Protected Habitat Management
Guidelines for Latvia

Forests

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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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Content

Introduction

(A. Priede)

The guidelines for the conservation, management, and restoration of protected habitats were developed during the period from 2013 to 2016 within the framework of the European Commission programme LIFE+ funded project "National Conservation and Management Programme for Natura 2000 Sites" (NAT-PROGRAMME, LIFE11 NAT/LV/000371) implemented by the Nature Conservation Agency. The purpose of the guidelines is to provide 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 emphasis of the guidelines is on the conservation, restoration and maintenance of a favourable conservation status of habitats, which have the required environmental conditions and are the home of native species. The guidelines are intended for the planning and implementation of habitat protection, conservation and restoration in Latvia, and it is one of the tools for the conservation of European Union protected habitats. The guidelines and active approach that follows is one of the ways 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 have been issued in six books, each devoted to a group of habitats. This edition provides recommendations for maintaining the natural diversity of forests.

The guidelines were prepared by experts involved in the project, bringing in other experts. All the interested parties could follow the process of developing the guidelines by giving opinions and recommendations, as well as commenting on the draft guidelines on the website and participating in meetings and seminars of working groups.

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. This book can also be read by those who want to explore and better understand the natural values of Latvia – students, friends of nature, and other interested parties.

The authors of the guidelines hope that the book will be both applicable and useful, and be a step towards a deeper understanding of ecosystems and provide an integrated approach to the conservation of the natural values of Latvia.

Part I

Chapter 1. Forest Habitat Characteristics

World ecosystems are integrated in biomes, which are wide regions with a relatively similar climate, soil conditions and living organisms. In Central and Northern Europe, the dominating types of terrestrial ecosystems are temperate broad-leaved forests (nemoral forests) and the northern coniferous forests (boreal forests). The boundary between these ecosystems is a wide transition zone called the boreo-nemoral biome, which includes the territory of Latvia. In Latvia, most of its natural terrestrial area (except the dynamic sea coast and raised bogs) develops into forest as the final succession stage (climax). Forest is a complex ecosystem, which includes a variety of interrelated elements, but the key elements here are trees, which are the main producers of organic matter. More than 50 species of trees and shrubs are found in Latvian forests but only nine species can dominate in the forest stand overstorey – *Pinus sylvestris, Picea abies, Betula pendula, Betula pubescens, Alnus incana, Alnus glutinosa, Quercus robur, Fraxinus excelsior* and *Tilia cordata*.

In a broad sense, a forest consists of many stands that have originated at different times, their growth and development have had different duration, and their composition has developed under different historical and economic conditions. To characterise forest ecosystems and habitats, various classification systems are used that reflect tree species composition, soil properties, plant species complex, natural processes etc. of the forest stand. In Latvian forestry forest typological classification is widely used for the characterisation of forest diversity. Currently in forest typology K. Bušs' system with 23 forest site types (Bušs 1976, 1981) is used. This forest typology is based on soil properties and moisture regime that determine the growth conditions and the characteristic species composition (Liepa et al. 2014).

Depending on moisture conditions, forest site types are divided into five forest type orders:

- forests on dry mineral soils;
- forests on wet mineral soils (organic layer thickness not exceeding 30 cm);
- forests on wet peaty soils (organic layer is thicker than 30 cm);
- forests on drained mineral soils;
- forests on drained peat soils.

Depending on soil (substrate) fertility, forest site types are divided into three groups differing in site fertility:

- forests on nutrient-poor soils *(oligotrophic* forests) – 10.2% of the total forest area;
- forests on substrates of moderate fertility (*mesotrophic* forests) – 56.1% of the total forest area;
- forests on nutrient rich substrates (e*utrophic* forests) – 33.7% of the total forest area (Laiviņš, *without date*).

Depending on human intervention and historical use, naturalness of a forest can be evaluated in a scale starting from intact natural forests to artificially established plantations of alien tree species (Peterken 1996). The presence of structural elements typical for natural, old-growth forests in a forest stand is a significant and sometimes decisive indicator of quality. The diversity of structural elements is also indicative of natural stand development in cases where a stand has been planted rather than regenerated naturally. Structural elements serve as habitats for a large number of various specific species that are usually not found in intensively managed forests because natural structure elements are too few (Lārmanis 2013a). The presence of structural elements indicates potential compliance with the criteria of a Woodland Key Habitat and high ecological value (Ek et al. 2002).

Protected habitat types of European Union (EU) importance are identified by stand structure, dominant species or their typical combinations, soil moisture conditions and topographical characteristics. Biologically valuable forests in Latvia belong to 11 EU protected habitat types:

- 9010* *Western Taiga*[1],
- 9020* *Fennoscandian hemiboreal natural old broad-leaved deciduous forests* (Quercus, Tilia, Acer, Fraxinus *or* Ulmus*) rich in epiphytes*,
- 9050 *Fennoscandian herb-rich forests with* Picea abies*,*

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

- 9060 *Coniferous forests on, or connected to, glaciofluvial eskers,*
- 9080* *Fennoscandian deciduous swamp woods,*
- 9160 *Sub-Atlantic and medio-European oak or oak-hornbeam forests of the* Carpinion betuli*,*
- 9180 * Tilio-Acerion *forests of slopes, screes and ravines,*
- 91D0 *Bog woodland,*
- 91E0 * *Alluvial forests with* Alnus glutinosa *and* Fraxinus excelsior (*Alno-Padion, Alnion incanae, Salicion albae*),
- 91F0 *Riparian mixed forests of* Quercus robur, Ulmus laevis *and* Ulmus minor, Fraxinus excelsior *or* Fraxinus angustifolia*, along the great rivers (*Ulmenion minoris*),*
- 91T0 *Central European lichen Scots pine forests.*

The most significant structural elements of a natural forest are biologically old or large-dimension trees, stumps and snags, large logs, hollow trees, canopy gaps, uneven age structure and indicator and specific species of woodland key habitats.

Biologically old or large-dimension trees are trees whose biological life is coming to an end. Depending on the species, it can be 60-70 years for an aspen, 300 years for a pine, and 400-600 for an oak (Ek et al. 2002; Nikodemus, Brūmelis (ed.) 2011). Specific light and microclimatic conditions occur when such trees are located in forest stand gaps. Many species (beetles, moss, lichens, snails, etc.) have adapted to these conditions and have specialised environmental requirements, but low ability to adapt to rapid climatic changes. Many of these species have become rare due to the low abundance of sunlit large trees in commercially managed forests and the lack of ability to colonise younger trees or trees of medium and small dimensions. These specialist species require the continuity of biologically old trees, in other words, the continued availability of suitable trees within the dispersal range of the species.

A tree can be considered as biologically old if, firstly, it has reached a mature age from a forestry point of view but is not completely healthy – it has hollows, polypores, many dead branches, i.e. its biological life is coming to an end. Such biologically old trees may not even be very old in years, e.g. biologically old aspen can be only 50-60 years old. Secondly, as biologically old trees can be considered really old trees whose active growing period has ended, their annual growth is very slow, but the tree's life can still continue for several decades or even centuries. In the inventory methodology of Woodland Key Habitats (Ek et al. 2002) it is recommended to consider externally healthy trees as biologically old if their age is greater than a specified number of years, e.g. for pine and oak trees – an age of more than 140 years old. Slow-growing small-dimension biologically old trees are not rare in wet coniferous forests, where small *Picea abies* trees grow very slowly, with short intervals between branch whorls, and annual rings that are sometimes microscopic.

Large-dimension old trees play an important role not only as habitats of rare species, but also for climate regulation. They have an important role in carbon storage. Large trees have high biomass and thus a larger amount of stored carbon than in young trees. Such trees die slowly, their woody debris remains for a long time, which means that the carbon that is stored into the tree's biomass is released into the atmosphere very slowly, which is important globally for the reduction of the greenhouse effect (Kauppi et al. 2015).

Snags and stumps. As a result of abiotic or biotic factors and age, the physiological life of a tree ends, which can occur rapidly or slowly, creating standing dead wood. A snag retains its branches, while a stump does not. In some conditions snags of some tree species can persist for a very long time, for example, a dead oak may stand for decades. Standing dead pines in dry conditions also persist for a very long time; their wood has specific characteristics and serves as a substrate for rare lichen species such as *Chaenotheca phaeocephala*.

Fig. 1.1. A dead large-dimension pine *Pinus sylvestris*. Photo: S. Ikauniece.

Also after **fire**, dead pine trees remain standing for a very long time (Fig. 1.1); some rare lichens grow on charred dead wood, and their presence can be used as evidence of past fire that occurred even several decades before. During a fire, the chemical composition of pine wood is altered, and after colonised by species that do not occur on other types of dead pine woody debris (Alén et al. 1996; Hosoya et al. 2009), for example, the rare lichen *Hypocenomyce friesii* (Moisejevs 2016). Stumps and snags provide suitable habitat for many invertebrates and fungi; many bird species utilise snags and stumps for the search of prey, e.g. *Dendrocopos leucotos* (Petriņš 2014).

Large logs is coarse woody debris formed when the tree dies and falls to the ground. Logs may consist of whole tree stems or parts, as well as large branches. They decay at different rates, depending on the tree species and environmental conditions. For example, large oak logs can remain in an initial decay stage for a very long time, even for decades.

Dead wood is colonised by various plant and animal species, including invertebrates, fungi, moss. Many insect species live in the fruit bodies of fungi, mycelium or decayed wood. A large proportion of rare moss and fungi species are found in dead wood in late decay stages (Ek et al. 2002). Many rare species have a very low dispersal range. It is therefore important that suitable substrate necessary for specialist species is available within the dispersal range, for example, dead wood of a suitable tree species at the particular decay stage required for colonisation (Vilks 2014).

Fig. 1.2. *Phellinus populicola*. Photo: S. Ikauniece.

There are many fungi species that utilise coarse woody debris (Fig. 1.1). Many insect species live in or feed on fungal fruiting bodies. Fungi weaken trees and promote the onset of mortality, and thus contribute to the production of dead wood. The wood of a growing, healthy tree is hard. Birds cannot make hollows in these trees; fungi causes rotting of the stem and changes in wood properties, enabling the construction of cavities.

Hollow trees. Hollows are important for many bird and invertebrate species. Hollows are cavities in tree stems, which are at least 5 cm deep. Large hollows in broad-leaved trees are probably the most important elements regarding protected and rare species. However, small holes are used by smaller birds for nesting. For example, *Jynx torquilla* uses the cavities created by *Dendrocopos minor*. *Glaucidium passerinum* nests in cavities formed by woodpeckers; this species does not make its own cavities (Petriņš 2014).

Canopy gaps. When a tree or a group of trees die in a mature or middle-aged forest stand, canopy openings are formed, thus allowing sunlight to penetrate to the ground layer. Canopy gaps are created by natural disturbance and self-thinning of the forest stand. They are common in broad-leaved forests, most wet forests and *Picea abies* forests. High air humidity and increased light are characteristic of canopy gaps. Forest regeneration is promoted by gaps; a sapling layer forms resulting in the development of an uneven-aged stand structure.

Canopy gaps are also very important in forests on dry mineral soils, such as pine forests where biodiversity is promoted by well-lit and warm conditions. In forests on dry mineral soils, at least 3-5 openings per hectare are necessary to maintain structural diversity (Ek et al. 2002).

Uneven-aged stand structure. The presence of both young and old trees in a forest stand indicates a diverse stand structure formed by natural disturbances and, probably, less intensive forest management. However, an uneven-aged stand structure can also develop in forests that have been managed using selective felling for a long period of time. Identification of a stand as uneven-aged should not be based on the presence of several younger or older trees, but on the presence of trees of various ages in the whole area of the stand,

Fig. 1.3. Indicator species of woodland key habitats – *Jungermannia leiantha*. Photo: S. Ikauniece.

Fig. 1.4. Specific species of woodland key habitats – *Herricum coralloides*. Photo: S. Ikauniece.

with more than two layers – at least in the canopy, sub-canopy and understorey.

Indicator species and specific (specialist) species of Woodland Key Habitats are species, the existence of which depends on specific habitats and conditions (Fig. 1.3, 1.4). Usually, the identification of a protected forest habitat in natural forest based on a specific species means that the habitat contains rare species. They depend on specific conditions that will disappear if the habitats are managed or used in a manner unsuitable to the species (Lārmanis 2013a), including non-intervention. According to the inventory methodology of woodland key habitats, such species were called special woodland key habitat species (Ek et al. 2002), but later, in the Latvia Interpretation manual of European Union protected habitats the term "specific species" is used (Auniņš 2013), and is also used in this book.

The presence of Woodland Key Habitat indicator species is associated with specific conditions in the forest. They prefer forest with a high level of naturalness, but their habitat requirements are not as particular as those of habitat specific species. Indicator species in woodland key habitats are common, often with high abundance. They can also be present in commercially managed forests or young, planted forest stands, but usually with low abundance (Ek et al. 2002). Therefore, when conducting a habitat survey, both the presence and number of woodland key habitat indicator species needs to be taken into account. No strict boundary exists between threatened specific habitat species and indicator species, as their requirements are similar.

Chapter 2. History of Use and Protection of Forest Habitats in Latvia

2.1 Use of the Forest at Different Times

Latvian forests developed over a period of many thousands of years; their development began with woody plants that appeared about 12 000 years ago after glacier retreat. After the Ice Age, the harsh tundra climate of Latvia was replaced by a warmer climate; trees appeared that nowadays are characteristic of a warmer climate zone – *Pinus sylvestris, Populus tremula, Betula* spp., *Picea abies*. In the even warmer Atlantic period approximately 5000 years ago, oak, lime, hornbeam and yew trees were widespread (Liepa et al. 2014).

Until the late Neolithic period (around the year 2300 BC), forest was one of the most important sources of food provision; trees were often cut selectively. People used forests in the vicinity of their settlements, which were typically at lakes or rivers; settlements could exist for centuries in the same place (Hamilton 1997; Williams 2000). Attitudes towards forests and the use thereof were associated with living traditions. For example, in the Iron Age rights of forest use were rooted in people's consciousness for centuries. The forest together with bogs, lakes and rivers belonged to the Earth of God that everyone was entitled to use, but had no ownership rights. Up to the 16th century and even later in the territory of Latvia, except for the plains of Zemgale and parts of Sēlija Regions, relatively large forest landscapes had survived, more than in Central European countries. The inhabitants of the territory of Latvia were free to use forest for their own needs (Strods 1999).

Restrictions began to be established with the rise of livestock farming and agricultural development in more densely populated areas. People started to establish agricultural land in new areas with fertile soils. The community attitude towards forests also changed. Selective cuts were replaced by slash-and-burn agriculture. Slash-and-burn agriculture initiated the onset of a major change in forest land use, not only in Latvia but throughout Europe (Hamilton 1997; Williams 2000; Kaplan et al. 2009).

Creation of agricultural land by slash and burn (Fig. 2.1) was achieved by the complete harvest of forest. Burning of branches, stumps, shrubs and ground vegetation enriched soil with minerals and decreased organic matter content. Harvest of planted crops also depleted the soil of nutrients causing deficiency. Cultivation was then terminated, and the area was left to overgrow naturally with forest.

Fig. 2.1. Slash-and-burn forest clearing in the late 19th century. Drawing by D. Segliņa

As a result of natural overgrowing or succession, stands of pioneer species developed; *Pinus sylvestris, Betula spp., Alnus incana* and sometimes *Quercus robur* grew on the abandoned land. The changes in tree species composition occurred over large areas, as the cleared land could only be used for 2 to 5 years before the depletion of nutrients, creating a need to clear a new area. During that period of time, consumption of wood increased for building, heating and for manufacture, e.g. for pottery firing. During the Iron Age, the development of agriculture expanded as the quality of tools improved, resulting in more rapid deforestation and slash-and-burn forest clearing (Kaplan et al. 2009). In Latvia deforestation affected Zemgale plain the most – where large fields were cultivated in fertile soils by logging broad-leaved forests (Zunde 1997); for example, in 1790, forest area in Zemgale Region was only 23% (Fescenko et al. 2014). Slash-and-burn agriculture lasted for a long time in various European countries, and even though it decreased significantly in the 19th century, there were, however, sites, e.g. in Finland, where it was used until the 1940s. (Lovén, Äänismaa 2004). Also, in the 1920s new farmers in Latvia still cultivated the land allocated to them using slash-and-burn forest clearing, as evidenced by historical photos and verbal records of people of the early 20th century (Vaivods 2008).

The volumes of forest use and cutting were significantly affected by changes in land law that occurred with the introduction of feudal rights in Latvia after the 13th century. Vassals obtained the right to collect fees in administrative areas, established manors and gradually took away the land that was cultivated by the local people. Farmers had to cultivate new arable land. Slash-and-burn forest clearing, that had decreased previously, now resumed more intensively. In the 15th century, manors started exporting more and more timber and agricultural goods, and the use of fuel wood increased. This resulted in the gradual disappearance of large and undisturbed woodlands (Zunde 1999). During the plague in Europe in around 1350, as the human population decreased, deforestation rapidly declined, and the forest area increased in many places (Kaplan et al. 2009). A greater decline in the human population having a major impact in Latvia took place in the latter half of the 16th century, when there were prolonged plague epidemics during the Livonian War. In the time that followed, many regions were covered by tree pioneer species that established in areas of previous forest (Zunde 1999; Gerhards 2011). In connection with events that occurred in the Polish-Swedish war in the early 17th century, land ownership verification and partial manor forest inspections were carried out for the first time, which may be regarded as the initial period of forest management in Latvia (Zunde 1999).

An important period in forest history occurred with the development of shipping and shipbuilding in the 17th century, especially in the northern Kurzeme Region, where many ships were built (Zalsters 2002; Freiberga (ed.) 2011; Ķeniņš 2014). As shipbuilding required a large quantity of wood, intense cutting of the *Quercus robur* stands suitable for shipbuilding started in Latvia (Zunde 1999).

The rapid development of Rīga City had a large impact on economic development, since wood was needed for the construction of buildings, as ground cover, for the construction of port wharfs and as fuel. A large quantity of fuel wood was consumed in the manufacturing industry, for iron, copper, tar, brick and glass kilns (Ķeniņš 2014). As cities formed and trade in timber developed, increased deforestation began along the greater rivers and then along smaller rivers, which were used for transporting the felled logs. The rivers Pededze, Veseta, Susēja, Roja, Irbe, Saka, Viesīte and others were used for this purpose. Log driving along the tributaries of the River Lielupe had already started during the period of the Duchy of Courland (Kurzeme), and the most dangerous places for log driving were improved in 1859 by the straightening of sharp river bends and levelling of rapids (Deksne *without date*.). Logs were drifted along the River Bārta to Lake Liepāja, and further on the lake to Liepāja City. In the 1920s there were several tree sawmills that processed *Quercus robur* trees from the Bārta River basin (Bušmane 2011). Due to clearcut belts along the river banks, large forest areas were fragmented into smaller continuous areas (Zunde 1999).

As the demand for timber increased and the forest area decreased, forest owners, i.e. noblemen, wanted to limit the use of forest for farmers' needs. An interest in faster forest regeneration and organised forest supervision began, that had already been introduced in some places in Kurzeme Region in the 16th century. At the end of the 17th century and in the early 18th century a rapid decline in human population took place as a result of famine and plague (Gerhards 2011), and thus the agricultural land was abandoned and overgrew with forests.

Around the mid-18th century, the population of Latvia had risen again, especially in Latgale Region, where extensive immigration from Belarus and Russia occurred (Baltiņš 2012). As the economy developed and farming intensified, slash-and-burn forest clearing resumed and timber sales and consumption increased significantly. At the end of the 18th century the forest area of Latgale was assessed to be around 40-35%, in Vidzeme around 50% (Zunde 1999). Forest area also continued to decrease in the 19th century; broad-leaved tree species were almost completely cut, but the artificial regeneration of *Pinus sylvestris* was promoted. In order to increase forest stand yield, the drainage of wet forests started in the 19th century, e.g. in the vicinity of Cēsis, targeted forest drainage was implemented in 1830. Starting from the 1850s in the forests of Rīga, the most extensive drainage project for that period of history was carried out – an 11- km-long channel was created in the Cena forest management unit (Zālītis 2006).

At the beginning of the 20th century in Lielvidzeme, which included part of the northern Vidzeme Region and southern Estonia, the forest area was slightly over 20%, whereas in Kurzeme Region it was about 30% (Zunde 1999). Rapid reduction of forest area and land-use changes across Europe were directly associated with economic and domestic policy changes; agricultural land area expanded, new farming technologies were introduced (Jepsen et al. 2015), and cities developed. Also, during and after World War I, a large amount of timber was required in war infrastructure, and later for the restoration of buildings (Zunde 1999).

When the Republic of Latvia was established in 1918, forests had been ruthlessly cut over the previous decades. Forestry records reported large amounts of decaying wood (many dry trees, trees damaged by pests, broken and uprooted trees) and large burnt areas. These were valued as negative factors from the point of view of forestry (Vasiļevskis 2007), but they were certainly significant forest structure elements for the conservation of biodiversity. In comparison with other European countries, in the early 20th century Latvia had one of the largest forest areas. Forests in Latvia covered 26.8% in the year 1929; further increase of forest area was very slow until World War II. Forest harvest, as well as artificial forest regeneration, was very intense, with an emphasis on the regeneration of *Pinus sylvestris*, which often occurred in unsuitable soil and climate conditions. Land drainage was also resumed (Zunde 1999; Zālītis 2006). In the 1920s, comprehensive forest organisation planning and a forest management practice standard were introduced. Since that time, it has been possible to conduct objective and detailed investigation of woodland history and structure (Lūkins, Nikodemus 2011). In the 1920s, through agricultural reform, large forest areas were allotted for farming, which in many cases were not suitable for agriculture; in those cases foresters and state policy recommended that the areas should be afforested again (Vasiļevskis 2007).

Increase in forest area continued much faster after World War II, when due to the repression of rural residents and collectivisation many fields were abandoned and overgrew with secondary forests. In 1961, the forest area was assessed to be almost 36%; the proportion of *Betula spp*. stands had increased from 15 to 23%, compared to 1935. In 1983, forest area in Latvia was around 41%; in the period from 1924, the proportion of *Betula spp*. and *Alnus incana* stands had increased, while the area of *Alnus glutinosa* had decreased (Bušs, Vanags 1987).

The overgrowing of agricultural lands and artificial afforestation continued during the post-Soviet period. At the end of the 20th century when the collective farming system collapsed and new land reform land property rights were regained, many new land owners chose to not continue with agricultural production. At the beginning of the 21st century, promoted by EU support payments to private land owners, extensive afforestation of the agricultural land was carried out, mostly by planting *Betula pendula* and *Picea abies*. For example, the afforested area in 2015 was 1717.89 ha (VMD 2015a). The forest area of Latvia had reached 51% in 2015, of which *Pinus sylvestris* stands covered 34%, *Betula spp*. stands covered 31%, *Picea abies* stands covered 18%, *Alnus incana* stands covered 7% and other tree species had a smaller area (VMD 2015a). Growth in young forest areas is predicted to continue, given the ongoing overgrowing of agricultural land and artificial afforestation, which is already causing a shortage of agricultural lands in some regions. At the same time, the area of mature forest stands that are older than 100 years represent only 11% of all forests (VMD 2015a).

2.2 History of Forest Conservation

The oldest known legislation on forest protection in Latvia was issued by a Livonian Order Master in the early 16th century. It strongly prohibited deforestation, for which a fine was levied (Bušs, Vanags 1987). As influenced by German forestry traditions, very strict laws on hunting and the use of forest trees existed when the forest survey system was created in the 16th and 17th century (Strods 1999).

As the shipbuilding and timber trade developed, intense deforestation of the Baltic Sea coast began, which was particularly intense in the 19th century. Extensive clear-cutting and forest fires contributed to the formation of large sandy areas and shifting dunes. Open rolling sand dunes buried both agricultural and residential areas. To limit the movement of sand and forest cutting along the sea coast, in 1838 the Office of Vidzeme governorate established a belt for soil and forest protection 320 m wide, in some places more than 500 m wide (Strods 1999).

The mid-19th century in Latvia was marked by a variety of community activities. In 1845, the Riga Baltic German Nature Researchers Society was established which brought together researchers of Baltic nature. Its aims were research, development of collections and popularisation of natural sciences. The most famous nature researcher of that time, botanist Karl Reinhold Kupffer, in the society meeting of 11 January of 1910 proposed to establish a nature reserve or a "region of natural beauty" on Moricsala Island, in Lake Usma.

On 6 June of 1912 Moricsala (Fig. 2.2) was removed from the state forest list of the Russian Empire and was declared as a nature monument of size 83 ha, by putting it under the supervision of the Riga Nature Researchers Society. The Moricsala Reserve is not only the first protected nature area in Latvia, but also the second oldest in the Russian Empire, which Latvia was a part of in that period of time (Reihmanis (ed.) 2009; Pilāts, Laiviņš 2013).

The first international conference on nature conservation was held in Bern in 1913, after which the concept "nature conservation" was introduced to broader use, although already well before the world was aware of various nature conservation measures and the terms to denote them by. German forest managers created the first forest reserve in 1836 in the territory of the present Czech Republic (Nikodemus, Brūmelis (ed.) 2012). In India, nature conservation measures were started in 1842 under the leadership of botanist Alexander Gibson, who created a forest protection programme based on scientific principles. It was followed by the large-scale permanent forest protection programme by Lord Dalhousie. Its model also spread to other countries, including the United States, where the first national park, Yellowstone, was established in 1872 (Singh et al. 2011). In 1888, a law on forest protection was also adopted in the Russian Empire. In 1909, two nature protection-related laws were issued in Sweden (Nikodemus, Brūmelis (ed.) 2012). Both globally and in Latvia, the so-called method of conservation was considered the best, and it was assumed that very beautiful and unique natural objects as well as rare and threatened species must be preserved.

Fig. 2.2. Moricsala Nature Reserve. Photo: A. Priede

Before World War I, 52 forest territories with a total surface area of 26 462 ha were under national protection in Latvia (Nikodemus, Brūmelis (ed.) 2011). In 1923, the Law on Forest Conservation was adopted in Latvia, which stated that nature monuments include forest districts and compartments that should be conserved in their natural condition due to historic importance, beauty, scientific value or rare tree species. On 10 July 1923, the "Government Bulletin" ("Valdības Vēstnesis", Issue 145) published list No. 3 "Forests and compartments, that did not belong to the protected forests before World War I but should be considered in the future as parks and nature monuments", mentioning, for example, the Šlītere nature monument, that "should be preserved in its natural splendour in the class of "nature monuments"" (Anon. 1923). The proposal to establish this nature monument was made by forest surveyors who had conducted inventory in forests of Kolka and Dundaga in 1921. They recommended to prohibit economic activities and conserve the nature diversity found in the forest stands (Sāmīte (ed.) 2010).

In the following years, several botanical reserves were established throughout the country to protect rare and unique plant communities.

Several reserves were established on lake islands (Fig. 2.3), such as in Lake Kāla, Ozolu Island of Lake Ciecere, Panu Island of Lake Istra, Upursala Island of Lake Cīrīša and others.

In 1932, the Cabinet approved the list of protected forests and parks. Three protected territories of 375 ha were created in the area between Sigulda and Turaida.

Fig. 2.3. Nature Reserve of Zvirgzdene Lake Islands, established in 1925. Photo: S. Ikauniece.

From 1918 to 1940, nature conservation issues were addressed by a variety of institutions – the Ministry of Education and its Monuments Board, Ministry of Agriculture, Forest Department, Rīga Society of Nature Researchers, Latvian Society of Science and the Latvian Society of Education. During the Soviet period the first law on nature protection in Latvia was first adopted in 1959 (Anon. 2004).

Nature conservation actions in different periods of the Soviet years were raised by various authorities, such as the Nature Conservation Commission of the Academy of Sciences (1955-1961) and the Nature Conservation Department of the State Planning Committee (since 1975). However, the major responsibility for the forests of protected nature areas, their research and conservation was in the competence of the Ministry of Forest Management and Commercial Forestry. The Nature Conservation Laboratory of the Institute of Forestry Issues was for a long period of time under the leadership of forest scientist Pauls Sarma (Nikodemus, Brūmelis (ed.) 2011; Tooma 2012).

In 1979, the Forest Code was adopted, which divided the forests of Latvia into two groups according to their economic value, location and functions (Bušs, Vanags 1987). The first group included forests that mainly had:

- a water protection function (forest protection belts along rivers, around lakes and water reservoirs);
- a protective function (anti-erosion forests, forest protection zones along railways, motorways, and other forests important for environmental protection);
- a sanitary-hygienic and health-strengthening function (urban forests, forests of green areas in towns and other populated areas, forests around resorts to support human health);
- special functions (forests of reserves and national parks, nature monuments, and forests of scientific or historical importance) (Bušs, Vanags 1987).

All other forests were included in the second group. Exploitable forests constituted the largest area of these forests. Specially protected compartments were distinguished in which the forest use was restricted. These were called non-exploitable forests of the second group: forest compartments with relict and endemic species, forest edges, capercaillie leks, forests along the rivers with a beaver population, forest compartments around health hotels and resorts, small woodland patches surrounded by non-forested territories and others (Bušs, Vanags 1987). Specially protected compartments were established in the period from 1977 to 2000. For example, in the vicinity of Ķemeri Town, in 1982, a protected area of 238 ha was established for the protection of the rare black-throated loon *Gavia arctica*. In 1989 five more protected areas were created in the Ķemeri surroundings – four compartments for the protection of black stork *Ciconia nigra* and one for the protection of short-toed eagle *Circaetus gallicus*. In 1996, shortly before the founding of Ķemeri National Park, 34 specially protected compartments with a total area of 1174.9 ha were established in the surrounding forests of Ķemeri (Strazds, Ķuze 2006).

From 1949 to 1983 the forest area of the first group in Latvia increased by 7.7 times, and in 1983 these protected areas occupied 12 045 000 ha due to wide areas that were allocated for the needs of environmental protection and regular increase of the forest territory of urban green areas. From 1949 to 1983 the area of exploitable forests decreased from 1 589 000 ha to 909 000 ha, as more and more forests were included in the first group and protected compartments were defined (Bušs, Vanags 1987).

A great event in the history of the protection of forests was the decision of the Council of Ministers on approving nationally protected objects in the territory of the Latvian Soviet Socialist Republic. At the end of the 1950s and the beginning of the 1960s, nature objects were divided according to morphological principles: river valleys, hills, forest areas, lakes, lake islands etc. In 1952 the first list of protected areas was approved in the Soviet period. For example, the nature reserves "Ventas ieleja" and "Klaucānu un Priekulānu ezers" were established at that time. The system of protected areas was fully established in 1977, when a new law regulated that territories should be divided into nature reserves, botanical, mire or complex restricted areas, nature parks, cranberry reserves etc. (Nikodemus, Brūmelis (ed.) 2011). On 2 March 1993 the law "On Specially Protected Nature Territories" was adopted, and it is still in force with several amendments.

In 1979 the objective of the State Reserve Administration, established under the auspices of the Ministry of Forest Management and Commercial Forestry, was to conduct scientific research and monitoring in the strict nature reserves of Slītere, Grīņi, Moricsala and Krustkalni, and to manage these territories (Anon. 1923).

From 1992 to 2000 the law "On Forest Management and Use" was in force. It divided forests into three categories by their economic and ecological significance, or the main task (function):

- category 1 – protected forests (forests of strict nature reserves, national parks, complex nature reserves, nature parks, and anti-erosion forests, as well as forest parks of green areas);
- category 2 – protection forests (forests of protected landscape areas, forests of green areas, and other forests that have an important role in environmental protection);
- category 3 – commercial forests (other forests).

Depending on tree species and site quality, the permitted harvesting age of trees at final felling differed. For example, the felling age of *Pinus sylvestris* and *Quercus robur* in commercial forests of site quality 1 forests was 101 years, in forests of category 2 - 121 years, and in forests of category 3 - 141 years. For *Picea abies* and *Fraxinus spp.*, the harvesting age was 81, 101 and 121 years respectively; for *Betula spp.* and *Alnus glutinosa* – 71, 81 and 91 years, and for aspen in forests of all categories – 51 years (Anon. 1992).

In the Forest Law adopted in 2000, forests are no longer divided into categories. An equal final felling age was defined for all forest types, for several species it is higher in stands of low growing quality, for example, *Pinus sylvestris* felling age is 101, but in slowly growing stands it is 121. For *Picea abies* in all stands 81, for *Populus tremula* 41. Exceptions can be for protected nature areas when stated otherwise in individual regulations on protection and use. As of that year, specially protected forest compartments were no longer established, but it was possible to create micro-reserves for the conservation of certain species and habitats. The area of micro-reserves usually covers 0.1-30 ha, with the exception of bird reserves that can reach 500 ha in size together with the buffer zone. The process of creating a micro-reserve is easier and quicker than creating a protected nature area, thus providing operational conservation of rare and endangered species. In 2014, micro-reserves in the forests covered 39.2 thousand ha, 93% of which were established on State-owned land (VMD 2015b).

Protected nature territories in Latvia were established throughout the 20th century and the beginning of the 21st century. The year 1977 was important in this respect. Many new areas were created in the 1990s. The last significant review of the protected area network in Latvia took place before joining the EU, when new and significant areas for forest habitat conservation were established. Territory establishment was based on new principles of nature conservation – to protect not only rare species, scenic areas or cranberry gathering sites, but to provide conservation of characteristic and significant habitats within an entire boreal biogeographical region, which also includes Latvia, to ensure the long-term existence of populations of typical and threatened species.

Chapter 3. Forest Ecosystem Services

Fig. 3.1. Rare moss species *Frullania tamarisci*. Photo: S. Ikauniece

Ecosystem services are the services provided by the natural environment from which people obtain some kind of benefit. In this sense, services are understood as goods, benefits and processes. Goods produced by the ecosystems include, for example, food, water, fuel and wood. Ecosystem services include processes like water supply, air purification, waste recycling, soil formation, pollination and self-regulatory mechanisms used by nature to control climatic conditions, as well as populations of animals, insects and other organisms. Ecosystem services can be classified according to various criteria. The *Common International Classification of Ecosystem Services* and *The Economics of Ecosystems and Biodiversity* have an increasingly important role in ecosystem service assessment (Anon. 2016, Anon. 2017).

Classifications recommend that all the ecosystem services are divided into several main categories: supporting and habitat services, regulatory and maintenance services, provision services and cultural services.

Supporting and habitat Services. Essential ecosystem services are the so-called supporting services – water, air and element cycles, soil formation, habitats for species (living, breeding, feeding places), species migration routes.

Forests provide habitats to many species. They are very important for conserving rare and protected plant species and their genetic resources, since 111 protected species (51% of all protected species in Latvia) and 143 species of the Red Data Book of Latvia are found in forests. (Fig. 3.2) About 46 of these protected species also occur in other habitats, and thus protection can include habitat other than forest.

The remaining species can only live in forests, in rare cases also in habitats related to forests (Laiviņš *without date*).

Regulating Services are:

- biological uptake of substances (including pollution) by micro-organisms, plants, animals;
- biophysical effects on substances (filtration, accumulation in soil and water);
- effects on particulate matter and fluid flow (erosion, landslides, sand movement processes);
- soil formation processes;
- gas exchange, etc.

Carbon sequestration and storage is one of the most important services of the forest ecosystem. The world's forests store 45% of the terrestrial carbon, of which 44% is in forest soils, 42% in above- and belowground living biomass, 8% in dead wood and 5% in the litter layer. In the presence of light, free oxygen, water and carbon compounds are created from water and carbon dioxide as a result of photosynthesis in leaves and needles. Carbon compounds form wood biomass, and accumulate in forest soil (Loehman et al. 2014) and non-drained peat soils. After drainage a large part of the sequestrated carbon in peat is released to the atmosphere during the decomposition of organic matter (Sievänen et al. 2013). Forestry researcher P. Zālītis emphasised that research on social benefits and the value of forests indicates that the larger part (54%) of the value of forests is contributed by the carbon accumulated and oxygen produced, and that the significance of the produced wood is only 5% (Zālītis 2011).

The capacity of carbon storage at the landscape level is defined as the mass of carbon assimilated in the ecosystem under the existing environmental conditions and natural disturbances, but excluding anthropogenic disturbance (Keith et al. 2010). One oxygen molecule is released per one assimilated carbon molecule. Factors that increase carbon storage are larger biomass and the standing volume of wood in a growing forest and larger annual increase of standing volume. Tree felling reduces the amount of biomass stored and its annual increase, and the removal of felling residue reduces carbon accumulation in soil (Sievänen et al. 2013). Young trees grow more rapidly. The annual increase in biomass is relatively small in young stands up to 20 years of age; it increases

Fig. 3.2. Old oaks *Quercus robur* in "Lake Lubāns Wetland" Nature Reserve. Photo: S. Ikauniece.

and remains relatively high up to 80 years of age. Then it gradually decreases (Jansons (ed.) 2011). When a tree becomes biologically old, the annual growth in biomass is much lower, and individual parts of the tree gradually start to die off (Fig. 3.2). At the same time, the biomass of a young tree is much smaller than that of a large tree, and thus the amount of carbon stored in a young tree is much lower and this difference will remain for many years (Kauppi et al. 2015).

Long-term carbon storage in biomass of biologically old unmanaged forests of the European temperate zone, which often occur in protected nature areas, has previously been underestimated, and is much more significant than in managed forests (Allen et al. 2016).

Forests have an important role in regulating ***the climate and circulation of water.*** Part of the atmospheric precipitation is retained in tree crowns, promoting gradual throughfall to the soil, which reduces nutrient leaching into watercourses. When the water evaporates, it returns to the atmosphere. When forests are felled in wet sites, evapotranspiration decreases, and paludification is often observed. Waterlogging can delay tree stand regeneration, and habitat conditions are altered.

Trees provide shade and reduce wind; thus a stable microclimate is typical in forests, particularly in old forests. Shade and evapotranspiration in a forest during summer reduces air temperature and temperature fluctuations during the day. These habitat conditions are important for the existence of many forest species. Forests reduce the devastating effects of wind, especially in multi-aged stands with diverse structure, which can better absorb the force of wind than even-aged forest stands. The role of lowland forests in reducing the effects of wind is also significant via an effect of reducing the risk of soil erosion.

The role of a forest is very important in air ***purification*** from dust and in the production of phytoncides, both of which positively affect human health. This is particularly important in urban areas, but also for tourists in popular nature areas, recreational sites and around resorts.

Provisioning Services. Provisioning services are products that people obtain from nature (berries, mushrooms, raw materials, water, bioenergy etc.). Forests provide timber and non-timber resources. According to the definition of the Food and Agriculture Organization of the United Nations (FAO), non-timber products are resources of biological origin other than wood, which are obtained from either forests or forest-like areas, or from trees outside forests (Dembner, Perlis (eds.) 1999). The list is extensive – recreation resources, food, medicinal plants, bee products etc.

Wood is a renewable natural resource, and harvest cycles occur over several decades. Wood biomass is formed by commercial wood of the stem (50-75%), tree crown and branches (8-10%), the foliage or leaves and needles (6-12%), bark (2-4%), stump and roots (5-10%) (Daugavietis 2012). Wood of smaller dimension that can be used for economic purposes can be obtained from stands aged 40-50 years, but woodchips can be produced from saplings. To obtain round timber of large dimension, trees must grow for a long period of time in the climate conditions of Latvia. Fast-growing species (*Betula spp*., *Populus tremula*) require at least 70 years, and *Pinus sylvestris* and *Picea abies* trees require 100-120 years, depending on growth conditions. Timber and processed timber products are very widely used. Traditionally they are used for fuel, in construction and furniture production, as well as in the pulp industry.

An essential component of any tree biomass is its non-wood biomass – the foliage and bark. Tree foliage contains many biologically active compounds. The foliage and the bark have multiple uses. They can be used in the production of pesticides, for soil improvement to increase stand yield, as additions to livestock feed, in food production and in the cosmetics and pharmaceutical industries.

Bark, chips, sawing and harvest residue, saplings from thinning, shrubs, as well as recycling wood (which can be collected during waste collection, from reconstruction sites, packaging material, etc.),

serve as sources of energy – wood energy. The wood waste can be used in both raw and processed forms. To make wood and its residue more convenient to use for heating, it can be chipped, slashed and turned into granules or briquettes (Kancāne 2005).

The majority of wood products from Latvia have been exported to other countries. Already in the 12th century Riga had established itself as an important commercial centre in the eastern Baltic region. Export of forest products began in this period of time. Tar, resin, ash, planks and oak blocks were shipped from Rīga Port. Processed wood products (ash, potash and tar) historically had an important role. In around the 16th century, almost 100 tar kilns already existed in the Duchy of Courland; the largest were in Skrunda, Kuldīga, Renda, Grobiņa, Taurkalne, Baldone etc. (Liepiņa 1999). Wood, especially oak, was an important exported resource for a long time; this undoubtedly influenced the cover of *Quercus robur* forests in Latvia. Later, one of the most valuable trees was *Pinus sylvestris* as masts for ships; *Pinus sylvestris* growing in Kurzeme was evaluated particularly highly (Ziedonis (ed.) 1995). Today, wood export is an important part of the economy. In 2012, 73.2% of wood products from harvested trees were exported. Export of unsawn logs is also high, however in recent years the proportion of processed wood has increased; for example, in 2013 it already comprised 43% of wood export (Zorgenfreija 2013). There is a need to improve the existing wood processing productivity, thus increasing the value of the finished product and exporting a smaller amount of harvested logs. In recent years the proportion of logs decreased in timber exports – from 14% in 2010 to 10% in 2014 and 7% in six months of 2015 (Pelēce 2015).

The value of ***non-wood resources*** produced in the forests of Latvia in 2011 was evaluated at approximately 102.1 million euros, and mushrooms represented half of this amount (51.08 million euros). Mushroom production represents 0.1-0.3% of Latvia's gross domestic product. The value of other non-wood products was as follows: 22% (22.48 million euros) – other plant products, 6.3% (6.4 million euros) – meat of wild game animals, 4.3% (4.4 million euros) – Christmas trees, 16.6% (16.93 million euros) – fruits, berries and nuts, 0.7% (0.71 million euros) – honey and wax, and 0.1% (0.05 million euros) – wild game hides and trophies (Anon. 2011b). Berries were already exported to countries like Germany, England, Denmark, France, and Belgium in the early 20th century, the main purchaser of berries was Germany (Vasiļevskis 1997).

Fig. 3.3. Lingonberries *Vaccinium vitis-idaea*. Photo: S. Ikauniece.

Berry and mushroom picking is a significant secondary use of forest, and is still an important means of food provisioning for a large part of the population today. For many residents of Latvia it is an important source of income. People mostly harvest bilberries and lingonberries in forests, and raspberries in clearings.

People also collect small amounts of common hazelnuts in forests, and the start of the period of time for collection was even decreed in the early 20th century, e.g. in 1930 it was 1 September (Vasiļevskis 1997). Acorns have been collected in *Quercus robur* forests for feeding pigs, although better acorn crops are found falling from trees that grow individually, in sparse plantations, parks and avenues.

Forests have been important in the procurement of ***bee products***. The oldest method of beekeeping is the creation of artificial cavities in trees (usually in *Quercus robur* and *Pinus sylvestris* trees) for the initiation of hives and the collection of bee products. Records show that this method was already practised in the 13th century, and most probably even earlier. In the 20th century this tradition gradually disappeared (Draviņš 2006; Eniņš 2013). In the Medieval period wax was the second most important export product after wood. Cathedrals and monasteries, castles and manor houses needed candles for lighting, and wax was in high demand. Wax was also the most expensive product that was exported from the eastern Baltic region to Western Europe (Liepiņa 1997). Bee honey was the main sweetener in the period before cane and beet sugar was discovered. Nowadays beekeepers often take their bee hives to the forest "apiaries", where in the vicinity there is flowering heather that bees use to produce a unique honey. Nowadays wax is used in small quantities, but it is still produced as a specific commodity.

Resin extraction attempts in industrial quantities in Latvia started in the early 20th century in Baldone and Cēsis. It was extracted from *Pinus sylvestris*, and with the industrial demand for processed resin products (rosin and turpentine) the amount of its extraction increased rapidly. Although relatively great work was invested, foreign specialists invited and various methods tried in the extraction of resin, it was assessed as non-profitable until the Soviet period (Vasiļevskis 2007). During the Soviet period resin extraction continued, but it was stopped in the mid-1990s. Some forest stands with old *Pinus sylvestris*, with scars acquired for resin extraction, still survive.

Already since antiquity, people have been ***hunting wild animals*** for food, clothing and raw materials to manufacture household objects. With the development of trade and contacts with other countries, wild animals were hunted more intensively; however, in the medieval period hunting had a secondary role compared to cattle breeding (Mugurevičs 1999). Animal pelts were already one of the most important export goods in the 12th century. At that time, squirrel pelts were exported for the most part, since they were not very expensive but were in high demand. Pelts of other wild animals – *Mustela nivalis*, *Lutra lutra*, *Martes* spp., *Vulpes vulpes, Lynx lynx, Mustela lutreola*, especially *Castor fiber* – were valuable and expensive. The pelt trade declined around the 15th century (Liepiņa 1997). As industry and agriculture developed, the contribution of hunting to the economy became quite small, as it rather served as an additional food source for a part of the society. In different time periods there have been various laws and rules that restricted and regulated hunting in forest. For example, in the early 20th century, hunting was banned in about 5% of the forest area in each forest management unit (Vasiļevskis 1997). Nowadays hunting is a form of recreation that a small part of the population engage in, while also supplementing their diet with meat of wild animals or acquiring horn or tusk trophies that are popular among hunters. Pelts of wild forest animals have lost their popularity and are not used in industrial production, while they are still being produced and used in households.

Gathering of ***tree seeds*** was begun in order to carry out artificial regeneration of forests, to afforest agricultural land and sandy areas. Systematic forest restoration was already started in the late 18th century (Zunde 1999). Originally, the seeds were imported from other countries, for example, pine seeds were imported from Darmstadt in Germany in the hope of achieving faster growth of wood. Unfortunately, the pines that had initially grown well began to wither away and died in 20-30 years. A small Darmstadt pine stand has remained intact as an original monument close to the Riga-Ventspils highway near Priedaine. In previous centuries, nobles required that *Quercus robur* acorn be planted in their forests, and many old *Quercus robur* stands that have survived in some places to present, are plantations of those times. Special cone dryers were made for the acquisition of seed, for example, the cone dryer at Vijciems started operation in 1895 and is still used today (Anon. 2009). Clearcuts were seeded with seed obtained from cones or planted with grown seedlings. These artificially created stands were then called forest "cultures". The first known forest planted stands were established during the period from 1823 until 1870 (Zunde 1999). Organised nationwide forest seed harvesting began when the first state of Latvia was established, and new dryers were built, for example, in Baldone and Iecava (Vasiļevskis 2007). Seeds of other trees were harvested as well, e.g. in 1919 wild apples and pears, also *Quercus robur* acorns were collected for nurseries. Regulations stating that only local *Pinus sylvestris* and spruce seeds may be used in forest regeneration came into force in 1938 (Vasiļevskis 2007). Already in the early 20th century when the first seed sales took place, it was anticipated that forest seed exports would have good prospects. In the late 20th century *Fraxinus excelsior*, *Betula pendula* and *Alnus glutinosa* seeds were also harvested.

Already since the mid-20th century the establishment of plantations for the harvest of *Pinus sylvestris* and *Picea abies* seeds has replaced that conducted from forest stands. Most of the established plantations have remained and are used nowadays. New plantations have also been established, such as for *Betula pendula* and *Alnus glutinosa* seed harvesting.

Plants and parts of trees are used in medicine and for other purposes. Preparations from *Sorbus aucuparia* and *Crataegus spp.* fruits, clubmoss spores, *Betula spp.* and *Pinus sylvestris* buds, *Frangula alnus* bark and other forest plants have traditionally been used in medicine. *Betula spp.* tree sap, which was used in the early 21st century for industrial purposes both in the production of cosmetics and sparkling drinks, is still tapped all

Fig. 3.4. *Pinus sylvestris* seed plantation. Photo: J. Jātnieks

over the country. Root, bark and bast fibre was used earlier and to a smaller extent even nowadays for the creation of household items – furniture, shoes, dishes and tools. A sauna in Latvia without a *Betula spp.* or other tree's branches is unimaginable. Also around Christmas time many families go to the woods to search for their Christmas trees.

Cultural Services. Cultural services are intangible benefits the society receives from nature, involving both physical and intellectual human interaction with nature (recreation, nature tourism, cultural heritage in natural landscapes, education).

Forests, particularly forests that have experienced little human activity, are of high ***scientific value***, as it is significant to explore the forest and obtain answers to questions about both the ecological processes in order to understand the best ways of conservation and maintaining the existing values of forest and on how to grow high quality wood and ensure the sustainable use of forest resources.

Forests have an important ***nature awareness value*** – a large part of natural trails wind through forests, providing experience and education on natural processes in forests, the species living there and the optimal ways of management.

Forests are also used for ***leisure and active recreation*** – both for individual relaxation and events with many participants. For example, cross-country ski slopes are widely used in winter; in other seasons, forests welcome orienteering enthusiasts. Orienteering is among the most widespread and most popular kinds of sport in Latvia. Also, runners, cyclists and motorcyclists are likely to use the opportunities that forests provide. Forests constitute important resort resources that are used in sanatoriums and rehabilitation centres to regain health.

As the daily lives of humans become urbanised, the ***aesthetic value of forests*** becomes highly rated, due to recreation in nature and spiritual practices that the forest offers. Recreation in nature has positive effects on human health and work ability, and thus it has a direct positive impact on the economy.

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

(A. Priede)

Different terms for the activities that focus on the provision of favourable conservation status of habitat have been used in the guidelines. In the broadest meaning these activities, both passive and active should be called **habitat conservation.** Habitat conservation in the widest sense includes various actions – establishment of protected nature areas and nature areas of conservation and micro-reserves, various forms of certain prohibitions and restrictions, nature conservation measures and development planning (the guidelines do not review those aspects), as well as active, targeted restoration, management or creation of degraded habitats in places where it has disappeared or has been destroyed. In this way, the protection covers all targeted activities, approaches and techniques, both active and passive, which are focused on the conservation of natural values (Fig. 4.1).

In these guidelines **habitat restoration** is considered as a set of biotechnical measures aimed at restoring the environmental conditions, structure and characteristic species composition in the place where the habitat has once existed or still exists, but is in a very poor protection position. Thus in bog woodlands that have been drained in the past, restoration for the purpose of these guidelines includes, for example, water table stabilisation (rewetting), filling up or blocking of ditches.

In Latvia the approach that the nature values should be restored in the sites that are still classified as EU protected habitats has dominated in recent years. But restoration or management should not always be planned only in an area already recognised as an EU habitat, as sometimes it can no longer ensure favourable conservation status of the habitat, i.e. too much of the area has already been destroyed. In this edition the scope has been expanded to also include conditions and sites that currently do not meet the minimum criteria of the protected habitat, but with determined action the conditions can be created or improved enough to increase the biodiversity after some period of time. This is necessary in order to ensure favourable habitat conservation status where an area is of importance.

For the purpose of these guidelines **habitat creation** is a set of biotechnical measures aimed at the creation of environmental conditions and structures necessary for the protected habitat, and for the introduction of characteristic species in a site where habitat does not currently exist. For example by creating a *Quercus robur* stand on agricultural land. Creation of a specific habitat also refers to the places where it has once existed, but the environment has been totally altered and the habitat characteristics have disappeared or have been destroyed. This can occur e.g. if *Picea abies* are planted in historic broadleaf forest habitats. Due to soil conditions, an admixture of broad-leaved trees usually forms naturally in the forest stand of such sites. Felling of *Picea abies* when tending and thinning the stand may foster the growth of broad-leaved trees and promote the stand to develop as a broadleaf forest. Creation of new protected habitats is not a goal itself, but in some cases of certain habitat types it can at least partially compensate their destruction and hence the consequences of the declining EU protected habitat area.

Habitat management in recent years is understood as activities in a very broad sense including both passive and active actions, and also non-intervention with natural processes. In this edition the understanding of management 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 regular activities such as cutting of shrubs. They can be single one-time activities or activities repeated with large time intervals, which promote the favourable conservation status of the habitat, for example, measures to improve the naturalness of the stand structure, the creation of gaps and dead wood, or controlled burning.

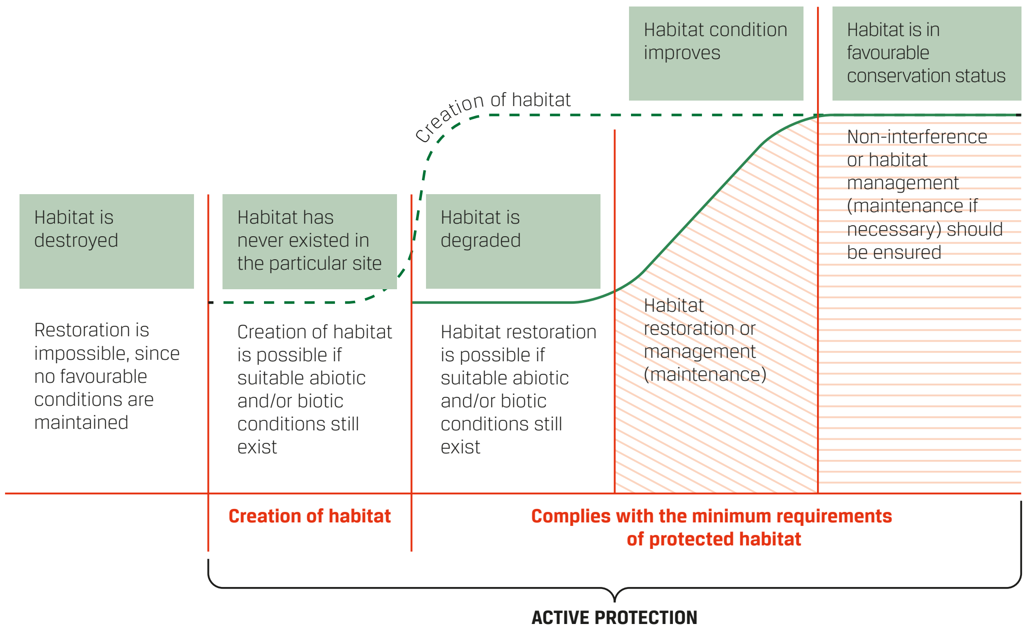

Fig. 4.1. The terms used for the purpose of these guidelines.

Chapter 5. Common Habitat Conservation And Management Objectives

5.1 Relation of the Guidelines to the European Union "Nature Directives" and Natura 2000 Network

(J. Jātnieks, A. Priede)

The main nature conservation legislative act 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 the European Parliament and Council Directive 2009/147/EC of 30 November 2009 on the conservation of wild birds (hereinafter – the Birds Directive). Both directives are the protection framework of natural habitats and species, the conservation of which is the responsibility of all EU Member States. Each country has developed national regulatory enactments to implement the "nature directives". One of the most important regulatory enactments in Latvia is the Law On the Conservation of Species and Biotopes and the related provisions.

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 Habitats Directive is intended to promote biodiversity by protecting natural habitats, wildlife and plant species within the territory of the EU Member States. In an international context the Habitats Directive shall assist Member States to achieve the objectives set in international conventions for nature conservation – the Berne Convention and the Convention on Biological Diversity, while creating a more detailed legal basis for area conservation and protection than the conventions themselves provide. The Habitats Directive defines the necessity for protecting rare, endangered and endemic species, in total approximately 1200 species in the EU. The Directive includes 231 habitat types, of which 71 are recognised as priority protected at the EU level. Of those, 58 habitat types are found in Latvia, 19 of which are priority protected at the EU level[2].

[2] 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 (they are already included in the guidelines).

Due to the intensification of agriculture and forestry, change of land-use practices, urbanisation and many other human influences, many of the natural and particularly semi-natural habitats in the EU and Latvia are in critical condition. The latest assessment about the situation of habitats was carried out in 2013, providing an overview of the years 2006 – 2012. Overall only 16% EU habitats were assessed as being in a favourable conservation status, and the conservation status of 23% species was assessed as favourable. According to the report on status of habitats and species (Anon. 2013), only 13% of the EU habitat types and 28% of species found in Latvia have a favourable conservation status.

The Habitats Directive provides the implementation of nature conservation in a way to maintain or restore the favourable conservation status of natural and semi-natural habitats, wildlife and plant species[3]. The guidelines provided in this edition include a set of techniques and methods to achieve and ensure the favourable conservation status defined in the Habitats Directive, for all habitat types found in Latvia that are included in Annex I of the Habitats Directive. However, the guidelines present only a part of the activities possible within nature conservation.

According to the Habitats Directive, one of the ways of conservation of Annex I habitats and Annex II species is the establishment of protected areas. Together with the areas established in accordance with the Birds Directive, they create the EU protected **area network Natura 2000**. Protected areas are established in accordance with scientific criteria provided in Annex III of the Habitats Directive. However, planning and implementation of nature conservation measures in accordance with the Habitats Directive, for example, developing nature conservation plans, also need to consider the economic, social and cultural requirements, as well as regional and local characteristics.

In Latvia in 2017 there are 333 Natura 2000 sites, including seven protected marine areas. In total terrestrial Natura 2000 sites occupy around 11.5% of the country's area. Latvia has the third smallest area of protected Natura 2000 territories in the country among the 28 EU Member States (in comparison, ten EU Member States have a total Natura 2000 area that occupies >20% of the respective country area).

Article 6 of the Habitats Directive sets out the requirements of Natura 2000 area conservation and management. Article 6 states that a suitable protection regime for habitat and species conservation should be implemented; the respective activity needs to guarantee adequate protection. The article raises the need for management to prevent degradation and adverse effects on species and thus a negative effect on status, under the condition that the conservation of a species or habitat is insufficient by non-intervention, and considering the precautionary principle. These guidelines are a part of the measures set out in Article 6 and offer recommendations for habitat restoration, maintenance, and also creation in sites where they have been lost, taking into account the condition of the EU habitats in Latvia and evaluating the existing conservation opportunities.

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

(A. Priede)

One of the EU biodiversity strategy 2020 objectives requires that by 2020 the Member States should restore at least 15% of the area of degraded ecosystems in their territories (European Commission 2011). The evaluation of restoration efforts is not estimated only by the total area of the restored habitats, but also through the improvement of the protection status as a result of changes in biotic and abiotic environmental conditions. Taking into account the degree of impact on ecosystems in Europe today, it is not possible to eliminate all of the adverse effects and improve all ecosystems – this would be too expensive and technically difficult, sometimes even impossible. However, restoration is a condition where considerable improvement has been reached, at least restoration of the main functions, processes, structures, species populations and suitable conditions. The reference point in Latvia is the year 2006, the year when the first report on the conservation status and areas of habitat types included in Annex I of the Habitats Directive was prepared for the European Commission (Lammerant et al. 2013).

This means that the restoration, management or creation of any habitat in a certain area will at the same time create a local positive effect (will restore the specific habitat area), but in general each restored area will be a piece of the mosaic that will help to maintain a favourable habitat protection status in the country as a whole. It is possible to gain insight into target and existing conditions by assessing and planning actions at a national level. Ideally, in an overall framework the major areas for restoration should be chosen, taking into account landscape ecological planning principles. However, even if we act at a local spatial level and not at the overall national scale, any restored or properly managed habitat area will slightly improve the overall situation.

In order to plan to achieve the biodiversity conservation goal, in 2013, Latvia like other EU Member States, prepared A Prioritised Action Framework for Natura 2000, which was an action programme that made provisions for how to conserve species and habitats, taking into account their degree of risk. This book provides instructions for the implementation of conservation of habitats and species of the habitats included in the priority activities framework, via management guidelines, including hands-off management.

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

5.3 Forest Habitat Conservation and Management Objectives in Latvia

According to the Law on the Conservation of Species and Habitats the objective of habitat conservation is to provide a set of such factors that favourably affect the habitat and its characteristic species and promote the natural distribution, structure and functions of the habitat, as well as the survival of the characteristic species, for a long period of time. An ecosystem approach and planning at the landscape-level is essential in forest habitat conservation and management.

The main objective is to provide a favourable protection status for forest habitats. Habitat protection status is judged as favourable when:

- its area does not decrease, but is stable or increasing;
- the characteristic structures and functions of its long-term functioning exist, and it is expected that they will also exist in the future;
- favourable conservation of the species characteristic to a specific habitat is provided.

To achieve this objective, it is necessary to conserve, maintain or restore abiotic conditions, including natural disturbances, that are characteristic and necessary to ensure the existence of the habitats, provide ecosystem functions (carbon sequestration, climate regulation etc.), to create preconditions for the existence of characteristic and rare species. In unsuitable conditions the existence of the characteristic species or their reestablishment is not possible.

To ensure favourable conservation status for the EU protected forest habitats in Latvia the following **objectives** have been set, which can be evaluated using specific characters.

(1) Halt the decline of the total habitat area in the country.

Indications:

- The total habitat area in the country is not declining;
- the number of habitat sites in the country is not decreasing (a decrease of total area and extinction of sites potentially reduces the conservation status of the habitat and characteristic species throughout the region, including decreasing of its distribution);
- The average size of a continuous habitat patch increases;
- The average distance between habitat patches is decreasing.

(2) To ensure the necessary environmental conditions for the habitats, i.e. no deterioration, and to improve habitat quality where it is required and possible.

Indications:

- Presence of characteristic tree canopy and groundcover vegetation composition;
- Occurrence of processes that have functional role (carbon sequestration, water accumulation and filtration, climate regulation etc.);
- Optimal occurrence of forest structure elements (dead wood, uneven age stand structure, canopy gaps, biologically old trees);
- Optimum hydrological conditions for the existence of the habitat.

(3) Provide habitat and characteristic species with optimum conservation and management.

Characters:

- Occurrence of typical and umbrella species of the habitat throughout the country;
- Occurrence of rare, threatened, vulnerable (protected) species in suitable conditions with distribution throughout the country;
- Lack or negligible cover of atypical species (species that indicate degradation), expansive and invasive species.

5.4 Development of Restoration and Management Objectives in a Specific Area

(A. Priede, S. Ikauniece)

Before determining habitat management objectives and measures for the restoration of specific conditions or habitat creation in a specific area, it is important to obtain information on the former and the present situation of the territory, the history of use and development of forest stands, as well as to identify the causes of change and the factors that have influenced the development of the habitat and triggered the changes.

Particularly in cases when habitat aggregation and creation of the future habitat is being planned, the history of the territory and the distribution of suitable environmental conditions for the habitat must be taken into consideration by devoting great attention to soils and the composition of the species found there. An analysis on the composition of forest stand species would be required on a national scale, taking into account the characteristics of soils, so that the potential biologically valuable forest habitat aggregation regions may be identified. Also, before carrying out the measures for natural disturbance imitation, it is necessary to evaluate the existing and the potential distribution of the future habitat on a broader scale, as well as the presence of rare and protected species and their ecological requirements.

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

(1) Reconstruction of the "ideal" situation. This means restoration of the former habitat areas so that they can be considered as habitats in favourable conservation status, thus also reconstructing the processes with functional importance necessary for existence of the habitats. Such an objective can be set if reliable detailed information is available about where exactly the habitat area was, the former conditions, and composition of species. Knowledge of the distribution of forest types in Latvia is available (Laiviņš 1994) but it does not provide information about their structural quality, which is important for protected habitats. The historical distribution of protected forest habitats in Latvia has not been studied in detail. For this purpose, a study conducted in 2005 at a regional level may be partly applied; the study indicated the weak points in the protection of forests by grouping them according to their characteristic natural disturbances in forest types (Angelstam et al. 2005). Decision-making on habitat restoration in general should be based on knowledge of the ecological development of the respective forest habitat and disturbance effects in the boreo-nemoral area, on knowledge of disturbance effects and their role, as well as on knowledge of species ecology and distribution.

Priority actions can be planned according to their significance, for example, by firstly managing locations where a number of natural values overlap (for example, a site with a *Tetrao urogallus* lek that is also a protected habitat), or areas with aggregations of habitat where sustainable ecological processes are possible, or areas where different habitats (for example, bog woodlands and mires) create a complex system, etc.

Restoration of the "ideal" situation in drained wet forests is possible if the characteristic species of the habitat have not disappeared. In this case restoration of the previous hydrological regime will most likely create the ideal condition. When planning habitat restoration actions, they need to be viewed as complex projects that comprise mires, forest, watercourses and water bodies, and also consider neighbouring territories and drainage systems.

(2) Restoration compromises. A significant obstacle to the restoration of characteristic communities of habitats may be fragmentation and local extinction of habitat characteristic species. Although habitat restoration measures should be focused more on aggregations of larger forest patches, small habitat fragments can also be important stages in the general ecological habitat network, even if in the future these small patches might not seem sustainable in the long term. They are important in conservation, as they may be important in ensuring the dispersal of a species within its range. Small isolated habitat patches may support rare species that require protection. Even if it is expected that in the future a rare species will disappear from a patch if the conditions do not improve by restoration activities, the patch might serve as a stepping stone between habitats of better quality.

Sometimes the priority objectives should be identified among several possibly conflicting objectives (for example, restoration of the characteristic understorey vegetation, different groups of organisms or species, natural values and cultural-historical values).

When the objectives are defined, the appropriate techniques of how to reach them should be selected (*see chapter 8*).

Chapter 6. Formation and Protection of a Biologically Diverse Landscape

6.1. Forest Landscape Characteristics

Forest habitat conservation, management and restoration are not possible without a broader understanding of the forest landscape and its significance in the protection of habitats and associated species.

Latvian landscapes have been developed over a long period of time in close interaction with natural processes and human activity. A decisive natural factor at the beginning of Latvian landscape development was the climate and glacial retreat 12 000-14 000 years ago. Glacial movement processes formed the topography, influenced soil diversity and vegetation distribution, and the future land use depended on these factors. With the arrival of people in the territory of Latvia, landscapes were significantly influenced by various human activities: deforestation, land use change, as well as the construction of ports and roads, and building of settlements (Anon. 2013a). Consequently, nearly all modern landscapes of Latvia have been directly or indirectly modified by humans.

The landscape is a dynamic, constantly changing system, its structure is a pattern of landscape elements and spatial units. A landscape structural element is any part of a landscape that characterises a specific landscape (Anon. 2013), for example, a road, avenue, quarry, ploughed field, woodland, young stand etc. A landscape is not only the visual appearance of a site, but also a set of ecological conditions. Its structure is composed of natural factors and formations that delimit and define the spatial form of the landscape. The landscape is influenced and shaped by people and society as users and modifiers of the landscape; understanding landscape structure encompasses not only the visual and visible landscape; the views of communities and the symbolic importance of the landscape also need to be considered.

The matrix of a forest landscape is heterogeneous forest (Fig. 6.1). It also includes forest clearings, wet depressions, small mires, waterbodies, roads and other infrastructure objects located in the forest (Anon. 2013a).

Although the biodiversity of a forest landscape is determined by natural conditions (e.g., soil fertility, homogenous or heterogeneous growth conditions, tree species, stand age and other factors), management also affects the forest environment and promotes changes.

Landscape changes are closely associated with both natural factors and socio-economic and political processes. Historically, Latvia has experienced large fluctuations of forest area, because as agriculture developed, the forest area periodically declined. A large area of forest developed on previously deforested land, due to the change in population density and

Fig. 6.1 Aiviekste River valley. Photo: S. Ikauniece.

management intensity due to wars, epidemics and political processes. Tree species composition has changed both due to natural processes as well as the intensive harvest of particular tree species, such as *Quercus robur*. Artificial regeneration of forests has had a crucial role regarding changes in the composition of tree species, as there has been a focus on economically important species like *Picea abies* and *Pinus sylvestris*. Natural overgrowing of agricultural lands has caused an increase in the forest area dominated by pioneer species – *Betula spp*. and *Alnus incana*. The landscape is also affected by forest harvest, its intensity and the types of felling.

The development of the landscapes of Latvia was gradual in some periods, with turning points marking rapid change due to natural disasters, war or changes in policy (Anon. 2013a). Landscapes can be assessed from different points of view, leading to different interpretation, for example, the assessment of patterns from economic, historical, functional or aesthetic points of view. Nature conservation requires sound ecological knowledge of the sustainability of forest ecosystems. Assessment of the role of habitats for species needs to consider that the landscape is built of multiple ecosystems (Anon. 2013a).

6.2 Importance of Landscapes in the Conservation of Forest Characteristic Species

It is impossible to ensure the protection of a species or habitat by only protecting and maintaining it in a favourable status in small areas of protected nature territories or micro-reserves. The habitat size, spatial form and its associations with other suitable habitats are significant for the existence of many species. These conditions often involve much larger territories than nature reserves. Habitat fragmentation occurs when habitat patches disappear or their area decreases due to natural factors or human activity. Fragmentation and loss of habitat have a negative effect on the existence of many species, and are considered to be the major cause of decline in biodiversity (Penttilä et al. 2006; Rybicki, Hanski 2013; Sonnier et al. 2014). Fragmentation and habitat loss are among the greatest threats to ensuring favourable conservation status (Anon. 2013c); therefore, increase of habitat area and aggregation of patches are important management objectives. Fragmentation reduces the overall habitat area available to a species, increases habitat isolation, reduces spatial continuity of suitable habitats and continuous habitat areas, and increases the edge effect (Laurence 2008). Such changes affect, for example, the composition of understorey communities. Many researchers have found a link between habitat fragmentation and the decline in biodiversity (Bailey 2007; Norden et al. 2014).

Fragmentation is understood as a reduction in habitat area along with an increase of distance between habitat patches. Changes occur also in habitat configuration and the edge effect increases. Reduction of habitat area and increase in isolation is associated with decrease of population and metapopulation size and increased risk of extinction. Species diversity also decreases. The maximum distance for successful dispersal between habitat patches differs between species – from many kilometres for some mammals and birds to several metres for some invertebrates and mosses. Spatial continuity of habitat for plants depends on seed dispersal; heavier seeds tend to have shorter dispersal distances (Sonnier et al. 2014). Forests become fragmented not only through conversion to other types of land use or the construction of roads, but also due to forest operations, such as clearcutting (Wallenius et al. 2010). Habitat configuration is also very important – a round area has a smaller perimeter and edge effect compared to an elongated area or complex form (Fig. 6.2).

Forest edges have different micro-climate conditions to the core central area of a forest patch, and a small core area can decrease the occurrence of species typical of a habitat (Hilmo 2009; Aragón et al. 2015). Even if the habitat area is relatively large, but due to its configuration it has a long edge, species characteristic of the habitat might be lacking or with low occurrence (Tērauds 2011; Pellissier et al. 2013).

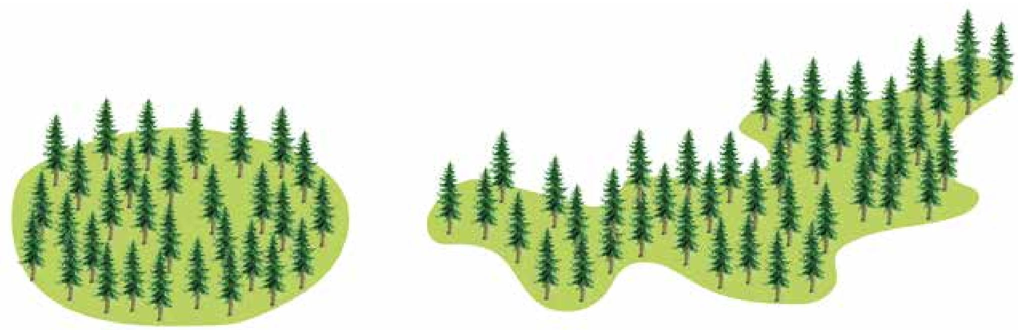

Fig. 6.2. Round and extended habitat configuration. Drawing by D. Segliņa.

Alongside conservation targets of habitat area, it is also necessary to ensure suitable structural quality. This requires planning of habitat management, protection and conservation at a landscape level, for example, to ensure the continuous availability and sustainability of dead wood. Continuous long-term availability of structures within the dispersal range of species is a precondition for the survival of populations. In countries where intensive forestry has caused a shortage of suitable structural elements such as dead wood, rare and protected species dependent on this substrate have become extinct due to a lack of continuity. Management to increase the supply of structural elements like dead wood might fail to prompt a return of the characteristic species, due to a lack of spatial continuity with suitable habitats (Wallenius et al. 2010). Conservation of forest habitat by non-intervention management will in the long term result in the increase of structural elements like biologically old trees and various types of dead wood. However, if the characteristic species of these substrates are not present in the surrounding area or if their habitats are isolated without the possibility of dispersal, then there is a big risk that the characteristic rare species will not colonise the suitable habitats; for example, dispersal of polypore spores can only be several hundred metres (Norros et al. 2012). When creating natural structures artificially, like dead wood, the decay process may differ from the natural process, affecting the composition of associated communities. Some rare polypores inhabit wood in later stages of decay, and thus these species will be lacking in the short term after dead wood creation (Pasanen et al. 2014).

In the protection of biological diversity in forests a significant aspect is the continuous and non-fragmented area of each habitat and sets of habitats, as well as their potential area or home range. This is the area in which, taking into account the set of specific natural conditions favourable to the habitat, each particular habitat can develop (Melluma (ed.) 2004). Sometimes it is needed to modify the habitat configuration to increase the area of target habitats in a particular location.

In the long term it is essential to maintain suitable landscape and habitat structure, the availability of habitats for species, and to ensure successful dispersal. Natural structures form slowly as a result of natural processes. Management focused on increasing the economic value of forest stands aims to minimise the effect of natural disturbances (for example, forest fire protection) and remove structures created by disturbance. Natural formation of forest structure under commercial management is in too low amounts to ensure spatial continuity of many species. An objective in habitats with minimal amounts of structures created by disturbances (wind, fire, snow, insect outbreaks), especially in young stands, might be the artificial creation of dead wood, which can be repeated to ensure the supply of logs and snags in various decay stages for the potential colonisation of species.

Studies by Finnish scientists show that the planning of controlled burning in habitat type 9010* *Western Taiga* can be implemented at the landscape level in such a way that in a particular year the habitats managed with controlled burning would be in sufficient distances that would allow the dispersal of species dependent on burnt wood from previously burnt areas. It is important that regularly, at least every five years, another burnt area that can be inhabited appears in the wider landscape within the dispersal range of species dependent on burnt areas (Hekkala et al. 2013). If a species requires forest stands of a particular composition, these issues need to be addressed when planning at the landscape level. Conservation of mature aspen (*Populus tremula*) stands is important for a number of very rare invertebrate species such as *Cucujus cinnaberinus*, as well as *Piciformes* birds. In protected nature areas, where forest harvest has not taken place in the long term, aspen is replaced by spruce (*Picea abies*) or broad-leaved tree species during natural succession. In commercial forest outside of protected areas the development of old mixed aspen stands is unlikely due to the low felling age for aspen, which is much younger than the age when aspen becomes suitable for a large number of protected invertebrate species (Vilks 2014).

To reduce the impact of fragmentation, it is very important to conserve or create corridors between existing habitats. It is not possible to determine the most suitable conditions for the dispersal of all species inhabiting forest habitat. Therefore, focus is placed on the so-called "umbrella species". One example is *Osmoderma barnabita* s. l., a threatened beetle species that inhabits living large deciduous trees. When there is a lack of a functional link between trees or forest stands inhabited by *Osmoderma barnabita* s.l., Swedish scientists recommend applying specific methods, such as boxes with punkwood of artificial origin that imitate cavities, or to promote the formation of cavities in younger trees by removing a few large branches at about 1.5-2 m height (LIFE project " MIA – Lake Mälaren Inner Archipelago", LIFE07/NAT/S/000902").

6.3 Ecological Landscape Planning for Forest Habitat Protection

To maintain genetic diversity and habitats of species, the principles of ecological planning at a landscape level must be considered. Initially, the geometrical approach dominated in the ecological planning of landscapes by using analysis of structure and land use. However, it is important to focus not only on the geometrical indicators of landscape structure, but also to understand the ecological and functional importance of each element (Lakovskis 2013).

When planning measures at a landscape level for habitat conservation, it is important to identify the habitats for which actions are planned and the action objectives. In landscape planning, habitats can be grouped according to the following criteria (Melluma (ed.) 2004):

- habitats that serve for a specified time and in a specific site as habitats for species dependent on the habitat and also for the formation of new habitats; these include, for example, *Populus tremula* forests;
- habitats that can function for a long period and can be self-sufficient if they cover a large enough area, and if the characteristic environmental conditions are stable; this includes all wet forests;
- habitats that function, but gradually lose the characteristic features and values; they require management, with the regulation of natural development processes or carrying out measures to restore the characteristic conditions, such as limiting the spread of *Picea abies* in *Quercus robur* woods or imitating natural disturbances (fire) in dry coniferous boreal forests;
- habitats that have degraded due to human activity – they require mitigation of the adverse influences, for example, restoration of the original hydrological regime.

One of the methods of planning at a landscape level is the **ecological network concept**, which is based on biological aspects. The main components of such network are biocentres (the core zone and buffer zone), ecological corridors and restorable areas. Other landscape planning models include social, economic and historical aspects, attempting to create a balance between all of these (Lakovskis 2013). In Latvia, the first attempt to develop an ecological network was made in 1998. This was carried out in Kuldīga district by mapping valuable nature areas with no legal protection and developing recommendations for the creation of ecological corridors (ECONET project, 1998-2001). Unfortunately, the idea was not implemented.

A landscape ecological plan was developed for North Vidzeme Biosphere Reserve in 2007, in which 42 landscape spaces were identified. Descriptions and recommendations for the management and development of each structural layer of landscape space were developed. The ecological landscape planning methodology used in North Vidzeme was also applied in the development of a landscape ecological plan for Rāzna National Park in 2008. Landscape inventory was conducted there at the level of smaller municipalities, for which detailed recommendations were made for development and management (Lakovskis 2013).

Biocentres include areas with a high degree of naturalness, high biodiversity and high concentration of rare species and habitats. The objective of a buffer zone is to reduce potential adverse effects and human activity. Corridors often contain linear structures, as well as mosaic-type landscapes with "green areas", which facilitate species dispersal, migration, spatial continuity within natural distribution ranges, and support suitable feeding conditions for the species characteristic of the landscape. In addition to these structures, areas for natural development can be planned, which can function as potential core or corridor territories, and include areas for habitat restoration (Nikodemus, Brūmelis (ed.) 2011). Since many of the protected habitat types are very fragmented and therefore threaten the long-term survival of species of the habitats, ecological corridors and areas for natural development require the most attention.

Based on the principles of ecological networks, the project "Management of Woodland Key Habitats in Latvia" (2003 to 2006) developed a methodology for determining natural forest habitat concentration sites and made recommendations for establishment of the ecological infrastructure of biologically valuable habitats of old forests (Ek, Bērmanis 2004). It was considered that this ecological infrastructure could provide suitable area and optimal spatial continuity of habitats for the conservation of species that cannot survive in commercially managed forests. The study was based on an inventory of natural forest habitats in State-owned forests, which was completed in 2002. The methodology involved the identification of biodiversity centres (aggregations of natural forest

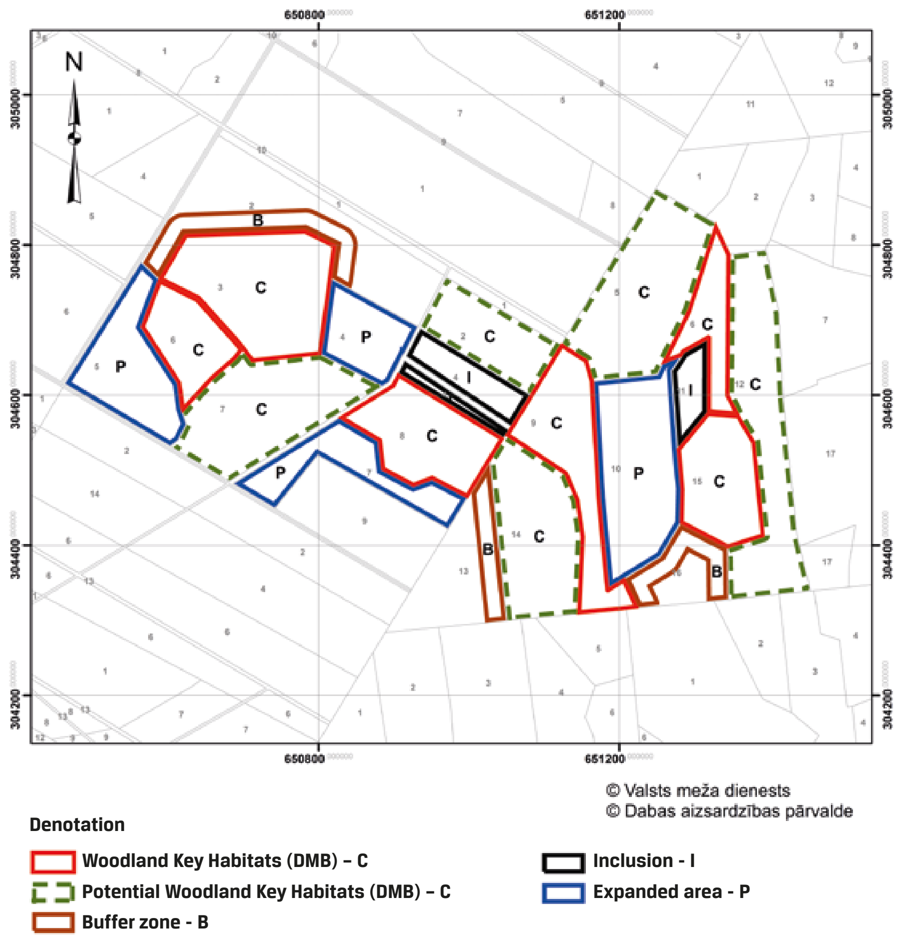

Fig. 6.3. Scheme of forest habitat concentration site (prepared by P. Rozenbaks).

habitats and potential natural forest habitats), with recommendations for expanding spatial continuity to increase the biodiversity of the habitat aggregation areas (Fig. 6.3: C (red) – Woodland Key Habitats; C (green) – potential Woodland Key Habitats; P (blue) – expanded area). The forest stands with less biological value incorporated in the expanded area would serve as a continuation of the biocentre, with the idea that through appropriate management or hands-off management, the biological value of these areas would increase over time. These expanded areas could thereby represent "habitats of the future", which serve to reduce fragmentation and increase the habitat area. The objective of buffer zones along watercourses in this network was to maintain the necessary hydrological regime and microclimate in the biocentres, but which can also function as extension. Mapped habitat concentration sites also included stands where the biological value was low, but which were incorporated into the habitat concentration site due to their location between biologically valuable stands or at their edges ("inclusions"). These areas could be commercially managed, but avoiding the risk of affecting the habitat aggregation site (Ek, Bērmanis 2004). Further, after appropriate management, inclusions can function as extensions (Fig. 6.3: B (brown) – buffer zone; I (black) – inclusion).

The development of areas with habitat aggregations is essential in reducing habitat fragmentation. Some of the identified concentration sites in national commercial forests in 2004 were included in the network of protected nature areas, but others continue to be managed by the joint-stock company "Latvijas Valsts meži" ("Latvian State Forests") in accordance with its plans and objectives. Detailed information on the locations of the concentration sites and their subsequent management after the completion of the project is not publicly available.

Chapter 7. Preparing for Forest Habitat Restoration or Management

7.1. Prerequisites of Successful Habitat Restoration and Management

(A. Priede)

Before planning and considering habitat management or restoration to promote ecological value, it is first necessary to understand what the condition of the habitat is – if it is degraded and to what degree, what and how intensive the negative impacts have been and whether they are continuing, what changes in habitat have occurred and what is the direction of the current development?

First the objective must be set – *what* do we want to achieve with our actions? This requires knowledge about the natural or ideal condition of the habitat, and ecological requirements of its species. It is also important to know the habitat area, the nature of the adjacent stands, soil characteristics and vegetation species complexes not only in the habitat, but also in the surrounding areas. Each site differs in specific geographical conditions which can rarely be generalised. In many places it is important to consider the socioeconomic conditions that influence both habitat protection status and its conservation and restoration options.

The target condition should cover both the area and quality of the habitat. In defining the target of a particular area it is necessary to consider the conditions that exist in the area and next to it, and the impacts that are long lasting and sometimes not avoidable with management. Sometimes only improvement of the situation is possible, which is a compromise with non-intervention or doing nothing.

If the objective is clear, the next step is to determine *how* to achieve it – with what actions the idea can be implemented. This requires a detailed study of the existing site conditions, choosing among potential habitat restoration and management techniques, assessing how suitable they are for the particular situation, and moreover taking into account the available resources. At the idea stage it is already necessary to be able to assess the extent to which the objective is achievable, and anticipate the obstacles. This will help to decide whether the investments comply with the expected result. If not, then, most likely, it is better to invest somewhere more worthwhile. The precautionary principle should always be kept in mind – when deciding on measures of restoration, it is necessary to evaluate the possible risks and consequences of actions in the future. The risk of negative impacts must be reduced as far as possible by selecting the best available solutions for the implementation of the measures.

In the restoration of habitats it is necessary to take into account the existing restrictions: environmental (climate, soil, geological and hydrological conditions, landscape fragmentation and its impact on species populations), economic (financial constraints), and social (public, often also the funders' opinion). These should already be considered during work planning, as circumstances may arise that demand more resources, more time, and result in a less successful outcome. However this does not mean giving up all plans and accepting that it is not worth doing anything. Even if in many cases it is not possible to achieve restoration of the original "ideal" condition of degraded ecosystems, improvement is definitely possible.

In these guidelines the guiding principle is the assumption that it is always better to protect and maintain the natural ecosystems (in the narrower sense – habitats) by, wherever possible, eliminating the adverse effect and increased loads, than to damage and then try to "repair" them. Restoration of degraded ecosystems is always associated with a great risk of failure and high costs, as well as irreversible damage to many natural values, loss of rare species, specific conditions, beautiful landscapes and resources necessary for the survival of not only nature, but also humans. Countless examples around the world confirm that the benefits not obtained in the conservation of natural ecosystems are smaller than the investments required afterwards to restore them. Moreover, the costs increase with the increase of the degradation level. Thus, suitable protection of natural ecosystems is always most important, and restoration or management are only to be used as tools to improve already degraded ecosystems.
A different approach should be used for semi-natural habitat (such as wooded meadows and pastures) restoration. For these habitats the set of characteristic species has been created during long-term interaction with moderate human impact; therefore their conservation requires the continuation or restoration of moderate intensity management.

The biggest disappointment usually occurs when one assumes that it is enough to restore the non-living environmental conditions for colonisation of the characteristic species. This can work in conditions that are still little-affected, but the success can be poor in the restoration of habitats in heavily fragmented landscapes. In habitats lacking characteristic species, the species must sometimes be introduced artificially in efforts to restore habitat. Although the artificial reintroduction of the characteristic species is nowadays quite a widely used technique, it can be unsuccessful even when seemingly suitable conditions have been restored or created (Hilderbrand et al. 2005), most likely because a significant component is missing. In these cases, the ecological requirements of the species might not be completely understood, or symbiotic relationships or other factors exist that do not allow species to establish in the new site, even if it has existed there before. Also, it is not easy to control the spread of "undesirable" species. Such species are most often invasive species of foreign origin that due to global changes are spreading more rapidly, occupying ecological niches of native species and creating significant, sometimes even irreversible changes in ecosystems and their functioning. These species usually benefit from changes in background conditions. Natural ecosystems usually have non-suitable conditions for invasive species, where they are not able to survive or at least reproduction is limited and large populations cannot establish. Environments affected by human action through eutrophication, landscape fragmentation, and artificially created migration paths are favourable to these species. The spread of the invasive species and limitation of their impacts is a difficult task, which locally always requires continuous and patient work that may also be unsuccessful if nothing is done to limit these species at a national or regional level.

Assuming that we have acted correctly 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 is correct, it is not known whether the outcome will be the same as in another case of success. We also do not know how the ecosystem "behaves" in a longer period of time after restoration. Only long-term observations can attest to whether the set goal is achieved, and even if not, to whether the result can be considered as successful.

In ecosystem restoration there is a need to take into account the background conditions of the current environment, such as climate change, pollution, and changes in land use, which in turn are related to human lifestyle changes. For example, European forests in the second half of the 20th century have been affected not only by the establishment of drainage systems, but also by climate change and air pollution-caused eutrophication, which are likely to promote the overgrowth of forests with atypical species. It is necessary to take into account this background in the restoration of many habitats when setting realistic goals.

7.2 Planning of Habitat Restoration and Management in a Specific Area

(A. Priede)

When starting to plan restoration or regular management, there is a need to attempt to answer the following questions (Pakalne 2013):

Table 7.1 Initial collection of basic information (planning before the start of the action).

The characteristics, conditions, impacts of the area – previous and existing	**Species and Habitats**
• The nature of the area (terrain, geological and hydrological conditions, soil conditions, etc.); • area as part of a broader habitat complex; • former area occupied by the habitat that is possible to identify in cartographic and other materials of different times; • historical species composition of forest stands, the planned and carried-out economic activities (information from historical forest management plans and maps, comparison with current data); • management in the past (mostly unpublished, sometimes information stored in the memories of local inhabitants); • previous and present impacts in the specific area and hydrologically related broader surroundings (such as drainage, land use, changes in land use objectives); • current impacts and threats to the habitat.	• The characteristic common species, rare species; • changes of habitat and species distribution and factors affecting it, causes of the changes; • habitat evaluation in the context of the landscape; • threats to the species and the affecting factors; • For some habitat types (9160 *Sub-Atlantic and medio-European oak or oak-hornbeam forests of the* Carpinion betuli, 9060 *Coniferous forests on, or connected to glaciofluvial eskers*, 9020* *Fennoscandian hemiboreal natural old broad-leaved deciduous forests)* mapping of habitats and species in the surrounding area.

- What are the expected limitations (legal, administrative, technical, etc.)?
- What is the estimated result of habitat restoration or management?
- What may the side-effects of the restoration process be (preferable, undesirable)?
- When and how soon may the goals be achieved?
- What can the impact be outside the area to be restored?
- What are the costs in achieving the target result (including planning, research, and other costs)?

In the planning stage it is not always possible to answer these questions fully, but careful feasibility studies can play a vital role in the implementation of the plan. References with the main aspects to be considered are summarised in table 7.1.

In the planning stage one must use all available information, including the findings of the feasibility study. Possible data sources are the following:

- monitoring data;
- cartographic material of different years, orthophotos;
- literature, unpublished notes;
- memories of the local residents and experienced people;
- photos of different ages;
- results of specific scientific research;
- other data sources.

The planning process typically requires additional research – territory survey, mapping of habitats and species sites (remote sensing data can also be used), detailed topographical analysis, and other methods. A good tool for hydrological change modelling is the LiDAR digital surface models.

Forest habitat management and its planning requires complex knowledge, so an expert in species and habitat conservation must be involved, but for complex and difficult cases additional specialists should be invited, for example, a hydrologist and aquatic biologist for hydrological regime restoration in cases when the habitat is hydrologically linked to watercourses or water bodies, or a geographic information system specialist for modelling, a soil specialist, etc.

The next step is the identification of pertinent legislation. It is important to know what is allowed, what actions are permitted or require permits and in which sites, whether there is any liability and obligation of managing the land when implementing the conservation of protected habitats and species. In specific situations it is always necessary to carefully examine the existing legal acts or consult professionals.

7.3 Legal framework

(Ē. Kļaviņa)

7.3.1 Habitat Conservation

To ensure the introduction of Council Directive 92/43/EEC of 21 May 1992 on the conservation of natural habitats and of wild fauna and flora in Latvia, national regulatory enactments have been passed. The **Law on the Conservation of Species and Biotopes**[4] provides the definitions of habitat and biotope. Unfortunately, the terms "habitat" and "biotope" with their definitions used in the official English translation of the Law do not comply with the terms used in Council Directive 92/43/EEC of 21 May 1992 on the conservation of natural habitats and of wild fauna and flora, and thus cause confusion. Further, we will use the terms as used in the Directive; the definitions given in both legislative acts are identical. *Habitat* (called *biotope* in the translation of the Law) is terrestrial or aquatic area distinguished by specific geographic, abiotic and biotic features, whether entirely natural or semi-natural. *Habitat of a species or species habitat* (called simply "*habitat*" in the translation of the Law) is an aggregate of certain specific abiotic and biotic factors in the territory in which a species lives at any stage of its biological cycle. The law prescribes that the protection of species and habitats is the package of measures required to conserve or restore populations and habitats in a favourable condition.

The law describes the characteristics that define the EU protected, including priority protected, habitats found in Latvia. Priority habitats are under the threat of extinction, and their conservation is a special EU responsibility in view of their rare occurrence or restricted distribution within the EU. The Cabinet Regulations defines the list of EU priority species and habitat types[5], including the following EU priority forest habitat types: 9010* *Western Taiga*, 9020* *Fennoscandian hemiboreal natural old broad-leaved deciduous forests (*Quercus, Tilia, Acer, Fraxinus *or* Ulmus), 9080* *Fennoscandian deciduous swamp woods*, 9180* Tilio-Acerion *forests of slopes, screes and ravines*, 91D0* *Bog woodland* and 91E0* *Alluvial forests with* Alnus glutinosa *and* Fraxinus excelsior, as well as a list of significant EU

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

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

plant and animal species[6] requiring protection at the national level. Other Cabinet Regulations define specially protected habitat types[7] and species[8] in Latvia. The list of specially protected habitat types is not identical to the EU list of protected habitat types, although they mostly overlap.

For the conservation of species and habitats, as well as cultural history and landscape, protected nature areas have been established. For the conservation of species and habitats outside protected nature areas or in the protected nature areas, if any of functional zones fail to ensure this, it is possible to create small (0.1-30 ha) protected areas – micro-reserves.

Micro-reserves can be established for habitats included in the list of protected habitats of Latvia, but not all stands designated as EU protected habitats outside the protected nature territories can be protected by the establishment of a micro-reserve. For example, the EU priority protected habitat type "Bog woodland", is designated as "Old natural bog woodland" in the list of protected habitats of Latvia in accordance with the regulations of the Cabinet of Ministers, and as such includes only the part of this habitat that is the oldest and of higher biological quality.

The law on specially protected nature territories[9] defines the fundamental principles of the protected nature territory system. It is stated that special areas of conservation are established with the aim to protect and conserve the nature diversity of Latvia. But only the protected nature areas that significantly contribute to maintaining and improving the favourable conservation status of protected habitats or species in the relevant EU biogeographical region are included in the Natura 2000 network. Protection measures are applied in these territories to maintain or restore a favourable conservation status for the habitats and species populations for which the respective territory was established. The land owner and the user of the territory are obliged to comply with the terms of protection and use of the protected areas and to implement these measures.

Micro-reserve creation, habitat restoration and management in micro-reserves is governed by Cabinet Regulations[10]. The boundaries of micro-reserves and the necessary management are described in the accepted decisions on the establishment of micro-reserves. Boundaries of micro-reserves can be viewed in the public information system—the State Management System of Nature Data "Ozols" (http://ozols.daba.gov.lv/).

7.3.2 Habitat Restoration and Management in Forest

The legal framework that defines forest management is applicable to all forests in Latvia. Unlike the rest of the territory of Latvia, there are specific restrictions on forest management in protected nature territories, which are described in legislation, including special laws, regulations for individual protection and use for particular territories, general regulations on the protection and use of protected nature territories and regulations on the management and conservation of micro-reserves. Nationally significant protected nature areas (national parks and nature reserves) have specific laws and associated individual protection and use regulations.

It should be taken into account that restoration and management of protected habitats and habitats of species in protected nature territories and micro-reserves must be coordinated with the responsible public authorities. For large-scale habitat restoration it may be necessary to conduct an environmental impact assessment, which would require planning for additional time and funding.

Conservation and management of protected nature areas is regulated by the **General regulations**[11] **for the protection and use of specially protected nature territories** or individual protection and use regulations. General regulations for the protection and use of protected nature territories are the main regulatory provisions that determine the permitted and restricted economic and other activities in areas that do not have their own individual protection and use regulations.

In order to harmonise the interests of nature conservation, use of natural resources and

[6] Cabinet Regulation No. 1055 of 15 September 2009, On the List of Those Animal and Plant Species of European Community Significance, for which Protection is Necessary, and the List of Those Specimens of Animal and Plant Species, for the Acquisition of which in the Wild, Conditions for Restricted Use may be Applied.

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

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

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

[10] 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.

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

regional sustainable development interests, while maintaining the nature values of the area, **a nature conservation plan** can be elaborated for a protected nature territory[12]. The nature conservation plan recommends the necessary measures for management of the nature values. On the basis of the nature conservation plan, **individual protection and use regulations** may be elaborated for protected nature territories.

Micro-reserves are managed, including by non-intervention management, to maintain the favourable conservation status for species and habitats for which the micro-reserve was established. According to expert recommendations on the necessary conservation or management activities for the habitat or species, various measures may be implemented: controlled burning of the ground cover, felling and removal of trees, saplings and shrubs, creating and maintenance of free fly zones for bird access to nests, conservation and restoration of hydrological regime, as well as other activities. An expert recommendation is not required for the mowing and removal of grass.

Outside of protected nature territories, management of woodland and nature conservation restrictions are regulated by general legislation.

The **Law on Forests**[13] defines forest land and describes the felling types, conditions and restrictions. Activities in the forest (including habitat restoration and management) can only take place after registering the land in the Land Register. To manage a forest, a forest inventory must be in force. A forest management plan must be drafted for forest stands foreseen for felling in national parks (with the exception of Rāzna National Park) outside the neutral protection zone. **Regulations on tree felling in forest**[14] regulate the procedure of felling and various specific requirements regarding forest management activities, such as:

- procedure for viewing cutting;
- procedure for deforestation;
- nature conservation requirements for treefelling;
- procedure for the establishment of felling areas;
- the procedure for obtaining a tree felling confirmation, and its validity period;
- tree felling procedures in coastal dune protection zone of the Baltic Sea and the Gulf of Riga.

The regulations are also valid in protected nature territories and micro-reserves, where they can be applied if they do not contradict the special regulatory enactments regulating the conservation and use of protected nature territories and micro-reserves.

The regulations prohibit clearfelling:

- in forest stands, where the dominant tree species are *Quercus robur*, *Tilia cordata*, *Acer platanoides*, *Ulmus spp.*, or *Carpinus betulus*;
- in *Pinus sylvestris* stands growing in dry mineral soils in the restricted economic activity zone on the coast of the Baltic Sea and Gulf of Riga (*Pinus sylvestris* constitutes more than 80% of the total stand basal area);
- in forest stands in the flood plains of watercourses and water bodies – in the part of the valley, which is periodically flooded and which has characteristic flood plain vegetation;
- in mire protection zones;
- on lake and mire islets.

The Regulations on nature protection requirements in forest management[15] 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 on forestry activities during the animal breeding season from 1 April to 30 June. In the limited economic activities zone of the Baltic Sea and Gulf of Riga the restrictions are in force from 1 April to 30 September. The Regulations also define the need to protect a variety of elements important for forest biological diversity (forest stands in mire islets, geological objects, springs, and others). The regulations are valid in protected nature territories and micro-reserves where they are applied if they do not contradict the special regulatory enactments regulating the conservation and use of protected nature territories and micro-reserves.

7.3.3 Activities in Protection Zones

When performing forest habitat management in the vicinity of surface water objects, the restrictions defined in the **Protection Zone Law**[16] must be taken in account, such as the ban on clearcutting in a zone of 50 m in width or throughout the whole width of the protection zone if the zone is narrower than 50 m, except in stands where the dominant tree species

[12] Cabinet Regulation No. 686 of 9 October 2007, On the Content of and Procedure Regarding the Elaboration of Nature Protection Plan for Specially Protected Nature Territory.

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

[14] Cabinet Regulation No. 935 of 18 December 2012, On Tree Felling in Forest.

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

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

is *Alnus incana*; in the zone of 10 m in width, final felling and deforestation is additionally prohibited.

Regarding clearcutting in stands where the dominant tree species is *Alnus incana*, there are several restrictions: *Quercus robur*, *Tilia cordata*, *Ulmus spp.*, *Pinus sylvestris*, *Acer platanoides*, *Alnus glutinosa*, *Salix spp.* and *Malus sylvestris* must be conserved; tree felling is prohibited on slopes that exceed 30 degrees of inclination; tree felling is prohibited from 1 April to 30 June and the clearcut area in the protection zone of a surface water body may not exceed one hectare.

7.3.4 Categories and Types of Land Use

Category of land use and purpose of use are defined for any particular land. According to the classification[17] of land use types the category is a set of land use types of similar features. Changes in the area of the land use category are available in the National Real Estate Cadastre Information System, which is maintained by the State Land Service, to which local municipalities and State Forest Service provide up-to-date information. The types of land use are depicted (explicated) in a document of legal boundaries or a respective forest inventory document.

According to the Cabinet Regulations[18] the State Forest Service is the administrator of the State Forest Register and maintains data on forest lands, inventory data, and the change or exclusion of land categories. Records are 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 protected species habitat in the forest.

7.3.5 Deforestation and Controlled Burning for Habitats and Species Habitat Restoration

Actions that should be carried out for the restoration of protected habitats and protected species habitats in forests take place in accordance with the criteria defined in the Cabinet Regulations[19]. The planned activity cannot be in conflict with the local territorial development planning documents. If the restoration of protected habitats or the habitats of protected species requires changing the terrain or surface water level, the activities must be carried out in accordance with the regulatory legislation on construction and amelioration.

To carry out deforestation or controlled burning for the restoration of protected habitat or species habitat, 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 is needed. When restoring habitats in forest the applicant should also clearly explain the planned activity types (felling, stump extraction, filling up ditches, digging of land, controlled forest burning or other types). In a territory where controlled forest burning is planned it is necessary to identify the species or features that characterise the protected habitats: an old or natural boreal forest or a coniferous forest on, or connected to, glaciofluvial eskers. Controlled burning is not allowed in the territories of towns and villages.

If the restoration of protected habitat or species habitat is required, deforestation or controlled burning can be performed upon the receipt of a permit issued by the Nature Conservation Agency. The competent authority issues the permit based on the conclusion of the certified species and habitat conservation expert of the relevant group of species or habitats.

If deforestation of the territory is planned, the forest can be transformed into the land use types such as grassland, pasture, mire, scrubland, land under water or other land according to the criteria defined in the legal acts on the classification of land use types. When properly performing the restoration of protected habitat or habitat, it is not required to compensate expenditures of preventing the negative consequences related to deforestation to the state.

7.3.6 Rewetting

Habitat restoration work related with rewetting (such as restoration and construction of ditches) is regulated by the **Amelioration Law**[20]. If the planned activities in habitat restoration include changes in the hydrological regime, for example, discontinuation of the function of drainage system or its part, one must apply the procedures defined in the regulations on

[17] Cabinet Regulation No. 562 of 21 August 2007, On the Procedures for the Categorisation of Types of Land Use and Specification Criteria.

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

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

[20] With the amendments as of 1 January 2015.

the amelioration cadastre[21], which emphasise that an amelioration system must be registered in the Land Amelioration Cadastre information system by assigning it an amelioration cadastre number.

If discontinuing of operation of a drainage system or part of it is planned, the amelioration cadastral data should be updated in the Land Amelioration Cadastre information system. The land owner or legal possessor must submit the inventory file of the amelioration system and report on its technical inspection to the regional amelioration department of the "Real Estate Properties of the Ministry of Agriculture" ("Zemkopības ministrijas nekustamie īpašumi"). If the drainage system is located in a protected nature territory, the planned activity must also be in conformity with the Nature Conservation Agency in order to ensure the favourable conservation status of the protected species or habitat. The amelioration system data are removed from the Land Amelioration Cadastral information system if the amelioration system is located in and affects the land water regime within the borders of one land property or legal possession, as well as when it does not worsen the ground water regime of other land ownerships or legal possessions.

According to the general regulations for the protection and use of protected nature territories, when rewetting territories adjacent to watercourses and water bodies, constructing waterworks, and installing an amelioration system, written permission is required from the responsible institution, the Nature Conservation Agency.

For the purpose of the **Construction Law**[22] a building is a physical object which has resulted from human activities and is linked to a foundation (ground or bed). Thus the majority of infrastructure objects planned with the aim to redirect the flow of tourists and physically protect habitats, are regulated under Cabinet Regulations[23] that describe the construction process, division of buildings into groups, required documentation, and other construction-related measures. A drainage system (engineering structure) of one owner is classified as a group I object with a simpler construction procedure. When planning the construction of small infrastructure or renovating an overgrown drainage ditch, the activities should be applied to the building authority of the local government, which according to the legal framework defines tasks that must be carried out before the implementation of these activities.

In order to carry out extensive and large-scale work for habitat restoration, for example, filling of drainage ditches and building of dams, a construction permit is required. When submitting the building conception at the building authority the applicant will be informed of which institutions they need to additionally receive the technical requirements, permissions from (public and municipal institutions shall issue them within 20 days), and informed of the need to carry out the initial impact assessment (State Environmental Service), and afterwards, probably, a complete environmental impact assessment as well (*see Ch. 7.3.8*).

7.3.7 Control of Invasive Species

If the abatement of invasive plant species is necessary for habitat conservation and restoration, then, in order to comply with the necessary safety precautions and avoid potential risks, the **Plant Protection Law**[24] and the related subordinated Cabinet Regulations must be followed. The law defines that it is prohibited in Latvia to grow the species included in the list of invasive plant species (currently one species is listed – *Heracleum sosnowskyi)*. The land owner or possessor is obliged to destroy the invasive plant species if they have spread to land that is his/her property or in their possession.

The regulations regarding the use of plant protection products[25] describe the requirements for the use and storage of plant protection products, liabilities and rights of professional users and operators of plant protection products, procedures for the issuing of permits for the aerial spraying of plant protection products and other measures to combat invasive species. In addition, other normative enactments should be taken into account that may restrict the use of the products in protected nature territories (for example, individual regulations of protection and use of the protected nature territory).

7.3.8 Environmental Impact Assessment

Preparation is required for the restoration and management of habitats and species habitats, which means not only careful planning, but also an estimated assessment of the impact of the activity. In order to implement habitat restoration, a certain procedure, examination, activity coordination and authorisation is required. Prior to the restoration of a habitat, it is necessary to assess whether the proposed activity will result in any environmental changes that may significantly affect human health and safety, landscape, cultural and natural heritage, as well as other species habitats or habitats. **The law "On Environmental Impact Assessment"**[26] regulates the activities[27] that meet specific criteria according to which the impact of the intended activity on the environment is assessed, especially if it is implemented in protected nature territories, micro-reserves, wetlands of international importance, in the coastal protection zone of the Baltic Sea and the Gulf of Riga, protection zone of surface water objects, and if it might affect protected species, their habitats and protected habitats.

The law describes that initial impact assessment is definitely required for the activities that may significantly influence the Natura 2000 area. Initial impact assessment is performed by the State Environmental Service.

Activities that require initial impact assessment are listed in the annex of the law. Such activities that may be applicable to habitat restoration are: agricultural land use category change, if the area of the land is greater than 50 ha; construction of new drainage and irrigation systems in cases where the land area is larger than 100 ha; reconstruction of existing drainage or irrigation systems if the area is greater than 500 ha; afforestation and deforestation if the area is greater than 50 ha.

If habitat restoration activities require an environmental impact assessment process in accordance with the initial impact assessment, then the State Environmental Service prepares a statement and the responsible institution makes a decision on the application or non-application of the environmental impact assessment. The minimum time required can be at least 130 days for the preparation of the initial assessment, decision, and statement (additional time must be planned for the preparation of the environmental impact assessment report).

If, in accordance with the results of the initial environmental impact assessment the intended activity does not require an environmental impact assessment, the State Environmental Service issues technical regulations on each specific intended activity in compliance with the Cabinet Regulations[28], which define activities that require technical regulations and that are related to or involve construction. These include hydrological construction and reconstruction projects.

7.4 Coordination of Activities

Restoration and management of protected habitats and species habitats, before implementation **in protected nature areas and micro-reserves, must be coordinated with the responsible public authorities** (Fig. 7.1). Before starting the activities all the necessary information needs to be collected and in the case of any uncertainties, the responsible authorities should be consulted.

In order not to lose time and so that the work can be carried out in the appropriate season, requests for the permits (if required) must always be submitted on time. If habitat restoration is planned in protected nature areas or micro-reserves, prior to this, the Nature Conservation Agency should always be contacted.

7.5 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 to improve the habitat condition. Cost differences of similar work can be great – depending on the geographic location, complexity of works, availability of workers and special equipment, and other factors. These guidelines are meant for use over an extended period of time, and therefore particular aggregate costs are not provided. We recommend that costs be assessed for each individual activity or for the whole work to be done in a particular place and time. In each case the costs will vary, determined on the factors mentioned above.

It is advisable that the following principles are used by the developers of nature conservation plans, LIFE and other large projects in order to estimate the cost of habitat management and restoration activities for a period of 2-5 years, in one large or several Natura 2000 sites in total.

In small areas (up to 1 ha), as well as in cases where management is regular or certain parameters are known (for example, digging or blocking

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

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

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

[24] With the amendments as of 26 November 2016.

[25] Cabinet Regulation No. 950 of 13 December 2011, On the Use of Plant Protection Products.

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

[27] An 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 influence the environment.

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

Is the activity planned in a protected nature territory or a micro-reserve? If it is located in a protected nature territory, what type of functional zone is it?	The State Management System of Nature Data „Ozols" ozols.daba.gov.lv	If the activity will not take place in a protected nature territory or a micro-reserve, consult with the respective Regional Board of the State Environmental Service prior to the activity. Individual regulation on protection and use of a protected nature territory defines the permitted, restricted and coordinated activities. **Consult with the Nature Conservation Agency prior to starting the activity.** If no individual regulation is applicable, the permitted, restricted and coordinated activities are defined by the general regulation on conservation and use of protected nature territories. **Consult with the Nature Conservation Agency prior to starting the activity.**
Who owns or is in possession of the land?	Clarify this at the local municipal authority or on www.kadastri.lv	If the land owner or possessor agrees with the proposed activity, both parties should harmonise this in writing.
What is the category of land use?	Specified in the land border plan	If the restoration of a protected habitat type or species requires transformation of land into another category (e.g. forest to grassland), it must be coordinated with the responsible authorities. According to the individual or general regulation on protection and use of a protected nature area, 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 muncipality 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 R**ural 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 areas outside the Natura 2000 – at the **Nature Conservation Agency**. More information is available on the websites of these institutions.

Fig. 7.2.1. Actions, when planning habitat restoration or management.

of ditches of a certain size), the costs can be generalised by comparing them to work performed elsewhere or by interviewing the potential workers, and agreeing on the total cost of all work.

The key principles to determine the justified cost of the planned actions.

After the surveying of the managed site **the most appropriate actions, methods and technical means are chosen.** It is advised to divide the work both by stages in time and types of work, for example, hand work, use of one or another type of equipment in order to determine the pricing of each activity separately and summing up to obtain a more objective assessment. The costs of the work and efficiency often depend on the season, for example, rewetting of mires should be carried out in the dry season, otherwise the cost can grow unpredictably, and the intended purpose cannot be implemented or the quality may be poor.

Direct costs should be calculated in appropriate units – in man-hours, person-days, the cost of equipment per hour, and cost of materials per area or volume of work (m^3, km, kg, t). The number of units required for all work should be assessed and agregated. Experience shows that errors are most common in these calculations, thus it is always advisable to use both the experience of similar and already implemented work, such as reports on projects, specific work, and the experience of the relevant institutions (Nature Conservation Agency, JSC "Latvia's State Forests", Rural Support Service, and municipal and non-governmental organisations). If the set of activities to be carried out consists of various types of work not performed before or their pricing is not known, at least three potential executors can be surveyed. In this case, the result can be obtained faster, but the risk increases that unforeseen costs may arise that can complicate the fulfilment of the aim. If wood is obtained during the measures that one can sell, the timber delivery distance to the road and transportation costs must be taken into account in the calculation.

The indirect preparatory costs of habitat management and restoration work should be assessed – site survey, expertise, technical projects, permits and agreements referred to in the regulatory enactments (*see Ch. 7.4*). This involves both work time and transport and administrative costs, which are often inadequately assessed. The time and resources 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, as well as the availability of the workers in the given region up to 30 km from the planned place of activity. 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, scarification of topsoil) will always be more expensive than simple activities (cutting of shrubs, felling).

It is desirable to entrust cost assessment to professionals – managers, managing specialists, practitioners, entrepreneurs, – and schedule this job and the adequate funding.

In financial planning of the planning stage, potential income should also be foreseen in relation to wood and other materials obtained during habitat restoration and management. Ideally, they can be used on the site at least partly (e.g., in dam construction when rewetting a marsh) or taken out of the area and used elsewhere (such as for wood chips or fire wood). However, it should be considered that the use of habitat restoration "by-products" may not always be economically beneficial.

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

Nature Conservation Agency: permitted and prohibited activities in protected nature areas and microreserves, 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 there of: 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.

Chapter 8. Main Methods of Forest Habitat restoration and management

The main forest habitat restoration and management methods that focus on the solving of specific issues, are summarised in Table 8.1. More on the influencing factors and risks that are significant for each EU forest habitat, as well as more detailed descriptions of restoration and management methods, are found in Chapters 10–14 of the habitat guidelines.

Table 8.1 Basic Approaches to Forest Habitat Restoration and Management.

Problem	Solutions	Habitats
Prevention of Adverse Impacts		
Eutrophication	Controlled burning of the ground cover. Regular felling and disposal of shrubs. Shrub root removal. In intensely In intensely visited places - construction and maintenance of toilets, waste removal.	Dry coniferous forests on poor soils.
Constant inundation due to *Castor fiber* activities (too high water level).	Destruction of *Castor fiber* dams, insertion of pipes below the dams, control of *Castor fiber* population (hunting, traps). Filling up of drainage ditches.	Swamp woods, alluvial forests.
Unwanted runoff from agricultural land, intensive erosion	Creation of a buffer zone where tree felling is less intensive.	Forests of slopes, screes and ravines, deciduous swamp woods, bog woodlands.
Rewetting		
Functioning of drainage systems (ditches, drainage channels, flood protecting dams, etc.) – draining the forest, promoting peat layer compaction and mineralisation, causing degradation of the typical vegetation, changes of habitat structure.	Blocking of ditches, filling up of ditches or parts of them, destruction of ditch soil, construction of dams to maintain the natural water table level.	Bog woodlands, swamp woods.
Transpiration (evaporation through tree leaves). Overgrowth with *Picea abies* as the draining effect increases.	Removal of the subcanopy and sapling layers of *Picea abies*, raise water table, thus causing mortality of woody plants (creation of inappropriate conditions for *Picea abies*).	Bog woodlands, swamp woods.
Loss of natural flood regime with drainage systems, the following changes in natural vegetation, overgrowth with habitat-atypical species, such as *Picea abies*.	Restoration of the flood regime – filling up of ditches, making water courses more natural, removal of berm along ditches. Felling and removal of the subcanopy and saplings of *Picea abies*.	Alluvial forests.

Table 8.1 Basic Approaches to Forest Habitat Restoration and Management. (Table continuation.)

Problem	Solutions	Habitats
Reconstruction and Improvement of Habitat Structure		
Intensive overgrowth with *Picea abies* as an effect of drainage systems.	Rewetting. Felling and removal of the subcanopy and saplings of *Picea abies*, removal of felling residues. Ring-barking of the subcanopy layer trees.	Bog woodlands, swamp woods.
Changes in tree species composition as a result of natural succession, establishment of *Picea abies*.	Felling and removal of the subcanopy and saplings of *Picea abies*, ring-barking of the subcanopy trees. Mandatory removal of felling residues.	Oak or oak-hornbeam forests of the *Carpinion betuli*, natural old broad-leaved deciduous forests.
Changes in tree species composition – establishment of *Picea abies* as a result of natural succession and lack of fire. Disappearance of understorey species characteristic of sparse species-rich *Pinus sylvestris* forests.	Felling and removal of the subcanopy and saplings of *Picea abies*, ring-barking of the subcanopy trees. Removal of felling residues, burning on site. Controlled burning of the ground cover. Soil scarification.	Coniferous forests on, or connected to, glaciofluvial eskers.
Spreading, dominance of invasive plant species.	Optimal rewetting. Cutting of invasive tree and shrub species, extraction of roots, brush cutting, digging of roots, spade cutting, etc.	All forest habitat types.
Lack of structures characteristic for a natural forest.	Creation of dead wood and canopy gaps. Ring-barking of trees, up-rooting trees, blasting, felling and leaving on site in the forest, etc.	All forest habitat types.
Lack of structures characteristic to a natural forest that are caused by fire disturbance in dry forests.	Controlled burning. Creation of mineralised soil patches.	Habitats of dry coniferous forests.
Restoration of habitat-characteristic species population		
Degradation or extinction of habitat-typical plant communities.	All activities restoring and improving the habitat structure (*see Activities Restoring and Improving the Habitat Structure*). Specialised thinning.	All forest habitat types.
Extinction of rare, endangered species typical for the habitat.	All activities for restoring and improving of the habitat structure (*see Activities Restoring and Improving the Habitat Structure*). Establishment or restoration of suitable conditions for certain species, such as creating openings around trees suitable for *Osmoderma barnabita*.	All forest habitat types.
Extinction of typical animal and bird species or population depletion.	Creation or restoration of suitable conditions for certain species, creation and management of nesting sites (artificial nests, bird boxes).	All forest habitat types.
Landscape fragmentation, habitat and species population isolation.	Habitat aggregation, creation of "future habitats". Tending to obtain appropriate tree species composition, protection of young stands. Reconstructive thinning of artificially planted stands to obtain species composition characteristic of a habitat. Creation of migration corridors at different scales.	All forest habitat types.
Prevention and Reduction of Visitor Load		
Adverse, degrading effect on the habitat and the inhabiting species related to visitor/tourist load: trampling, rubbish, undesirable disturbance to animals (noise, physical presence), aesthetic damage, etc.	Creation of infrastructure to redirect and reduce load of tourist flow, shifting the load to less sensitive adjacent or other territories (trails, footbridges, platforms, barriers). Placement and distribution of educational information (information boards, demonstrative objects, educational objects, educational lessons, guided excursions, etc.).	All forest habitat types, especially forests of slopes, screes and ravines.

Chapter 9. Evaluation of the Success of Management and Restoration

(S. Ikauniece, A. Priede)

Evaluation of success means to systematically document the changes or perform monitoring, or at least to compare the situation before and after the restoration or management of the habitat. A reliable and scientifically based result can only be obtained if the changes are documented systematically, following certain techniques and on a regular basis. The monitoring results should be able to answer the questions - whether restoration and management have reached the initial target, and to what extent and why the target has not been reached. The monitoring will only provide reliable results if the vegetation and other parameters are assessed in the habitat both before (control) and after restoration. If it is not possible to compare the changes with a control habitat similar in conditions to that in which the restoration was conducted, it is obligatorily to document the initial conditions before management or restoration. In any case, vegetation and other parameters before and after restoration must be compared with a habitat in which management was not conducted.

Before management it is necessary to assess the territory by collecting the data that describe the existing condition, for example, the species composition of ground cover, understorey vegetation, sapling density and characteristics, tree canopy data, tree density, etc. This information should be further used for comparison in assessing the success of forest habitat restoration and management.

Before establishing monitoring sampling plots, it is important to consider the following:

- Which method will be used – how much time and human resources will be required at each time of monitoring, and is it affordable?
- Is the selected number and size of sample plots representative of the area and potential changes and sufficient for statistical analysis (this preferably requires replication of both control and treatment/restoration sites).

It creates difficulty if many sample areas were established in the initial year of monitoring, but it would be impossible to follow them up in subsequent years. Also, a too small number of sampling plots will not reflect the nature of the area and the changes, and it will not be possible to perform statistical analysis.

Assessment and monitoring of changes in a habitat is mandatory for adaptive management – to modify management or implement additional measures depending on the results of monitoring. Mortality of trees cannot be used as an indicator for the quick reaction because, like significant changes in vegetation, it is a delayed response to adverse processes. In rewetting cases, observations should be performed regularly each year.

Change in water level is one of the basic indicators that can help evaluate the success of rewetting. In restored sites the water level typically increases, fluctuations decrease, and plants characteristic of wet soil establish. For monitoring of the hydrological regime in sites of mire habitat restoration, usually several rows of bore-holes (profiles) are made that are located perpendicular to the ditches. Observations must be regular – preferably once a week or at least 1-2 times a month over at least 10 years. Detailed information on monitoring methods can be read in the Guidelines for Mire Habitat Management (Priede (ed.) 2016).

Evaluation of success also includes the assessment of specific methods, instruments, technical or other resources used.

Management efficiency depends on the management objective and on specific habitat. Table 9.1 summarises the main indicators of various management methods, but the detailed evaluation parameters must be determined in each particular case, based on the indications that characterise habitat quality under a favourable conservation status, as well as important processes, structures for habitats, and natural development (succession) of habitats. The evaluation must be conducted during the vegetation season by establishing sample areas and documenting all measurements and records according to the standard research methods.

To assess measures of habitat conservation, management and restoration on a larger scale and in more detail, further research and long-term monitoring are necessary, which might give answers and suggest modifications in the methods used.

Table 9.1 Indicators for the management efficiency assessment.

Type of Habitat Management or Restoration	Indicator of the assessment of efficiency
Creation of dead wood and canopy openings	Development of dead wood and mosaic-type forest stand structures at levels optimal for the habitat. Colonisation of species dependent on dead wood.
Controlled burning of the ground cover (continuous or by patches in a large area) (habitats 9060, 9010*).	Development of burnt dead wood and mosaic-type forest stand structures at levels optimal for the habitat. Colonisation of species dependent on fire disturbance. Development of vegetation characteristic to the habitat, the increase of cover or abundance of characteristic species.
Groundcover scarification, formation of mineralised soil patches (habitat type 9060)	Development of vegetation characteristic to the habitat, the cover or abundance of characteristic species.
Removal of the subcanopy and saplings of *Picea abies* (habitats 9060, 9160, 9020*)	Development or restoration of characteristic tree and shrub layers and understorey vegetation, increase in cover of characteristic plant species.
Felling and removal of shrub layer	Development or restoration of characteristic tree, shrub layers and understorey vegetation, increase in cover of characteristic plant species.
Creation of a buffer zone where felling is less intense	Development or restoration of characteristic tree, shrub layers and understorey vegetation.
Optimal rewetting (filling up and blocking of ditches, damming, restoration of high water regime, demolishing of *Castor fiber* dams)	Restored hydrological conditions characterised by the establishment of the respective tree and understorey species such as *Sphagnum* spp. and *Eriophorum* spp. in bog woodlands; loss of dense stands of *Ledum palustre* and other low shrubs. Water level increases (or decreases on sites where *Castor fiber* dams are being destroyed), water level fluctuations decrease, water level stabilises. In a restored natural flood regime, development of morphological structures, such as sand deposits (the amount needs to be evaluated because sand deposits can indicate both natural and adverse effects), microtopography formed by water flows (wet slacks).
Reconstructive felling, "future habitats"	Development or restoration of characteristic tree, shrub layer and understorey vegetation, increase in cover of characteristic plant species.
Abatement of invasive tree and shrub species	Development or restoration of characteristic tree, shrub layer and understorey vegetation; disappearance of invasive species in the territory of the habitat.
Creation of an infrastructure reducing and redirecting the tourism load	Development or restoration of characteristic understorey vegetation, increase in cover of characteristic plant species.

Part II

Chapter 10. 9010* *Western Taiga*, 91T0 *Central European Lichen Scots Pine Porests*, and 9050 *Fennoscandian Herb-Rich Forests with* Picea Abies

10.1. Boreal Forest Habitat characteristics

10.1.1. Brief Description

As all the protected coniferous forest habitats of the boreal forest zone have similar natural development, characteristic disturbances and ecological processes, guidelines for the management of EU protected habitat type 9010* *Western Taiga* are compiled into a single chapter with guidelines for two other EU protected habitat types – 91T0 *Central European Lichen Scots pine forests* and 9050 *Fennoscandian herb-rich forests with* Picea abies. The conservation of these habitats requires similar management to the habitat type 9010* *Western Taiga*

Habitat type 9010* *Western Taiga* (Fig. 10.2, 10.3) includes both natural, old forests and new forests, that have evolved naturally after fires. These belong to the *Vaccinio Piceetea* forest class (Laiviņš 2014). The habitat has relatively frequent occurrence in Latvia (Fig. 10.1), but not in large areas and it is highly fragmented.

Forests representative of the habitat are divided into two large groups: *Pinus sylvestris* forests of various ages in dry, oligotrophic conditions, where the most important natural disturbance is fire, and coniferous forests in the late stage of development (succession), where the most important natural disturbance is gap formation. Most of today's old forests in Latvia have been influenced by humans, but many features of natural forests have survived, which are crucial for identifying the habitat. Important habitat structures are dead wood in different stages of decay (snags and fallen deadwood), features of uneven forest stand age (cohort) and biologically old trees. The overstorey is composed of species characteristic of boreal

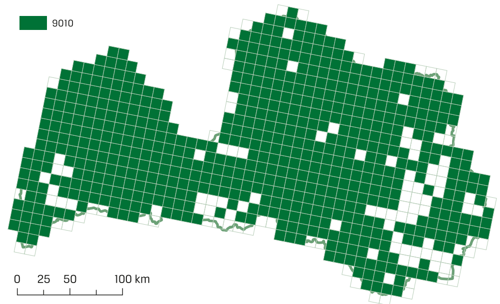

Fig. 10.1. Distribution of the habitat type 9010* *Western Taiga* in Latvia (source: Anon. 2013c).

Fig. 10.2. Natural old boreal forest, corresponding to the habitat type 9010* *Western Taiga* where *Picea abies* are dominant. Photo: S. Ikauniece.

Fig. 10.3. Natural old *Picea abies* and *Pinus sylvestris* forest, corresponding to the habitat type 9010* *Western Taiga*. Photo: S. Ikauniece.

forests – *Pinus sylvestris*, *Picea abies*, *Betula pendula*, *Betula pubescens*, and *Populus tremula*.

The previous forest fire regime in the boreal region resulted in a component of young stages of boreal forest development that have formed naturally, without human intervention. But nowadays, due to effective fire protection and intensive forest management, they are rare.

Old or natural boreal forests grow on various soils: from well-drained to periodically wet mineral soils, from poor to rich in terms of fertility, and sometimes also on drained soils where mineralisation of the peat layer has occurred. The character of forest vegetation varies depending on the environmental conditions.

Six subtypes of the habitat type 9010* *Western Taiga* are found in Latvia: (1) natural old *Picea abies* forests; (2) natural old *Pinus sylvestris* forests; (3) natural old mixed forests; (4) natural old pioneer tree species forests; (5) recently burnt forest; (6) younger forests that have evolved after forest fires (Lārmanis 2013c).

Given the broad spectrum of forest stand types for the habitat, five variants that to some extent determine the necessary conservation and management measures have been distinguished. For a forest stand to be qualified as an EU protected habitat type, the first four variants must comply with the quality criteria of Woodland Key Habitat or potential Woodland Key Habitat (Lārmanis 2013c).

variant 1: the typical variant that is characteristic to stands of the boreal class in dry or variable moisture conditions;

variant 2: habitat with partially characteristic vegetation where broad-leaved tree species occur in the canopy, and the understorey contains both boreal and nemoral species;

variant 3: forest stands on drained soils with characteristic features of this habitat, where organic layer mineralisation has occurred and the vegetation has developed in the direction of dry boreal forests;

variant 4: recent burnt forests where charred patches occur on the ground and trees and shrubs have burnt bark;

variant 5: younger forests that have developed naturally after forest fire, if all burnt trees have not been removed after the fire and artificial restoration of stands has not been performed.

Habitat type 91T0 *Central European lichen Scots pine forests* (Rove 2016) resembles variant 1 of habitat type 9010* *Western Taiga* (variant 1 – forest stands in dry conditions and early stages of succession, where the dominant tree species is *Pinus sylvestris*). The most significant difference is that forest stands corresponding to habitat type 91T0 occur on inland dunes outside the coastal lowlands. The habitat includes both individual inland dunes with dry forests of *Pinus sylvestris*, as well as compact groups of dunes and wide areas of dunes, where the dunes are interspersed with depressions of various width and areas with previously overblowing sand. An important criterion is a habitat-typical ground cover where *Cladonia* spp. and *Cladina* spp. is at least 25%. As a result of succession, if there are no ground cover disturbances, the cover of moss and dwarf shrubs increases, the humus layer develops, more nutrients leach into the soil, the soil becomes more fertile, and lichen cover decreases. In the cases when the habitat meets the criteria of a Woodland Key Habitat or potential Woodland Key Habitat, according to the protected habitat mapping methodology of 2015 (Lārmanis 2013c) it can be included in variant 1 of the habitat type 9010* *Western Taiga*.

Fig. 10.4. Variant 5 of habitat type 9010* – young forest, that has naturally evolved after forest fires. The dead wood has not been removed after a fire. Photo: S. Ikauniece.

Habitat type 9050 *Fennoscandian herb-rich forests with* Picea abies (Ikauniece et al. 2015) resembles variant 2 of the habitat type 9010* *Western Taiga* if it has the representative vegetation. Habitat type 9050 *Fennoscandian herb-rich forests with* Picea abies is included in this variant according to the mapping methodology until the year 2015 (Lārmanis 2013c) (Fig. 10.5).

In forest stands characteristic for this habitat type, the canopy and subcanopy are dominated by *Picea abies* and at least 30% of the understorey vegetation cover consists of species typical for broad-leaved forests. A large diversity of herbaceous plant species can be observed in the understorey, sometimes spring blooming is well-marked, ferns are often found.

Fig. 10.5. Habitat type 9050 *Fennoscandian herb-rich forests with* Picea abies. Photo: S. Ikauniece.

Further in the text, all three of the above habitat types are called “boreal forests”. In other cases the particular habitat type or its subtype is listed.

10.1.2 Indications of Favourable Conservation Status

Favourable conservation status of boreal forest is characterised by the presence of typical species composition and long-term persistence of natural structural elements and natural processes that promote the formation of characteristic structures (Norden et al. 2014). An important factor promoting the ecological value of a habitat is the presence of protected and rare species, whereby the habitat can serve as a centre of dispersal for these species (Fig. 10.6).

Habitat type 9010* *Western Taiga* belongs to the *Vaccinio-Piceetea* class. Although the habitat type covers six different forest sub-types, dominance of boreal coniferous forest species is characteristic to all of them. The species complex present in the understorey varies depending on the fertility and moisture of the soil. In oligotrophic and dry *Pinus sylvestris* forests, also in habitat type 91T0 *Central European lichen Scots pine forests*, besides *Cladonia* spp., there are also *Vaccinium vitis-idaea, Empetrum nigrum, Calluna vulgaris, Deschampsia flexuosa* and *Melampyrum pratense* in the understorey. In more fertile mixed woods where forest stands also contain *Picea abies* and *Populus tremula*, the understorey also contains *Oxalis acetosella, Maianthemum bifolium, Trientalis europaea* and *Vaccinium myrtillus.* A moss layer is characteristic of the habitat, *Pleurozium schreberi, Hylocomium splendens* and *Dicranum* spp. are usually dominant. The borderline cases with habitat type 9050 *Fennoscandian herb-rich forests with* Picea abies must be considered when identifying the habitat, since the management may differ. In habitat type 9050 *Fennoscandian herb-rich forests with* Picea abies at least 30% of the species composition of the understorey consists of herbs and ferns characteristic of broad-leaved forests, e.g. *Anemone* spp., *Asarum europaeum, Galium odoratum, Geum urbanum, Galeobdolon luteum, Lathyrus vernus, Phegopteris connectilis, Gymnocarpium dryopteris* etc.

Species composition also characterises the habitat continuity, where the so-called ancient forest species have a significant role. These species are characterised by low rate of establishment and low dispersal ability, which can reflect the land use history to some extent (Hermy, Verheyen 2007). One such species is *Oxalis acetosella* (Honnay et al. 1998).

Since boreal forests include forests of different stages of succession and types, the range of rare species present is very wide, and it is associated with the conditions characteristic to the habitat. Boreal forests are important for species that use dead wood as their habitat, such as epixilous moss species and polypores. Conifer logs are habitats for rare moss species *Anastrophyllum hellerianum, Odontoschisma denudatum*, several species of *Lophozia spp.* Also rare species of polypores, such as the protected polypores *Phellinus ferrugineofuscus* and *Fomitopsis rosea,* and rare *Climatocystis borealis* and *Leptoporus mollis*, are associated with dead wood. Also many rare invertebrate species require wood in different stages of decay. For example, relatively decayed wood is required as substrate for *Ceruchus chrysomelinus,* dead large branches of *Pinus sylvestris* are necessary for *Buprestis octoguttata.*

Old *Populus tremula* and *Picea abies* stands are habitats for rare epiphytic lichens, such as *Nephroma* spp. and *Arthonia leucopellaea*. *Pulsatilla patens, Dianthus arenarius*, and *Diphasiastrum* spp. grow in sparse oligotrophic and burnt forests. Well-lit stems of *Pinus sylvestris* are suitable for protected beetle species, such as *Nothorhina punctata* and *Tragosoma depsarium*. *Melanophila acuminata and Stephanopachys linearis* require dead burnt wood, and the long-term survival of these species without forest fires is very restricted (Vilks 2014).

Biologically old trees and forest stands that have little been affected by human activities and are characteristic to old and natural boreal forests are important habitats for rare bird species, such as *Dryocopus martius* and *Picoides tridactylus; Dendrocopos leucotos* may live in old pioneer deciduous tree forests. *Bonasa bonasia* selects habitat in different types of *Picea abies* and mixed

Fig. 10.6. Natural forest of old pine, spruce and aspen, corresponding to the habitat type 9010* *Western Taiga.* Drawing by D. Segliņa

forests with *Betula spp*., *Populus tremula* and *Pinus sylvestris* (Petriņš 2014).

10.1.3 Important Processes and Structures

10.1.3.1 Processes

In natural conditions and those affected by humans, **fire** is one of the widest and most typical disturbances in the forests of the boreal zone, even though natural fires nowadays are no longer typical in Latvia, and most of the burning in forests has been caused by human activity. In general, the natural fire regime in the boreal forests of Eurasia can be described as a fire mosaic of differing intensity, from a strong crown fire followed by secondary succession (substitution) of a forest stand, to a ground fire after which almost all trees remain living (Shorohova et al. 2011). It is a process that creates a large volume of burnt dead wood in the forest, while individual or groups of trees survive. In dry *Pinus sylvestris* forests, a portion of trees remain after the fire, an uneven-aged structure develops if regeneration has taken place after several fires. Then the forest stand is formed by living trees of different generations (cohort structure). Complex ground level structures including bare soil or sand patches are formed. In *Picea abies* forests, which are usually more humid, fires occur less frequently, but their impact is much greater, since *Picea abies* tree mortality is much higher than for *Pinus sylvestris* in the case of fire. Great spatial diversity is characteristic of boreal forests, with patterns formed by forest stands of different age and stages of succession, as well many dead and dying trees that are generally removed in commercial forests. After a fire fully destroys the forest stand, an even-aged stand may form as a result of natural regeneration.

Wind-throws, especially in *Picea abies* forests, are wide-scale disturbances that result in significant changes in insolation, which determine the course of regeneration in a forest stand, and result in even-aged forest stands. Although individual trees may remain, most of the trees are uprooted or broken due to wind, creating stumps of different height and creating a large volume of dead wood. Exposed soil and root plates alter the microtopography and create new ecological niches.

Massive **insect damage** to coniferous stands, similar to the impacts of wind-throws and fire, may cause a wide-scale disturbance if the larger part of the tree canopy dies. In *Picea abies* stands, wide damage is usually caused by *Ips typographus*. Depending on the intensity of the impact, many dead standing trees appear in large areas or patches of various size (so-called bark beetle nests). Damage due to other insects, such as *Lymantria monacha* or *Ips acuminatus*, in Latvia is mostly local.

Gap formation is a process whereby individual trees or small groups of trees suffer mortality due to, for example, wind-throw, snowbreak, insect infestation or age. Pioneer tree species usually regenerate in gaps (*Betula spp*. and *Populus tremula*), an understorey tree and shrub layer rapidly develops, sometimes from advance growth. These small scale disturbances, when other conditions are stable, promote the formation of an uneven-aged structure (Ek et al. 2002; Bottero et al. 2011). Tree response to gap formation, particularly regarding insolation, differs depending on gap size and stand age. Firstly, tree canopies expand into gaps. Gaps formed in older stands can persist for a longer period of time, promoting development of a tree understorey. Secondly, advance growth increases in height rapidly. Thirdly, if the gap is sufficiently large, new groups of trees establish (Johanson et al. 2002). Mosaic of uneven-aged stands and gaps develop, with the presence of standing and fallen dead trees in various stages of decay.

10.1.3.2 Structures

The presence of structural elements characteristic to natural, old forests and indicator species of Woodland Key Habitats and habitat-specific species in the stand are crucial quality indicators. One of the preconditions to identify the EU protected habitat type 9010* *Western Taiga*, is compliance with the quality criteria of Woodland Key Habitat or potential Woodland Key Habitat (Lārmanis 2013c). It is not a precondition for the habitat types 9050 *Fennoscandian herb-rich forests with* Picea abies and 91T0 *Central European lichen Scots pine forests*, but it significantly increases the evaluation of habitat quality. To determine the quality of a habitat, one must assess both the structure and species of the forest stand. The most significant indicators are coarse woody debris, biologically old trees, gaps, uneven-aged forest stand structure, etc. (*see Ch. 1*). Their presence and diversity indicates on potential compliance with the criteria of Woodland Key Habitat and high ecological value. Structural elements of natural forests serve as habitats for a large number of habitat characteristic species that are not usually found in intensively managed forests where there is little natural structure (Ek et al. 2002). They indicate natural development of forest stands even if human intervention has occurred in an earlier period, for example, thinning that was conducted several decades ago.

10.1.4 Succession

In natural conditions, ecological disturbances affecting the stand structure may occur in boreal forests of any age:

- complete regeneration of a forest stand – substitution of a stand takes place after a strong and extensive disturbance (after wind-throws, fires);
- cohort dynamics – a non-intensive disturbance causing death of some of the trees, characteristic to boreal *Pinus sylvestris* forests after fire;
- patch dynamics – formation of gaps larger than 200 m^2;
- gap dynamics – mortality of individual trees or small groups of trees, with gap size < 200 m^2 (Kuuluvainen, Aakala 2011).

A large-scale intensive disturbance (fire, storm) can be considered as the beginning of the development of a boreal forest stand. As a result of severe wind, a forest stand can be completely destroyed, i.e., almost all mature trees are uprooted or broken. The effect of fire depends on its intensity, which is determined by a variety of climatic and soil conditions, the stand structure and the composition of tree species. The whole forest stand or only a part of the standing trees might die as a result of fire.

If a disturbance has occurred in a forest where all mature trees have perished, the stand regenerates by secondary succession and an even-aged stand is formed. Not only *Pinus sylvestris* stands, but also young stands of *Betula spp*., or less often, *Populus tremula*, can form after fires (Fig. 10.7, Fig. 10.8). A large amount of dead wood that persists for a long period of time is typically found after burning (Shorohova et al. 2011). When a stand, including large dimension trees, suffers mortality in one event, there might be a lack of wood of various stages of decay after some period of time. However, although an even-aged stand forms after burning, after a longer period of time structures important for the biodiversity build up, and an even-aged biologically old forest can develop after 180-200 years of succession after fire.

More intensive natural tree death occurs in old stands, creating gaps and uneven-aged structure (Shorohova et al. 2011). Thinning occurs at the beginning of the formation of a stand due to competition, creating snags and logs with small dimensions; later the dimensions of dead wood increase in relation to the size of the growing trees.

As the ground cover burns, individual animals may die, but this does not endanger the population in general, as in natural conditions the population sizes recover. Some of the species that inhabit forests that tend to burn have often adapted to this disturbance. For example, ant nests are located largely below ground with open sand cleared of needles and other debris above the nests, thus creating a kind of security zone around the nest, which cannot be reached by the fire.

Some trees die in medium-intensity fires in dry forests, but in cases of low-intensity burning, only part of the shrub layer and vegetation dies. Patch and gap dynamics are typical of mixed coniferous forests that burn less frequently. In this case, there are two types of forests: (1) trees of various ages are evenly distributed in the stand as a mosaic, small gaps with one or some trees are formed; (2) larger gaps, developing tree groups of different ages (Angelstam, Kuuluvainen 2004).

Fig. 10.7. *Betula* spp. trees have started growing in an opening after a fire. Photo: S. Ikauniece.

Fig. 10.8. A dense *Betula* spp. stand has naturally regenerated after a fire. Photo: S. Ikauniece.

An uneven-aged forest stand can exist for a long time in forest types that burn less frequently, but a large-scale, intense disturbance (fire, storm) can destroy mature stands, resulting in secondary succession.

After clearcutting, the development of a stand takes place similarly to that after a natural large-scale, intense disturbance, if the area is left to restore naturally. However, after a fire disturbance, dead wood is present in the forest stand and the ground cover is greatly disturbed, causing significant decrease of moss cover, which is not typical after clearcutting.

Since Latvia is located in a forest zone, open areas (grassland, heaths, grey dunes) naturally afforest over the course of time without human intervention and management. Also in these cases the stand development is similar to that after a large-scale disturbance, with pioneer species appearing first. Later, natural processes occur as in forest stands. These overgrowing areas differ from old-growth forests in the diversity of structural elements. Diversity of structural elements in secondary forests is low, for example, there are no biologically old trees or dead wood in several decay stages, and species composition of the understorey is not indicative of an ancient forest stand, as a longer period of time must pass before ancient forest species appear (Honnay et al. 2008).

10.1.5 Pressures and Threats

10.1.5.1 Logging

Logging is considered the major factor threatening old or natural boreal forests, because the forest stand is totally or partially destroyed; in the case of clearcutting the whole forest stand is destroyed. Even though in accordance with the legislation the retention trees are conserved (5-10 pcs./ha), their ecological functions will not balance the loss of the forest stand. After clearcutting, as after a large-scale, intense disturbance, an even-aged forest stand is formed, which is not comparable to natural disturbance, because dead wood does not remain in the forest to the extent that is typical of natural disturbance. After clearcutting, burnt dead wood and bare mineral soil patches do not form, unlike after fire. Other types of felling cause adverse effects as well if they include the removal of medium and large-dimension dead and dying biologically old trees, which are important to many species associated with old forests such as cavity-nesting birds. For example, it has been observed that *Dryocopus martius* will only build nests in trees with a diameter such that it is possible to excavate cavities of 15-20 cm in diameter at a height of 10 m, where wood of approximately 5 cm remains around it. This means that *Dryocopus martius* will only inhabit trees that have reached at least 40-50 cm at breast height, and *Pinus sylvestris* mostly only reaches such size after the age of final felling. A study in Latvia found that the average tree age where *Dryocopus martius* nests is 165 years (Petriņš 2014).

Clearcutting can also cause changes in the hydrological regime, as after tree removal, evapotranspiration rapidly declines, the water remains in the soil, and waterlogging may occur in wetter stands.

Clearcutting substantially affects nutrient cycles in the ecosystem. Since the biomass of trees contains many nutrients, their removal means that the nutrients are taken away from the ecosystem. After clearcutting, the input of nutrients in plant biomass drastically decreases in the ecosystem, and decomposition of organic matter and flow of the released nutrients to the groundwater increases. Surface runoff also often increases, which generally means that nutrients are drained from the forest stand. By only removing tree stems, the carbon and nitrogen level initially increases in the soil due to the retention of felling debris. Denitrification increases (Lībiete-Zālīte 2012), affecting the species composition of the ground cover as well.

10.1.5.2 Fragmentation

Fragmentation causes a reduction of continuous habitat area. Decrease of patch number is also associated with an increase of distance between habitat fragments, changes in habitat configuration, and increased edge effect (Tērauds 2011). The decline in the total area of habitat is directly associated with fragmentation of forest landscape as a result of changing land use, such as for residential or commercial building, agriculture, quarries, as well as by separating forest stands by roads and railways. Fragmentation of the forests important for the natural diversity also occurs due to clear-cutting, altered hydrological regime, or otherwise reducing the biological value of the forest. Thus, the forest area important for the natural diversity has declined and distances between important forest patches have increased. Fragmentation reduces the overall habitat area suitable for the species, increases habitat isolation, reduces the connectivity of suitable habitats and continuous habitat areas, and increases edge effect (Laurence 2008). Such changes affect, for example, the species composition of the understorey vegetation in stands. Many researchers associate fragmentation with a reduction in the number of species at a regional or national level (Bailey 2007). The reduction in the continuous area of habitat and the reduction in the species population density increase the risk of local extinction of species. The increasing isolation of the continuous habitat areas, where habitat patches become more distant, reduces the capacity of individuals of many species to disperse from one habitat patch to another, to maintain the genetic diversity of the population and other processes that are important for the population (Hanski 1998).

Fragmentation by clear-cutting forests has a significant negative impact on numerous bird species, for example, *Tetrao urogallus*. The population size of *Tetrao urogallus* depends on the density, quality and contiguous area of suitable habitats (Petriņš 2014).

10.1.5.3 Synanthropisation

The vegetation of Latvia has rapidly changed in recent decades as a result of the deposition of airborne pollutants, climate change and land use. The natural plant communities generally become less stable, and the process of synanthropisation (establishment of species non-typical to the habitat) takes place. Synanthropisation of vegetation in Latvia is also associated with a large number of alien species entering and naturalising habitats that are transformed at different degrees, and the formation of alien, mainly invasive plant species communities. Synanthropisation mainly occurs in artificial or man-made habitats, also in boreal forests. Eutrophication is caused by changes in soil fertility. It is characterised by altered moisture and increase of nutrients available to the plants, as well as neutralisation of soil reaction. The increase of nutrients has multiple causes.

Sulphur and nitrogen compounds that enter the environment through transboundary fluxes and local sources of pollution, create the pollution background in Latvia. Changes in the element cycle of calcium can occur at local and regional levels in the surroundings of dolomite and limestone quarries and reprocessing plants (Laiviņš 1998). Forest stands mostly receive these compounds from precipitation: nitrogen reaches forests in the form of ammonium with precipitation, and calcium in the form of dust from sites of extraction and processing (Laiviņš 1998).

As soils become richer, the shrub layer forms intensively in urban and suburban *Pinus sylvestris* forests, less often in commercial forests outside of towns. This process started in the late 20th century. M. Laiviņš noted in 1998 that the most common species in the shrub layer were *Frangula alnus*, *Corylus avellana* and *Sorbus aucuparia* and relatively small areas – *Salix spp.*, *Lonicera xylosteum*, *Sambucus racemosa*, *Cotoneaster lucidum*, *Amelanchier spicata*, and *Ribes* spp. (Laiviņš 1998). The shrub layer in *Pinus sylvestris* forests is mainly formed in sites with normal moisture in various types of dry forests. Overgrowth with shrubs occurs more intensively in nutrient-rich soils, even though the distribution of *Amelanchier spicata* and *Sorbus aucuparia* can also be observed in poor *Pinus sylvestris* forests (*Cladinosa-callunosa* and *Vacciniosa types*).

Urbanisation has significantly influenced the typical *Pinus sylvestris* forest vegetation in suburban forests. Relatively high levels of ground cover trampling, recreational load and organic waste are characteristic to these forests. Forest animal feeding places in forests have a similar impact, when seeds of non-characteristic plants and weeds and additional nutrients are brought into the forest together with animal food. As a result, 'ruderalisation' of the understorey takes place – extensive proliferation of ruderal plant species communities that are non-typical to the forest.

There may also be extensive proliferation of grasses and overgrowth with shrubs. Invasive species in the stands are consequences of environmental changes. As a result of human activities, and as the environment is enriched with nutrients, the soil becomes more fertile. Overgrowth with shrubs, also dense swards of *Amelanchier spicata.* understorey, cause changes in the composition of the forest litter and thus loss of species of poor natural sites. There are also changes in light conditions, and the well-lit conditions characteristic to boreal *Pinus sylvestris* forests and their typical species are lost, including rare species.

The invasive shrub *Amelanchier spicata* has increased in area and distribution in the understorey not only in suburban forests, but also in commercial forests and in the EU protected habitat type 2180 *Wooded dunes of the Atlantic, Continental and Boreal region* (Rūrāne 2004) (Fig. 10.9).

Amelanchier spicata is a shrub of North American origin that was first cultivated in Europe due to its decorative characteristics and edible fruits in the early 19th century, by planting it in parks and hedges (Fig. 10.10).

In the vicinity of Riga the species was first recorded in the wild in 1896. It has now completely naturalised. In the second part of the 20th century it spread rapidly in dry urban *Pinus sylvestris* forests

Fig. 10.9. Invasion of *Amelanchier spicata* in a dry *Pinus sylvestris* forest. Photo: V. Lārmanis.

Fig.10.10. *Amelanchier spicata*. Photo: S. Ikauniece.

by creating dense swards in the understorey. This alters light conditions in stands, as well as limits the natural regeneration of native tree and shrub species (Kabuce, Priede 2010).

The invasive plant species *Impatiens parviflora* often occurs in fertile soils of drained and urbanised forest stands. Its impact on biodiversity depends on the conditions at the specific site. The species easily occupies empty niches in forest plant communities, successfully competes with other plants and can become the dominant species, changing the characteristic composition of the habitat vegetation and displacing protected species (Branquart et al. 2007; Hejda 2012). Although invasions are often a consequence of environmental changes after habitat degradation, such as due to the establishment of drainage systems in variant 3 of habitat type 9010* *Western Taiga*. *Impatiens parviflora* also occurs in natural forest stands of habitat type 9050 *Fennoscandian herb-rich forests with* Picea abies.

10.1.5.4 Drainage

Drainage system construction in wet forests on peat soils promotes peat mineralisation, and the ecological conditions, soil characteristics and species composition of the habitat change. If natural structures develop in the forest stand over time, such as dead wood, species characteristic to boreal forests may appear, including protected species. In the case that the peat layer sinks due to mineralisation, and it is no longer possible to restore bog woodlands without compromising the current common protected species in the forest stand, if there is adequate stand quality corresponding to a Woodland Key Habitat, the area can be identified as variant 3 of habitat type 9010* *Western Taiga* or habitat type 9050 *Fennoscandian herb-rich forests with* Picea abies on drained peat soils.

In forests with drainage ditches, the natural water table is sometimes restored as ditches become clogged or *Castor fiber* create dams.

10.2 Restoration and Management Objectives in the Conservation of Boreal Forest Habitats

The main objective in the conservation of boreal forest habitats is to ensure a favourable conservation status and characteristic natural structures to the extent that it fosters and provides the long-term and stable existence of the typical and rare species associated with it.

One of the most important tasks is expansion and aggregation of the boreal forest habitat area, as the habitat areas in Latvia are very fragmented. This means that management measures must be focussed not only on the territory of a particular habitat, but also on the adjacent stands that are suitable for the development of the habitat. Management can create a diverse set of preconditions for the development of boreal forest habitat (for example, the adequate conservation regime or the natural hydrological regime).

Bearing in mind the adverse impact of fragmentation on protected species, wider use of management methods that are friendly to biodiversity should be introduced in commercial forests as well.

10.3 Boreal Forest Habitat Restoration and management

10.3.1 Habitat Conservation

Different approaches may be used in the conservation and management of boreal forest habitats: (1) non-intervention that provides passive protection; (2) non-traditional forestry methods directed at the creation and management of forest stands of a certain tree species composition and ensuring the ecological requirements of the target species (including protected species). Non-traditional methods include emulation of natural disturbance.

Management methods with their benefits and disadvantages are summarised in table 10.1.

It is always very important to assess the conditions of a specific site and the site's conservation objectives. It is important to consider the land relief, soil characteristics and the properties of the adjacent stands, species composition of the vegetation and shrub layer and other factors.

Non-intervention means that no active human work takes place that is associated with the felling of trees or shrubs or has impact on soil, and there is no effect from automobile transport and artificially created changes in the hydrological regime. Natural processes are not limited or disturbed. To maintain a favourable conservation status of boreal forests, non-intervention of natural processes is generally the best solution.

Boreal forests can be used for recreation, berry and mushroom picking, and hunting, which do not have negative effect, as long as the activities do not eliminate habitat structures or species, or the use of the forest is not too intensive. Intensive recreation can cause eutrophication and trampling with subsequent changes in the shrub and herbaceous layer, significantly lowering the quality of habitat (*see Ch. 10.1.5.3*).

An essential quality indicator in boreal forests is the amount of natural structure elements, including dead wood. The amount of dead wood is important due to the rare and protected species associated with it. However, nowadays the dead wood amount is often insufficient even in protected nature territories, for future survival of the species associated with natural forest. For example, the minimum volume of snags required for *Picoides tridactylus* habitat is at least 10–15 m^3/ha in a continuous area exceeding 1 km^2, but the optimal volume is larger (Petriņš 2014). Management measures to increase the volume of dead wood can be divided into several broad groups: (1) maintaining the effects of natural processes; (2) protection of the existing dead wood; (3) creation and increase of dead wood amounts; (4) improving the continuity between habitats with dead wood (Humprey, Bailey 2012). In the first and the second case, results are ensured by non-intervention in protected habitats, and in commercial forests by the conservation of dead wood, including after fires and wind-throws. To improve continuity, landscape ecological studies and planning is required, as well as the readiness to also conserve

Table 10.1 Management Methods of Boreal Forests

Method	Ecological benefits	Disadvantages
Increase of the volume of dead wood	Increase in the amount of suitable habitats for species dependent on dead wood.	None.
Creation of gaps	The formation of a natural stand structure with uneven aged, well-lit areas. Positive impact on invertebrates, birds, lichen, moss species that require an uneven-aged forest stand structure, as well as on light-demanding species of vascular plants.	None.
Controlled burning	Increase in the amount of suitable habitat for species dependent on dead wood. The formation of a natural uneven-aged stand structure. Positive impact on disturbance-dependent species (invertebrates, vascular plants, fungi), charred wood specialist species.	Risk to adjoining stands (due to incorrectly implemented burning).
Cutting of the shrub layer (native and invasive woody plants)	Reduction of shading. Reduction of soil effects from leaf litter.	Low efficiency (regrowth of sprouts). Cutting of sprouts must be carried out regularly and continuously for many subsequent years.

important structures for biological diversity outside of protected habitats.

Active management can improve habitat quality, by the increase of both the standing and lying volume of dead wood (see *more in Ch. 10.3.2*). Before the start of active management it is necessary to evaluate the current situation in detail. It should be noted that the volume of dead wood in habitats on dry mineral soils naturally forms more slowly and is lower, while logs are more common in more fertile and wet forest types, where the artificial creation of dead wood is not required. In habitats near urban or heavily visited sites, an artificial increase of the volume of the dead wood may not give the expected results, if the logs and snags are regularly removed by the surrounding residents for personal use or if they are used for tourist campfires in the vicinity of the targeted areas for management.

The increase of the quantity of wood can be combined with gap formation (*see Ch. 10.3.2*), which contributes to the formation of an uneven-aged forest stand structure, making it more suitable for a larger number of species. Better light conditions promote the growth of young trees as tree groups of various ages develop in the gaps (Fig. 10.11).

Natural disturbances are one of the essential habitat quality conditions and structure builders. Natural disturbance emulation methods can be distinguished according to their purpose – restoration of habitat-characteristic light conditions and understorey structure, improvement of forest canopy structure and habitat restoration, but often the application of one method can help to achieve multiple purposes. For example, with controlled burning one can improve both the structural quality of a stand and the growing conditions of characteristic species (*see Ch. 10.3.3*).

10.3.2 Improvement of Habitat Structures

10.3.2.1 Increase of the Volume of Dead Wood

In natural boreal forests, especially forests that have rarely burnt, the volume of dead wood is large, reaching even 100 m^3/ha (Siitonen 2001). In Latvia the average volume of dead wood is 24.3 m^3/ha (Anon. 2015b), but the amount of dead wood with larger dimension is even smaller. The aim of management in such forests can be the increase of dead wood amounts with a diameter greater than 25 cm to at least 20 m^3/ha, which might be the minimum amount necessary (Müller, Bütler 2010). The volume of both lying and standing dead wood can be increased by imitating natural disturbances. The applicable method depends on conditions of the site and the objective.

If the objective is to rapidly increase the availability of habitat and substrate for fungi or bryophytes that inhabit dead wood, and for invertebrates, selected trees with a diameter of at least 25 cm can be felled and left on the ground. Depending on the technical possibilities, the height of the retained stump can vary, even leaving stumps with a height of up to 2-3 m. In northern European countries several other methods are used, such as tree toppling with tractors or trunk blasting (Viilma 2004). These methods are mainly used in boreal coniferous forests on dry mineral soils (Fig. 10.12).

For the conservation of the populations of protected species and to improve conditions, it is

Fig. 10.11. Opening with advance growth in a boreal forest. Photo: S. Ikauniece.

Fig. 10.12. Dead wood created by blasting in the Protected Landscape Area "Ādaži" (also military training area). Photo: S. Ikauniece.

necessary to ensure the continuity of dead wood availability. An essential feature of continuity is dead wood of various age, size, stage of decay and moisture. This means that, when lacking adequate natural disturbances (wind, fire, snow, insect activity), especially in younger forest stands, it might be necessary to promote the creation of dead wood repeatedly. In such a way logs and snags of various stages of decay are created in a forest stand, and the species have a chance of colonisation of new micro-niches.

The continuity of dead wood can be provided by creating gaps in the canopy of a forest stand to improve light conditions as well as by maintaining dense groups of trees. Some of the trees in dense groups will die off during self-thinning, which will decrease the need to increase the quantity of logs and snags artificially (Vilks 2014). Often the increase of dead wood in coniferous stands is associated with mass-reproduction of *Ips typographus* or other bark beetles. Before the creation of dead wood, the composition of tree species in adjacent stands needs to be considered in view of the potential infestation of bark beetles. The risk can be reduced if no more than 20 m^3/ha of dead wood is created at the same time in each particular forest stand, and trees are felled during the second half of summer, when bark beetles are not flying, and if felling of the largest *Picea abies* is avoided (Vilks 2014).

Fig. 10.13. Creation of gaps and dead wood by felling individual trees, leaving stumps of various height, and by ring-barking of trees. Photo: J. Andrušaitis.

To increase the volume of standing dead wood, which is essential for many bird species, slow withering of trees should be promoted. Tree ring-barking is the most common method, which involves cutting the bark and the cambium layer to 2-3 cm in depth around the stem in the form of a ring. The creation of scars on the root collar of the tree has a similar effect (Viilma 2004). The tree will then gradually die off, but will remain as a snag for a long time. After falling to the ground, it will increase the volume of lying dead wood.

10.3.2.2 Creation of Canopy Gaps

A canopy gap is an opening in a canopy of forest, developed by the falling of one or several trees, where there are different light and microclimate conditions from the rest of the stand (Ek et al. 2002). The desired gap diameter is approximately 1.5-2 times the average tree height in the stand, and 4-5 gaps per 1 ha are optimal (Viilma 2004); gaps can have irregular form. Biologically old trees of large dimension should not be selected for felling, it is advisable to cut trees of average age and dimension (diameter of 20-25cm). It is possible that in order to create a gap, several trees growing close to one another need to be felled (or ring-barked).

Over time ring-barked and gradually dying off trees will also create gaps. Trees that have been cut to create a gap and left on site increase the volume of dead wood (Fig. 10.13). The creation of gaps can be applied in low-quality habitats or in territories where the construction of a future habitat is planned.

In winter 2014, management of boreal forests in Gauja National Park was conducted as part of the LIFE+ project FOR-REST. In an area of ~ 200 ha, boreal forest management was conducted that promoted the development of natural forest elements by creating dead wood in combination with the creation of gaps. The programme of activities necessary for improving naturalness of boreal forest habitats was developed for the period until 2020 (Lārmanis et al. 2014a).

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10.3.3 Controlled Burning as Emulation of Natural Disturbances

Controlled burning is commonly used in boreal forest management in Fennoscandia. Fire disturbance can be used to create biologically valuable areas of habitat type 9010* *Western Taiga*. Controlled burning is not applied in *Picea abies* forests and mixed forests, but mainly in dry *Pinus sylvestris* forests.

Controlled burning (Fig. 10.14) is also applied in the management of habitat type 9060 *Coniferous forests on, or connected to, glaciofluvial eskers*. This method is applied to improve the conditions of rare species habitats, to reduce shading and reduce the soil organic layer in areas where burning has not taken place for a long period of time. In habitat type 9060 *Coniferous forests on, or connected to, glaciofluvial eskers*, young and middle age *Picea abies* have often established, increasing shading, and with thick moss and organic layers, causing loss of species characteristic of well sunlit forests from the understorey (Vanha-Majamaa et al. 2007). The aim of controlled burning in habitat type 9010* *Western Taiga* is associated mostly with the creation of structures formed by natural disturbances, which also includes the creation of suitable habitats for species dependent on disturbance. Studies have found that controlled burning has a positive impact on the diversity of saproxylophagous beetles, which can increase even twice compared with forest stands that have not been affected by controlled burning (Hekkala et al. 2013). As the number of saproxylophagous beetles and other insects is crucial for the existence of some protected species of birds, burning also indirectly has a positive impact on this group of animals (especially on woodpeckers). Changes and structures created in the habitat by burning can persist for a very long time, and suitable dead wood at a particular stage of decay and light conditions for protected saproxylophagous invertebrates is available even 20 years after burning, which is confirmed by observations after the burning of Bažu Bog in Slītere National Park (Vilks 2014).

Forest burning can promote the establishment of rare and common plant species characteristic of boreal forests. These species are associated with well-lit coniferous forests where thick moss and organic layers are not typical, and there is no significant establishment of *Picea abies* and a subcanopy. For example, *Pulsatilla* spp., *Geranium bohemicum* and *Diphasiastrum* spp. depend on periodical disturbances (Fig. 10.15). *Chimaphila umbellata* and *Vaccinium uva-ursi* are common in sunny *Pinus sylvestris* forests.

A forest stand with *Pinus sylvestris* of various ages, heights and dimensions and a relatively open, sparse stand structure that has formed as a result of regular fires is typical for natural dry *Pinus sylvestris* forests. In such forest, fires naturally occur every 50-150 years depending on soil characteristics, relief, stand age and human impact. However, there are always areas in the forest that have not been affected by fire for a long time. Most of the existing *Pinus sylvestris* stands in Latvia have not experienced fire for more than 120 years, since

Fig. 10.14. Immediately after burning. Photo: S. Ikauniece.

Fig. 10.15. Sprouts of *Diphasium tristachyum* two years after burning. Photo: S. Ikauniece.

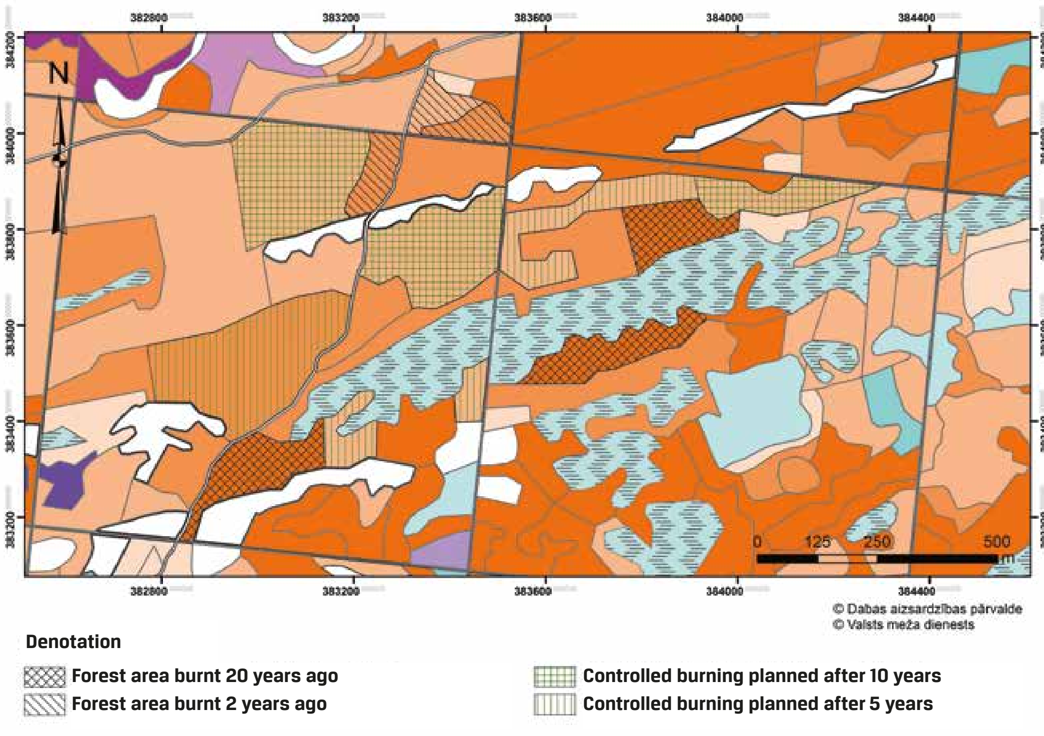

Fig. 10.16. Example of controlled burning planning (prepared by P. Rozenbaks).

the end of slash-and-burn agriculture and start of effective forest fire suppression.

Controlled burning as an effective method for diversifying forest structure and increasing species diversity can be applied in dry *Pinus sylvestris* stands where burning has not taken place for a long time, where thick moss and organic layers have developed, where young and middle age *Picea abies* have created relatively large shade, and where there is almost no dead wood. Depending on the particular situation and habitat conservation objectives (to improve naturalness, to improve the availability of habitat for protected species etc.), fire management is suitable in medium-aged to mature stands. The fire intensity is regulated depending on the objective of management. To restore the diversity of habitat structure elements and species, fire can also be applied in younger stands, creating wood substrates suitable for endangered invertebrate species. Species and habitat structures that have already formed in old forest stands are not threatened by burning.

Controlled burning must be planned at the landscape level ensuring that restoration of forest habitats 9010* *Western Taiga* occurs in various years. Natural disturbance emulation should be conducted in younger forest stands that are located close to old stands (Vilks 2014). The stands where controlled burning is planned must be located in such a way that the introduction of invertebrate or other target species is possible in the target areas from other forest stands nearby, taking into account the distribution characteristics and potential distances between species sites. Stands must be functionally linked, otherwise the desired result may not be achieved (Fig. 10.16).

Planning at a landscape level helps to ensure long-term and continuous availability of the necessary habitats for fire-dependent species. Controlled burning at a landscape level should be performed with at least a five year interval in different stands that are located at such a distance from one another to ensure the dispersal of species.

Controlled burning should not be performed in stands where rare plant and invertebrate species can be found. To avoid the loss of dead wood, rare invertebrate, bryophyte, lichen species, and other important values (for example, biologically old trees) that are present in the habitat before management by controlled burning, planned stands for controlled burning should be bordered with firebreaks and the fire should be directed in such a way that it does not affect elements with biological value. Under natural conditions the majority (20-45%) of dead wood in the forest would be lost during burning.

During the planning of controlled burning, it is important to take several aspects into account related to fire safety in order to prevent the outbreak of uncontrolled forest fires (Similä, Juuninen 2012).

- The location of the stand – whether it is possible to provide access for fire trucks (there are roads, passable tracks), or it is possible to localise the burnt area.
- The nearest water source location (preferably as close as possible, no more than 1 km). If there is no water in the vicinity, it is possible to install a temporary water storage area near the site by digging a pond, lining it with polyethylene film and filling it with water. It must be checked whether the water in the source is usable. For example, it may be slimy or the reservoir is filled with litter that would make it difficult for use by fire trucks. In such a case, the reservoir must be cleared from litter before use.
- Whether the risk of crown fire has been eliminated. If there is *Picea abies* advance growth and a subcanopy in the stand, *Picea abies* must be felled to the extent necessary for safety. When preparing timber or wood chips, this might be a source of income. Felling residues must be removed from the stand, but if there is a small amount of combustible burning material in the stand, then part of the felling residue can be shredded and spread on the soil cover. Individual *Picea abies* of a larger dimension can be left on the ground after felling for the creation of burnt dead wood.
- Creation of a mineral soil zone around the area to be burnt – may be implemented with ploughs, disc harrow or other equipment, but shredded moss should not be left in this zone. Scarification should be carried out to reach the mineral soil, or shredded moss should be removed so that it is not possible for the fire to move into the adjacent stands. (Fig. 10.17) While implementing burning, one must carry out groundcover wetting around the outermost perimeter of the burn, and canopy wetting of adjacent stands in an area of at least 2 m width, if necessary.
- Monitoring after burning – continuous monitoring should be done at least 24 hours after burning to control the ignition of charcoal and the recurrence of burning, especially in cases when wind strength intensifies. The territory should be visited and monitored for the next few days until the burning is fully extinguished or if it has been raining.

Fig. 10.17. Preparation and fire protection measures – mineral soil zone and water hose along the perimeter of the plot. The trees of the nearby stand and the soil cover are also wetted at least 10 m away from the border (Finland). Photo: S. Ikauniece.

Fig. 10.18. Firing in zones (Finland). Photo: S. Ikauniece.

Controlled burning in boreal forest habitats of dry *Pinus sylvestris* forests usually occurs as ground fire, and its intensity is regulated using various practical techniques (U-shaped burning, burning against the direction of the wind, burning in narrow zones (Fig. 10.18) and other methods).

Controlled burning must be carried out at a time when the understorey and moss layer is dry enough for the burning to take place down to the mineral soil, at least in part of the territory. The most appropriate time is from mid-July until mid-August, which is typically a high fire risk period. It is better to implement burning after dew has dried, and when the wind speed does not exceed 5 m/s.

For the management of *Pinus sylvestris* forests on poor soils in commercial forests in a nature-friendly manner, one option is to reduce the continuous clearcut area and not prepare the soil by tillage, but choose controlled burning before forest regeneration.

The management of the boreal habitat does not conflict with the requirements of the protected species. Some individuals may die, but it does not affect the status of the population.

10.3.4 Improvement of the Conditions of *Tetrao urogallus* Leks

Tetrao urogallus is one of the few bird species that inhabits both *Pinus sylvestris* stands of the habitat type 9010* *Western Taiga*, and habitat type 91D0* *Bog woodland*. The necessary conditions for the *Tetrao urogallus* are sparse, open *Pinus sylvestris* stands. The lack of fire in dry boreal forests results in overgrowth with *Picea abies*, causing unsuitable conditions for *Tetrao urogallus* mating. To improve the conditions, controlled burning can be applied. In situations where burning is not applicable, felling of *Picea abies* can be carried out. Felling should be conducted as selectively and unevenly as possible throughout the whole mating area, removing no more than 30% of the standing volume of *Picea abies* (both canopy and subcanopy). Depending on the amount of logs in the lek, some of the large felled trees must be left, depending on the initial amount. Gaps (0.05-0.1 ha) should be created to promote growth of bilberry *Vaccinium myrtillus* shrubs (Petriņš 2014).

Fig. 10.19. Cutting of *Amelanchier spicata* in Abava Valley near Čužu Mire – repeatedly cut *Amelanchier spicata* with new sprouts on the right, on the left – cutting has not been carried out. After cutting, *Amelanchier spicata* actively regenerates vegetatively by sprouts in the next year. Photo: A. Priede.

However, this method can be insufficient for the promotion of *Pinus sylvestris* regeneration, the establishment of which requires light and bare soil patches. Felling of undesirable tree species as the only management method does not create the conditions emulating dry burnt *Pinus sylvestris* forests, and will not provide suitable habitat for rare invertebrate species like *Bombus schrencki*, which requires bare soil or sandy patches. Soon after felling new, dense stands of *Picea abies* often regenerate in gaps. Therefore, if the management aim has been to improve light conditions and promote the regeneration of *Pinus sylvestris* and uneven-aged tree structure, felling of *Picea abies* must be carried out regularly (Brūmelis, Jankovska 2013; Vilks 2014).

10.3.5 Management of Eutrophic Boreal Forests and Control of Invasive Species

Urban and suburban forests are very important for recreation, and they also provide other ecosystem services (produce oxygen, filter the air from dust etc.). Due to human impact in these forests, also in protected forest habitats, the understorey is often degraded, and overgrowth with shrubs and the occurrence of invasive species is typical. However, biologically significant structures, protected species and their habitats have usually survived in stands.

The dense shrub layer contains various species, both native (*Corylus avellana*, *Acer platanoides*, *Sorbus aucupari*, and *Lonicera xylosteum*) and invasive species, most commonly *Amelanchier spicata*. The only method in Latvia so far employed to control *Amelanchier spicata* and other invasive shrubs is regular brush-cutting, but this method is not very effective (Fig. 10.19, Fig. 10.20).

After the cutting invasive woody plant species soil fertility remains. Even if invasive shrub overgrowth is controlled, it is not possible to restore the understorey species composition characteristic of poorer soil conditions.

In dry *Pinus sylvestris* forests on poor sandy soils (*Pinus sylvestris* forests, *Myrtillosa* forests), controlled burning can be used to combat *Amelanchier spicata*. Fire burns the organic layer and damages the roots of shrubs, thus reducing their regeneration. In more fertile forests the method will be less effective, but can temporarily reduce the regeneration of shrubs, as suggested from observations in forests surrounding Rīga on sites where the organic layer has burnt in forest fires.

Fig. 10.20. Studies show that one year after the cutting of *Amelanchier spicata*, at least 50% of the sprouts form from dormant stump buds. Each cut stem produces one to six new sprouts, and their height at the end of the vegetation season may even reach 75 cm (Rūrāne 2004; Kabuce, Priede 2010). Photo: S. Ikauniece.

The use of herbicides is not desirable, although their effectiveness in combating sprout regeneration can be relatively high. The associated negative effects and risks (soil, water pollution, impact on invertebrates, etc.) are too large. Due to its aggressive nature, *Amelanchier spicata* should not be used in gardens, and should be removed from gardeners' supply stores.

The invasive herb *Impatiens parviflora* found in the understorey can be controlled like other annual plant species by cutting or weeding before seed ripening and removing the plant residues (Hejda 2012). This is not a one-time measure, since *Impatiens parviflora* produces many seeds that spread very well. Therefore, effective control of the species needs to be carried out for several years throughout the invaded area. Given the wide distribution of the species, its control is likely more theoretical than practical (*see Ch. 16.*).

10.3.6 Management Unfavourable to Boreal Forests

Effects of unfavourable management impact can be observed both in protected habitats and boreal commercial forests.

Mature tree harvest by selective felling for wood harvest reduces the potential quantity of dead wood in the future, as well as reduces the number of trees that have the potential to become biologically old trees and form natural structures that are important for biodiversity in the future, including habitats for protected species. Thus the number of available ecological niches and substrates for species in the habitat is decreased. Selective felling produces gaps in the canopy, thus diversifying the stands structure, but the unfavourable effects of removing the felled trees are more significant.

Felling including the removal of dead and damaged trees is in sharp conflict with the habitat requirements of *Dendrocopos leucotos* and other bird species, because it reduces the amount of dead wood in the stand. It adversely affects the amount of available habitat for other species as well – invertebrates, fungi, moss. Stump extraction has the same adverse effect.

Both in protected habitats and in commercial forests, the following activities are not recommended after fires:

- removal of burnt wood and fire-damaged trees from burnt forests in medium- to older-aged stands;
- artificial regeneration of forest stands after fire in dry forests on poor soils.

10.4 Conflicts of Conservation and Management

The recommended habitat management measures are not inconsistent with the requirements of the known rare and protected species, which are dependent on the presence of structures characteristic of mature stands and natural forests, and on a non-intervention regime.

Landscape and forest parks have developed in many previously populated areas and estates, which have often not been managed for several decades and have been left for natural development. Many of the overgrown parks are currently included in the forest land where natural values have developed, allowing them to be identified as protected habitat types – more often as habitat type 9020* *Fennoscandian hemiboreal natural old broad-leaved deciduous forests*, sometimes as habitat type 9010* *Western Taiga* or 9050* *Fennoscandian herb-rich forests with* Picea abies. If the park has a significant culturally historical, dendrological or scenic value, and if its reconstruction and further management is desirable, exclusion of the territory from a protected habitat and forest land must be assessed in compliance with the procedure according to legislation. Restoration of the park must be carried out considering the possibility of implementing compensatory measures in the destroyed habitat. See *more in Ch. 11.4.*

Chapter 11. 9020* *Fennoscandian Hemiboreal Natural Old Broad-leaved Deciduous Forests* (Quercus, Tilia, Acer, Fraxinus OR Ulmus) Rich in *Epiphytes*

11.1. Characteristics of old broad-leaved deciduous Forests

11.1.1. Brief Description

Habitat 9020* *Fennoscandian hemiboreal natural old broad-leaved deciduous forests* (Quercus, Tilia, Acer, Fraxinus *or* Ulmus) *rich in epiphytes* further below referred to as Old broad-leaved deciduous forests includes old broad-leaved mixed forests in the transition zone between boreal coniferous and deciduous forest zones or hemiboreal forests, belong to the European class of broadleaf forests *Querco-Fagetea* (Laiviņš 2014). Several canopy layers are typical. Broad-leaved tree regeneration and shrub and understorey herbaceous layers form in a mosaic pattern.

Age structure of trees is uneven and young trees occur in groups. The canopy layer is usually composed of broad-leaved tree species: *Fraxinus excelsior*, *Tilia cordata*, *Quercus robur*, *Acer platanoides*, *Ulmus glabra* or *Ulmus laevis*. *Populus tremula* and *Betula spp.* can occur, particularly in stands after clearcutting or large-scale natural disturbances, such as wind-throws. In naturally developed stands, the habitat has a large quantity of dead wood in various stages of decay, and the epiphytic flora is rich in lichen and bryophyte species (Ikauniece 2013a). A spring aspect is characteristic in the understorey – in spring there is abundant light in the forest, and while tree branches are still bare, ephemeral spring flowering plants flower, such as *Anemone nemorosa*, *Hepatica nobilis*, *Gagea lutea*, *Corydalis* spp., and *Mercurialis perennis*. Later, after leaf-out, these plants have already set seed.

In Latvia, broad-leaved forests may contain boreal species. *Picea abies* can occur in the tree canopy, and the understorey can include plant species characteristic of boreal forests, such as *Trientalis europaea* and *Vaccinium myrtillus*. When *Picea abies* and other boreal species are frequent in a forest stand, possible compliance with the habitat type 9050 *Fennoscandian herb-rich forests with* Picea abies must be assessed when identifying the habitat, as the preferred habitat management may differ between the habitats.

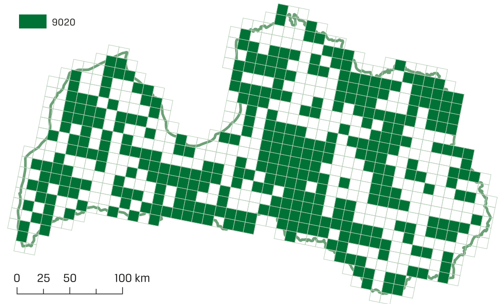

Fig. 11.1. Distribution of the habitat type 9020* *Fennoscandian hemiboreal natural old broad-leaved deciduous forests* (Quercus, Tilia, Acer, Fraxinus or Ulmus) rich in *epiphytes* in Latvia (source: Anon. 2013c).

Fig. 11.2. Habitat type 9020* typical variant 1 (a) and variant 2 (b) with *Populus tremula* in the canopy layer. Photo: S. Ikauniece.

The habitat age is associated not only with structures, but also with the composition of understorey species, particularly regarding the so-called ancient forest species, which have a low capacity of establishment and low dispersal ability; the occurrence of these species can reflect the land use history to some extent (Hermy, Verheyen 2007). In broad-leaved forests of Latvia, *Galium odoratum* and *Corydalis cava*, among many others, belong to these species.

In Latvia there are four Old broad-leaved deciduous forests variants, which to some extent also determine the required methods for management (Ikauniece 2013a).

variant 1 (typical): mixed broad-leaved forests on dry mineral soils; forest stands where the *Fraxinus excelsior* is dominant, mostly found in Zemgale Region.

variant 2: mature *Populus tremula* with other tree species in the canopy, advance growth with broad-leaved tree species.

variant 3: mixed broad-leaved stands on drained mineral soils, may contain *Picea abies*, but it develops towards broad-leaved forest, and species characteristic to the habitat are found in the understorey.

variant 4: mixed *Pinus sylvestris* and broad-leaved stands, formed in forests that were previously used for hay making or pasture, *Pinus sylvestris* may currently be dominating after colonisation as a pioneer species when management ceased, however, a subcanopy of broad-leaved trees or a characteristic shrub and herbaceous understorey has formed earlier.

11.1.2 Indications of Favourable Conservation Status

Favourable conservation of a habitat is characterised by its typical species composition and long-term presence of natural structures, as well as natural processes occurring in the forest stand, which determines the development of such structures (Norden et al. 2014). An important factor that may increase the ecological value of a habitat is the presence of protected and rare habitat specialist species.

Biologically old broad-leaved trees can reach large dimensions, providing diverse microhabitats for various species of birds and invertebrates. The habitat is important for woodpeckers and other birds that require biologically old, large dimension trees for both feeding and the establishment of nesting cavities. *Glaucidium passerinum* and *Dendrocopos medius*, as well as *Ficedula parva*, *Ficedula hypoleuca* and other species that use cavities created by *Dendrocopos leucotos* live in old broad-leaved forests (Petriņš 2014).

The habitat is important for epiphytic species of lichens and bryophytes, including indicator species of Woodland Key Habitats and protected species, a large part of which are associated with old broad-leaved trees; these species include *Lejeunea cavifolia*, *Lobaria pulmonaria*, *Metzgeria furcata*, *Pertusaria hemisphaerica*, *Anomodon* spp., *Arthonia vinosa*, *Isotecium alopecuroides*, *Dicranum viride* and others. Broad-leaved forests are important habitats for rare vascular plant species, such as *Poa remota*, *Festuca altissima*, *Cypripedium calceolus*, and *Cinna latifolia*. A habitat can serve as a source of dispersal for rare and threatened species. An important feature associated with the diversity of species is trees with hollows, which may be inhabited by saproxylophagous beetles (associated with dead wood) long before the dieback of the trees.

Saproxylophagous beetles are characteristic to the habitat. Both light-requiring species, such as *Lymexylon navale,* and species of shaded areas, such as *Ceruchus chrysomelinus* can occur. Characteristic beetles inhabiting hollows include *Liocola marmorata*, *Anthrenochernes stellae* and *Melandryia dubia* (Vilks 2014).

11.1.3 Important Processes and Structures

11.1.3.1 Processes

Gap dynamics is a process whereby individual trees or small groups of trees suffer mortality due to wind-throw, snowbreak, insect infestation or naturally when the biological age of the tree is reached. Advance growth rapidly develops in gaps. Such small-scale disturbances, where other conditions remain stable, cause the development of an uneven-aged structure (Ek et al. 2002; Bottero et al. 2011). This is a very characteristic disturbance in broad-leaved forests. The response of a forest stand to environmental changes in gaps, especially light, can vary depending on gap size and tree stand age. Firstly, tree canopies expand into gaps. Gaps formed in older stands can persist for a longer period of time, promoting the development of a tree understorey. Secondly, advance growth increases in height rapidly. Thirdly, if the gap is sufficiently large, new groups of trees establish (Johanson et al. 2002). Uneven-aged stands develop with a mosaic formed by gaps, with standing and fallen trees in various stages of decay.

In recent decades large-scale **damage due to disease** causing the death of the majority of trees has been observed in the *Fraxinus excelsior*, *Ulmus glabra* and *Ulmus laevis* stands. Particularly wide dieback of *Fraxinus excelsior* stands has been observed. Due to natural factors, in Zemgale Region during the period from 2000 to 2011, the area of *Fraxinus excelsior* has decreased by 1.4 times, an average of 570 ha per year (Cekstere et al. 2013). As a result, a change in dominant species or formation of a very sparse stand occurred. Although there have been many hypotheses on the causes of the dieback, the currently dominating view is that the dieback of trees is caused by the pathogenic fungus *Hymenoscyphus fraxineus* (Kenigsvalde et al. 2010). This pathogenic fungus develops in the tissue of shoots, causing their death. It is believed that the dispersal of the fungus occurs by wind-dispersed spores and by insects feeding on sap. Dieback has also been observed for *Ulmus laevis* and *Ulmus glabra* in Latvia, due to *Ceratostomella ulmi*, resulting in a decline of abundance.

As mature trees die off and fall, dead wood accumulates, the forest stand becomes sparse, and a dense understorey of *Corylus avellana* may develop. The *Corylus avellana* understorey can remain for a long time, but it is a temporary phase in the succession of the forest stand. During the first half of the 20th century when the forest typology was forming, a so-called temporary forest type of hazel *Corylus avellana* ("*lazdulājs*") was distinguished, which was assessed as a transitional period of succession that temporarily replaced the characteristic vegetation (Melderis 1939). In such cases, although the forest canopy may have become relatively sparse, but the vegetation structure characteristic to the habitat remains, as well as the natural disturbance processes and the subsequent natural succession. Biological values related to dead wood are very important factors for this EU protected habitat.

11.1.3.2 Structures

The presence of structures characteristic to natural old forests, Woodland Key Habitat indicator species and specialist species are indicators of stand quality. One of the preconditions to identify the habitat is compliance of the forest stand with the quality criteria of Woodland Key Habitats or potential Woodland Key Habitats. To determine the quality of a habitat, one must assess both the structure and species of the forest stand. Diversity and types of structural elements indicate natural development, also in cases when the stand has been planted or if the habitat has formed in an overgrown wooded meadow. The most significant indicators are dead wood of large dimension, biologically old trees, gaps, uneven-aged forest stand structure, etc. (*see Ch. 1*). Their presence and diversity indicates potential compliance with the criteria of Woodland Key Habitats and high ecological value. Structural elements of natural forests serve as habitats for a large number of various habitat specialist species that are not usually found in intensively managed forests where there is little natural structure (Ek et al. 2002). They are important habitats for many protected species (Norden et al. 2014). For example, the presence of the bird *Dendrocopos leucotos* in the habitat indicates that the amount of dead wood in the wider surrounding area is sufficient for the species (10–20 m^3 of dead wood per hectare around 1 km^2), and that the amount of coniferous trees (predominantly *Picea abies*) is less than 20% (Petriņš 2014).

In natural broad-leaved forests the volume of dead wood is high, even exceeding 100 m^3/ha (Bobiec 2002). Dead wood is an important structural element for many species. The aim of management in such forests can be to increase dead wood volume with a diameter greater than 25 cm to at least 20 m^3/ha. The volume of both lying and standing dead wood can be increased by emulating natural disturbances. The applicable method depends on conditions of the site and the management objective.

11.1.4 Succession

Old mixed broad-leaved forests are stable, long-lasting ecosystems, the prevailing tree species composition of which is largely associated with the historic distribution of the habitat, suitable soils and moisture conditions.

In previous centuries in Latvia, as with elsewhere in Europe, the forest area rapidly decreased as agriculture developed. In Latvia transformation to agricultural land use affected Zemgale Region the most – formerly the main distribution region of broad-leaved forests in Latvia. Clearances were established in fertile soils where broad-leaved forests had previously grown, which was particularly rapid at the end of the Iron Age (Zunde 1999). Fields where agricultural activity was interrupted began overgrowing with trees of pioneer species. *Pinus sylvestris* and *Quercus robur* often appeared as pioneer species in suitable soils (Jones 1959; Hytteborn et al. 2005; Brūmelis et al. 2011), with development of the habitat-specific understorey vegetation and a shrub layer with shade-tolerant broad-leaved tree species. Under natural development, *Pinus sylvestris* can persist for a long period of time and reach large dimensions, while the abundance of broad-leaved tree species with their associated biological values increase in a stand.

After clearcutting or large-scale disturbances, such as due to wind-throws, natural regeneration with pioneer species occurs. Secondary *Betula spp.* or *Populus tremula* stands develop. The proportion of pioneer tree species in the canopy may be relatively large. Shade-tolerant broad-leaved tree species (*Tilia cordata, Pinus sylvestris* and *Ulmus spp.*) appear in the shrub and subcanopy layers over time, sometimes with *Picea abies*. In Zemgale after clearcuts in *Fraxinus excelsior* stands a large proportion of young *Fraxinus excelsior* may regenerate, but damage from large ungulate animals and late frosts affect its survival. As established pioneer trees become biologically old and die off, gaps are formed, improving light conditions for broad-leaved tree regeneration and development of a broad-leaved tree canopy.

The amount of dead wood significantly increases due to the disease causing dieback of *Fraxinus excelsior* forests (*see Ch. 11.1.3.1*). In these stands, the overstorey becomes very sparse, and a dense *Corylus avellana* and *Padus avium* understorey shrub layer forms, affecting light conditions and competition for the regeneration of broad-leaved tree species. However, in the long term, these changes are considered a temporary stage of succession, which is substituted by a broad-leaved forest that develops naturally over time (Fig. 11.3).

Fig. 11.3. The dead *Fraxinus excelsior* have fallen, canopy layer is dominated by *Populus tremula*; *Padus avium* and *Corylus avellana* are abundant in the understorey Photo: S. Ikauniece.

Studies in Lithuania have shown that *Alnus incana* or *Betula spp.* are first to regenerate in the stands where sanitary clearcutting has been conducted after death of *Fraxinus excelsior*, establishing secondary successional stands (Lygis et al. 2014). As more shade-tolerant species appear, and taking into account the relatively short life-span of *Alnus incana*, the development of a stable broad-leaved forest canopy is expected in these stands in the future.

11.1.5 Pressures and Threats

11.1.5.1 Logging and Deforestation

Many broad-leaved forests at some stage in their history have been cut, and the present landscape shows the result of historical land use, which is also reflected in the composition of plant species. In Latvia, the area occupied by broad-leaved tree forests has decreased substantially for several reasons. One of the reasons was the increase in land area used for agriculture. In the 1920s and 1930s, broad-leaved tree stands occupied only 0.2-0.3% of the forest area, and total forest cover was 26% of the country (Zunde 1999). Later, forest management had an important role as well, as *Picea abies* was abundantly planted after clear-cutting on soils suitable for broad-leaved trees. *Picea abies* was considered to be economically more important. In the mid-1960s, according to P. Sakss' (1969) survey, stands dominated by *Quercus robur*, *Fraxinus excelsior, Tilia cordata* and *Carpinus betulus* covered an area of 15 000 ha. At the end of the 20th century, forest cover increased, and in 2015, *Tilia cordata*, *Quercus robur* and *Fraxinus excelsior* stands covered 25 800 ha or a little under 0.9% of the forest area (Anon. 2015a). Artificial regeneration by planting broad-leaved trees is carried out in very small amounts, during the past decade to a greater extent by afforesting the lands used in agriculture, where *Fraxinus excelsior* was planted (Anon. 2015a).

Nowadays the conversion of forests into agricultural land is almost absent in Latvia. The most significant reason for why broad-leaved stands disappear is clearcutting. Selective felling to remove old, dead and damaged trees has an adverse impact on the quality of the habitat and reduces the volume of dead wood and number of existing or potential biologically old trees.

11.1.5.2 Fragmentation

Fragmentation causes a reduction of continuous habitat area, increase of distance between habitat fragments, changes in habitat configuration, and increased edge effect (Tērauds 2011). The decline in the total area of habitat is directly associated with fragmentation of forest landscape as a result of changing land use, such as for residential or commercial building, agriculture, quarries, as well as by separating forest stands by roads and railways. Fragmentation of the forests important for the natural diversity also occurs due to clear-cutting, altered hydrological regime, or otherwise reducing the biological value of the forest. Thus, the forest area important for the nature diversity has declined and distances between important forest patches have increased. Many species require continuous, old forests and biologically old broad-leaved forests for habitat. As many of these have low dispersal ability (such as many moss and lichen species), fragmentation is one of the most significant adverse factors in the protection and conservation of broad-leaved forests.

The increasing isolation of the continuous habitat areas, where habitat patches become more distant, reduces the capacity of individuals of many species to disperse from one habitat patch to another, to maintain the genetic diversity of the population and other processes that are important for the population (Hanski 1998). Fragmentation reduces the overall habitat area suitable for the species, increases habitat isolation, reduces the connectivity of suitable habitats and continuous habitat areas, and increases edge effect (Laurence 2008). The reduction in the continuous area of habitat (and the reduction in the species population density) increases the risk of local extinction of the species. Such changes affect, for example, the species composition of the understorey vegetation in stands. Many researchers associate fragmentation with a reduction in the number of species at a regional or national level (Bailey 2007; Norden et al. 2014).

Fig. 11.4. Invasive foreign species *Impatiens parviflora*. Photo: A. Priede.

11.1.5.3 Invasive Plant Species

Invasive plant species in the forest stand are a consequence of environmental changes, even if these changes are not immediately visually detectable. In general, invasive plant species have previously had low occurrence, and particularly low in forests in Latvia.

Spread of *Heracleum sosnowskyi* has been observed in some broad-leaved tree forests of Latvia. Initially they spread along forest tracks and along ditches and rivers. In recent years individuals have been recorded in forest gaps and clearings. *Heracleum sosnowskyi* successfully outcompetes native plant species by completely altering the structure of the vegetation, light conditions in the understorey, and most likely also the nutrient content of the soil. It spreads primarily by seed, but it is also able to proliferate with root fragments.

Another common invasive species *is Impatiens parviflora* (Fig. 11.4) which grows mainly in drained

Fig.11.5. *Impatiens noli-tangere* is similar to *Impatiens parviflora*. This native species occurs widely in forest. Photo: A. Priede.

forests, but also in dry broad-leaved forests. The species is annual and spreads only by seeds. Its impact on biodiversity depends on the conditions of the specific site. The species easily occupies empty niches in forest plant communities, successfully competes with other plants and can become the dominant species, changing the characteristic composition of the habitat vegetation and displacing protected species (Branquart et al. 2007; Tanner 2008).

In several locations the alien shrub species *Sorbaria sorbifolia* and *Spiraea* spp. have escaped from gardens and colonised broad-leaved forests adjacent to old parks, cemeteries, house gardens or sites otherwise transformed by people. They spread vegetatively, sometimes by invading wide areas and outcompeting native species in the shrub and herb layers, and alter light and nutrient conditions in woodland.

The colonisation of these and potentially other invasive plant species in forests, including broad-leaved forests, is promoted by forest fragmentation – clearcuts provide suitable light conditions, less competition with native plant species), and building of new roads, tracks and ditches create artificial distribution corridors. Colonisation by these species may also occur from food left at feeding sites of game animals.

11.2 Restoration and Management Objectives in the Conservation of old broad-leaved Forests

The main aim of habitat protection is to ensure a favourable conservation status (*see Ch. 5.3*) in the country as a whole. It is important to conserve the main structures to an extent that is sufficient for the long-term existence of the typical and rare species associated with the habitat.

One of the most important conservation aims is expansion of the habitat area and reduction of fragmentation, as the habitat areas in Latvia are very fragmented. This means that management must be focused not only on the territory of a particular habitat, but also on the surrounding stands that are suitable for the development of the habitat. To increase habitat area and reduce fragmentation in the long term, future habitats need to be created by respective management in young stands.

An important task is also the conservation of existing habitat continuity in the whole habitat distribution area, which is very important for the existence of many protected and rare species (Norden et al. 2014).

11.3 Old broad-leaved Forest Habitat Restoration and Management

11.3.1 Habitat Conservation

Different approaches can be used in the conservation and management of the habitat:

- non-intervention, which provides passive protection;
- non-traditional forestry methods aimed at the creation and management of forest stands of a certain tree composition, ensuring the environmental requirements of the target species (including protected species); non-traditional methods include the emulation of natural disturbances (table 11.1).

It is always very important to assess the conditions of a specific site and the conservation objectives. When selecting management methods, one must take into account the terrain, soil characteristics, properties of the adjacent stands, species composition of the vegetation and advance growth and other factors.

Table 11.1 Management methods for Old broad-leaved deciduous forests

Method	Ecological benefits	Disadvantages
Improvement of Structures		
Increase of the volume of dead wood	Increase in the amount of suitable habitat for species dependent on dead wood.	The number of potential biologically old growing trees in the future is decreased.
Creation of gaps	The formation of natural uneven-aged stand structure.	None.
Reducing fragmentation		
Felling to reduce the proportion of tree species not characteristic of the habitat	Increased proportion of broad-leaved trees in the stand, which are characteristic for the habitat	None.

Non-intervention implies that no active management occurs in the habitat by felling of trees or shrubs, there is no impact on the soil, and no effect from vehicle transport and alteration in the hydrological regime. Natural processes are not limited or disturbed. The habitat can be used for recreation, mushroom picking, and hunting, as long as no adverse effect occurs on habitat structures or species. Non-intervention is the best conservation approach for Old broad-leaved deciduous forests and is also commonly used.

In low quality or potential future habitats, management can include creation of mosaic forest structures, gaps, and dead wood of various types, if it is necessary to improve the habitat conditions of a particular protected species dependent on dead wood or good light conditions in the forest (*see Ch. 11.3.2*). This type of management can generate diverse micro-climatic conditions – both well-lit areas and retained shaded patches with a shrub layer. Management can be expected to have a positive impact on populations of epiphytic mosses and lichen. For example, *Metzgeria furcata* prefers shaded stems of trees, while *Flavoparmelia caperata* requires improved light conditions (Ódor et al. 2014). Emulation of natural processes is not required in habitats of good and medium quality, except in specific cases where it is required for the conservation of a specific habitat of a protected species. In some cases, low-intensity improvement of forest stand structure can be performed in habitats of low quality. If a forest stand is left to natural processes, development of structures will occur naturally in the long run. It is recommended to mostly conduct management for the improvement of forest stand structure (diversification) in relatively young stands adjacent to Old broad-leaved deciduous forests, which will reduce habitat fragmentation and increase the continuous area of the habitat.

In these cases the management occurs in areas around the habitat. In areas suitable for the development of the habitat, reconstructive felling can be used to increase the proportion of broad-leaved trees in the overstorey and promote the development of vegetation characteristic of the habitat (*see Ch. 11.3.3*).

11.3.2 Improvement of Forest Stand Structure Elements

11.3.2.1 Increase of the Volume of Dead Wood

In old, natural broad-leaved forests the minimum volume of dead wood with a diameter > 25 cm is recommended to be at least 20 m^3/ha. The volume of dead wood can be increased by creating lying and standing dead wood. The selected method depends on site characteristics and purpose.

If the management aim is to increase the availability of habitat and substrate for fungi, bryophytes, and saproxylophagous (species inhabiting dead wood) invertebrates, selected trees are felled and left on the ground. Biologically old, large-dimension trees (with a diameter above 35 cm) should not be selected for felling, as they have high biological value when living. If the cut trees are *Picea abies*, the branches should be removed from the stand immediately after felling to prevent soil acidification by needle litter, which is not desirable for this habitat. Depending on the technical possibilities, the height of the stump that is left can vary. Also other methods are described in literature, such as uprooting trees with tractors or blasting, which are methods used to a greater extent in coniferous boreal forests on dry mineral soils (Tainio, Siitonen 2012).

To increase the volume of standing dead wood, which is essential for many bird species, management can aim to cause slow withering of trees. Tree bark-ringing, the most commonly used method, involves removal of the bark and cambium layer around the stem in the form of a ring with a width of 15 cm. This causes gradual death of the tree, which can remain for a long time as a snag. After falling to the ground, it increases the volume of lying dead wood.

11.3.2.2 Creation of Gaps

A gap is an opening in the tree canopy layer formed by mortality of one to several trees, which changes light and microclimate conditions from that in the remaining stand (Ek et al. 2002). As advance growth usually occurs in broad-leaved forests, better light conditions promote the growth of the young trees, and tree groups of various ages develop in the openings (Johanson et al. 2002). This creates the development of an uneven-aged structure and higher diversity of tree species.

Creation of gaps can be combined with increasing the amount of dead wood. The size of

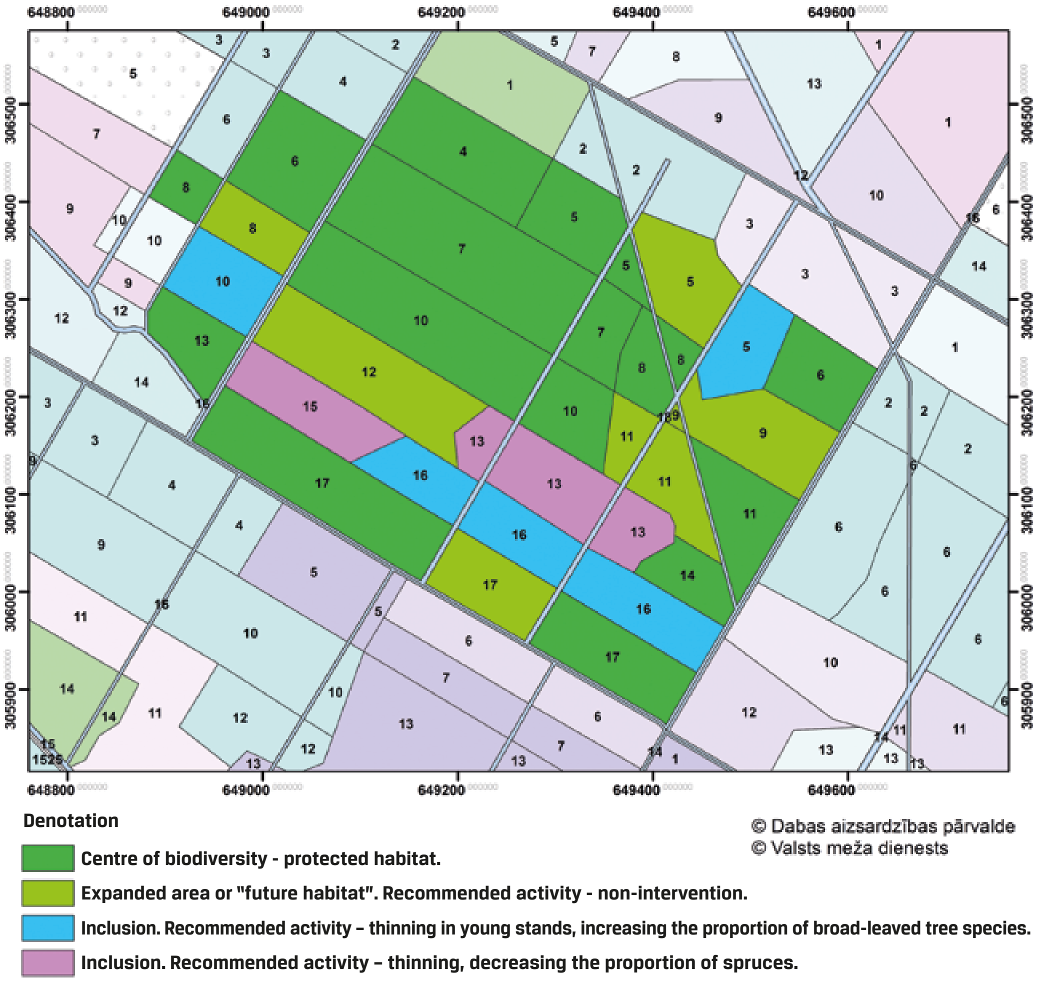

Fig. 11.6. Habitat aggregation scheme (prepared by P. Rozenbaks)

gaps should not be smaller than 4 m. Biologically old trees of large dimensions should not be selected for felling, but rather trees of average age and dimension (diameter 20–25 cm). Creation of a gap might require felling or ring-barking of several adjacent trees. Over time, ring-barked trees will also develop gaps. Trees that are felled to create a gap are left on the site, and *Picea abies* residues are removed from the stand.

11.3.3 Reducing Habitat Fragmentation

A separate group of measures is associated with increasing the area of habitats and the creation of future habitats in aggregations of high quality habitats (Norden et al. 2014) with the aim to increase area of Old broad-leaved deciduous forests. Since the continuous areas occupied by a habitat can be very small and they can be highly fragmented, one of the major aims is to form habitat aggregations by creating new habitats around the existing ones. Future habitats can be created from lower quality forest stands in the direct vicinity of the existing habitats, with the target of creating future habitat areas. This can be done in locations with suitable environment conditions (soil and moisture conditions) for the development of Old broad-leaved deciduous forests, expecting that vegetation typical to the habitat will develop.

To create an aggregation, the potential concentration sites of habitats should be identified and field work should be conducted to determine if the area is suitable for this purpose. In stands surrounding existing habitats tree species both in

canopy and subcanopy, regeneration (if available), age, growing conditions, information from topographic maps and historical maps of stands etc. should be analysed. Field survey then identifies habitats where protected habitat may develop after management or non-intervention. These additional locations are called extensions according to the methodology of identification of Woodland Key Habitat concentration sites (Ek, Bērmanis 2004), as they can contribute to increasing the biological diversity of the concentration area. These include both stands where active management is not necessary and those requiring the establishment of suitable structures and tree composition. In stands regenerating on former wooded meadows, the development of a broad-leaved forest can be promoted by shrub removal (Ek, Johannesson 2005).

Analysis of fragmentation should be carried out on a national level for the planning of aggregations in areas with stands of higher biological quality in higher concentration. At the initial stage, this can be done by using information obtained in the project "Woodland Key Habitat Management in Latvia" ("Dabisko meža biotopu apsaimniekošana Latvijā", 2004 to 2005) where habitat concentration sites were identified in forests managed by the JSC "Latvian State Forests" (Anon. 2005). The proposed methodology of the project (Ek, Bērmanis 2004) should be modified according to the identification criteria of Old broad-leaved deciduous forests in future planning to create aggregations.

11.3.4 Felling Types Suitable for the Increase of Proportion of Tree Species Suitable for the Habitat

In the course of the natural succession a mixed stand of *Picea abies* and broad-leaved trees can develop. Litter of *Picea abies* contributes to podsolisation of the soil, which has a negative impact on broad-leaved forest vegetation in the understorey. Therefore, *Picea abies* is considered a non-desirable species in broad-leaved forests in the sense that it transforms the habitat and causes conditions that are not suitable for broad-leaved forest vegetation. In such situations, the habitat may be left for natural development, expecting that in the course of natural succession another protected habitat may develop – 9050 *Fennoscandian herb-rich forests with* Picea abies. It is also possible to manage these stands for the conservation of Old broad-leaved deciduous forests. This is particularly relevant in situations when rare or protected species are present, as they might perish as a result of succession.

Fig. 11.7. Planted *Picea abies* stand in a clearcut with regenerating broad-leaved trees. Photo: S. Ikauniece.

To create a tree species composition typical for broad-leaved forests, felling can be carried out in planted *Picea abies* of medium age, as well as in pre-mature *Picea abies* stands where the previous stand was dominated by broad-leaved trees. Usually broad-leaved trees have already established in these stands (Fig. 11.7).

To increase the proportion of broad-leaved trees, a part of *Picea abies* may be felled. The amount of trees to be felled depends on the particular situation; felling can be carried out in patches. Felling should not be carried in secondary stands of *Populus tremula* or *Betula* spp. with a subcanopy of broad-leaved trees.

In pre-mature stands, the reduction of *Picea abies* in the canopy composition requires careful consideration. *Picea abies* can be reduced in one step or in two steps with a 2-3 year interval. Felling in one step reduces the negative effects on the ground-cover and regeneration. Felling in two steps allows one to assess the previous works and to modify the choice of trees to be felled. If the work is carried out in two steps, then the first step needs to include the felling of all *Picea abies* in the direct vicinity of broad-leaved trees, particularly when growing in their crowns. Trees in the remaining stand are felled in the next step after 2-3 years. Felling of *Picea abies* in the form of patches can only be carried out in stands where they are abundant, creating a heterogeneous stand structure resembling natural forest.

During management by felling, all logs and snags should be conserved to the greatest extent possible. If there is a small amount of dead wood, part of the cut canopy trees with a diameter larger than 25 cm must be retained (at least five trees per hectare). Cut shrub and subcanopy *Picea abies,* with associated debris, should be removed from the stand. If the majority of the stems of felled *Picea abies* are left to increase the volume of dead wood, their branches must be cut and removed from the stand to reduce soil acidification caused by needle litter, which is not desirable in this habitat. If there are surrounding commercial *Picea abies* stands, it is not recommended to leave felled logs of *Picea abies*.

Felling should be carried out in winter, preferably when the ground is frozen, in order to avoid the influence on the soil. It is recommended to use equipment with wide tyres or undercarriage equipped with light caterpillars, low-capacity tractors, small tractors or other equipment that has low impact on soil and does not leave deep tracks. It is also recommended to carry out felling in one step, two steps use only in special cases, because unlike the necessary gradual improvement of light condition around individual trees, at a stand level the microclimate changes are not so large as to have a negative effect on growth of the trees.

Thus management can create canopy gaps, which is a desirable structural feature of the habitat. The formation of dense advance growth of deciduous trees or understorey in gaps is not considered undesirable.

In order to increase the proportion of broad-leaved trees in young stands, felling should be carried out in mixed stands up to 20 years of age in which environmental conditions are suitable for the habitat and broad-leaved trees are present, besides other species (most often *Picea abies* or *Betula spp.*). A larger proportion of broad-leaved trees may be present in young stands in which a large number of broad-leaved trees were retained as retention trees. When carrying out the felling, the proportion of broad-leaved trees should be increased by felling trees of other species. *Picea abies* felling residues must be removed.

11.3.5 Providing Favourable Conditions for Protected Species

11.3.5.1 Birds

Dendrocopos leucotos is a good habitat specialist species, and is used as a flagship or umbrella species. It feeds on insects and their larvae, which are found in dead or dying deciduous trees. The proportion of dead and dying trees in the stands selected by *Dendrocopos leucotos* is almost twice as high as in randomly selected stands. For nesting it selects withered (43% of cases) and withering (14% of cases) trees (Petriņš 2014, cited Bergmanis *without date*). In other cases it usually nests in either *Populus tremula* with heart rot, or in dead parts of living trees – dead tops, branches etc. If the habitat has a sufficient volume of dead wood (approximately 10-20 m^3 per 1 km^2 with a diameter > 25 cm), management is not required (Petriņš 2014). If the area suitable for the species is too small, the creation of dead wood, e.g. by ring-barking deciduous trees can be conducted in adjacent stands suitable for the development of broad-leaved forests.

11.3.5.2 Invertebrates

In some cases, conservation of rare invertebrate species requires specific management. Detailed investigations must be carried out prior to this, with determination of the occurrence and ecological requirements of all the protected species, including bryophytes and lichens, and identification of the conservation targets.

If younger trees especially *Picea abies* have grown into the canopies of biologically old large-dimension broad leaved trees, negatively affecting growth of the old trees, it is best to fell them at least in the crown projection area, even if it has generally been decided not to disturb the forest stand (Fig. 11.8).

Cutting trees and shrubs in the crown projection area improves light conditions and air circulation, decreasing humidity and shade. It can increase the overall tree life, and thus the trees can serve for a longer time as a habitat for rare, endangered insects, such as *Osmoderma barnabita* or *Liocola marmorata*.

Tree hollows are important for various beetles, but there may not be a sufficient amount of these trees for survival of the population. If there is a small number of hollow trees, their establishment can be promoted by cutting several large branches from medium-aged trees at a 10-20 cm distance from the stem; subsequently hollows will form as a result of fungal growth (Vilks 2014). Such trees occur more often at edges of forests or in woodland formed on overgrown wooded meadows (more: Rūsiņa (ed.) 2017, Ch. 19).

Some of the protected invertebrate species found in broad-leaved forests utilise various habitats during their lifetime. For example butterflies and other pollinating insects as well as saproxylophagous beetles visit adjacent grasslands to additionally feed on flowering plants. It is necessary to maintain an open, well-insolated border of the forest with flowering plants, as well as to regularly manage the adjacent grassland habitats, if there are any in the particular area (Vilks 2014).

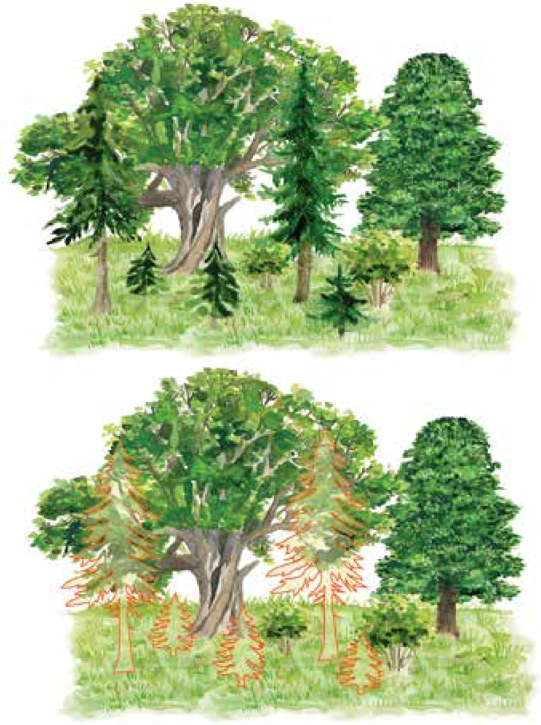

Fig. 11.8. Choosing the trees to be felled for the increase of insolation of old broad-leaved trees (the trees to be felled are marked with an orange outline). Drawing by D. Segliņa.

11.3.5.3 Lichens and Mosses

The protection of epiphytic lichens and mosses can be best ensured by non-intervention. Their dispersal is often limited. For example, a study in Estonia found that the dispersal range of *Lobaria pulmonaria* from one tree to another was only 15-30 m (Jüriado et al. 2011). Localities of rare epiphytic lichens and mosses can be destroyed even by the removal of one single tree inhabited by these species.

In some cases, if a tree inhabited by the species is destroyed, vegetative transplantation of epiphytic lichen or moss may be applied, which has proven to be a sufficiently effective method and is recommended for wider use (Mežaka 2014). However, this has only been applied in some studies locally so far. During the transplantation a fragment from a thallus of a lichen, such as *Lobaria pulmonaria* is removed and transferred to another suitable tree, and is mechanically fixed to the bark by various means (tied with a fishing line, fixed with a net or a metal hook). Epiphyte transplantation can reduce the impact of fragmentation, especially on less common species, the distribution capacity of which in the boreo-nemoral zone is limited (Mežaka 2014).

11.3.6 Control of Invasive Plant Species

In the abatement of *Heracleum sosnowskyi* four types of control are applied – mechanical, chemical, biological and combined. The only type that can be applied in old broad-leaved deciduous forests, is cutting of plants with manual labour.

One of the suitable methods for combating *Heracleum sosnowskyi* is cutting of flower clusters. The technique is based on the biology of the plant. *Heracleum sosnowskyi* is a monocarpic plant, which means that after flowering seeds ripen and the plant then dies. If at the time when the *Heracleum sosnowskyi* has flowered the seeds have not yet ripened, the flowering stems should be cut, causing death of the individual. To ensure that the plant dies, the main flowering stem of the *Heracleum sosnowskyi* should be cut when it starts flowering (from the end of June until mid-August) (Gulbis 2013).

Heracleum sosnowskyi can be eliminated or at least localised by embedding a shovel or a similar tool through the main flowering stem of *Heracleum sosnowskyi* 5–10 cm below the soil surface. If the method is applied in spring, it should be repeated at least 2-3 times during the season and, if necessary, for several years in a row, because of vegetative regeneration from rhizomes, as well as establishment from seed in the soil seed bank. Both types are effective in small areas for localising individual plants in the early stages of the invasion (Gulbis 2013).

An effective but expensive method is to cover plants with a light impervious film, limiting the plant's photosynthesis (Pyšek et al. 2007). This method is more suitable for open non-forest areas or forest clearings.

Abatement of *Heracleum sosnowskyi* must be carried out very carefully, as it is possible to get burnt by the sap. One must use clothing that does not allow skin contact with plant sap, preferably special clothing and safety goggles. Waterproof gloves must be used in cases of contact with the plants. All excavated, cut and mown parts of *Heracleum sosnowskyi* that are able to regenerate (root fragments, flowers with seeds, also those that are not ripe) must be removed and burnt.

The impact of *Impatiens parviflora* on biodiversity depends on the conditions of the specific site. The species easily occupies the free niches of forest plant communities where there have been no herbaceous plants or their coverage has been sparse due to poor light conditions prior to *Impatiens parviflora* invasion. *Impatiens parviflora* competes successfully with other plants and can become the dominant species. It is considered that *Impatiens parviflora* can out-compete the native *Impatiens noli-tangere* and other plant species, but only under conditions that are suboptimal for the native species, for example if it is too dry. Like other annual species, *Impatiens parviflora* can be controlled by cutting or weeding to prevent seed set and removing the plant residues from the forest (Hejda 2012). This is not a one-time measure, since *Impatiens parviflora* produces many seeds that disperse very well. Therefore, to be effective, control throughout the invaded area must be carried out for several years.

Controlling of the shrub *Sorbaria sorbifolia* and *Spiraea* spp. is time consuming, and there are no known effective methods. They can be controlled by repeatedly cutting them for many consecutive years until the sprouts do not grow back, by extracting the rhizomes or by using herbicides. Herbicides can be the most efficient method, but if a natural, biologically valuable forest has been invaded, herbicides can cause irreversible adverse effects on invertebrate populations, which is almost never justified. To apply this method the surveying of the territory is needed, identifying the potentially endangered natural values.

11.3.7 Unfavourable Management of Old Broad-Leaved Forests

Selective mature tree felling for wood harvest with removal of the cut trees from stands reduces the potential quantity of dead wood, as well as reduces the number of trees that have the potential to become biologically old trees and form natural structures that are important for biodiversity in the future, and also habitats for protected species. Thus, the volume of the available ecological niches and various substrates to species in the habitat can decrease. Such felling may cause openings in the canopy, thus diversifying the structure of the stands, however, the unfavourable effects of removing the felled trees are more significant.

Felling and removal of damaged and withering trees is in sharp conflict with the habitat requirements of *Dendrocopos leucotos* and other bird species, because it reduces the amount of dead wood in the stand. Similarly it adversely affects the amount of available habitat for other species as well – invertebrates, fungi, moss.

Artificial forest restoration or afforestation with *Picea abies* and *Betula spp.* plants in stands where broad-leaved stands have existed earlier, or which are directly adjacent to the territories of the habitat type 9020* *Old broad-leaved deciduous forests* has a negative effect on spatial continuity. This can hinder regeneration of the broad-leaved forest, the structures and composition of species characteristic, which might at least partly be possible in a long period of time, by leaving the forest stand to develop naturally after felling.

11.4 Conflicts of Conservation and Management

Habitat management may be inconsistent with the requirements of the known rare and protected species, which are dependent on the presence of structures typical for natural forests and on the non-intervention regime.

Restoration of the habitat 6530* *Fennoscandian wooded meadows*. If a broad-leaved forest habitat has developed as a sparse wooded forest stand or wooded meadow, or grassland has overgrown, the possibility and need to restore the EU habitat 6530* *Fennoscandian wooded meadows* should be considered in some cases. This may be important in cases that are associated with the conservation of a rare, protected species population, if the species, e.g. *Osmoderma barnabita,* depends directly on circumstances of wooded meadow habitat. Restoration of wooded meadows and pastures should be carried out after landscape ecological planning and a study of the protected species of all groups, taking into consideration the requirements of the species protection plan (Bāra (ed.) 2014; Lārmanis 2015). Management for the restoration of wooded meadow habitat may have a significant adverse effect or cause extinction of protected species associated with Old broad-leaved deciduous forests. If future regular management of restored grassland is not feasible, the best choice is most probably to conserve the forest habitat.

Restoration and Management of Parks. Landscape and wooded parks have been created in many areas around ancient populated areas and estates, which have not been managed in

Fig. 11.9. Edge of an English landscape park. Biologically old trees, snag, large log and understory at the edge of the meadow are conserved. Photo: G. Leiburgs.

recent decades and have been left for natural development. A large part of the overgrown parks is presently classified as forest, and natural values have developed that allow them to be included in the habitat type Old broad-leaved deciduous forests. These areas often have numerous biologically old trees that are important habitats for the protected species of invertebrates, lichens, mosses and fungi.

If the park has a significant cultural, historical, dendrological or scenic value, and if its restoration and subsequent management is possible, the exclusion of the territory of the habitat from forest land must be assessed in compliance with the procedure defined by legislation and the park can be restored, at the same time considering the possibility of implementing compensatory measures in the destroyed forest habitat.

Landscape gardens (English parks) are common in Latvia; they can be managed for the conservation of structural elements significant for habitat type Old broad-leaved deciduous forests – biologically old trees, large coarse woody debris, and broad-leaved trees of various ages (Fig. 11.9). It is usually possible to find compromises in the management of old parks of Latvia – conserve both the landscape and values of culture, history and nature (old large trees, withered trees, individual shrubs and retained patches of regeneration, etc.). These elements will not decrease the landscape value of the park, but are very important and are sometimes even the only habitats for many species (for example, in the intensively managed Zemgale Region landscape).

An old landscape park is a combination of wooded grassland and Old broad-leaved deciduous forests. It is a mosaic landscape with trees of various ages, species and light conditions. In order to conserve both the historical and nature values, it is recommended to conserve the structures characteristic to the protected habitat in an area of 20-40% of the park territory, by simultaneously maintaining a park that is scenically, dendrologically and otherwise valuable. Eleja and Iecava Manor Parks are examples of biologically diverse and scenically rich parks. Skrunda Manor Park and Gulbene Park are examples of less diverse and biodiverse parks, as they have been restored by covering the tree stumps with soil and cutting the entire shrub layer.

Historical forest parks (forest territories with park elements – trails, avenues, footbridges etc. – that are used for recreation) may also be maintained by conserving fragments of protected habitat and elements important for biodiversity. For example, Zaļenieki Forest Park (a forest area near an intensively managed park) contains natural forest elements. Some forest stands in Zaļenieku Forest Park conform to the criteria of a Woodland Key Habitat, but this does not interfere with maintaining paths with gravel cover when necessary and clearing shrubs and small logs in a 4-10 m wide belt along the trails.

Chapter 12. 9060 *Coniferous Forests on, or connected to, glaciofluvial Eskers*

12.1. Habitat characteristics of Forests on Eskers

12.1.1. Brief Description

The habitat 9060 *Coniferous forests on, or connected to, glaciofluvial eskers* further below referred to as Forests on eskers consists of a dry coniferous forest vegetation complex on eskers or land relief formed by eskers. *Pinus sylvestris* is usually dominant in the forest stand, with *Picea abies* and *Betula pendula*. The habitat has a specific species-rich flora and fauna, which includes species of dry grassland and eastern steppe, and legumes. The complex of plant communities depends on the terrain and the soil parent material. Eskers may have a steep slope on one side, and a gradual slope on the other, causing differences in plant communities (Bambe 2013a).

Fig. 12.1. Forest on the southern slope of an esker. Photo: S. Ikauniece.

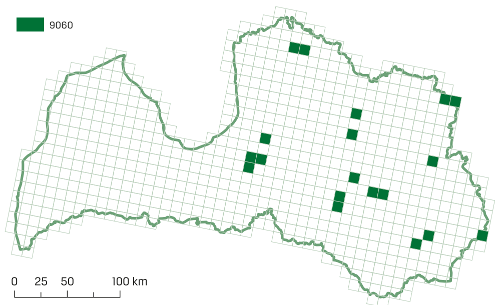

Fig. 12.2 Occurrence of habitat type 9060 *Coniferous forests on, or connected to, glaciofluvial eskers* in Latvia (Anon. 2013c).

Differences in vegetation composition are particularly evident when an esker is orientated in the north-south direction. Important factors in the functioning of habitats and species composition are the slope cardinal direction of exposure and inclination, which affect insolation and temperature at ground level and in the soil. The micro-climate of sunlit and shaded slopes differs. The southern side of a slope is always more insolated and drier, and is the preferred location for habitat characteristic species, including rare species (Bambe 2013a).

Northern slopes have higher moisture content in soil, and are more shaded with a thick moss layer. *Picea abies* may be abundant in the shrub and subcanopy layers. The species composition in the understorey is usually uniform and not rich in species, compared to southern slopes (Bambe 2013a). In the lower part of slopes, the formation of the soil and the habitat may be affected by springs, around which there may be species characteristic to more fertile and wet soils or seepage springs.

This is one of the rarest protected forest habitat types in Latvia and occupies no more than 0.02 % (approximately 14 km^2) of the territory of Latvia. It is more common in the central and eastern part of Latvia (Fig. 12.2).

The occurrence of eskers as a geological form in Latvia is more frequent (Celiņš 2010), and the majority have not yet been surveyed to assess conformity with Forests on eskers. It is possible that the occurrence of this EU protected habitat is generally more frequent than is presently known, especially regarding habitats with lower quality and poor species richness.

Many eskers are covered by shaded *Picea abies* or deciduous forests with a *Corylus avellana* shrub layer and understorey vegetation characteristic of broad-leaved tree forests. *Picea abies* is common together with broad-leaved trees like *Quercus robur* and *Acer platanoides* on northern slopes. The vegetation may resemble that of habitat type 9180* Tilio-Acerion *forests of slopes, screes and ravines* or 9050 *Fennoscandian herb-rich forests with* Picea abies. Such forest stands do not conform with the criteria of the protected habitat type 9060 *Coniferous forests on, or connected to, glaciofluvial eskers,* but may be classified as the protected forest habitat type 9*050 Herb-rich forests with* Picea abies, but not 9180* Tilio-Acerion *forests of slopes, screes and ravines.*

12.1.2 Indications of Favourable Conservation Status

Favourable conservation status of the habitat is characterised by its typical species composition and long-term presence of natural structural elements, as well as the occurrence of natural processes in the forest, which promotes the formation of structures characteristic to natural forests (Norden et al. 2014). An important factor that enhances the ecological value of the habitat is the presence of protected and rare species. Thus, the habitat can serve as a dispersal source for rare and threatened species. A sparse forest canopy, and sunlit small and large gaps are typical. A very important factor in assessing the quality of the habitat is the presence of protected and rare species, which are associated with the soil characteristics – gravel or gravel-sand which is determined by the esker landform.

The habitat consists of a plant community complex associated with calcareous soils and a micro-climate specific to eskers. The herb layer contains species characteristic of coniferous forests, dry grasslands, and forest edges. The following plant communities are typical on eskers: *Convallario-Pinetum*, *Vaccinio vitis-idaeo-Pinetum* var. *Pulsatilla patens*, *Vaccinion myrtilli-Pinetum* var. *Pteridium aquilinum*, *Melico nutantis-Pinetum*, and *Melico-Piceetum* (Bambe 2013a; Bambe 1998; Laiviņš 2014).

Pinus sylvestris grows on sunlit southern slopes. Sometimes *Betula pendula* occurs in mixed stands, especially in burnt areas, and may dominate in freshly burnt areas. *Juniperus communis* is found in the understorey.

Picea abies is typical on shaded slopes, with *Calamagrostis arundinacea, Brachypodium pinnatum*, *Melica nutans*, *Pteridium aquilinium*, and *Rubus saxatilis* in the groundcover.

This is an important habitat for populations of rare and protected species of Latvia, the presence of which indicates favourable conservation status, for example, *Onobrychis arenaria* (Fig. 12.4), *Arenaria procera*, *Dracocephalum ruyschiana* (Fig. 12.5), *Lathyrus niger*, *Pulmonaria angustifolia*, and *Pulsatilla patens* (Fig. 12.3) (Bambe 1998, 2013a).

A habitat in a favourable conservation status is likely to be inhabited by protected invertebrate species associated with *Pinus sylvestris* forests and biologically old, well-lit *Pinus sylvestris* trees, for example, *Nothorhina punctata*. Dead *Pinus sylvestris* may be inhabited by *Boros schneideri* and *Tragosoma depsarium*. *Stephanopachys linearis*,

Fig. 12.3. *Pulsatilla patens*. Photo: R. Indriķe.

Fig. 12.4. *Onobrychis arenaria*. Photo: A. Priede.

Fig. 12.5. *Dracocephalum ruyschiana*. Photo: D. Marga.

a species associated with burnt wood, may also be found. Species like *Bembix rostrata*, *Oedipoda caerulescens, Podisma pedestris*, and *Meloe* spp. are associated with sunlit patches with bare mineral soil (Vilks 2014).

Some invertebrate species that inhabit herb species are very important for the habitat, like *Maculinea arion* on *Thymus* spp. and *Agrodiadetus damon* on *Onobrychis arenaria*. Larvae of rare butterfly species, for example, *Grapholita caecana* and *Zygaena carniolica* develop on *Onobrychis arenaria. Bombus schrencki,* which nests in the soil in dry *Pinus sylvestris* forests and their edges, feeds on legumes (Vilks 2014).

12.1.3 Important Processes and Structures

12.1.3.1 Processes

One of the most significant processes in the conservation of forest diversity is **fire**. Forest fires of various intensities occur naturally in boreal forests, including *Pinus sylvestris* forests on eskers. While naturally occurring fires may be common in the boreal region, in Latvia the majority of forest fires are caused by humans (Donis et al. 2015).

The natural fire regime in the boreal forests of Eurasia can be described as a mosaic of fires, the intensity of which varies from a severe crown fire followed by substitution of the forest stand, to a light ground fire that leaves almost all trees living (Shorohova et al. 2011).

After fire a large volume of burnt dead wood and individual or groups of living trees remain in the forest. In dry *Pinus sylvestris* forests some trees typically survive fire, promoting the development of an uneven-aged structure. If natural regeneration has occurred after several fires, the forest stand consists of living trees of different generations (cohort structure). A heterogeneous understorey forms, with patches of bare soil. Fire improves insolation in the forest stand and the soil organic layer burns to various depths, promoting the establishment of herb species characteristic to the habitat, for example *Pulsatilla patens* (Kalamees et al. 2012; Juškiewicz-Swaczyna, Choszcz 2012). After a fire that fully destroys the forest stand, regeneration can occur with *Betula spp.* and *Pinus sylvestris* (Fig. 12.6), in some places with *Populus tremula* (Brūmelis, Jankovska 2013), with the formation of an even-aged stand and large volume of dead wood (Shorohova et al. 2011).

Other disturbances characteristic to boreal forests, like **wind-throws, gap dynamics and insect**

Fig. 12.6. Natural regeneration with deciduous trees after burning in Finland. Photo: S. Ikauniece.

infestation, may occur in various degrees in Forests on eskers (*see Ch. 10.1.3.1*).

Some Forests on esker landforms have been used for **grazing**, because they have a relatively sparse forest canopy and species-rich herb layer. For example, according to local people, 70 years ago cattle were still pastured on Grebļakalns Hill. The grazing prevented overgrowth with shrubs and maintained a mosaic structure.

12.1.3.2 Structures

The main criterion in determining the habitat is **the genesis of the terrain and its form.** Esker landforms were shaped by melting glaciers; sand and gravel material in glaciers that accumulated in the subglacial cavities and tunnels became exposed as winding ridges and chains of hills as the ice melted.

An esker is a narrow winding ridge from several tens of metres to 8–10 km long or a chain of hills of glaciofluvial origin with steep slopes, the axis of which is stretched parallel to the movement of the glacier.

Eskerine relief forms are visually similar to eskers, but have formed in other conditions related to glacial processes, and they have a different geomorphological origin and internal structure. Visual features like steepness and exposure are the same as for eskers.

Eskers and eskerine relief forms are composed of pebbles, gravel or sand, and consequently the soil tends to be gravelly and pebbly, usually slightly acidic or neutral, rich in carbonates, which determine the plant species composition.

Fig. 12.7. Esker of Grebļakalns Hill. Photo: S. Ikauniece.

An important quality criteria, as for all forest habitats, is the presence of **structural elements** characteristic for natural forests that meet the criteria of Woodland Key Habitats. Structural elements serve as habitats for a large number of habitat specific species that are usually not found in intensively managed forests where there are few structures characteristic to natural forests (Ek et al. 2002). Important structures include, for example, large coarse woody debris, biologically old or large-dimension trees, and canopy gaps (*see Ch. 1*). Since dry *Pinus sylvestris* stands are characteristic to the habitat, the potential number of indicator species of Woodland Key Habitats, particularly regarding bryophytes and lichens, is lower than in wet and broad-leaved tree forests.

12.1.4 Succession

In Forests on eskers in natural conditions, like in other boreal forests of any age, development of forest structure and composition differs depending on the disturbance and its cause:

- complete regeneration of a forest – full substitution after a strong and severe disturbance (after wind-throws, wildfires);
- cohort dynamics – an incomplete disturbance causing loss of a part of the trees, characteristic to boreal *Pinus sylvestris* forests after fires;
- large gap dynamics – formation of gaps larger than 200 m^2;
- small gap dynamics – form as a result of mortality of individual trees or small groups of trees, with gap area < 200 m^2 (Kuuluvainen, Aakala 2011).

A large-scale continuous disturbance (fire, storm) results in secondary succession. Forests on eskers or eskerine relief forms, like all dry *Pinus sylvestris* forest habitats, historically have been subjected to regular burning, which reduced the organic and moss layers, allowing the growth of light-loving plant species associated with soil disturbance and gravel deposits containing free carbonates. Mineralisation in calcareous soils occurs faster, and a thick litter layer does not accumulate. If the soil reaction is close to neutral, then microbial decomposition of plant litter is rapid. The plants in such forests contain less tannins, which interfere with the degradation of organic matter.

Storms can cause complete destruction of forest stands, i.e., almost all mature trees are broken or uprooted. The effect of fire depends on its intensity which is determined by climatic and soil conditions, as well as on stand structure and the composition of tree species. The whole or part of the canopy can be destroyed as a result of fire. If all the mature trees have perished, the stand regenerates by secondary succession and an even-aged stand develops. Not only *Pinus sylvestris* stands, but also *Betula spp.* can regenerate after fire. Regular burning ensures suitable conditions for vascular plant species characteristic to the habitat.

Light conditions are suitable for the establishment of *Pinus sylvestris* and groundcover species characteristic to the habitat. If the disturbance occurs in patches, then *Pinus sylvestris* may regenerate in the openings, forming an uneven-aged stand and natural structure. Mortality due to self-thinning creates dead wood and gaps. In older stands mortality of trees will also occur, creating gaps and an uneven-aged stand (Shorohova et al. 2011).

If the habitat is not managed and is allowed to develop naturally, a *Picea abies* understorey will potentially develop on the fertile soils and later it may enter the canopy. By limiting fire, the stand may develop into another habitat and permanently lose its value as Forests on eskers. An example is a slope of Grebļakalns Hill with old *Picea abies* forest, where due to the shade a small amount of light reaches the ground layer. As no disturbances have occurred there for several decades, during succession the habitat has transformed into habitat type 9010* *Western Taiga*. Although the landform is an esker, plant communities characteristic to Forests on eskers and the associated protected plant species are no longer present in the habitat.

12.1.5 Pressures and Threats

12.1.5.1 Logging

Clearcutting eliminates the forest canopy, which means that for several decades mature and large trees will be lacking, which are an essential element of habitat structure. Although after clearcutting succession occurs similarly to after a natural disturbance, their ecological effects widely differ, as burnt dead wood is present after fire, the ground layer is disturbed and thickness of the moss layer has significantly decreased, which is not typical after clearcutting. The stand structure after a natural disturbance is diverse, but after clearcutting it is poor in structures. In accordance with legislation, structures important for biodiversity must be retained in clearcutting, such as retention trees (5-10 /ha) and snags and logs of large dimension. However, forest stand as the main component of a protected habitat no longer exists. Other types of felling also cause adverse effects, such as removal of dead and dying biologically old trees from the stand, which are crucially important to many species associated with old forests, including cavity-nesting birds, such as woodpeckers. Although habitat characteristic species are an important criteria for the habitat, an important quality factor is also natural structures, which are lacking or at low levels in commercially managed stands.

Since the main criteria for the habitat is a geological landform (esker or eskerine), the felling of trees in the long term does not, however, permanently destroy the habitat. In a longer period of time as the forest stand regenerates, the Forests on eskers may develop. When the characteristic overstorey and understorey develop, it can be considered that the habitat has regenerated.

12.1.5.2 Fragmentation

The distribution of the habitat is determined by geological conditions – this habitat type can only exist in areas of eskers and eskerines. Habitat fragmentation has an adverse effect on the survival of the species populations dependent on the habitat. Some of the habitat localities have not yet been identified, and thus are not included in the protected areas. Part of the area probably has a non-characteristic species composition to the habitat, overgrown with *Picea abies* and *Corylus avellana*, and eutrophication might have occurred. Management in known and newly identified areas may improve the conservation status of the habitat, reduce the impact of fragmentation and improve conservation of the characteristic populations of the habitat.

12.1.5.3 Mineral Extraction

Although it is considered that the biologically most valuable and geomorphologically most unique eskers and eskerines are included in protected nature territories, relatively many coniferous Forests on eskers are located in commercial forest areas. Esker forests outside protected nature areas and microreserves are threatened by sand and gravel extraction. As a result of mineral extraction the esker or eskerine and the associated forest habitat is completely destroyed, and restoration is no longer possible.

12.1.5.4 Eutrophication and Synanthropisation

Starting from the 20th century, as soils became richer, the development of the shrub layer intensifies in *Pinus sylvestris* forests. M. Laiviņš noted in 1998 that the most common species in the shrub layer in coniferous forests were *Frangula alnus*, *Corylus avellana* and *Sorbus aucuparia*. In smaller areas also *Lonicera xylosteum*, *Sambucus racemosa*, *Cotoneaster* lucidus, *Ribes spp.*, and *Amelanchier spicata* are found. Emissions of sulphur, nitrogen and calcium compounds enter element cycles and cause local environmental effects (Laiviņš 1998). Forest stands mostly receive these substances through precipitation. Nitrogen deposition in forests occurs as ammonium, while calcium compounds are emitted in the form of dust from extraction and processing sites (Laiviņš 1998). For more information on this impact on forest habitats *see Ch. 10.1.5.3*.

The shrub layer in *Pinus sylvestris* forests is mainly formed on sites with normal moisture in various types of dry forests. Overgrowth with shrubs occurs more intensively on richer soils, even though *Amelanchier spicata* and *Sorbus aucuparia* can also establish in poor *Pinus sylvestris* forests (*Cladinosa-callunosa* and *Vacciniosa types*). Fire suppression leads to soil eutrophication, the establishment of *Picea abies*, and accumulation of the organic and moss layers. The characteristic light and soil conditions of the habitat change, and rare plants and their associated invertebrate species disappear. Unless targeted management is carried out, which restores the typical light conditions, the characteristic and protected species will occur only in zones of contact with open sunlit areas – along mineralised zones, gaps, roads, clearcuts, forest edges.

One of the affecting factors, especially in territories near populated areas, is recreation. In small quantities it can have a favourable effect on the habitat; trampling disturbs the ground layer, but recreation usually causes intensive eutrophication, causing the establishment of shrubs and ruderal species; also graminoids may become too abundant.

Table 12.1 Management methods for habitat type 9060 *Coniferous forests on, or connected to, glaciofluvial eskers*

Method	Ecological benefits	Disadvantages
Controlled burning	Light conditions improve. Organic and moss layers reduced in thickness. Bare soil patches.	Difficulty in implementation of the work due to poor accessibility of equipment in the territory. Negative reaction of society.
Felling and removal of shrubs and trees in the understorey, if (1) *Picea abies* is present in the advance growth and subcanopy layers; (2) if *Corylus avellana* occurs in the understorey	Light conditions improve. During cutting patches of bare soil may be created, where the characteristic plant species of the habitat may establish.	Density of organic and moss layers is not reduced. In the case of *Corylus avellana* the felling must be repeated regularly, as *Corylus avellana* regenerates from stumps.
Thinning or selective cutting with removal of felling residues or their burning in piles	Light conditions improve. During cutting patches of bare soil may be created.	Density of organic and moss layers is not reduced. Suitable habitats for species dependent on the dead wood do not increase.
Artificial increase of the volume of dead wood	Increase in the amount of suitable habitats for species dependent on dead wood.	Organic and moss layers are not reduced. Light conditions do not improve.
The creation of bare soil patches (in combination with cutting of saplings and gap creation; not recommended, if *Corylus avellana* occurs in the understorey)	Light conditions improve. Patches of bare soil are created.	Organic and moss layers are not reduced.
Grazing	Light conditions improve. Areas of bare soil may develop.	Possible trampling of protected plants, as well as soil compaction and establishment of ruderal species.

12.2 Restoration and Management Objectives in the Conservation of Forests on Eskers

The main objective in the conservation of the Forests on eskers is to ensure a favourable conservation status (*see Ch. 5.3*) and habitat-characteristic natural structures to the extent that fosters and provides the long-term and stable existence of the typical and rare species associated with the habitat. Conservation of an esker implies protection of the geomorphological formation and its inherent soil conditions. A specific goal is to conserve the habitat-characteristic rare plant and invertebrate species that depend on maintaining the typical conditions and periodic disturbances in the habitat. The characteristic species are light demanding and depend on disturbances and calcareous soil characteristic to eskers. Some invertebrate species like butterflies feed only on one rare plant species that are found almost exclusively on eskers.

12.3 Habitat Restoration and Management of Forests on Eskers

12.3.1 Different Approaches of Habitat Conservation

Stands that comply with the characteristics of the habitat and stands that do not meet these criteria can both grow on eskers or eskerines, such as shaded *Picea abies* stands on the northern slopes of the esker or mixed stands with broad-leaved trees on fertile soils, and it is not always necessary to create the abiotic conditions characteristic of the protected habitat – dry, sunlit forests with *Pinus sylvestris*. In these cases the forest stands should be left to develop naturally.

The following methods apply to stands where it is possible and necessary to restore and maintain the conditions and species characteristic to Forests on eskers. The quality and composition of the characteristic species of this habitat directly depend on disturbances that provide suitable light conditions in the forest stand for development of the typical groundfloor structure of the habitat. Different approaches may be used in the conservation and management of the habitat: (1) non-intervention that provides passive protection; (2) forestry methods aimed at wood harvest; and (3) habitat management methods, which include the emulation of natural disturbances.

Non-intervention has been applied most often in the conservation of forest biodiversity in Latvia – exclusion of human activity that is associated with felling of trees or shrubs, impact on the soil, vehicle transport. Natural processes are not limited or disturbed. The territory may be used for recreation, berry and mushroom picking, and hunting. Since structures like dead wood and mosaic forest patches are significant indicators of habitat quality, measures to create dead wood may be implemented in the habitats where the structural quality is very low.

In territories which are managed for timber harvest, it is possible to diversify forest stand structure and improve light conditions in the forest (*see Ch. 12.3.4*). For example, by selective felling, whereby part of the trees are cut, light conditions can be improved. Felling activities can turn over the organic layer, partly exposing the soil. Although generally the thickness of the organic and moss layers is not reduced, vascular species characteristic to the habitat may establish on bare mineral soil patches.

Natural disturbance emulation methods are classified according to their objective – restoration of habitat-characteristic light conditions and ground cover, improvement of forest canopy composition and habitat restoration, but often the implementation of one method may serve to achieve multiple purposes. For example, with controlled burning both the structural quality of a stand and the growing conditions for the characteristic species can be improved (*see Ch. 12.3.2*). If it is not possible to carry out controlled burning due to various reasons, a dense shrub layer or *Picea abies* advance growth and larger trees may be felled in order to improve light and reduce eutrophication. However, the results are temporary, especially when felling *Corylus avellana* and the thickness of the organic and moss layer does not decrease (*see Ch. 12.3.3*). The presence of a thin organic layer and bare soil patches in the habitat are preconditions for the survival of many rare and threatened species. Such conditions can be created in small amounts by soil scarification (*see Ch. 12.3.5*).

12.3.2 Controlled Burning and Emulation of Natural Disturbances

A forest with *Pinus sylvestris* of various ages, heights and dimensions and a relatively open, sparse forest stand structure that has formed as a result of regular fires is characteristic to dry *Pinus sylvestris* forests in natural conditions. In such forests the fire interval is 50-150 years, depending on soil characteristics, topography, stand age and human impact. However, there are always areas that have not been affected by the fire for a long time. Today, *Pinus sylvestris* forests have mostly not experienced burning for more than 120 years, since intensive forest fire control was initiated (Montiel, Kraus (eds.). 2010).

Controlled burning is a widely used esker forest management method in Fennoscandia in order to improve light conditions and reduce the organic and moss layer, improving living conditions of rare species (Hovi et al. 2008; Species rich LIFE 2015). It is applied in forests that have not experienced burning for a long time, young and middle aged *Picea abies* have established and create shading, where there is a thick moss and organic layer, and the characteristic herb species have disappeared from the groundcover (Vanha-Majamaa et al. 2007). For example, since 2002 in Finland the METSO (forest biodiversity) programme was implemented, aiming at the protection and restoration of important ecosystems in Finland (METSO 2015). Since forests on eskers are one of the most degraded forest ecosystems in Finland due to fire control, targeted habitat restoration is conducted by establishing small clearcuttings, implementing controlled burning and increasing the volume of dead wood. In Finland, one of the largest LIFE projects "Light & Fire LIFE 2016" was started in 2014 and covered 69 Natura 2000 sites. The aim of the project was to improve the habitat of the species that depend on fire disturbances, such as *Pulsatilla patens* and *Thymus serpyllum*, and conduct management of habitats in large areas by applying controlled burning (Light & Fire LIFE 2016).

Prior to burning it should be assessed whether it is necessary to cut the *Picea abies* advance growth and subcanopy in order to decrease the risk of crown fire, where the fire from the burning

Picea abies understorey may reach the crowns of *Pinus sylvestris*, creating wider disturbance than the initially planned controlled burning of ground cover, possibly affecting adjacent forest stands where this disturbance is not intended or advisable. If controlled burning is planned in a stand with *Corylus avellana* understorey, it should be cut prior to the burning. Unlike *Picea abies,* the needles of which burn very well, more heat is necessary for the incineration of *Corylus avellana* branches, and the fire effect on the ground cover may decrease.

During preparation for controlled burning, several aspects related to fire safety most be considered in order to prevent uncontrolled forest fire (Similä, Juuninen 2012).

- The location of the stand – whether it is possible to provide access for fire trucks (there are roads, passable tracks); it is possible to localise the burnt area.
- The nearest water source location (preferably as close as possible, no more than 1 km). If there is no water in the vicinity, it is possible to install a temporary water storage area near the site by digging a pit, lining it with polyethylene foil and filling it with water. It must be checked whether the water in the source is usable. For example, it may be slimy or the reservoir is filled with litter that would make it difficult for use by fire trucks. In this case, the reservoir must be cleared from litter before use.
- Whether the risk of crown fire has been eliminated. If there is *Picea abies* advance growth and a subcanopy, *Picea abies* must be felled to the extent necessary for safety. Obtained timber or wood chips might be a source of income. Felling residues must be removed from the stand. If there is an insufficient amount of combustible burning material in the stand, part of the felling residues can be shredded and spread on the groundcover. Individual *Picea abies* of a larger dimension can be left on the ground after felling for the creation of burnt dead wood.
- Creation of a mineralised zone around the area to be burnt – may be established with ploughs, a disc harrow or other equipment, but shredded moss should not be left in this zone. Scarification should be carried out to reach the mineral soil, or shredded moss should be removed so that it is not possible for the fire to move into the adjacent stands. While implementing burning, one must carry out wetting around the external perimeter of the burn, and canopy wetting of adjacent stands in an area of at least 2 m in width, if necessary.
- Monitoring after burning – continuous monitoring should be ensured for at least 24 hours after burning to control the ignition of charcoal and the recurrence of burning, especially in cases if the wind strength intensifies. The territory should be visited and monitored for the next few days until the burning is fully extinguished or if it has been raining.

Controlled burning should not be performed in places where rare plant and invertebrate species are found, such as in sites of *Agrodiadetus damon,* where *Onobrychis arenaria* also grows.

Observations on other species in the managed sites indicate that, for example, in the Nature Park "Driksnas sils", *Thesium ebracteatum* and *Geranium sanquineum* established next to a patch where branches were burnt. In the nature park "Numernes valnis" *Dianthus arenarius* had already richly established in the first summer after the burning of felling residues in spring. In burnt areas along the railway on the edge of Teiči Nature Reserve, *Pulsatilla patens* and *Thymus serpyllum* were observed sprouting from dormant buds after fire.

The beneficial effect of controlled burning on rare plant and insect species

In the Komio protected area in Finland, controlled burning had a positive effect on many species dependent on such habitats – improved conditions for *Thymus serpyllum* and the butterfly *Maculinea arion*, which feeds on *Thymus serpyllum*, as well as for species of open dry and sandy sites, such as *Antennaria dioica* and *Hieracium* spp. (Light & Fire LIFE 2016).

Fig. 12.8. *Thymus serpyllum.* Photo: R. Indriķe.

It is recommended that the territories managed over various years are functionally linked and that the target species can disperse to suitable areas.

Controlled burning should be carried out when the understorey and moss layer is dry enough for burning down to the mineral soil, at least in part of the territory. If the fire is of low intensity and affects only the upper layer of moss (ground fire), the result is evaluated as unsuccessful, and the objectives have not been met.

The most appropriate time for controlled burning is from mid-July until mid-August, which is typically a high fire risk period. It is a suitable time to prevent extinction of, for example, *Maculinea arion*, as the imago have flown and the fire does not destroy the sedentary larvae on plants or soil. Burning must be implemented after the dew has dried, and when the wind speed does not exceed 5 metres per second.

Many vascular plant and invertebrate species characteristic to the habitat are strongly linked with fire or the presence of bare mineral soil, so it is difficult to ensure a favourable conservation status of these species without burning (Reier et al. 2005). If one performs only cutting of shrubs and *Picea abies*, suitable conditions are not ensured to protected species dependent on fire disturbance (pyrophiles) and above-ground invertebrate species. If it is not possible to carry out burning in a continuous area, local controlled burning of some tens of square metres in patches is recommended, in order to create dead wood suitable for pyrophile species. It is recommended to create openings in the forest stand canopy in the rest of the forest and perform mechanical loosening of the soil or moderate grazing in order to improve insolation and create bare soil patches.

Changes Induced by Forest Burning in Driksnas Sils

In the nature conservation plan of the nature park "Driksnas sils" (Vāveriņš (ed.) 2004) it was planned to fell the *Picea abies* in shrub and canopy layers in several forest compartments. On the Sāviena castle mound, due to negligence the organic layer burned in a relatively large area in 2007 after felling *Picea abies*. The stand conforms to the habitat type 9060 *Coniferous forests on, or connected to, glaciofluvial eskers*.

About seven years after the burning, forest on the Sāviena castle mound was well insolated, *Picea abies* were absent, in some places the groundcover density and the thickness of the organic layer had significantly decreased. The slope vegetation regenerated, and structure characteristic to the habitat developed and the characteristic species established, including protected plant species *Pulsatilla patens*, *Arenaria procera*, and *Dianthus arenarius*.

Rare species *Lathyrus niger* grows on the castle mound (Kreile, Lēne-Līne 2003), but in general the circumstances here are not optimal for the habitat and its characteristic species. The stand is relatively densely overgrown with *Calamagrostis arundinacea*. Perhaps the development of rich vegetation was promoted by very good light conditions – the formerly dense *Juniperus communis* understorey burnt, and the mature *Betula pendula* and *Populus tremula* trees that remained after the burning were uprooted during the storm in 2010 and subsequent snowbreak.

Fig. 12.9. Sāviena castle mound, 2007. Photo: V. Kreile.

Fig. 12.10. Sāviena castle mound in 2014. Photo: R. Mežaks.

Examples of Habitat Management

Habitat management by felling of *Picea abies* was carried out in the Nature Park "Laukezers" in 2011 in accordance with the nature conservation plan (Urtāne (ed.) 2007). Habitat survey carried out in 2013 indicated good light conditions, but small volumes of dead wood. No protected species were found in the managed territory, but characteristic species were present.

Fig. 12.11. Forests in eskers in Nature Park "Laukezers", 2015. Photo: S. Ikauniece.

Results of *Corylus avellana* cutting in Grebļukalns Hill

In the southern part of the nature reserve Grebļukalns the habitat contains rather dense and old patches of *Corylus avellana*, and protected shrubs like *Euonymus verrucosa* and *Cotoneaster niger* are present in the understorey. In the northern part of the nature reserve, *Picea abies* is abundant in the understorey and subcanopy.

Corylus avellana was cut in several compartments in 2010, 2012 and 2013. The light conditions improved, which might be the reason why a *Lithospermum officinale* (Fig. 12.14) abundantly established on the slope. However, *Corylus avellana* sprouts still develop, and cutting must be repeated with an interval of a few years.

Fig. 12.12. Grebļukalns slope after management. Photo: S. Ikauniece

Fig. 12.13. A *Lithospermum officinale* locality on the Grebļukalns slope after management. Photo: S. Ikauniece

12.14. att. *Lithospermum officinale*. Photo: S. Ikauniece.

12.3.3 Cutting and Removal of Understorey, Advance Growth and Subcanopy

Understorey and subcanopy trees can be removed to increase fire safety during controlled burning. It can also be applied in cases when controlled burning is not possible. For example, if controlled burning is difficult from the point of view of fire safety or the costs are too high, at least shrubs and trees in the understorey should be cut and removed. This type of management and its result depend on stand composition: (1) *Picea abies* in the shrub and subcanopy layers; (2) *Corylus avellana* abundant in understorey.

12.3.3.1 Cutting of the Picea abies in the Advance Growth and Subcanopy.

The *Picea abies* advance growth is cut to improve the light conditions in the stand. Part or the entire subcanopy of *Picea abies* can also be cut. It is advised to create soil disturbance by scarification with equipment used for felling works. Spruce residues may either be removed or burnt. If residues are not burnt, they must be removed and not left on transportation tracks. If they are burnt, it is advised to burn small to medium-sized piles, creating wide patches affected by fire, burning the moss and organic layer down to the mineral soil.

12.3.3.2 Cutting of Corylus avellana Understorey

Unlike *Picea abies*, *Corylus avellana* regenerates rapidly from stumps, and its felling must be repeated after few years. Cutting residues must be removed and burnt, similarly to after the felling of *Picea abies*. Burning of cutting residues should be done on groups of *Corylus avellana* stumps, as well as in combination with the creation of bare soil patches. Currently the information is lacking regarding whether regular cutting of *Corylus avellana* sprouts after a longer period of time contributes to the decrease of regeneration.

12.3.3.3 Cutting of Other Shrub Species

In forests subjected to eutrophication, other species of deciduous trees and shrubs are present, including both native (*Acer platanoides, Sorbus aucuparia, Lonicera xylosteum*) and invasive foreign species, most often *Amelanchier spicata*. The only method in Latvia practised to control *Amelanchier spicata* and other invasive shrubs has been the cutting of sprouts, but the method is not very effective. In dry *Pinus sylvestris* forests on poor soils (*Cladinosa-callunosa* and *Vacciniosa* forest types), controlled burning can be applied to combat *Amelanchier spicata*. Fire significantly reduces the organic layer depth and damages the roots of shrubs, thus reducing their growth potential (for more on controlling invasive species *see Ch. 10.3.5*).

Also protected shrub species may be present in the understorey – *Cotoneaster niger* and *Euonymus verrucosa,* especially in the eastern part of Latvia. In these cases all of the shrubs should not be cut, and a viable and qualitative species population should be conserved. It is better to carry out selective felling in patches, creating sunlit gaps. If shrubs form dense stands, a proportion should be cut, conserving better growing individuals.

12.3.4 Improving the Natural Structure of Forest Stands

The structure of forest stands can be developed to be more natural by selective felling in stands of various ages, while ensuring that the felling residues are removed or burnt. This method can be applied to planted even-aged stands of *Cladinosa-callunosa, Vacciniosa* and *Myrtillosa*. Naturalness can be improved in stands where it is not possible to carry out controlled burning for various reasons. The method is not effective in fertile forest types (for example, *Hylocomiosa* type), and where there is a *Corylus avellana* understorey.

The basal area of a stand of medium age can be reduced until the critical value multiplied by a factor of 1.5. Thus stands with this basal area have a density close to 4. It is better to carry out felling in groups, creating up to 0.25 ha openings, as well as conserving the tree and shrub understorey in some places. It is advised to create soil disturbance, scarifying the soil with the equipment used for felling.

Felling residues can either be removed or burnt. If they are not burnt, they must be removed from the stand and from transportation tracks. If burnt, then small to medium-sized piles are recommended, creating wide fire sites such that fire affects the widest possible area, burning the moss and organic layers down to the mineral soil. Felling residues should not be spread in transportation tracks or dispersed throughout the plot, since this will promote the development of a humus layer, which is not desirable for this habitat.

Selective felling on Numernes rampart

The nature conservation plan of Nature Park "Numernes valnis" (Rove (ed.) 2004) provides requirements for Woodland Key Habitat management (felling of *Picea abies* and shrubs) and describes in detail the necessary thinning of *Picea abies* and shrubs, and also describes thinning in *Pinus sylvestris* stands in dry growing conditions. No special habitat management has been started. In order to eliminate the consequences of the snowbreaks of 2012, sanitary felling was carried out in *Pinus sylvestris* premature stands for economic purposes in combination with habitat-suitable management – burning of the felling residues in stands with rare species localities.

Thus, light conditions were improved, which may explain the increase in number of *Dracocephalum ruyschiana* individuals from 10 prior to habitat management to 21 in the year after management, 15 of which were flowering (Fig. 12.15 and 12.16). Also, new individuals of *Dianthus arenarius* appeared in the burnt places (D. Marga, pers.report).

Fig. 12.15. A managed esker forest habitat in "Numernes valnis" Nature Reserve. Cutting waste is left dispersed and in the skid trails. Photo: S. Ikauniece.

Fig. 12.16. A managed esker forest habitat in the "Numernes Valnis" Nature Reserve. Burning of felling residues in piles. Photo: D. Marga.

12.3.5 Creation of Bare Soil Patches, Soil Scarification

Creation of bare soil patches and soil scarification is very time-consuming and is associated with rather high costs, so it is better to apply it in smaller areas where it is not possible to implement controlled burning, but where it is necessary to uncover the mineral soil so that soil conditions develop that are suitable for the establishment of rare species characteristic to eskers. For example, the method has been proposed for habitat management in the "Ogres Zilie kalni" Nature Park (Laiviņš (ed.) 2011). A greater positive impact on the increase in the number of individuals of rare species can be expected if source localities of flowering plants are located nearby, enabling dispersal. For example, the seed of *Pulsatilla patens* has hairs which aid dispersal with wind.

Soil can be scarified in patches or zones. It is recommended to create areas of irregular shape and various sizes (25 m² on average). They can be organised as a mosaic in the forest stand or can be concentrated closest to sites of the habitat target plant species.

Prior to uncovering mineral soil patches it must be assessed whether, in order to improve light conditions, this should be conducted together with the felling and removal of the understorey shrub layer (*see Ch. 12.3.3*). Bare soil patches can also be created after thinning or selective cutting for timber harvest. By using hand tools (such as rakes) or equipped small tractors (such as with a harrow), the soil is scarified and the moss and organic layers are removed, thus uncovering the mineral soil.

An essential condition is that the removed moss and organic layers are taken out of the stand. Possibilities for use of the removed layer for wood nurseries or household needs have not yet been identified. However, it is possible to use this layer in creating greeneries and plant nurseries, as well as for the growing of *Rhododendron* spp., *Vaccinium corymbosum*, *Erica* spp. and *Calluna vulgaris*.

The method is less efficient in fertile forest types (*Hylocomiosa* type), where there is a *Corylus avellana* understorey and a thick humus layer, which are too difficult and time-consuming to be removed down to the mineral soil. This method does not provide as good results as controlled burning, and only partially prevents leaching of

Fig. 12.17. Bare soil patches in the esker forest habitat in Rāzna National Park. Photo: S. Ikauniece.

Fig. 12.18. Dead wood formation through ring-barking in Finland, carried out several years ago. Photo: S. Ikauniece.

nutrients to the soil, and thus does not improve the conservation of rare plant and invertebrate species populations associated with esker forests.

12.3.6 Increase of the Volume of Dead Wood

Dry *Pinus sylvestris* stands are often easily accessible for logging, and thus the habitat has always been exposed to intensive management. Consequently the volume of dead wood may be insufficient (less than 20 m^3/ha), especially in the younger forest stands or near populated areas. If controlled burning is planned for habitat management, the necessity of increasing the dead wood volume must be assessed. It may not be necessary. However, if death of trees is not expected to reach at least 5-10 logs per ha with a diameter > 25 cm after burning, dead wood creation with the formation of gaps can be considered (for more on gaps *see Ch. 10.3.2*).

Ring-barking is the most common method of dead wood creation. The bark and layer of cambium in 2-3 cm depth around the trunk is removed in the form of a ring. The creation of scars on the root collar of the tree has a similar effect (Viilma 2004). The tree gradually withers, but remains as a snag for a long time. After falling to the ground, it increases the volume of lying dead wood.

12.3.7 Grazing

A sparse forest canopy characteristic of the habitat and a rich herb layer may indicate that the habitat was probably pastured. If a pasture is located next to an esker forest, the territory may be included in the pasture by the construction of fencing. It is recommended to pasture sheep or horses at a low density, with no more than 0.3 cattle units per hectare (the lowest density in accordance with the Rural Support Service conditions for grasslands in 2016). Pasturing is more recommended in richer growing conditions with a *Corylus avellana* understorey, rather than in forest types on poor soils.

Grazing can also have undesirable side-effects – trampling, eutrophication in the case of a high number of animals, and possible adverse effects on invertebrates, both due to feeding on flowering plants, and by destroying larvae (eating them together with plants, trampling them). If the cattle stay in one site for a long time, ruderal plant species may appear in the intensively trampled areas (such as *Urtica spp*., *Chenopodium spp*.), and graminoid species may establish.

12.3.8 Habitat Restoration

Since the main prerequisite for the existence of this habitat is geological conditions, habitat restoration is possible as long as the esker remains as a geological landform, even if it has been severely degraded, i.e., the typical species complex is no longer found neither in the understorey, nor in the canopy.

A shaded forest stand with a developed subcanopy and understorey of *Picea abies* may develop on an esker, as well as a thick moss layer (Fig. 12.19).

It is possible that structures and species characteristic to the protected habitat type 9010* *Western Taiga* have developed.

It must be assessed in such situations whether the goal is to restore the Forest on eskers or classify the area as habitat type 9010* *Western Taiga* in the stage of its formation and manage it accordingly, or leave it to natural processes.

Fig. 12.19. Shaded *Picea abies* forest in Grebļukalns. Photo: S. Ikauniece.

Restoration of an esker forest habitat may be considered in cases when there are adequate soil conditions and qualitative Forests on eskers with typical species located close to the degraded territory. After restoring the degraded habitat, the total habitat area will increase and the living space for the typical species, including rare species, will increase, improving the overall favourable conservation status of the habitat in the country. The most effective and actually the only suitable habitat restoration method is controlled burning. Burning must be planned so that burning in the soil cover is more intensive. *Picea abies* must be felled prior to this, thus decreasing the risk of crown fire.

Artificial forest regeneration after clearcutting for timber harvest with species unsuitable (*Picea abies*) for the habitat should be avoided; *Pinus sylvestris* should be preferred. It is recommended to avoid creating furrows from the top of the slope downwards when preparing the soil for planting as this can promote erosion. Before planting trees it is desirable to burn the organic layer in clearcuts. Soil scarification is recommended to promote succession in clearcuts where dense overgrowth of grasses should not be allowed. It is recommended to plant *Pinus sylvestris* at a lower density than required in forestry regulations, for example, planting of 1000 trees per ha, in order to avoid dense regeneration. Trees can be planted in groups, leaving up to 0.1 ha large unforested areas for natural development.

The habitat may be restored in *Pinus sylvestris* young stands on eskers and eskerines by means of targeted management, if the species characteristic to the habitat are found there. By thinning the critical basal area should be achieved, creating the best possible light conditions, and removing the felling residues.

If *Picea abies* have been planted on the slopes of southern exposure, they need to be felled for the restoration of Forests on eskers and replaced by *Pinus sylvestris* over a longer period of time. Well-lit and habitat-characteristic forest stands are not expected on north-facing slopes, where mixed stands with *Picea abies* are more common; however in these areas planting of *Picea abies* should be avoided in favour of creating *Pinus sylvestris* stands.

12.3.9 Management Unfavourable to Esker Forests

Permanent habitat destruction occurs when an esker is used for gravel extraction. Although nowadays environmental impact assessment is carried out prior to quarry establishment, in the cases of poor habitat quality and lack of typical and protected species, there is a risk that the territory may not be classified as a protected habitat and the esker may be destroyed.

As for other forest habitats, clear-cutting with destruction of the tree canopy layer is clearly unfavourable management for the habitat.

12.4 Conflicts of Conservation and Management

Non-intervention, which is also associated with suppression of natural disturbances (fire), is usually not the most suitable management for this habitat, as it promotes the formation of a shrub understorey, worsening of light conditions, and accumulation of the moss and organic layers.

Since habitat management is targeted at improving habitat conditions for species, no contradictions between the requirements of the species and habitat management are anticipated. An exception might be the felling of understorey when protected species are found in the shrub layer, as is the case in the "Grebļukalns" Nature Reserve. In these cases it is not recommended to completely cut the shrub layer, to retain the growth capacity of the protected species population. Burning results in burnt wood necessary for pyrophile invertebrate species, good insolation for light-loving invertebrate species. At the same time, burning of the organic layer exposes mineral soil, which is necessary for rare above-ground invertebrate species.

Contradictions may only arise in cases if habitat destruction occurs or unsuitable management is carried out – mineral extraction, clearcutting or artificial forest restoration with *Picea abies*.

Chapter 13. 9080* *Fennoscandian deciduous swamp Woods*

13.1. Characteristics of Fennoscandian Deciduous Swamp Woods

13.1.1. Brief Description

The EU protected habitat type 9080* *Fennoscandian deciduous swamp woods* further below referred to as Swamp woods includes wet deciduous woodlands that are under the permanent influence of surface water and usually flooded annually. They are moist or wet, wooded wetlands on wet mineral and peat soils, and vegetation belongs to the *Alnetea glutinosae* class. The most typical tree species is *Alnus glutinosa*, often with *Alnus incana*, *Betula pubescens*, *Salix spp.*, less common are *Picea abies* and *Fraxinus excelsior.* A distinct microtopography is characteristic to the habitat, which creates a mosaic vegetation structure. Flooded areas may often dominate. Most of the trees grow on hummocks, which support vegetation differing from the rest of the groundfloor (Ikauniece 2013b).

According to forest typology in Latvia, swamp woods are most often included as forest types on wet mineral soils (*Myrtilloso-polytrichosa* and *Dryopteriosa*) and forest types on wet peat soils (*Dryopterioso-caricosa* and *Filipendulosa*). The wet forest type class "*slapjaiņi*" are forest types on wet mineral soils with an organic layer thinner than 30 cm. The forest type class "*purvaiņi*" are forest types on wet peat soils with a peat layer thicker than 30 cm, which may belong to Swamp woods, in cases where over time the wet mineral soils may have accumulated peat, but the soil still receives underground water flows (Liepa et al. 2014).

In Latvia there are three variants of the habitat, which to some extent determine the necessary habitat management types.

Variant 1 (typical): stable, long-term deciduous forest stands on wet soils that are periodically flooded or receive nutrients from underground water. A vegetation structure is typical for the habitat, there are no dominant species, and there is a distinct microtopography characteristic to the habitat (Fig. 13.1).

Variant 2: habitat formation phase – young forest stands in soil and water regime conditions typical to swamp woods; often form on overgrown wet meadows and lake shores (Fig. 13.2). In the

Fig. 13.1. Variant 1 (typical) of the habitat type 9080* *Fennoscandian deciduous swamp woods*. Photo: S. Ikauniece.

Fig. 13.2. Variant 2 of the habitat type 9080* *Fennoscandian deciduous swamp woods* – habitat formation phase. Photo: S. Ikauniece.

early stages of succession it is possible that there is a dominance of one or several species in the groundfloor. The characteristic vegetation structure of the swamp woods is in its formation stage. Habitats of this development phase are found in humid dune slacks in coastal dune complexes

Variant 3: degradation phase of the habitat – biologically valuable forest stands on drained wet soils that correspond to Woodland Key Habitat criteria. The natural hydrological regime of the habitat is altered and partial mineralisation of the peat layer has taken place; however, the characteristic structures have remained, such as hummocks and flooded depressions, as well as the characteristic species (Ikauniece 2013b).

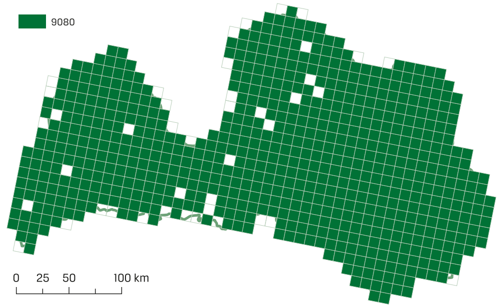

Fig. 13.3. Distribution of the habitat type 9080* *Fennoscandian deciduous swamp woods* in Latvia (source: Anon. 2013c).

Swamp woods are found throughout Latvia (Fig. 13.3), but rarely in large continuous areas. Small localities of the habitat are more common.

13.1.2 Indications of Favourable Conservation Status

A habitat under a favourable conservation status is characterised by a natural hydrological regime. The microtopography is formed by wet depressions and hummocks. Natural processes ensure the typical structure (wet depressions and hummocks), the nature of the vegetation of the mosaic groundfloor, and the presence of characteristic species.

In the herb layer there are no dominating species, except in variant 2 of the habitat (formation phase). Species found on wet depressions and hummocks differ in ecological requirements. Characteristic species of the wet sites are, for example, *Solanum dulcamara*, *Lycopus europaeus*, *Galium palustre*, *Carex* spp., and *Iris pseudacorus*. *Carex* spp. may dominate in variant 2 of the habitat. Wet depressions may lack herb and moss vegetation. *Oxalis acetosella*, *Vaccinium myrtillus*, *Dryopteris* spp., and *Lysimachia vulgaris* grow on hummocks. *Frangula alnus*, *Ribes nigrum*, and *Salix spp.* are present in the shrub layer. Characteristic moss species on hummocks are *Climacium dendroides*, *Calliergoniella cuspidata*, *Plagiomnium elatum,* and *Rhytidiadelphus triquetrus*. *Sphagnum squarrosum* is common in depressions.

In the course of succession, trees of various ages and dead wood accumulate in the habitat, which in combination with the permanently humid microclimate is particularly important for moss species diversity (Darell 2011). The habitat includes the characteristic tree species, and trees typically grow slowly. Biologically old trees with a low diameter and height are common. For example, *Picea abies* with densely set branches indicate slow growth and small annual increment in volume. Active human operations that are associated with rewetting, tree or shrub felling or impact on the soil are excluded.

An important indication is the presence of rare and protected species that are dependent on the characteristic structures and environmental conditions of the habitat. The habitat is important for rare epixilous moss species and epiphytic lichens, such as *Jungermannia leiantha*, *Geocalyx graveolens*, *Arthonia spadicea*, *A. vinosa*, and *Menegazzia terebrata*. (Ikauniece 2013b; Petriņš 2014). The rare fungus *Gloiodon strigosus* may grow in such forests (I. Leimanis, *pers. report*). Swamps are the only known habitats for the very rare snail *Vertigo moulinsiana* in Latvia (Pilate 2009). The habitat is important for nesting and feeding for the rare and endangered woodpecker species *Picoides tridactylus* and *Dendrocopos leucotos*. The smallest owl in Latvia, *Glaucidium passerinum*, inhabits old stands with *Picea abies* (Petriņš 2014; A. Avotiņš jun., *pers. report*).

13.1.3 Important Processes and Structure

13.1.3.1 Processes

Swamp woods are characterised by **wet growing conditions**, a permanently high ground water table, and frequent flooding depending on season and precipitation; in particular summer swamp woods can periodically be dry.

Natural disturbances that cause wide changes are not characteristic for swamp woods. Important processes in the habitat are associated with water level fluctuations of different frequency and duration (Priedītis 1999). **Gap dynamics** is a process where individual trees or small groups of trees suffer mortality due to wind-throw, snowbreak, or high biological age. Gaps develop in the canopy, which gradually overgrow with new trees, while new gaps are formed elsewhere. Gaps in swamp woods remain for a long time, fast regeneration is not characteristic and natural recovery progresses slowly.

Relatively **rapid changes** are characteristic to young swamp woods (variant 2 of the habitat), where intensive competition between species takes place. The trees have small dimensions, natural thinning takes place with the formation of snags and logs of small dimension.

13.1.3.2 Structures

Swamp woods are characterised by an uneven-age structure, many standing and fallen dead trees in various stages of decay, which indicate a high ecological value. Structural elements (snags, logs, stumps, trees with cavities, biologically old trees with large dimensions, old and slowly growing trees) indicate natural stand development and possible compliance to the quality criteria of a Woodland Key Habitat. They serve as habitats for a large number of specific habitat species that are usually not found in intensively managed forests where there is little natural structure (Ek et al. 2002). For example, *Dendrocopos leucotos* nests in forest stands in a 100 ha area with at least 10-20 m^3/ha of large dimension standing dead deciduous trees. In such areas species survival depends on both natural and human-caused disturbances. In optimal habitats for the species (which are in good condition and can be used as a species distribution centre), there is about 55 m^3/ha of dead standing trees in at least a 100 ha area (Czeszczewik, Walankiewicz 2006).

In order to consider a forest to be EU protected habitat type 9080* *Fennoscandian deciduous swamp woods,* it does not always have to comply with the quality criteria of a Woodland Key Habitat, however, the presence of characteristic species is an important quality indicator.

13.1.4 Succession

Wet Swamp woods, especially *Alnus glutinosa* woods (*Alnetea glutinosae)* are relatively stable communities of the final succession stage (climax) of the ecosystem, and in suitable environment conditions they may exist for thousands of years, as indicated by the results of peat analysis (Priedītis 1997). The key factor for the development and existence of the Swamp woods are wet soil conditions.

Studies of succession indicate that natural development in medium-fertility (mesotrophic) conditions may gradually move from freshwater submerged and floating *Potametea* or *Phragmitetea* plant communities in the direction of *Alnetea glutinosae,* often including the shrub stage with dominance of *Salix aurita* and *Salix cinerea*. Usually succession to forest is caused by water level changes, debris accumulation and litter mineralisation (Priedītis 1997). Swamp wood development is observed as overgrowth of wet meadows and lake shores (Schrautzer et al. 2007).

Natural regeneration from seeds is usually not possible under the canopy of a mature stand, and requires gaps of about 0.1 ha. Natural regeneration of *Alnus glutinosa* by seeds depends on soil disturbance by animals or floods or changes in the canopy as a result of gap development. Tall herbs like *Filipendula ulmaria* and *Carex* spp. impede the establishment of seedlings (Claessen et al. 2010). As individual trees die-off, regeneration usually occurs from stump sprouts, forming raised hummocks over time. Natural structures form after natural disturbance (e.g., logs, stumps, and snags develop after withering of trees) and the biodiversity associated with these structures increases.

Even though these swamps and particularly the *Alnion glutinosae* community is considered as a final stage of succession, there may be several courses of further development as a result of natural or human-caused changes. If the groundwater table declines, especially in forests near water courses, where there are indications of the Swamp woods, plant communities with *Ulmus glabra* or *Ulmus laevis* may form. Then mineralisation of peat gradually takes place, the peat layer disappears, and plant communities characteristic to deciduous forests develop. Consequently, the Swamp woods develop into another protected habitat, for example, 91F0 *Riparian mixed forests of* Quercus robur, Ulmus laevis *and* Ulmus minor, Fraxinus excelsior *or* Fraxinus angustifolia*, along the great rivers*. In other cases, as *Picea abies* and understorey boreal plant species establish after draining, natural development may take place in the direction of habitat type 9010* *Western Taiga*.

Fig. 13.4. Habitat type 9080* F*ennoscandian deciduous swamp woods* (variant 2) has been inundated due to *Castor fiber* dams, as a result of which trees have withered, high herb understorey has formed, and in the future a fen may develop. Photo: S. Ikauniece.

If the habitat is permanently constantly inundated over a long period due to the activity of *Castor fiber* or evapotranspiration decreases after clearcutting, significant changes may occur in the habitat due to intensive paludification. Peat accumulates and succession occurs in the direction of boreal forests or *Alnion glutinosae* on thick peat, and in the future habitat type 9010* *Western Taiga* or 91D0* *Bog woodland* may develop.

In some cases a high permanent water level and paludification can contribute to the development of *Caricetum elatae* or *Magnocaricion* or *Phragmition* communities (Priedītis 1997) (Fig. 13.4).

13.1.5 Pressures and Threats

13.1.5.1 Drainage Systems

The most significant adverse effect is associated with interruption of the natural hydrological regime characteristic to swamp woods. Wet forests in Europe have been widely drained and deforested. They have been transformed to agricultural land. Environmental conditions and related herbaceous and woody species composition in the drained woodlands are completely changed due to peat layer mineralisation.

Draining with the objective to increase timber harvest is the main cause of degradation of wet forests. In the 19th century, as the area of agricultural land increased at the expense of forests, there was a lack of fire wood and timber; therefore, to increase the productivity of wet forests, they were drained in the early 19th century. Systematic draining of forests in Latvia already began in 1929 (Zālītis 2006). Particularly intense forest drainage was carried out during the period from 1960 to 1980 (Šnore 2004). Drainage played a great role in habitat fragmentation.

Draining affects the entire complex of natural forest growing conditions – hydrological, soil and microclimatic conditions. Both the stand structure and species composition change. As moisture decreases, aeration of soil improves, and microbial decomposition rate and mineralisation increase (Indriksons 2007). Visually this is observed as a reduction of peat layer thickness (peat sinking), exposure of tree roots, and degradation of habitat-characteristic hummocks. Microbial activity releases nutrients from peat, increasing availability to plants, causing ruderal plants such as *Urtica dioica* to appear, and characteristic species of the habitat with a wide ecological niche may become expansive (such as *Phragmites australis)*. The microclimate and soil thermal regime change, which altogether contribute to the replacement of species by generalist species of frequent occurrence, such as *Trientalis europaea*, *Deschampsia cespitosa*, *Pleurozium schreberi*, *Hylocomium splendens*, *Oxalis acetosella*, and *Lycopodium annotinum* (Prieditis 1999; Korpela 2004). Species characteristic of wet forest are lost, such as *Carex remota, C. disperma*, *C. paupercula,* and orchids such as *Corallorhiza trifida, Dactylorhiza fuchsii* and *Listera cordata* (Prieditis 1999).

Naturally old swamp forests are islands of biodiversity of rare species that can disperse to other suitable sites, but drained wet forests lose this function. The species adapted to wet soil conditions are replaced by species that require less moisture; these are common generalist species that grow in various habitats. The artificially promoted reduction of soil moisture contributes to microclimatic changes, which have an adverse effect on bryophytes (such as *Geocalyx graveolens)* and lichens.

Studies in Estonia indicate that drained areas that have previously been covered by *Alnus glutinosa* are no longer suitable for species of wet forests. Even when drained a very long time ago, the habitat is also not suitable for species of old forests on dry mineral soils, and generalist species dominate in such communities (Remm et al. 2013), but there may have been the formation of structures that are characteristic to protected forest habitats (biologically old trees, dead wood).

Drainage also affects tree growth. The productivity and biomass of a forest stand increases, tree canopies enlarge, and the surface area for evapotranspiration increases (Zālītis 2012). The conditions also improve for *Picea abies* growth and establishment, and the previously slowly growing trees cause overgrowth of the habitat. In drained areas in general, water transpiration by tree needles and leaves increases, which further reduces the groundwater table. As the proportion of *Picea abies* increases, a greater amount of precipitation is also held in the canopies of *Picea abies* and does not reach the soil.

However, if the structural quality of drained forests is sufficient, drained swamps can be suitable habitats for some rather rare species, that have no specific requirements regarding the environmental conditions, and which benefit from the increased shade and nutrients that are released during peat mineralisation (Remm et al. 2013).

13.1.5.2 Logging

The habitat is adversely affected by tree felling. The natural regeneration of *Alnus glutinosa* occurs very slowly in clearcuts, which is hindered by several factors, such as dense overgrowth of herb species that established after the disturbance. A relatively dense layer of old grass develops, which acts as a barrier for seed germination and the establishment of *Alnus glutinosa.* Clearcutting reduces evapotranspiration and can promote paludification, impeding tree regeneration, and reed communities and later fens can develop in clearcuts. Clearcutting is incompatible with the existence of the habitat. Other types of felling where the oldest trees or trees of largest dimensions are felled has an adverse effect, reducing the potential volume of biologically significant structures.

13.1.5.3 European Beaver *Castor Fiber* Activity

Beaver activity almost always has an adverse effect on the vegetation of Swamp woods, as opposed to 91D0* *Bog woodland* where beaver activity may have a positive effect (*see Ch. 17.1.5*).

Swamp woods are adversely affected by a constantly high water level caused by beaver dams that change the natural water regime and alter its characteristic fluctuations. The soil is inundated, and the stand may wither in 2-3 years. The accumulation of organic matter increases, soil paludifies, thus changing the plant species composition and causing loss of habitat characteristic species (Fig. 13.5). Species composition and vegetation structure is also affected by selective feeding characteristic to beaver (Czerepko et al. 2009).

Fig. 13.5. A continuously inundated Swamp wood as a result of beaver activity. Photo: S. Ikauniece.

For variant 3 of the habitat (habitat degradation phase), which comprises degraded (i.e. drained) habitats, beaver activity of small intensity can be positive, if soil moisture and air humidity are maintained as suitable for rare species. A great deal of dead wood is created by beaver activity. The dead wood is inhabited by saproxylophagous beetles, which is one of the most important biodiversity components of woods flooded by beaver. Groups of beetles with different ecological requirements are present, including rare species: *Peltis grossa, Mycetophagus quadripustulatus, M. piceus, Drapetes mordelloides,* and *Dircea quadriguttata* (Vilks, Klētniece 2011). Consequently, the flooded woodlands are important feeding habitats for many bird species, e.g. all *Piciformes*. Many species of waterfowl, as well as *Grus grus,* use them for nesting. These forests are dynamic ecosystems that change over time – snags fall and their significance for beetles and *Piciformes* may decrease, mud accumulates, and the vegetation changes. With the increase of water table level, the soil cover is constantly wet, promoting the establishment of *Sphagnum* species, and development of the habitat into habitat type 91D0* *Bog woodland* (Priedītis 1997).

13.1.5.4 Invasive Plant Species

Water flow ensures that seeds spread over longer distances, thereby promoting the dispersal of invasive plants. They can dominate the forest groundfloor by outcompeting native species characteristic to the habitat. *Impatiens glandulifera* is a common invasive species near water courses. It may reach a height of 3 m, shading other species and preventing their growth; consequently the vegetation in the lower herb layer becomes very sparse (Hejda 2012). Although the habitats located near running water are threatened the most by invasive species, Swamp woods may become potential habitat for invasive species.

Another common invasive species, *Impatiens parviflora,* grows mainly in drained stands. Its impact on biodiversity depends on the conditions of the specific site. The species easily occupies empty niches in forest plant communities, successfully competes with other plants and can become the dominant species, changing the characteristic composition of the habitat vegetation and replacing the habitat characteristic species, including protected species (Tanner 2008).

Table 13.1 Management methods of habitat type 9080* *Fennoscandian deciduous swamp woods*.

Method	Ecological benefits	Disadvantages
Rewetting		
Blocking of ditches	The hydrological regime characteristic to the habitat is restored. The restoration of the vegetation characteristic to the habitat is promoted.	Open water areas in ditches are created, which may be dangerous for the young of a variety of animals, e.g. birds. Increased evaporation continues. A relatively long time is needed for ditches to overgrow with vegetation and obtain the characteristic features of the natural habitat. Inundation of peat may cause the release of nutrients due to past mineralisation of peat, and following eutrophication. Intensive overgrowth with *Sphagnum* and peat accumulation may take place, causing loss of the Swamp woods.
Filling of ditches	The soil hydrological regime characteristic to the habitat is restored. The restoration of the vegetation characteristic to the habitat is promoted. Ditches become natural and soon fit in a forest environment.	Can be technically difficult to implement (access of equipment to ditches is impeded or impossible due to trees). Little information about the expected impacts and results. Improper works can degrade the vegetation. Inundation of mineralised peat may cause release of nutrients and following eutrophication. Due to intensive changes in vegetation, the proportion of *Sphagnum* may increase and habitat may develop into habitat type 91D0* *Bog woodland*.
Other measures		
Felling of *Picea abies*	An improved sparse forest structure characteristic to the habitat. Reduction of the total evapotranspiration.	This is not a long-term solution to eliminate the effects of the degradation of the hydrological regime.
Conservation of the buffer zone	Reduced wind impact and conserved conditions characteristic to the habitat in cases when clearcutting is being carried out nearby.	Economic losses arise from the wood that has not been harvested from the territory of the buffer zone.

13.2 Restoration and Management Objectives in the Conservation of Fennoscandian Deciduous Swamp Woods

The main objective is to conserve the area and natural structures that are necessary to ensure a favourable conservation status (*see Ch. 5.3*) to such an extent that it can ensure long-term and stable existence of the typical and rare species associated with the habitat.

For the conservation of Swamp woods it is important to ensure natural development of the habitat or restore the characteristic wet conditions, promoting the restoration of natural structures and species composition. A forest stand that is natural or has little been affected usually does not require special management. The main management of the degraded (drained) habitat variant should be focused on the restoration and maintenance of the typical vegetation and heterogeneity (Remm et al. 2013).

13.3 Conservation and Management of Fennoscandian Deciduous Swamp Woods

13.3.1 Habitat Conservation

The priority of Swamp woods (variant 1, typical, and variant 2, habitat formation phase) is conservation by the non-intervention of natural processes and conservation of the natural hydrological regime.

Non-intervention means the avoidance of active measures such as artificial changes in the hydrological regime, felling of trees and shrubs, impact on the soil transportation that affects the habitat. Natural processes are not limited or disturbed. This is generally the ideal method for maintaining favourable conservation status of Swamp woods. The habitat type 9080* *Fennoscandian deciduous swamp woods* is not normally used for recreation, so human recreational impacts are minimal.

The maintenance of the hydrological regime in an optimal condition is required in the territory of the habitat, but also in the adjacent areas; construction of new ditches or reconstruction of the existing ones can affect groundwater table in a wider area. In drained areas, the hydrological regime can be restored (*see Ch. 13.3.2*). The aim of restoration is to ensure that the water remains in the habitat, and its drainage is prevented. Two methods can be applied – construction of dams on ditches (*see Ch. 13.3.2.1*) or filling up the ditches (*see Ch. 13.3.2.2*). It is essential to respect the precautionary principle in planning rewetting by carrying out a careful feasibility study, identifying possible risks and choosing the best methods. Rewetting in swamp woods must not alter the condition of other hydrologically linked habitats, for example by contributing additional nutrient output to lakes (Urtāns (ed.) 2017, Ch. 15.3.2) or worsening the environmental conditions. It is also important to examine the legal framework and the permitted activities in the territory (*see Ch. 7*).

If it is not possible to carry out rewetting, *Picea abies* regeneration can be felled in the forest stands of variant 3 in order to reduce evapotranspiration (*see Ch. 13.3.3*). The impact from adjacent areas can be reduced by creating buffer zones, which can reduce the effect of drainage systems and wind effects by maintaining a stable microclimate in the habitat (*see Ch. 13.3.4*).

Restoration methods of swamp woods are listed in table 13.1.

13.3.2 Rewetting

13.3.2.1 Basic Principles of Rewetting

The restoration of degraded and affected swamp woods depends mainly on the possibilities to eliminate drainage systems or reduce their impact, and to restore the optimal moisture conditions of the ecosystem.

Drainage significantly changes soil conditions by increasing the decomposition rate and mineralisation of organic matter. Prior to drainage, the groundwaters of forests in many places can be rich in iron and sulphur compounds, which change due to chemical processes after draining. Oxidation of iron compounds releases phosphorus and sulphur compounds for plant uptake (Lamers et al. 2002; Lucassen et al. 2005), increasing the amount of nutrients in soil that is available to plants. Restoration of the habitat by establishing a permanently raised water level can increase the amount of nutrients in soil water that is available to plants. This causes changes in the vegetation, by proliferation of algae, free-floating aquatic plants (*Lemnoideae*) and gramineous plants characteristic to wetlands, while the proportion of wet forest vegetation, such as *Caltha palustris* or *Carex elongata* is reduced (Lucassen et al. 2005). In such conditions *Sphagnum squarrosum* usually establishes, which indicates rapid changes of moisture (Lamers et al. 2002).

The commonly used methods to restore and improve the hydrological regime of wet forests is blocking or filling up of drainage ditches, as a result of which the soil moisture increases and the ecosystem functions and biodiversity related to these conditions are restored (Maanaviljaa et al. 2014). Construction of dams can cause a permanently increased water level and stagnant water, which creates conditions which differ from the former fluctuating water level. The restored water level should not cover tree hummocks, but should cover a part of the soil, such that the characteristic periodically wet depressions characteristic for the habitat form. The extensive proliferation of algae and *Lemnoideae* indicates adverse processes. In natural conditions at least in part of the habitat area the surface layer of soil dries out during summer, which impedes the formation of the vegetation that is not characteristic to the habitat. Therefore in cases when dams are used for rewetting, it is recommended to decrease the water table in the summer and let the surface layer of the soil dry periodically in some part of the inundated territory, imitating the natural process (Lucassen et al. 2005). It may be needed to develop a rewetting plan of a given area that implements the construction of dams over several years, observing changes during this time. It is necessary to comply with the precautionary principle by increasing the water level gradually, and to monitor effects on the hydrological regime to be able to react quickly if a negative impact is detected. Observations should be carried out regularly each year. Evidence of withering trees does not imply a need for quick modification, since like significant changes in vegetation, it is a delayed reaction to adverse processes.

Significant increase of the water level by permanent flooding may degrade the habitat, like the flooding created by beaver. Therefore rewetting may be possible in places where substantial degradation has not occurred after the construction of ditches and where structures characteristic to wet habitats (hummocks and permanently or periodically wet areas of the soil) and their typical species still remain in the forest stand. In these cases the conditions can be improved by restoring the appropriate moisture. In intensively drained swamp woods the saturation of mineralised peat with water may worsen the condition more than leaving the drained forest untransformed.

It is recommended to apply blocking of ditches as a method of habitat restoration, while filling up of ditches should be conducted as a scientific experiment to gather more knowledge on the application of this method to degraded swamp woods. If the results of monitoring indicate negative results, the modification of water level can be easier in the case of a blocked ditch rather than if the ditch has been filled up. When evaluating the necessary actions, one must take into account the width, depth and length of the ditches, the soil conditions (wet mineral soil or peat soil), direction of water runoff, the topographic characteristics of the area, as well as the functional role of the ditches and their impact on the forest stands in a larger territory. Even relatively remote ditches which are not in a direct contact with the habitat territory may have an adverse effect. Ditches which are dug in mineral soils often have a more substantial and wider impact than ditches in peat. Also partly overgrown ditches where the water flows under the surface layer of vegetation have a drying impact.

13.3.2.2 Blocking of Ditches

The aim of creating ditch dams is to raise the water level and prevent water outflow from the territory. The method has been successfully applied in the restoration of degraded raised bogs in many parts of the world and in Latvia. In Swamp woods it is recommended to apply this method by blocking small ditches.

Different types of dams can be used, the technical solutions of which are determined by site conditions, ditch parameters, locally available materials, and transportation costs and accessibility. In the construction of dams, wood, plastic, peat or local soil can be used. The potential lifetime and the maintenance and restoration costs of the dam must be taken into account. After constructing the dams monitoring and regular reparation are needed, such as reparation of leaks.

Whenever possible, felling of mature and biologically old trees should be avoided, except for those on the soil berm along the ditches. Construction of dams of wood and plastic piling walls using manual labour should be used in places that are difficult to access with equipment. When constructing dams of peat or mineral soil, the material must be compacted, and it is best to build them wider and higher than the sides of the ditch, such that water does not wash them away, or flow over the top or through them. The construction is best done with an excavator, but dams can be built manually on small ditches or on sites that cannot be reached by an excavator. If the soil berms are low, the excavation of soil material next to the ditch by creating elongated depressions should be avoided; it is better to produce a smooth surface in a gentle slope in a larger area near the ditch. However, this is not possible in places with dense tree cover.

Fig. 13.6. Wooden dam in Estonia. Photo: S. Ikauniece

When considering which ditches are to be blocked, a detailed study and modelling of the territory should be carried out, determining the importance of each ditch in the drainage of the territory, because sometimes small ditches can also play an important role. For blocking it is recommended to primarily choose the ditches that most effectively ensure the retaining of water in the area of target habitat. According to the precautionary principle, dams should not be created on ditches that will cause very significant, rapid changes of the water level.

A cover of *Picea abies* may have formed along the ditches. The soil berm may have the same function as a hummock, and provide drier conditions for the trees growing on it. Natural mortality of *Picea abies* can rarely be expected due to soil moisture changes thus they can be felled to reduce the total evapotranspiration.

More about dam types: Priede (ed.) (2017).

13.3.2.3 Filling up of ditches

Filling up of ditches can be carried out in places where filling material is available, i.e., where the ditches can be filled using adjacent soil of berms. However, as mentioned above, the filling up of ditches in Swamp woods in Latvia should only be applied experimentally until more information is obtained on the results of the method in this habitat. The history of water regime changes need to be evaluated – if the ditch was established by digging up a natural water course, it should not be filled and the natural water course must be conserved.

For rewetting of drained swamp forest, it is possible to fill ditches with peat or mineral soil from the berm. It is necessary to remove shrubs and trees to provide sufficient space for the digging equipment to move in an approximately 4 m area near the ditch. The felled trees may be used for economic purposes or used in constructing access roads for the digging equipment. The ditches must be totally filled up to the top; felled trees must not be used for filling as they will function to aid water flow through the dams even if they are covered with soil.

Berms are low in forests on drained wet mineral soils, and if the ground near the ditch is to be used for filling, pits and depressions form, which is not desirable, since they will cause water flows. This is not the case for the restoration of mire habitats, where depressions will overgrow with *Sphagnum* and perform the ecological functions of bog pools. There are a number of benefits of ditch filling as opposed to ditch blocking – the water regime is restored close to the natural condition, there is no infrastructure (constructions) that must be maintained in the future, and open water with intensive evaporation is not created. In addition, ditches limit the movement of animals, especially the small ones – these barriers are eliminated when filling up ditches.

Filling of ditches in Swamp woods has only been carried out in some locations in Latvia (in Gauja National Park and in a *Tetrao urogallus* microreserve in the vicinity of Smiltene). Habitat restoration conducted in Finland indicates that the water level increases and stabilises a few years after ditch filling (Maanaviljaa et al. 2014).

Potential risks:

- a detailed survey of the territory must be carried out and it is important to understand the direction of the water flow and how important each ditch is in the general drainage system, in order to avoid paludification outside the target territory due to ditch filling or dam construction, as well as in order not to fill up straightened natural water courses;
- filling of ditches should not increase the water level in nearby lakes, or change their ecological status (Priede (ed.) 2017);
- as the soil becomes saturated with water, the forest stand withers, but in the long term the forest regenerates, adapting to the particular conditions, as observed in, e.g., areas that are constantly inundated by beavers in Ķemeri National Park.

13.3.3 Reducing the Proportion of *Picea abies*

Establishment of forest drainage systems causes changes in the species composition of trees, usually by the development of a dense *Picea abies* understory and subcanopy. Before rewetting it is recommended to fell and remove the *Picea abies* trees (Johansson 2004). If rewetting is not possible, then this might be the only management method to improve structure that can be implemented in such habitats. Felling of *Picea abies* reduces evapotranspiration, the soil remains wet for a longer time, and the speed of degradation may be slowed, but it does not prevent habitat degradation in general.

When implementing the joint project "Management of Natural Forest Habitats in Latvia" of the State Forest Service, JSC "Latvijas Valsts meži" and the forest service of Eastern Gotland in Sweden in 2004, felling of the *Picea abies* subcanopy and understory was carried out in a 3.4 ha area in a habitat that conformed to the criteria of a Woodland Key Habitat and to variant 3 of the EU protected habitat type 9080* *Fennoscandian deciduous swamp woods*, according to the current methodology (Fig. 13.7). The oldest *Picea abies* trees were conserved; hydrological regime was not changed. There is no information about whether monitoring of the groundcover was carried out, and presently, now more than 10 years after felling, the changes can only be assessed visually and compared to a similar adjacent area where the *Picea abies* trees were not cut.

The aim of the management was to conserve the forest dominated by deciduous trees (*Alnus glutinosa*), with many old trees, dead wood, and habitat for the special habitat species (Johansson 2004). The aim has been reached to a large extent – even though the stand is sparse, there are old trees and logs, and the development of a new *Picea abies* advance growth was not observed 10 years after management. There is a relatively dense groundcover with raspberries, *Urtica* spp., *Impatiens noli-tangere,* and there where individual young *Alnus glutinosa* trees, but characteristic species of Swamp forest are almost lacking (Fig. 13.8, 13.9). Although the evapotranspiration from the territory after felling the *Picea abies* trees was likely reduced, the existing ditch network continues to drain the forest stand.

13.3.4 Creating a Buffer Zone

The aim of a buffer zone is to prevent increased impact of the wind in the forest edge area, to maintain the microclimate characteristic to the habitat and to protect the sensitive species, if an adjacent stand is felled (Ek et al. 2002; Johansson 2004). Creation of a large open area will cause sharp microclimate fluctuations by increased wind and insolation. Groundfloor vegetation will be affected, and trees at the edge of the forest stand will be more prone to wind damage. Although the increase in the volume of dead wood will not have negative impact, the changes of microclimate conditions and structure will likely promote the development of a dense shrub layer atypical to the habitat and changes in the groundfloor vegetation. Studies of L. Liepa and I. Straupe (2012) show that the cover of the herb layer is larger about 10 m away from forest edges, compared to 40-50 m from the edges. The cover of the herb layer is larger in swamp woods that border with young forest stands (up to 10 years old), i.e., former clearcut areas. The impact of the edge effect on vegetation, tree structure elements and epiphytic lichen species decreases 20-30 years after

Fig. 13.7. Variant 3 of habitat type 9080* *Fennoscandian deciduous swamp woods* – degradation phase with a relatively dense subcanopy of *Picea abies* near the managed site. Photo: S. Ikauniece.

Fig. 13.8. Site managed in summer 2004, photo taken in 2015. Photo: S. Ikauniece.

Fig. 13.9. Site managed in summer 2004, photo taken in 2015. Photo: S. Ikauniece.

Table 13.2 Planning principles of the buffer zone (according to Johansson 2004).

Factors that influence the size of the buffer zone	A wider buffer zone	A narrower buffer zone
Exposure of the forest edge	To the south	To the north
Terrain	Flat	Hilly, undulating terrain
Vegetation	No vegetation or sparse vegetation	Dense vegetation
Tree height	Small trees; shrubs	Tall trees; mature forest
Soil moisture	Moist	Wet

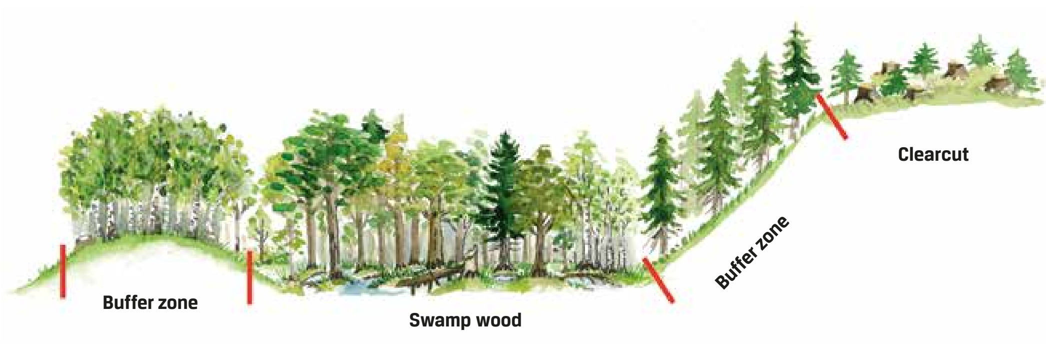

Fig. 13.10. Planning of buffer zones. Drawing by D. Segliņa

disturbance in adjacent stands. The forest canopy structure is also influenced – if felling has been carried out in an adjacent stand (in a 10 year period), more dead wood forms in the 30-m zone around the edge (Liepa, Straupe 2012).

Larger continuous areas of swamp woods are less threatened, since conditions at the edge cover only a small proportion of the entire stand, in contrast to the edge effects in small areas of habitat fragments where the entire stand can be affected. However, the need for buffer zones is equally important for both small and large habitat areas, as the aim is to conserve biodiversity throughout the entire habitat area (Johansson 2004). It is recommended to choose the width of the buffer zone that is equal to the canopy tree height, taking into account exposure direction and terrain. It is recommended to create buffer zones on the south and southwest edges of the habitat, as these directions are exposed to direct sunlight and hence are associated with the greatest edge effect on cover of herb and shrub layers. The buffer zone width should be wider on the side of prevailing winds.

If the swamp forest is located in low area besides a hill with steep slopes, then the buffer zone can be established at the top of the adjacent hill. For less steep hills it is recommended to choose edge width by the length of the largest tree. Selective cutting of various intensities can be conducted in the buffer zone for timber harvest if there are trees and shrubs of various ages and if the buffer zone generally protects the habitat well. Then it is possible to cut individual economically valuable trees, starting from the border of the clearcut (medium intensity) up to the edge of the habitat (very low intensity). Felling should be carried out in a way that does not reduce the ability of the buffer zone to protect the habitat and prevent damage to the remaining trees and shrubs (Johansson 2004).

13.3.5 Control of Beaver Dams

Although flooding caused by beaver *Castor fiber* dams has adverse effect on the vegetation of swamp woods and the whole stand may wither due to drastic water level changes, the created habitat is associated with suitable living, feeding or breeding conditions for many species (beetles, woodpeckers, waterfowl, cranes, etc.).

To make a decision on the liquidation or conservation of beaver flooded areas, one must assess the importance of the flooded habitat, as well as the occurrence of protected species. In each case it is important to comparatively assess

the benefits and losses regarding habitat and species diversity, as well as the age of the flood zone, and how altered the conditions already are, i.e., how possible it is to restore the characteristic conditions of swamp woods in the flooded areas. For example, assessment should include evaluating whether the trees are dying or dead, or have started to regenerate, and whether the groundfloor has already changed significantly under the influence of increased water level.

After the destruction of beaver dams and avoiding a high water level *Alnus glutinosa* can recover fairly soon. If the mature trees have not withered completely, they form new branches and restart normal growth, and stumps of dead trees produce sprouts. However, the restoration of habitat structure and typical vegetation does not occur in a short period of time.

Limiting beaver activity (population control with hunting, regular destruction of dams, pipe insertion in the dams) is recommended for new, recently created beaver inundations, where a protected forest habitat has been flooded but withering of trees has not begun and characteristic species to standing waters, e.g. *Lemna* spp., have not yet established. Control needs to be regular to prevent the return of *Castor fiber*.

13.3.6 Control of Invasive Plant Species

Impatiens glandulifera has relatively rare occurrence in Swamp woods, it is more common in floodplain habitats. *Impatiens glandulifera* is an annual plant, and can be controlled easier than perennial plants. Mechanical methods for control include cutting before seed ripening. Cutting should begin as soon as possible, when only some invasive plants have appeared in the habitat. The cut parts of the plants must be removed from the habitat. It is very important to work in the season when cutting has the greatest impact on the viability of the plants and limits spreading of seeds – prior to seed ripening. Cutting and removal of plant debris needs to be repeated several years in a row, as new plants can establish from the seed bank. If only a few individuals are present at the initial stage of invasion, they can be weeded manually before the flowering and seed ripening.

Impatiens parviflora, another common invasive species, occurs relatively often in drained swamp forests. Drainage creates environmental conditions more suitable for *Impatiens parviflora*, which uses an increased amount of nutrients released as the soil is drained, and good light conditions. Combating *Impatiens parviflora* with mechanical methods (mowing, weeding, cutting) in these situations may have a low efficiency; because this species is usually found in large numbers in relatively wide areas. It is possible that rewetting and making the environment less suitable for *Impatiens parviflora* will lead to its loss from invaded stands (Priede (ed.) 2017).

13.3.7 Management Unfavourable to Swamp Woods

Management unfavourable to the habitat includes not only the construction of new drainage systems, but also renovation and reconstruction of the existing ditches in areas that are hydrologically linked to swamp woods. The maintenance of ditches by cleaning the ditch bed and reducing clogging by improving the water runoff, also causes an adverse effect on the habitat. Construction, reconstruction and maintenance of roads and related ditches have a similar negative impact.

Logging, especially if trees of largest dimensions and the oldest trees are felled, reduces the potential volume of dead wood in the habitat in the future. Thinning and sanitary felling in younger naturally developed forest stands is not necessary for the favourable status of the habitat; they rather have a negative impact on the habitat by changing light conditions, which can promote the extensive proliferation of habitat-atypical species, reduce evapotranspiration, increase soil moisture, may promote paludification, and transportation tracks from equipment serve as drainage ditches.

13.4 Conflicts of Conservation and Management

Rewetting and the formation of buffer zones do not conflict with the known requirements of rare and protected species characteristic to swamp woods, which depend on the hydrological regime characteristic to the habitat and the presence of the structures characteristic to natural forest.

Reducing the proportion of *Picea abies*, especially if slow-growing, biologically old *Picea abies* are felled, may negatively affect rare and protected species present on these trees such as *Lecanactis abietina* and *Arthonia leucopellaea*.

Chapter 14. 9160 *Sub-atlantic and Medio-European Oak or Oak-Hornbeam Forests of the* Carpinion Betuli

14.1. Sub-atlantic and Medio-European Oak or Oak-hornbeam Forests of the *Carpinion Betuli*

14.1.1. Brief Description

Characteristic forests of habitat type 9160 *Sub-Atlantic and medio-European oak or oak-hornbeam forests of the* Carpinion betuli further below referred to as Oak forests are composed of *Quercus robur*, *Tilia cordata* or *Carpinus betulus* as dominant or mixed stands. In many places in Europe this habitat type is more common on hydromorphic soils or soils with a high ground water table (Anon. 2013b). Forest stands corresponding to this habitat type in Latvia are found on various but most often dry soils. Such forest can also be found on drained soils. Oak forests may be of artificial origin either by planting or seeding. Since Latvia is situated in the transitional zone between the boreal (northern) and nemoral (European deciduous) forests, mixed stands may contain tree species of the boreal forests – *Picea abies* and *Populus tremula* (Nilson 1997; Ikauniece 2013c).

Although *Quercus robur* forests are widely distributed in Latvia according to the database of the State Forest Register (Fig. 14.1), these are most often small stands or old planted gardens with some large oak trees near old houses, which do not correspond to the minimal criteria for habitat type 9160 *Sub-Atlantic and medio-European oak or oak-hornbeam forests of the* Carpinion betuli (Ikauniece 2013c).

In Latvia there are three variants of the habitat, which to some extent also determine the necessary management for habitat conservation.

Variant 1 (typical): the typical variant with *Carpinus betulus* covers small areas in Latvia near Sventāja and Rucava (Krauklis, Zariņa 2002), forest is dominated by *Quercus robur* and *Carpinus betulus,* with other tree species (Fig. 14.2).

Variant 2: various transitional and mixed variants dominated by *Quercus robur* or *Tilia cordata* or a combination of these species. Spring-blooming herbaceous plants are characteristic, presence of boreal forest species is possible (Fig. 14.3).

Variant 3: oak-spruce forest with *Quercus robur* as the dominant species in the forest stand,

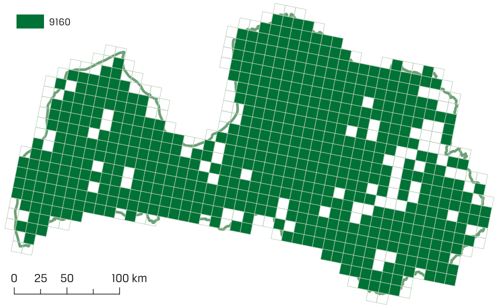

Fig. 14.1. Occurrence of the habitat type 9160 *Sub-Atlantic and medio-European oak or oak-hornbeam forests of the* Carpinion betuli *forests* in Latvia (source: Anon. 2013c).

Fig. 14.2. *Sub-Atlantic and medio-European oak or oak-hornbeam forests of the* Carpinion betuli: Variant 1 (typical variant) with *Carpinus betulus*. Photo: S. Ikauniece.

14.3. *Sub-Atlantic and medio-European oak or oak-hornbeam forests of the* Carpinion betuli: Variant 2 – dominated by *Quercus robur*. Photo: S. Ikauniece.

Picea abies may occur in advance growth and subcanopy, spring-blooming herbaceous species are characteristic in the vegetation, but there is a substantial proportion of boreal forest species (Ikauniece 2013c).

It may be difficult to distinguish Oak forests from the overgrown protected grassland habitat 6530* *Fennoscandian wooded meadows*. The necessary further measures are planned depending on whether the area qualifies as a wooded grassland or a forest habitat. If the habitat 6530* *Fennoscandian wooded meadows* has developed into a biologically valuable forest and its restoration is not possible due to various economic or ecological conditions, the territory is classified as Oak forest and the adequate management method for this habitat is selected.

Variant 3 of the Oak forest can resemble habitat type 9050 *Herb-rich forests with* Picea abies. As a distinguishing feature, in Oak forests the proportion of *Quercus robur* should be at least 50%. During the natural course of succession, as the proportion of *Quercus robur* decreases, it is possible that the forest transforms into a herb-rich forest with *Picea abies*.

14.1.2 Indications of Favourable Conservation Status

In Central Europe, which is the home range of this forest type, habitat in a natural, unchanged form has only remained in small areas due to intensive land exploitation and landscape fragmentation. Usually these are economically exploited forests, where the groundcover species richness with nemoral species characteristic to deciduous forests is much richer than in Latvia. Compared to Central Europe, Oak forests in Latvia are much less affected and less intensively managed.

An important quality indicator of the habitat is the presence of the characteristic species. The Oak forests belong to European deciduous forests *(Querco Fagetae, Querco Tilietum*, or much less frequently – *Tilio Carpinetum)* (Laiviņš 1986). Several canopy layers are typical; usually there is well-developed regeneration and understorey of deciduous trees, however, there may be even-aged stands, where vegetation layers have not yet formed. *Corylus avellana* and *Lonicera xylosteum* are present in the shrub layer. A mosaic vegetation structure is typical (Laiviņš 1986, 2014). Common species are *Anemone nemorosa*, *Stellaria holostea*, *Mercurialis perennis*, *Pulmonaria obscura*, *Lathyrus vernus*, *Galium odoratum*, *Polygonatum multiflorum*, *Galeobdolon luteum,* etc. The moss layer usually contains *Eurhynchium* spp., *Atrichum undulatum*, and *Plagiomnium undulatum*; common epiphytes are *Anomodon* spp. and *Homalia trichomanoides.* Since Latvia is located in the transitional zone of boreal and nemoral forests, boreal species may be present. *Picea abies* may be present in the tree layers, and in groundcover – plant species characteristic to boreal forests, such as *Trientalis europaea* or *Vaccinium myrtillus*.

Of particular importance is the proportion of *Quercus robur*, *Tilia cordata* and *Carpinus betulus* in the forest stand. If there is a large proportion of *Picea abies* and boreal groundfloor species, it is necessary to assess whether the habitat conforms to 9050 *Fennoscandian herb-rich forests with* Picea abies, since the necessary management measures differ for each habitat type.

Not only the composition of typical species, but also the presence of natural forest structures and processes that create such structures are important for a favourable habitat status (Norden et al. 2014).

Biologically old deciduous trees may reach large dimensions in an Oak forest under a favourable conservation status, ensuring diverse microhabitats for various bird and invertebrate species, such as *Dendrocopos medius* and *Dorcus parallelopipedus* (Petriņš 2014; Vilks 2014). The habitat is important for epiphytic lichen and moss species, including indicator species of Woodland Key Habitats and protected species, a large part of which are associated with old deciduous trees, especially *Quercus robur.* For example, rare lichens include *Arthonia vinosa*, *A. bysacea* and *Pertusaria hemisphaerica.* Oak forests are important habitats for rare vascular plant species, such as *Dentaria bulbifera, Poa remota* and *Festuca altissima.* The habitat is also important for rare bryophyte species – *Metzgeria furcata*, *Antitrichia curtipendula* and *Dicranum viride* (Ikauniece 2013c).

Rare invertebrate species, especially beetles, are associated with Oak forests, and the habitats may serve as the dispersal sources for these species. Both light-loving rare beetle species, such as *Lymexylon navale,* and species that prefer shaded areas, such as *Ceruchus chrysomelinus,* are found in Oak forests. Tree cavities are inhabited by various invertebrate species, such as *Liocola marmorata*, *Anthrenochernes stellae* and *Velleius dilatatus.* The latter species is associated with a specific microhabitat – sappy *Quercus robur* wood. Well-lit dead *Quercus robur* trees are a habitat of *Lymexylon navale,* a saproxylophagous beetle species that inhabits hard, dry, standing trees. Oak logs and large dead branches may be inhabited by less demanding (in terms of light conditions) species like *Anoplodera sexguttata, Ampedus erythrogonus* and *Dorcus parallelopipedus* (Vilks 2014). Dead *Quercus robur* wood of large dimension is also an important habitat for rare fungi species, such as *Xylobolus frustulatus*.

14.1.3 Important Processes and Structures

14.1.3.1 Processes

Gap dynamics is a process by which individual trees or small groups of trees die off because of wind-throw, snowbreak, insect infestation or withering when the tree is old (Angelstam, Kuuluvainen 2004). In gaps, pioneer species usually establish and advance growth rapidly establishes or grows. Such small-scale disturbances, if other conditions do not significantly change, encourage the development of an uneven-aged tree structure (Ek et al. 2002; Bottero et al. 2011). The response of the forest to changes of conditions in gaps, especially light, can vary depending on the size of the opening and tree age. The crowns of trees grow into the gaps taking up the unoccupied space. Openings that have formed in older stands can persist for a longer period of time, promoting regeneration. Simultaneously, the height of advance growth trees can increase rapidly. If the opening is large enough and long lasting, new groups of trees form (Johanson et al. 2002). Uneven-aged stand structure and a mosaic of gaps develop, and it is typical that a large amount of standing and fallen trees in various stages of decay is present. *Quercus robur* does not regenerate in small gaps, or it does not survive (Day 2014). It is expected that in the future *Quercus robur* in the canopy will be replaced by other broad-leaved species or *Picea abies*, depending on the species composition of the advance growth (Ikauniece 2008; Day 2014). Regeneration with *Picea abies* is typical in small gaps in Latvia (Kokarēviča et al. 2015).

High-intensity extensive disturbances in forests are fire, wind-throws and large-scale insect outbreaks (Angelstam, Kuuluvainen 2004). Usually such disturbances are characteristic to boreal coniferous forests, and in *Quercus robur* forests in Europe high-intensity extensive disturbances (wind-throws, animal damage) occur rarely. These large-scale disturbances are more common in North America where there are large continuous forest landscapes (Hart, Buchman 2011). Disturbances covering a large area are essential preconditions for the regeneration of *Quercus robur* (Day 2014). In some ways clearcuts emulate such disturbances, after which a rapid development of the formerly slowly growing advance growth of *Quercus robur* can be observed, which increases the proportion of *Quercus robur* in young stands.

According to the hypothesis of Dutch scientist F. Vera (Vera 2000) on the origin of the grasslands in the biome of European forests, the broad-leaved tree landscape was formerly a mosaic of open grazed grassland, wooded park and denser stands, developed by large herbivorous animals (aurochs, horses, European bison). In Latvia, the establishment of grasslands was rather associated with slash and burn agriculture by which shrubland and often secondary *Quercus robur* stands developed.

14.1.3.2 Structures

The presence of structures characteristic to natural, continuous forests and indicator species of Woodland Key habitats or habitat-specific species in the stand are significant quality indicators. The diversity of structural elements indicates natural development of a forest, also in cases when the origin of the stand is artificial or if the habitat has developed by overgrowth of wooded grassland (Peterken 1996). The major criteria of natural structure are coarse woody debris, biologically old or large trees, canopy gaps, and trees of various ages (*see Ch. 1*). The presence of these structural elements indicates the compliance with Woodland Key Habitat criteria and a forest habitat and high ecological value. Natural structures serve as habitats for a large number of species that are not usually found in intensively managed forests (Ek et al. 2002).

14.1.4 Succession

Quercus robur has features of a pioneer species, such as requirements for light, suitability to a large range of soil conditions and nutrient reserves in seed (characteristic of dicotyledonous plants), which allow successful colonisation of open areas (Jones 1959; Hytteborn et al. 2005). Like tree species such as *Pinus sylvestris*, *Quercus robur* can also appear as an early stage pioneer species after disturbances in open territories and various growing conditions (Jones 1959; Brūmelis et al. 2011). *Quercus robur* can establish in forests after natural or artificial large-scale disturbances that create large gaps in the canopy (Nilsson 1997; Day 2014). A study conducted in Moricsala Island indicates that *Quercus robur* stands developed here after *Pinus sylvestris* woodlands burnt down

Fig. 14.4. Floodplain meadow naturally overgrowing with *Quercus robur*. Photo: S. Ikauniece.

(Kokarēviča et al. 2015; Nikodemus et al. 2016). Young *Quercus robur* stands can also form in unmanaged meadows or pastures (Fig. 14.4).

After a wide, continuous disturbance in broad-leaved tree forests, succession usually begins with a deciduous tree stage with the establishment of *Quercus robur* or rapid growth of existing saplings. In the young stands the proportion of *Quercus robur* varies and it may even dominate (Fig. 14.5). Further development of the young stand into a *Quercus robur* forest depends on the survival of the young trees, which can suffer damage of ungulates and rodents. Tending can be used for the conservation of *Quercus robur*.

As a new *Quercus robur* forest develops, self-thinning occurs as in other forest stands,

Fig. 14.5. Establishment of *Quercus robur* in a clearcut. Photo: S. Ikauniece. .

creating small logs and gaps (Johanson et al. 2002). Shade-tolerant broad-leaved tree species appear under the canopy of *Quercus robur,* such as *Tilia cordata,* sometimes *Picea abies*. Later, as the trees grow and mature, self-thinning begins, gap formation starts, and trees that survive competition grow more rapidly, forming a significant proportion in the forest canopy. Although under *Quercus robur* canopies regeneration is possible by seed, seedlings do not usually survive under a closed canopy. Shade-tolerant species like *Picea abies* establish more successfully. Both in Latvia and elsewhere, in the nemoral and boreonemoral area, the succession of Oak forests in the future tend to development of mixed stands (Ikauniece et al. 2012; Day 2014). Therefore, the habitat may develop further in the direction of habitat type 9020* *Fennoscandian hemiboreal natural old broad-leaved deciduous forests* or *9050 Fennoscandian herb-rich forests with* Picea abies. In North America, mixed stands with *Quercus* spp., which probably develop mainly due to the lack of fire, which can create large open areas (Hart, Buchman 2011).

Some Oak forests may have developed from wooded pastures (EU protected habitat type 9070 *Fennoscandian wooded pastures),* included in habitat type 6530* *Fennoscandian wooded meadows* in Latvia, which may have developed earlier from broad-leaved forests. After the abandonment of grazing or hay making, trees and shrubs establish in the territory again, creating a stable forest in a longer period of time.

14.1.5 Pressures and Threats

14.1.5.1 Succession

Latvia is located in the transition zone between the boreal and nemoral forests, near the northern border of the distribution range of habitat type *9160 Sub-Atlantic and medio-European oak or oak-hornbeam forests of the* Carpinion betuli. Mixed *Quercus robur-Picea abies* or mixed broad-leaved forests develop as a result of non-interrupted natural processes. The location on the border of the distribution range of *Quercus robur* and the associated climatic factors are the main reasons why a large part of Oak forests in Latvia change and transform under the influence of natural processes, causing an increase in the proportion of other broad-leaved tree species and *Picea abies*.

A paradox thus occurs – succession is one of the main factors that in the long term can worsen the status of the habitat and affect the characteristic species composition, and reduce the habitat area that conforms to the criteria of protected habitats. However, the Oak forests may transform into other protected habitat types of high ecological value – 9020* *Fennoscandian hemiboreal natural old broad-leaved deciduous forests* or 9050 *Fennoscandian herb-rich forests with* Picea abies.

14.1.5.2 Logging

Quercus robur as a wood resource is not very important in the national economy, as the total area of commercial oak forest is small. Mature *Quercus robur* stands that are not located in protected nature territories or microreserves and are not protected in any other way, are still being cut, which is promoted by the market demand for *Quercus robur* wood. For example, the planned felling volume based on logging confirmations issued between 1 January and 31 October, 2015 included the felling of 185.6 ha of *Quercus robur* stands (Anon. 2015a).

More often the *Quercus robur* stands are felled in forests that do not belong to the state – in private forests or forests belonging to other owners. In 2014, approximately 300 m^3 (or 6% of the annually felled volume of oak) was harvested in state forests, while 4584 m^3 was obtained in the other forests (Anon. 2015a). This extent of logging reduces the area of mature *Quercus robur* (and possibly protected habitats) forests and worsens the general habitat conservation status in the country. From a biodiversity conservation perspective, selective cutting in *Quercus robur* forests is assessed as negative, as the potential future volume of dead wood and the number of biologically old trees declines.

After clearcutting, similarly to after wide continuous disturbances, natural regeneration of *Quercus robur* occurs on suitable soils, forming a substantial proportion in the young stand during the first years. Since various natural factors make *Quercus robur* silviculture difficult in Latvia, they are often felled during thinning, giving preference to more advantageous and rapidly growing tree species, such as *Picea abies* (Fig. 14.6). Although the overall area of *Quercus robur* young stands up to the age of 20 has increased in Latvia over the last decades, there is a deficiency of medium-aged and biologically old (older than 170 years old) *Quercus robur* forests. *Quercus robur* stands up to 20 years of age comprise 7.5% of forests where the dominant tree species is *Quercus robur*. 90-120 year old *Quercus robur* forests are the most common (Anon. 2015a).

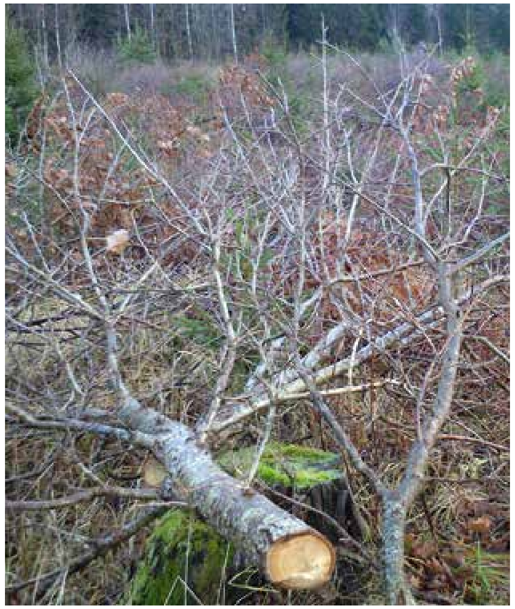

Fig. 14.6. In young stands outside protected nature areas and microreserves, where in the course of natural regeneration after clearcutting stands with a significant proportion of *Quercus robur* can develop, *Quercus robur* trees are not always conserved as the target retained species during tending. Photo: S. Ikauniece..

The lack of young and medium-aged *Quercus robur* stands, especially in protected nature territories, may negatively affect the total habitat area and its availability in the future.

14.1.5.3 Impact of Large Mammals

Animals are not a threat to mature *Quercus robur* trees. Even though *Sus scrofa* forages for acorns near their roots in autumn, it does not have a substantial adverse effect on the growth of mature *Quercus robur*. However, *Sus scrofa* disrupts the ground layers, causes a higher rate of decomposition of organic matter in the soil and humus formation, and increased concentration of available nitrogen. By unearthing soil and mechanically damaging or feeding on plants, *Sus scrofa* causes a decline in the cover of vegetation and number of plant individuals (Wirthner et al. 2012).

A significant threat to *Quercus robur* young saplings is damage by ungulates. The tops and branches are browsed, causing slower growth or mortality. Other tree species start dominating in young stands and a *Quercus robur* forest will not develop. Establishment of feeding areas and stations can increase the population size and density of game animals (Milner et al. 2014).

14.1.5.4 Invasive Plant Species

See Ch. 11.1.5

14.1.5.5 Other Influencing Factors

Oak forests are a common component of a visually highly valued landscape, and they are included in several tourism routes. In these cases, adequate tourism infrastructure must be established that protects the groundfloor from trampling and forest structural elements from damage (such as burning of dead wood in fires). Efforts to make trails as safe as possible for visitors by felling potentially dangerous trees along their sides may have a significantly adverse effect on habitat quality, as the oldest, biologically most valuable trees are usually assessed as dangerous.

Sometimes withering of *Quercus robur* in forest stands on drained soils is observed, which is associated with the changes in the hydrological regime. Most likely *Quercus robur* trees die off as a result of the cumulative influence of various factors, including altered hydrological regime caused by drainage, increased ground water table fluctuations, intensive development of *Picea abies* in advance growth and subcanopy layers and others.

Young *Quercus robur* trees may suffer from late spring frosts and cold winters, when new sprouts, buds or leaves are frozen, which negatively affects the habitat (Liepiņš 2004).

14.2 Restoration and Management Objectives in the Conservation of Oak Forests

Oak forests in Latvia are much more sensitive to environmental changes than habitats, which are located in the central part of their distribution range in Latvia. Dendrological studies of *Quercus robur* trees in Central Europe indicate that in the past there have been individual phases of high abundance and extinction. Reasons for these phases have been changes in hydrological conditions caused by climate changes or anthropogenic influence (Leuschner et al. 2002). Oak forests in Latvia historically, especially during periods of warmer climate were more common than nowadays (Zunde 1999). In regions with fertile soil where *Quercus robur* earlier was more abundant, forests were transformed to agricultural land and Oak forest stands have almost disappeared. The transformation of Oak forests into agricultural lands or planting of *Picea abies* has significantly reduced the earlier habitat area, and not only in Latvia. In recent centuries the distribution of *Quercus robur* stands has rapidly decreased in the entire area of Europe (Lindbladh et al. 2000).

Succession typically leads to the development of mixed stands during the long-term conservation of Oak forests. Nevertheless, national nature conservation objectives include maintaining, development and ensuring the continuity of the Oak forests of high quality. Oak forests should be protected outside the protected nature territories, as this habitat is dynamic and changing, and depends to a great extent on the activities of people, limiting natural processes, promoting of *Quercus robur* regeneration, and or impeding *Picea abies* establishment. Thus there are two possible scenarios for the conservation of Oak forests and the diversity of species associated with them: (1) maintenance of *Quercus robur* stands by limiting natural factors and succession; (2) natural development of *Quercus robur* stands, when old woodlands gradually transform into other protected habitat types while new *Quercus robur* stands develop in other sites.

The main objective of habitat protection is to ensure a favourable conservation status and the necessary area at a national level. It is important to conserve the natural structures to the extent that is sufficient for the long-term and stable existence of the typical and rare species associated with the habitat.

Special attention should be paid to habitat variant 1 (typical), which covers a small area in Latvia. Latvia is located outside the natural distribution ranges of the dominant and characteristic species of broad-leaved forests – *Fagus sylvatica*, *Carpinus betulus* and *Quercus petraea*. Small stands of *Carpinus betulus* are only found in the south-west part of Latvia in the vicinity of Dunika and the River Sventāja valley on the border of the distribution home range of this species. Therefore, this habitat variant in Latvia has very high conservation value.

One of the most important objectives of habitat conservation is the expansion of the continuous habitat area and reduction of fragmentation, as the habitat areas in Latvia are very fragmented. This means that management must focus not only on the territory of the particular habitat, but also on the stands adjacent to Oak forests that are suitable for development of the habitat. It is important to increase the habitat area and to restore habitats by adequate management in young stands.

14.3 Restoration and Management of Oak Forests

14.3.1 Habitat Conservation

Different approaches may be used in the conservation and management of the habitat: (1) non-intervention that provides passive protection; (2) non-traditional forestry methods aimed at the creation and management of forest stands of a certain tree species composition, ensuring the ecological requirements of the target species (including protected species); non-traditional methods include the emulation of natural disturbances.

The methods should be studied further, and they may be combined (Götmark 2013). It is always important to assess the conditions of a specific site and the conservation objectives. It is important to consider the terrain, soil characteristics and the properties of the adjacent stands, species composition of the groundfloor and advance growth, etc.

Non-intervention means no active human work associated with the felling of trees or shrubs or impact on soil; no impact from vehicle transport, no artificial changes in the hydrological regime. Natural processes are not limited or disturbed. At the same time, the habitat can be used for recreation, mushroom picking, and hunting, as long

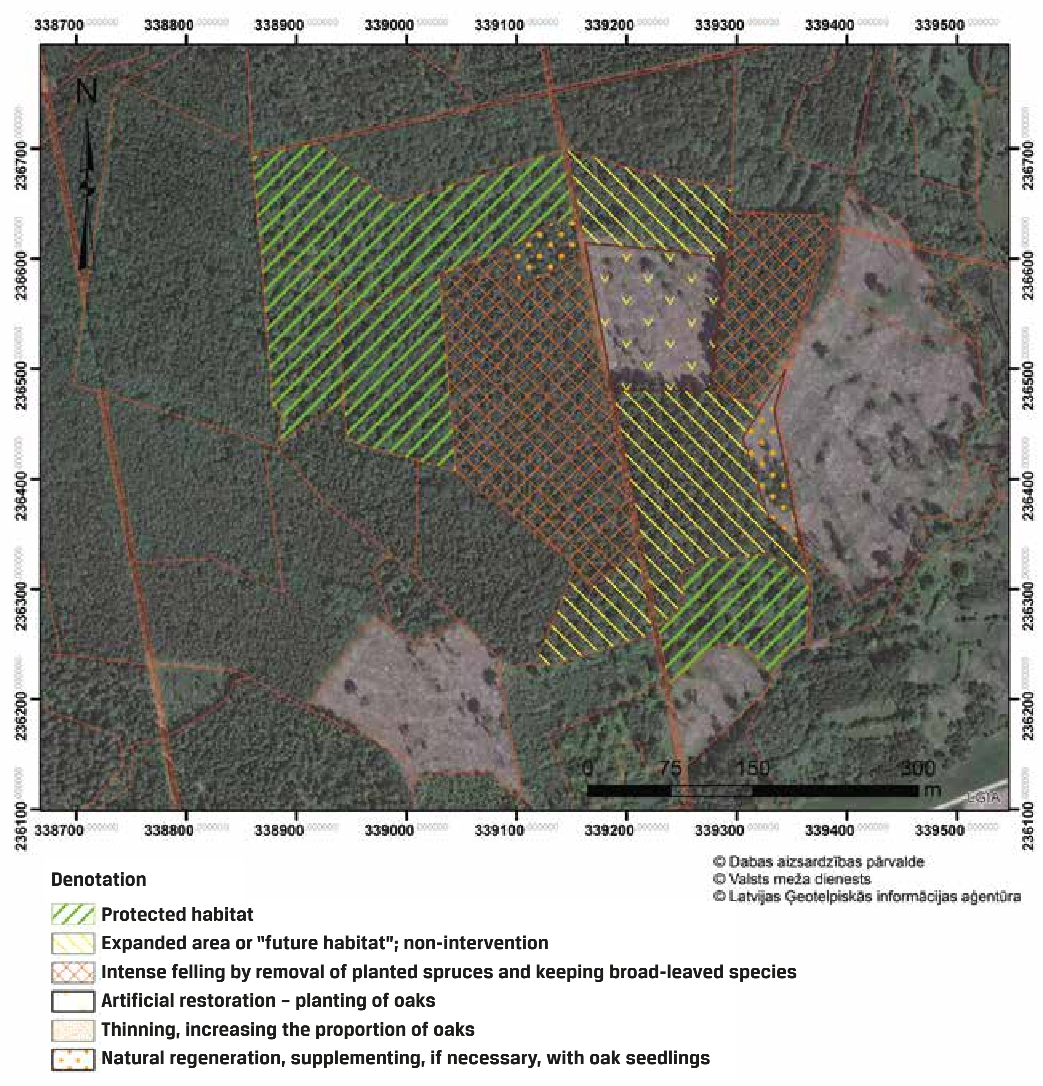

Fig. 14.7 Habitat aggregation scheme (prepared by P. Rozenbaks).

as there is no adverse effect on habitat structures and species. Non-intervention may be the best and most often applied conservation method for Oak forests of high quality. At the same time, it may be necessary to prolong the life of *Quercus robur* trees by appropriate management, as biologically old, large-dimension trees are important habitats for many rare and protected bird, invertebrate, lichen and fungi species (*see Ch. 14.3.9*).

By allowing natural development and as the proportion of *Picea abies* increases, in many areas changes are expected in the forest canopy structure (*see Ch. 14.1.4*). To prolong and maintain the existing successional stage, the proportion of *Picea abies* can be decreased by felling. This measure is described in the chapter on methods of reducing the proportions of other tree species (*see Ch. 14.3.2*). In such cases monitoring should be carried out, assessing the results of management and changes in vegetation composition. There may be a need for repeated felling of *Picea abies* to maintain the adequate species composition in the habitat in the long term.

As one of the most significant processes that adversely affect the favourable conservation status of the habitat is fragmentation, attention should be paid to the increase of the habitat area by aggregation and reduction of fragmentation. Conservation of the habitat requires analysis of habitat fragmentation on a national level, with planning of habitat aggregation in places where there are stands of higher biological quality or in sites where the habitat concentration is higher. The aim of aggregation is to increase the habitat area and create future habitats in regions where habitats of high quality are concentrated (Norden et al. 2014). The creation

Table 14.1 Management methods of habitat type
9160* *Sub-Atlantic and medio-European oak or oak-hornbeam forests of the* Carpinion betuli.

Method	Ecological benefits	Disadvantages
Reducing fragmentation		
Felling for the reduction of the proportions of tree species non-characteristic of the habitat	Increased proportion of broad-leaved trees characteristic for the habitat.	Risk of groundfloor damage due to transportation tracks. Possible introduction of non-characteristic species associated with the felling disturbance.
Tending of young stands	*Quercus robur* forests area increases. Habitat fragmentation decreases.	None.
Picea abies stands are replaced by *Quercus robur*	*Quercus robur* forests area increases. Habitat fragmentation decreases.	Planting material and seedling protection against ungulates are necessary.
Protection of young stands from ungulates,	*Quercus robur* forests area increases. Habitat fragmentation decreases.	Relatively high costs of planting material and labour.
using protective tubes and spirals	The tree stem is fully protected against damage. Movement of animals is not disturbed.	Tubes must be removed in time, as they can grow into the bark. Tree apices are not protected when growing rapidly.
with repellents	The top apices are protected and movement of animals is not disturbed.	The stem and all side branches cannot be protected, the repellents usually only protect the top.
with fences	Efficient – every individual tree does not need to be treated.	Restricted movement of wild animals. Regular maintenance and repair is needed. If an animal enters the fenced area and remains there for a longer period of time, it may damage many young trees.
Improvement of Structures		
Increase of dead wood volume	Increase in the amount of suitable habitats for species dependent on dead wood.	The number of potential biologically old trees is decreased in the future.
Creation of gaps	The formation of multi-aged natural stand structure.	The number of potential biologically old growing trees is decreased in the future.

of such concentration sites or aggregations may be implemented in the forests near Oak forests, where there are suitable environmental conditions for the development of this habitat. In areas of suitable soil and moisture conditions, the development of groundcover vegetation and tree layers characteristic to the habitat might be expected (Ek, Bērmanis 2004). Larger continuous areas covered by the Oak forest may be created from forest stands of various quality, including future (potential) habitat areas. Habitat aggregation example – in Fig. 14.7.

Habitat aggregation can include multiple activities. At first, reconstructive felling can be used in low quality habitats to create a desired tree species composition (*see Ch. 14.3.2*) Habitat structure can also improve itself in the course of natural thinning without special intervention over a longer period of time, so felling must be carried out very carefully, and is recommended in cases when it is necessary to improve the living conditions of a very rare or threatened species. In low quality or potential future habitats it is possible to create a mosaic forest canopy structure with gaps, in combination with the creation of dead wood of various types, if it is necessary to improve the habitat conditions of a particular protected species dependent on dead wood or good light conditions (*see Ch. 14.3.7*). In *Quercus robur* forest stands which have developed by overgrowing of wooded grasslands, the development of broad-leaved trees in openings can be promoted by tending (Ek, Johannesson 2005). The effect of shrub cutting is temporary and must be repeated after a few years to maintain light conditions necessary for the development of broad-leaved advance growth.

In other cases, reconstruction of tree species composition may be implemented in forest stands of various ages near existing habitats in stands suitable for the development of the habitat, including naturally regenerated and artificially planted *Quercus robur* stands (*see Ch. 14.3.3*). Complete transformation of stand composition is also possible (*see Ch. 14.3.4*). Protection of the trees against damage from ungulates is needed in young stands (*see Ch. 14.3.6*).

14.3.2 Felling types for Increasing the Proportion of Habitat Characteristic Tree Species

To maintain or create the adequate *Quercus robur*, *Tilia cordata* or *Carpinus betulus* proportion in a stand, felling can be applied to decrease the proportions of other tree species. Firstly, this method can be used to construct species composition and future habitats of the very rare *Carpinus betulus* stands by increasing the total habitat area. Stands with *Carpinus betulus* in Latvia have developed naturally in clearcuts, or *Carpinus betulus* regenerated as admixture species in planted *Picea abies* stands. In the first case, the tree species composition likely contains *Betula spp*. and *Picea abies*, as well as other tree species; *Picea abies* dominates in the second case. *Carpinus betulus* is usually found in the subcanopy layer and advance growth. By the felling of other species, light and growing conditions improve for *Carpinus betulus* and herbaceous plants, and a species composition characteristic to the habitat develops. In "Dunika" Nature Reserve there are outstanding, old *Carpinus betulus* stands in which other tree species has been cut a long time ago, perhaps even several times (Zariņa, Krauklis 2002). Also in Lithuania, where the *Carpinus betulus* forests are more common, other tree species are felled in *Carpinus betulus* stands, contributing to the increase in the proportion of *Carpinus betulus*.

In other habitat variants the natural development in the future will lead to mixed stands. Later the habitat may conform to the habitat types 9020* *Fennoscandian hemiboreal natural old broad-leaved deciduous forests* or *9050 Fennoscandian herb-rich forests with* Picea abies of high quality. In these cases it is very important to evaluate the conditions of the particular site and the priorities of conservation of habitats and species, taking into account the soil conditions, habitat location, characteristics of neighbouring stands, growing conditions, and species composition of the herbaceous and woody species (Fig. 14.8).

Fig. 14.8. A *Quercus robur* stand in the vicinity of Apriķi. Photo: S. Ikauniece.

Examples of *Quercus robur* Forest Management

So far the cutting of *Picea abies* advance growth and subcanopy to promote the development of characteristic broad-leaved tree composition and nemoral vegetation has rarely been used in Latvia.

Cutting of the *Picea abies* subcanopy and advance growth was carried out in several forest stands in the years 2007, 2009, 2012 and 2013 in the Nature Reserve "Tebras ozolu meži". In a stand where very high intensity felling removed all *Picea abies* in 2007, wide gaps formed, which promoted both the growth of shrubs and *Quercus robur* establishment. In other plots where cutting of the subcanopy of *Picea abies* around *Quercus robur* was carried out, the light conditions improved.

Fig. 14.9. *Picea abies* in the shrub and subcanopy layers were cut in areas around *Quercus robur* in "Tebras Ozolu Meži" Nature Reserve. Photo: S. Ikauniece.

In "Paņemūnes meži" Nature Reserve experimental management in an area of 2 ha was carried out at the beginning of 2014, cutting *Picea abies* in the subcanopy and advance growth in circular plots. *Quercus robur* and other deciduous trees were retained (*Populus tremula*, *Betula pendula*) (Fig. 14.9, 14.10). Rapid changes in the groundfloor and establishment of ruderal species were observed during the first two years, which was also expected. It will be possible to assess the long-term impact on *Quercus robur* survival and growth, as well as on the groundcover vegetation after approximately ten years.

Fig. 14.10. A *Quercus robur* stand with a large number of *Picea abies* in the subcanopy in "Paņemūnes Meži" Nature Reserve. Photo: S. Ikauniece.

Fig. 14.11. Experimental management in "Paņemūnes Meži" Nature Reserve in 2014. Felled *Picea abies* and their branches were removed from the stand. Photo: S. Ikauniece.

If the dispersal of species characteristic to broad-leaved forests is typical in a particular region, then broad-leaved trees will probably dominate in the future. Then a priority should be the conservation of species and natural values that are characteristic to broad-leaved forests, not boreal forests, i.e. the future priority in such territories will be broad-leaved forests (9020* *Fennoscandian hemiboreal natural old broad-leaved deciduous forests* or 9160 *Sub-Atlantic and medio-European oak* or *oak-hornbeam forests of the* Carpinion betuli*),* and not coniferous forests (9050 *Fennoscandian herb-rich forests with* Picea abies).

If there are changes in the direction of habitat type 9050 *Herb-rich forests with* Picea abies with *Picea abies* establishment on broad-leaved forest, and if there are suitable environmental conditions for *Picea abies* stands, the best solution is most probably the undisturbed course of natural processes.

Felling to reduce the proportion of non-characteristic tree species may be used in medium-aged and younger stands, as well as in pre-mature and mature stands, under certain conditions. If *Quercus robur, Tilia cordata* and *Carpinus betulus* trees in admixture with medium age *Picea abies* or *Betula spp*. (other species may be of much rarer occurrence, *Alnus glutinosa* may also occur in drained forests), the proportion of broad-leaved trees can be increased by selectively felling 20-40% of the trees, conserving all broad-leaved trees.

In mature stands the reduction of proportion of other species must be carried out very wisely. Firstly, trees, especially *Picea abies* that are in the direct vicinity of broad-leaved trees and are growing in their crown should be felled. This is especially important for the survival of *Quercus robur*. Gaps can be created in places where *Picea abies* occurs in groups, creating a heterogeneous structure. All subcanopy *Picea abies* trees can be felled throughout the habitat. The felled *Picea abies* trees, especially saplings and branches of larger trees, must be removed from the stand, as *Picea abies* litter promotes soil acidification, which may have an adverse effect on the development of the vegetation characteristic to the habitat. If large stems of felled *Picea abies* are left in the habitat to increase the volume of dead wood, their branches must be cut and removed from the stand.

All dead wood must be retained in the felled forest. If there is a low amount of dead wood in the stand, part of the felled trees of the canopy layer with a diameter > 25 cm must be left (at least five trees per 1 ha). Cutting should be carried out in winter when the soil is frozen, to leave the least possible impact on the soil and roots of trees. It is recommended to use low-power tractors, small agricultural tractors adapted for forestry, or forwarders equipped with caterpillars, or other equipment that has minimal impact on the soil and do not create deep tracks. Felling is to be carried out once.

Selective felling will improve light conditions and provide a wider space for the remaining *Quercus robur* trees, likely prolonging survival and providing ability of reaching larger dimensions. This is particularly important for the conservation of *Quercus robur* as habitats for invertebrates. A dense deciduous advance growth may develop in gaps after felling *Picea abies*, and therefore felling will have to be repeated to improve light conditions. This method is not very efficient in the long term, as it need to be constantly repeated.

14.3.3 Creation of the Characteristic Species Composition of Habitat in Young Stands

A mixed composition of tree species usually naturally regenerates in clearcuts. Tending can be conducted in the first years to obtain the target species composition that is characteristic to the habitat, by increasing the proportion of *Quercus robur* or *Carpinus betulus* in the young stands. Tending and thinning should be carried out in mixed stands up to 20 years of age, if there are environmental conditions suitable for the habitat, and if *Quercus robur* or *Carpinus betulus* trees are present among other species (most often *Picea abies* or *Betula spp*.). More successful results may occur in naturally regenerating stands on clearcuts where large numbers of broad-leaved trees have been retained as retention trees. During tending, the largest possible proportion of broad-leaved trees should be conserved, while cutting other species. Cut *Picea abies* trees must be removed from the stand. Tending is not necessary in young *Quercus robur* and *Pinus sylvestris* forests on poor mineral soils (forest types *Myrtillosa* and *Vacciniosa*).

Since *Quercus robur* is a pioneer species according to its ecology, it can also be found on naturally overgrowing agricultural land. In areas of habitat aggregations it is recommended to apply young stand management aimed at the development of future *Quercus robur* forests – thinning, conserving the maximum possible *Quercus robur* proportion, and artificial planting of *Quercus robur* in areas of poor regeneration, as well as protection against ungulates (*see Ch. 14.3.6*).

A certificate stating origin should be given with planting material purchased in a tree nursery. Since the number of *Quercus robur* seedlings available in nurseries is very low, nurseries in Latvia are not classified by regions from which seedlings must (according to legislation) be purchased for planting in the respective regions. However, it must be remembered, that the planting material from an area with harsh climatic conditions may be successfully planted in locations with a milder climate, but not vice versa. This means that *Quercus robur* seedlings should not be transported from a nursery in western Latvia to eastern Latvia, as there is a large possibility of poor establishment. Regenerating is also possible with locally obtained *Quercus robur* seedlings.

14.3.4 Replacement of Stands

For economic reasons, forestry in the 20th century became focused on *Picea abies* as the target planted species, and was often planted after clearcutting on soils suitable for *Quercus robur*. In stands where *Picea abies* was planted in site suitable for Oak forests*,* their replacement with young stands of *Quercus robur* may be carried out if the soil characteristics have not yet substantially changed as a result of podsolisation due to accumulated needle litter and if species characteristic of broad-leaved forests are present in the understorey. In order to create or restore *Quercus robur* forests in such stands, the *Picea abies* could be felled in reconstructive felling, which should be done only up to age 50-60 years. Also, *Quercus robur* can be planted after clearcut of mature *Picea abies* stands, if there are conditions suitable for the development of *Quercus robur* forests and if habitat aggregations are planned (*see more in Ch. 3.1*).

14.3.5 Protection of Young Trees from Damage due to Ungulates

Protection from damage due to browsing by ungulates is needed in young *Quercus robur* stands. Mechanical protection may be used for very young trees (tubes or spirals). Repellents can be applied to tree tops and the ends of the upper branches. It is also possible to fence entire stands, but this is costly, fencing might require repair, and an animal that has entered the fenced area by chance may remain in the enclosure for a long period of time, damaging a great number of trees.

Fig. 14.12. Proportion of *Populus tremula* in the subcanopy was reduced by bark-ringing in a *Quercus robur* microreserve located in Bulāni Village of Čornaja rural area of Rēzekne municipality at the end of 2013. Increase in the volume of dead wood and naturalisation of the stand structure is expected. It will be possible to assess the results after a longer period of time. Photo: S. Ikauniece.

14.3.6 Improvement of Habitat Structures

In natural broad-leaved forests the volume of dead wood is high, even exceeding 100 m^3/ha (Bobiec 2002). In Latvia the average volume of dead wood with a diameter larger than 20 cm is 24.3 m^3/ha (Anon. 2015b). Dead wood is an important structural element for many species. The aim of management in such forests can be to increase dead wood amounts with a diameter greater than 25 cm to at least 20 m^3/ha. The volume of both lying and standing dead wood can be increased by emulating natural disturbances. The applicable method depends on conditions of the site and the objective.

Measures to improve structure are not needed in habitats with good and medium quality. In low quality habitats it is possible to improve natural structure and habitats of protected species. Non-intervention by leaving the territory to natural processes will lead to structural diversification in the long term. Such measures are recommended in forest stands situated adjacent Oak forests, as this will increase the continuous area of biologically valuable *Quercus robur* stands in the future.

If the purpose is to increase the availability of habitat and substrate for fungi, bryophytes, and saproxylophagous (organisms that inhabit dead wood) invertebrates, then selected trees can be felled and left lying on the ground. Trees with a diameter of 20-30 cm at a height of 1.3 m from the root collar should be chosen for felling, with preference given to *Populus tremula* and *Picea abies,* particularly targeting trees situated in the direct vicinity of *Quercus robur* trees and growing inside their crowns. If the felled trees are *Picea abies*, the branches should be removed from the stand, so that the needle litter does not additionally acidify the soil, which is not desirable for this habitat. Depending on the technical possibilities, the height of the stump that is left can be 1.3 m to even 3 m height.

To increase the volume of standing dead wood, which is essential for many bird species (such as *Dendrocopos leucotos*), slow death of individual trees can be initiated. Tree ring-barking is the most common method (Fig. 14.12), which involves removing bark and the layer of cambium around the stem in the form of a ring with 15 cm width. As a result the tree will gradually die, and then stand as a snag for a short to long time. Later, after falling to the ground, it contributes to the volume of logs.

14.3.7 Control of Invasive Plant Species

See Ch. 11.3.6

14.3.8 Providing Favourable Conditions for Rare Species

In specific cases, management can be conducted to protect or create habitats of rare invertebrate species. Young trees, especially *Picea abies*, can grow into the canopies of biologically old large-dimension deciduous trees, affecting their survival. In these cases it is recommended to remove them, at least in the crown projection area, even if it has generally been decided not to influence the forest stand. Cutting of trees and shrubs in the crown area of *Quercus robur* trees (Fig. 14.13) improves light conditions and air circulation, decreases humidity and shade, and it can increase tree life span, also as a habitat for rare and endangered insects, such as *Osmoderma barnabita* and *Liocola marmorata*.

Cutting trees and shrubs in the crown projection area improves light conditions and air circulation, decreasing humidity and shade. It can increase the overall tree life, and thus the trees can serve for a longer time as habitat for rare, endangered insects, such as *Osmoderma barnabita* or *Liocola marmorata*.

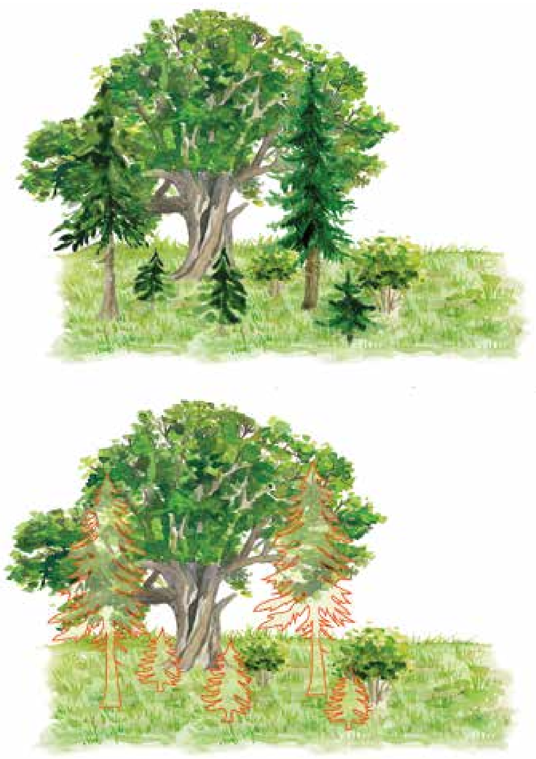

Fig. 14.13. Choosing the trees to be felled for the increase of insolation of old broad-leaved trees (the trees to be felled are marked with an orange outline). Drawing by D. Segliņa.

Fig. 14.14. A *Quercus robur* around which first thinning was carried out by felling *Picea abies* trees of the subcanopy in "Ukru gārša" Nature Reserve. Photo: S. Ikauniece.

In "Ukru gārša" Nature Reserve trees and shrubs under crowns of large *Quercus robur* were felled in various places in 2013, in accordance with the management guidelines for Woodland Key Habitats (Ek, Johanneson 2005). This type of thinning for *Quercus robur* cannot be directly attributed to specific management of Oak forests. Rather, it represents overall improvement of light conditions for *Quercus robur* trees, which is favourable for the associated species. If the *Quercus robur* trees have been very shaded, felling should be carried out gradually, at least two times, by first of all felling the trees closest to the stem in the projection zone of the crown.

Studies in Sweden indicated that cutting of trees and shrubs in a 5-8 m radius around large *Quercus robur* trees promoted *Quercus robur* regeneration in the first 2-3 years after management, depending on light conditions.

Fig. 14.15. A management example of a sparse *Quercus robur* stand that was managed by shrub cutting in the valley of Abava. Shrubs are now densely resprouting. Photo: A. Priede.

However, after 8 to 10 years, monitoring indicated that cutting of the understorey had promoted the development of dense *Corylus avellana* and other shrubs, which hindered further development of *Quercus robur* regeneration (Götmark 2013). This indicates that one-time management may create an unfavourable long-term effect on the habitat and the large-dimension trees, and that cutting of shrubs needs to conducted repeatedly (Fig. 14.15).

Tree hollows are important for some beetle species, but many stands lack sufficient number to sustain beetle populations. If there is a low amount of hollow trees, their formation can be promoted by cutting several thick branches at a 10-20 cm distance from the stem on medium-aged trees; tree cavities will begin to form as a result of fungi activities (Vilks 2014). Such trees will be present more often at forest edges or in forests developed on former wooded meadows.

Some protected invertebrate species found in broad-leaved forests also utilise other habitats. For example, butterflies and other pollinating insects, as well as some saproxylophagous beetle species, visit adjacent grasslands in order to additionally feed on flowering plants. Therefore, it is necessary to maintain an open, well-illuminated forest edge with flowering plants, as well as to regularly manage and maintain the diversity of adjacent grassland habitats when present (Bāra 2014; Vilks 2014).

14.3.9 Management Unfavourable to Oak Forests

Selective felling of mature trees for timber harvest will potentially cause a reduction in amounts of dead wood in the future, and reduce the number of trees that might become biologically old trees and form natural structures that are important for biodiversity in the future, including habitats for the protected species. Thus, the volume of available ecological niches and various substrates for species in the habitat will decrease due to this type of management. Even though such felling may cause openings in the canopy, thus diversifying the stand structure, the adverse effects of removing the felled trees are more significant.

The felling and removal of dead and dying trees is in sharp conflict with the habitat requirements of *Dendrocopos leucotos* and other bird species, because it reduces the amount of the dead wood in the stand. Similarly, it adversely affects the amount of available habitat for other species like invertebrates, fungi, moss.

Artificial forest regeneration or afforestation by using *Picea abies* and *Betula spp.* plants in places where broad-leaved stands have existed, which are directly adjacent to the territories of the habitat type 9020* *Fennoscandian hemiboreal natural old broad-leaved deciduous forests* will increase or at least maintain fragmentation. For a long period this type of management will arrest natural regeneration of broad-leaved tree forest and the characteristic structures and composition of species, which might be possible in a long period of time by leaving the forest stand to develop naturally after felling.

14.4 Conflicts of Conservation and Management

The management and conservation of *Quercus robur* forests may be inconsistent with the requirements of rare and protected species, which are dependent on the presence of structures and non-intervention regime for natural mature broad-leaved tree forests. In some cases, non-observance of the non-intervention regime may cause substantial changes in the habitat and result in its transformation, along with the extinction of its characteristic, including rare and specialist, species.

Restoration of the habitat type 6530* *Fennoscandian wooded meadows*. If a *Quercus robur* forest habitat formed as a sparse wooded forest stand or wooded meadow, or grassland overgrew, the possibility and necessity to restore the EU habitat 6530* *Fennoscandian wooded meadows* should be considered in some cases. This may be important in the conservation of populations of rare, protected species and if the species depends directly on the condition of the woods, such as *Osmoderma barnabita*. Restoration of wooded meadows and pastures should only be carried out after landscape ecological planning, survey of all protected species in the habitat, and consideration of species conservation plans (Bāra 2014, Lārmanis 2015), as the management will transform the Oak forests and potentially negatively affect protected species associated with this habitat. It is also important to consider the options for carrying out further traditional means of management of the restored habitat. Habitat restoration may also be important in places where it has a significant tourism value.

Undisturbed Natural Succession. As a result of natural succession, *Quercus robur* as a dominant species will be replaced by other broad-leaved species (Ikauniece 2008) or *Picea abies*. Over time, the canopy of these stands will potentially be dominated by other broad-leaved trees (*Tilia cordata*, *Fraxinus excelsior*, *Ulmus spp.*), and it is possible that *Quercus robur* forests turn into the habitat type 9020* *Fennoscandian hemiboreal natural old broad-leaved deciduous forests*. As the proportion of *Picea abies* increases, a fertile boreal mixed *Picea abies* stand may form with *Quercus robur* and other broad-leaved species, as the *Quercus robur* forest becomes habitat type 9050 *Fennoscandian herb-rich forests with* Picea abies. *Picea abies* regeneration develops in *Quercus robur* stands, and accumulated needle litter changes soil conditions, causing changes in vegetation composition.

Management by reducing the proportion of a tree species in a stand can redirect or stop the course of succession. In each case the priorities must be assessed – whether the objectives of the management and maintenance are to conserve the habitat or maintain natural development processes. It is also necessary to take into account the particular conditions of the site, the species composition, the degree of existing changes, the continuous area occupied by the habitat and the nature of the adjacent stands. In order to make grounded decisions, information on habitat distribution and quality in the country in general is also required.

Chapter. 15. 9180* *Tilio-acerion Forests of Slopes, Screes and Ravines*

15.1. Characteristics of *Tilio-Acerion* Forests of Slopes, Screes and Ravines

15.1.1. Brief Description

The habitat 9180* Tilio-Acerion *forests of slopes, screes and ravines* further below referred to as Slope and ravine forests, is found on slopes of river valleys and on side ravines, as well as on hill slopes of uplands. Forest stands of *Tilio-Acerion* forests of slopes, screes and ravines have mixed species composition with *Tilia cordata*, *Acer platanoides*, *Quercus robur*, *Ulmus glabra*, *Ulmus laevis* and *Fraxinus excelsior*. There may be a relatively large proportion of *Alnus incana* or *Populus tremula*. Herb species that flower in spring in broad-leaved forests dominate in the groundcover. There are sometimes plant species characteristic to boreal coniferous forests in the groundcover, especially on slopes that face to the north. Varying amounts of *Picea abies* are also common.

The essential habitat characteristic is its location on a slope or ravine. The EU protected habitats 9010* *Old or natural boreal forests* and also 9050 *Fennoscandian herb-rich forests with* Picea abies can also occur on this terrain type. When distinguishing this habitat, one must assess the proportion of *Picea abies* in the habitat and the vegetation of the groundcover. Spring outflows or seepages that correspond to the EU protected habitats 7160 *Fennoscandian mineral-rich springs and springfens* and 7220* *Petrifying springs with tufa formation (*Cratoneuron*)* also occur in small areas on slopes or ravines, and in large areas there may be bedrock exposures corresponding to habitat types 8220 *Siliceous rocky slopes with chasmophytic vegetation*, 8210 *Calcareous rocky slopes with chasmophytic vegetation* and 8310 *Caves not open to the public*. The diversity of the habitat is enriched by rocks and rock groups, and small streams that may periodically be dry. Variants are not distinguished for the habitat (Bambe 2013b).

15.1.2 Indications of Favourable Conservation Status

The favourable conservation of the habitat is characterised by a natural and artificially unchanged terrain – hill or river valley slopes and side ravines. The ground vegetation is not dense, and low cover of moss is characteristic. The terrain can be transformed due to the impact of natural processes – soil erosion and river bank erosion, but generally a groundcover with species that typically flower in spring and a canopy with broad-leaved tree species is found in the entire area of the habitat.

Not only the characteristic groundcover, but also the presence of Woodland Key Habitat structures indicate a favourable conservation status of the habitat. Large-scale erosion that destroys forest trees and vegetation is assessed as negative. In such cases the slope most probably no longer conforms to the criteria of a protected habitat.

Mesotrophic or eutrophic communities of these mixed stands, most often broad-leaved stands, correspond to the *Querco-Fagetea* European vegetation class, and communities *Alno-Ulmion* and *Tilio-Acerion* (Laiviņš 2000; Bambe 2013b) (Fig. 15.1, 15.2). The composition of herbs and mosses is very sparse, and a mosaic vegetation structure is characteristic due to erosion or shade. A larger plant cover may be found on slope terraces and the lower part. Groundcover species include *Anemone nemorosa*, *Actaea spicata*, *Carex sylvatica*, *Aegopodium podagraria*, *Dryopteris filix-mas*, *Mercurialis perennis*, *Asarum europaeum*, *Hepatica nobilis*, *Pulmonaria obscura*, *Galeobdolon luteum*, *Melica nutans*, *Poa nemoralis*, *Carex digitata*, *Phyteuma spicatum*, *Campanula* spp. etc. The moss layer includes *Eurhynchium* spp., *Brachythecium rutabulum*, *Plagiomnium affine* etc.

A number of canopy layers in the stand is characteristic, with a sparse shrub

Fig. 15.1. *Tilio-Acerion* forests of slopes, screes and ravines. Photo: S. Ikauniece.

Fig. 15.2. *Tilio-Acerion* forests of slopes, screes and ravines – a small ravine. Photo: S. Ikauniece.

Fig. 15.3. Habitat type 9180* Tilio-Acerion *forests of slopes, screes and ravines*. Photo: S. Ikauniece.

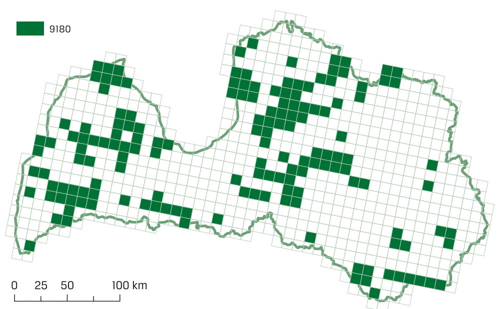

Fig. 15.4. Distribution of the habitat type 9180* *Tilio-Acerion forests of slopes, screes and ravines* in Latvia (Anon. 2013c).

layer and broad-leaved tree regeneration. Specific vegetation communities form near springs or streams. The presence of rare and protected species in forests of slopes and ravines is an essential indicator of the habitat quality. Rare species of vascular plants found in the habitat include: *Dentaria bulbifera*, *Lunaria rediviva*, *Bromopsis benekenii*, *Carex pilosa*, *C. brizoides* etc.

The habitat is an important living habitat for rare species, particularly snails, such as *Clausilia dubia*, *Ena montana*, and *E. obscura*, fungi, epiphytic bryophytes (*Lejeunea cavifolia*, *Metzgeria furcata*, *Dicranum viride*) and lichens (*Pertusaria pertusa*) requiring forest on soil with high moisture and fertility.

Slope and ravine forests (Fig. 15.3) is one of the rarest natural forest habitat types in Latvia, and occupies approximately 0.1% (65 km^2) of the country's territory (Bambe 2013b). The habitat is most common on valley slopes of the Gauja, Daugava, Ogre, and Venta rivers and their tributaries, and in small areas in valleys of small rivers and on hill slopes (Fig. 15.4). There is little information on their occurrence outside protected nature territories (on uplands, ravines, and valleys of small rivers).

15.1.3 Important Processes and Structures

15.1.3.1 Processes

Gap dynamics is a process whereby individual trees or small groups of trees die off because of windthrow, snowbreak, insect activity or as the trees become biologically old (Angelstam, Kuuluvainen 2004). Gaps form in the tree canopy, which gradually overgrow with new trees and shrubs, while new openings form in other places (Ek et al. 2002; Bottero et al. 2011). The response of a forest stand to changes of conditions in gaps, particularly regarding light conditions, can vary depending on the size of the opening and forest age. After gap formation, the trees at the edge enlarge their canopies into the gap, taking up the unoccupied space. Openings that have formed in an older stand can persist for a longer period of time, promoting regeneration. The increase in height of existing advance growth can increase rapidly. If the opening is large and persists for a sufficiently long time, a new group of trees can develop (Bottero et al. 2011).

Uneven tree age and a gap mosaic are characteristic to such woods, with many standing and fallen dead trees in various stages of decay. The forest stand structure and structure

elements develop and change very slowly, and the replacement of tree species occurs very slowly over a long period of time.

A natural process is **water erosion and landslides**. Soil particles are rinsed down the slope with water runoff as a result of water erosion, which can occur particularly intensively after the destruction of the forest canopy and groundcover vegetation. Also the spatial distribution of soil nutrients along the slope changes due to soil erosion, which in turn promotes changes in the vegetation. Ravines may form over a longer period during the soil erosion process.

Landslides may form on river valley slopes where as a result of water runoff or as the soil saturates with water, soil surface layers slide down the slope due to gravity, the topsoil and the vegetation get torn off exposing soil or bedrock, and the soil together with herbaceous plants, shrubs and trees slides down the slope (Fig. 15.5). Gap formation may also contribute to the formation of landslides. The formation of landslides depends on the steepness of the slope, parent soil material, and precipitation. Landslides may cover bedrock exposures, destroying valuable habitats.

Also human activity (such as felling of trees, trampling, establishment of trails) may cause erosion and the formation of landslides (Fig. 15.6). New ecological niches form, and the soil cover structure and species composition diversifies. Restoration of the soil cover on the eroded sites takes a long time.

Succession processes in river valleys, especially after landsliding, have little been studied so far. In recent decades the largest landslide in Latvia formed in Gauja National Park in Turaida in the year 2002. The earth became saturated with water near the castle tower slope, and substantially increased the weight of the soil. Two slides in a relatively wide and long strip were observed – the length of the first slide was about 95 m and the width was about 38 m, the second strip was about 110 m long and 25 m wide (Anon. 2011a). Today a dense, stable shrub storey has formed in this area.

15.1.3.2 Structures

The development of Slope and ravine forests are determined by the specific microclimate, which to a great extent is affected by the terrain – direction of slope exposure and the proximity of watercourses or springs, as well as the inflow of nutrients from a larger area of the valley. The shade and air humidity in a wooded ravine create different conditions to in a lowland. At the same time drastic differences in temperature are characteristic in sunny south-facing slopes.

The most significant structure elements are dead wood of large dimension, biologically old trees, canopy gaps, stand structure of various ages etc. (*see Ch. 1*). High diversity of structural elements indicates potential compliance with Woodland Key Habitat criteria and high ecological value (Ek et al. 2002). Dead wood, biologically old trees and other structure elements serve as habitats for many rare and protected (specialist) species, which are usually not found in intensively managed forests, where there is a small amount of natural structures.

Fig. 15.5. A soil landslide in a slope of a brook valley. Photo: S. Ikauniece.

Fig. 15.6. Landslide in Imula valley. Photo: A. Priede.

Since the majority of Slope and ravine forests are not intensively managed, they often conform with the quality criteria of Woodland Key Habitat.

15.1.4 Succession

In many parts of Latvia river valleys were formerly used for agriculture and wood production. As cities formed and timber trade developed, intensive deforestation began firstly along the greater rivers and then along smaller rivers, using them for log driving (Zunde 1999). The small rivers and ravines were better protected from deforestation and, taking into consideration the specific conditions of the terrain, the forest may have been growing in these locations for a long period of time. If the slopes were used in agriculture in some period, the habitat developed after afforestation.

In initial stages of afforestation, the tree storey can be formed by pioneer species like *Alnus incana, Betula pendula* and in some places *Pinus sylvestris*. Gradually broad-leaved trees (*Tilia cordata*, *Fraxinus excelsior*, *Acer platanoides*, *Ulmus glabra* and *Ulmus laevis*) establish in the understorey, and form a stable stand over a longer period of time. For example, forests of old *Pinus sylvestris* trees with broad-leaved trees in the advance growth and subcanopy are characteristic to some locations in the Gauja Valley (Anon. 2004). A small volume of dead wood is characteristic to the pioneer phase of the habitat.

Slope and ravine forests may also form as a wooded landscape overgrows on the slopes of river valleys that have been used for hay making or pasture in the past. This is more characteristic to the valleys of the greater rivers. In such cases biologically old, wide-crowned *Quercus robur* or other old broad-leaved trees of large-dimensions are found in the forest (Lārmanis et al. 2014a). Natural processes create structures of a natural forest and the biodiversity associated with them increases.

On north-facing slopes where there is greater shade and moisture, gradual establishment of *Picea abies* in forest layers may occur.

15.1.5 Pressures and Threats

15.1.5.1 Logging

Slopes and ravines were usually less available for economic activity, especially for logging, due to the steepness of slopes and lack of roads. Slopes were inconvenient for the removal of felled trees, so already in the past intensive use of Slope and ravine forests did not occur in many places. This does not apply to slopes along the great rivers where the stream of the river was used for log driving. In the 17th and 18th century, as cities and trade with timber developed, afforestation intensified in Latvia, firstly along the greater and then along the small rivers. Many rivers, even relatively small ones, were used for log driving, such as the rivers Padedze, Veseta, Susēja, Roja, Irbe, Saka, Viesīte etc. (Zunde 1999). Wood was still floated along the Daugava, Gauja and other greater rivers even in the first part of the 20th century; therefore many of the forests growing on slopes in river valleys are not old.

Tree felling, especially clearcutting, and the impacts associated with it on the groundcover have adverse effects on the habitat. Tree felling on slopes and ravines nowadays is not widely common due to the complex terrain conditions, and clearcutting is carried out very rarely. Clearcutting destroys the habitat, as the characterising element (forest canopy) is no longer present. It also promotes soil erosion. Any other type of logging when the oldest and largest-dimension trees of the stand are removed from the habitat also has adverse effects.

Forest management in the adjacent territory that is located above the slope can have an adverse effect on the habitat structure if the forest is felled up to the edge of the slope. This exposes the upper trees of the slope to increased impact from the wind, and sometimes large harvesting equipment tracks near the edge of the slope may cause and promote soil leaching and erosion of the slope, causing the formation of new ravines. There is also an increased risk of tree uprooting or breakage in the upper part of the slope. The volume of dead wood increases in the territory, but the number of biologically old trees, which are important habitats for epiphytic moss and lichen species, may decrease. Tree uprooting or breakage cannot only be assessed as negative, as the increase in the volume of dead wood has a positive effect on species of fungi and invertebrates. Ploughing of fields up to the edges of slopes may also promote erosion and the formation of ravines.

In places visited by tourists, such as Gauja Valley in the territory of Gauja National Park, biologically old or large dimension trees are felled along tourism trails, due to safety considerations regarding visitors. However, felling of the biologically valuable trees substantially decreases the quality of the protected habitat, negatively affects the structure of the forest stand and reduces available habitats for epiphytic lichen and moss species. Fragmentation of microhabitats also occurs. In this case, the felled

wood shall be left on the site, increasing the volume of dead wood.

15.1.5.2 Slope Erosion

Soil erosion, rock collapses and landslides on steep slopes are considered natural processes. However, intensive erosion may also be caused by management (agriculture, forestry). Erosion promoted by human activities has an adverse effect on the conservation status of Slope and ravine forests.

If erosion intensifies due to human activities (tourism infrastructure, tree felling, tracks created by vehicles, trampling caused by visitors), especially in cases when this impact remains for a long time, it should be evaluated as negative, since the vegetation cannot optimally regenerate, and species richness and cover in the habitat may decline (Fig.15.7).

Fig. 15.7. Erosion processes in Gauja National Park along the "Serpentine road" ("Serpentīna ceļš"). Photo: S. Ikauniece.

Also, erosion causes leaching of soil particles in streams and rivers, and it affects the watercourse characteristics and processes (Urtāns (ed.) 2017). If arable land is located near the slope edge, in addition to the risk of erosion, eutrophication of the slope and watercourses also occurs due to leaching of nutrients (fertilisers) from the agricultural land.

15.1.5.3 Tree Diseases

Slope and ravine forests like other habitats where broad-leaved tree species have an important role, are affected by diseases of *Fraxinus excelsior*, *Ulmus glabra* and *Ulmus laevis*, which cause tree dieback. Dieback of broad-leaved tree stands has occurred in some areas in Latvia, with mortality of trees in all or part of the stands. A large volume of dead wood forms both as snags and logs. There have been many hypotheses about the causes of the disease, but presently it is believed that the pathogenic fungus *Hymenoscyphus fraxineus* (sin. *Chalara fraxinea*) is the cause of dieback of *Fraxinus spp*. (Kenigsvalde et al. 2010; Bakys 2013). Dieback of *Ulmus minor* and *Ulmus laevis* is caused by *Ceratostomella ulmi* which is a fungi spread by the bark beetle *Ophiostoma novo-ulmi* (von Oheimb, Brunet 2006). Consequently, the occurrence of these trees has substantially decreased.

As wide gaps form, intensive growth of *Corylus avellana* may develop, which can persist for a long time as a temporary phase in the succession of the forest stand. During the first half of the 20th century when the forest typology was initiated, a so-called temporary forest type of *Corylus avellana* ("lazdulājs") was distinguished, which was considered to be a transitional stage of succession that temporarily replaced the typical forest type (Melderis 1939). Natural disturbance and the following natural succession, as well as biological values related to dead wood are very important, so stands with dieback still belong to the EU protected habitat type 9180* Tilio-Acerion *forests of slopes, screes and ravines*. If suitable environmental conditions for the broad-leaved species remain, broad-leaved tree regeneration forms in the openings, including of *Ulmus minor* and *Ulmus laevis* with sprouts (von Oheimb, Brunet 2006), and in the future over a longer period of time a typical forest tree composition is expected. However, it has been observed that in clearings where clearcutting has been performed after dieback of *Fraxinus excelsior*, the formation of viable *Fraxinus excelsior* regeneration does not occur. The young trees are infected, and in places where the disease has spread over a long period, *Fraxinus excelsior* trees in the stand is replaced by tree species of early succession – *Alnus incana*, *Betula spp*. and *Populus tremula*.

15.1.5.4 Tourism and Sport Activities

Slopes and ravines are popular not only for tourism on trails, but are also revered by a variety of sport lovers. Orienteering races and other types of active recreation are often organised on such terrain. Tourism and active recreation in *Tilio-Acerion* forests of slopes, screes and ravines have a negative effect on the habitat and its characteristic structure elements, species and their habitats. The extent of the impact can vary from slight to substantial, which also depends on the infrastructure elements that reduce the load and their effectiveness. Trampling degrades groundcover vegetation, exposes and damages tree roots, and causes loss of vascular plant and moss cover in sites of intensive load. Bryophytes, lichens and fungi, including rare species, can be torn off logs. Trampling also promotes slope erosion, especially in the autumn-spring season when the top layer of the soil is moist. There is a particularly high risk of damage to the ground cover in wet soils with springs, where even the presence of a few visitors can have a substantial impact.

In the animal breeding period in spring, the presence of people or mass events may cause significant disturbance, especially for birds, which may leave their nest causing a risk of mortality to nestlings. This particularly affects birds of prey and landfowl (*Galliformes*) (Anon. 2014b). This refers to forests in general, but the most impact may occur in Slope and ravine forests, as they are attractive due to difficult terrain that is often used for races.

The habitat may also be negatively affected by improperly planned tourism infrastructure that does not reduce, but intensifies the load by increasing the number of visitors and promoting their movements outside paths. Increase of visitor load can be promoted if boardwalks are old and worn out on paths along the popular routes.

15.1.5.5 Other Adverse Factors

Municipal and agricultural waste, weeds, branches and tree leaves from the farm households and gardens have often been dumped in forests, ravines and slopes in many places of Latvia, especially near populated areas and country houses. This worsens the condition of the habitat, adversely affecting the typical vegetation composition and structure. Waste also serves as the source of distribution of habitat-atypical, as well as invasive alien plant species. In public places the situation may be solved by placing signs or fences along the slope edge. In private territories (near houses, gardens) it is difficult to influence the situation, and it requires education of the managers and owners.

15.2 Restoration and Management Objectives in habitat Conservation

The objective of conserving Slope and ravine forests is to conserve their ecological role and ensure a favourable conservation status for the habitat and the associated species (*see Ch. 1*). An important objective is also the conservation of habitat continuity in its distribution area, which is very important for the survival of many protected and rare species (Norden et al. 2014). Slope and ravine forests are not only important habitats for protected and rare species, but they also serve as species distribution corridors along rivers.

It is important to conserve the aesthetic value of these forests, as they are often components of landscapes that are visually high valued, especially along the great rivers.

15.3 Management and Restoration of Tilio-Acerion Forests of Slopes, Screes and Ravines

15.3.1 Habitat Conservation

Different approaches may be used in the conservation and management of Slope and ravine forests: (1) non-intervention or passive protection; (2) non-traditional management methods directed at the creation and management of forest stands of a certain tree species composition, ensuring the ecological requirements of the target species (including protected species) (Götmark 2013) (Table 15.1).

One of the habitat conservation approaches is non-intervention in natural processes, or passive protection. Non-intervention of natural processes ensures that active human work does not occur in the habitat – felling of trees or shrubs, impact on the groundcover or soil, no human impact on other natural values characteristic to Slope and ravine forests (exposures, springs, brooks), or that the effect is insignificant. In places that are left to natural processes, tourism infrastructure should not be established, and sports or active recreation events should also be avoided. By only allowing the natural processes to occur and observing them over a longer period of time, knowledge can be acquired on natural development of the habitat and natural values and processes that are associated with pristine forests. Non-intervention of natural processes can be relatively efficiently ensured in protected nature territories and microreserves by establishing adequate functional zoning with a protection regime.

In Latvia, the Slope and ravine forests mostly do not need management and the priority is to ensure adequate protection and non-intervention of natural processes.

In order to prevent the influence of severe wind and other effects from the adjacent area on the top of slopes that may cause additional erosion of the slopes, a buffer zone can be created (see *Ch. 15.3.2*). If pioneer species such as *Alnus incana* dominate in the forest stand, they can be selectively felled to promote the development of habitat-characteristic broad-leaved species. Such situations must be carefully assessed in planning to determine if the stands will develop in a direction that meets the preconditions of Slope and ravine forests (see more in *Ch. 15.3.3*). This measure may be combined with the increasing of natural structures like dead wood (see *Ch. 15.3.4*). In areas that already conform to the Slope and ravine forests, dead wood and other structures should be allowed to form naturally. In some cases, in order to conserve the habitats of protected species or maintain a socially significant cultural landscape, felling can be conducted to expose biologically old, scenic trees to sunlight (see *Ch. 15.3.5*). Slope and ravine forests often occur in combination with other protected habitats – river rapids, springs, caves and rock outcrops. When planning conservation and various activities in such places, it is necessary to take into account the management recommendations of these protected habitats (see *Ch. 15.3.6*).

15.3.2 Establishment of a Buffer Zone

The purpose of the buffer zone is to prevent intensive wind-throws in the upper slope and additional erosion. The buffer zone is established behind the slope edge (delimited by a sharp change in slope) on the flat or gently sloping land. Thus, if it is necessary, it is formed in the area adjacent (forest or agricultural land) to the territory of the target habitat.

Table 15.1 Management methods of habitat type 9180* *Tilio-Acerion* forests of slopes, screes and ravines.

Method	Ecological benefits	Disadvantages
Establishment of a buffer zone	In the case that clear felling occurs in adjacent areas, the trees of the largest dimensions in the upper part of the slope are retained.	In the buffer zone on top of the slope all trees cannot be harvested (economic losses). Additional costs for planning and for delimiting (marking) in the field.
Development of the habitat characteristic tree species composition	The proportion of habitat-characteristic tree species increases..	Difficult conditions for work. Risk of erosion promotion and affecting the spring discharges and seepages during the work.
Increase of the volume of dead wood	Improved natural structure of the stand. Created habitats for species that depend on the presence of dead wood.	Difficult conditions for the work. Risk of promoting erosion during work.
Exposure of biologically valuable old and/or scenic trees to sunlight	Extended lifetime of the biologically/scenically valuable trees, improved living conditions for the species dependent on them.	Difficult conditions for the work. Risk of promoting erosion during the work.
Management of watercourses – tree felling to ensure the optimum shade mosaic to the river section	The desired shade mosaic is ensured for the river, falling of trees into the river is prevented, there is a higher possibility of the uninterrupted flow of the river and the conservation and/or improvement of the biodiversity of the river section.	There is a risk of altering the existing microclimate (moisture and shading) and expose the forest habitat to greater wind impact, increasing the probability of tree uprooting. Risk of erosion and water eutrophication may increase.
Spring discharge site management – improvement of popular water taking sites	The adverse effect of the visitors on the natural understorey and soil has been prevented.	The spring habitat may be damaged. Difficult conditions for the work. When working, there is a risk of encouraging erosion, influencing the spring discharge site and adversely affecting the spring habitat.
Cutting of shrubs and trees above and below the rock outcrops	The living conditions of sun-loving species improve. Maintenance of the traditional/cultural landscape.	Difficult conditions for working. Risk of promoting erosion during the work. It may cause rock outcrop collapse and subsequent area decrease or loss of this habitat. May adversely affect shade-loving species.

When planning felling in a forest that is adjacent to the habitat, clearcutting should be restricted in a zone of 20-30 m from the slope (Fig. 15.8). Selective felling of various intensities may be carried out in the buffer zone, starting from the border of the clearcut (high felling intensity) up to the edge of the slope or the area occupied by the habitat (low felling intensity). The trees of the subcanopy, which additionally help in preventing the effects of the wind, should be preserved in the buffer zone. It is recommended to create buffer strips in the areas that are adjacent to habitats of medium or high quality, where many biologically old trees are present.

Ploughing is not recommended in agricultural land adjacent to the habitat behind the slope edge in a buffer zone at least 5 m in width, in order to prevent intensive run-off of the surface water from agricultural land and reduce erosion risk. This requirement was not included in the legal regulations in 2016. If agricultural land territory is sloping and run-off of the surface water is expected, it can be regulated by channels at one or several places.

15.3.3 Establishment of the Characteristic Tree Species Composition of the Habitat

The characteristic tree species composition of the habitat may be restored in the case when pioneer species like *Alnus incana* or *Betula pendula* dominate in the forest, when Slope and ravine forests has formed as the agricultural land overgrows or when a forest has naturally regenerated after clearcutting. Firstly, it is important to assess whether there are suitable development conditions for the habitat: whether *Fraxinus spp.*, *Tilia cordata*, *Pinus sylvestris* and other broad-leaved trees are found in the advance growth and whether the habitat-characteristic vascular plant species occur in the understorey. If species characteristic to boreal forests dominate, habitat formation cannot be expected.

Pioneer trees species (*Alnus incana* and *Betula spp.*) should be felled selectively, and not to exceed the minimum tree density or basal area defined by legal regulations. Felling can be carried out in areas of 0.05-0.1 ha to emulate the formation of gaps. It is necessary to conserve the trees and shrubs in the advance growth and understorey that characteristic to the habitat.

Felling of the pioneer species may be combined with increasing the volume of natural structures, leaving the felled trees with a diameter greater than 20 cm, thus increasing the volume of dead wood.

15.3.4 Increase of Dead Wood Volume

The volume of dead wood is important due to the specialist and protected species associated with it. However, nowadays the volume of dead wood even in protected nature areas is often insufficient even in protected nature areas for the species associated with natural forests to survive. The objective of increasing the volume of dead wood is to diversify the ecological niches available for various organisms dependent on dead wood.

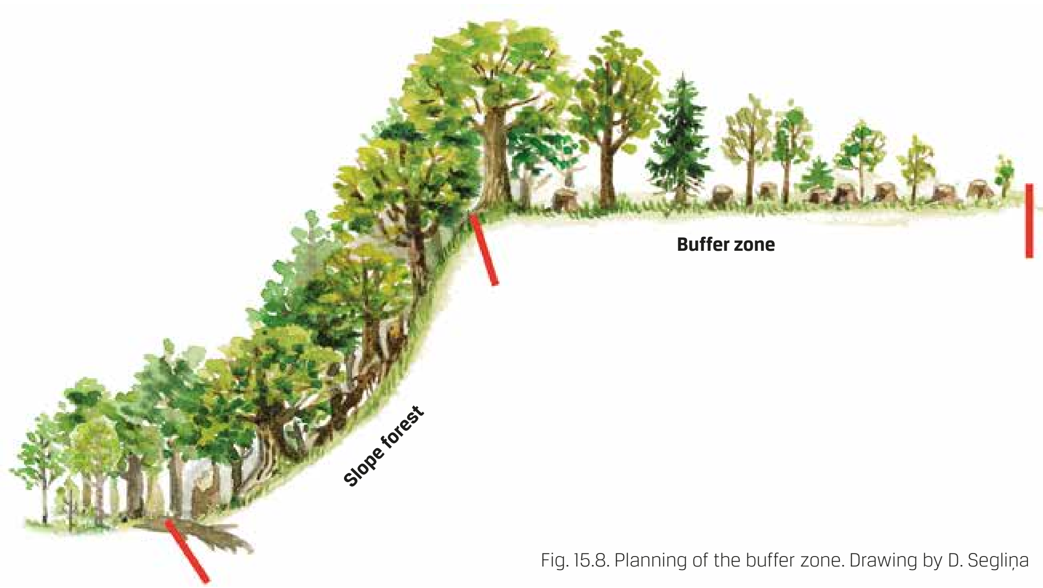

Fig. 15.8. Planning of the buffer zone. Drawing by D. Segliņa

Increase of dead wood volume is necessary in cases when forest of slopes or ravines developed after by overgrowing of agricultural land, forest canopy is dominated by pioneer species (*Alnus incana*, *Betula pendula* and *Populus tremula*), and broad-leaved trees are common in advance growth. The volume of dead wood can be increased by development of the characteristic species composition in habitats of very low quality and in territories that in a future would correspond to the minimal requirements of the Slope and ravine forests in the future.

The volume of lying and standing dead wood can be increased by imitating natural disturbances. In order to increase the volume of natural structures, it is recommended to fell individual trees (diameter 25-35 cm) and leave them on the ground. The height of sawing may be varied, creating stumps of various heights. It is recommended to choose *Populus tremula*, coniferous trees, and *Betula spp.* Felling may be replaced by tree ring-barking, whereby the bark and the layer of cambium around the stem is removed in the form of a ring with 15-cm width. The tree then gradually dies, but remains for a variable period as a snag. Then, after falling to the ground, it adds up to the volume of logs. The intensity of root sprout formation for *Populus tremula* is reduced by ring-barking. Broad-leaved trees (*Quercus robur*, *Tilia cordata*, *Ulmus spp.*) should not be ring-barked or felled, as these species are important in the restoration of the typical canopy composition, and provide suitable substrate for protected epiphytic bryophyte, lichen and snail species, often to a greater extent than pioneer tree species.

15.3.5 Exposure of Biologically Valuable Old Trees to Sunlight

Biologically old, large broad-leaved trees (most often *Quercus robur*, *Fraxinus spp.*, *Tilia cordata*), typical of Slope and ravine forests, serve as habitat for invertebrates and substrate for rare epiphytic mosses and lichens. Depending on whether these trees are sun-lit or whether they are shaded, they may be inhabited by different species. If the trees were growing in well-lit conditions earlier, they have formed a wide crown with low branches. As the forest canopy develops, stems become shaded by younger trees and shrubs, which later grow into the crown of the old tree, causing mechanical damage and increased shading.

Natural overgrowing of meadows formerly used for grazing or hay making creates a dense forest stand. This happens over a long time, gradually changing moisture and light conditions in the stand. In general, the course of undisturbed natural processes is the most suitable development for Slope and ravine forests, however, in some cases exposing old trees to sunlight can be used in management.

Exposure of biologically valuable old trees to sunlight can be carried out for two purposes.

- **For the conservation of very rare species with biologically old, large broad-leaved trees as habitat.** Exposure of large trees to sunlight should be carried out in cases when there is a complex of wooded meadows and pastures which must be maintained (Bāra (ed.) 2014). Prior to exposure works, it must be clarified if the management will have an adverse effect on other protected species to which the existing conditions are optimal, and conservation priorities must be evaluated. It is better not to carry out the felling on north-facing slopes, as in that case to improve light conditions, a large forest area must be felled, thus negatively affecting the habitat as a whole.
- **In important recreation and cultural history landscapes,** with the aim to expose biologically old branched trees to sunlight along the nature trails, in sight lines of landscape views, and in aesthetic landscapes that historically were associated with solitary old trees or their groups. In such cases, felling is not a priority to increase biodiversity, and is recommended to maintain or restore the cultural landscape. Usually such places have formerly been partially open – most probably they resembled park-like landscapes where trees grew in open conditions, not in forests.

The older a tree is and the longer it has been growing in shaded conditions, the more sensitive it is to changes. Therefore, the felling of surrounding trees must be carried out carefully. It can be carried out gradually, so as not to drastically change the light conditions at once. If a tree is exposed to light too quickly, the leaves may burn in the sun, it may suffer from intensive transpiration, and drying and increased light may affect survival of the organisms using the tree as habitat (Johannesson et al. 2005; Bāra (ed.) 2014). However, multiple interventions with small intervals of time may intensify the risk of erosion on slopes and negatively affect the groundcover that is already sensitive to disturbances.

Firstly, the youngest trees growing directly under the crown that may mechanically damage the tree should be cut. Trees should be selectively cut, retaining some trees that cast shade, especially

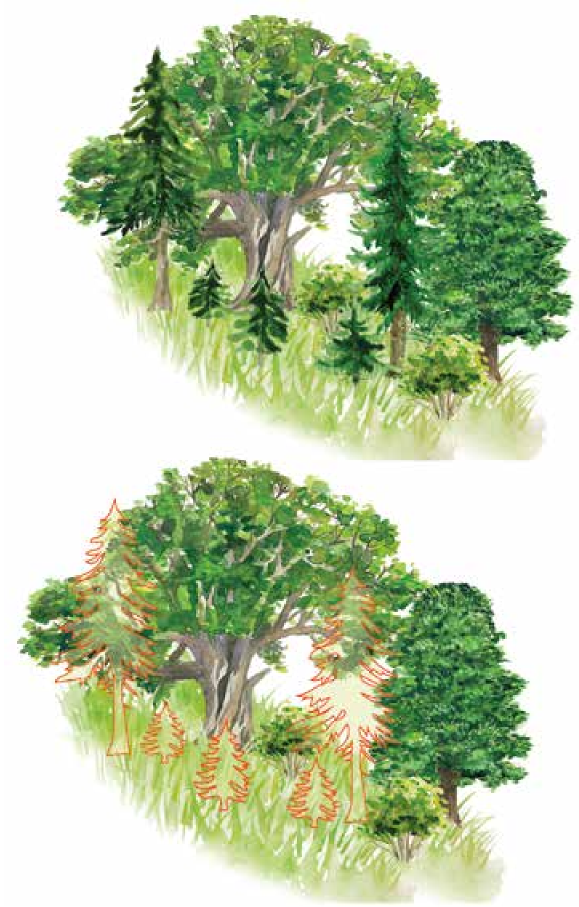

Fig. 15.9. Exposure of a biologically old tree to sunlight. The trees to be felled are in orange. Drawing by D. Segliņa.

on the south side or on the side which was previously the most shaded. After that, trees that reach the outer edge of the crown with their top or side branches should be felled, generally creating a well-lit area in the projection zone of the tree's crown (Fig. 15.9).

It is recommended to retain richly flowering shrub species in the proximity, if they are not close to the stem, as invertebrates (butterflies, beetles and other insects) use these shrubs in feeding.

Felling should be avoided during long periods of drought. The most suitable period for felling is autumn to early spring (Bāra (ed.) 2014), avoiding the bird breeding season. If felling is carried out in multiple attempts, an interval of two to three years should be observed. Felling should be carried out without heavy equipment that might promote erosion. It should be done during the period when the soil is frozen and should also be avoided if there is a risk of erosion. Brush cutting of regenerating

Fig. 15.10. Cleaning of the River Pērļupe from fallen logs. Photo: S. Ikauniece.

shrubs should be conducted regularly (every 3-4 years) to ensure continued light conditions in the future.

15.3.6 Activities to Ensure a Favourable Conservation Status of Other Habitats

15.3.6.1 Watercourse Management

Small rivers or streams are common to Slope and ravine forests, as they flow through ravines, and sometimes slope forests of slopes are located in the valleys of greater watercourses. It must be determined on a larger scale if the watercourses in ravines or near slopes should be managed, taking into account the territory outside the habitat. Management includes the logging or thinning of trees on the shores of rivers or streams, as well as the removal of trees fallen into the watercourse (Fig. 15.10).

If the largest part of the watercourse flows though agricultural land that is not overgrown by trees, trees should not be felled in the wooded part on the river bank inside the borders of Slope and ravine forests. Overgrowth in the habitat territory compensates the lack of shade in the agricultural lands.

When managing watercourses in high quality forest habitats, trees designated for felling include those that have inclined over the river and might break or otherwise fall into the river, causing undesirable barriers to river flow, promoting blocking of flow and decrease of biodiversity. Felling must ensure a mosaic of shaded sectors in the river

Fig. 15.11. The River Pērļupe cleaned from fallen logs. Photo: S. Ikauniece.

section. The trees removed from the river and those felled on the bank must be left in the forest stand on the bank, placing them above the level of flood waters (Fig. 15.11).

Felling on river banks is more important in cases of a secondary forest with *Alnus incana* in the stage of self-thinning, or if it is necessary in order to improve the habitat of a protected species, such as *Margaritifera margaritifera* (Rudzīte (ed.) 2004; Urtāns (ed.) 2017, *Ch. 17*). In small ravines, management of watercourse banks is not needed and not desirable.

15.3.6.2 Protection of Springs and Spring Discharges

Both small and large springs, as well as larger seepage areas with a diffuse outflow of water, are found in ravines and on slopes. Sometimes a large amount of water outflows forming a stream, which is often used for obtaining water, especially near populated areas.

Intervention is not recommended in spring discharges, they should not be included in tourism routes or sports race territories, and it is not allowed to use any technical equipment that may damage the groundcover in the territory. If spring discharges are included in tourism routes, it is necessary to install footbridges to reduce the trampling load.

If springs are traditionally used for water taking, sometimes a suitable infrastructure must be built in order to prevent trampling (Priede (ed.) 2017, *Ch. 13*).

15.3.6.3 Protection of Rock Outcrops and Caves

Rock outcrops are important not only as habitats of rare species, but also as geological objects. If outcrops (8220 *Siliceous rocky slopes with chasmophytic vegetation*, 8210 *Calcareous rocky slopes with chasmophytic vegetation*) or caves (8310 *Caves not open to the public*) are found in the habitat, the most suitable method in the conservation of the habitat of Slope and ravine forests is undisturbed natural processes or non-intervention (Čakare (ed.) 2017). To limit landslides above rock outcrops and caves, it is important not avoid water runoff in area above them, and to assess the factors that may influence this.

If the outcropped rock is important as a historical and highly aesthetically valued open landscape component, sometimes the felling of shrubs and trees to open the view should be assessed for the conservation of scenically valuable exposures or sightseeing points, and for aesthetic and tourism objectives. Improved light conditions are also necessary for the rare light-loving species living on exposed bedrocks. However, it should not be allowed if it endangers the specialist species associated with exposures (such as rare moss and lichen species).

15.3.7 Reduction of Tourism Load

In order to reduce the consequences of excessive visitor load, especially regarding damage to

Recommendations for environmental friendly nature tourism in Slope and ravine forests.
In 2014, the Nature Conservation Agency in collaboration with the Latvian Orienteering Federation, established guidelines aimed to reduce the impact of orienteering sport on the environment, also providing recommendations for the organisation of competitions in various habitats. For example, it was recommended not to plan the crossing of steep slopes in one place by no more than 50 participants, even though a much smaller number of participants would be optimal. It is also recommended to avoid running down perpendicular to the slope, and placing control points above rock outcrops or at their base in such a way that requires one to climb up or slide down the outcrop. The maximum number of people per control point (except start-up and last control point) in forests of slopes was set at 50 (Anon. 2014b).

vegetation, tourism infrastructure needs to be constructed. When organising mass sports events in a territory without an infrastructure, it is important to take into account the ground cover, its stability against trampling and erosion risk. As ravines and slopes are popular among enthusiasts of active sports, slopes with a more stable ground cover dominated by vascular plants and mosses of boreal coniferous forests should be chosen, not areas of broad-leaved forests with a much sparser ground cover.

When building stairs, foot bridges or sightseeing areas in Slope and ravine forests, it is important to fix the supports and foundations for the reasons

Tourism infrastructure examples in Gauja National Park

Trails of various construction types and management practices, as well as visitor impacts in forests of slopes, can be seen in Gauja National Park. Nature trails in forests of ravines and slopes have also been established in other places in Latvia. Figures 15.12-15.15 show several solutions and their impact on Slope and ravine forests. The construction process negatively affects the groundcover, the recovery of which will occur over a longer period of time.

Fig. 15.13. A small walkway (~0.7 m wide), slightly dug into the slope. The edge of the trail has been fixed with logs of small dimension, preventing potential erosion. Photo: S. Ikauniece.

Fig. 15.12. Stairway on slope (A), raised above the ground on dug-in wooden posts (B). Photo: S. Ikauniece.

Fig. 15.14. A stairway of wooden planks built on a slight slope. Wooden chips were used for the trail and adjacent area to the stairway. Photo: S. Ikauniece.

Fig. 15.15. One should definitely avoid the construction of large trails with heavy material on slopes, as part of the habitat is thus irreversibly destroyed and erosion is promoted like here. Photo: S. Ikauniece.

of long-term use and safety. However, such construction work may also have an adverse effect on the ground cover and intensify erosion.

It is best, if possible, to avoid the building of new tourism infrastructure objects in areas which are not popular tourist destinations. It is more important to maintain existing trails and redirect visitors from sensitive, biologically valuable territories, rather than build new infrastructure objects that inevitably create additional load and adverse effects.

Felling of biologically old trees valuable for natural diversity in the zone adjacent to trails is justified when it is necessary to remove dangerous trees for the safety of visitors, but it has adverse impact on Slope and ravine forests by reducing the diversity of microniches and reducing or even destroying many species habitats. If there are, however, potentially dangerous trees along trails and there are no other solutions, they can be felled and left on the site. In the felling of trees, stumps of various heights can be created, imitating the formation of dead wood. The establishment of new trails must take into consideration that the total length of trails increases the number of potentially dangerous trees from the point of view of the trail manager, and by cutting them, the quality of the habitat can be negatively affected.

15.3.8 Management Unfavourable to Slopes and Ravine Forests

Slopes and ravine forests are adversely affected by the felling of mature trees and by the removal of dead wood. The removal of biologically old and valuable trees in the vicinity of tourism infrastructure objects also has an adverse effect on the quality of the habitat, especially if it is carried out by the manager of the trail, as this gives visitors the wrong notion about the values of nature.

Visitors tend to damage vegetation beside trails when the tourism infrastructure like footbridges is old and dangerous. Sports events, during which a large number of people are traversing slopes, have a similar impact.

If snags do not directly endanger visitors or when they are not situated close to intensively used tourism sites, they must be conserved and natural forest stand regeneration should be allowed to take place. If the snags endanger buildings, vehicles or visitors, they may be felled and left lying on the ground. In some cases, *Corylus avellana* can be cut around young broad-leaved trees to improve light conditions, but this provides only temporary results and the cutting will usually have to be repeated. The cover of *Corylus avellana* will naturally decrease with tree canopy closure.

15.4 Conflicts of Conservation and Management

The habitat management measures recommended in these guidelines do not contradict the requirements of the known rare and protected species dependent on mature broad-leaved trees and structures characteristic to natural forests.

If a particular habitat Slope and ravine forests formed after an overgrowing of wooded meadow, which was formerly used for hay making or grazing, the restoration of historical landscape might be necessary.

Felling a part of the trees will totally change the conditions of the existing habitat. Before such works, a detailed study of the territory is needed and a well-founded argument, after assessing the restoration influence on protected species in the broad-leaved forest.

16. Chapter. 91E0* *Alluvial Forests with* Alnus Glutinosa *and* Fraxinus Excelsior, 91F0 *Riparian Mixed Forests of* Quercus Robur, Ulmus Laevis *and* Ulmus Minor, Fraxinus Excelsior *or* Fraxinus Angustifolia, *Along the Great Rivers*

16.1. Floodplain Forest habitat Characteristics

16.1.1. Brief Description

EU protected forest habitat types 91E0* *Alluvial forests with* Alnus glutinosa *and* Fraxinus excelsior *(Alno-Padion, Alnion incanae, Salicion albae)* and *91F0 Riparian mixed forests of* Quercus robur, Ulmus laevis *and* Ulmus minor, Fraxinus excelsior *or* Fraxinus angustifolia, *(Ulmenion minoris) along the great rivers* (further below referred to as floodplain forest habitats) are mainly situated along rivers, in their floodplains and terraces above the flood-plain.

Similar environmental conditions and ecological processes are characteristic to both habitat types, and therefore the characteristics and recommendations for their management are combined into a single chapter.

Both habitats have formed along rivers on nutrient-rich soils developed on alluvial deposits (Lārmanis 2013b). The soils are well drained and aerated, periodically inundated. In some locations they may be wet throughout the entire year due to the influence of groundwater.

Habitat type 91E0* *Alluvial forests with* Alnus glutinosa *and* Fraxinus excelsior (Fig. 16.1) includes deciduous forests in valleys of rivers and streams. *Fraxinus excelsior*, *Alnus glutinosa* and *Alnus incana* may dominate in tree layers, and in a zone along the rivers also by *Salix alba* and *Salix fragilis*.

The characteristic vegetation and ecological conditions develop in interaction between spring discharges, high ground water table and seasonally drying brooks. Therefore, floodplain forests are not always associated with stable watercourses, but a high water level is characteristic at least seasonally.

Depending on the dominant tree species, several subtypes are distinguished for the EU habitat (Anon. 2013b). Three of its variants have been defined in Latvia (Lārmanis 2013b):

variant 1: wet broad-leaved forests dominated by *Fraxinus excelsior* and *Alnus glutinosa*;

Fig. 16.1. 91E0* *Alluvial forests with* Alnus glutinosa *and* Fraxinus excelsior (Alno-Padion, Alnion incanae, Salicion albae) Photo: S. Ikauniece.

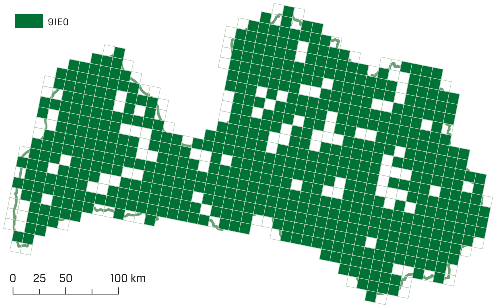

Fig. 16.2. Distribution of the habitat type 91E0* *Alluvial forests with* Alnus glutinosa *and* Fraxinus excelsior (Alno-Padion, Alnion incanae, Salicion albae) in Latvia (Anon. 2013c).

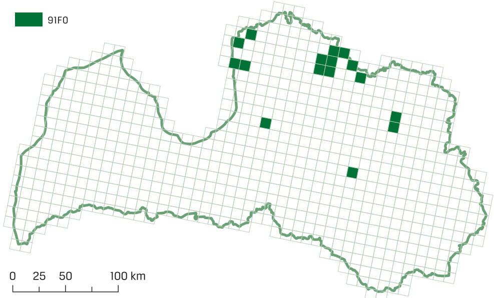

Fig. 16.3. Distribution of the habitat type 91F0 *Riparian mixed forests of* Quercus robur, Ulmus laevis *and* Ulmus minor, Fraxinus excelsior *or* Fraxinus angustifolia, *along the great rivers* (Ulmenion minoris) in Latvia (Anon. 2013c).

variant 2: *Salix spp.* and *Alnus incana* woods in floodplains;

variant 3: partially degraded stands corresponding to variants 1 and 2, if they correspond to criteria of Woodland Key Habitat quality or potential Woodland Key Habitat.

Fig. 16.4. Soil particles sedimented by floods are often attached to lower parts of trunks. Epiphytic bryophyte community composition at the tree base differs from that higher on the stem, or may be lacking due to abrasion by regular flooding. Photo: S. Ikauniece.

Fig. 16.5. The bases of tree stems appear darker in colour due to sediments deposited by flood water. Photo: S. Ikauniece.

Habitat type 91E0* *Alluvial forests with* Alnus glutinosa *and* Fraxinus excelsior (Alno-Padion, Alnion incanae, Salicion albae) is found fragmentarily in small areas throughout the country (Fig. 16.2) and occupies about 0.1% of Latvia. The total area of *Alnus incana* and *Salix spp.* forest stands in banks is unknown; thus far the most substantial areas have been recorded in the middle course of the River Gauja (Anon. 2013c). Research is needed to specify the distribution and total area of this habitat in the country.

Habitat type 91F0* *Riparian mixed forests of* Quercus robur, Ulmus laevis *and* Ulmus minor, Fraxinus excelsior *or* Fraxinus angustifolia, *along the great rivers (*Ulmenion minoris*)* unlike the other floodplain forest habitat described above, is located near the great rivers, such as the Gauja, Daugava, and Pededze, in their floodplains and terraces above floodplains. Broad-leaved trees (*Ulmus glabra*, *Quercus robur*, *Fraxinus excelsior*) dominate in the forest stand. Habitat type 91F0* *Riparian mixed forests of* Quercus robur, Ulmus laevis *and* Ulmus minor, Fraxinus excelsior *or* Fraxinus angustifolia, *along the great rivers (*Ulmenion minoris*)* may develop in early succession after the habitat type 91E0* *Alluvial forests with* Alnus glutinosa *and* Fraxinus excelsior (Alno-Padion, Alnion incanae, Salicion albae).

Habitat type 91F0 *Riparian mixed forests of* Quercus robur, Ulmus laevis *and* Ulmus minor, Fraxinus excelsior *or* Fraxinus angustifolia, *along the great rivers (*Ulmenion minoris*)* has been little studied in Latvia. It occupies the smallest area of all EU forest habitat types in Latvia (Fig. 16.3), 0.006% of the whole national territory. Presently, only small habitat areas have been described on the banks of some of the largest rivers (Gauja, Ogre, Pededze) (Anon. 2013c).

16.1.2 Indications of Favourable Conservation Status

Floodplain forest habitats are the rarest protected forest habitats in Latvia (Anon. 2013c). The favourable conservation status of both habitat types is characterised by a natural, artificially unchanged floodplain terrain of the river or stream, as well as a naturally spring flood (high water) regime. Canopy is dominated by the characteristic tree species. A favourable status is characterised by occurrence of broad-leaved tree species typical of the habitat, vegetation of periodically inundated forest and structures of natural forest (Fig. 16.4, Fig. 16.5).

Since forests along rivers were historically logged for transformation into agricultural land and for timber harvest (Zunde 1999), these floodplain deciduous and broad-leaved forests can be considered to be secondary forests that developed by overgrowing of former agricultural land (Austin 1999). The dominant tree species in the wet forests are *Fraxinus excelsior* and *Alnus glutinosa*. *Alnus incana* may dominate in drier soils in forests on banks during the initial stage of succession, and *Padus avium* and *Salix* spp. are common. An admixture of *Ulmus* spp. establishes over time. The herb communities contain species that can rapidly colonise new ecological niches formed by fluctuating moisture conditions. More dense cover of shrubs and herbs develops over

16.6 *Matteuccia struthiopteris* on a river bank. Photo: S. Ikauniece.

Fig. 16.7. *Lunaria rediviva*. Photo: S. Ikauniece.

a longer period without flooding. Understorey species include *Humulus lupulus*, *Carex acutiformis*, *C. remota*, *C. sylvatica*, *Crepis paludosa*, *Cirsium oleraceum*, *Geranium robertianum*, *Glechoma hederacea*, *Matteuccia struthiopteris* (Fig. 16.6), *Stachys sylvatica*, and sometimes the protected species *Lunaria rediviva* (Fig. 16.7). As increased air humidity is characteristic to floodplain forests, the stems of trees are often covered with epiphytic mosses and lichens.

Floodplain forests along watercourses serve as dispersal corridors for species. They are important habitats for rare species characteristic in forest on moist and fertile soil, especially snails, epiphytic bryophytes (e.g. *Lejeunea cavifolia* and *Metzgeria furcata*), lichens (e.g. *Collemma* spp., *Leptogium* spp., *Cetrelia* spp., *Sclerophora* spp.) (Lārmanis 2013b), and the fungus *Gloiodon strigosus* (I. Leimanis, *pers. report*).

In floodplain forests saproxylophagous beetles are common in dead wood. Species associated with *Alnus glutinosa* and *Salix spp.* (usually the dominant tree species in such forests) are characteristic. These include *Aromia moschata, Necydalis major* and on polypores – *Oplocephala haemorrhoidalis*. The larvae of *Xylomoia strix* develop on *Equisetum hyemale,* which is common in floodplain forests (Vilks 2014).

The major floodplain forests are important nesting and feeding habitats for *Dendrocopos leucotos*, which is the umbrella species of high quality deciduous forests. In floodplain forests dominated by broad-leaved tree species, *Dendrocopos medius* can also occur, which forages in bark crevices of old broad-leaved trees.

Fig. 16.8. Floodplain of the River Irbe during a spring flood. Photo: S. Ikauniece.

16.1.3 Important Processes and Structures

16.1.3.1 Processes

Important processes of both floodplain forest habitats are associated with the hydrological regime characteristic to floodplains. An important process is regular flow of water as spring high water levels or floods. Periodic inundation is an important feature that indicates the function of floodplain forest habitats (Fig. 16.8). The main functions of floodplains are the regulation of spring high waters and floods, provision of nutrient circulation, filtration of surface waters by the sedimentation of organic matter and pollutants, enrichment of floodplain soil with mineral substances, and reduction of sedimentation in rivers (Fig. 16.9) (Urtāne (ed.) 2012). Running

Fig. 16.9. Sediment and debris brought by a spring flood in a floodplain forest. Photo: S. Ikauniece.

Fig. 16.10. The oxbow lake in the River Gauja floodplain. Photo: S. Ikauniece.

water has an important role in the distribution of plant propagules. The recurrence and duration of spring flooding affects the structure of floodplain forests, and the composition and characteristics of the soil, which determine the species composition and the structure of plant communities (Lārmanis 2013b). The sediments formed by spring flooding forms an uneven, wavy microterrain (Rūsiņa 2013). The proximity of water and wet soils create a constantly high atmospheric humidity in the forest stand.

Spring flooding is important in spreading *Alnus glutinosa* seeds. Its fruits fall to the ground during autumn and winter, and in spring they are spread by means of high waters. When the seeds reach bare soil, there is a high possibility that they will germinate. *Alnus glutinosa* is well-adapted to spring flooding conditions. During periods of increased water table when roots are inundated, gas exchange occurs through lenticels in the bark, which act as pores.

Not all floodplain forest habitats are located near watercourses that are periodically flooded. In other cases, a high water level is due to **groundwater discharges** – springs or seepages. The spring discharges may develop wet soil areas or streams both continuously or seasonally.

Gap dynamics is a process whereby individual trees or small groups of trees suffer mortality due to wind-throw, snowbreak, insect infestation or as the trees become old. Pioneer species usually regenerate in gaps, advance growth forms or grow rapidly. These small-scale disturbances, when other conditions are stable, promote the development of an uneven-aged stand structure (Ek et al. 2002).

16.1.3.2 Structures

The river slope water flow, as well as the size and topography of the valley define the nature of the floodplain, thus the conditions may differ in various locations of the habitat. Narrow floodplains are formed on rivers with a high gradient, such as rivers on upland slopes flowing through moraine sediments in narrow valleys, or downriver before outflow to the sea, where it flows through the dunes. Rivers in lowlands may have wide floodplains without a distinct valley, and there may be no terraces or valley slopes.

High waters define the mosaic of microhabitats in the forest – areas with sedimented sand, fertile areas with plant debris, and washed out pockets that flood occasionally. Different plant species are found in the various microhabitats, forming a mosaic groundcover structure. Permanently flooded slacks may lack woody plants; they are often parallel to the river, with rows of *Salix spp.* or *Alnus glutinosa* on the edges.

In wider river floodplains oxbow lakes (Fig. 16.10) can form when a meander from the river is separated by deposits. Oxbow lakes are usually U-shaped or circular.

Gap formation creates canopy openings, which gradually overgrow with trees while new gaps form in other places, creating dead wood and an uneven-aged stand. If spring floods are regular, there may be few logs as they might be washed away in floods, but snags may persist for a long time. Dead wood serves as a habitat for a large number of rare and sensitive species that are usually not found in intensively managed forests where there is little natural structure. For example, *Dendrocopos leucotos* may nest in forest stands where standing large-dimension deciduous dead wood of volume 10–20 m^3/ha is in a continuous area of at least 100 ha. However, in optimal habitats for the species, which are in good condition and from which the dispersal of the species takes place, about 55 m^3/ha of suitable wood is required in at least a 100 ha area (Czeszczewik, Walankiewicz 2006).

The presence and diversity of various structural elements indicate potential compliance with Woodland Key Habitat criteria and high ecological value (Ek et al. 2002).

16.1.4 Succession

Floodplain forests develop by the afforestation of fertile, flooded river and stream valleys, as well as in places with spring outflows, high groundwater table or seasonally dry streams, or in places where there is a high groundwater table and high soil moisture level at least during spring floods or flooding.

In Latvia, most river floodplains and fluvial terraces have formerly been used in agriculture or for wood harvest (Zunde 1999). Usually, *Alnus incana* initially colonises these overgrowing areas. *Alnus glutinosa* forests may develop on periodically flooded zones along rivers. Natural regeneration of *Alnus glutinosa* occurs relatively slowly. Flooding was the main factor that promoted the regeneration of *Alnus glutinosa* before large-scale hydrological management in river floodplains (Claessen et al. 2010). Gradually broad-leaved trees appear in the advance growth of such forests – *Fraxinus excelsior, Acer platanoides, Ulmus glabra* and *Ulmus laevis,* which form a stable stand over a longer period of time (Lārmanis 2013b). Habitat type 91E0 * *Alluvial forests with* Alnus glutino*sa and* Fraxinus excelsior *(*Alno-Padion, Alnion incanae, Salicion albae) develops, which may later transform into the habitat type 91F0* *Riparian mixed forests of* Quercus robur*,* Ulmus laevis *and* Ulmus minor, Fraxinus excelsior *or* Fraxinus *angustifolia, along the great rivers (*Ulmenion minoris*)* in the course of succession. According to criteria of the habitat, it does not occur along smaller rivers, although the tree layers and vegetation in the late stages of succession may be similar. A low volume of dead wood is characteristic to the pioneer phase of the forest. Natural processes result in the formation of structures of a natural forest and the associated biodiversity.

Sometimes the habitat type 91E0* *Alluvial forests with* Alnus glutino*sa and* Fraxinus excelsior *(*Alno-Padion, Alnion incanae, Salicion albae) has formed after the deposition of sediment and debris in meander loops of rivers, forming a new land area on which succession results in forest stands characteristic to the habitat.

Both habitats may form by the overgrowing of park-like landscape including grassland that has been used for hay making or grazing. This is particularly characteristic to the valleys of the greater rivers. In such cases biologically old, wide-crowned *Quercus robur* or other old broad-leaved trees of large-dimensions are found in the stands.

16.1.5 Pressures and Threats

16.1.5.1 Drainage

Drainage, especially in floodplain forests near small watercourses, has an adverse effect, which also includes the regulation of natural watercourses by their straightening and deepening, the construction of ditches and flood protecting dikes. In the second half of the 20th century, river straightening was widely carried out throughout Europe. The construction of flood barriers also belonged to these measures. In such a way, natural flooding was prevented, but rapid degradation of the rivers and the natural ecosystems on their shores, and a decrease of biodiversity took place as a result. Even if the characteristic species and structures have remained after straightening of a river, the river ecosystem has lost its principal function of flooding during high waters. This affects the circulation of nutrients, as previously organic matter accumulated in the former floodplain with the formation of a thick organic layer. The species composition of the groundcover changes with draining, and the habitat-characteristic microhabitats formed by floods and the species associated with them disappear (Urtāne (ed.) 2012).

Since drainage systems prevent flooding of floodplains and inundation in spring discharge sites, consequently causing changes in the soil, the plant species composition changes not only in the groundcover, but also in the canopy layer. A denser shrub layer forms, and *Picea abies* establishes causing soil acidification due to the altered chemical composition of litter. As a denser storey of herbs and woody plants forms, evapotranspiration increases, and the soil becomes even drier.

Picea abies may establish not only gradually in the process of succession, but also as a result of artificial regeneration. Drained peat and mineral soil forest types develop in places of former natural forest types. For example, in floodplains and former groundwater

discharge sites, *Mercurialiosa mel.* and *Oxalidosa turf. mel.* forest types develop on the drained soils, where *Picea abies* has often been planted. Thus, the growing conditions have been completely altered by changes that have occurred in the chemical composition of the soil, in light conditions and species composition of the groundcover, as well as in the soil fauna (Verstraeten et al. 2013).

16.1.5.2 Logging

Logging, especially clearcutting, has the most negative impact on floodplain forests. Clearcutting and also other types of final felling are not compatible with the existence of natural, diverse floodplain forest habitats if the oldest or largest trees are removed. After clearcutting, the input of nutrients in the plant biomass drastically decreases in the ecosystem, and the decomposition of organic matter and leaching of nutrients into the groundwater increase. Surface runoff also increases, which generally means that nutrients are drained from the forest stand. The rate of decomposition and denitrification of organic matter increase (Lībiete-Zālīte 2012), resulting in a change in composition of understorey species.

Management of the stand and felling of trees for timber harvest may decrease the volume of dead wood in the future, as well as reduce the number of trees that potentially become biologically old trees and form natural structures important for biodiversity in the future.

Sanitary felling where dead and dying trees are felled and removed is in sharp conflict with the habitat requirements of *Dendrocopos leucotos* and other bird species, because it reduces the amount of dead wood in the stand.

16.1.5.3 Beaver Activity

Beaver *Castor fiber* activity has a greater impact on smaller rivers and their floodplains. Forest stands and floodplain forest habitats on their banks become inundated after the building of beaver dams. The natural moisture regime with its characteristic seasonal level fluctuations changes, the soil becomes inundated, and the forest may die off in 2-3 years. The sedimentation of organic matter in the watercourse and the inundated territory increases, and paludification of soil begins. The plant species composition changes in wet conditions, and the characteristic species of the habitat disappear. Species composition is also affected by the selective feeding characteristic to beavers (Czerepko et al. 2009). Due to inundation caused by beaver, the number of species characteristic to wet deciduous swamp woodland increases in the herb storey, while the number of species characteristic to forests on river banks decreases. Species characteristic to floodplain broad-leaved tree forests disappear (such as *Anemone ranunculoides, Ranunculus cassubicus,* and *Plagiochila asplenioides*), while plants associated with stagnant waters appear – *Sium latifolium, Veronica scutellata,* and *Carex elongata* (Czerepko et al. 2009). In continuously inundated forests, a fen may develop after the dieback of trees.

Linear floodplain forests along rivers near beaver habitats are subjected to another risk; beaver feed on the bark of trees causing tree mortality. This is common near both small and great rivers where beaver do not create flood zones, but live in excavated bank lodges on river sides. Although sometimes only individual mature trees have remained in a forest stand and there are many stumps, the beaver activity in such cases is considered to be a natural disturbance, like after a wind storm.

16.2 Restoration and Management Objectives in the Conservation of Floodplain Forest habitats

The main objective of habitat protection is to ensure a favourable conservation status (*see Ch. 1*). It also means the conservation or restoration of an adequate hydrological regime, which is a prerequisite for the existence of the characteristic and rare species. One must also ensure the conservation of the necessary area and natural structures of the habitat to the extent that is sufficient for the long-term and stable existence of the typical and rare species associated with the habitat.

It is a priority to preserve a natural hydrological regime characteristic to the natural ecosystem or restore it.

16.3 Habitat Restoration and Management of Floodplain Forests

16.3.1 Habitat Conservation

Different approaches can be used in the conservation and management of floodplain forest habitats: (1) non-intervention or passive protection; (2) non-traditional management methods aimed at the creation and management of forests of a certain tree species composition, ensuring the ecological requirements of the target species (including protected species) (Götmark 2013); and (3) restoration of the hydrological regime (Anon. 2014a).

An undisturbed course of natural processes is optimal for the habitat, allowing the stand to develop naturally. Non-intervention means that no active human work takes place in the habitat that is associated with the felling of trees and shrubs, has impact on the soil, and there is no effect of vehicle movement and artificially created changes in the hydrological regime. Natural processes are not limited or disturbed. The forest does not usually require special management. When there is no human disturbance, dead wood gradually accumulates in the forest, which is needed for the invertebrates associated with dead wood (saproxylophagous), and the microclimate characterised by shade and stable air humidity remains. A moist microclimate is necessary for protected species of snails, fungi and saproxylophagous invertebrate species, as well as for many protected epiphytic bryophyte and lichen species.

Management of floodplain forests for the protection of forest habitat has not been carried out in Latvia. Economic activity along rivers has been limited for a long time in accordance with legal regulations. In the Soviet Period, a protected forest compartments were established along rivers, in which economic activity was prohibited (Fig. 16.8). Later, logging in floodplain forests was limited by other restrictions placed on permitted activities in river protection belts.

Management activities in floodplain forests are usually associated with the construction of tourism infrastructure, especially where there are *Tilio-Acerion* forests of slopes, screes and ravines occurring in combination with rock outcrops or springs. However, such infrastructure has only been established in small areas throughout Latvia. If popular tourist destinations are not equipped with stairways or footbridges, people create wider trails, promoting erosion and trampling of the vegetation. Proper management of the existing trails and redirection of the flow of tourists from sensitive sites is more important than the building of new trails.

Fig. 16.11. Floodplain forest zones along the River Ogre. Photo: S. Ikauniece.

If the natural hydrological regime has been interrupted in a floodplain forest due to a drainage system, habitat quality may be restored by preventing the negative effects of draining or by rewetting *(see Ch. 16.3.2)*. Prior to this, the territory should be carefully surveyed, assessing the possible impact of restoration on adjacent territories in a wider scale and taking into consideration that the activities should not worsen their status and management potential.

If the priority is to restore the floodplain regime in a large continuous drainage system, the works may include the restoration of a wider habitat complex (forests, grasslands, watercourses) associated with stabilisation and raising of the water level, restoration of the seasonal flooding regime, filling of ditches, diversification of the structural diversity of forest stands and other activities. In the case of degraded floodplains, it is always useful to assess the possibilities of habitat restoration in as large a territory as possible during the planning stage, as this will increase the efficiency of habitat restoration.

In order to ensure a qualitative habitat structure that is necessary for the existence of the typical, protected and rare species associated with it, a number of methods can be used: diversifying of stand structure *(see Ch. 16.3.4),* promoting development of the vegetation characteristic to the habitat by felling *Picea abies* (*see Ch. 16.3.3)* and pioneer tree species *(see Ch. 16.3.5)*. In specific cases, measures to extend the survival of biologically or culturally-historically valuable trees may be carried out in specific cases to improve the species habitats or scenic value *(see Ch. 16.3.8)*. Floodplain habitats tend to be complex territories including other protected habitats, and therefore it is necessary to consider the conservation requirements of other habitats as well, such as management requirements for river banks or springs (*see Ch. 16.3.8)*. The spread of invasive plant species causes threat to habitat quality in floodplain forests and river banks. Chapter 16.3.7 focuses on the control methods of three vascular species.

Table 16.1 summarises methods of restoration of floodplain forest habitats and the improvement of their status, as well as their advantages and disadvantages.

Table 16.1 Management methods of floodplain forest habitats.

Method	Ecological benefits	Disadvantages
Elimination of the negative effects of drainage; rewetting (filling of ditches; dams; elimination of flood barriers)	Renewed flood and/or hydrological regime characteristic to the habitat. Restoration of the vegetation structure characteristic to the habitat.	Adjacent territories can be negatively affected if risks are insufficiently evaluated.
Reduction of the proportion of coniferous species by felling	Cutting of *Picea abies* in the subcanopy and canopy layer promotes the development of a vegetation characteristic to broad-leaved forests.	Possible damage to the soil and the ground cover, carrying out work at an unsuitable time and with inappropriate equipment.
Diversification of the structure of forest stands, increasing the volume of dead wood and creating gaps	Diversified structure of forest stands. Created ecological niches for species that depend on the presence of dead wood.	Possible damage to the soil and the ground cover, carrying out work at an unsuitable time and with inappropriate equipment.
Tending in stands of pioneer species	Increase in proportion of species characteristic to the habitat, improving of stand structure.	None.
Exposure of biologically valuable old and/or scenically important trees to the sun	Prolonged survival of biologically and scenically valuable trees. Improved living conditions for species dependent on old trees.	Possible damage to the soil and the ground cover, carrying out work at an unsuitable time and with inappropriate equipment.
Control of invasive plant species (digging, cutting)	Decreased adverse effects and reduced area occupied by the invasive plant species. Improved composition of understorey species, promoting a higher proportion of native plant species characteristic of the habitat.	Incorrectly implemented measures may promote the spreading of invasive plant species.
Felling of undesirable trees growing on river banks, ensuring the desired shade mosaic to the river section	The desirable shade mosaic is ensured in the river. Falling of trees into the river is reduced. The undisturbed flow of the river is improved; The biodiversity of the river section is conserved and/or increased.	There is a risk of interrupting the existing microclimate (moisture and shading).
Establishment of infrastructure at popular springs – water taking and religious sites.	The adverse effect of the visitors on the ground cover and soil (trampling) has been prevented.	Incorrectly performed management may negatively affect spring discharge sites and increase the impact of visitors (trampling) on the natural vegetation and soil.

16.3.2 Rewetting

Spring flood regime is the main process for the existence of floodplain forest habitats. The refore, rewetting is almost always a priority activity in restoring the natural processes of floodplain forest habitats. Rewetting is most often needed in areas were drainage ditches have been dug and the river has been straightened, interrupting the spring flood regime. The measure can be implemented as a priority in areas where the natural river bed and the spring flood water regime has still remained.

Most often there is no use in carrying out other habitat management works in drained floodplain forests, if the draining impacts have not been eliminated. Without restoring the spring flood regime, floodplain forest habitats cannot exist in the long term with their characteristic species diversity. Rewetting of floodplain forests must be carried out together with the restoration of the river flow and of microniches – only then will habitat restoration be effective and sustainable.

One of the methods for rewetting are activities that promote natural processes. This means that the natural physicochemical and biological processes are renewed in the river, such as oxygenation. By placing barriers in the river, large stones being the best, coastal erosion will intensify with the formation of meanders, and in a longer period of time create natural patterns of bends (Cowx, Welcomme 1998). This is not possible in all cases, especially if very deep ditches have been constructed, and when the formation of meanders is expected to take a long time, even several decades. As the drainage system above the restored bent river section remains, the high water regime cannot be renewed by only making the river bed more natural. Since the formation of meanders in the river impedes runoff and raises the water level, part of the lower sections of drainage systems cease functioning as a result of these activities, especially if agricultural land with a closed drainage system is situated in the section. Rewetting must be planned as a complex of restoration activities, including elimination of the drainage system in a wider area, i.e. in the zone where rewetting of floodplain forests is planned, if allowed by other considerations. It is important to consider the topography of the area, such as whether the floodplain is located on a lowland or an upland, as well as the soil type.

If there are ditches in floodplain forests through which water rapidly flows away during spring flood, methods described in detail in the management guidelines for the habitat type 9080* *Fennoscandian deciduous swamp woods* may be applied *(see Ch. 13)*. In this case it is recommended to fill ditches instead of creating dams, in order to create free water flow throughout the floodplain during spring flood. It is necessary to carefully assess the possibilities of rewetting and also drainage systems in the wider vicinity. Most probably it will not be possible to fill ditches that drain water from a large area. However, it will be possible to fill small ditches that only drain the floodplain, the elimination of which does not cause changes in a wide territory, thus adversely affecting areas that can be used economically (agricultural and forest lands, populated areas). The elimination of flood barriers would also have a positive effect on the high water regime, but this method is only a theoretical possibility, especially near populated areas.

Rewetting is not possible in all cases, especially in habitats where there have been sites of underground spring discharges that have been degraded and likely with irreversible adverse effect.

16.3.3 Reducing the Proportion of Picea abies

If the natural spring flood regime in floodplains has been altered or interrupted and drainage ditches have been created, the drier growing conditions promote the establishment of *Picea abies* trees in the advance growth of broad-leaved forests, which otherwise could not survive the natural flooding conditions. Over a longer period of time the litter of *Picea abies* causes soil acidification and the introduction of boreal groundcover species. In general, massive establishment of *Picea abies* in floodplain forest habitats indicates drainage. Very rarely it may occur in the course of natural succession in habitat type 91F0* *Riparian mixed forests of* Quercus robur*,* Ulmus laevis *and* Ulmus minor*,* Fraxinus excelsior *or* Fraxinus angustifolia*, along the great rivers (*Ulmenion minoris*)*. Thus, the restoration of floodplain forest habitats should always be carried out both by rewetting and by felling of *Picea abies* trees that established after drainage. Although felling of *Picea abies* in floodplains without rewetting will only have a temporary effect, it may still be carried out in order to improve the species composition of the habitat.

The felled trees and branches must be removed from the forest stand. Felling of *Picea abies* in wet stands must only be carried out without heavy equipment to avoid soil damage and compaction, and damage to water discharge sites. It is best to carry out the activities during winter when the soil is frozen.

16.3.4 Diversification of the Forest Stand Structure

Natural habitat structure can be improved by diversification of the forest stand structure. This is necessary if the pioneer species *Alnus incana* dominates in forest stand, which indicates the young forest stand and the absence of disturbances. Pioneer *Alnus incana* forests in the early stages of succession

Restoration of floodplains

Restoration of floodplain forest habitats has not yet been carried out in Latvia. The restoration of the natural flow of rivers (bending) and restoration of the spring flood regime in floodplain grasslands has been performed by two LIFE projects – in the River Slampe in Ķemeri National Park in 2005, and in "Dvietes paliene" Nature Park in 2004. It has been concluded that the best solution for restoring the high water regime is filling ditches instead of building dams. By restoring the spring flood regime in such projects, the habitat conditions for birds such as geese, various waders, and corncrakes, have been improved both in the periods of migration and breeding (Priede et al. 2015).

The LIFE+ project HYDROPLAN in Ķemeri National Park plans to restore the river bed in degraded alluvial forests in 2017, restoring the characteristic flooding, promoting the restoration of the conditions suitable for the species associated with this habitat.

Restoration of the floodplain in Arnsberg forests in Germany

The natural flow of the river and the alluvial forests was restored during the LIFE project "Stream Valleys in the Arnsberg Forest" (2009–2014) in Germany. Both the watercourse in its natural bed and the floodplain forests were restored during the project. *Picea abies* trees were removed and the natural development of vegetation was promoted (Fig. 16.12).

Fig. 16.12. Restoration of the natural flow and the vegetation characteristic to the floodplain. Photo: K. Lapiņš.

Before the the project was commenced careful mapping was carried out to identify the characteristic conditions and the river sections to be restored. Various habitats were marked in the maps and planning was carried out by identifying the sections where the natural flow of the river should be restored and where *Picea abies* trees should be removed. Two main principles were observed when removing the *Picea abies* trees: heavy equipment was not used on the sensitive soil of floodplains, and the felling residues of *Picea abies* was left on site as rarely as possible. These were essential prerequisites in order to restore floodplain forests with the characteristic understorey vegetation rich in species (Anon. 2014a). The implemented activities included complete replacement of the dominant species in floodplain forests by felling all *Picea abies* trees including single trees which had developed after the straightening of the river as well as complete *Picea abies* plantations. Three types of areas were distinguished: (1) even-aged *Picea abies* stands with individual *Alnus glutinosa* trees along watercourses; (2) stands with old *Picea abies* trees, which border with alluvial forests with *Alnus glutinosa* or *Quercus robur*, and where the advance growth contains broad-leaved trees; and (3) alluvial and *Picea abies* forests, where *Picea abies* trees regenerate naturally. Both large and small *Picea abies* trees were felled and naturally established *Picea abies* seedlings were weeded manually. Tree roots were extracted and the felling residues were removed. In areas where the natural regeneration of deciduous trees was problematic, they were planted and the young trees were fenced in order to avoid animal damage. By establishing a water regime that is close to natural, the restored watercourse promoted the formation of a natural mosaic vegetation. Shading was reduced, and it was possible for the tree species characteristic to the floodplain to develop (Anon. 2014a).

that have invaded agricultural land are not classified as protected floodplain forest habitats (Lārmanis 2013b). Diversification of the forest structure in these stands can only be carried out if it is decided to create wider territories of future habitats.

By diversifying the forest stand structure, better growing conditions for broad-leaved trees are created. Small gaps (< 15 m in diameter) can be created, felling up to 30% of the total standing volume and leaving dead wood on the ground (Kuris, Ruskule 2006). However, it should be considered that in regularly flooded areas, logs may not remain on the ground for a long time, as the flood waters may float them away. The creation of openings is only recommended when the stand density exceeds 0.7 (Kuris, Ruskule 2006). If increasing of the dead wood volume is planned together with forest diversification, it is recommended to choose trees of large dimensions with a diameter of at least 25-35 cm, which are left on the ground after felling. Deciduous trees like *Alnus incana, Betula spp.* and *Populus tremula* should be selected for felling, while broad-leaved trees are retained. The height of created stumps can vary.

16.3.5 Creation of the Characteristic Tree Species Composition of Floodplain Forests

The formation of the characteristic tree species composition of the floodplain forest habitats may be promoted if pioneer species like *Alnus incana* or *Betula pendula* dominate in a young forest which has developed by overgrowth of agricultural land or naturally regenerated after clearcutting. It is more appropriate to carry out these activities in habitat type 91F0 *Riparian mixed forests of* Quercus robur, Ulmus laevis *and* Ulmus minor, Fraxinus excelsior *or* Fraxinus angustifolia, *along the great rivers (*Ulmenion minoris*)*. It can also be done in territories that do not yet qualify as EU protected floodplain forest habitats, for example, in overgrown agricultural lands in the initial stages

Fig. 16.13 Floodplain forest dominated by *Alnus incana* with *Ulmus glabra* undergrowth. Photo: S. Ikauniece

of succession, but where forest stands conforming to protected floodplain forest habitats may develop in the future (Fig.16.13). This should be preferred in territories near natural or little affected floodplain forests in order to decrease the adverse impact of fragmentation and to increase the continuous area of floodplain forests.

The aim of the action is to promote the increase of broad-leaved tree species in the forest stand and the introduction of broad-leaved forest characteristic plant species in the groundcover. In the planning stage it must be determined if suitable conditions exist for the development of broad-leaved tree species: whether saplings of *Fraxinus excelsior*, *Tilia cordata*, *Acer platanoides* and other broad-leaved trees occur in the shrub layer, and whether the habitat-characteristic plant species appear in the groundcover. Trees of pioneer species (*Alnus incana, Betula spp.*) should be selectively felled at low intensity or up to the minimum number of trees or up to the minimum basal area in accordance with legal regulations. Felling can be carried out in areas of 0.05 to 0.1 ha, imitating the formation of openings.

In order to promote the diversity of structural elements, the felled trees are left on the ground, increasing the volume of dead wood. This increases the diversity of species associated with decaying wood (invertebrates, fungi, mosses).

16.3.6 Exposure to the Sun of Biologically Valuable Old Trees

If there are trees in the forest stand that have clearly been previously growing in an open place, and they are important habitats for species associated with broad-leaved trees exposed to the sun, gradual felling of younger trees and trees in the crown projection can be conducted. Such biologically old, large broad-leaved trees (most often *Quercus robur*, *Fraxinus spp*., *Tilia cordata*) found in floodplain forests serve as habitat for various beetles and other invertebrates, and their bark is a substrate for epiphytic bryophytes and lichens. Depending on whether such trees are sun-lit or whether they have been growing in the shade, they may be inhabited by various species. The trees may also have a high scenic and cultural-historical value.

Exposure of biologically valuable old trees to the sun may be carried out in two cases.

- If it is necessary to improve the conditions for light-loving species inhabiting biologically old large broad-leaved trees that are well-lit. The cutting around large trees should be carried out in cases when it is planned to restore or maintain a park-like landscape of a larger area, and there are wooded meadows and pastures, as well as other forest stands nearby with the occurrence of species dependent on large, well-illuminated trees (Ek, Johannesson 2005) (more – Rūsiņa (ed.) 2017, *Ch. 19*)
- If there are old, wide-crowned trees in places important for tourism and the conservation of cultural-historical values, along the nature trails, or in scenic sightlines or landscapes with high aesthetic value that are historically linked with individual old trees or their groups. In this case, the felling of individual trees is not as much associated with increasing biodiversity as with the creation of the landscape and conservation of cultural history elements. However, thinning around large trees along the trails and in sightseeing spots may also have a favourable effect on the light-loving species associated with large, old trees. It is never desirable to fell large old trees or remove dry standing trees, as species specialised for such conditions often inhabit these trees. Also, these trees are usually scenically important, and with the adequate public information available they can serve as good objects for nature education.

If younger trees grow into the canopies of biologically old, large deciduous trees, especially regarding *Picea abies*, which unfavourably affects survival of the old trees, it is best to remove them at least in the crown projection area, even if it has generally been decided not to disturb the forest. Cutting of trees and shrubs in the crown projection zone improves light conditions and air circulation, reducing humidity and shade. It may prolong the life of the old trees, which thus serve for a longer period as habitats for threatened insects of rare occurrence, such as *Liocola marmorata* (Vilks 2014).

16.3.7 Control of Invasive Plant Species

Watercourses and coastal habitats are significant distribution corridors for species, including invasive plant species. Proximity to water ensures seed dispersal over long distances, promoting the introduction of invasive plants and increase of their occupied territory. Thus, the invasive plants can take over river banks, fully displacing the native species characteristic to this habitat.

The main factor in controlling the spread of invasive plant species is not to allow the seeds or propagules of invasive plants to reach floodplain forests and their vicinity, for example, with garden waste. When such species have already been introduced in the forest plant community, their control is very difficult and time-consuming, the work must be repeated multiple times, and the prospects of eliminating these species completely are low. Insight into the control of invasive plant species of frequent occurrence in floodplain forests is provided here. One of the most frequently found invasive species in forest habitats on river banks in Latvia is *Heracleum sosnowskyi*. Its spread is quickened by land abandonment, as these areas became suitable for *Heracleum sosnowskyi*. The spread of *Heracleum sosnowskyi* is promoted by the production of many seeds that are dispersed by wind, water and birds. In spring *Heracleum sosnowskyi* germinates very early and can out-compete plants typical to the habitat.

Four methods of controlling *Heracleum sosnowskyi* are applied in practice – mechanical, chemical, biological or combined (VAAD *without date*). The chemical method by using herbicides is not allowed on coasts of watercourses to avoid polluting water with toxic compounds.

The biological method (grazing) is almost unusable for practical reasons, the invasive plants are found along the watercourses, which are usually difficult to reach for cattle, and organic fertiliser left by cattle leaches into the water affecting its quality.

The only practically applicable method in floodplain forests is mechanical control of the plants, which may be implemented with manual tools. The method is based on the biology of the plant. *Heracleum sosnowskyi* dies after flowering and seed maturation. If *Heracleum sosnowskyi* is cut before flowering and ripening of seeds, the plant will die naturally. To ensure the death of plants, flowering stems of *Heracleum sosnowskyi* should be cut at the start of flowering before the end of June, and repeated before mid-August).

Heracleum sosnowskyi can be eliminated or at least localised by piercing a shovel or a similar tool through the main flowering stems of *Heracleum sosnowskyi* at 5–10 cm soil depth. If the method is applied in spring, it should be repeated at least 2-3 times during the season and, if necessary, for several years in a row, because of possible vegetative regrowth of *Heracleum sosnowskyi* from rhizomes and the establishment of new plants from the soil seed bank. Both methods are effective in small areas in order to localise individual plants in the early stages of invasion (Nielsen et al. 2005).

A relatively effective but expensive method is to cover plants with light impervious sheets, limiting the plant's photosynthesis. The sheet must be applied at the beginning of the vegetation season and must be kept in place for three months while the plant dies (Pyšek et al. 2007). This method is more suitable for open non-forest areas, as the application and fixing of sheets in a forest is very difficult due to trees and shrubs, and it may be damaged by the forest animals.

All the excavated and cut parts of the *Heracleum sosnowskyi* that are able to regenerate (root fragments, flower clusters with seeds, also those that are not ripe) must always be collected and burnt, or otherwise, to ensure that the plants will not newly establish. Abatement of *Heracleum sosnowskyi* must be carried out very carefully, as it is possible to get burnt by the sap. Clothing must be used that does not allow skin contact with plant sap, preferably special clothing and safety goggles. Waterproof gloves must be used for the collection of the cut plants.

Impatiens glandulifera (Fig. 16.14) is commonly found in floodplain habitats. *Impatiens glandulifera* may reach a height of 3 m, shading other species and causing their loss, and creating a sparse herb layer. Soil becomes unstable, which causes extensive

Fig.16.14. *Impatiens glandulifera*. Photo: A. Priede

erosion of river banks and leaching of nutrients. Since *Impatiens glandulifera* is an annual plant, its control is easier than that of perennial plants.

For abatement, mechanical methods can be used, such as cutting the plants or tearing them out with roots before seeds have matured or even better, before flowering. They should be cut as early as possible, at the time when only a few plants have invaded the territory. The cut and torn-out plant parts must be removed from the habitat if plants have already flowered. The measures must be repeated for several years, as the seed bank can survive in the soil (Pyšek et al. 2007; Hejda 2012).

Another invasive plant of the same genus, *Impatiens parviflora,* is common in floodplain forests that have been drained, and less frequently in natural floodplain forests. The species is annual and spreads only by seeds. Its impact on biodiversity depends on the conditions of the specific site (Tanner 2008) (see more in *Ch. 11.3.6*).

In Latvia there are also a number of other invasive species found near rivers, particularly in the vicinity of populated areas (e.g. *Acer negundo* is frequently found on river banks, and *Swida spp*. and *Spirea spp*. have spread in some wet forests). Their control is also difficult (repeated cutting, root extraction, removing the cut biomass), and it must be repeated several years in a row. Application of herbicides may be more effective, but is not allowed near rivers as there is a high risk of pollution to the surface waters resulting in the loss of characteristic native species, especially invertebrates.

16.3.8 Ensuring Favourable Conservation Status of Habitats of Rare Species and Other Habitats

16.3.8.1 Watercourse Management

The need for watercourse management in floodplain forests should be analysed in a wider scale, assessing the landscape structure and land use outside the forest. If the watercourse is flowing through an agricultural land without trees on the banks, trees on the banks should not be felled in floodplain forest habitats, as the protected habitat compensates the lack of shade in the area of agricultural lands. The only trees felled in high quality floodplain forest habitats should be those that have inclined over the river and might break or flow with water currents, causing undesirable barriers to the river flow, promoting a decrease of biodiversity. The shaded mosaic recommended for a river section is to create a mosaic of 3:1 for shaded: sun-lit section length.

The trees removed from the river and those felled on the bank must be left on the bank by lifting them out of the water and placing them above the flood level. This type of felling is more important when there is a secondary *Alnus incana* stand in the self-thinning stage, or if it is needed for the improvement of a protected species habitat, such as for *Margaritifera margaritifera* or *Unio crassus* (in more detail – Urtāns (ed.) 2017, *Ch. 17.3*).

16.3.8.2 Protection of Springs and Spring Discharges

Springs may outflow on the slopes of river and creek valleys and ravines, as well as in floodplains. The outflow sites of springs may form a wider spring discharge with many seepages of low intensity, or flow out in a small area with a relatively large discharge forming a creek.

The best protection of springs, spring discharges and the surrounding area is no interference in the natural processes, by not popularising them and by not including them in tourism routes or territories for sports races, as well as by not allowing any use of heavy equipment in spring discharges and near them for the purposes of logging, sports, leisure and other.

If springs are used for water taking and are often visited by people, suitable infrastructure must be constructed (footbridges, platforms, stairways) in order to prevent trampling of the groundcover. The same applies to springs that are frequently visited as ancient religious sites. Sometimes simple solutions are the use of wooden planks or boulders for stairs to avoid the need for wading by visitors in the spring zone. More complex solutions like stairways, footbridges, information signs and barriers are required in other situations to limit extensive, degrading load on the groundcover.

16.3.9 Management Unfavourable to Floodplain Forests

Selective felling of trees for wood harvest reduces the volume of dead wood in the future, as well as the number of trees that will potentially become biologically old trees. The habitat is also adversely affected by the felling and removal of dead and dying trees, as this, for example, is in sharp conflict with the habitat requirements of *Dendrocopos leucotos* and other bird species, because it reduces the volume of the dead wood in the stand.

In some sites, most often near the great rivers, an adverse effect of water tourism is possible by camping in the protected habitat. The dead wood is used for camp fires, and there is also a possibility of local trampling and pollution with municipal waste.

If the floodplain forest habitat formed after an overgrowth of park-like landscape, which was formerly used for hay making or pasturing, in some cases it is needed to restore the historical landscape for the protection of some species or for the conservation of a historically highly valued landscape. In such cases transformation of the forest might be needed by felling the forest and totally changing the conditions of the existing habitat. Before implementing such important changes, a detailed study of the territory and a sound argument is needed, after the evaluation of the impact on other protected species.

16.4 Conflicts of Conservation and Management

The habitat management may be inconsistent with the requirements of rare and protected species dependent on the presence of the structures of mature broad-leaved trees characteristic to natural forests and the non-intervention regime.

If a floodplain forest habitat formed as a sparse park-like woodland or wooded meadow, the possibility and necessity to restore habitat 6530* *Fennoscandian wooded meadows* should be considered in some cases. This may be important in order to conserve a rare, protected species population that depends on the former land use, such as *Osmoderma barnabita* (sin. *O.eremita*). Restoration of wooded meadow landscapes in areas that have overgrown with forest should only be carried out after detailed landscape-ecological planning, evaluating the occurrence and ecological needs of all protected species to the greatest extent possible, also taking into account the recommendations in species conservation plans (such as Bāra (ed.) 2014; Lārmanis et al. 2014b). Sometimes the creation of favourable conditions for one species can create unfavourable conditions for another species. Restoration of the tree stem insolation characteristic to a wooded meadow landscape may have a negative effect on lichen species (such as *Collema* spp.) that have colonised tree stems in shaded conditions. In such cases, the rarity, threat, and importance of the particular site in the conservation of the species must be taken into consideration, and only then should the decision on the purpose and methods of habitat restoration or management be made.

Chapter 17. 91D0* Bog Woodland

17.1 Characteristics Of Bog Woodland

17.1.1 Brief Description

The EU protected habitat type 91D0* *Bog woodland* includes coniferous, broad-leaved and mixed forests on periodically or constantly wet mineral soils and peaty substrates poor in nutrients. In Latvia, forest stands on soils that are medium-rich in nutrients (mesotrophic) are also included in this habitat. Habitat type 91D0* *Bog woodland* covers about 3% (2000 km^2) of the territory of Latvia (Bambe 2013c). The habitat is relatively common in Latvia, and almost the entire national territory (Fig. 17.1) contains large continuous areas in raised bog complexes and edges of bogs.

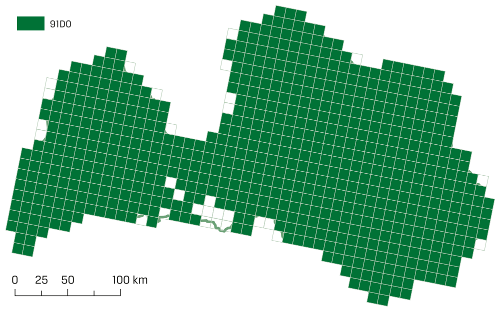

Fig. 17.1. Distribution of the habitat type 91D0* *Bog woodland* in Latvia (Anon. 2013c).

A constantly high groundwater table is characteristic for bog woodlands, but it may be variable in forests on wet mineral soils. The thickness of the peat layer may vary. In wet, poor sand soils after burning (site type *Cladinoso-sphagnosa* (poor *Pinus sylvestris* forests on wet, sandy soils with an impervious shallow soil horizon), overgrowing wet heathlands) it may be thinner, but the characteristic groundcover shrub and dwarf shrub species can also be found on substrates with a thin peat layer. Bog woodlands may also often form in periodically flooded wet lowlands (Bambe 2013c).

The forest stand can be formed of *Pinus sylvestris*, *Betula pubescens*, *Picea abies* and *Alnus glutinosa*. The groundcover structure is characterised by a hummock microtopography, with a mosaic of dwarf shrubs (*Ledum palustre*, *Andromeda polifolia*, *Oxycoccus palustris*, *Vaccinium uliginosum*).

In Latvia there are three variants of the habitat, which to some extent also determine the necessary management (Bambe 2013c).

variant 1 (typical): peat-land forests on wet peaty substrates, where the peat layer is thicker than 30 cm, in poor or medium rich growing conditions, with slightly or medium decomposed peat. *Pinus sylvestris* stands that have developed by overgrowth of raised and transitional mires in a process of succession are included in the habitat (Fig. 17.2).

Fig. 17.2. Variant 1 of habitat type 91D0* *Bog woodland*. Photo: S. Ikauniece.

variant 2: swamp forests in poor or medium rich growing conditions with a peat layer at initial stage of formation, of less than 30 cm in thickness.

variant 3: drained bog woodlands, if drainage systems work weakly and hygrophytic species are found in groundcover, and the habitat quality corresponds to the criteria of Woodland Key Habitats or potential Woodland Key Habitats.

Pinus sylvestris stands on the edges of raised bogs, developed as a raised bog overgrew after draining, do not belong to this habitat. Also the mosaic *Pinus sylvestris* stands on hummock-ridge bogs in the largest raised bogs do not belong to this habitat, such as in Teiči Bog, where they have formed in the natural development of the bog and are a characteristic element of the bog structure.

17.1.2 The Features of Favourable Conservation Status

The favourable conservation status of the habitat is characterised by an unchanged hydrological regime – a constantly or seasonally high water table and wet slacks. Peat accumulation occurs. There are no active human activities related to tree or shrub cutting or the impact on the soil or groundcover. Due to non-intervention, there is a great deal of dead wood in old forests, which is a habitat for saproxylophagous invertebrates and species of other organism groups. The presence of natural forest structures, such as logs, snags, stumps, biologically old trees and slowly growing trees indicates a favourable conservation status.

Oligotrophic *Pinus sylvestris* and *Picea abies* forest communities are characteristic to bog woodlands, but mesotrophic coniferous communities and mixed *Betula spp.* and *Alnus glutinosa* communities can also be found. The EU protected habitat type 91D0* *Bog woodland* corresponds to the plant communities *Vaccinio Piceetea* or *Piceo-Vaccinienion uliginosi* (*Betulion pubescentis*, *Ledo-Pinion*), less frequently to *Alnetea glutinosae* (the poorest variant of *Alnus glutinosa* with *Sphagnum* and boreal forest species in the understorey) (Brūmelis 2015). After M. Laiviņš (2014), plant community associations *Vaccinio uliginosi-Pinetum, Vaccinio uliginosi-Betuletum pubescentis* and *Ledo-Pinetum* are related to this habitat. A slow growth rate is characteristic to the trees. The height and diameter of biologically old trees are small. Densely whorled branches of *Picea abies* indicate low annual growth increment.

Groundcover is dominated by *Sphagnum* species: *Sphagnum angustifolium*, *Sph. capilifoliium, Sph. girgensohnii*, and *Sph. russowii*. Characteristic herb species are *Eriophorum vaginatum,* and various *Carex* spp. (*Carex cinerea*, *C. nigra*, *C. globularis*, and *C. echinata*). Characteristic vascular species like *Calla palustris*, *Comarum palustre*, and *Menyanthes trifoliata*, have adapted to wet growing conditions.

Moss species are also common, such as *Polytrichum commune*. In places where burning or other disturbances have occurred, hummocks of *Polytrichum juniperinum* develop (Marozas et al. 2007). Characteristic mosses (*Pleurozium schreberi* and *Hylocomium splendens*) of coniferous forests on dry mineral soils are found only on the raised microtopography. Dwarf shrubs, especially *Ledum palustre,* are common, but they do not form wide, continuous stands.

The habitat is an important living habitat for rare epixilous moss species and hygrophytic vascular plant species, such as *Listera cordata*. Rare shrub species are associated with bog woodland, such as *Betula nana*, *Betula humilis*, and *Salix myrtilloides*. Among natural structures found in the habitat, dead wood in different stages of decay is an important substrate for rare liverworts *Anastrophyllum hellerianum, Lophozia ascendens,* and *Odontoschisma denudatum,* as well as for the very rare lichen *Cladonia parasitica* (Bambe 2013c). Lichen *Evernia divaricata* may occur on the branches of coniferous trees. Bog woodlands of *Pinus sylvestris* are particularly important for the protected bird species *Tetrao urogallus* (Petriņš 2014). The characteristic complex of protected and rare invertebrate species of the habitat includes saproxylophagous species inhabiting *Pinus sylvestris*, *Alnus glutinosa* and *Betula pubescens* trees. Bog soils and the characteristic groundcover plants are inhabited by invertebrate species, such as *Necydalis major*, *Carabus clathratus*, and *Erebia embla*. Some rare species inhabit can be found both in bog woodlands and habitat type 9010* *Western Taiga*, such as *Boros schneideri* and *Tragosoma depsarium* (Vilks 2014).

17.1.3 Important Processes and Structures

17.1.3.1 Processes

Important processes of the habitat are associated with wet conditions and a relatively stable water level, which may fluctuate depending on the amount of precipitation and season, but sudden seasonal changes are not typical. The exception is poor *Pinus sylvestris* forests on wet, sandy soils where the hydrological regime is determined by an impervious ortstein (hardpan) layer, which creates very wet conditions during autumn and spring when the water level exceeds the ground surface, but dry conditions in summer. Due to excess humidity, anaerobic conditions are created that limit the rate of decomposition of organic material and promotes **the formation and accumulation of peat**. As in mires, this indicates favourable conditions in the habitat.

Gap dynamics are characteristic to the habitat, whereby openings form in the tree canopy. Individual trees or small groups of trees die as a result of a wind-throw, snowbreak, insect infestation or as the trees become very old. Gaps gradually overgrow with new trees, while new openings form in other places. Uneven-aged stand structure and an open mosaic are characteristic, with many standing and fallen dead trees in various stages of decay.

Like boreal forests, bog woodlands may also be disturbed by fires, however, much less frequently. **Burning** in bog woodland occurs very rarely, usually after longer periods of drought, when the peat has dried out.

Not only the soil cover, but also part of the peat layer burns in a fire, thus the burning process is slower and longer than in forests on mineral soil. Consequently, a large part of the living trees die. In such areas, *Betula spp*. stands often develop after fire (Fig. 17.3).

Fig. 17.3. Bog woodland naturally regenerated after a fire in Lithuania. Photo: S. Ikauniece

Fig. 17.4. *Ledum palustre* young sprouts after a fire in Ādaži military training area. Photo: S. Ikauniece.

The fire intensity in wet forests on wet mineral soils is lower, as the peat layer is thinner. Dwarf shrubs die in the fire, but in the same year their rapid regeneration can be observed (Fig. 17.4).

17.1.3.2 Structures

Tree growth in bog woodlands is slow compared to that in other habitats, and small dimensions are characteristic to biologically old trees. Natural forest structure with characteristic elements develop and change very slowly, and the replacement of tree species also occurs very slowly over a long period of time.

The major elements of a natural forest stand structure are coarse woody debris, biologically old or (relatively) large trees, canopy gaps etc. (*see Ch. 1*). The presence of these structural elements indicates potential compliance with Woodland Key Habitat criteria and high ecological value. Natural structural elements serve as habitats for many specialist species that are not usually found in intensively managed forests where there are little natural structures (Ek et al. 2002). For example, *Tragosoma depsarium* inhabits logs of *Pinus sylvestris* that are raised above the ground, and *Nothorhina muricata* selects sun-lit biologically old *Pinus sylvestris* trees, which are available in natural bog woodlands due to a lack of dense *Picea abies* advance growth.

For a forest to be considered the EU protected forest habitat type 91D0* *Bog woodland,* it does not have to totally conform with the quality criteria of a Woodland Key Habitat (Bambe 2013c), but the presence of the characteristic structures and Woodland Key Habitat indicator species or specific species of the habitat are essential quality indicators.

17.1.4 Succession

The determining factor for the development and existence of bog woodland habitat is wet conditions. Bog woodlands develop in relief depressions, as well as on the edges of mires, most often – raised bogs. As in other parts of the boreal and boreo-nemoral zone in the northern hemisphere, mires in Latvia formed in the post-glacial period as lowlands paludified and water bodies overgrew. The paludification was promoted and is still promoted by the dominance of precipitation over evaporation, which is characteristic in Latvia (Kalniņa 2008). Paludification in Latvia is also promoted by poor natural drainage of soils in relief depressions and sites with flat topography as well as outflow of groundwater under pressure (Zālītis 2012). The formation of bog woodlands continues nowadays, as mires overgrow and mineral soil paludifies, for example, in relief depressions and interdune slacks.

Forest types both on wet mineral soils and on wet peaty substrates may conform to habitat type 91D0* *Bog woodland* according to the forestry typology used in Latvia. Forest types on wet mineral soils have a layer of peat thinner than 30 cm. Forest types on wet peat soils have a layer of peat thicker than 30 cm, and have formed either from forests on wet mineral soils, as the layer of peat formed over the course of time, or as mires overgrew. Under the prolonged influence of inundation, forests on wet peat soils may become bogs, as the soil paludifies and peat accumulates (Bambe 2013c; Liepa et al. 2014).

Bog woodlands have developed in various conditions. They may form on mineral soils, as **the paludification process occurs** without a mire stage, or the mire stage has been short. Such forests, especially paludified *Picea abies* woods, may also form in spring discharge sites. Bog woodlands that developed from **overgrown bogs** form a complex of wetland habitats with raised bogs, where the occurring processes are interrelated. Raised bogs in Latvia are considered as the climax (final) stage of succession. However, if the bogs become drier because of natural reasons or due to human activities, or as they reach the final stage of the development, they gradually overgrow with trees (Kalniņa 2008). Stumps found in peat layers indicate that bogs and forests can replace one another several times over a very long period of time due to climatic conditions.

Bog woodlands may also form by overgrowth of fens and transitional mires, without the raised bog stage. In such forests there are richer growing conditions than in forests that have developed on overgrown raised bogs, there is a larger admixture of *Picea abies* in the forest canopy, and a unique species composition that is not found in oligotrophic bog woodlands is often characteristic; for example, the rare orchids *Listera cordata* and *Corallorhiza trifida* may occur.

In the course of natural processes structures of a natural forest form and the biodiversity associated with them increases.

17.1.5 Pressures and Threats

17.1.5.1 Drainage

Establishment of drainage systems to increase timber harvest is the main cause of degradation of bog woodlands. In the 19th century, as the area of agricultural land increased at the expense of forest areas, there was a lack of fire wood and timber. Therefore, land drainage was started in the 19th century in order to increase productivity. Later it was attempted to combine forest draining systems with log driving. Systematic forest drainage started in 1929 (Zālītis 2006). Up to the year 1941, 224 500 ha of forest lands were drained, and the total length of ditches exceeded 13 000 km (Vasiļevskis 2007). Peat extraction and drainage of bog woodlands to increase forest productivity was particularly intensive in the period from 1960 to 1980 (Šnore 2004). In Northern Europe as a whole, the area of wet *Picea abies* forest particularly decreased in the last 100 years due to drainage (Maanavilja et al. 2014).

The establishment of drainage systems affects the entire natural complex of conditions of forest – the hydrological, soil and microclimate conditions,

also the soil temperature regime (Indriksons 2008). Hydrological changes of bog woodland caused by drainage halt the natural development and cause other processes that result in development of dry forest types. As the soil moisture decreases, soil aeration improves, which promotes the rate of biological processes, microbial activity, and peat mineralisation. The impact of drainage is observed very quickly, and the effect is long term. The growth of trees improves, the biomass of the forest stand increases, and the surface area of the canopy for evapotranspiration increases (Zālītis 2012), which in turn promotes additional loss of soil moisture. The ground vegetation changes with a substantial decrease of the cover of *Sphagnum* and loss of hygrophytic species. In response to improved soil aeration and available nutrients, overgrowth with *Picea abies* may begin. Thus, *Picea abies* regeneration continuously develops and enters the tree canopy over time.

Peat extraction from areas adjacent to bog woodland have an adverse effect on the hydrological regime. Peat extraction is associated with lowering of the water level, which almost always has an impact not only in the area of extraction, but also in a wider territory. The impact of individual ditches may be cumulative and leave a greater draining effect on the habitat in general. The vegetation also changes, with an increase in the cover of mosses characteristic of dry habitats and overgrowth with dwarf shrubs, which in turn increases evapotranspiration and intensifies the drainage effect. The distance from a ditch that is affected can vary from some metres near recently dug, shallow ditches up to several hundreds of metres from ditches that have functioned for a long time (Priede (ed.) 2017, *Ch. 10*).

17.1.5.2 Logging

The habitat is adversely affected by tree felling, especially by clearcutting. Tree felling reduces evapotranspiration and can promote paludification, impeding the regeneration of forest canopy. Clearcutting is not compatible with the existence of bog woodland. Also other types of felling where the oldest trees or trees of largest dimensions are felled have an adverse effect, by reducing the potential volume of biologically significant structures in the forest stand.

Thinning in medium aged stands has an adverse effect due to soil compaction, transportation tracks and groundcover damage caused by tractor equipment. The tracks created by equipment function similarly to small ditches by draining the wet forest if they are deeper than 20-25 cm. The tracks fill up with organic material very slowly in peat substrates (over 15-20 years) as the standing water overgrows with moisture-loving plants.

Over time, the natural vegetation regenerates and stabilises, and the characteristic forest stand structure and species composition of bog woodlands regenerates, but after logging the previous rare species will not always reappear. Similar plant growth can occur in wide natural gaps, but compared to logging, for a shorter time and a smaller area of the habitat will be affected, and the natural vegetation will regenerate faster.

17.1.5.3 Beaver activity

Beaver *Castor fiber* dams on small watercourses or ditches create water reservoirs, the size of which depends on the surrounding topography. Beaver activity is promoted by drainage systems and the overgrowth of the adjacent areas with deciduous trees (Gackis 2009). The groundwater table may increase in the surrounding forests, and surface waters may form. Beaver activity may affect bog woodlands both adversely and favourably, depending on the particular situation.

In degraded bog woodlands, as the groundwater table increases due to beaver activity, the soil of the forest is rewetted, and as a result *Sphagnum* cover increases, the degradation process stops, and the characteristic vegetation and peat formation processes of the habitat may be restored (Fig. 17.5).

However, beaver activity may have an adverse effect on bog woodland with a network of ditches

Fig. 17.5. Rapid increase of the cover of *Sphagnum* and regeneration of the bog woodland habitat near a beaver pond. Photo: S. Ikauniece.

or beside lakes. By raising the water level, soil is inundated, and a part of or all trees of the forest stand may die, and characteristic species of the habitat may be lost. Trees of low dimension react more sensitively, especially *Picea abies*, the growth of which rapidly decreases (Gackis 2009). If the inundation covers a wide territory and the surface water level in bog woodland is much higher than the natural water level of an adjacent lake, the changes in the vegetation will be much more significant and it is expected that the majority of trees will die. The territory inundated by beaver will acquire other features important for biodiversity, such as large volumes of dead wood, which will attract associated invertebrate species, as well as create nesting opportunities for waterfowl, habitats for water invertebrates, reptiles and amphibians. However, the protected forest habitat will disappear.

17.1.5.4 Excessive Visitor Load

Bog woodland, similar to raised bogs, is visited by forest berry pickers. Ground cover trampling can be observed in intensively visited sites, trails are formed, and municipal waste is left. The magnitude of impact depends on the availability of the particular woodland and the population density in the region. It is difficult to prevent and control the impact.

17.2 Restoration and Management Objectives in the Conservation of Bog Woodland

Since the habitat type 91D0* *Bog woodland* often occurs in a complex with other protected mire habitats (7110* *Active raised bogs*, 7120 *Degraded raised bogs still capable of natural regeneration*, and 7140 *Transition mires and quaking bogs)*, habitat restoration and management must focus not only on the particular forest habitat, but on all of the wet habitats.

The main aim of habitat protection is to ensure a favourable conservation status (*see Ch. 1*). This also means the conservation or restoration of a suitable hydrological regime, which is a prerequisite for the existence of the characteristic and rare species of the habitat.

It is important to preserve natural structures in amounts that are sufficient for the long-term stable existence of the typical and rare species associated with the habitat. The most important structures for species habitat are coarse woody debris and old trees. Trees of very large dimensions are usually not common in the bog woodland, as slowly growing biologically old trees of small dimensions are more characteristic to wet conditions Therefore, dead wood with a diameter > 20 cm has great value.

An important aim is also the conservation of habitat continuity in its distribution area, which is very important in the existence of many protected and rare species (Norden et al. 2014).

17.3 Management and Restoration of Bog Woodland

17.3.1 Habitat Conservation

The conservation priority of habitat type 91D0* *Bog woodland* (for variant 1 and 2 of the habitat) is non-intervention in the natural processes and conservation of a natural hydrological regime. Non-intervention means that no active human work takes place in the habitat that is associated with the felling of trees or shrubs or has an impact on soil; there is no influence of vehicle transport, and there are no artificially created changes in the hydrological regime. Natural processes are not limited or disturbed. At the same time, the habitat can be used for recreation, mushroom and berry picking, and hunting, as long as there is no negative effect on habitat structures and species. Non-intervention is the most suitable conservation method in these habitats, which is also most often applied.

The conservation and improvement of the conditions of variant 3 of the habitat, which includes degraded bog woodlands, requires rewetting or at least improvement of the conditions to the greatest extent possible *(see Ch. 17.3.2)*. Improvement of the forest stand structure that was altered as a result of drainage may require cutting of shrubs as an additional measure, especially for the improvement of *Tetrao urogallus* habitat quality *(see Ch. 17.3.4)*.

The hydrological regime is affected not only by conditions in the territory of the habitat, but also in the adjacent areas. Construction of new ditches, reconstruction of existing ditches and peat extraction in adjacent mire territories affect the water level in a wider area. Therefore, in order to ensure habitat protection and conservation, it is necessary to evaluate the planned activities in the surrounding area. Another method to decrease the impact from activities in adjacent territories is the creation of a buffer zone, which will help to maintain a constant microclimate in the forest stand *(see Ch. 17.3.3)*.

Restoration methods of bog woodland habitats are summarised in table 17.1; they are further described in the following chapters.

Table 17.1 Management methods of habitat type 9160* *Bog woodland*

Method	Ecological benefits	Disadvantages
Filling of ditches	Better efficiency if compared to dams, constant monitoring and repair is not required. Soil humidity characteristic to the habitat is restored. Restoration of characteristic vegetation habitat is promoted. The habitat rapidly becomes natural, the ditch overgrows and incorporates into the forest environment.	Technically difficult to implement, if the ditch does not have a raised soil berm. Higher costs compared to the construction of dams.
Blocking of ditches	Habitat characteristic soil humidity is restored. Restoration of habitat characteristic vegetation is promoted.	Open water area forms, dangerous for the chicks of *Tetrao urogallus* and other *Galliformes*. A relatively long time needed for ditches to overgrow with *Sphagnum* and obtain the characteristic features of the habitat.
Establishment of a buffer zone	Reduced wind impact and stable conditions characteristic to the habitat in cases when the adjacent stand is clearcut.	Economic losses from the wood that has not been harvested from the buffer zone.
Cutting of advance growth	Improved forest structure characteristic to the habitat. Decreased total evapotranspiration from the forest.	Not a long-term solution to eliminate the effects of the hydrological regime changes (dense advance growth), should be repeated after a while. Should be combined with rewetting for greater efficiency (higher costs).

17.3.2 Rewetting

17.3.2.1 Main Rewetting Methods in Bog Woodland

It is essential to respect the precautionary principle when restoring the habitat, by carrying out a careful feasibility study prior to starting the activity, identifying possible risks and choosing the best methods. Habitat restoration must not impair the condition of other hydrologically related habitats, such as through outflows of additional nutrients in lakes and promoting changes in their conditions (Urtāns (ed.) 2017), or worsen the condition of the habitats in adjacent areas. One must also know the legal regulations and permitted activities in the territory (see Ch. 7). Rewetting in raised bogs has often been carried out in Latvia as well as in other places around the world during various projects. There is less experience in the restoration of bog woodlands, however, regarding the conditions and implementation, restoration and management in mire and bog woodland habitats are similar.

The aim of rewetting is to ensure that water remains in the forest by not allowing it to flow away, as well as to prevent rapid fluctuations of the water table. The most often used rewetting and improvement methods are the blocking of draining ditches or filling them up to increase the moisture level in the soil and restore the functions of the ecosystem and the biodiversity. A good indicator is the cover of *Sphagnum*, as due to draining it is always low, and after successful rewetting the cover of *Sphagnum* increases relatively quickly (Maanavilja et al. 2014) showing successful recovery of the ecosystem.

If bog woodlands are situated in the periphery of mires, their rewetting must be integrated as complex mire habitat restoration and improvement of hydrological conditions. Planning of restoration must consider the width, depth and length of the ditches, direction of water runoff, the topographic characteristics of the area, as well as the functional role of the ditches and their impact on the forest stands in a larger territory. Partially overgrown ditches, where the water flows under the surface layer of sphagnum, also has a draining effect.

Drainage and overgrowth of raised bogs as well as bog woodlands can also occur naturally. In Europe, climate changes with related increase of temperature are considered to be among the most important factors that influence mire ecosystems (Anon. 2012). The dry and warm period in Latvia in 1960-1980, as well as environmental eutrophication, especially nitrogen enrichment, are also contributing factors (Čugunovs, Nikodemus 2013).

Rewetting is usually divided into two stages. Firstly it is necessary to carry out practical preparation by felling trees on the berms of ditches. This must be carried out while the soil is frozen.

Felled trees should not be put into ditches, and it is advised to remove them from the territory or spread them throughout the surrounding area. Part of the felled trees may be used in the construction of dams, if it was planning to construct wooden dams. It may be necessary to fell rapidly growing *Picea abies* and *Pinus sylvestris* in the habitat territory, especially in cases when an area is also a habitat for *Tetrao urogallus* (*see Ch. 17.3.4*). Rewetting reduces evapotranspiration and restores the necessary light conditions for the habitat (Vestarinen et al. 2014). Felling of *Betula spp*. must be carefully considered, as it tends to regenerate rapidly with sprouts. This in turn promotes evapotranspiration and slows down the desired restoration of the hydrological conditions. The living *Betula spp*. may be left, as part of them will die as soil humidity increases, or they may be ring-barked, promoting slow death and retarding the formation of sprouts (Vestarinen et al. 2014).

Blocking or filling up of ditches must be carried out in the next stage of activities.

17.3.2.2 Blocking of Ditches

Ditches can be dammed in various ways. The aim of creating dams is to stabilise the water table and prevent water leakage from the territory. The method is well tested and applied in the restoration of degraded raised bogs around the world and in Latvia. So far it has less frequently been applied for bog woodland restoration.

The technical solutions of dam construction are determined by the conditions of the site, the parameters of the ditch, the locally available materials, as well as transportation costs and possibilities. For more on the principles of dam construction: Priede (ed.) (2017), *Ch. 10.3.3.*

Dams may be constructed both by excavator and manually. Already during the planning period, one must take into account the potential lifetime and the maintenance and restoration costs of the dam. They may be constructed of wood (logs, planks, plywood), plastic or peat. When constructing a dam cascade, the dam located in the upstream of the ditch must be constructed first, as it holds up water and facilitates the construction of the other dams (Bergmanis 2005). If old, slowly growing trees are in the vicinity of the ditch (*Pinus sylvestris, Betula* spp.), they should be conserved, but rapidly growing *Pinus sylvestris, Betula spp*. and *Picea abies*, which may sometimes create relatively dense groups, should be felled. It is very important to compact the ends of the dam strongly, so that leakage does not occur and the dam does not get washed away. After constructing the dams their regular inspection and repair is necessary, such as repair of leakage areas.

The peat of ditch berm is highly decomposed and it weakly absorbs water, and therefore dams built of such peat may not be firm. It is best to gather the material necessary for the construction of the dam in a gentle way from the surface in a wider territory around the ditch (if it is possible depending on tree cover). Peat extracted from unearthed pits in the forest stand may be used for the dam (Ķuze, Priede 2008). In places where the construction of larger dams has been planned, it is often necessary to find a solution for the access of excavation equipment to the site planned for the dam. There should be a zone of 8 metres that is free of tree cover in the area of dams where the equipment will work, therefore the trees closest to the ditch must be felled (Anon. 2014a).

The first bog rewetting project in Latvia took place in Teiči Bog in the time period from 1999 to 2001, when 25 dams were constructed on drainage ditches, most often using logs that were acquired by felling trees growing in the proximity. Three types of dam construction were used in Teiči Bog: dam construction of two rows of logs, dams of a single horizontal row of logs, supplemented with sphagnum mosses and peat, and filling up deep and wide ditches with gravel and sand (Bergmanis et al. 2002; Bergmanis 2005). It has been concluded over time that dams of one row of logs serve for a short period of time and soon become permeable, while dams in peat soils of two rows of logs with dense peat and *Sphagnum* fill are optimal (Bergmanis 2013).

Peat dams were constructed in the western side of Great Ķemeri Mire in Ķemeri National Park in 2006 (Fig. 17.6, 17.7, 17.8), obtaining peat next to the ditch and establishing small ponds. Each dam was about 10 m long and was constructed using an excavator. During construction, the top of the dam was created higher than the edges of the ditch, taking into account that the peat would settle. The flow of water in the ditch was prevented, a cover of *Sphagnum* developed over time, and the ditches gradually overgrew. 10 years later, the site was evaluated and it was concluded that a better method would have been complete filling up of the ditch or felling and removal of trees (*Betula spp., Picea abies*) on the ditch berm or at least the removal of berm and its pushing into the ditch. The ditch still partially performs the drainage function, therefore the desired result of reduction of the drainage effect was partially reached.

Fig. 17.6. Construction of peat dam with excavator on the side of Great Ķemeri Mire. Photo: J. Ķuze.

Fig. 17.7. Peat dams in the bog woodland on the western side of Great Ķemeri mire in 2015. Photo: A. Priede.

Fig. 17.8. Partially overgrown peat dams on the western side of Great Ķemeri Mire in 2015 – approximately 10 years after dam construction. Photo: A. Priede.

Fig. 17.9. Wooden dam in Gauja National Park. Photo: S. Ikauniece

Restoration of bog woodlands by constructing wooden dams on small ditches was carried out in Gauja National Park (in 2014 and 2015) by the LIFE+ project "Forest Habitat Restoration within the Gauja National Park", LIFE10 NAT/LV/000159 (Fig. 17.9). It is difficult to make comprehensive conclusions, but water accumulation near dams indicates that the dams are performed their task of holding the water in the forest very well.

Constructed dams have several disadvantages.

Linear areas of open water remain, from which the water continues to intensively evaporate. Ditches limit the movement of animals, especially small animals and birds. For example, in *Tetrao urogallus* leks they increase the frequency of chick drowning (Ludwig et al. 2008).

Dams are constructions that should be maintained; they should be regularly monitored and renovated if damage has been detected. Given the large areas where rewetting is necessary, the number of such dams can become very large in the future. Experience with dam construction in mires shows that dams can be washed away, they are sometimes damaged by *Castor fiber* and *Sus scrofa*, and people also sometimes cause damage.

17.3.2.3 Filling up of Ditches

Filling up of ditches is the most effective method of rewetting. Ditch filling does not form surface water inundation, as the water table does not increase above the level of ground surface. This method can be implemented where there are berms along the ditches. If berms are settling, i.e., the peat has mineralised and has become hydrophobic, it can no longer accumulate water and therefore is not useful

Fig. 17.10. Filling of a ditch with an excavator in Gauja National Park. Photo: S. Ikauniece.

Fig. 17.11. A recently filled ditch in Gauja National Park. Photo: S. Ikauniece.

for this purpose. In Finland ditches are often filled by an excavator that collects the soil cover and the surface layer of peat in the reach of the excavator bucket. In addition, low dams perpendicular to the ditches are constructed, providing additional water dispersal (Vesterinen et al. 2014).

Before carrying out the activities, in most cases it is necessary to fell trees growing on berm, in order to move the material of berms for filling up the ditches and to provide a place for the excavating equipment in a 4 m width alongside the ditch. The felled trees may be used for economic purposes or may be used in constructing roads for access by the excavators. Felled trees, branches and stumps should not be placed in the ditch, as then it is not possible to compact them firmly and water flow will continue through the additional space between them, even when the tree and shrub debris is covered by peat when filling the ditch.

When an excavator is used for filling ditches, the ditch must be filled completely up to the upper edge. During excavation the dense peat material at the bottom of the ditch can be mixed and dispersed.

So far the filling of ditches has only been carried out in some places in Latvia, such as in a microreserve for a *Tetrao urogallus* lek near Smiltene (in 2012, 6.3 km of ditches were filled in total) and in Gauja National Park in Gulbjusala Bog (2014-2015, 8.7 km in total) (Fig. 17.10, 17.11).

Bog woodland restoration examples in Finland and Sweden show that the water table has stabilised, the ground is humidified and a cover of *Sphagnum* developed on the filled ditch after a few years. Within a few years the filled ditches are almost invisible in nature (Maanavilja et al. 2014) (Fig. 17.12, 17.13).

Potential risks:

- In order not to fill natural straightened watercourses, it is necessary to carry out a detailed feasibility study of the territory and bog runoff, including the exploration of maps of various times; this is also important so that the filling of ditches or damming does not flood the forest or agricultural lands in surrounding areas;
- filling of ditches should not increase the water level in nearby lakes, or change their ecological status.

17.3.3 Establishment of a Buffer Zone

The aim of creating a buffer zone is to prevent the increased impact of the wind in the forest edge, if a forest stand in the territory adjacent to the habitat area is felled and the forest is rapidly uncovered to the impact of the wind (Johansson 2004). A similar situation may occur in cases when the trees of a bog are cut to restore the bog habitat; then a buffer zone should also be established.

The drying effect of wind and increased light in open areas cause drastic fluctuations of the microclimate, which influences the groundcover vegetation, and increases risk of wind breakage and uprooting of trees in the forest edge. Although the increase of dead wood volume cannot be assessed negatively, the changes of microclimate conditions and forest structure may promote the formation of a dense shrub layer atypical to the habitat and promote changes in the groundcover vegetation. In some cases, uprooting of trees may cause excessive inundation as evapotranspiration decreases, which in turn intensifies paludification. As a forest regenerates naturally, additional overgrowth with

Fig. 17.12. A site of a filled ditch in Finland, which has overgrown with *Sphagnum* and vegetation similar to that of bog woodland. Photo: S. Ikauniece.

Fig. 17.13. The hydrological regime has been restored in a boggy *Picea abies* forest by filling a ditch. Finland. Photo: S. Ikauniece.

tree pioneer species, such as *Betula pubescens* can be observed in such places. In late successional forests, such as *Picea abies* bog forests, the development of the characteristic dominance of *Picea abies* is expected over a long period of time (Maanavilja et al. 2014).

A buffer zone should not be established in the territory of the habitat. If clearcutting is being carried out in the adjacent forest, part of the stand near the habitat should be left uncut. It is recommended to create a buffer strip with a width at least equal to the dominant tree height, taking into account cardinal directions and topography. A wider buffer strip should be left on the side of the dominant winds. If the bog woodland is located in a lowland between hills and the hill has steep slopes, the buffer strip may be established on the upper edge of the adjacent hill. For less sloping hills, buffer width should be equal to dominant tree height. Selective felling of various intensities may be carried out for economic purposes in the buffer zone (Ek, Bērmanis 2004; Johanson 2004), starting from the border of the clearcut (medium to strong intensity, up to 70% may be cut) up to the edge of the bog woodland (very low intensity, up to 20% may be cut). Advance growth and shrubs should not be felled in the buffer zone.

17.3.4 Improvement of the Conditions of Capercaillie *Tetrao urogallus* Leks (mating places)

Peat mineralisation takes place in bog woodlands as a result of drainage system establishment; the amount of available nutrients increases, and the growth rate of trees increases. The growth of *Pinus sylvestris* increases, intensive overgrowth with *Betula spp.* and *Picea abies* may start, and dense and high patches of *Calluna vulgaris* and *Ledum palustre* develop. Evapotranspiration increases, promoting additional water loss, improvement of the growing conditions for saplings (Zālītis 2006) and subsequent increase in the density of the forest. These factors have negative effect on species that inhabit sparse bog woodlands, such as capercaillie *Tetrao urogallus*.

The ideal habitat for capercaillie is a mosaic uneven-aged forest stand with a composition that changes little over time and has a diverse groundcover. Thinning of forest is one of the most often used habitat restoration methods for improvement of the conservation status of capercaillie in Latvia. Thinning in leks has been carried out both in dry and in wet coniferous forests (Strazds et al. 2010). Restoration of the leks should be carried out if there is partial or total overgrowth of shrubs and tall saplings, which reduces visibility during mating and can affect mating success. If the adverse changes have occurred due to draining, rewetting should be carried out, by additionally reducing the density of the forest stand if needed.

The best solution is to completely fill the ditches. This significantly reduces the death rate of chicks of capercaillie and other *Galliformes* by drowning. If ditch filling is not possible due to financial or technical limitations, the ditches may be blocked. However, by constructing dams, the surface of open water in ditches should be reduced as much as possible. One solution is to fill the open ditches between dams with the branches and tops of the felled *Picea abies* trees. Ditches with water are more dangerous for *Galliformes* than empty

Fig. 17.14. Thinning in a *Tetrao urogallus* lek in Ziemeri Parish. Photo: S. Ikauniece.

Fig. 17.15. Managed *Tetrao urogallus* lek after cutting the shrub layer in Ziemeri Parish. Photo: S. Ikauniece.

ditches, as they increase the drowning frequency of the chicks. Another solution is to create bridges of branches and wood over the ditch at regular intervals. This would eliminate the need for small birds to cross the ditch by flying (Strazds et al. 2010; Petriņš 2014).

To reduce the density of the forest stand, not only *Picea abies* saplings, but also rapidly growing *Pinus sylvestris* should be cut. It is recommended to ring-bark *Betula spp.* trees, so that they slowly die and less sprouts form. The wood acquired by felling may be used for economic purposes, but felling residues (tops, branches) may be left dispersed throughout the plot. If the wood cannot be removed, it can be left after the removal of branches, especially from the crown and the top.

The management must be performed while the soil is frozen. Biologically old, slowly growing *Picea abies* should not be felled, also some of the *Picea abies* with low branches should be conserved as hiding places for capercaillie – small groups of young *Picea abies* may also be left (Strazds et al. 2010; Hofmanis, Strazds 2012). Snags should not be cut.

The protected landscape area "Northern Gauja" ("Ziemeļgauja") was the first area in Latvia where improvement of capercaillie habitat was conducted. This was done in 2004 according to the species protection plan. Three capercaillie leks were managed by cutting *Picea abies* trees in the advance growth.

In the nature reserves "Stiklu purvi" and "Klāņu purvs" in 2005 (LIFE04 NAT/LV/000196 project "Implementation of the Mire Habitat Management Plan for Latvia") a survey of capercaillie leks and assessment of the need for management was initiated. Cutting of the overgrowth in three leks was conducted in the following years in the mentioned nature reserves, covering a total area of 30 ha.

In 2012, the project "Green corridor" ("Zaļais koridors") ("Harmonised management of Latvian-Estonian cross-border territories") managed capercaillie leks in four locations. The *Picea abies* trees up to 16 cm diameter were felled in overgrown patches, branches were removed and left in ~1 m long pieces. In wet areas with less *Picea abies* trees, branches were dispersed, attempting to leave them in depressions (Fig. 17.14, 17.15). Although initially there was a great deal of elevated branches and stem debris, which could have an adverse effect on the transparency of the territory from the viewpoint of the capercaillie, precipitation of the first winter compressed them, and after a few years the debris was overgrown by wet mosses. It will be possible to assess the impact on the changes of capercaillie populations after a longer period of time by carrying out an inventory.

Due to drainage, high patches of *Ledum palustre* may form in capercaillie leks, and *Eriophorum spp.* may disappear, which negatively affect the quality of the lek. High *Ledum palustre* decreases the transparency of the lek, which poses a greater threat from predators during mating. It also adversely affects movement of the birds on the ground. Also felled *Pinus sylvestris* and *Picea abies* trees, especially their tops, which are not cross-cut and dispersed, may cause the same effect. The loss of *Eriophorum spp.* also decreases food resources (buds and new shoots of *Eriophorum spp.* for capercaillie).

In order to improve the transparency of the habitat at the eye height of capercaillie, dwarf

Fig. 17.16. Brush cutting of *Ledum palustre* in a capercaillie lek in Vijciems Parish. Photo: S. Ikauniece.

shrubs can be mown. If favourable conditions for rapid tree growth are not prevented, i.e., if rewetting is not carried out, cutting of saplings will only improve the conditions in the short-term, and cutting in the lek will have to be repeated. Thinning in leks must be carried out in a short period of time, in order to decrease the disturbance caused by the activities. The work should be carried out from 1 September to 31 December (Strazds et al. 2010). Brush cutting of *Ledum palustre* can temporarily improve the quality of the lek, but to prevent overgrowth, rewetting should be carried out.

17.3.5 Management Unfavourable to Bog Woodlands

Management unfavourable to the habitat is not only the construction of new drainage systems, but also the renovation and reconstruction of the existing ditches. The maintenance of ditches associated with cleaning the ditch bed and reducing clogging by improving the water runoff also causes an unequivocally adverse effect on the habitat.

Tree felling, especially by felling the largest and oldest trees, reduces the potential volume of dead wood in the future. Thinning in young naturally formed forests is not necessary for the favourable habitat status, although sometimes it is carried out for wood harvest. In such cases it is important to carry out the work while the soil is frozen. Tracks (deeper than 10 cm) left by equipment should be avoided, as the tracks drain the soil and have an adverse effect on hydrological conditions.

17.4 Conflicts of Conservation and Management

Rewetting and the formation of buffer zones do not conflict with the known requirements of rare and protected species that depend on the presence of the structures characteristic to a natural forest.

Contradictions may emerge in cases when a choice must be made between the conservation of bog woodlands or restoration of raised bogs (more – Priede (ed.) 2017, *Ch. 10*). Most often uncertainties arise regarding the edges of raised bogs, where bog woodland has formed after draining the bog. When making the decision about the restoration of a raised bog or conservation of a bog woodland, it is important to take into account the sustainability and cost efficiency, for example, if a particular habitat of a rare species is restored. The decision should be made by assessing the situation as a whole (see also Ch. 7.2). If gradual overgrowth of the bog is a natural process and drainage systems are not evident, it is best to leave the forest for undisturbed development.

If ditches of a drainage system have overgrown or do not function, and the water table has stabilised, then rapid establishment of young trees, especially *Picea abies*, no longer occurs, and the existing trees start growing slowly.

Rewetting often does not cause death of *Picea abies* trees and self-thinning does not occur. The prior density of *Picea abies* may remain as an adverse factor for capercaillie mating, and one should consider felling them. At the same time, a stable bog woodland has formed, and cutting of *Picea abies* may be in contradiction with the non-intervention regime most favourable to the habitat. Most probably in such cases, the creation of favourable conditions for the capercaillie by cutting *Picea abies* saplings should be favoured, if the lek has an important role in the conservation of this species population.

Not all adversely affected habitats can be restored, especially near the main ditches, which have an important role in draining economic forest stands, agricultural lands and peat extraction places of wider territories; therefore it is expected that habitat degradation will continue in many places in the future. In especially valuable habitats where ditch filling and dam construction is not possible, a layer of moisture tight geotextiles can be laid in ditches to prevent water flowing into them, in cases where the habitat is surrounded by territories used for economic purposes.

Glossary

Abiotic conditions – conditions of the non-living environment, influencing the structure and functioning of the ecosystem.
Anthropogenic impact – direct or indirect impact of humans and their economic activities on nature as a whole or on its individual components and elements (landscapes, natural resources, etc.). Excessive anthropogenic impact may cause the loss of natural characteristics of the territory.
Biotic factors – the living environment conditions. Biotic conditions form and change in mutual relations of living organisms.
Calcareous - containing calcium carbonate ($CaC0_3$). Connectivity – the opposite meaning to the term "fragmentation" (see *Fragmentation*).
Ecosystem services – various types of benefits, resources and processes of the ecosystem provided to society.
EU priority habitat *(also EU priority protected habitat)* – types of natural habitats and of wild fauna and flora.
European Union (EU) protected habitat (also habitat of European Union interest) – a habitat that, in terms of the environmental conditions 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.
Eutrophic – rich in nutrients.
Eutrophication – the increase in the amount of nutrients in the environment as a result of natural processes or human activities, which causes changes in the environment.
Expansive species – a native species which can quickly spread and dominate over the other species. These species only become expansive in certain conditions (for example, the change of the management method or interruption of the management, rapid inflow of nutrients, etc.).
Flood – flooding of the land that is usually not covered by water, which may be caused not only by spring flood (high waters), but also intensive, long rainfall, storms, breakage of dams.
Flow rate – regarding springs – the water volume given by the spring within a definite time. Flow rate is usually measured in l/s or m^3/s.
Forest canopy – upper layer of trees in a forest.
Forest stand – the set of all tree layers, including the special abiotic environment aspects caused by them.
Fragmentation – division of the landscape or the habitat into smaller isolated patches changed in shape. The opposite meaning to the term "connectivity".
Ground cover – the cover of herbaceous plants, dwarf shrubs, mosses and lichens
Ground water – the upper horizon of the underground waters, located above the first water holding layer, the regime of which (level, composition, etc.) is mainly determined by the meteorological conditions and the geological conditions of the territory.
Groundwater – the water in the Earth's pores, gaps and cracks, able to move under the impact of gravitation or pressure.
Groundwater table – the top of the underground water saturation zone.
Habitat – this book uses the concept of habitat in the meaning of Council Directive 92/43/EEC of 21 May 1992 on the conservation of natural habitats and of wild fauna. Habitats are natural or semi-natural terrestrial or aquatic areas characterised by specific non-living environment conditions, a set of species and their mutual relations.
Habitat (of a species) – the concept used in this edition for the purpose of the Law on Species and Habitat Conservation. A habitat of a species is a set of specific abiotic and biotic factors in the area where the species exists in every stage of its biological cycle.
Habitat management – a set of biotechnical measures aimed at maintaining the habitat in a favourable conservation status.
Habitat restoration – a set of biotechnical measures aimed at restoring 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 protection status.
Hygrophyte – a plant growing in wet habitats.
Indicator species of Woodland Key Habitats and specific species – here according to the inventory methodology of Woodland Key Habitats – species that have adapted to a narrow set of particular conditions, indicative of the degree of naturalness. Due to the limited availability of the conditions, the specific species are usually rare.
Invasive species - an invasive alien species that can quickly reproduce in the wild, invade large areas and dominate over the native species. The spread of invasive foreign species in natural or semi-natural ecosystems is usually related to the reduction of biodiversity, economic loss, or threats to human health.
Litter layer – the surface layer of the soil formed by tree litter (needles, leaves, bark, chips) and the undecomposed or slightly decomposed debris of other plants.

Metapopulations – multiple spatially isolated local populations, among which the migration of specimens takes place.
Natura 2000 site — a protected site that has been included in the Natura 2000 network - a joint network of the protected areas of the European Union countries, which aims at 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.
Nutrients – chemical elements and compounds required for plant growth and development.
Oligotrophic - poor in plant nutrients, especially nitrogen and phosphorus (soil, water).
Organic layer - the surface layer of soil formed of tree litter and humus (decomposed organic matter).
Overstorey – the canopy and subcanopy tree layers.
Paludification – accumulation of an organic layer due to high soil moisture and other factors.
Population – a set of individuals of one species, which inhabit a particular territory for a long time.
Priority habitat type of European Union interest *(also priority habitat type of Community interest)* – Habitat type of European Union interest with priority status.
Protected Habitat – a habitat (*see. Habitat*) that has been included in Cabinet Regulation No. 421 of 5 December 2000 *Regulations of the List of the Specially Protected Biotopes.*
Protected species – a species, the conservation of which is regulated by the national regulatory enactments. In Latvia, the protected species have been included in the Regulations of the Cabinet of Ministers of the Republic of Latvia.
Rewetting – a restoration measure aimed at raising the water table in a drained wetland (mire, forest or other) in order to achieve the optimum hydrological conditions for the particular ecosystem or habitat type and related species complex.
Ruderal plant – plant species of weedy area (dumps, abandoned sites, construction sites, overgrown agricultural lands).
Seepage springs – diffuse outflow sites of underground waters.
Shrub layer – all trees and shrubs below the tree canopy layers.
Spring – a natural, concentrated outflow of underground waters (pressure or ground waters) on the land surface or under the water.
Spring flood (also high water) – a water regime phase that repeats annually in particular climatic conditions during the same season and which is characterised by the highest water level of the year and flooding of floodplains as a result of snow and ice melting; high waters of spring in March and April are typical in Latvia.
Subcanopy – the tree layer below the upper canopy.
Succession – the formation process of an ecosystem where habitats sequentially replace one another, such as a *Quercus robur* forest is replaced by a *Picea abies* forest rich in species. Primary succession occurs in places with no existing vegetation, for example, on the open sand in a quarry. Secondary succession occurs in the places of pre-existing soil and vegetation, which is totally or partly destroyed but abiotic environment remained.
Synanthropisation – spread of species associated with humans outside the living and working environment of people.
Tending – felling in young stands to remove less favoured trees and create the optimal species composition.
Thinning – felling of part of the stand to reduce competition or for other reasons.
Umbrella species – a most sensitive species of the habitat, the protection of which is set as a priority in this habitat. By protecting this species, many other species with similar ecological requirements inhabiting this habitat are protected.
Understorey – all plants in layers below the tree canopy layers.
Vascular plants – flowering plants and ferns; plants that have vascular tissues.

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