote the establishment of relatively common, however habitat-characteristic species, which may be absent in the surrounding, severely modified landscape.

All actions targeted at native species reintroduction must be well documented and monitored.

15.3.13 Restoration of Severely Degraded Alkaline Fens and Creation of New Alkaline Fens

15.3.13.1 Target areas

Restoration of significantly degraded alkaline fens and habitat creation applies to places where:

- alkaline fens are significantly deteriorated by drainage, afforestation, drainage, or other human-caused impacts, however the characteristics typical for alkaline fens can still be observed (peat substrate and substrate wetness, calciphilous plant species, vegetation structure, etc.);

habitat has been destroyed or where abiotic conditions favourable for the characteristic species and communities have developed resulting from human activities – post-harvested peatlands with discharges of calcareous groundwaters, tufa quarries, dolomite, limestone or carbonate gravel quarries with

Fig. 15.60. *Schoenus ferrugineus*. Photo: A. Priede.

Fig. 15.61. *Cladium mariscus*. Photo: A. Priede.

Fig. 15.62. *Campyllium stellatum* Photo: A. Priede.

Fig. 15.63. *Calliergonella cuspidata*. Photo: A. Priede.

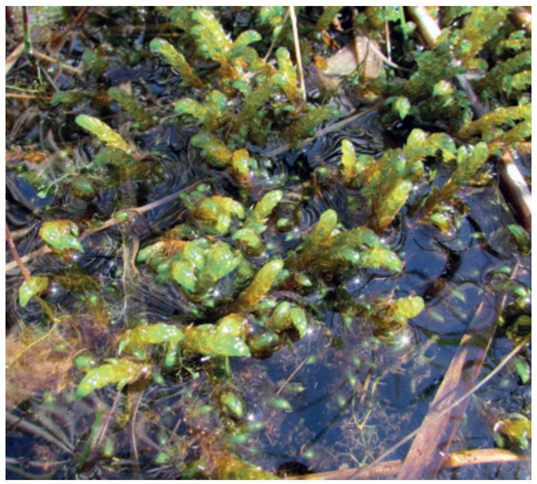

Fig. 15.64. *Scorpidium scorpioides*. Photo: A. Priede.

shallow depressions filled up with water and a constantly moist substrate. In some cases the creation of alkaline fen conditions in wet depressions and on the shores of artificial water bodies in post-mining areas may be a good alternative among other after-use options in quarries.

In such areas restoration or creation of an alkaline fen is possible, though it may take a longer time, as the establishment of fen pioneer communities takes at least several decades. Such areas, even if there is not a "complete" mire ecosystem, are significant in the sheltering of typical and rare species.

115.3.13.2 Creation of alkaline fens in agricultural lands

In Latvia, the need for the restoration of alkaline fens in heavily drained lands converted into arable lands and heavily drained grasslands has not been assessed. However, in the future, if the degradation of mires is not reduced and their areas continue to decrease, the restoration of heavily transformed fens or fen meadows – could become more topical.

In fens that have been transformed into agricultural lands, the drained upper layer of peat is highly decomposed, and, upon rewetting, bioavailable phosphorus is released (Klimkowska et al. 2010b; Zak et al. 2010). The unavailability of phosphorus in mires is an important limiting factor. In intact fens, phosphorus is organically bound and not available to plants. Rewetting of highly decomposed fens may result in eutrophication. It affects both the rewetted fen and surface water runoff, thus also affecting the surface waters in the surrounding area. Due to increased phosphorus availability in the fen, the recovery or establishment of the target vegetation will be not achieved, even if the optimal hydrological regime is restored. Instead of alkaline fen vegetation, most likely, ruderal species or species of eutrophic waters will establish (Fig. 15.52, 15.53).

In Western and Central Europe, topsoil removal has been practised for more than a decade. Its purpose is to remove the well-decomposed, nutrient-rich upper layer of peaty substrate (or soil), simultaneously raising the groundwater table by lowering the level of the soil surface. This method is applied in areas that have been used in agriculture – severely drained fens that have been transformed into highly productive grasslands or arable lands, have been fertilised and ameliorated (Šefferová Stanová et al. 2008; Klimkowska et al. 2010b; Hedberg et al. 2014).

On the one hand, the removal of the upper layer of peat destroys the vegetation and soil fauna. Therefore, in the planning stage it must be assessed how valuable the existing habitat and species are. Most likely, the severely drained fens converted into agricultural lands do not have any characteristics of natural or semi-natural habitats. In intact alkaline fens, the formation of the specific vegetation is defined by the limited availability of nutrients, whereas in the heavily drained former fens the excessive amount of nutrients due to drainage and peat decomposition has caused local extinction of the habitat-specific and rare species.

On the other hand, removal of the highly decomposed peat layer creates wet, bare peat, suitable for the establishment of alkaline fen vegetation, and,

Fig. 15.65. Pioneer plant community characteristic for young alkaline fens with *Carex flacca*, *Carex scandinavica*, *Carex flava*, *Molinia caerulea*, and *Liparis loeselii* in an extracted quarry on wet dolomite substrate. In depressions filled up with shallow water, vegetation is dominated by *Cladium mariscus*. The plant community has developed within approximately 30 years. Photo: A. Priede.

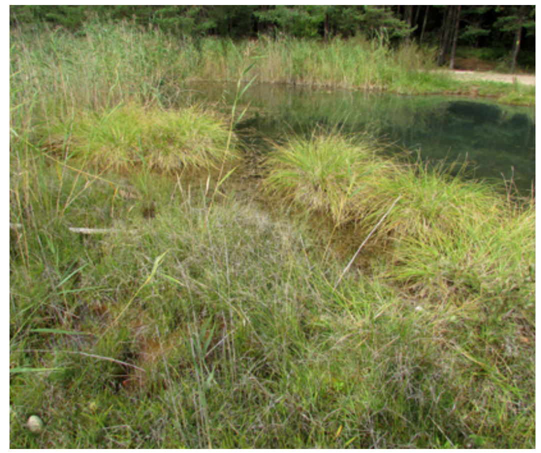

Fig. 15.66. Alkaline fen vegetation in the gravel quarry with calcareous spring discharge. Species composition resembles natural alkaline fens. Photo: A. Priede.

over time, for the establishment of animal species characteristic for alkaline fens. Most often, to restore the fen-specific conditions, both the removal of the shrubs and the upper layer of peat as well as raising of the groundwater table up to the soil surface is necessary in such places. The upper layer of peat (around 30–50 cm) must be removed to reduce the amount of phosphorus and also to lower the surface, thus rewetting the substrate (Klimkowska 2010b).

The peat layer removed from the habitat

restoration area can possibly be used for horticultural or agricultural purposes, though in many cases its disposal may be problematic on a practical level.

In Latvia, so far there is no experience in the use of this method, therefore first it is advisable to test it in small, experimental plots along with detailed documentation of the work performance and monitoring of vegetation, species dynamics and groundwater table.

15.3.13.3 Renaturalisation of the post-harvested peatlands

According to the regulatory enactments in Latvia (Cabinet Regulation of 21 August, 2012, No. 570, On the Procedure of Mineral Deposit Extraction), the after-use options for peat extraction sites are defined: renaturalisation (restoration of mire-specific environment), preparation of areas for agriculture (for example, berry or willow plantations), preparation of areas for forestry, creation of water bodies, recreation, and other. However since this edition is aimed at recommendations for restoring biodiveristy, only two renaturalisation options are described here: restoration of the mire ecosystem and creation of water bodies. Other after-use options, such as afforestation, agricultural lands, biomass plantations, are not discussed here.

Creation of alkaline fens in post-harvested peatlands in Latvia has not been tested. The experience in other countries is also still insufficient. However, the promising results of spontaneous recovery in several harvested fens of Latvia suggest that the creation of alkaline fens is one of the after-use options. Spontaneous recovery leading to species-rich alkaline fens could partly compensate the loss of natural habitat areas due to peat extraction and the decreasing areas of intact alkaline fens (Priede et al. 2016). However, this is a specific and little studied way of fen restoration.

15.3.13.4 Are the post-harvested fens able to recover without special measures?

Sometimes the fen can spontaneously recover without targeted activities, if the groundwater table increases as the ditches get clogged by overgrowing or due to beaver dams. Recovery of the fen is not possible if the drainage system still functions, since then the substrate is too dry (Fig. 15.54). In abandoned peat milling fields where the ditches and drains do not function anymore, the effect is similar to purposefully rewetted peatlands – within a longer period of time the recovery of the fen is possible. In some cases, the fen vegetation cannot recover, e.g. in peat quarrying pits filled up with water (Fig. 15.55).

15.3.13.5 Planning of renaturalisation

For aspects to be evaluated when starting to plan the renaturalisation of a post-harvested peatland: see *Chapter 103.8*. It is important to distinguish between the conditions that are suitable for the recovery of a bog and a fen, including recognising conditions potentially suitable for the development of alkaline fens.

The areas where alkaline or other types of fen could be restored are abandoned peat milling fields with residual fen peat. Substrate should be slightly acidic to alkaline, formed on carbonate-rich bedrock or with discharges of carbonate-rich groundwaters. Generally, such conditions are rare.

When considering the possibility to restore alkaline fen habitat in post-harvested peatlands or create suitable conditions for spontaneous recovery, first of all, **the characteristics of the residual peat layer** must be understood. The type of residual peat layer (fen peat, bog peat, transitional type peat) and its physical and chemical properties (pH, conductivity, decomposition, etc.) are the main factors that determine the potential vegetation.

Alkaline fen recovery is possible in post-harvested peatlands with a high content of carbonates in the bedrock and with slightly acidic, neutral or alkaline residual peat (pH ranges from 6 to 8) (Priede et al. 2016) (Fig. 15.56, 15.57). In such an environment, sphagnum and other raised bog plants cannot establish and survive. Typically, if rewetted, such areas are dominated by small-sedges (*Carex lepidocarpa*, *C. flacca*, *C. panicea*, *C. serotina*), *Phragmites australis*, brown mosses (*Campylium stellatum*, *Calliergonella cuspidata*, *Drepanocladus* spp., *Scorpidium scorpioides*). The properties of the residual peat must be tested in cases when the (re)introduction of alkaline fen species is planned, e.g. dissemination of seeds, spreading of species-rich hay, planting of species-rich turf. The outcome can only be successful when the substrate in the target area is suitable for the transferred species.

15.3.13.6 Renaturalisation of peat quarries and block-cutting peatlands

In Latvia, fens where peat has been extracted using the block-cutting method are almost always completely overgrown with forest, converted into agricultural lands, or the pits are filled up with water and a mosaic of ponds and reed beds has developed (Fig. 15.58, 15.59). In Latvia, no block-cutting fen areas are known where renaturalisation would be necessary and possible. In such areas, if they are not recovered spontaneously, the drainage system should be blocked and the areas should be left for natural succession. Only the lowering of the water level (including demolition of beaver dams) must be prevented.

15.3.13.7 Renaturalisation of post-harvested peat milling fields

Peat surface preparation. The first step in the renaturalisation of a post-harvested peatland is the preparation of the surface. To achieve raising of the water table, accurate levelling of the surface is important to understand the surface topography and runoff directions. The surface models obtained using remote sensing methods can also be used for this purpose (Rydin, Jeglum 2013).

If the peat surface has been left dry for a long time, the upper layer is highly decomposed, which means that it has low water accumulation capacity. Then, raising of the water level causes the release of bioavailable phosphorus and eutrophication of surface waters. Due to phosphorus mobilisation numerous fen restoration projects in have failed (Klimkowska et al. 2010b) as the eutrophic waters and rewetted substrate overgrows with nutrient-demanding plants. To avoid the increased eutrophication risk, the best option is to raise the water level in the harvested peat milling fields as soon as possible after peat extraction.

Due to the eutrophication risk, which may, most probably, lead to restoration failure, the decomposed upper layer of peat (at least a 10–20 cm) must be removed first. Also, the trees and shrubs must be removed so that they do not encumber the movement of vehicles, do not increase the evapotranspiration, and do not preclude recovery of the vegetation after rewetting (Rochefort, Lode 2006). Bulldozers can be used for piling up the removed layer. Then the peat layer must be removed and transported away from the restoration area. It can be used in horticulture and the amelioration of soil in agricultural areas. Due to the low water accumulation capability, the highly decomposed peat taken from the upper layer is not suitable for the building of dams in ditches.

Raising the water level, blocking the drainage system. The next step is blocking of the drainage system and raising of the water level so that the water level reaches the peat surface. This means that ditches must be closed by building dams. Filling up of the draining ditches is also recommended, following the same principles as for rewetting in drained mires, i.e. planning the number of dams depending on the topographical situation and taking into account the runoff directions (*see Chapter 15.3.3*).

The optimal moisture conditions cannot be immediately ensured in large peat extraction areas, where renaturalisation has been planned in a separate, already extracted sector. In adjacent peat fields still being extracted, the drainage ditches, drain-pipes or pumping system are still functioning, thus lowering the water level. However, the water level can be raised partially – first the optimal conditions can be achieved in the low-laying depressions, later on – in the rest of area after closing the drainage system in the entire post-harvested area. Over time, drained peat fields will partially overgrow with trees, which should be removed (see *Preparation of the peat surface*).

Introduction of target species (plants). Introduction of the plants characteristic for alkaline fens, especially in areas which do not neighbour with species-rich intact fens or other donor habitats, promotes faster recovery of the ecosystem. This is of particular importance if the fen is completely destroyed by peat extraction, and no remnants of the pristine ecosystem have survived. Lack of donor habitat in the surroundings mean that the vegetation recovery will be slow. Many of the target species will probably never establish themselves, especially in regions with few alkaline fens and other calcareous habitats.

Introduction of the target species has been successfully carried out in post-harvested peatlands with residual acidic sphagnum peat. However, there is almost no experience in introducing the target plant species in peat milling fields with residual alkaline fen peat. Also in Latvia, there is no practical experience in this, therefore the method should first be tested in small experimental areas along with recording the work performance and monitoring of the outcome.

Above all, before introducing the target plant species it is important to determine the properties of the residual peat layer. The minimum parameters are the peat type and pH, which would help to understand the potential vegetation, so as not to waste resources by introducing plants which are unsuitable for the particular conditions. If the residual peat layer is composed by transitional type or acidic fen peat, the development of alkaline fen vegetation also cannot be expected after introducing the target species.

The target plant species in the restoration of alkaline fen habitats are vascular plant species (especially sedges, rushes, and grasses) and brown mosses typically occurring in habitats 7230 *Alkaline fens*, 7210* *Calcareous fens with* Cladium mariscus *and species of the* Caricion davallianae, and 6410 Molinia *meadows on calcareous, peaty or clayey-silt-laden soils*. Some species suitable for such conditions are presented in Fig. 15.60-15.65. For more on species suited to acidic and alkaline conditions, *see Table 9.1 in Chapter 9.2*.

On slightly acidic to acidic fen peat substrate, species of poor fens and transitional mires can establish, for example, *Carex rostrata, C. lasiocarpa, Juncus* spp., *Eriophorum vaginatum, E. polystachion*. Sphagnum mosses can be introduced on acidic to slightly acidic substrates, but they are not suitable for alkaline conditions.

Transplantable material. Transplantable material may be turf containing living plants, propagules (roots, seeds, spores) and soil fauna. The bigger the turf pieces, the more they will be protected from desiccation, and the better the survival of the replanted plants. It is important that the extraction of turf does not destroy the donor site. Transplantation targeted at restoration of protected habitats as well as extraction of turf in the donor sites must be obligatorily coordinated with the responsible authorities and the land owners.

Instead of turf transplantation, which is not easy to implement, hay or fresh mown grass can be spread to bring the propagules of the target species into the area to be restored. The hay or fresh mown biomass should be gathered in species-rich intact or slightly altered alkaline fens. In Europe, spreading of species-rich hay has been successfully performed in restoring fens and wet grasslands in heavily transformed former mire areas (Klimkowska et al. 2010b). To disseminate the seeds of the target plant species, the hay must be mown and gathered in the second half of summer (end of July to the first half of August) when the seeds are ripe. In the area to be renaturalised, hay must be spread out in a thin (up to 10 cm) layer. Hay is the source of the seeds, and while it decomposes, it serves as a "shelter" for the recently established seedlings (Klimkowska et al. 2010b). The use of this method does not guarantee the desirable result, especially as it has rarely been tested in post-harvested peatlands. First of all, prior to spreading the hay or fresh mown grass, it should be tested in smaller areas and only if acknowledged as applicable after a few years of monitoring, can it be implemented in the entire area.

Overall, the method is similar to that used in grassland restoration. For more on the method, see Rūsiņa (ed.) 2017.

Where and how to collect the transplantable material. It is important to avoid damaging the donor territory as much as possible. Turf must not be collected in large continuous areas. This must be carried out by selectively digging the turf in patches so that the vegetation is able to recover. Heavily degraded fens are not suitable as donor areas, because, most probably, the vegetation contains lots of undesirable species (e.g. nitrophilous plants). Turf should not be extracted in untouched alkaline fens and in moist depressions in wet calcareous grasslands, as well as in post-harvested peatlands where the vegetation of alkaline fens has spontaneously recovered. Collection of hay does not harm the donor area, therefore it can be collected in any suitable place where mowing is advisable and is being carried out, both in wet fen meadows and alkaline fens.

More on the renaturalisation of post-harvested peatlands: Priede, Silamiķele (2015).

15.3.13.8 Wet depressions in post-mining areas – potentially valuable habitats in the future

The post-mining areas, such as extracted tufa, limestone, dolomite, sand and gravel quarries, if remaining without any rehabilitation or afforested, are often filled up with water, thus creating water bodies. Most likely, spontaneous regeneration is the best method for preserving and supporting their biodiversity, especially species and communities related to early successional phases (Tropek et al. 2010). Calcareous shallow soils (superficial soils) in natural conditions can rarely be found in Latvia, therefore such habitats are very rare. Occasionally the pioneer communities composed of calciphilous plants occur on the shores of recently created water bodies. The shallow water zone and the damp substrate along the shores, as well as wet depressions may sometimes be the habitats of rare species, and are valuable from the point of view of biodiversity preservation, even though they were formed under an anthropogenic impact (Priede 2011). Although such sites cannot be equated to natural alkaline fen habitats, they are significant in hosting alkaline fen species. With moderate intensity management, such as clearing shrubs time after time, species-rich calciphilous vegetation may develop within several decades (Tropek et al. 2010). Such habitats can also be suitable for rare species. In areas neighbouring donor areas rich in calciphilous species, habitat-specific mosses may also establish. In the long term, perhaps several decades or a century, alkaline fens with a shallow layer of peat may also develop on the shores of artificial quarry lakes (Fig. 15.66, 15.67).

15.3.14 Examples of Alkaline Fen Restoration and Management in Latvia

Ķemeri National Park. Small areas of alkaline fens have been restored and managed since 2004 by clearing the shrubs and mowing the herbaceous vegetation. Larger areas (3.1 ha) were restored in 2013 by clearing shrubs in heavily overgrown sites on the shores of Lake Kaņieris and in Raganu Mire (the restoration was funded by the LIFE+ project NAT-PROGRAMME, LIFE11 NAT/LV/000371). Additionally, experimental mowing along with monitoring of the impact of management with and without the removal of hay was carried out.

In 2014, shrubs have been cleared in an area of >10 ha in the alkaline fens on the shores of Lake Kaņieris. In 2015, fens at Lake Kaņieris were mown by using a triple-wheeled tractor and a brush-cutter, and hay was raked (Fig. 15.68).

All restored fen patches cover small areas (up to 2 ha each) and were overgrown with birches and pines established due to long-term abandonment. Till the second half of the 20th century, the cattle were pastured there, which maintained the fens open. After abandonment, most of the fens overgrew as the grazing was ceased. Overgrowing has also been promoted by the lowering of the water level in the adjacent lake since 2010.

Restoration of fens on the lakeshores initiated the recovery of the vegetation structure typical for alkaline fens, suppressed the expansive plant species, improved the light availability to small ground-dwelling species, and contributed to recovery of the traditional landscape characteristic for this area.

Slītere National Park. In 2014, within the LIFE+ project NAT-PROGRAMME, LIFE11 NAT/LV/000371, trees and shrubs were removed in an area of 5.2 ha (Fig. 15.69). Fens were partially overgrown with pines and black alders.

Trees were felled in frost conditions in winter, thus reducing trampling and not disturbing breeding birds. The majority of young pines were removed, especially those with large annual increment. Old, crooked pines and junipers were preserved, creating a mosaic of old tree groups and an open fen. Dense reed stand (0.3 ha) was mown two years in a row, but so far there are no significant changes in the vegetation structure and apparently mowing for several years in a row, or even several times a year is necessary.

Dubļukrogs micro-reserve. This is one of two localities of *Saussurea esthonica*, a very rare plant species, in Latvia. Until the mid-20th century, the

Fig. 15.67. Hay gathering on the shore of Lake Kaņieris in 2015. When mowing, some clusters of *Myrica gale*, junipers and old pines were left untouched. Since there was no demand for hay and the transportation costs are high, it was collected in heaps and burnt. Photo: A. Priede.

Fig. 15.68 Burning of the cut shrubs in a restored fen in Slītere National Park. Photo: Ē. Kļaviņa.

Fig. 15.69 The area in Dubļukrogs micro-reserve cleared of dense shrub cover in an area of 2 ha, by preserving individual pines and junipers. Photo: A. Priede.

Fig. 15.70. Clearing of shrubs and mowing in the slope fen in Drubazas helped not only to preserve the species diversity, but also the entire landscape complex. Photo taken in 2011. Photo: S. Rūsiņa.

Fig. 15.71. In the 1950s tufa was extracted in Čužu Mire. Nowadays the pits are filled up with water, serving as habitats for several species, e.g. stoneworts and newts. Recently, the surroundings of the ponds were cleared of shrubs, improving the conditions of the light-demanding plant species, e.g. *Primula farinosa*. Photo taken in spring 2016. Photo: A. Priede.

fen area in the Dubļukrogs micro-reserve was still probably used as a meadow or pasture. Half a century of abandonment led to shrub encroachment, thus making the conditions less favourable for Saussurea esthonica and other rare fen plants. In 2014–2016, JSC "Latvian State Forests" organised clearing of shrubs, restoring the open landscape (Fig. 15.70). In this and similar cases it must be taken into account that cutting of shrubs will be followed by intense re-sprouting, since the conditions are relatively dry, therefore cutting of shrubs must be a re-current action.

Drubazas farm in "Abavas senleja" Nature Park. In Drubazas farm in Abava Valley (Fig. 15.71), an alkaline spring fen has developed at the basal part of valley slope, next to the splendid, scenic, species-rich juniper stand and dry calcareous grasslands. The Carex davalliana dominated alkaline fen is rich in rare plant species, especially orchids. A botanical trail has been established there and information boards have been placed introducing the visitors about the characteristic plants of both calcareous grasslands and alkaline spring fens. To prevent the open fen from overgrowing, in the beginning of the 21st century the area has been repeatedly cleared of shrubs and mown.

Čužu Mire. Čužu Mire near Kandava has developed on tufa sediments, however due to the specific flora and fauna it cannot be considered a typical alkaline fen. Calcareous habitats have been restored by the gradual removal of trees and shrubs, and re-current mowing of shoots in the following years. In the beginning of the 20th century cattle were pastured in this area, but in the last decades the pasturing has been ceased. At the end of the 20th century, Čužu Mire was affected by several accidental fires, which helped to maintain the area open, preventing overgrowing with forest. Targeted management of the habitats began in 2005, and is still on-going (performed by JSC "Latvian State Forests") (Fig. 15.72).

The trails and information boards installed for the visitors introduce them to this peculiar area, its nature values and management carried out during the last decade.

15.3.15 Rehabilitation of Damaged Alkaline Fens

Alkaline fens may be affected by various activities, for example, digging of new ditches or renovating of old ones, damage of the peat surface, including removal of the upper layer of peat, burying with debris, etc. All the activities causing these impacts are illegal, however, they still happen, though rarely, and in the damaged sites rehabilitation measures are necessary. For more on the unfavourable impacts on alkaline fens, *see Chapter 15.3.17*.

The alkaline fen habitat can be considered as destroyed when all or most of the ecosystem functions and components have disappeared or been severely damaged, e.g. accumulation of peat and water, carbon sequestration, typical vegetation composed of particular plant species, and fauna. If at least some characteristics of the vegetation or the peat layer have been preserved, the habitat can perhaps be restored, though not always achieving the desirable condition. Irreversible changes may be

caused by, for example, drying up of the springs in alkaline spring-fed fens. To ensure their favourable conservation status, the habitats must be restored in each damaged site, or, if it is not possible, the same habitat type should be created in another area. In Latvia, the only way to do this is the creation and promotion of the conditions characteristic for alkaline fens in peatlands and calcareous rock quarries.

It is impossible to predict all the damage or destruction types that could be found in alkaline fens, thus the guidelines cannot provide solutions for all cases. Here only a few examples are presented, and the possible solutions thereto (Fig. 15.73–15.78).

15.3.16 Creation of Tourism Infrastructure in Alkaline Fens

When planning and creating tourism trails and other places of interests in alkaline fens, the same principles should be used as in raised bogs (*see Chapter 10.3.10*).

15.3.17 Inappropriate Management and Use of Alkaline Fens

Management and use unfavourable to the habitat is the following:

- all activities that may alter the groundwater table (excavation of new ditches, renovation of the existing ditches in the fen and the adjacent area, etc.);
- demolition of beaver dams on the ditches if they maintain an optimal moisture level;
- shredding of mown grass and leaving the mown material on site;
- mulching of topsoil (if used more than once after a long time of abandonment);
- high intensity grazing;
- movement of heavy vehicles across the fen in the frost-free period (except for tractors equipped with wide wheels or tracks);
- fertilisation, including the use of manure;
- use of herbicides (to eliminate the shoots after the clearing of shrubs and trees, to eradicate expansive and invasive plants);
- burning of plant litter (except for prescribed burning coordinated with the responsible authorities in restoring heavily overgrown fens and fen meadows);
- establishment of tourism infrastructure that increases the visitor pressure on the fen and vulnerable species, attracts too many visitors, etc.);

Fig. 15.72. Deep tracks created by tractors and other heavy vehicles in an alkaline fen, severely damaging the vegetation. However, since only one of the habitat components – the vegetation – has been affected, without damaging the hydrological regime and peat layer, recovery of the habitat is possible in a relatively short period. In such cases, if disrupting the disturbance, complete recovery of the vegetation can be expected within a few years. Photo: A. Priede.

Fig. 15.73. The topsoil in a fen with a shallow peat layer is removed, and dolomite bedrock is exposed. Hydrological regime is not modified. Such damage can be considered as significant – the habitat has been destroyed, since both the soil and the vegetation have been removed. However suitable conditions are still preserved. In such a situation, the best solution would be the prevention of further undesirable disturbances and to leave the territory for natural succession. If the target species can be found in the surroundings, the spontaneous recovery of alkaline fen vegetation might be possible within several decades. Photo: A. Priede.

- supplemental feeding of game animals (causes eutrophication and the establishment of ruderal and invasive plant species);
- afforestation;
- any damage of the upper layer of peat and vege-

tation (removal of topsoil, burying, building up), that destroys the habitat irreversibly or makes its restoration very complicated, except for scientifically based restoration or management coordinated with the responsible authorities, for example, removal of the nutrient-rich upper layer of peat.

Fig. 15.74. Unauthorised excavation of a new ditch in an alkaline lakeshore fen. This must be considered as significant damage threatening the further existence thereof. The best solution would be to fill up the ditch as soon as possible by levelling the ditch berms and to leave the area to natural succession, or manage it according to the habitat condition, in this case – by clearing the shrubs and ensuring re-current mowing to prevent invasion of woody species. Photo: A. Priede.

Fig. 15.75. Peat layer is removed in an alkaline fen and buried with debris and nutrient-rich soil. Habitat is completely destroyed, since the soil, hydrological regime, and the vegetation have been deteriorated, as well as abiotic conditions are completely changed and become unsuitable for species of alkaline fens. In order to restore the habitat, the buried material should be removed and the area should be left for natural regeneration. Reintroduction of target species by turf planting or spreading species-rich hay rich would speed up the fen recovery. Photo: A. Priede.

15.4 Conservation and Management Conflicts in Alkaline Fens

15.4.1 Bog Woodland vs. Fen

It is not always possible to provide a clear answer, as to whether in a heavily overgrown undrained or slightly drained alkaline fen, the trees should be removed or the development of bog woodland should be allowed. Sometimes, the restoration of open fen in heavily overgrown places is difficult and very costly; moreover, the overgrown areas may also be valuable as bog woodland, and species communities related to forests may have already established.

In drained fens with ditches, where there is degraded ground vegetation and a dense cover of trees and shrubs that have established due to drainage, the priority is to restore the natural hydrological regime together with the removal of the tree cover, i.e. restore an open mire habitat. In areas where the hydrological regime has been preserved or recovered itself by overgrowing of the ditches, the trees and shrubs should most probably be removed, re-current mowing of shoots and re-current grass mowing should be ensured. Since alkaline fens are rare habitats in Latvia, the priority is the restoration of an alkaline fen, and it is worth investing the effort therein. If it is not possible, then it is better to leave the area to natural succession, for the formation of another, however also valuable habitat type. *See also Chapter 10.4.*

15.4.2 Creating other Habitat Types instead of Alkaline Fen

If the optimal hydrological regime of alkaline fens cannot be restored, the drained fen may further be managed as a fen meadow (most commonly – the EU habitat type 6410 Molinia *meadows on calcareous, peaty or clayey-silt-laden soils*). However, this is only possible if the drainage has not caused decomposition of the upper peat layer by mobilising phosphorus and creating an eutrophication effect. In a severely drained fen, the only effective way to eliminate the influence of eutrophication is the removal of the upper substrate layer after the felling of trees. In fact, it means creation of the habitat anew (*see Chapter 15.3.13*).

In exceptional cases, in drained alkaline fens on a shallow peat layer with a large proportion of junipers, where the restoration of optimal hydrological system is not possible, the EU importance habitat 5130 Juniperus communis *formations on heaths or calcareous grasslands* can be created.

15.4.3 Maintenance of Old Ditches

In some cases, distinguishing between an alkaline fen and a few meadows is nearly impossible and depends on the criteria used in their classification. Upon clogging up and overgrowing of the old, hand-dug ditches, fen grasslands transform back into fens. Originally the fen meadows have been alkaline fens that after draining have transformed into habitat type 6410 Molinia *meadows on calcareous, peaty or clayey-silt-laden soils*, or rarely into habitat type 6270* *Fennoscandian lowland species-rich dry to mesic grasslands*.

Prior to restoring the old ditches, such situations must be viewed from a wider perspective. Both habitats – both the fen meadow and the fen – are valuable as regards nature diversity. Both of them depend on mowing or grazing. If the grassland characteristic features still dominate in the area and it is possible to renovate the old drainage ditches so that it resembles the historical situation, then it is most likely easier to ensure regular mowing or grazing in a grassland, rather than in a fen. Therefore, in areas where the characteristics of semi-natural grasslands (vegetation composition, substrate properties) dominate over the fen, and the maintenance of a semi-natural grassland is more realistic, the substrate wetness optimal for semi-natural grassland should be restored by clearing the ditches from the tree and shrub layer and restoring the old ditches (see Rūsiņa (ed.) 2017). However, the restoration of drainage systems in grasslands should not worsen the condition of the neighbouring mire habitats, since they are often a hydrologically joint system.

If the priority in the area is the conservation of fens, then the renovation of drainage ditches should be prevented. By clogging up the ditches, the natural wetness of the fen can recover itself. In such cases, only biotechnical measures are necessary to preserve the open areas (felling of trees, clearing of shrubs, re-current mowing, low intensity grazing). In any case, whether we decide to preserve a fen or to restore a fen meadow, the creation of a new drainage system in any of these protected habitats is not acceptable.

15.4.4 Mowing of Reeds vs. Conservation of Birds

Mowing of reeds in June or July has higher efficiency than mowing in autumn or winter. In the second half of summer the nutrients are accumulated in the roots, thus the removal of the aboveground biomass does not significantly reduce the proportion of reeds in the next years, or even creates the opposite effect – stems become lower, whereas the number of shoots increases. However, it must be taken into account that fens and the adjacent areas may be significant for bird nesting, therefore mowing in June and early July may destroy the bird nests. In areas important for bird conservation, mowing of the reeds should not be performed or it is not allowed earlier than 1 August, which, in turn, makes the reduction of the reed proportion less efficient. Therefore, prior to mowing reeds in alkaline fens and adjacent areas the conservation targets should be prioritised for the particular site.

15.4.5 Protected Plants vs. Protected Habitats

The management of alkaline fens may cause confusion in situations when rare, protected species become expansive and outcompete other habitat specialist species. Such species, especially in the alkaline fens in Coastal Lowland in western Latvia, may be *Myrica gale* (Fig. 15.79) and *Cladium mariscus*. Both species are rare and protected in Latvia, but in the areas where they occur, they can be abundant. In alkaline fens, both species successfully outcompete the species-rich small-sedge vegetation. Their dominance (but not their presence in a small proportion) may cause the extinction of small, light-demanding plants.

Fig. 15.76. A supplemental feeding place of game animals in an alkaline fen. Supplemental feeding damages the naturally nutrient-poor habitat by overloading the substrate with an excessive amount of nutrients and promotes the establishment of ruderal and invasive plant species. Such impact should be prevented by strict control of game management in protected nature territories. In this case, all the organic material must be removed from the area as soon as possible. Photo: A. Priede.

Fig. 15.77. Slow recovery of alkaline fen vegetation takes place in an abandoned tufa extraction area in "Diļļu pļavas" Nature Reserve with alkaline springs. In favourable conditions, the spontaneous recovery of species-rich vegetation may take several decades. Successful recovery might be hindered in cases when the damaged habitat is isolated from the habitats harbouring the target species (calcareous grasslands, alkaline fens). Photo: A. Priede.

Fig. 15.78. *Myrica gale* stands in an alkaline fen in Ķemeri National Park. Photo: A. Priede.

In order to preserve the alkaline fen habitats in the long term, in alkaline fens, where *Myrica gale* and/or *Cladium mariscus* have taken the dominant role in the vegetation, both species can be mown, and there is no special need to preserve all the individuals of those species, e.g. by applying selective mowing. Mowing will reduce their expansion on account of other less competitive plant species (Fig. 15.80). *See also Chapter 14.3.*

Fig. 15.79. Mowing of *Cladium mariscus* and hay gathering in an alkaline fen on the shore of Lake Kaņieris. *Cladium mariscus* has taken the dominant role in the vegetation, outcompeting small-sedge vegetation with *Schoenus ferrugineus*. Photo: A. Priede.

When managing alkaline fens, the mowing of other protected plants, especially if these species are dominating (for example, *Schoenus ferrugineus*, *Carex davalliana*) does not damage their populations, except for in the cases of intense mowing, applied several times per year or mowing by using destructive methods. Individual groups of flowering plants can be preserved to promote the dissemination of their seeds. Since mowing reduces the proportion of expansive, highly competitive plants, removal of biomass is more beneficial in the conservation of rare species than absence of management, which is often wrongly regarded as favourable for rare plant species.

Glossary

Abiotic – non-living.
Acrotelm – one of two distinct layers in undisturbed peat bogs overlaying the catotelm. The acrotelm consists of the living vegetation and partially decomposed peat layer in a bog, where oxygen is available and active processes take place (activity of aerobic bacteria and other microorganisms, degradation of organic substance). In the acrotelm, the water level is fluctuating. See also *Catotelm*.
Alkaline – having a pH value greater than 7. See also *Calcareous*.
Amelioration – (= *Land amelioration*) – land improvement, reducing the adverse effects of climatic conditions and ensuring long-term use of natural resources.
Anthropogenic – created by people or caused by human activity.
Artesian waters – underground pressure waters overlain by one or more layers of impermeable rock or soil.
Benthic – refers to the living organisms living on or in the bottom of the water courses or water bodies.
Berm – an artificial ridge or embankment, for example, a linear rise along a ditch that can consist of soil excavated when digging the ditch.
Biotechnical measures – actions targeted at the maintenance of habitats in a particular state or conditions. Biotechnical measures include, for example, cutting of shrubs, mowing and haymaking. 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.
Block-cutting – a method of peat harvesting when the blocks of peat are cut vertically and stocked in piles for drying over a longer period of time. In the past, blocks were cut using hand work, whereas nowadays cutting is done by machines.
Brown mosses – an ecological group of mosses occurring in rich fens, usually having brownish, yellowish, or golden colour.
Calcareous – see *Alkaline*.
Calciphilous – a plant that has adapted to growth in soils rich in calcium.
Capacity – regarding springs – the water volume given by the spring within a certain time. The capacity is usually measured in litres per second or square metres per second.
Carbonatic – containing calcium carbonate ($CaC0_3$), or carbonate-rich.
Catotelm – the non-living lower layer of peat below the acrotelm (see Acrotelm) in the peat bog that is constantly saturated with water and there are no water level fluctuations.
Connectivity (= landscape connectivity) – the degree to which the landscape facilitates or impedes movement among the patches of the same or similar ecosystems and/or species localities.
Donor area – place which serves as a source of spreading of living organisms into other areas, both regarding natural spreading and targeted, human-assisted spreading, i.e. introduction or reintroduction.
Drainage – here – artificial removal of surface and sub-surface water from an area.
Ecosystem services – various types of benefits the ecosystem provides to society.
Ecosystem – functional unit of the biosphere, which consists of the living organisms in a certain area (biocoenosis or the species community) and non-living (abiotic) environment (soil, climate, hydrological conditions, etc.), and having the energy flow and circulation of substances.
EU priority habitat (*also EU priority protected habitat*) – types of habitat that are in danger of extinction, and that are located in the territory of the EU Member States, and for the conservation of which the communities have a particular responsibility taking into account the proportion of the natural range of those habitats in all Member States. The priority natural habitat types are marked with an asterisk (*) in Annex I of Council Directive 92/43/EEC of 21.05.1992, on the conservation of natural habitats and of wild fauna and flora.
European Union (EU) protected habitat – a habitat that, in terms of the environmental conditions and the species community, conforms to any of the habitat types listed in Annex I of Council Directive 92/43/EEC of 21.05.1992, on the conservation of natural habitats and of wild fauna and flora.
Eutrophication – environmental enrichment with plant nutrients (see *Plant nutrients*) in a water body or stream, or soil, caused by natural processes or human activities.
Expansive species – a native species that is able to quickly spread and dominate over the other species. These species only become expansive in certain conditions (for example, change of the management method, eutrophication, etc.).
Favourable conservation status – the natural range and the area of the habitat is stable or expanding; the specific structures and functions of the habitat that are required for the long-term existence of the habitat exist, and it is expected that they will exist in the nearest future; the conservation status of the habitat specific species in the area of the Member State of the European Union is favourable.
Fen (= *minerotrophic mire*) – a type of wetland that mainly receives nutrients from the groundwater.
Fen meadow – a damp lowland meadow (or pasture), which develops if a fen is drained in a traditional way by hand-dug shallow ditches. Fen meadows were/are traditionally managed in the same way as hay meadows and pastures. The vegetation is usually composed by species of *Molinion*.
Fragmentation – here – the reduction of the landscape or habitat into smaller units that have changed in shape and become mutually isolated. The opposite meaning of the term “connectivity” (see also *Connectivity*).
Groundwater – the water beneath the surface of the ground, consisting largely of surface water that has seeped down, not overlain by a layer of impermeable rock or soil. The groundwater lies in the upper constant horizon of the groundwaters, located above the upper water holding layer.
Gyttja (= *sapropel*) – organic lake sediment formed by the residues of aquatic plants and animals. In the admixture there are also compounds of clay, sand, carbonates.
Habitat – the concept used in this edition for the purpose of the Law on Species and Habitat Conservation. A habitat is a set of specific abiotic and biotic factors in an area where a species exists in every stage of its biological cycle.
Habitat creation – a set of biotechnical measures aimed at the creation of the environmental conditions, structure (species composition, age structure, etc.) necessary for the habitat, and the introduction of a species in a place where the habitat has never existed. This also applies to sites where the habitat has once existed, but the environment has been completely transformed and no features of the habitat have been preserved.
Habitat management – a set of biotechnical measures aimed at the maintenance of the habitat in a favourable conservation status.
Habitat restoration – a set of biotechnical measures aimed at the restoration of the environmental conditions, structure (species composition, age structure, etc.) and species in a place where the habitat has once existed or still exists, but is in poor 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.
Hollow (= *bog hollow*) – here – a negative terrain form (depression) in the mire.
Invasive species – an invasive alien species that can quickly reproduce in the wild, invade large areas and dominate over the native species. Usually, the spread of the invasive species in natural or semi-natural ecosystems is related to the decline of biodiversity, economic loss, or threat to human health and ecosystem services.
Land amelioration – see *Amelioration*.
Limonite – an iron ore consisting of a mixture of hydrated iron(III) oxide-hydroxides in varying composition. It is formed in the processes of weathering and iron compound migration, it petrifies from the springs, mires, lakes, and sea water.
Littoral – the part of a sea, lake or river (here – lake) that is close to the shore.
Minerotrophic mire – see *Fen*.
Mire – here – a general term for boggy, marshy, wet areas (bogs, transitional and quaking bogs, fens).
Natura 2000 site – a protected area included in the Natura 2000 network – a joint network of the protected areas of the European Union countries, which aims at the preservation of the most endangered species and habitats of Europe, which are registered in Directive 2009/147/EC of the European Parliament and of the Council of 30 November 2009, on the conservation of wild birds, and Council Directive 92/43/EEC of 21 May 1992 on the conservation of natural habitats and of wild fauna and flora.
Nitrophilous – preferring or thriving in a habitat rich in nitrogen (regarding organisms).
Nutrients – see *Plant nutrients*.
Ochre – powder-type limonite (see *Limonite*), yellowish, yellow-brownish of various shades, used in the manufacturing of colours.
Oligotrophic – poor in nutrients, especially in nitrogen and phosphorus (soil, water).
Ombrotrophic – rain-fed; soils or vegetation receiving the water and nutrients from precipitation (see also *Raised bog*).
Peat milling – a method of peat harvesting that requires a special cutting operation, which results in a loose crumb-like structure in a thin layer across the field. This structure is then air dried and harvested using the vacuum method.
Plant nutrients – here – chemical elements and compounds required for plant growth and development. See also *Macroelements*.
Pool (= *bog pool*) – a small open water body in the bog.
Post-harvested peatland – a peat extraction site with completed or partially completed extraction by

using different peat extraction methods.

Protected habitat – a habitat (see *Habitat*), which is included in Cabinet Regulation No. 350 of 20 June 2017, On the List of Specially Protected Habitats, and/or Annex I of Council Directive 92/43/EEC of 21 May 1992 on the conservation of natural habitats and of wild fauna and flora.

Protected species – a species that is included in the list of protected species of Latvia (Cabinet Regulation No. 396 of 14 November 2000, On the List of Specially Protected Species and Specially Protected Species Whose Use is Limited) and/or in the Red Book of Latvia, and/or in the annexes of Council Directive 92/43/EEC of 21 May 1992 on the conservation of natural habitats and of wild fauna and flora.

Quaking bog – an unsteady layer composed of plants and their roots on the surface of overgrown water bodies (lakes).

Raised bog – a rain-fed mire dominated by sphagnum mosses as the main peat formers. The raised bogs develop from the fens and are considered as the climax stage of succession. They are usually dome-shaped with one or more cupolas. See also *Ombotrophic bog*.

Recultivation – here the definition from the national regulatory enactments in Latvia is used: recultivation is the restoration of the initial value of the degraded site to prevent threats to environmental quality, human health and life, as well as to facilitate the integration of the post-mining area in the surrounding landscape.

Reintroduction – here – restoration of the (locally) extinct species.

Renaturalisation – an after-use option in post-mining areas including post-harvested peatlands; restoration of the characteristic environment (non-living environment, vegetation, fauna). It is used here to describe the restoration of a mire-specific environment within the sense of the national regulatory enactments.

Ruderal plant – weedy plants; plants that first colonise disturbed grounds (landfills, abandoned sites, construction sites, etc.).

Sapropel (= *gyttja*) – see *Gyttja*.

Saprophytic – micro-organisms, fungi, plants feeding on the residues of dead organisms.

Seepage spring (= filtration spring, seep) – spring with small flow rate in which the source water has filtered through permeable ground. The seepage spring looks like a wet soil patch, can seasonally dry out.

Specialist species, specialist – here – a species that has adapted to a narrow range of environmental conditions. Due to the limited availability of the conditions, specialist species are often rare.

Spring – a natural, concentrated outlet of the subsurface waters (artesian or groundwaters) on the land surface or under the water.

Spring capacity – see *Capacity*.

Spring fen – fen that has formed around the spring discharges with spring-specific species composition and, depending on the mineral contents of the springs, with the presence of fen species (e.g. calciphilous plant species in calcareous spring fens).

Succession (= *ecological succession*) – a process of change in the species structure of an ecological community over time. It means that the habitats replace each other, for example, a fen transforms into a transitional mire, and then into a raised bog. Primary succession occurs in places where there has not been any vegetation at all, for example, on bare sand in a quarry. Secondary succession occurs in sites with pre-existing soil, but where the vegetation has been destroyed and the specific conditions of the abiotic environment have been kept and part of the species (seeds or vegetative propagules) are preserved.

Target habitat – habitat at which the restoration or management measures are aimed.

Target species – species at which the restoration or management measures are aimed.

Transitional mire – a type of minerotrophic mire, where the impact of the groundwater in the mire recedes, but the role of the atmospheric precipitation increases. Both the species of acidic, nutrient-poor environment, and the species of richer soils can be found (various sedges, cotton-grasses, sphagnum mosses, brown mosses).

Umbrella species – here – a species whose requirements include those of many other species. Umbrella species characterise the environment, thus it can be used in detecting the ongoing changes in habitat quality over time and indirectly testify to the condition of other species in the habitat. Umbrella species are species selected for making conservation-related decisions, typically because protecting these species indirectly protects the many other species that make up the ecological community of its habitat.

Vascular plants – flowering plants and ferns; plants with vascular tissues.

Woodland key habitat – a site in the forest, which provides for the existence of rare and endangered species having highly specific demands for the habitat. The forest structures and features essential for these species are most commonly found in places where the forest has continuously existed for hundreds of years and where no or insignificant management has been carried out for a long time. Similar sites are distinguished by a high concentration of endangered species, mainly flowering plants, bryophytes, lichens, fungi as well as insects and molluscs.

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Annex

Indicative costs for the most commonly applied restoration and management methods of the mire habitats

The costs have been summarised by using recent (2010–2015) data, interviewing the project implementers and practitioners. However the costs are approximate and can vary significantly depending on various circumstances. The table below indicates the average costs and the possible variations thereof. The costs can vary considerably depending on the geographical location, interest of the contractors and other factors. For all the methods recommended in the guidelines it is not possible to define the costs, especially those that have not been ever used in Latvia.

Method	Aproximate cost	Units	Factors affecting the total cost
Rewetting (includes felling of trees on the berms along ditches and **filling up of ditches**), excluding the planning and technical project costs	600	EUR/100 m	• The availability of the contractors and equipment in the particular region (transportation of the equipment over long distances can significantly increase the costs); • the revenues gained from the sold timber (felling the trees on the berms along ditches if provided) – can reduce the total cost, if the volume of timber is large and economically realisable; • additional surveys (a hydrologist, a species and habitat conservation expert) and technical project preparation costs.
Rewetting (includes felling of the trees on the berms along ditches and **building of peat dams with an excavator**), excluding the planning and technical project costs	40	EUR/pcs.	*See regarding the filling up of ditches.* • Distance to the restoration area (transportation cost); • cost of access road renovation (if necessary); cost of tree felling; • the width and depth of the ditches (volume of peat required for the building of one dam).
Rewetting (felling of trees on the berms along ditches and **installing of wooden dams by manual work**), excluding the planning and technical project cost	500–1300	EUR/pcs.	• Distance to the restoration area (transportation cost); • cost of tree felling in terms of person-days; • the width and depth of the ditches (volume of peat and wood required for the building of one dam).
Rewetting (felling of trees on the berms along ditches and **manual building of peat dams**), excluding the planning and technical project cost	70	EUR/m³	• Distance to the restoration area (transportation cost); • cost of person-days, etc.); • the width and depth of the ditches (volume of peat required for the building of one dam).
Removal of trees and shrubs in very wet, marshy places with difficult access, burning the cleared shrubs on site or moving out of the area	800–1000	EUR/ha	• Availability of contractors in the particular region; • the amount of work (the volume and number of trees to be felled; the volume of shrubs to be cleared); • site accessibility – if the site cannot be accessed by road, the transportation of the tools and reaching the site are encumbered, which may increase both the time required for implementation and the total cost.
Removal of trees and shrubs in moderately difficult conditions, burning the cut shrubs on site or moving out of the area	600–800	EUR/ha	• Availability of contractors in the particular region; • the amount of work (the volume and number of trees to be felled; the volume of shrubs to be cleared); • site accessibility.
Manual cutting of the shrub sprouts with a brush-cutter (with collection)	150–300	EUR/ha	• Availability of contractors in the particular region; • the amount of work (the volume and number of trees to be felled; the volume of shrubs to be cleared); • site accessibility.
Mowing with special equipment (a tractor equipped with wide wheels or tracks), with the mechanised collection of the fresh biomass or hay	200–350	EUR/ha	• Availability of contractors and equipment in the particular region; • site accessibility. • the complexity of the working conditions.
Mowing with special equipment (a tractor equipped with wide wheels or tracks), with the mechanised collection of the fresh biomass or hay	200–250	EUR/ha	
Mowing with tractor equipment, collecting the mown grass in relatively dry places	500–700	EUR/ha	
Manual mowing with a brush-cutter, collecting the mown grass, in complicated conditions using hand work	1100–1600	EUR/ha	• Availability of contractors and equipment in the particular region; • access possibilities to the site.
Removal, composting, burning of the fresh biomass or hay (if the site accessible to vehicles)	40–50	EUR/ha	
Manual mowing of invasive plants with a brush-cutter	300–400	EUR/ha	• The density of plant stand, number of invaded patches; • the development stage of plants; • the soil wetness (difficulty of work conditions).
Digging out of invasive plants, piercing of the roots	300–500	EUR/ha	
Manual demolition of beaver dams	80	EUR/m³	• Availability of contractors and equipment in the particular region; • the volume and the character of the dams.
Demolition of beaver dams using an excavator or other equipment	5	EUR/m³	• Site accessibility by vehicles; • the volume and the character of the dams; • soil wetness.