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PROTECTED
HABITAT MANAGEMENT
GUIDELINES FOR LATVIA

Coastal, inland dune and heath habitats

Protected Habitat Management Guidelines for Latvia

Coastal, Inland Dune and Heath Habitats

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Protected Habitat Management Guidelines for Latvia

Volume 1

Coastal, Inland Dune and Heath Habitats

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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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CONTENTS

INTRODUCTION (*A. Priede*)

Guidelines for the conservation, management, and restoration of protected habitats have been developed during the period from 2013 to 2016 within the framework of the European Commission LIFE+ programme funded project "National Conservation and Management Programme for Natura 2000 Sites" (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, Council Directive 92/43/EEC on the Conservation of Natural Habitats and of Wild Fauna and Plants (hereinafter – the Habitats Directive), in Latvia. The guidelines are one of the tools to promote the introduction of the Habitats Directive and 2009/147/EC Council Directive 2009/147/EC on the Conservation of Wild Birds (hereinafter– the Birds Directive) in Latvia. The guidelines have been issued in six books, each devoted to a separate group of habitats. This edition provides recommendations for the conservation of the diversity of coastal, inland dune and heath habitats.

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 a useful step towards a deeper understanding of ecosystems and a common approach to the conservation of natural values in Latvia. As time goes by, the knowledge will improve, techniques and capabilities will change. However, these guidelines will remain the most complete summary of nature conservation experience of the last 25 years, and they will form the basis for solving problems in the future. The authors hope that this publication will serve as a source of inspiration for active work in maintaining natural values of Latvia.

PART I

Chapter 1. Characteristics of the Sea Coast Habitats, Open Inland Dunes and Heaths (B. Laime)

1.1 Characteristics of the Sea Coast Habitats

Coastal zone can be divided into the coastal terrestrial zone and foreshore zone (Fig. 1.1) (Eberhards 2003). The coastal terrestrial part can extend tens of kilometres inland; foreshore – an average of 6–10 m in depth. Most of the habitat types discussed below are associated with the present sea coast which is usually a zone only a few hundred metres wide, and is very dynamic due to the influence of wind and waves. The oldest coastal areas have been a subject to the influence of the sea since the glacial retreat over the last 14,000 years. Nowadays, due to increasing coastal erosion processes, some of these areas are involved in active coastal geological processes again (Eberhards 2003, 2004).

1.2 Geological Origin of the Baltic Sea Coast in Latvia, Types of Coasts and their Relevance to the Processes of Modern Coastal Development

Development of the sea coast in Latvia is related to the ancient basins of the Baltic Sea. First, Lake Ancylus occupied the southern part of the Baltic Sea depression 13.3 to 11.7 thousand years ago. A large part of modern coastal habitats is based on the relief forms shaped by the accumulation of Lake Ancylus. Second, the Littorina Sea transgression and subsequent regression occurred 2800–7000 years ago (Ulsts 1998). According to the geomorphological zoning, Latvia's seacoast belongs to the Coastal Lowland geographical zone, and is divided into four regions: open Baltic seacoast, North Kurzeme coast, Rīga sand plain and Vidzeme coast (Āboltiņš, Zelčs 1995).

Both during the historical development of the Baltic Sea and nowadays, various coastal development processes can be observed, mainly sediment accumulation and coastal erosion, and these determine several types of coast (Ulsts 1998; Eberhards 2003):

- accumulative shores with sand accumulation and foredune formation;
- erosion shores, which can be active, slowly retracting or inactive;
- dynamic equilibrium shores, where both foredune regeneration and erosion occurs, with very slight coastal retreat.

According to the morphological types of the modern Baltic Sea coast, Latvian shores are mainly formed under the influence of waves, and belong to the straightened erosional and depositional coasts. Together with the coastal underwater slope, the sea coast forms a dynamic system. This means that coastal processes, erosion and accumulation are directly dependent on the processes on the coastal underwater slope. The coastal underwater slope is flat, slightly wavy, and is characterised by a small volume of sand sediments, except in the Irbe Strait and the southern part of the Gulf of Riga (Ulsts 1998). This is due to the fact that the coastal underwater slope, ranging from 8–12 m depth in the eastern coast of the bay, and even from 1.5 to 3.5 m depth, is covered by boulders and pebbles, eroded from moraine sediments. The rocky zone of the underwater slope has a wavy relief, consisting of hills, rock piles, often covered with gravel with pebbles and sand. Underwater slope extending from the water's edge to 0.5–1.5 m depth is an inclined uneven surface. Further, to 2.5–3.5 m depth, a 150–350 m wide zone of sand bars is located. In the southeastern part of the Baltic Sea, the so-called Eastern Baltic long-shore sediment drift can be observed, starting from the south of the Curonian Spit – Sambian Peninsula, in the coastal section with steep abrasion coasts (Russia, Kaliningrad Oblast) (Ulsts 1998). Currently, the Latvian coastline stretches for 496 km (Eberhards, Saltupe 1996).

1.3 Characteristics of Beach, Coastal Dunes and Open Inland Dunes

Beach is a coastal formation that marks the coastline and which usually consists of readily washed out sedimentary rocks (sand, gravel, pebbles) and cockleshells. Beach is directly subjected to the regular influence of coastal currents, waves and wind. It is a terrestrial part of the coast, starting from the

minimum level of the sea water and ending with its maximum level (during storms) (Eberhards 2003).

In Latvia, sandy beaches are the most common, and their total length is around 240 kilometres (Eberhards 2003). Gravelly-pebbly beaches are less common (150–180 km), as well as boulder beaches. Beach width varies: it can be 5–10 m to 25 m in the narrowest areas, 30–50 m to 80–100 m in the widest, in some places reaching 150–200 m and wider. Beach flora, fauna and habitats in general are influenced by beach humidity, which is directly related to the height of the beach. Specific beach types can be found in some sites. For example, wet beaches with springs and bordering with black alder stands can be found south of Kolka, between Uši and Ēvaži. Near Nida, peat can be found in the beach and foredunes. In Ainaži and Bērzciems, beaches with *Scirpus tabernaemontani* develop to coastal grasslands which border with coastal lagoons (Eberhards 2003).

Dunes are hills of sand built by wind. Dunes are formed in places where there is a sufficient amount of sand, low groundwater level, exposure to prevailing winds and sparse vegetation. The most common and fastest method of dune formation is when windblown sands meet an obstacle – relief protuberance, plants, twigs, beach debris, etc. (Eberhards 2003). Coastal dunes can be divided into primary and secondary dunes.

Primary coastal dunes are dunes closest to the sea which usually border with the beach on the sea side, and where there is an active wind blowing of sand. The formation of primary dunes is directly dependent on the amount of sand on the beach. Primary dunes are divided into embryonic dunes and foredunes. **Embryonic dunes** are the first step in the dune development process. They are small, about 50–100 cm high sand ramparts with sparse vegetation. **Foredunes** are 1–6 m high ridge-like dunes with sparse or continuous vegetation consisting of sand-loving plants (Eberhards 2003).

Grey dunes develop as the first stage of secondary dunes. They are relatively stable dunes, and their vegetation consists mainly of mosses, lichens and low herbaceous plants, as well as of solitary trees, shrubs and their groups. Grey dunes are a type of secondary dune and they develop mainly from foredunes.

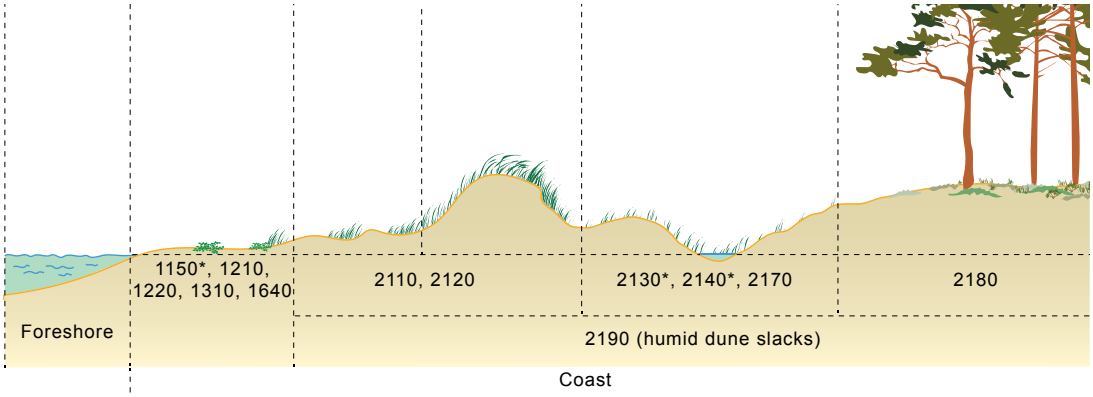
The total length of coast with primary dunes in Latvia is about 230 km, or 45% of the seacoast (Eberhards 2003). The average height of a foredune is 1–3 m, and width about 50 m. For some coastal sections, a 5–6 m high and several kilometres long foredune is characteristic. In other sections, several, usually 2–3, foredunes, with an overall width of 120 m and more, are typical. Between these dunes, small dune slacks are formed. Sandy beaches and dunes are the main habitats for coastal plant and animal species. At the same time, they are high quality sites for recreation. Grey dunes in Latvia cover a relatively small area, and usually they form narrow belts. The small areas of grey dunes can be explained by afforestation. Due to afforestation, foredunes also border forest in many coastal areas (Laime 2010).

Open inland dunes are located outside of the Coastal Lowland. The habitat is characterised by nutrient-poor, dry, sandy soil, sparse vegetation with a high proportion of pioneer species and lichens (Rove 2013h). It is regarded as an early succession stage of inland dune vegetation development.

1.4 Characteristics of Heaths

Heath development is determined by climatic and soil factors: moderate but regular rainfall (600–1100 mm per year), little difference between the average highest and average lowest annual temperature, as well as nutrient-poor soil (Hampton 2008). Heaths, both dry and wet, should ideally be open, or with some old trees. Vegetation is dominated by plants of the heather family *Ericaceae*, which form a mosaic with other dwarf shrubs, mosses and lichens (Auniņa, Rove 2013). Heaths in Latvia are mainly developed secondary – by burning and cutting down forests, by overgrowing sands or nutrient-poor grasslands and then grazing, mowing, using vehicles or otherwise inhibiting their overgrowing with shrubs and trees. Similarly to other countries, in Latvia the heath area has also dramatically declined during the second half of the 20th century. Heath was influenced by amelioration, afforestation, intensive agriculture, and also by land abandonment (Auniņa, Rove 2013).

Dry heaths develop in dry to moderately moist sandy soils. They are divided into: dry heaths, located in Coastal Lowland, and other heaths, located outside of this area (Rove 2013i). Wet heaths in Latvia develop on wet sandy soils, where water accumulates due to gleying and due to an ortstein (hardpan) horizon. The paludification is hindered by the large fluctuations in groundwater level and by periodic drought. However, in depressions, up to a 10–20 cm thick layer of peat can develop on the sand. In Latvia, not only open dwarf shrub areas but also sparse forest stands are considered as a wet heath, mainly with *Pinus sylvestris*, and scrub, if *Erica tetralix, Calluna vulgaris, Molinia caerulea* occur, as well as other characteristic groundcover species are present. Wet heaths in Latvia are found



Habitat	Beach (brackish habitats)	Primary coastal dunes		Secondary dunes	
		Embryonic dunes	Foredunes	Grey dunes	Wooded dunes
Surface layer soil pH	8,5	8,0 7,5...7		6,5–6	5–4,5
Calcium carbonate %	10	8–5		1	〈 0,1
Humus %	〈1			1–5	20–40 un 〉
Characteristics, processes	Periodically inundated	Active sand overblowing		Slight sand overblowing, soil formation starts	
Dominant plant ecological groups	Halophytes, succulents	Succulents, psammophytes	Psammophytes	Xerophytes	
Approximate age, years		1–5	5–50	20–...	40...
Dominant life form	Annual herbaceous plants	Perennial herbaceous plants (in some places also shrubs)		Moss, lichens, perennial herbaceous plants, rarely dwarf shrubs	
Typical plant species	*Salsola kali* *Cakile baltica* *Atriplex littoralis* *Agrostis stolonifera* *Juncus bufonius* *Equisetum arvense*	*Honckenya peploides* *Leymus arenarius* *x Calammophila baltica* *Ammophila arenaria* *Festuca arenaria* *Calamagrostis epigeios* *Hieracium umbellatum* *Tragopogon heterospermus* *Salix daphnoides*		*Festuca sabulosa* *Carex arenaria* *Koeleria glauca* *Thymus serpyllum* *Sedum acre* *Jasione montana* *Calluna vulgaris* *Empetrum nigrum* *Mosses, lichens*	*Pinus sylvestris* *Picea abies* *Juniperus communis* *Vaccinium vitis-idaea* *Vaccinium myrtillus* *Lerchenfeldia flexuosa* *Mosses, lichens*

Fig. 1.1. Classification and characteristics of the coastal zone. Drawing of D. Segliņa, according to G. Eberhards (2003), B. Laime (2000), D. Holmes (2001).

only in the Coastal Lowland (Auniņa 2013).

Still in the middle of the 20th century, fairly large areas of dry heaths (20, 000 ha) were located in Inčukalns, Ugāle, Dundaga, Ventspils and other forestry management areas; large continuous areas (10,000 ha) of wet heaths were in Liepāja and Alsunga districts, located between Ziemupe and Pāvilosta. P. Mūrnieks explains that the persistence and slow afforestation of heath can be explained not only by the frequent forest fires but also by a "hard as stone" ortstein layer at a depth of 50–70 cm in the poor sandy soil. At the same time it has been noted that infertile sandy areas and heaths were afforested by the establishment of mixed forest stands, by the establishment of black alder and grey alder stands as well as by soil enrichment with "mycorrhiza mulch": forest litter (74%), brewery waste of spent hops (25%), blood flour or ammonium phosphate (1%) (Mūrnieks 1951).

In Latvia, 17 sea coast, inland dune and heath habitat types listed in the Habitats Directive's Annex I can be found, and most of them are also specially protected in Latvia.

Brackish habitats:
- 1150* *Coastal lagoons,*
- 1210 *Annual vegetation of drift lines,*
- 1220 *Perennial vegetation of stony banks,*
- 1230 *Vegetated sea cliffs of the Atlantic and Baltic coasts,*
- 1310 Salicornia *and other annuals colonising mud and sand,*
- 1640 *Boreal Baltic sandy beaches with perennial vegetation.*

Coastal and inland dune habitats:
- 2110 *Embryonic shifting dunes*,
- 2120 *Foredunes*,
- 2130* *Fixed coastal dunes with herbaceous vegetation (grey dunes),*
- 2140* *Decalcified fixed dunes with* Empetrum nigrum,
- 2170 *Dunes with* Salix repens *ssp.* argentea (Salicion arenariae),
- 2180 *Wooded dunes of the Atlantic, Continental and Boreal region,*
- 2190 *Humid dune slacks,*
- 2320 *Dry sand heaths with* Calluna *and* Empetrum nigrum*,*
- 2330 *Inland dunes with open* Corynephorus *and* Agrostis *grasslands.*
- Heath habitats:
- 4010 *Northern Atlantic wet heaths with* Erica tetralix*,*
- 4030 *European dry heaths.*

Habitat of brackish soils 1630* *Boreal Baltic coastal meadows* is described in the management guidelines for grasslands (Rūsiņa (ed.) 2017).

The key precondition for the function of habitats of brackish substrates as well as embryonic dunes and foredunes is the ensuring of coastal processes. Human intervention is not necessary and is even not desirable for the existence of these habitats. However, habitats of grey dunes, open inland dunes and heaths can generally develop and persist if people manage the area by maintaining the open landscape. Preferable management activities are, for example, grazing and mowing, algae drying. It is closely linked to the conservation and care of traditional cultural landscape.

Chapter 2. History of the use and Protection of Coastal, Inland Dunes and Heath Habitats in Latvia (B. Laime, D. Tjarve)

2.1 The Use of the Seaside at Different Times

Evidence of coastal settlements is found from the late Palaeolithic (10,500–9,000 BC), when the reindeer hunters entered Latvia (Zagorska 2012). The second important prehistoric period is the mid-Neolithic (3,300-2,300 BC), when due to the retreat of the Littorina Sea new terrestrial territories emerged (Vasks 2015). Archaeological research reveals Stone Age settlements in the shores of the ancient lagoon, mostly in the North Kurzeme coast of the Gulf of Riga. Assessing the age of settlements, it was found that Pūrciema–Ģipkas dunes were possibly visited during the period more than 4700–4400 years ago and were seasonally populated (Loze 2006). There have also been more permanent accommodation places; the main occupation of inhabitants has been seal hunting, thus obtaining meat for food, fat for lighting and fur for clothing, and the insulation of housing (Loze 2006). Activities such as fishing, hunting, gathering of wild plants, which were later added by livestock breeding generally dominated. Due to fluctuating levels of the Littorina Sea, earth layers containing amber were washed out and driven by currents, and the amber was washed ashore. Beads, charms were made out of amber and used in exchange for other things. During the Neolithic Period, some dunes in North Kurzeme also served as a spiritual centre, where various rituals were carried out (Loze 2006; Vasks 2015).

The gathering of amber has been an important activity at all times. More vast trade with amber began to flourish in the Bronze Age. By the development of the Amber Road, connections between the Baltic Sea coast, the territory of Latvia and the Roman Empire, and later also with Arab countries, were developed (Ansulis 1979). People exchanged amber for household items. Bartering and having connections has played a major role in culture development. Amber continued to be an expensive and widely used product, its collection and transmission was controlled differently over time. During the Duchy of Courland the gathering of amber was controlled by special coast supervisors (Ansulis 1979).

In the subsequent history the coastal use has mainly been associated with the sea. Upon the increase in the number of people arriving, especially at the beginning of the 15th century, residential areas were created, fishing, boat and ship construction were developed. In connection with the expansion of fishing and the development of cooperatives, fish processing was also developed. Sometimes it all happened right there on the beach, for example, "when fishing for flounder, there was a table nearby for fish gutting" (Šuvcāne 2015). If the house was further from the sea, then close to the beach, in the dunes or dune pits a place called *sedums* was created – a place to store boats, and build net storing huts. Some of them were heated, and used for various works linked to fishing, such as Ovīšu *sedums*, which had 16 net huts with chimneys.

In places where cooperatives were formed and the catch became larger, fish dryers, processors were built. When the sea froze solid, the fishermen gathered ice and stored it in the basements, to ensure longer fish storage (Veldre 1963). For thousands of years the fishing-related jobs were mostly performed on the beach and in the open dunes (Fig. 2.1). Alongside the men, fishermen's wives worked hard; they repaired and dried the nets. In open spaces on the seaside special poles for net drying or *vabas* were raised (Fig. 2.2). *Vabplači* (sites with net drying poles) were located in dunes, close to home, by the stables and other places and they could even be spread over a fairly large area (Laumane 1996). In Upesgrīva they were called *vabdārzi* that were even fenced so the livestock would not stomp them (Mīlenbahs, Endzelīns 1923). In Plieņciems Village, *vabas* were situated in wide areas called *vabu laukums*.

In their spare time from fishing in the winter, and when fishing did not pay off, the men went to work in the forest. The chopped trees were transported to

Original craft – amber gatherers

In Courland the governorate over the 18th and 19th century had a special position – amber gatherer. It is confirmed by the Permit of 6 June, 1830; approved by The Russian Ministry of Finance, State property Department for gathering. The relevant document applies to the five households who were entitled to gather amber at certain areas of the Liepāja–Rucava coast. These peasants were freed from the corvée of the Manor. The collected amber was stored in warehouses, and sold in markets, for example, in the year 1880 12.5 pounds were sold for nine thalers.

From the personal archive of Andris Maisiņš, descendant of an amber gatherer.

Fig. 2.1. Nearly every farm had a horse. It dragged the boats into the sea and onto shore, transported fish, sea weed manure, wood, etc., in the 1930s. Photo: Digital library collection *Lost Latvia* of the National Library of Latvia.

Fig. 2.2. Fishing nets were dried and repaired in the coastal dunes, using net drying poles (*vabas*) situated in rows. At the forefront Vaira Pesse (from the left, born in 1938 as Vamze) with her mother Anna Vamze remove herrings from nets. Pape, after World War II. Photo: the archive of Rucava History Museum.

the seaside with horses, stacked in high piles and in summer they were transported by boats to the transport ships and sold to collectors. In some villages, like Kaltene, in 1938 the entire seaside was laden with stacked firewood and lumber (Veldre 1963). Habitants of Mazirbe also worked in the woods. For them the chopping of trees was beneficial because it could earn even more than going fishing or farming. In some places timber mills were built that produced lumber, which became a much needed asset when the new owners began active building (Šuvcāne 2015). Part of the chopped trees was used as firewood, which was not always enough. Women would collect pine branches in the woods, transport them to the beach and build heaps, which were later transported home for firewood.

Tree cutting and burning of forests on a large scale had already begun in the 17th century when trade with the mast trees, ash and tar, widely expanded (Liepiņa 1999). Coastal forests were readily available, the ports were also developed, so pine cutting rose to enormous volumes. The depletion of forests was also affected by the adjacent open dune areas that were burnt down, travelled over, blown over or otherwise affected. A vivid example is the events of around the year 1650 on the seaside in Nīca, where in the pine forest with plenty of woody debris and stumps, large tar distilleries and coal-burning kilns were built (Janševskis 1928). The kiln and the whole forest burnt down in a fire. In the burnt areas active overblowing

Dune reinforcement

After excessive deforestation the area of moving sands in the beginning of the 19th century reached 7700 hectares. Already in 1835, preparations began for the stopping of travelling dunes in Nīca. It was managed by Nīca forester F. Zengers, who had gained experience in strengthening the sands in Prussia. In two years 461 ha of sands were strengthened with:

- twigs – 313 817 m^3,
- dune grass seeds (*Leymus arenarius, Ammophila arenaria* etc.) – 393 kg,
- willow cuttings – 21,200 pieces,
- seedlings of herbaceous plants – 418,800 pieces,
- cuttings – 356,966 pieces,
- tree seeds – 3686 kg.

Work was carried out in corvée, labour (total 44 700 man-days, 5250 horse-days) was used free of charge. The strengthening of the sandy dunes at the end of the 19th century and beginning of the 20th century was also carried out in Carnikava, Buļļi, Ventspils, etc., and in 1925 the area of shifting dunes in Latvia had decreased by half. Work continued, mainly covering the sand with branches, *Juniperus* spp. and *Calluna vulgaris*. In Liepāja and Ventspils *Salix* spp., *Pinus nigra* and *Pinus mugo* were widely introduced (Bušs 1960).

of sands began. Sand covered slacks, meadows, fields and even people's homes. Tar boiling continued in the seaside villages up to the beginning of the 20th century, because it was a necessity of life. Of life in that time V. Šuvcāne writes that the boat had to be tarred at least twice a year, the wheels had to be smeared, ropes and leather also had to be soaked, and the tar was also transported by boat for selling (Šuvcāne 2002). Deforestation and burning of forests continued into the 20th century (Fig. 2.3).

Upon the development of fisherman villages, at the beginning of the 20th century farms were developed where an increasingly important place was taken by farming. A big influence was the agricultural reform of 1920, which provided each fisherman a household with agricultural land (Šuvcāne 2015). In many parts the land was allocated in three places: one for the home and garden, the other as a forest area and the third as a meadow further in the forest or mire. Buildings were constructed on dune ramparts or elsewhere, where the ground could not be used in agriculture. To protect the home and yard, the sea side was strengthened with woven willow fences. In the older, better cultivated farms almost everything necessary was raised on the spot (Fig. 2.4). That which was caught or raised could be sold or traded at market (Fig. 2.5). As there were few fertile meadows in the coastal region, cattle were grazing in the forest too. In order not to hinder forest regeneration, the animals could not go over the felling areas (Veldre 1963). Pape Village, that in the 1930s looked like seaside steppe, had "small fields of oats, barley and spring wheat. Across this expanse there was not a tree nor a bush, only a few cows and about twenty sheep grazing in the middle" (Veldre 1963, p. 15).

A special seaside land management method is the construction of *aizjomi*. These are fields in depressions between dunes, established by deepening the dry places and replenishing humid sites, and forming something similar to ramparts around the field. Thus, the plants are provided with moisture and protected from the wind. Nowadays *aizjomi* are most widely seen in Jūrmalciems and Bernāti, but the evidence has survived elsewhere, such as in Medze, Mazirbe, Vaide and Melnsils (Veldre 1963; Stūre 2009). Often alongside the abandoned *aizjomi,* berry bushes and lilac also appear, which also indicate the historical coastal management. It is possible that the establishment of *aizjomi* was started in the ancient past, when the inhabitants of Latvian coastal areas began to engage in farming. While there was enough land, fields could be created in places more protected from wind and sand, but with time the situation changed. Building of *aizjomi* increased at the end of the 18th cen-

Fig. 2.3. Lāvas hill – one of the highest dunes in Latvia after forest cutting, 1951. Photo: the archive of Rucava History Museum.

Fig. 2.4. Rye harvest in Ziemupe. Around 1940. It is apparent that the fields and grazing paddocks are reaching up to the sea. Photo from the archive of Daina Vītola.

Fig. 2.5. Annual fair near Ziemupe Village cemetery in 1930; grey dune and sea cliff can be seen behind the pine zone. Photo from the archive of Daina Vītola.

Fig. 2.6. Sea weed heaps close to Pape. Algae was collected in heaps with pitchforks, and then taken to gardens and farms by horse. In the distance to the right, piers can be seen. Photo: R. Knaps. From *Lauksaimniecības mēnešraksts*, 1937, No. 5.

Fig. 2.7. The docks or piers on the seaside at Mazirbe, as they still were in 1987. Photo: V. Strautniece.

tury and at the beginning of the 19th century, when land shortage increased and poor areas of the dunes had to be used for agriculture (Stūre 2009). The sand was dug and moved both by hand and by horse. With the arrival of the Soviet army, in many places, homes in the coastal area were demolished and farming was banned. Many *aizjomi* were overgrown, and forest or shrubland formed. The creation of *aizjomi* is an effective method if a field or garden must be created close to the coast, where the sea winds have a large impact. Nowadays *aizjomi* are created and maintained less and less. They are used both for agricultural and recreational purposes.

At different times coastal use has been strictly regulated. For example at the end of the 19th century, upon getting a house and land as private property, the landlord had certain rights such as "may freely use the road to the seaside" and "gather sea mud for needs of their home lands" (Šuvcāne 2015, p. 38). Sea weed was always important to get a good yield, because part of the arable land was in poor dune sand.

Thanks to algae, from 1880 onwards the coast inhabitants received a huge profit by selling potatoes and rye to the distillery of a Dundaga baron. Algae gathering was hard work and the fields had to be fertilised each year. As observed in 1937 by V. Veldre in Nida, every year the fields were supplemented with approximately 100 horse carts with "black benefits", which the sea washed out in higher winds (Veldre 1963) (Fig. 2.6). To make it easier to gather seaweed, in Jūrmalciems racks were piled in the direction from the shore into the sea. When seaweed clung to the racks, it was gathered and thrown out of the water with a fork or a special rake. In several coastal locations piers

Sand mining

With the opening of the silicate bricks factory in Liepāja in 1959, the extensive excavation of dunes began. In the beginning, the sand dunes were excavated in the place where Dienvidu cemetery is currently located, then 9 km from Liepāja, across Kūlas cemetery. Large dunes were supposedly located there. Within a year the excavation of sand began at Reiņi forest, 11 km from Liepāja. During the period from 1960 to 1962 the extraction of sand was carried to Bernāti forest, at the beginning the Green Dune was excavated – it had been coated with a beautiful forest; then they started to excavate the White dune (Fig. 2.9). Trees were not cut down. Upon digging, the excavators left them aside, and later these trees were used for firewood. When both dunes were already excavated, his superiors ordered the drivers, including Arturs Štībelis, to choose the next dune for excavation. A local said that Pūsēna Hill was big enough. It was then chosen as the next object for excavation. There was quite a long reconciliation in Rīga, but in late 1968 or in 1969 the works were started. The sand, however, was of low quality, because it turned out that the dune had been blown over several times, thus there were layers of fertile soil in the middle as well as remains of tree stumps. So for a couple years works here were stopped and the sand was taken in Beberliņi. When Beberliņi dune was excavated, works were renewed in Pūsēna Hill. Works were stopped at the end of the 1970s, when the whole reconciled area was excavated.

From Andris Maisiņš personal archive, 2015

Fig. 2.8. Sea coast in Pitrags. In 1938 docks or piers were constructed to catch sea weed. In the early 1990s. Photo: G. Janaitis. From the Archive of National Oral History.

Fig. 2.9. The excavation of White dune in Bernāti in the 1960s. Photo from the archives of Gita Vanaga.

were even built from the pine logs and large rocks for this purpose (Fig. 2.7, 2.8). Local people considered sea weed as their "bread". Farmers who had to enrich the soil, often drove more than 10 km to the pier of Liepāja to get sea weed. "Mud" together with flour and turnips was even given to pigs (Veldre 1963).

In Soviet times, the algae washed up on the beach, and mostly *Furcellaria lumbricalis* was gathered in a systematic manner in considerable amounts for drying and processing. In 1965 Dobele district collective farm "Nākotne" began producing agar from algae. It produced around 200 tonnes of agar per year and exported it to 57 cities in the Soviet Union. Due to oil tanker accidents in the ports of Ventspils and Klaipeda in the 1980–1990s, algal resources decreased dramatically (Anon. 2013b).

Nowadays, when the coastal lifestyle has changed drastically and the area of previously cultivated gardens and fields has diminished, the collection of sea weed has reduced as well. An example is Jūrmala City, where algae is washed up on a beach in large quantities and has become a problem in the management of the recreational area. Liepāja Municipality has informed the inhabitants of Liepāja City and nearer municipalities who have an interest in the use of sea weed in allotments and other green areas as fertiliser, that as of 15 June, 2015, they may collect it at any time. Coordination with the municipality is only required when transport should be used and a permit is necessary to enter the beach for the transport of sea weed. Thus in Liepāja the gathering of algae is supported as an ancient and traditional occupation of the coastal population.

Other resources available from the beach and dunes, such as pebbles and stones, have always been used as well, albeit to a smaller extent. V. Veldre, in travels along Ovīši seaside in 1937, met men in single-horse carts driving along the water line and throwing gravel with stones in the cart through a mesh. It was a good profit (4.5 lats per cubic metre) that one could get for pebbles collected on the beach. Pebbles were later transported to Rīga and used for asphalt and walkways (Veldre 1963). Beach substrate is also used elsewhere in private households and sold to others. Seashells or *mušuļi* are widely collected as well, which are crushed and fed to chickens (Strubergs 2015).

A strong impact has been left on the coastal landscape by war time events. When in 1915, all coastal residents had 24 hours to leave a 10 km wide

On the impact of World War I, in the village of Vaide

"Moral and material losses due to the war were huge. Although direct military action did not happen in the seaside of Kurzeme, parts of the occupying German army were located in the seaside fishermen villages. Along with many other buildings soldiers also destroyed *kūres* (fish processing buildings). After the war they were not restored. Houses of Liv fishing villages were ruined, fishing and farm equipment destroyed and lost. The fishermen had to start life from scratch, and in the post-war years they lived in great poverty." (Šuvcāne 2015, p. 63)

"When the Russians came, you could not go ashore. All boats were taken to Saunags. The coast was harrowed. Harrows were large, and it was prohibited to walk there and leave a trail. After half a year barbed wire was placed along the coast. You could only go up to the wire. When the barbed wire was taken down, the Russians also harrowed behind the dunes. An observer was located in the guard tower all the time. The only option was to hear the sea with your ears." (Šuvcāne 2015, p. 84)

zone, whole villages died out. Cultivated fields, pastures were overgrown, boats were destroyed. The various traces of war are still visible in many places in the dune terrain where entrenchments and ramparts were dug. They can be seen in Vaide dunes where in World War I Germans dug deep formations similar to trenches to hide horses (Šuvcāne 2015).

Significant changes happened in coastal areas during the Soviet occupation from 1940 to 1990, when along many parts of the coast houses were destroyed and the traditional way of life was limited, including farming. In 1939, Soviet troops entered the sea shore of Kurzeme. In Užava, Pape, Lūžņa, Pitrags and other places army bases were built. Consequently, an environment cultivated for centuries was destroyed (Upmalis et al. 2006). It was followed by the deportation of people, eliminating entire villages and families. Kurzeme seaside became a forbidden zone that could only be visited with special permits (Fig. 2.10).

Fig. 2.10. During the Soviet occupation the movement of civilians and cultivation of sea coast areas was severely restricted. Students of Ezera school (Kalnišķi Village) hiking along the Baltic Sea, in 1954. Photo by the teacher Valentīna Kāle, the archive of Rucava History Museum.

Due to limiting the possibilities to use the coastal region, in 50 years the heritage and natural environment has been dramatically degraded, in particular the open dune areas. Bushes grew in the clearings, in many places pines were planted on purpose, some livestock was eliminated due to the high taxes, the boats was taken away, burnt or damaged (Šuvcāne 2015). Afforestation was not carried out in coastal sections which belonged to the Red Army, as the border was supposed to have good visibility. Dunes in military areas were often levelled and the relief was transformed. Cables many kilometres in length were dug in the ground. Hiding places for tanks and other military machinery were constructed.

The Latvian coastal dunes and beaches are very widely used as recreational and tourism resources. Jūrmala, Saulkrasti and Rīga also have a long history in this field, as they were some of the first summer cottage areas in the 19th century, with landscaped beaches and dunes. Agrarian reform during the 1920s in Bernāti summer houses were built. Later, in the 1930s this area was earmarked as a prospective resort. The cities Liepāja and Ventspils also have historical meaning, where recreation places in dunes have been developed over many years in close connection with the expansion of the ports of these cities. After 1991, with the removal of the Soviet border closed zone at the coast, extensive development of recreation and tourism started. There are landscaped recreational areas with viewing platforms, towers, trails and toilets, car parks and information boards; the beach is also used for different sports. Sea fishing from the shore has become more popular. Not only the flounders that are caught, but the excitement of fishing, gather many visitors all year round,

"Once there was an open field, the Lekši fields. Everything changed after the war. In Soviet times large agricultural lands of the previous owners, that the collective farms refused to own, were given to municipalities. Some of the lands came into the possession of the National forest Foundation. Then there was only one way – planting. All the great land areas in Vaide were planted with forests." (Memories of Edgars Hausmanis after Šuvcāne 2015, p. 14)
Afforestation was implemented both where there were open "moving" sands and also in sufficiently stable dunes where nothing indicated the emergence of shifting dunes. During a few decades, open coastal areas overgrew with trees. The landscape changed, and the possibility to use the land for agriculture was lost.

especially in autumn.

2.2 A Brief History of Coastal Protection

2.2.1 Coastal Protection Belt

The sea coast in Latvia has been protected for more than 160 years. Coast protection orders were already issued at the time of the Russian Empire. At different times the width of the zone ranges from 100 to 300 metres. There is now at least a 300 m wide protection belt outside towns and villages (150 m in urban areas and villages), where construction, forestry and other activities are limited.

The major protection standards with respect to the protection belt.

1838 Order by Governorate of Livonia.

1839 Order by Governorate of Courland.

A protective belt of forests should be designed along the entire coast of the Baltic Sea, it must be of 150 axes (approximately 320 m) wide, in particularly dangerous places up to 2 versts (2.13 km) wide. Felling of living trees, pasturing of cattle, collecting of litter, burning and mowing of grass was prohibited there.

On 4 July, **1962** Latvian SSR Council of Ministers decision No. 422 "On measures to protect the sea coast from erosion and to establish new protected nature objects":

"1. To designate in the Latvian SSR territory, a 600 m wide belt along all of the Baltic Sea and Gulf of Riga Coast (300 m on the shore and 300 m below water). Here, the gathering of building materials (stone, gravel, sand), as well as the performance of any earthwork is prohibited.

2. To designate a 1 km wide belt of protected forests along the Baltic Sea and the Gulf of Riga coast..."

15 April, **1977** Decision No. 241 of the Council of Ministers of the Latvian SSR, *On The Approval of State Protected Nature Objects in the Territory of the Latvian SSR*.

"3. Determine along the coast of the Baltic Sea and the Gulf of Riga in the Latvian SSR:

3.1. one kilometre wide belt, where forest clear-cutting is prohibited, as well as it is prohibited to reduce the forest cover and destroy the vegetation and soil cover;

3.2. six hundred metre wide (300 m terrestrial and 300 m underwater) protection zone, in which any earthwork is prohibited: moving of soil, excavation, explosion works; collection, use and transportation of bedrock — gravel, sand, boulders, etc., as well as any construction works."

10 April, **1987** Decision of the Latvian SSR Council of Ministers No 107, section VIII. "Protection belt along the coast of the Baltic Sea and the Gulf of Riga":

"1. .. The width of the protection zone – 1 km from the coastline, along roads, forest block borders and natural borders.

2. To ensure the protection of the most important parts of the coast, a special protection belt is determined as 300 m from the coastline towards the mainland, including the beach and coastal formations ..."

3. ... a 300 m wide zone is designated from the coastline towards the sea."

18 June, **1990** Republic of Latvia Council of Ministers decision No. 30 "On the extension of the Baltic Sea and the Gulf of Riga coastal protection belt".

300 m special protection belt is retained; 1 km protection belt is extended to several kilometres.

The use of forests was defined, as well as restrictions on vehicle parking and the creation of recreational areas, and provisions on the conservation of traditional historical landscapes and their elements.

"Law On Protected Belts" (05.02.**1997**)

Defines a 300 m wide coastal dune protection belt, 300 wide sea protection belt, and 5 km wide limited economic activities zone.

Protection belt boundaries must be marked in the land plans and recorded in the Land Register. General restrictions can also be determined with binding rules of the local municipalities.

Human movement can be limited, especially in the protected nature areas.

In coastal dune protection belt, there are restrictions for building development, forest management and mineral resource use.

Law On Protected Belts (05.02.**1997, amendments 19.11.2015**).

The following zones are distinguished in the protected belt of the Baltic Sea and the Gulf of Riga:

1) coastal dune protection belt that is no less than 300 m wide in the direction of the mainland, starting with the border of natural vegetation, with exceptions in towns and villages; where the width of the coastal protection belt is at least 150 m, it is mandatory to include protected habitats;

2) sea protection belt, covering the beach and underwater shelf from continuous natural terrestrial vegetation up to the 10 m isobath;

3) limited economic activities belt up to 5 km landwards, is demarcated according to the natural conditions.

Initially, the coastal protection belt was targeted mostly towards the protection of coastal forests and mineral resources. In 1977, certain restrictions in building development were set. Upon analysing the previously mentioned normative documents, it can be concluded that the coastal protection was established

to a much more complete extent in 1987 with Latvian SSR Council of Ministers decision No 107, supplemented in 1990 with Council of Ministers of the Republic of Latvia decision No. 30. With the "Law On Protected Belts" (1997), the legal protection of coastal territories has become even wider. It was largely determined by the increase of anthropogenic load and various influences.

2.2.2 Protected Nature Territories

To ensure a favourable conservation status of the coastal, inland dune and heath habitats, 23 protected nature territories have been established in Latvia. They are also included in the Natura 2000 network (Fig. 2.11). These include two national parks, five nature parks, 15 nature reserves and one protected landscape area. Two Natura 2000 sites are included in the North Vidzeme Biosphere reserve. There are 15 Natura 2000 sites along the coast of the Baltic Sea in Latvia; their length is about 232 km or 40% of the country's total coastline.

Most often, protected nature territories in coastal areas were established for the protection of coastal forests. However, they also include many habitats of open dune landscape, and nowadays are often the main value of these territories. Also the "Slītere Nature Monument" established in 1923 close to the sea coast, mainly targeted the protection of forests. Later it became Slītere State Reserve, since 2000 it is a national park. Today it covers a much wider territory, and is one of the most important areas not only in the context of habitat type 2180 *Wooded dunes of the Atlantic, Continental and Boreal region*, but also for the protection of many other coastal habitats, including beaches, open dunes and dune slacks. Equally important in the protection of the previously mentioned habitats is Ķemeri National Park.

Many nature parks were created or enlarged in the 90s of the 20th century, and their main mission is the protection of recreation resources and protection of wooded dunes. The oldest nature parks of this type are "Ragakāpa" and "Piejūra", established in 1962. "Piejūra" Nature Park was later enlarged and is very important for the protection of beach habitats, open and wooded dunes, and priority protected habitat 1150* *Coastal lagoons*. Also "Engures ezers" Nature Park, initially established for the protection of freshwater habitats, is important for the protection of coastal habitats. "Bernāti" and "Pape" nature parks which include both habitat type 2180 *Wooded dunes of the Atlantic, Continental and Boreal region* and wide areas of open dunes are very important nature areas.

Protected habitats characteristic to the sea coast

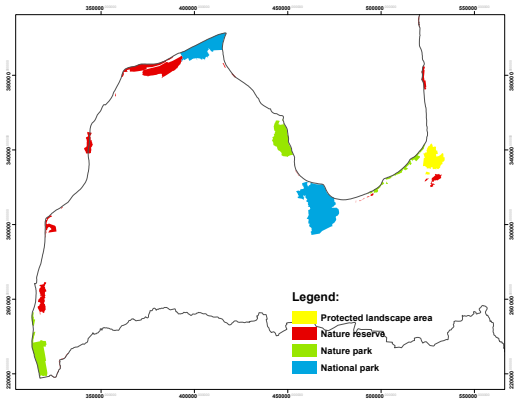


Fig. 2.11. Protected nature territories (Natura 2000 sites) for the protection of coastal, inland dune and heath habitats and species. Data from the State Management System of Nature Data "Ozols" have been used. The map was prepared by P. Rozenbaks.

can also be found in 12 nature reserves and in "Ādaži" Protected Landscape Area, which is particularly important for the conservation of habitat type 2320 *Dry sand heaths with* Calluna *and* Empetrum nigrum.

Habitats of marine and brackish substrates, except for habitat type 1630* *Boreal Baltic coastal meadows*, are found in ten protected nature territories. The priority habitat type 1150* *Coastal lagoons* develops in four protected nature territories. The most important for lagoon conservation are "Randu Pļavas" Nature Reserve and "Piejūra" Nature Park. Habitat type 1210 *Annual vegetation of drift lines* periodically develops in eight protected nature territories. The most common are in "Engures Ezers" Nature Park, the nature reserves "Randu Pļavas" and "Vidzemes Akmeņainā Jūrmala". In six protected nature territories, habitat type 1310 Salicornia *and other annuals colonising mud and sand* is found. Its largest areas are located in Slītere National Park and "Ragakāpa" Nature Park. Habitat type 1220 *Perennial vegetation of stony banks* occurs primarily in "Engures Ezers" Nature Park and "Vidzemes Akmeņainā Jūrmala" Nature Reserve. Ķemeri National Park and "Randu pļavas" Nature Reserve are the main localities for habitat type 1640 *Boreal Baltic sandy beaches with perennial vegetation.*

Habitat types 2110 *Embryonic shifting dunes* and 2120 *Shifting dunes along the shoreline with Ammophila arenaria (white dunes)* are found in all the protected nature territories along the Baltic Sea coast. However, these areas are very inconstant and depend on storm influence.

Secondary open dune habitat types – 2130* *Fixed coastal dunes with herbaceous vegetation (grey dunes)*, 2140* *Decalcified fixed dunes with* Empetrum nigrum,

Fig. 2.12. Pebble beach in Nida. Photo: B. Laime.

Fig. 2.13. Coast of Vidzeme, "Veczemju klintis". Photo: B. Laime.

2170 *Dunes with* Salix repens *ssp.* argentea – are found in 15 protected nature territories. The most important are the nature parks "Piejūra" and "Pape", Slītere National Park, the nature reserves "Užava", "Ovīši", "Ziemupe" and "Pāvilostas pelēkā kāpa". Habitat type 2170 *Dunes with* Salix repens *ssp.* argentea is the least common, in large areas found only in "Užava" Nature Reserve.

The most important territories for the conservation of habitat type 2190 *Humid dune slacks* are Slītere National Park and the nature reserves "Ovīši" and "Ziemupe". In smaller areas it is remained also in "Ģipka" Nature Reserve and "Bernāti" Nature Park.

Habitat type 2330 *Inland dunes with open* Corynephorus *and* Agrostis *grasslands* is only found in small areas in "Sventājas upes ieleja" Nature Reserve.

Heath habitat 2320 *Dry sand heaths with* Calluna *and* Empetrum nigrum occupies extensive areas in "Ādaži" Protected Landscape Area and "Garkalnes meži" Nature Reserve. Habitat type 4010 *Northern Atlantic wet heaths with* Erica tetralix is concentrated in "Grīņi" Strict Nature Reserve.

Individual regulations on conservation and use as well as nature conservation plans have been elaborated for most of these protected nature territories.

2.2.3. Protected Nature Monuments

Several geological and geomorphological nature monuments at the coast are approved as protected nature objects. They include Nidas pebbly beach (Fig. 2.12), Pūsēna Hill – the highest dune in Latvia, the rampart of a Baltic Ice Lake by Rīva, Strante–Ulmale cliff, Staldzene cliff and several sections along the Vidzeme coast, with rocks that are unique to Latvia: "Ežurgu Sarkanās klintis" and "Veczemju klintis" (Fig. 2.13).

2.2.4 Protected Heritage Areas

A number of important coastal nature areas are also approved as protected heritage areas of national or local significance. According to the "Law On the Protection of Cultural Monuments", several coastal villages are approved as urban development monuments of national significance, including Papes Ķoņu fisherman village, fisherman farm "Gaiļi" and fisherman-farmer farm "Jūrmalnieki" in Nida, as well as fisherman villages in Košrags and Sīkrags. Their construction refers to the second part of the 19th century and the 1930s.

To preserve the language, traditions and cultural heritage of Livs, on 4 February 1991, the Cabinet of Ministers of the Republic of Latvia adopted the decision "On the creation of the culturally protected territory "Līvõd rānda"". The legal status of the territory remained until 24 December, 2003.

There are ancient Stone Age camping places in Pūrciems, Ģipka and Melnsils. They are unique in an archaeological sense and also interesting with their geological development over many thousands of years (Loze 2006).

Attention should be given to Sventāja valley with the Manor Hill, where the Manor of the Duke of Courland was located in the 16–18th century. Plieņciems, where the wife of Russian Tsar Alexander I, Empress Elizabeth Aleksejevna came in 1810 for health improvements, is historically interesting. These are just a few facts, which describe the important role of coastal areas in people's lives.

CHAPTER 3. Ecosystem Services and Other Values of Sea Coast, Inland Dunes and Heaths (A. Širovs)

On the processes ongoing in ecosystems of the sea coast, inland dunes and heaths, one can look through a prism of people's subjective needs and interests.

Like any other ecosystems, these also provide various kinds of public benefits, called "ecosystem services" (Anon. 2005). Nowadays the discussion of ecosystem services is one of the most important topics of discussion in the whole world, as the benefits of nature have an impact on society in social, cultural and economic fields and are important for overall human well-being. Deliberate and sustainable use of ecosystem services provides the successful preservation of nature diversity (Anon. 2015b).

Ecosystem services can be grouped and classified according to various criteria, however the General international classification of ecosystem services (European Environment Agency 2016) takes an increasingly important role. This classification provides for the division of all the ecosystem services into three main categories: regulating services, provisioning services, cultural services. In this way, services of sea coast, inland dunes and heath ecosystems can also be classified (Fig. 3.1).

Provisioning ecosystem services are products that the society may receive directly from nature, including energy (crops, berries, mushrooms, raw

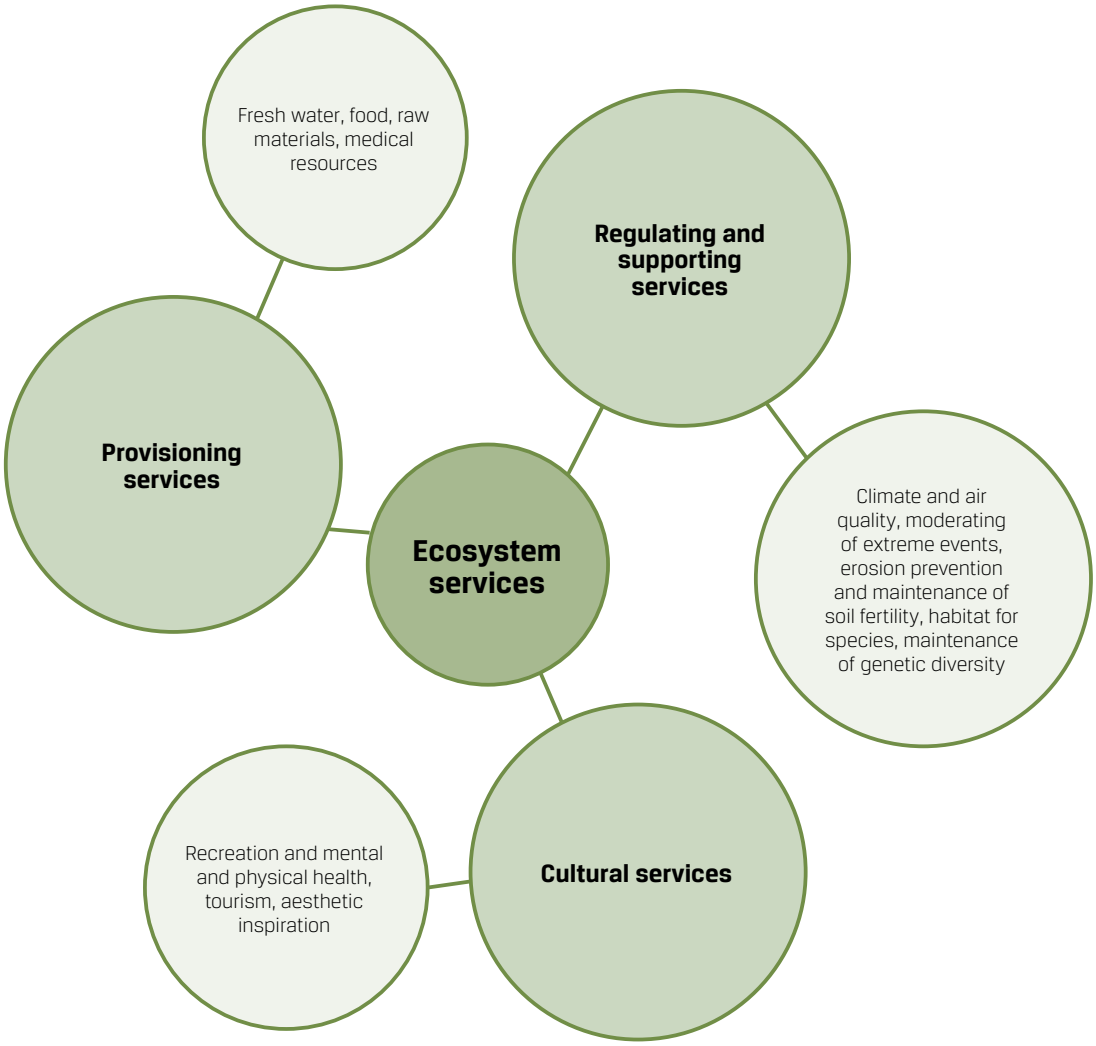


Fig. 3.1. Classification of ecosystem services according to the Common International Classification of Ecosystem Services. Picture of the ecosystem service project materials (LIFE 2016).

materials, drinking water, bioenergy etc.). Coastal forests are favourite sites for mushroom and berry picking, and are also used for hunting. In Latvia, the total relative value of total non-wood forest products (mushrooms, berries, wild game meat, honey, etc.) is 101 million Euros, and a portion of these values is also provided by coastal forests. For example, the value of mushroom products constitutes a major proportion, about 51 million Euros; fruits, berries, nuts – 17 million. Most of the forest bounties are used for domestic consumption, approximately 13% of the total forest products reach the market (Anon. 2015c).

Blueberry *Vaccinium myrtillus*, a typical plant of wooded dunes, in 2013 reached the export value of more than 8 million Euros. Demand for Latvian blueberries in the world increases each year. A third of the country's population are involved in blueberry picking in Latvia (Grivins, Tisenhofs 2015) (Fig. 3.2).

Coastal, inland dune and heath habitats are rich in medicinal plants — *Arctostaphylos uva-ursi, Calluna vulgaris, Vaccinium vitis-idaea, Thymus* spp. and many others. From *Pinus sylvestris*, buds, young shoots, needles, pollen and resin are used as well as the pine oil and ash obtained after processing.

Coastal beaches are periodically abundant with washed out algae, which has been used traditionally (*see Chapter 2.1*). Today our knowledge and experience in this area is constantly growing. Brown algae, for example, *Fucus vesiculosus*, has a large concentration of the trace elements iodine, calcium, magnesium, sodium, sulphur, silicon, iron, vitamin B, phosphorus, selenium, manganese, and zinc, as well as small quantities of vitamins A, C, E and G (Truus et al. 2001).

Furcellaria lumbricalis is an important resource for the production of agar. Agar is defined as extract obtained from certain *Furcellaria* species, consisting of two polysaccharides, agarose and agaropectine, and is 70% of the entire mixture. Agar has a wide-range of uses associated mostly with its high capacity of gelling and special gel structure, but most often it is used in the production of foods, such as pastries and in bread bakeries as a stabiliser, coagulant, thickener and otherwise. Nowadays the Estonian company "Est-Agar" Ltd. produces agar from algae *F. lumbrica-*

Fig. 3.2. Blueberry picker in wooded dunes in Ķemeri National Park. Photo: K. Lapiņš.

Fig. 3.3. Beehives in heaths of "Ādaži" Protected Landscape Area. Photo: I. Mārdega.

Fig. 3.4. The number of "wind hunters" or kiteboarders on the coast is growing. Photo: project LIFE13 ENV/LV/000839 "LIFE EcosystemServices".

lis, it is also used in the production of "Laima" zephyr "Maigums" (Grickus, Jelagina 2013).

Presently, denser growths of *Furcelaria* are found in the area of Nida–Liepāja, where they cover more than 80% of the hard bottom substrate. High distribution potential remains up to Akmeņrags, where bottom substrate is suitable for algal growth.

In the coastal section from Akmeņrags to Ventspils, the abundance of *Furcelaria* decreases. The total amount of the potentially gathered *Furcelaria* in Kurzeme's coastal areas can reach more than 50 000 m^3 (Vides attīstības biedrība 2012).

The heaths also provide provisioning services, mainly by promoting the development of beekeeping and production of heather honey. For example, heather honey is particularly popular in the United Kingdom, where it is twice the price of other types of honey, and it is considered a traditional lifestyle product (UK National ecosystem assessment 2016). Some beekeepers in Latvia gather heather honey by moving their hives when heather is in bloom. "Ādaži" Protected Landscape Area is very suitable for this purpose. Several dozen beehives are placed here every year, thus combining different goals of land use – nature protection, military exercises and honey gathering (Fig. 3.3).

Not only in Latvia, but also in other countries, more and more energy is gained in coastal ecosystems like wind power, wave power, biomass (energy from plants and animals).

Coastal, inland dune and heath ecosystems have an important role in the provision of **regulating ecosystem services**. These services are:

- biological fixation of substances (including pollution) by microorganisms, plants, animals;
- biophysical effects on various substances (filtration, accumulation in soil and water);
- effects on particulate matter and fluid flow (erosion, landslides, sand movement processes);
- soil formation processes;
- freshwater and saltwater formation processes;
- gas exchange, climate regulation, etc.

Vegetation of coastal forests and other habitats absorbs carbon dioxide and releases oxygen during photosynthesis and is involved in water circulation, which prevents flood formation and influences sand

Tourism in coastal areas

There is a comparatively high concentration of tourist accommodation in coastal areas. In 2013, this parameter in Latvia exceeded the average in the EU — 67% or 25,700 of all available beds in the country were located in coastal areas (in municipalities that are located by the sea or those that have at least half of the territory located 10 km from the sea). In summer, the average daily number of visitors for a 1 km long beach ranges from a few up to 9200 people per day. Overall, the number of visits on the coast area is estimated at around 4.7 million people a year (Anon. 2016).

Fig. 3.5. "Bird-watching days" in Ķemeri National Park. Photo: project LIFE13 ENV/LV/000839 "LIFE EcosystemServices".

flows. Beaches and dunes create an important natural barrier that reduces coastal erosion, thus eliminating the risk to human residences and saving the terrestrial area of Latvia. Coastal ecosystems play an important role in reducing the impact of pollution in the Baltic Sea and the Gulf of Riga.

In the Netherlands, dune habitats are used for drinking water purification, due to the physical and chemical properties of sand. Water of the River Rhine is artificially infiltrated in the sand of dunes, later collected, additionally treated and delivered to consumers in Amsterdam (Waternet 2016).

Coastal and inland dunes, as well as heaths, are habitats of various insects, including pollinators, which play a role in the vegetation and plant regeneration and the provision of natural resources (medicinal plants, blueberries, cranberries, etc.) to the population.

Perhaps the most important ecosystem service category in the eyes of residents of Latvia and guests are **cultural ecosystem services**, understood as intangible benefits that society receives from nature. It is the enjoyment of heritage landscapes, silence or strong winds, photography, running or just a stroll on the beach, etc. Nowadays, the demand for cultural services is constantly increasing.

The Baltic Sea coast is an important resource for the development of coastal municipalities. The large number of coastal visitors is associated with the unique sandy beaches in Latvia and hilly wooded dunes, the peculiar geological objects (such as White Dune in Saulkrasti, sea cliff in Jūrkalne, boulder beaches in Vidzeme), and unforgettable sunsets, opportunities to build sand castles, sunbathe and swim. In terms of attraction, coastal ecosystems definitely

Fig. 3.6. Ovīši lighthouse is surrounded by coastal forests. It is considered to be the oldest remaining navigation structure in Latvia, included in the national list of protected cultural monuments, 2016. Photo: P. Ozols.

occupy first place among all the other ecosystems (Anon. 2016). When the winds and waves are suitable, the beach and dunes are filled with kiteboarders or "wind hunters", who kite on water, ice or snow (Fig. 3.4). Coastal ecosystems are traditionally used for orienteering. For decades, orienteering events like "Magnēts" and "Kāpa" bring together orienteering sport competitors from all over the country. The most popular sites are Garkalne, Vecāķi, Gauja, Kalngale, Lilaste where there is a pronounced dune terrain with old coniferous forests and wide beaches.

The coast has always attracted many bird watching professionals and amateurs. Most of the bird watching sites recommended by the Latvian Ornithological Society are located directly at the coast (Fig. 3.5). Interesting areas include the Kolka Cape, the coast at Liepāja, Akmeņrags, Ovīšrags, Pape, Vitrupe–Ainaži, Bērzciems, Kaltene, Mērsrags, etc. (Latvijas Ornitoloģijas biedrība 2016).

The coast of Latvia is an important ecological complex of landscapes. It includes slightly transformed landscapes of sea, coast and natural forests, as well as landscapes that have developed in close interaction between human and nature, and are related to ports, wharfs, lighthouses, and traditional fisherman villages. Landscapes also include intangible cultural heritage, such as knowledge, skills and traditions (Fig. 3.6).

In coastal areas, there are 630 cultural monuments under special protection. They are designated as national (237 monuments) or local (393 monuments) cultural monuments. The cultural space "Suiti" is included in the UNESCO Intangible Cultural Heritage List, and together with the culture of Latvian Livs it is also included in the Latvian Cultural Canon (Anon. 2016). These cultural values can be considered as particular cultural services. In many cases, they directly depend on habitat diversity and management.

Evaluation of ecosystem services in Latvia

Comprehensive mapping and evaluation of ecosystem services has not been carried out in Latvia. However, pilot mapping and evaluation of coastal ecosystem services has been performed in two coastal municipalities – Jaunķemeri and Saulkrasti, under the project "Ecosystem services" financed by the LIFE programme (LIFE13 ENV/EN/000839, "Assessment of ecosystems and their services for nature biodiversity conservation and management"), implemented by the Nature Conservation Agency (LIFE 2016). The evaluation of ecosystem services includes:

- ecological assessment (habitat mapping; description of habitat quality, function and structure),
- social assessment (describes the importance of ecosystem services to the community),
- economic evaluation (describes the economic value of services provided to the community).

Using the results of ecosystem services mapping and biogeographical assessment, habitat quality in pilot territories of Jaunķemeri and Saulkrasti was evaluated in four quality classes: low, average, good, and excellent. In accordance with the "Common International Classification of Ecosystem Services", 22 ecosystem services were identified (four provisioning services, 13 regulating, five cultural ecosystem services). To describe the current situation and its changes over time, the indicator approach was used.

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 a habitat have been discussed in the guidelines. In the broadest meaning these activities – both passive and active – should be called **habitat protection.** It includes the establishment of protected nature territories and microreserves, prohibitions and restrictions of various forms, planning of nature protection measures and development (the guidelines do not review these aspects), as well as active, targeted restoration, management and establishment of habitat in sites where it has disappeared or been destroyed. The concept "**conservation"** is increasingly used as an alternative term for habitat protection. In these guidelines both terms are used as synonyms. So protection and conservation covers all targeted activities, approaches, and techniques – both active and passive (Fig. 4.1).

In these guidelines, **habitat restoration** is a set of biotechnical measures aimed at restoring the environmental conditions, structure and typical species composition in a site where a habitat has once existed or still exists, but is in bad conservation status. In the sea coast, habitat restoration includes, for example, the enlargement of open grey dunes by felling trees and shrubs that have established during the succession or are planted.

The dominant attitude in Latvia in recent years is that nature values should be restored in sites which can still be classified as EU protected habitats. But restoration should not always only be planned in an area which is currently recognised as a habitat of EU importance. There may be cases when the protected habitat area has decreased to the point that it may not ensure the favourable conservation status of a habitat. In this edition, the understanding of habitat restoration is broadened, to also include conditions and sites which currently (not anymore) do not meet the minimum criteria of a protected habitat, but under targeted actions their conditions can be established or improved enough to increase their biodiversity in the future. It is necessary to ensure favourable conservation status for habitats by, for example, providing a sufficiently large area.

For the purpose of these guidelines **habitat creation** is a set of biotechnical measures aimed at the establishment of environmental conditions and structure characteristic for habitat, and the introduction of characteristic species in a site where habitat has never existed. Creation of a particular habitat also refers to sites where it existed previously but the environment is completely transformed, and characteristic features of this habitat have disappeared or been destroyed.

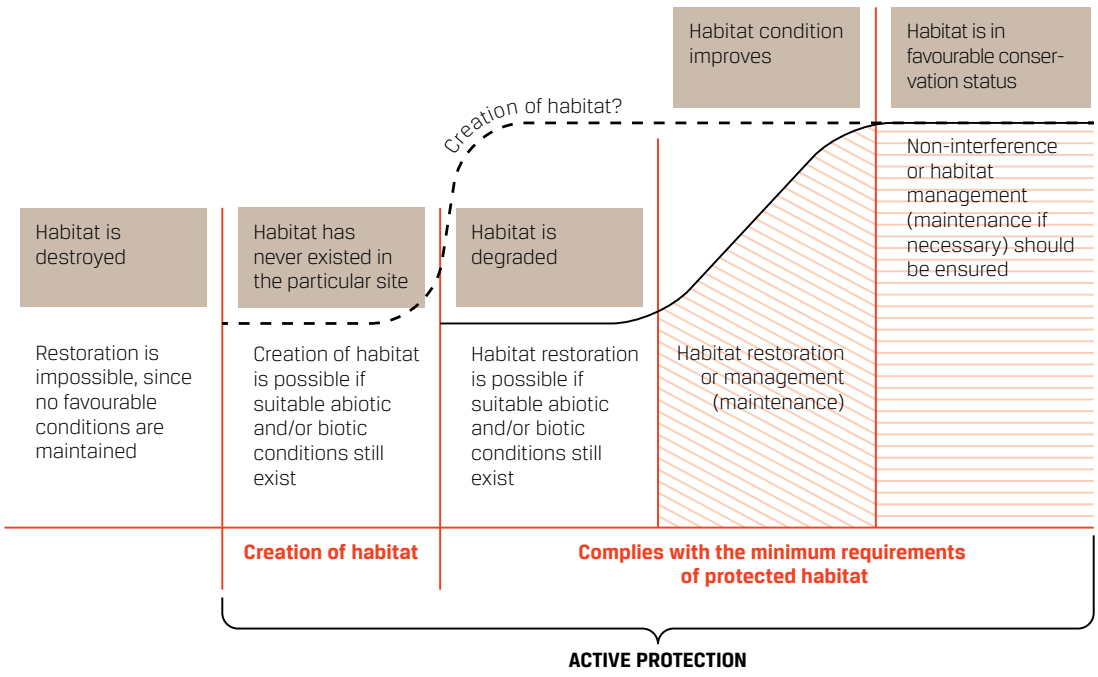


Fig. 4.1. Concepts used in the context of these guidelines concerning habitat restoration and protection.

Habitat creation is not a goal in itself. However, in the case of some habitat types it may at least partially compensate the consequences of loss of coastal, open inland dune and heath habitats, and hence also the loss of EU protected habitat areas. Created or restored coastal or sands habitat can be approved as a protected habitat if it corresponds to all of the minimum quality criteria defined for habitats of EU importance (Auniņš (ed.) 2013).

Habitat management is understood as a broad range of activities including both passive and active actions, also non-interference with natural processes. In this edition the understanding of the management notion has been narrowed. It is a set of biotechnical measures aimed at maintaining the habitat in favourable conservation status. Management or **maintenance** for the purpose of these guidelines includes repeated activities such as mowing and haymaking, cutting of shrub shoots, pasturing.

CHAPTER 5. Habitat Conservation and Management Objectives

5.1 Relationship of the Guidelines with the European Union "Nature Directives" and Natura 2000 Network (J. Jātnieks, A. Priede)

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

The Birds Directive is intended to protect all species of wild birds and their habitats in the EU. The Directive provides for the protection of threatened bird species in the EU, determines the protection of feeding and resting sites most important for migratory birds, particularly emphasising wetlands of international importance. The Directive includes around 450 species. **The Habitats Directive** is intended to promote biodiversity by protecting natural habitats, plant and animal species in the territory of EU Member States. The Habitats Directive defines the necessity for protecting rare, endangered and endemic species; approximately 1200 species in the EU in total. The Directive includes 231 habitat types, out of which 71 are recognised as priority protected habitats at the EU level. In Latvia, 58 habitat types of Annex I of the Habitats Directive can be found. Of them, 19 are priority protected at the EU level[1].

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

The Habitats Directive provides for the implementation of nature conservation in a way that maintains and restores natural and semi-natural habitats and wild flora and fauna[2]. Guidelines proposed in this edition include a set of methods which facilitates the reaching of favourable conservation status of the EU protected habitats found in Latvia. However, it is only a part of the activities related to nature conservation (*see Chapter 4*).

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

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

Natura 2000 sites of Latvia vary from small (up to 1 ha) to more than 90,000 ha, depending on characteristics of their species and habitats, and their conservation objectives. The area of Natura 2000 sites in Latvia varies mostly from 100 to 1000 ha. Many of them are known to the public and are popular natural heritage sites – national parks, nature parks and nature reserves, as well as areas which create and maintain our agricultural, forest, mire, water and coastal landscapes, forming significant part of natural and cultural history heritage.

Article 6 of the Habitats Directive sets out the requirements for the conservation and management of Natura 2000 sites. According to this Article, the protection regime appropriate for the conservation of species and habitats must be defined and imple-

1 In 2016 three more forest habitat types, found in Latvia, were discussed for inclusion in the list of EU protected habitat types.

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

mented. It also includes active action in a case when following the non-intervention and caution principles do not ensure habitat conservation. These guidelines are a part of the measures defined in Article 6. They offer recommendations for habitat restoration, maintenance and creation in sites where they have been destroyed.

5.2 The Objectives of the European Union for the Conservation of Habitats and Species (A. Priede)

One of the objectives of the EU biodiversity strategy 2020 requires that by 2020 the Member States should restore at least 15% of the degraded ecosystems in their territories (European Commission 2011). The restoration result is not only the total area of the restored habitats, but mostly the protection situation – improvement of living and non–living environmental conditions. Taking into account the degree of ecosystem degradation nowadays in Europe, it is not possible to eliminate all the adverse effects and completely "fix" their consequences. It would be too expensive and technically difficult, sometimes even impossible. Restoration is considered as successful if a considerable improvement has been reached, at least concerning the restoration of main habitat functions, structures and species populations. The reference point is 2006, as this was when the first report on the conservation status and areas of habitat types included in Annex I of the Habitats Directive was prepared (Lammerant et al. 2013).

This means that any habitat restoration in a specific area will at the same time cause a local favourable effect (will restore the specific habitat area). However, each restored area will be a mosaic piece, which helps to maintain favourable habitat conservation status in the country as a whole. It is possible to gain insight into the overall situation (desirable or real) by assessing and planning the action at a national level. Ideally, the most important target areas should be chosen first, taking into account the principles of landscape ecological planning. But even if we act at a local level and do not analyse the whole picture, any restored or properly managed habitat area will improve the overall situation slightly.

In order to achieve the biodiversity conservation goal, in 2013, Latvia, like other EU Member States, prepared a Prioritised Action Framework for Natura 2000 – a document, which defines activities for species and habitat protection, taking into account their levels of endangerment. This guideline book provides instructions for the implementing the conservation of habitats and related species provided for in the priority activities framework when performing (or in some cases – on the contrary – not performing) certain activities.

5.3 Coastal, Inland Dune and Heath Habitat Conservation and Management Objectives in Latvia (A. Priede, B. Laime)

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

For the protection and management of coastal, inland dune and heath habitats, the ecosystem approach is important in promoting the ecological functioning of the system as a whole, and thus conservation of certain habitats and species. First, favourable conservation status of these habitats means to conserve and restore the specific abiotic conditions (sand overblowing, brackish, dry and poor substrate, etc.), which in turn supports the ecosystem functions and their sustainable existence, which is the most important characteristic of the species as a whole, including their existence. In the protection of coastal, sands inland dune and heath habitats, the landscape ecological approach is of similar importance. It analyses habitats and species as components of a landscape (*see Chapter 8*).

To ensure favourable conservation status for the EU protected coastal, inland dune and heath habitats in Latvia, the following **objectives** have been set, which can be evaluated using specific features.

(1) Decrease of habitat areas is stopped.
Indications:

- total habitat area in the country does not decrease (reference: total habitat area in Latvia and Natura 2000 sites in 2006);
- number of habitat localities in the country is not decreasing (with disappearance of locality, the possibilities of conservation of habitat and its characteristic species in the whole region and distribution range also decrease).

(2) No-deterioration of abiotic conditions ensured; where it is necessary and possible, habitat quality improved.
Indications:

- there are optimal hydrological conditions for habitat existence;
- processes with functional importance occur (sand overblowing, inundation, burning, etc.);
- there are habitat specific structures (relief, micro relief, characteristic species, vegetation etc.);
- there is a contact area with natural or semi-natural habitats which are significant for biodiversity conservation (potential influence from adjacent areas).

(3) Conservation and management optimal for the habitat and its characteristic species ensured.
Indications:

- umbrella species and habitat characteristic species are present; distribution area of these species in the country is beneficial;
- rare, endangered, vulnerable (protected) species are present in the habitat; their distribution area nationwide is beneficial;
- atypical species (species indicating degradation), expansive and invasive species are absent or their abundance is decreasing.

5.4 Setting of Conservation and Management Objectives in a Specific Area (A. Priede, B. Laime)

When setting restoration or management objectives for a specific area of habitat it is important to thoroughly investigate the earlier (before the impact, if any) and current situation, as well as the reasons and factors for changes that promote habitat degradation or regeneration.

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

(1) **Restoration of the "perfect" situation.** It means restoring of the former habitat area so that it can be considered as a habitat under favourable conservation status, thus also restoring the processes with functional importance necessary for the existence of the habitat. Such an objective can be set if reliable and detailed information is available (what the area covered by habitat was earlier, what species composition and environmental conditions where). Restoration of the "perfect" situation is only possible if there are no permanent or too significantly degraded conditions in a territory or its surrounding, which makes the restoration of habitat and its necessary processes impossible. Natural coastal geological processes (no structures in the sea and seashore) are important prerequisites for the restoration of the "ideal" situation for coastal habitats.

(**2) Restoration compromise.** In the case that for various reasons the "perfect" situation cannot be restored, restoration of part of the earlier habitat area may be possible, and also partial restoration of the earlier species complex. For example, complete restoration of natural grey dunes and foredunes in an area of intense recreation which causes continuous vegetation destruction, is not possible. A significant obstacle in the restoration of the species complex characteristic for the habitat can be fragmentation and local extinction of the species characterising the habitat, disturbance of the life cycle of biogeochemical substances making the restoration of the habitat ineffectual. There are also cases when the ecosystem is irreversibly degraded and restoration is no longer possible or the funds to be invested are not commensurate to the predicted result.

Mostly only partial restoration of the habitat is possible, i. e., it is not possible to restore all the features of the original ecosystem. Thus one should focus on specific objectives that should be precisely defined. Sometimes the priorities should be selected between several possibly conflicting objectives (for example, restoration of the characteristic vegetation, different groups of organisms or species, nature values and cultural historical values). When the objectives are defined, appropriate methods should be chosen to implement them (*see Chapter 7*) and results should be assessed (*see Chapter 9*).

Chapter 6. Preparation before Management or Restoration

6.1 What does the Success of Habitat Restoration and Maintenance Depend on? (A. Priede)

It is not easy to plan the ecosystem or, in a narrower sense, habitat restoration. Each site is different, with specific geographical conditions often difficult to generalise. In many places the socioeconomic conditions that influence the habitat conservation status and its conservation and restoration options, should be considered.

Prior to starting habitat restoration, the most important thing is to define the objective – what do we want to achieve with our activity? It requires knowledge about the natural or ideal condition of the habitat, ecological requirements of the species present. The target status should include both the area and quality of the habitat. In order to determine the status, in each separate case it is necessary to understand the real potential, taking into account the impacts and obstacles. In defining the target in a particular area one should take into account the conditions that exist in the area and next to it, and the impacts that are long lasting and sometimes are not avoidable with our action. Sometimes only improvement of the situation is possible – a sort of compromise that is better than non-interference or doing nothing. Sometimes, various errors are made upon setting the objective to be achieved, as the current situation, causes of degradation, and background conditions are not adequately assessed. For example, in Europe, which has been heavily modified by human action, affected both by the transfer of pollution and climate change, even in the Natura 2000 areas we cannot expect the restoration of pristine "wild nature". It is certainly more useful to try to restore a functioning and self-regulating ecosystem instead of a degraded ecosystem, even though it only vaguely resembles our imagined primeval nature (Thorpe, Stanley 2011; Hilderbrand et al. 2005).

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

The biggest disappointment usually happens when one assumes that it is enough to restore the non–living environmental conditions, and the set of characteristic species will establish soon. It can work in conditions that are still little–affected, but the success can be poor when trying to restore habitats in heavily fragmented landscapes. If characteristic species are absent, they can also be introduced artificially. Although the reintroduction of the characteristic species is quite a widely used technique nowadays, it can be unsuccessful even when seemingly suitable conditions have been restored or created (Hilderbrand et al. 2005), most likely because of the lack of a vital component, for example, the ecological requirements of the species are not completely understood, symbiotic relationship or other factors do not allow species to adjust themselves in the new site, even if it has also existed there before.

Also, it is not easy to control the spread of "undesirable" species. Most often this is due to undesirable species that are considered invasive species, which nowadays are spreading more rapidly due to global changes, taking the ecological niches of local species and creating significant, sometimes even irreversible changes in ecosystems and their functioning. The control of invasive species dispersal is a difficult task which requires permanent and patient work that may also be unsuccessful if these species are not combated 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 for all similar cases (Hilderbrand et al. 2005). Even if the chosen technique is correct, you may not know whether the outcome will be the same as in another success story; probably not. We also do not know how the ecosystem "behaves" in a longer period of time after restoration. Only long-term observations can show whether we have reached the goal and even if not, whether the result can be considered as successful.

In ecosystem restoration one should take into account the background of the modern environment – climate change, pollution, changes in land use which, in turn, are related to human lifestyle changes. For example, the European dunes in the second half of the 20th century have been affected by overgrowth with grass and bushes caused by depositions of phosphorus and nitrogen that most likely cause a decrease of open areas. If Latvia is still considered as being

relatively little affected by these changes, this can be misleading. One should take into account this background in the restoration of many habitats when setting realistic goals.

In the restoration of an ecosystem or, in a narrower sense, – habitats – one should always take into account the restrictions: environmental (climate, soil, geological and hydrological conditions, landscape fragmentation and its impact on species populations), economic (financial constraints), social (public, often also funders', opinion). This should already be taken into consideration when planning the works – possibly, more money, more time will be needed and worse success will be expected because of these restraints. However it does not mean giving up all the plans and deciding that it is not worth doing anything. In many cases, it is not possible to restore degraded ecosystem in the original "perfect" condition. However, the situation can definitely be improved.

Smart planning and the evaluation of risks urge one to act smarter than in the case of not realising these obstacles, thus risking making more mistakes.

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 excessive pressures, rather than to damage and then try to "fix". Restoration of degraded ecosystems is always associated with the risk of failure and high costs, as well as many natural values may be irretrievably damaged losing rare species, specific conditions, beautiful sceneries and resources necessary for the survival of not only nature, but also humans. Countless examples around the world confirm that the funds invested in restoring the damaged ecosystem are much greater than the benefits derived from ecosystem use.

Moreover, the costs increase accordingly with the increase of the degradation level. Thus the proper protection of natural ecosystems is always most important, and restoration or management is only to be used as a tool to "fix" already degraded ecosystems.

A different approach should be used for the restoration of semi-natural habitats (traditionally managed habitats, for example, open inland heaths and grey dunes). Species composition characteristic to these habitats was established and must be maintained under continuous but moderate human influence.

6.2 Planning of Habitat Restoration and Management in a Specific Area (A. Priede, B. Laime)

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

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

In the planning stage it is rarely possible to answer these questions, but careful preliminary studies can play a vital role in the implementation of the plan. References with the main aspects to be analysed are summarised in Table 6.1.

In the planning stage all the available information should be used, which is quite often insufficient. Possible data sources are the following:

- monitoring data;

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 excessive pressures, rather than to damage and then try to "fix". Restoration of degraded ecosystems is always associated with the risk of failure and high costs, as well as many natural values may be irretrievably damaged losing rare species, specific conditions, beautiful sceneries and resources necessary for the survival of not only nature, but also humans. Countless examples around the world confirm that the funds invested in restoring the damaged ecosystem are much greater than the benefits derived from ecosystem use.
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A different approach should be used for the restoration of semi-natural habitats (traditionally managed habitats, for example, open inland heaths and grey dunes). Species composition characteristic to these habitats was established and must be maintained under continuous but moderate human influence.

Table 6.1 Gathering of basic information (planning before the start of works).

Characteristics, conditions, influences to the area – before and now	• Site description (relief, geological and hydrological conditions, soil, etc.). • Site as a part of broader habitat complex. • Area previously occupied by habitat, as identified in cartographic and other materials of various times. • Management in the past – whether it was favourable or unfavourable (information is usually unpublished, stored in memories of local people). • Past and modern influences in specific area and in hydrologically related broader area (drainage, land use, land use change etc.). • Current impacts and threats to habitat.
Species and habitats	• Characteristic common species, rare species. • Changes of habitat and species distribution, their influencing factors, causes of changes. • Threats to the species and the influencing factors. • Mapping of target area and, depending on the extent of potential influence, also mapping of adjacent habitats.

- cartographic material of various times, orthophoto;
- literature, unpublished notes;
- memories of local people and experts;
- photos of different times;
- site-characterising information recorded in other ways.

If such information is not available, it is incomplete or old, additional study is required – habitat and species mapping (including remote sensing), detailed analysis of topography, and other methods. Restoration of coastal, open inland dune and heath habitats need complex knowledge, therefore both experts of species and habitat conservation and other experts (geologist, hydrologist, landscape expert) should be involved. Involved professionals should have prior experience in restoration of the mentioned habitats. Finally, creative collaboration between experts is important, because it helps to work more efficiently.

Concerning coastal, open inland dune and heath habitats, during the preparation phase, while specifying objectives and targets, it is already important to use the landscape-ecological approach, evaluating particular habitat as a part of landscape.

When assessing the biological values of landscape, the following criteria should be used.

Representativeness. This criterion shows how coastal, inland dune and heath area represents habitats and species of a specific region, geobotanical region or state. The more typical the biological elements, the more valuable the landscape. For example, sandy beaches, wide embryonic dunes and foredunes bordering with dry pine forest are characteristic for the coastal section between the River Daugava and the River Gauja.

Rarity. A very important criterion that describes how much of the habitats and species found in the territory are also found outside it. For example, if the habitat is found in only one or two places, the conservation of this landscape certainly needs special attention. In Latvia very rare habitats are boulder beaches with perennial vegetation and annuals colonizing mud and sand. For more about the distribution of particular habitat types please see the respective chapters.

Regional distinction of distribution. There can be habitat types and species that are common in a particular site but are only distributed in certain regions. Distinctive landscape elements are, for example, *Atriplex* spp. stands on drift lines which are rather common in some sections of the Gulf of Riga coast but are almost absent along the open Baltic Sea coast.

Location, ecological unity. Landscape value is higher if adjacent areas are rich with natural ecosystems and species. As the coast is a relatively narrow belt, the location of the habitat is of great importance. Although the wind and water are powerful drivers of dispersal, the plants and animals may encounter insurmountable barriers, such as building areas, woodlands, etc. It is important to assess the ecological integrity for habitats such as lagoons and dune slacks because their functioning depends on the hydrological regime being maintained.

Diversity. This criterion applies to different levels of biodiversity. One can analyse the representation of species, their communities, habitats and other elements in the particular area. The greater the diversity,

3 With the amendments as of 1 January 2016.

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

5 Cabinet Regulation No. 396 of 14 November 2000, On the Lists of the Specially Protected Species and the Specially Protected Species Whose Use is Limited.

the more valuable the area.

Naturalness. The more dominating local species and habitats are, the more natural the area. The opposite will be the case when, for example, there are dense stands of *Rosa rugosa*, buckthorn or other alien species in the foredune.

Size (area). The size refers to the area as a whole and on its individual parts (ecosystems, their complexes, etc.). From two similar areas, the highest rating is given to the one which is larger because of its greater stability, and self-regeneration ability.

Dispersal, migration routes. Areas that serve as species dispersal pathways are of great importance. This is particularly important in areas where natural vegetation is fragmented and habitat connectivity has to be ensured.

Biological evaluation of the landscape must include habitat mapping, as well as analysis of species distribution.

Next steps – analysis of various requirements of legislation (*see Chapter 6.3 the transfer*).

6.3 Legal framework (Ē. Kļaviņa)

6.3.1 Protected Habitat Types and Species

The Cabinet of Ministers, based on the **Law On the Conservation of Species and Biotopes**[3], approved the Regulations determining protected habitat types and species in Latvia[4 5], plant and animal species important in the European Union[6], as well as priority species and habitat types of the European Union[7]. The list of protected habitat types in Latvia is not identical to Annex I of the Habitats Directive, or the list of EU protected habitats (see Chapter 1). The following habitat types are not included in the list of protected habitat types in Latvia: 2110 *Embryonic shifting dunes*; 2120 *Shifting dunes along the shoreline* with *Ammophila arenaria* (white dunes); partially 1230 *Vegetated sea cliffs of the Atlantic and Baltic coasts*. The following habitats are priority protected in Latvia: 1150* *Coastal lagoons*; 1630* *Boreal Baltic coastal meadows*; 2130* *Fixed coastal dunes with herbaceous vegetation (grey dunes)*; 2140* *Decalcified fixed dunes with* Empetrum nigrum.

6.3.2 Protected Nature Territories and Micro-reserves

The Law "On Specially Protected Nature Territories"[8] defines the basic principles of the system of specially protected nature territories (further below referred to as protected nature territories). To protect and maintain biodiversity in Latvia, strict nature reserves, national parks, nature reserves, nature parks and other protected nature territories are established. These territories can be divided into functional zones with approved different regimes of protection and management. Micro-reserves[9] are small areas (0.1–30 ha), established for the conservation of habitats or animal, plant, fungus, lichen, and algae species. The procedures for micro-reserve establishment, management and conservation are defined by the Cabinet Regulation[10]. Boundaries of protected nature territories, their functional zones, micro-reserves, are determined in the regulatory enactments and displayed in the public information system – the State Management System of Nature Data "Ozols" http://ozols.daba.gov.lv/).

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

Protection and management of protected nature territories is regulated by the **General Regulations on the Protection and Use of Specially Protected Nature Territories**[11] or their individual regulations on protection and use. To harmonise interests of nature conservation, nature resources use and sustainable development of the region, while maintaining the natural values of the area, a **nature conservation plan** can be elaborated for the protected nature territory[12]. The nature conservation plan recommends the

6 Cabinet Regulation No. 1055 of 15 September 2000, 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 the Conditions for Restricted Use may be Applied.

7 Cabinet Regulation No. 153 of 21 February 2006, On the List of the Priority Species and Habitats of the European Union in Latvia.

8 With the amendments as of 11 January 2014.

9 Law on the Conservation of Species and Biotopes (as amended on 1 January 2016.).

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

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

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

Fig. 6.1. Activities upon habitat management planning.

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

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

actions required for the conservation and management of nature values.

6.3.3 Coordination of Activities

Many activities for the restoration and management of protected habitats and species habitats before their implementation **in protected nature territories and micro-reserves, must be coordinated with the responsible public authorities** (Fig. 6.1). Before the works, all the necessary information should be gathered. In case of uncertainties, responsible authorities should be consulted.

According to the General Regulations[13] a written permit of the Nature Conservation Agency is required when performing, for example, the establishment of hydrotechnical constructions and drainage systems, their reconstruction and renovation, restoration of protected species and habitats, land category change, as well as the establishment of public nature tourism and education objects.

Within the meaning of Construction Law[14] a building is a physical object which was created by human activities and is linked to a foundation (ground or bed). Thus for the majority of infrastructure objects planned with the aim to redirect the flow of tourists and physically protect habitats, construction must be performed under the Cabinet Regulation[15], which describe the construction process, required documentation, and other construction-related measures. For example, drainage system (engineering structure) of one owner should be classified as a group I object with a simpler construction procedure. When planning the construction of small infrastructure or, for example, overgrown ditch cleaning, an application should be made to the building authority of the local government prior to any activity.

If the building of a car park, viewing tower, or footpath should be erected to regulate visitor flow in the protected nature territory, a construction permit is required. When applying to the Building authority for consent, the applicant will be informed of the additional technical regulations and requirements which should be received from various institutions. State and municipal institutions issue their requirements within 20 days.

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

A written permit is not required for grass mowing, felling of shrubs and trees with a diameter of stump less than 20 cm outside the forest, except if restrictions are defined by the individual regulations on the protection and use of a protected nature territory.

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

12 Cabinet Regulation No. 686 of 9 October 2007, On the Content of and Procedure Regarding the Elaboration of Nature Conservation Plans for Specially Protected Nature Territories.

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

14 With the amendments as of 1 January 2017.

15 Cabinet Regulation No. 500 of 9 August 2014, General construction regulations.

6.3.4 Categories and Types of Land Use

Land use category and land use type are defined for every particular land area. According to the classification of land use types[16] the category of land use is a set of land use types of similar features. There are eight categories of land use, among them: land for agricultural use (meadows, pastures); water object area (rivers, streams, ditches); forest; shrubs; mire; other lands (openings, flooded plains, etc.). Areas of land use categories and their changes are described in the National Real Estate Cadastre. The State Land Service maintains the National Real Estate Cadastre Information System, and it receives actual information from local governments and the State Forest Service.

According to the **Law on Forests**[17], forest land is the land covered by forest, overflowing clearings, mires, openings, adjacent mires and also the land under forest infrastructure. According to the Cabinet Regulation[18] the State Forest Service is the administrator of the State Forest Register and it maintains up-to-date information on forest lands, inventory data, change or exclusion of land categories. Information is removed from the State Forest Register if the area is deforested, based on the administrative deed of the Nature Conservation Agency. **Types of forest lands** included in the Cabinet Regulation[19], their management and conformity with the **type of land use** explains the extension of land use types if restoration or management of protected habitats or species habitats is planned. For example, grey dunes partially conform to the land use type and category "meadow" or "pasture" to remove trees in such habitats, regulatory enactments that define the felling of trees outside forest are applied). Forest stands and clearings correspond to the land use type "forest" to which regulatory enactments of forest management apply.

Land use types are displayed in certainland document of legal boundaries or in the respective documents of forest inventory. To change land use categories in a protected nature territory, with the aim to restore protected habitats and habitats of protected species, it is necessary to obtain written permission of the Nature Conservation Agency.

6.3.5 Environmental Impact Assessment

Restoration and management of habitats and species habitats includes not only careful planning, but also the assessment of the estimated impact of an activity.

For important habitat restoration, a certain procedure, expert examination, activity coordination and authorisation is required. The assessment of whether the proposed activity will result in any environmental changes that may significantly affect humans, landscape and cultural heritage is required prior to habitat restoration. The Law "On Environmental Impact Assessment"[20] is applicable to the activities that meet criteria according to which the impact of the intended activity[21] on the environment can be assessed, especially if it is implemented in protected nature territories, micro-reserves, wetlands of international importance, coastal protection zone of the Baltic Sea and the Gulf of Riga, surface water body protection zones, and may influence protected species, their habitats and protected habitats.

Law defines that an initial impact assessment is required for activities that may significantly affect a Natura 2000 site and they are listed in Annex 2.[22].

If the State Environmental Service concludes that the intended activity may significantly affect a protected nature territory of European significance (Natura 2000), the initial assessment of the impact on the Natura 2000 site is performed in accordance with the procedure provided for by the Cabinet Regulation[23].

The initial impact assessment is required for the change of the category of use of agricultural land (〉 50 ha); construction of drainage and irrigation systems (if land area 〉 100 ha); reconstruction of the existing drainage or irrigation systems (if land area 〉 500 ha); afforestation and deforestation (if land area 〉 50 ha).

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

17 With the amendments as of 1 January 2016.

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. 562 of 21 August 2007, On the Procedures of Land Use Classification and Definition Criteria.

20 With the amendments as of 1 January 2017.

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

22 The Law on Environmental Impact Assessment, Annex 2.

23 Cabinet Regulation No. 300 of 19 April 2011, Procedure Regarding the Assessment of Impact on a European Specially Protected Nature Territory (Natura 2000).

If the results of the initial impact assessment show that habitat restoration requires an environmental impact assessment procedure the State Environmental Service informs the responsible authority that shall make a decision on the application or non-application of the environmental impact assessment. One should recognise that the decision will take at least 130 days. If the results of the initial impact assessment on the intended activity does not require an environmental impact assessment, the State Environmental Service issues the technical regulations in accordance with the Cabinet Regulation[24].

6.3.6 Rewetting

If the restoration of coastal habitat requires the disruption of a drainage system or its part, the process is regulated by **the Amelioration Law**[25] and the Cabinet Regulation[26]. They determine that the drainage system, regardless of its ownership and status, shall be registered in the Amelioration cadastre by assigning a drainage cadastral number. The administrator of the amelioration cadastre information system is SLLC "Immovable Properties of the Ministry of Agriculture". The land owner or legal possessor must submit the application to the regional department of SLLC "Immovable Properties of the Ministry of Agriculture", adding the inventory case of the drainage system and the statement of the technical examination prepared in accordance with the regulatory enactments on the construction of drainage systems and hydrotechnical buildings.

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

6.3.7 Habitat Restoration and Management in Forest

When restoring protected habitats and protected species habitats in forest, the activities can only take place after land registration in the Land Register. The Law on Forests defines that for all the state-owned forests and other forest properties the area of which is more than 10 000 ha, forest management plans must be elaborated. Such plans must also be elaborated for forests located in national parks regardless of the area of the land (except the neutral protection zone). Prior to forestry activities in forest one should receive a tree felling confirmation from the State Forest Service. Forest trees, the stump diameter of which is less than 12 cm can be felled without the confirmation.

Nature Protection Requirements in Forest Management[27] define the general nature conservation requirements in forest management, restrictions in protection zones around mires, conditions for the determination and conservation of biologically important forest structure elements, and limits forestry activities during the animal breeding season from 1 April to 30 June. In the restricted economic activity 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 (geological objects, springs, and other).

In protected nature territories and micro-reserves these regulations are applied if they do not contradict the regulatory enactments regulating the conservation and use of protected nature territories and micro-reserves. Regulations define: prohibition of final felling in mire protection zone and mire islands; prohibition of felling for landscape forming in protection zones along mires and in buffer zones of micro-reserves. Wooded dunes are often located at mire edges.

6.3.8 Deforestation for the Restoration of Dune and Heath Habitats and their Species Habitats

Protected habitats and their species habitats in forests are restored in accordance with the criteria defined in the Cabinet Regulation[28]. The planned activity can not contradict the local government spatial plans.

If restoration of a dune, dune slack or heath habitat or species habitat requires the removal of trees, deforestation can be performed upon the receipt of a permit issued by the Nature Conservation Agency.

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

25 With the amendments as of 1 January 2015.

26 Cabinet Regulation No. 623 of 13 July 2010, Regulations Regarding Land Amelioration Cadastre.

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

28 Cabinet Regulation No. 325 of 18 June 2013, Restoration of Specially Protected Habitats and Specially protected Species Habitats in Forest".

The Nature Conservation Agency issues the permit based on the opinion of a certified expert in the conservation of species and habitats. To carry out deforestation for the restoration of protected habitat or species habitat, one should have a valid forest inventory of the respective area in accordance with the regulatory enactments on inventory and information flow in the State Forest Register.

The regulations provide that deforestation must meet at least one of the four criteria. One of them – there must be protected habitat characteristic species or indications. This means that currently the area may not meet the criteria of protected habitat, but there are characteristic indications (such as bare soil patches, at least a few characteristic species of grey dunes, dune slacks or heath) which allow one to assume that the habitat can be restored.

The following dune, dune slack and heath habitats are considered as nationally protected habitats which can be restored by afforestation:

- Fixed coastal dunes with herbaceous vegetation (grey dunes);
- Humid dune slacks;
- Grey dunes with *Salix repens*;
- Grey dunes with dwarf shrubs;
- Open inland dunes;
- Coastal Lowland dry heaths*;*
- Dry heaths;
- Wet heaths.

6.3.9 Tree Felling Outside Forest

If habitat restoration is planned by felling trees outside the forest land (according to the Law on Forests, mires are located on forest land, but forest is not their land use type), then it is performed in accordance with the Cabinet Regulation[29]. Such a procedure would be applicable upon wet heath habitat restoration. The appropriate land use must be registered in the information system of the National Real Estate Cadastre Information System. In such cases a permit of local government is required for the felling of trees outside forest.

6.3.10 Habitat Restoration and Management in Micro-reserves

Establishment of micro-reserves, habitat restoration and management in micro-reserves are regulated by the Cabinet Regulation[30]. Borders of micro-reserves are defined in decisions on the establishment of micro-reserves and are described in the public information system – the State Management System of Nature Data "Ozols" (http://ozols.daba.gov.lv/).

Micro-reserves are managed in compliance with the procedures provided for in the regulatory enactments in order to ensure a favourable conservation status for the species or habitats for which the micro-reserves have been established. Micro-reserves are managed in compliance with the opinion of a certified expert in the field of the conservation of species and habitats. In this judgement, necessary conservation or management measures of habitat are listed, such as reed cutting and removal, prescribed burning, cutting or mowing and removal of trees, shrubs and dwarf shrubs, rewetting. Expert opinion is not necessary for the mowing and removal of grass in micro-reserves.

6.3.11 Species Reintroduction

Most probably, the reintroduction of native species is not and in the near future could hardly be widely applied in the restoration of natural diversity in Latvia. The concept of "species reintroduction" is defined by the Law on the Conservation of Species and Biotopes where it is interpreted as "re-population of extinct species". However, the Law does not specify whether the term includes only protected species or all wild species. The Law determines in which cases acquiring individuals of protected species is allowed. This activity requires the decision of the Nature Conservation Agency. The procedure for issuing a reintroduction permit is determined by the Cabinet Regulation[31]. In order to obtain the permit a detailed argument is required, as well as public discussions.

6.3.12 Invasive Species Control

For habitat conservation and restoration, eradication of invasive species is necessary. In order to comply with the necessary safety precautions and avoid potential risks, the **Plant Protection Law**[32] and the related Cabinet Regulations must be followed[33, 34]. The Law provides that in Latvia it is prohibited to cultivate the species included in the list of invasive plant species. The land owner or possessor is obliged to eradicate invasive plant species, if they occur on their land.

The Cabinet Regulation[35] mentions *Heracleum*

29 Cabinet Regulation No. 309 of 2 May 2012, On Tree Felling Outside Forest.

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

sosnowskyi as the only invasive plant species. In the Cabinet Regulation[36] the methods for *Heracleum sosnowskyi* control are defined by describing the forms of limitation and methods in detail in Annexes.

The Cabinet Regulation[37] provides for 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 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 these products in particular protected nature territories. For eradication of invasive species important is the EU Regulation (1143/2014) on invasive alien (non-native) species and Commission Implementing Regulation 2017/1263.

6.3.13 Prescribed Burning

Prescribed burning for the restoration of protected habitats or species habitats can be performed in protected nature territories and micro-reserves; outside of the mentioned territories, it can only be performed in forests. This activity must conform to the Cabinet Regulation[38]. Prescribed burning is particularly important in heaths and forests. Prescribed burning can be organised if there are indications of protected habitat which are verified by scientific research or environmental monitoring which shows that habitat has disappeared due to afforestation or other environmental condition change. To carry out prescribed burning of dead grass, reeds, heaths and forest, a written permit of the Nature Conservation Agency is required. The State Forest Service issues this permit if the territory is located outside of a protected nature territory or micro-reserve and if deforestation is not planned. The institution responsible for fire safety and fire-fighting must be informed in writing.

6.4 Cost estimation (J. Jātnieks)

Cost estimation is one of the most important steps in the preparatory process. Cost varies over time and can rarely be generalised for specific types of work or a set of actions required for the improvement of habitat condition. The difference in cost can be great for similar works – depending on the geographic location, complexity of works, availability of workers and special equipment, and other factors. These guidelines are to be used over a longer period of time, thus we do not offer exact costs for all types of works, and only the indicative costs are given (Annex 1). Costs should always be assessed separately for every individual action or for the set of activities for a particular place and time.

The following principles should be used by developers of nature conservation plans, LIFE and other large projects to estimate the costs of habitat management and restoration activities for a 2–5 year period of, in one large or several Natura 2000 sites.

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

Key principles to determine reasonable costs of planned actions.

- After surveying the managed site **the most appropriate actions, methods and technical means are chosen**. It is advised to divide works into parts, by stages, timing and type of work. For example, manual labour, use of particular equipment. In this way, costs can be estimated for each activity separately, and summed costs are more objective. Cost effectiveness often depends on the season. For example, rewetting in lagoons and coastal wetlands should be carried out in the dry season, otherwise costs can grow unpredictably, but the objective may remain unrealised or the quality may be poor. To be sure that the actions of habitat management and restoration are chosen correctly, a species and habitat expert should be invited.
- **Direct costs should be calculated in approp-**

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

32 With the amendments as of 26 November 2016.

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

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

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

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

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

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

riate units – man-hours, person-days, cost of equipment per hour, cost of materials per area or volume depending on works (m^3, km, kg, t). The number of units required for all the works should be assessed and summed up. Experience shows that mistakes in these calculations are the most common. Therefore it is always advisable to use the experience of similar, already implemented works, such as reports on the projects or specific works, and the experience of institutions (Nature Conservation Agency, JSC "Latvia's State Forests", Rural Support Service, municipal and non-governmental organisations). Costs of technical works for various habitat restoration and management works over the years are published on the Rural Support Service website. Costs of materials and construction works are published annually on the Latvian Rural Advisory and Training Centre webpage. Such cost estimates are also available on the webpages of construction companies and the biggest forest management companies. If the set of planned activities consists of various works which have not been carried out previously or their pricing is not available, at least three potential executors should be surveyed. In this case, the result can be faster, however the risk increases that during the works unforeseen costs may arise that can complicate the fulfilment of the aim.

- **The indirect preparatory costs of habitat management and restoration works** should be assessed – site survey, expertise, technical projects, permits and agreements referred to in the regulatory enactments (*see Chapter 6.3*). It involves both working time and transport and administrative costs, which are often inadequately assessed. The time and means to inform the public and explain the necessary steps must be scheduled in complex work projects.
- **Regional cost differences in Latvia should be taken into account** and also the availability of work performers in the given region up to 30 km from the planned place of activity. The costs may rise significantly if the executors and/or equipment must travel from a greater distance. For this reason, specific activities that require special equipment or skills (e. g., dam construction on ditches, topsoil removal) will always be more expensive than simple activities (mowing, felling of shrubs).
- **It is desirable to entrust cost assessment to professionals** – managers, managing specialists, practitioners, entrepreneurs, – and schedule this job and adequate funding.

The planning, including financial planning, should also consider potential income related to habitat restoration and management – wood, mown grass, removed topsoil and other materials. Ideally they can at least partially be used on site (pine twigs, heather for strengthening of sand) or can be transported outside the territory and used otherwise (for example, wood as chips or firewood, reeds for thatching, groundcover in composting or gardening). However in practice, a practical application is rarely found for these materials, if the volumes are small, and extraction sites are dispersed over a wide and hard-to-reach area. Therefore it should be considered that the use of habitat restoration "byproducts" may not always be economically beneficial.

Annex 1 shows the indicative costs for various types of works referred to in the Guidelines. Costs are summarised after surveys (project implementers, managers, practitioners, publicly available price lists) and are approximate – attributable to years 2010–2016. Costs in each case are different, depending on the factors mentioned above.

Chapter 7. Main Methods of Habitat Restoration and Management (D. Tjarve, B. Laime)

The main coastal, inland dune and heath habitat restoration and management methods that focus on the solving of specific issues, are summarised in Table 7.1. A more detailed description of these methods can be found in the third chapter of the management guidelines for every habitat. Methods used most frequently are: removal of trees, shrubs and invasive and expansive species cover; sod cutting and topsoil removal; sand stabilisation with branches.

More detailed information on the factors and threats significantly influencing every habitat of Community importance can be found in the guidelines and summary for every habitat type or their group (Annex 2). Indicators of problems in different habitat type are listed in Annex 3.

Table 7.1. Main problems and methods of restoration and management of coastal, inland dune and heath habitats.

Problem	Methods	Habitats
Prevention and mitigation of impacts of climate changes and constructions located in the sea and on shore.		
Extreme erosion after which natural habitat regeneration is difficult or impossible, or it threatens other areas.	Fence/mesh systems for dune formation. Sand stabilisation with branches, mulch or woven materials – nets, wicker basketry, geotextiles. Mechanical restoration of foredune ridge. Planting of grasses (*Ammophila arenaria, Leymus arenarius, Carex arenaria, x Calammophila baltica*). Willow planting in exceptional cases.	Primary coastal dunes, rarely grey dunes.
Extreme erosion, destroying all vegetation.	Preservation of uprooted trees	1230 *Vegetated sea cliffs of the Atlantic and Baltic coasts.*
Rewetting		
Species composition change due to excessive drainage.	Ditch infilling or blockage.	4010 *Northern Atlantic wet heaths with* Erica tetralix.
Species composition change due to deficit of brackish water.	Lagoon connection with ditches.	1150* *Coastal lagoons*
Activities restoring and improving the habitat structure		
Overgrowth of open areas with trees and shrubs.	Felling of trees and shrubs, removal of seedlings, ring-barking of trees which form stump sprouts, mowing of stump sprouts, grazing.	1230 *Vegetated sea cliffs of the Atlantic and Baltic coasts,* primary coastal dunes, all grey dune habitats, 2190 *Humid dune slacks,* 2320 *Dry sand heaths with* Calluna *and* Empetrum nigrum, 4010 *Northern Atlantic wet heaths with* Erica tetralix, 4030 *European dry heaths.*
Formation of dense layer of litter and humus.	Litter gathering, moss layer and topsoil removal, loosening, covering with sand, litter and groundcover burning.	All grey dune habitats, 2180 *Wooded dunes of the Atlantic, Continental and Boreal region,* 2190 *Humid dune slacks,* 2320 *Dry sand heaths with* Calluna *and* Empetrum nigrum, 4010 *Northern Atlantic wet heaths with* Erica tetralix, 4030 *European dry heaths.*
Overgrowth with invasive tree and shrub species.	Felling, digging up shrubs, root and stump extraction, mowing of stump sprouts, herbicide application in specific cases.	1150* *Coastal lagoons*, primary coastal dunes, all grey dune habitats, 2180 *Wooded dunes of the Atlantic, Continental and Boreal region*, 2190 *Humid dune slacks*.

Problem	Methods	Habitats
Overgrowth with invasive moss species.	Moss removal, exposing bare sand.	All grey dune habitats, 2180 *Wooded coastal dunes of the Atlantic, Continental and Boreal region*, 2190 *Humid dune slacks*.
Overgrowth with expansive herbaceous plant species.	Removal of plant aboveground and underground parts by mowing, pulling out, repeated ploughing, gathering.	1150* *Coastal lagoons*, beaches, primary coastal dunes, 2180 *Wooded coastal dunes of the Atlantic, Continental and Boreal region*
Overgrowth with expansive tree and shrub species	Felling, stump sprout mowing and/or treatment with herbicides.	2320 *Dry sand heaths with* Calluna *and* Empetrum nigrum, 2180 *Wooded coastal dunes of the Atlantic, Continental and Boreal region*, 4030 *European dry heaths*
Extinction of vegetation typical for oligotrophic forest stands.	Prescribed burning. Gap creation by felling.	2180 *Wooded coastal dunes of the Atlantic, Continental and Boreal region*
Targeted restoration of species diversity		
Extinction of halophytic species due to a lack of brackish water.	Species transportation from other sites after the restoration of brackish water.	1150* *Coastal lagoons*
Totally degraded wooded dune; surrounding territories endangered due to severe sand overblowing.	Restoration of wooded dune by pine planting and fence building.	2180 *Wooded coastal dunes of the Atlantic, Continental and Boreal region*
Prevention and Reduction of Visitor Load		
Ecosystem degradation due to anthropogenic pressure which degrades the ecosystem by trampling and pollution.	Establishment of infrastructure (boardwalks, footbridges, car parks) that guides visitors away from the valuable habitats. Establishment of boardwalks in areas with excessive visitor load. Restoration of wooded dune by pine planting and fence building. Gathering of litter and wastes	All coastal habitats.

Chapter 8. Formation and Protection of a Biologically Diverse Landscape (B. Laime)

8.1 The Role of Landscapes for the Conservation of Characteristic Habitats and Species of the Sea Coast, Inland Dunes and Heaths

For several thousands of years, people and their way of life played a crucial role in the development of coastal, inland dune and also heath landscape. While creating, using, excessively exploiting and protecting their living environment and natural resources, people, without realising it, created and destroyed, cultivated and protected habitats for plants and animals of dunes and heathlands. It happened, while thinking about themselves, their survival, family and well-being. At the same time we should not forget that nature has always been like the centre of spiritual life. On the coast, its origins are rooted in the Stone Age with the first human settlements in dunes (*see Chapter 2.1*). Life has encouraged people to transform the natural landscape in order to meet the needs of practical life, as well as to save joy, peace and harmony for themselves. Reverence to nature is felt in different rituals and traditions. Often these spiritual values have been those which have affected landscape formation by preserving solitary trees, their clusters and forest glades.

In the context of habitats under consideration, landscapes can be divided into two groups: natural – insignificantly modified landscapes, developed mainly under the influence of environmental factors, and slightly modified or modified landscapes, developed under human influence. Natural vegetation dominates in both landscape types.

Ensuring of natural processes is a key prerequisite for the conservation of many coastal habitats. Beaches, lagoons, sea cliffs, embryonic dunes and foredunes, partly also humid dune slacks, are habitats which directly depend on sea wave activity, flooding, wind, storms and sand overblowing (Fig. 8.1, 8.2). They can exist independently of human activities. In addition, excessive anthropogenic load causes degrading effects on species of these ecosystems. First of all, it is manifested in the life cycle of annual plants. These plants have only 2–3 months to germinate, grow and ripen their seeds. In landscapes where natural processes are prevailing, such life cycle has fewer obstacles than in landscapes constantly visited by humans, where a plant is often trampled just after germination. Natural landscapes are important for species of invertebrates, amphibians and birds, which are sensitive to sand compaction, micro-relief transformation, noise and other interference caused by humans. For bird species, such as the *Sterna paradisaea*, the most critical factor is human presence during the breeding period.

With grey dunes, open inland dunes and heaths, the situation is different. These habitats persisted for a long time in a landscape created and maintained by humans. The basic prerequisite is open space with no or few trees and shrubs. In such circumstances, light demanding plants can grow, including those who can survive in poor soils. Human impact, which includes vegetation destruction from time to time and soil formation prevention, is one of the main factors for the recovery of vegetation characteristic for these habitats. This reduces the chance for more competitive, nutritionally demanding plant species to beco-

Fig. 8.1. Almost unmodified landscape on the coast between Bernāti and Jūrmalciems, 2008. Embryonic dunes with the annual plant *Cakile baltica* are formed. Photo: B. Laime.

Fig. 8.2. Sand-pebble "desert" on Užava coast. In this landscape, coastal geological processes are prevailing, and sand overblowing dominates periodically. However, the dune gradually overgrows with trees, 2004. Photo: K. Goba.

me established. Periodical use of dune habitats also decreases intraspecific competition. Otherwise, for example, pioneer species *Corynephorus canescens* can develop vegetation which is dense enough to hinder the seed dispersal of this species (Fig. 8.3). Similarly this applies to heaths for which not only grazing but also burning, preferably in mosaic, is beneficial.

Such landscapes, saturated with pioneer species habitats, developed in coastal villages and their vicinity. Cattle were pastured and a variety of agriculture-related works were carried out there. For example, V. Veldre describes the coastal landscape in Ziemupe in the 1930s. There was a lot of cultivated land around houses but "beside them, neglected open dune spaces can be seen where there is low and lean grass" (Veldre 1963). In depressions between dunes, land was more humid and grass was greener. Cows and sheep were pastured here. Goats were also grazing in roadsides, yards, edges of forests. They ate sprouts of shrubs and trees, so preventing dune overgrowth (Fig. 8.4, 8.5).

Aizjomi is a peculiar landscape type, the historical formation of which was studied by I. Stūre. Poverty and harsh living conditions were the factors that encouraged local people to establish some fields between dunes near the sea. At first, the soil surface was removed in the driest places, and put on the dune ridge around the field to be established. On wet patches, soil was sifted to ensure moisture conditions optimal for plants (Stūre 2009). In *aizjomi*, cereals were sown, potatoes and root vegetables planted. Crops were partially protected from marine winds and sand overblowing. In *aizjomi*, habitats for grey dune plants were also created (Fig. 8.6). Thus people, while adapting to natural conditions, managed dunes, formed landscape, and unconsciously maintained the diversity of local species. *Aizjomi* landscape shows that traditional cultural

Fig. 8.3. Stands of *Corynephorus canescens* (left) indicate open dunes without vegetation a few years ago. *Corynephorus canescens* is one of the pioneer species for which self-regeneration is more successful if bare sand patches and wide dune landscapes are present. Photo: B. Laime.

Fig. 8.4. Behind the foredune ridge, partly surrounded by forest, the grey dune has been preserved for a long time due to sheep grazing. View from Akmeņrags lighthouse, 2000. Photo: B. Laime.

Fig. 8.5. One of the typical species of "dune pasture" is *Thymus serpyllum,* which is also important for the feeding of the butterfly species *Maculinea arion*. Photo: B. Laime.

landscape is closely linked to environmental protection, in particular to species conservation.

Open landscape area and vegetation structure was determined by the intensity of dune use. Historically, in territories where there were a lot of fishermen, large *sedums* were established, fishing net drying and even fish processing occurred, and overblown sand patches were continuously created (Fig. 8.7–8.9). This obviously promoted pioneer species growth. However, excessive use of dunes could slow down the establishment and long-term existence of plants. The optimal solution would be to maintain vegetation mosaics, the diversity of ecological niches and processes. This management formula can be expressed in a simple way as follows: a particular site should be managed, then "left in peace", allowing plants to establish and vegetation to develop. Then management should become more active again, inhibiting the further development of vegetation. In this way, landscape which is favourable for dune vegetation develops.

Also trees, shrubs, their clusters, rows and avenues are important elements of both natural and slightly modified landscapes. Although litter of woody species causes soil enrichment and hinders the recovery of dune plant and animal species, trees and shrubs may be ecologically very important in small numbers. They enrich ecological niches, providing a habitat for some species of invertebrates, determine special features of microclimate and contribute to bird species diversity (Fig. 8.10, 8.11). In intensively visited sites, willow clusters are like "islands" or shelters for dune species.

8.2 Approach of Landscape Ecology in Habitat Conservation

In coastal areas, it is difficult or even impossible to

Fig. 8.6. Aizjomi landscape in Jūrmalciems, 2016. By maintenance of open landscape with farmsteads and *aizjomi*, grey dune conservation is also ensured. Vegetation and characteristic species succession is ensured by the management of adjacent fields. Photo: A. Maisiņš.

Fig. 8.7. Pāvilosta Town, in around 1930. View from the side of the bridge: dune sands, northern part of town, behind which wide grey dunes appear. The great building beside the open space is Baptist Church. Photo: Ž. Kūdriņš, personal archive of Marita Horna.

Fig. 8.8. Kolka coast is one of the few places where nowadays dunes are used for net drying and for fishing tool repair. It is one of the preconditions for the preservation of a traditional cultural landscape and also of species-rich grey dunes with *Dianthus arenarius*. Photo: B. Laime.

Fig. 8.9. *Dianthus arenarius*. Photo: B. Laime.

Fig. 8.10. Pine and willow clusters create leeward sites which are important habitats for invertebrates. Open dunes of Užava. Photo: B. Laime.

Fig. 8.11. Washed out, uprooted trees on the seashore are both landscape elements and significant material for coast strengthening. This can be a habitat for rare invertebrate species, such as *Laphria flava*. Photo: I. Priedniece.

"mark" the border between the individual habitats, since they are closely related. In many cases, the transition from one habitat to another is almost imperceptible. Rather, the sea coast can be seen through a prism of landscape, separating visually similar "land surface compartments with their characteristic natural conditions, and also with an aggregate of man-made elements" (Melluma, Leinerte 1992). In this respect, the Latvian coast is very diverse: it is a mosaic of sandy beaches – wide foredune landscape; landscape of various beaches, sea cliffs and river mouths; grey dune-grassland landscape around farmsteads and surrounded by forest; sand-pebble "deserts" with pine stands; coastal grasslands with reedbeds and lagoons; as well as a variety of coastal forest landscapes.

Nowadays, the process of landscape unification is occurring. We must act knowingly and purposefully in order to preserve the mosaic of coastal landscapes, formed during the last centuries (Ņitavska 2014). Traditional cultural landscapes such as grey dune and heath habitats may be conserved by restoration and maintaining the balance of interaction between humans and nature. It is important to realise that such a landscape protection process is active, associated with practical maintenance of the territory (Nikodemus et al. 1996), but at the same time protective and suitable for a sensitive coastal environment.

Protection and management of coastal biodiversity can only be successful if it is included in the coastal spatial planning process. As noted in the Coastal Spatial Development Guidelines for the years 2011 to 2017 (Anon. 2011), until now, the development of planning along the coast has been fragmented and poorly coordinated. In all spatial plans related to the coast, it should be taken into account that the most important value and resource for development is the heritage of

nature and culture, and sustainable development is the fundamental principle of coastal development (Anon. 2011).

One of the most effective instruments for coastal nature conservation and resource use is landscape ecological planning, based on the change of natural processes over time and space. Any coastal situation assessment must be started with the abiotic environment (geological origin, topography, climatic factors etc.), which will determine the development of the territory. Researcher I. Stūre (2009) points out that the territory protection must be such that the landscape is maximally approximated to the vision of the landscape's desired state. It follows that subsequently, in the course of studying and evaluating the complex of biological, cultural and socio-economic factors, targets and priorities must be set as accurately as possible (*see Chapter 6*). Key landscape elements (trees, forest edges etc.) and their ecological importance are explained in chapters of every habitat or habitat group.

With regard to the coastal habitat group, there are two strategies.

1. **The development of natural processes must be ensured (by restoration and/or maintenance),** with minimal transformation and influence on the ecosystem structure and function. This refers to natural landscapes (dominated by beaches, sea cliffs, embryonic dunes and foredunes, lagoons, wooded dunes).

2. **Taking into account the natural processes, landscapes created under human influence must be restored or maintained.** This refers to traditional cultural landscapes (dominated by grey dunes, heaths, dune slacks, wooded dunes, lagoons).

Taking in account the multifunctional character of coastal areas and the fact that coastal population density and use were historically of great importance for the development of coastal habitats, it should be remembered in all cases, that, in addition to ecological quality evaluation, it is also important to assess the aesthetic, cultural and historical value of landscape. As highlighted in the European Landscape Convention, "landscape protection" means actions for the conservation and maintenance of significant or characteristic landscape features (Anon. 2000). The approach of landscape ecology can be an effective tool in preserving landscapes as important components of local cultural development and also as key elements of heritage of European nature and culture (Anon. 2000).

In landscape development, there are both relatively peaceful landscape development periods, and "breaking points" (such as natural disasters, wars or change of political system), after which the landscape changes significantly and rapidly. One such "breaking point" was the renewal of Latvian independence in 1991. Then, with the change in people's lifestyles and economic conditions, a radical impact on coastal dune habitats also began. Since then, major changes in the Latvian coastal landscape structure were caused by construction and forestry (Veidemane 2013). Therefore, the activities of these industries in relation to coastal landscape protection must be examined with particular care. Due to possible climate change in the future, the frequency of severe storms may increase, sea level may rise, and beaches, open dunes and wooded dunes will be the most influenced. Areas of open landscape located close to the sea may decrease significantly (Veidemane 2013).

The approach of landscape ecology should be used in coastal development planning at all levels and sectors, and in the implementation of these plans. Everywhere, the coastal landscape should be seen as an ecological system which develops dynamically and continuously. Using this method, the benefits would be reflected not only in environmental protection, but also in the economy. In particular, it relates to the restoration and development of traditional cultural landscapes.

It is stressed in the Coastal Architecture Guidelines that an "almost unchanged environment without buildings is recognised as the largest value of the Latvian coast" (Saknītis 2011). Therefore, in the process of planning and construction, the natural environment must be preserved to the extent possible, harmoniously joining it within the landscape. In the light of historical continuity, land partition in narrow strips in the process of real estate partition should be avoided. Such linear and dense arrangement of buildings is unfamiliar to traditional fishing villages. A partition of land parcels and the construction of roads must be subordinated to natural vegetation and dune relief. Historically, winding roads are characteristic for the coast, curving around the dune hill, large pine or other natural object, behind which a different scene is revealed. With the development of any infrastructure plans, a balance must be maintained with the coastal natural environment. Too dense arrangement of buildings must be avoided because it destroys both coastal nature, and also the resources of recreation and tourism (Saknītis 2011).

In the Landscape Policy Guidelines for 2013–2019 it is planned that important areas of valuable landscapes will be designated at a national-level, and integrated guidelines on the development and planning of particular nationally valuable territories will be developed (Anon. 2013a). For the guidelines of designated areas of the coast, a landscape ecological approach must definitely be used, as well as the habitat management guidelines included in this book.

Chapter 9. Evaluation of the Success of Management and Restoration (B. Laime)

The evaluation of the management and restoration success is significant both for the effective management of the particular site and also for the acquisition of experience as a whole, since each individual case gives a chance to improve the future work. It is also very important to analyse the experience gained for the improvement of these guidelines, because the experience is still relatively small regarding coastal habitats in Latvia. In view of the above described actuality, it is obvious that the evaluation of the success of habitat restoration and management measures should be seen as mandatory with management of any scale.

For this purpose, indicators of habitat quality should be used. Main indicators are summarised in tables for the assessment of habitats or their groups (Annex 3). Only basic indicators are included which can be easily observed and evaluated by any interested person. The list of indicators may be complemented or reduced depending on need. The evaluation must be comprehensive, taking into account the maximum number of potential indicators. Drawing of hasty conclusions based on one or two indicators must definitely be avoided.

To make the habitat quality assessment easier, it is recommended to first get acquainted with the characteristics of habitats in a favourable conservation state, and to study structures and processes important for the habitat, and also natural development or succession (*see Chapter 10.18*).

Several indicators are related to vegetation structure (cover, abundance, height and other characteristics of trees, shrubs, herbaceous plants, mosses and lichens). These indicators must be assessed in several (preferably 10) points. We recommend using the transect method, which means going over the habitat along an imaginary line, stopping after a certain number of steps or metres, and describing the specific characteristics. By doing this, we can get a more objective assessment than by characterising the situation at one point. The optimal evaluation period for coastal habitats is the end of July, August, and early September, when annual plants are clearly visible beside perennial plants. Habitat assessment should be performed repeatedly in order to understand the habitat development better after the particular management activity. Taking into account bird species protection and other factors, coastal habitat management measures should be carried out mainly from autumn to early spring. This means that progress should be evaluated twice per growing season – at the end of May and at the end of August. It may differ in the case of invasive species control which occurs two or three times a year, and progress should be evaluated at least once after every management activity.

Management and restoration and the evaluation of its success must be documented, and the date recorded. The simplest methods are:

- photography and/or filming; it is recommended to do it repeatedly, using several but always the same viewpoints; this is very useful for the visual assessment of changes occurring in habitat;
- indicator evaluation and data recording; it is easiest to create a condensed table (Table 9.1).

A necessary requirement is to describe the habitat **before** the management or restoration measures. The obtained data will make it easier to objectively assess the changes occurring in the habitat.

Nowadays it is possible to quickly specify plant and animal species found in a habitat by using photography and internet communications and sending photos to a coastal expert or specialist of specific groups of organisms, or to the Faculty of Biology, University of Latvia.

Evaluation of success also includes the assessment of the specific methods, instruments, technical or other resources used. It is often crucial for successful habitat management. It is advisable to promote the experience gained, and provide information about it in local newspapers, on county websites and other internet sites, as well as in meetings.

We must always understand why the habitat condition is bad or good. One should not forget that coastal habitats are very dynamic, and are developing constantly. They are influenced by many factors and by adjacent habitats, so it is recommended to also evaluate the changes at the landscape level. The social and economic processes affecting the habitat must also be taken in account.

To carry out the extended analysis, it is necessary to invite a coastal habitat expert whose task will be to look at the site-specific species composition and to evaluate habitat development or succession. The results of Biodiversity Monitoring (Environmental Management Programme in Latvia), including Special Monitoring "Habitats of Sea Coast" and Natura 2000 Sites Monitoring should be used. To understand what is happening in a habitat, at least a minimum knowledge of coastal geological processes in a given coastal section is necessary. Therefore, monitoring data of Latvian coast geological processes are very useful. If habitat management is associated with

Table 9.1 Habitat status evaluation table – example.
Evaluation of restoration and management success in grey dune habitat in Ziemupe.

Indicator	Evaluation							Notes
	1	2	3	4	5	6	7	
Bare soil patches	c	b	b	b				
Tree and shrub cover	c	a	a	a				
Tree and shrub litter	c	b	b	b				
Vegetation mosaic	b	b	b	a				
Lichens	b	b	b	b				
Invasive plant species	b	a	a	b				Repeated cutting is necessary
Number of characteristic species	b	b	b	a				
Moss layer thickness	c	c	c	b				

Comments:

On 21 March 2017, trees and shrubs were cut, litter was removed partially, topsoil was removed.
Date of evaluation: **1** – 10.10.2016; **2** – 23.03.2017; **3** – 29.05.2017; **4** – 29.09.2017
Scale for habitat quality evaluation: a – good; b – medium; c – poor.

beaches, foredunes, sea cliffs and lagoons, it is highly recommended to already consult an expert in coastal processes at the planning stage, for example, from the Faculty of Geography and Earth Sciences, University of Latvia.

PART II

Chapter 10. 1150* *Coastal Lagoons* (B. Laime, J. Lapinskis, J. Priednieks)

10.1 Lagoon Characteristics

10.1.1 Brief Description

Coastal lagoons are shallow coastal water bodies, often parallel to the sea, separated from the sea by sand banks or ridges or, less frequently, by bedrock. Due to sea level fluctuations, water can flow into a lagoon, or, having a lower sea level, substantially reduce or even dry up. Since a lagoon is generally shallow, it is highly influenced by precipitation and evaporation, causing fluctuating water temperatures and salinity. In such lagoon estuarine ecosystems, formed in relief depressions, conditions are favourable for the development of a special habitat type, which is defined as lagoon habitat 1150* *Coastal lagoons* (Fig. 10.1), further below referred to as **lagoons**. This unique habitat includes: water area separated from the sea, terrestrial belt between the lagoon and the sea; coastal areas directly

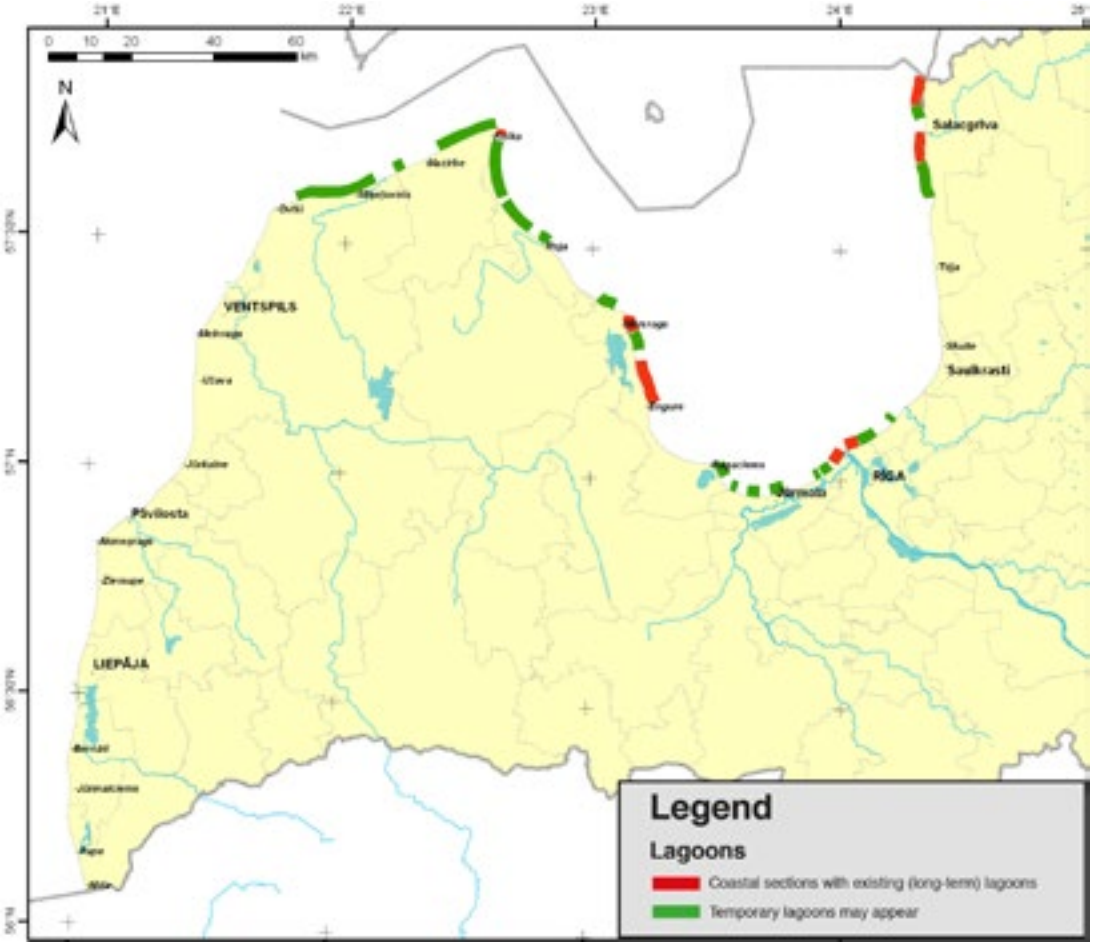


Fig. 10.2. Sections of seacoast in Latvia where long-term lagoons are located or where the establishment and persistence of temporary lagoons is possible. Map prepared by J. Lapinskis.

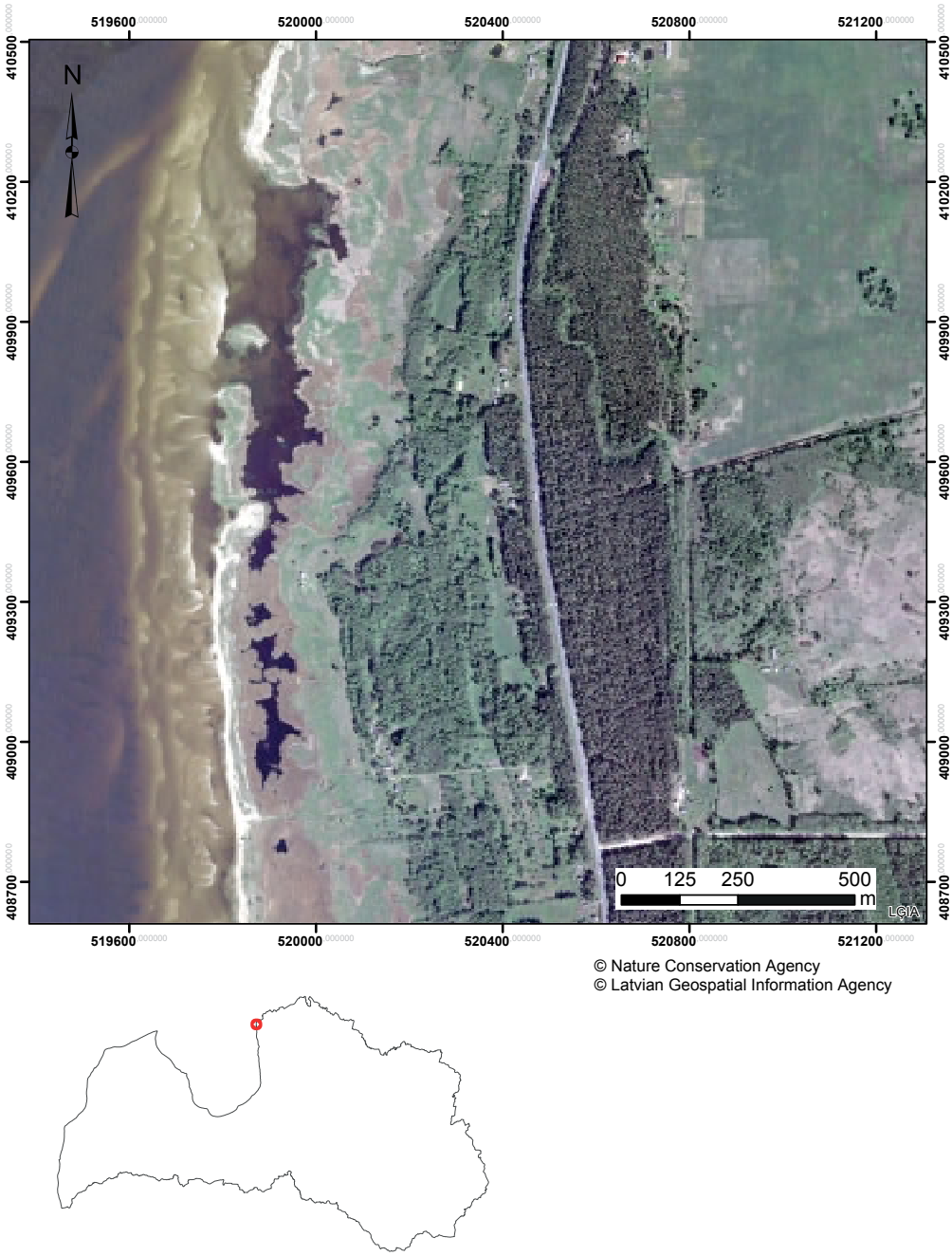


Fig.10.1. Coastal lagoons parallel to the sea, bordered mostly by the growth of *Phragmites australis* and coastal meadows, forming a joint habitat complex in Randu meadows located between Kuiviži and Ainaži. Map prepared by P. Rozenbaks.

influenced by the lagoon (Rove 2013a).

These guidelines cover coastal lagoons: both long-term lagoons surrounded by coastal grasslands, and temporary lagoons that often only exist for a few years. Lagoon habitat can form in both lagoon types. Long-term lagoons are very rare in Latvia. They are located along the coasts of the Gulf of Riga, on the following sections: Kuiviži–Ainaži, between the River

Fig. 10.3. Narrow and shallow coastal pool in Uši, at the coast of the Gulf of Riga, developed by sediment accumulation after erosion caused by the storm of January 2005. Photo: J. Lapinskis.

Fig. 10.4. About a one year old temporary lagoon in Upesgrīva in the year 2014. This lagoon also existed in 2015 and 2016, and it is surrounded by wet beach with annual and perennial vegetation. Photo: J. Lapinskis.

Svētupe and Salacgrīva Town, on Buļļi Island, in Mērsrags and Upesgrīva (Fig. 10.2). Lagoon area varies depending on the type and intensity of coastal processes. According to data on the period from 2008 to 2012, long-term lagoon habitat occupies only 22 ha or 0.0003% of the total area of Latvia (Anon. 2013c).

10.1.2 Important Processes and Structures

Lagoons are located in the active coastal zone. Lagoon water salinity and vegetation depend on coastal processes, and the water level is very close to the sea level at a given moment. The time of lagoon existence is often short; often they are small, relatively narrow, elongated, shallow, and orientated parallel to the shore. Lagoons develop when under moderate wave activity sediments are transported upwards from the lowest part of the coastal underwater slope, and an accumulative body of sediments develops, separating the lagoon from the sea proper. The formation and persistence of young, long-term lagoons on the Latvian seacoast is very rare. Their persistence for longer than a few years can be regarded as exceptional, and is only possible in some short coastal sections under special circumstances – when a very strong storm is followed by a prolonged period without storms. For example, in the eastern part of Kolka Cape, an unusually wide and deep lagoon remained for a long time in the 1990s; it only ceased to exist after the storm of December 1999.

Favourable conditions for the existence of a lagoon are:

- wide and flat foreshore and subareal part of the coastal slope (in these guidelines, subareal part of the coastal slope is understood as the part of coastal slope which is normally not affected by wave action, but can be flooded during storms when the water level is high) and foreshore;
- presence of a large amount of fine-grained sediments on the coastal slope (accumulation predominates erosion);
- relatively weak wave intensity/activity ("lee" position).

Such conditions typically develop in the Kurzeme Coast of the Gulf of Riga, in the sections Kolka–Roja, Bērzciems–Engure, Salacgrīva–Ainaži (Fig. 10.3).

Fig. 10.5. Outlet of the River Lāčupīte in Klapkalnciems. Left – summer of 2001, in the middle – 2002, right – 2005. Photo: J. Lapinskis.

These narrow and shallow coastal pools formally comply with the characteristics of the lagoon, but they exist for a very short period of time (a few days to months). They may develop almost anywhere along the coast of the Irbe Strait and the Gulf of Riga, and most commonly they are in the sections Kaugurrags–Pabaži and Vitrupe–Salacgrīva. These coastal pools usually exist for a time which is too short for the development of a lagoon habitat (1150* *Coastal lagoons*).

According to these guidelines, a lagoon is considered a temporary lagoon if its time of existence is minimally sufficient for the convincing development of lagoon habitat. Usually, a temporary lagoon remains for 1–5 years. Morphogenetically, temporal lagoons are identical to coastal pools, and their type cannot be determined in the initial stage due to a lack of visual criteria. Temporary lagoon formation and disappearance is directly dependent on the intensity of cross-shore transport of sediments in the coastal slope (Ulsts 1998; Eberhards 2003). The development of temporary lagoons is most active soon after the coastal erosion caused by a storm, when fine-grained sediments are slowly, even over several years, transported by wave activity upwards on the coastal underwater slope. In the foreshore belt, it may create a kind of accumulation bar, the apex of which is situated above the average water level, forming a temporary lagoon – a shallow waterbody which is separated from the sea (Fig. 10.4). Such a lagoon ceases to exist when, in continuation of the coastal slope's evolution after the storm, a sand accumulation body that was separating lagoon from the sea moves up the beach, and the depression previously filled by the temporary lagoon becomes filled with sediment.

Both long-term and temporary lagoons can also disappear when separating accumulated sediments are washed away by wave action, and the previous lagoon becomes "open" – connected to the sea. The formation of most of the long-term lagoons on the Latvian coast has occurred under special circumstances: erosion due to severe storms and following accumulation in combination with peculiar geological conditions (very flat coastal slope and land uplift in the surroundings of Salacgrīva, Ainaži and Bērzciems) as well as particularly active sediment accumulation started by anthropogenic causes (Daugavgrīva Island, Mangaļsala). Conditions which ensure the "rejuvenation" of these large, long-term lagoons, can only arise in relation to new catastrophic storm erosion and the subsequent accumulation phase (Ulsts 1998). In the absence of such storms, the gradual overgrowing and "ageing" of long-term lagoons occurs, and in the long term it can also cause their disappearance.

Lagoon formation is also possible at small river mouths along the coast of the Irbe Strait and the Gulf of Riga. If there is a considerable long-shore sediment drift, river estuaries usually deviate along the dominating sediment drift direction, and flow parallel to the sea shore in a length of several hundred metres. Under intensive wave activity, the earlier river mouth may become clogged, and a new river mouth is formed. Thus, the previous river bed converts into a lagoon-like zone of stagnant water. Although the existence of such objects is relatively temporary and does not exceed a few years, lagoon habitat can develop in the separated water body (Fig. 10.5).

A lagoon can be considered long term if it is located in a deeper and wider depression and if the sediment barrier separating the lagoon from the sea is partly overgrown with vegetation, thus promoting the accumulation of windblown sand and the establishment of aeolian accumulation relief (embryonic dunes and foredunes). Lagoon water salinity may vary depending on the meteorological conditions (evapo-

Fig. 10.6. Temporary lagoons are important feeding sites for waders in the migration period, in Kolka. Photo: B. Laime.

Fig. 10.7. *Calidris ferruginea* feed in a coastal pool; *Motacilla alba* in the background. Photo: I. Priedniece.

ration and precipitation), ice conditions, groundwater input and wind driven sea water inflow. In a cold winter, the foreshore freezes over, and the probability of lagoon flooding and storm initiated erosion decreases. It also decreases the loss of tall herbaceous plants and shrubs, thus promoting lagoon overgrowth in the long term, because during storms in ice-free conditions, the micro-relief becomes more diverse, and plant residues (mud) are partly washed out.

Long-term lagoons surrounded by coastal meadows and temporary lagoons have a different role in attracting bird species. In general, conditions for birds are more favourable in lagoon habitats with a large diversity of vegetation, open water areas and natural disturbance regime. For waders, several species of ducks (*Anas clypeata*, *Anas querquedula*) and yellow wagtail *Motacilla flava*, the most important area during breeding is the bordering zone between long-term lagoons and grasslands. The most suitable breeding sites for *Fulica atra*, gulls (*Larus ridibundus, L. canus*), *Sterna hirundo* and duck species – *Anas platyrhynchos, Aythya fuligula, Aythya ferina* – are places with emergent swamp vegetation, consisting of remains of *Typha latifolia* and old reedbeds. *Porzana parva* can also be found in such places. Old reedbeds unmown for a long period of time, especially in places where they border open water, creating floating quagmires with relatively dry locations with another plant species, are also important for birds. In such places, characteristic bird species are *Acrocephalus arundinaceus*, *Panurus biarmicus*, *Locustella luscinioides*. Breeding of the protected species *Botaurus stellaris* and *Ixobrychus minutus* is also likely. The formation of continuous reed growth is not desired in most cases, as it reduces the diversity of birds' habitats. Most bird species breed in the margins of old, lush reedbeds, close to the open water. However, the total reedbed area can also be significant, especially for *Botaurus stellaris*, *Ixobrychus minutus*, *Locustella luscinioides*, *Panurus biarmicus*, so there may be a need to also maintain a larger reedbed area if it does not conflict with the higher priority targets for a particular site. Consequently, when planning reed reduction in a coastal habitat complex, it is important to preserve the long-term existing reedbeds and *Typha latifolia* growths in lagoons and their directly bordering sites. At the same time, the open water areas are also very important. However, the total area of lagoons in Latvia is so minimal that it only provides suitable conditions for a small part of the Latvian population of most bird species.

For waders, coastal pools and temporary lagoons in the early stage of development are significant feeding areas during the migration period (Fig. 10.15). They develop on beaches periodically, usually they are vegetation-free but rich with algae. Such sites can be found in the Kolka–Vaide section, and Kolka–Uši section along the Gulf of Riga coast (Fig. 10.6, 10.7).

In winter, *Panurus biarmicus* flocks permanently reside and feed in reedbeds; *Parus caeruleus* can also be found. In warmer winters, birds can stay for winter in places with small unfrozen water areas or with quagmires: *Gallinula chloropus*, *Lymnocryptes minimus*, *Botaurus stellaris*, *Ardea cinerea* and *Fulica atra* and several *Anseriformes* (Priednieks 2015).

In coastal lagoons, distinctive communities of invertebrate species develop. They may include both brackish water and terrestrial species, especially if a lagoon is connected to the sea. In temporary lagoons which are separated from the sea and receive ground water, invertebrate communities typical for freshwater habitats develop. Diptera species such as Ephedridae, Chironomidae, Hydrophilidae, Ostracoda are abundant here. Dipterous insects are also the main food source for sand toad *Bufo calamita* juveniles. Lagoon invertebrates also provide food for waders.

10.1.3 Natural Succession

Natural disturbances are an important factor in lagoon succession. Under periodic flooding by sea water, brackish plant communities with *Ruppia maritima*, *Zannichellia palustris*, *Potamogeton* spp., *Chara* spp. can dominate for a long time. Such plant community can be observed, even in temporal lagoons. In places where the lagoon is "ruptured" and connected to the sea, *Najas marina* often dominates. In the initial stages of succession, lagoon shores are occupied by annual plant communities with *Atriplex* spp., *Salsola kali*, and other plants specific to the sea coast. If the separating sandbank is wide enough, embryonic dune vegetation can even develop.

If the lagoon is isolated from the direct influence of the sea and disturbances are reduced, the muddy lagoonal sediment layer is rapidly increasing and the lagoon overgrows with *Scirpus tabernaemontani* and *Phragmites australis*. Typical coastal grassland plant species occupy lagoon shores. Shallower sites paludify, fen and intermediate mire species become established. In the following succession, the lagoon overgrows with *Phragmites australis*; eutrophic lagoons with *Typha* spp. and other tall herbs; shrub stands develop in dryer coasts.

In cases when the lagoon is washed off, its regeneration restarts after severe storms, when there is extensive sedimentation on the coastal underwater slope and a sand bar is formed. Later in the vegetation season, typical lagoon plant communities develop. In

Fig. 10.8. Ideally, there is a great variety of bird and plant species as well as ecological niche diversity in a lagoon: aquatic plant and animal communities in the brackish waterbody; beach and dune species on the sandy bank; coastal mire and grassland species along the lagoon shores. Drawing by D. Segliņa.

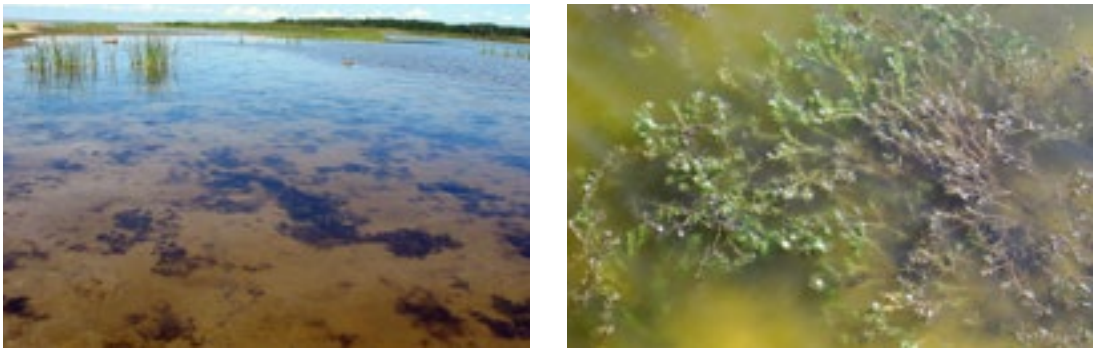


Fig. 10.9. Lagoon connection to the sea and the clean sand bottom facilitate the distribution of *Najas marina* and other aquatic species of brackish waters. Coast between Kuiviži Town and Ainaži Town, 2013. Photo: B. Laime.

such circumstances, there is an opportunity for vegetation to develop both in the lagoon and the foreshore. In this habitat development stage, diasporas (seeds, roots and other plant parts) have an important role, whose dispersal and entry to a suitable site depends on long-shore sediment drift and currents. Diaspora presence is particularly crucial in young lagoons. The highest and most lasting species diversity is present in lagoons which are periodically connected to the sea and where natural disturbances are dominant (Bamber et al. 1992). Lagoons without permanent vegetation also belong to the lagoon habitat (Rove 2013a).

10.1.4 Indications of Favourable Conservation Status

In most cases, lagoons are shallow waterbodies, the main prerequisite for the development of which is a

Fig. 10.10. Annual plant communities with *Atriplex* ssp., *Salsola kali*, and other halophytic species along the lagoon shores indicate the favourable conservation status of a lagoon habitat. Coast between Kuiviži and Ainaži, 2013. Photo: B. Laime.

Fig. 10.11. *Zannichellia palustris* (pictured left) and *Ruppia maritima* (pictured right) belong to the most characteristic indicators, the presence of which indicates favourable conditions of the lagoon habitat functioning. Photo: B. Laime.

brackish environment. It is provided by the periodic inflow of sea water into the coastal relief depressions. Salt concentration may vary both in the lagoon water and in the substrates of the lagoon ground and coast (Rove 2013a). The larger the open water area of lagoon, the ecologically more lasting the lagoon habitat. Dense, stabilised reedbeds are rarely desirable. These are important habitats for protected bird species. A favourable conservation status can also be attributed to lagoon shores with predominantly sparse herbaceous vegetation and patches of bare ground (Fig. 10.8).

The adjacent habitats and the coastal landscape as a whole play an important role in the functioning of lagoon habitat as they directly determine the lagoon persistence and conservation status. One of the more favourable situations develops if coastal grasslands and reedbeds bordering the lagoon are grazed or regularly mown, and the development of extensive reedbeds is prevented. The exceptions are long-term reedbeds, which should be maintained without interference if they are adjacent to open water areas and if specially protected bird species are present here. Also, seashore sections with low and wet beaches indicate the actual or potential lagoon formation sites. The wider and longer the coastal section where the complex of coastal wetlands, grasslands (1630* *Boreal Baltic coastal meadows*), lagoons (1150* *Coastal lagoons*) and beaches (1310 Salicornia *and other annuals colonising mud and sand*, 1640 *Boreal Baltic sandy beaches with perennial vegetation*, 1220 *Perennial vegetation of stony banks*) develops, the more favourable the environment for lagoon functioning. It is necessary that the lagoon hydrological regime is not affected by human activities (lagoons are not connected with ditches, are not filled up, damaged by vehicles or built-up), their shores and the connection to the sea are formed naturally.

Fig. 10.12. Lagoons with a mosaic structure of open water areas and surface vegetation are particularly important breeding sites for many bird species. Rīga. Photo: B. Laime.

Fig. 10.13. Groups of old reeds and cattails are important elements for bird breeding in Daugavgrīva. Photo: B. Laime.

Fig. 10.14. Due to the decrease in grazing in coastal areas, lagoon shores rapidly overgrow with *Phragmites australis*, and open water areas and suitable habitats for birds and plants decrease. Photo: B. Laime.

In an optimal situation, plant communities of brackish waters dominate both in the lagoon and on its shores. The habitats where *Ruppia maritima*, *Zannichellia palustris*, *Batrachium baudotii*, *Najas marina*, *Potamogeton pectinatus*, *Tolypella nidifica* are present in the water body are considered outstanding (Ločmele 2015) (Fig. 10.9, 10.11). These species often form a mosaic with *Bolboschoenus maritimus*, *Scirpus tabernaemontani* and *Alopecurus arundinaceus*. On lagoon shores, *Spergularia marina*, *Triglochin maritimum*, *Montia fontana*, *Glaux maritima* are present, and annual plant communities with *Atriplex* ssp. are formed (*Atriplex calotheca*, *A. glabriuscula*, etc.) (Fig. 10.10).

Lagoon habitats are both important as feeding and resting areas for birds during their migration, and as breeding sites, especially for *Charadriiformes*, gulls (*Larus*), terns (*Sterna*) and ducks (*Anatidae*). Bird species composition is determined by vegetation diversity and by the area of open water (Priednieks 2015) (Fig. 10.12, 10.13).

10.1.5 Pressures and Threats

10.1.5.1 Intervention in Coastal Geological Processes

Lagoon formation and persistence is directly related to undisturbed geological processes along the sea coast. The presence of lagoons, especially temporary lagoons in the coastal relief, indicates a typical but transitional step in the development of a coastal slope. Consequently, the main threat for the existence of the lagoon is interference in coastal processes – large-scale erosion prevention and other activities that disturb the long-shore and cross-shore sediment drift. Even an interference many kilometres away from the lagoon, can cause a threat. For example, hydroelectric cascade construction on the River Daugava and the strengthening of its coast in the territory of Rīga has significantly decreased sediment input to the Daugavgrīva and Mangaļsala coastal sections (Gulf of Riga). As a result, coastal erosion increases, and it increases the likelihood that "old" long-term lagoons will connect to the Gulf of Riga aquatorium (Eberhards 2003; Eberhards, Lapinskis 2008).

10.1.5.2 Hydrological Regime Change

Lagoon is a component of a coastal wetland landscape. Often, lagoons are wet, hard to manage sites. For trail and road construction, embankments and ditches are created, which certainly have a negative influence on the lagoon's natural hydrological regime and is one of the main reasons for change in the lagoon's

ecosystem function, structure and species composition. Water exchange with the sea and also with other lagoons is disturbed. Drainage causes accelerated lagoon overgrowth, and also reduces the diversity of bordering habitats.

10.1.5.3 Management reduction or cessation

Overgrowth with shrubs and tall herbs, especially with common reed, can also be induced by insufficient management. Up to the end of the 20th century, shores and surrounding habitats were managed by mowing or grazing. In this way, conditions favourable for coastal grasslands and lagoons were maintained. Nowadays, most of the management in lagoon areas has decreased or even ceased, and, consequently lush reedbeds and in some places willow shrubs develop in and around lagoons. The proportion of sandy substrate in the lagoon decreases, water eutrophication rises, the mud layer increases (Fig. 10.14).

10.1.5.4 Excessive visitor load

The influence of the use of coastal areas is constantly increasing. Lagoons are used for fishing and recreation. For example, in Daugavgrīva, due to established picnic sites, lagoon shores and surrounding habitats are depleted, and lagoons are polluted. The biggest problems are: litter, car pollution and noise.

Temporary lagoons are significantly influenced by excessive vehicle use, soil compaction, excessive trampling on beach and dunes. At sites of recreation and tourism, lagoons are considered as undesirable; they are mechanically modified and destroyed.

Lagoon habitats and birds are also adversely affected by fishing during the waterfowl breeding period. It disturbs birds in their feeding sites and also counteracts the development possibilities of nature tourism and nature-friendly recreation in these areas. During the bird breeding season, vacationers, especially if they are accompanied by unleashed dogs, are a threat to bird species. Birds are disturbed and their breeding may end unsuccessfully.

10.1.5.5 Pollution

Similarly to all watercourses, lagoons are sensitive to environmental pollution. Ditches have a great negative impact on lagoon sustainability and quality if they are connected with developed areas (buildings, gardens, parking and industrial areas). Habitats are also adversely affected by municipal waste, marine litter, waste water, and air pollution. Due to water pollution, reedbed areas increase, which in turn changes vege-


Phalaropus lobatus


Philomachus pugnax


Limosa lapponica


Limicola falcinellus

Fig. 10.15. Characteristic bird species for lagoon habitat during migration. Photo: I. Priedniece.

tation structure; the abundance of halophytic species decrease, or they even disappear.

10.1.5.6 Invasive plant species

Several invasive plant species have been found on lagoon shores. The most common are: *Hippophaë rhamnoides*, *Impatiens glandulifera* and *Solidago canadensis*. Large stands are also formed by *Aronia melanocarpa*. This is a particular problem in "Piejūra" Nature Park where lagoons are located in the city administrative territory and the majority of them are directly related to housing or former garden areas.

10.2 Restoration and Management Objectives for Lagoon Habitat Conservation

- Restored and preserved: functioning of halophytic habitats as well as diversity of plant communities and species in all their distribution area along the sea coast of Latvia.
- Suitable breeding and stopover sites during migration for lagoon-related bird species are ensured.

10.3 Habitat Restoration and Management

Since lagoons usually belong to the complex of coastal grasslands, wetlands and low, wet beach habitats, the influence of planned activities on every habitat and its species must be evaluated before the start of any restoration and management measures. It is necessary to understand and take into account the marine geological processes in Latvia, and in the whole south-eastern part of the Baltic Sea, because the development of this coastal section, including lagoon development, is largely determined by the peculiarities of long-shore sediment drift. The persistence of existing erosion sections is an important prerequisite for the stability of accumulation belts (sites of possible lagoon formation).

10.3.1 Non-interference

The coastal zone, where lagoons are located, is an area in which the changes occur most rapidly and their specific restoration and management is usually not needed. Exceptions are cases when habitats are disturbed due to human economic activities or excessive recreation. In such cases, the most appropriate measures are those that compensate the disturbances, as well as the elimination of influence and the restoration of the continuity of the initial nature processes (Anon. 2014). Non-interference in particular refers to temporary lagoons which are located very close to the sea, and are periodically flooded with seawater.

In long-term lagoons with fish, fishing should be prohibited during the bird breeding (the most important period is from 1 April to 31 July). The waterfowl hunting should be prohibited in coastal habitats since they not only disturb non-game migratory birds in their feeding and resting places but are also incompatible with recreation and bird watching which is a significant objective of coastal area use. Specific problem areas are: Mērsrags–Bērzciems and Ainaži–Salacgrīva (Priednieks 2015).

10.3.2 Action after Catastrophic Erosion Episodes

During severe storms, pre-existing temporary lagoons usually disappear or are transformed very significantly. In most cases, natural regeneration of the lagoon will occur in the next few months or a year, in about the same place or within the same coastal section.

Nowadays lagoon formation in most of the Latvian coastline is only possible temporarily – it marks a certain phase of coastal slope cyclical evolution when washed away sandy sediments from the coastal underwater slope during calm weather conditions are transported upwards, and a lagoon enclosing accumulation bar is created. Lagoon formation starts on the coastal underwater slope where interference with any protection or management measures is not reasonable. Coastal slope is a subject of continuous wave activity. Artificial measures of sediment accumulation that contributes to are very resource intensive, and such actions adversely affect the overall stability of the coastal system (Anon. 2014).

10.3.3 Lagoon Connection

Establishment of lagoon connections is only necessary and possible in sites where due to coastal processes, natural succession or human influence, some lagoons are separated from the sea and adjacent lagoons for a long time, but are still relatively close to other lagoons. By connecting such closed lagoons with open lagoons, the maintenance of a brackish environment can be significantly improved. Work must be carried out by heavy machines, which is customised to work in wetlands. Biotechnical measures must be implemented in the period of the smallest expected impact on bird species (from August to February). All excavated substrate must be transported away from the lagoon area. It can be used for compost making, greenery. Establishment of a lagoon connection would be necessary for long-term lagoons, for example, in "Randu Pļavas" Nature Reserve, between

Kuiviži and Ainaži. Establishment of a lagoon connection does not affect the overall stability or intensity of sediment exchange in the coastal section as a whole.

10.3.4 Removal of Expansive and Invasive Woody and Herbaceous Plant Cover

All the invasive woody and herbaceous plant removal must be carried out from August to the end of March, to avoid the bird breeding season. The management objective must be clearly defined because the applicable method depends on it. Since plants are removed from lagoon shores or even from the lagoon, the whole mown or sawn plant mass must be removed from the coastal wetland complex, which includes lagoons and adjacent habitats. Harvested plants must be transported to a site where it does not conflict with nature conservation and socio-economic objectives. If removal from the territory is complicated, plants can be burnt in fires in several places. It is better to do it further away from the lagoon, to avoid eutrophication. The removal of plant mass does not significantly influence coastal stability, because for the coastal sections with long-term lagoons, the prevalence of long-term sediment accumulation is characteristic.

10.3.4.1 Reed mowing

Before reed mowing, the micro-relief of the territory must be evaluated (using maps and field surveys). In wet areas, "floating" or non-road mobile machines and tractors with wide tracks must be used. Such techniques work slowly but are sufficiently effective in small areas and wet places. In drier areas, tractors with wider tyres (large surface) should be used. Reeds should be mown twice in a growing season (August and September). A combination of mowing and grazing is recommended. Reed mowing must be continued for at least several years in a row. If the area is too large and it cannot all be cut in one year due to financial reasons, it should be mown in zones at least once every year (Fig. 10.16). Such management will reduce the density and height of reed stands, and will facilitate the restoration of lagoon habitat and surrounding grasslands. More on grassland management: Rūsiņa (ed.) 2017.

If the management objective is to ensure the protection of reedbed related bird species, it is necessary to retain some old reed growths or even larger areas of reedbeds which are connected to the open water areas. Reedbeds with floating quagmires are particularly recommended. For grassland birds, grasslands that border with an open water area are desirable.

For management aiming at the conservation of brackish plant species and communities, sandy substrate and sandy coasts must be ensured. In some cases, especially in small or old lagoons, reed mowing is not sufficient. Removal of rhizomes and mud is necessary. This requires the use of tractors. Extracted rhizomes must be removed from the area; mud can be left in adjacent grassland (as far as possible from the lagoon), or it should be removed from the area and used, for example, for composting. The restoration of sandy substrate will be much more effective if mud removal is combined with other measures, such as lagoon interconnection, ensuring the inflow of sea water. It is possible that measures will need to be repeated; this necessity is determined by eutrophication of

Fig. 10.16. Reed mowing complemented by leaving an unmown belt creates a mosaic which favours bird species diversity. Daugavgrīva. Photo: B. Laime.

Fig. 10.17. Prescribed burning of reeds should be combined with other management methods and used in sites where it does not conflict with the infrastructure of built up area and tourism. Photo: D. Tjarve.

the lagoon and surrounding habitats.

10.3.4.2 Prescribed burning

Prescribed burning of reeds is a cheaper and more efficient method than mowing. It is preferred in sites with very old and dense reed stands. However, one must remember that these sites are important for birds. Therefore, possible risks to birds and other species must be assessed before the works. Reed burning outside the bird breeding season will only be successful if the reed is dry (mainly in autumn or in March). After burning, management must be continued. Grazing is one of the most effective measures. If grazing is not possible, regular mowing should be maintained, followed by grass removal. Reed burning can mainly be used for the initial habitat restoration – to increase the open water surface area and insolation. However, it cannot be used for regular habitat management because its influence will be degrading. To ensure the complete safety of the people and avoid damaging the surroundings, all necessary approvals must be obtained from the relevant state institutions (*see Chapter 6.3.13*), before reed burning (Fig. 10.17).

The method is restricted if lagoons are located in cities or other settlements. Moreover, eutrophication caused by reed burning is not desirable for lagoon development. Therefore, one must assess whether the burning may be replaced by another management method.

10.3.4.3 Removal of tree and shrub cover

For the management of lagoons and coastal grasslands, shrubs and trees must be removed completely, and only in some places can solitary trees or their groups be left as scenic elements. If the area is important for bird protection, all trees must be removed, to avoid the concentration of crows and reduce waterfowl nest predation. The method can be combined with mowing and grazing, at the latest up to the emergence of the first stump shoots.

Large shrub stands should be sawn off repeatedly, at least once a year over several years. Leaving of tall stumps should be avoided because they may hinder mowing and other management. Particular attention should be paid to combating invasive woody species. Effective methods are: shrub uprooting, stump and root milling. Then, all the roots and above-ground parts of the plant should be removed from the area. These works are expensive, but recommended because the abundance of woody plants is reduced significantly.

10.3.4.4 Removal of invasive herbaceous plants

Invasive herbaceous species must be removed before their seeds are ripe. *Impatiens glandulifera* must be repeatedly mown or weeded. *Solidago canadensis* can be limited by mowing several times per season. Plant mass must definitely be removed from the area. Herbicide use for invasive species control is not allowed in the lagoon area.

The direct elimination of invasive plant species must be accompanied by preventive protective measures: species dispersal to natural habitats from the garden and greenery must be avoided; planting of such plants in the lagoon area and surroundings must be stopped; people should be informed on the influence of these species on the local nature.

Fig. 10.18. A successful solution: viewing tower in Daugavgrīva. Both the tower location and information boards promote the conservation of the lagoon; interests of habitat conservation and visitors are harmonised. Photo: B. Laime.

Fig. 10.19. Boardwalks raised above the water level save habitats and help to organise recreation and the education of people. Daugavgrīva, "Piejūra" Nature Park, 2006. Photo: B. Laime.

10.3.5 Grazing

Grazing may be applied to lagoon shores with coastal grasslands, or to former reedbeds which are mown or burnt. Herds of mixed species, breeds, ages and genders should be used because each of them has its own kind of impact. Grazing is recommended in places where the lack of low vegetation is a limiting factor for birds such as *Calidris alpina schinzii*. Also some halophytic plant species, like *Glaux maritima*, will grow better among low plants along the lagoon shore, where the substrate is saltier, than further in the grassland, where the competition with other herbs is higher. Taking into account lagoon flooding and other adverse conditions during severe winds and swell, grazing and fence maintenance in a lagoon habitat can be problematic (during storms, fences can be washed away or broken). Therefore it is recommended to use mobile fences, and only bring the herd in suitable weather conditions. To avoid overgrazing of the lagoon shores and the following degradation of living conditions of plant, invertebrate and bird species, grazing should be organised for a limited time (one season or just a few weeks), with continuous observation of the grazing impact. Lagoon shores represent only a small area of the total area of the coastal habitat complex, which should be managed by grazing. Grazing refers mainly to habitat 1630* *Boreal Baltic coastal meadows*. More on grazing: Rūsiņa (ed.) 2017, *Chapter 9, 22.3.1.*

10.3.6. Establishment of Tourism Infrastructure

To reduce the impact of coastal visitors to the lagoon habitats, the building of boardwalks raised above the groundwater level and the installation of viewing platforms is acceptable (Fig. 10.18, 10.19). They must be easily removable and transportable, and environmentally friendly materials should be used. The arrangement of these elements should have a positive impact on the hydrological regime and micro-relief of lagoons and their surroundings. To inform visitors on the significance of a lagoon habitat for the preservation of nature values, various types of information boards and signs must be installed. Waste containers should not be placed at the lagoon shores because waste can end up in the water in the case of lagoon overflow, and such pollution is difficult to remove. Therefore, containers should be placed in parking areas, or at roads or trails farther away from the lagoon. Waste containers with a cover or closed aperture should be used to prevent the possibility of the wind blowing waste into the lagoon.

To reduce the visitor impact on the lagoon habitats and species, it is recommended to concentrate visitor impact in a smaller number of localities. Thus, the birds will be provided with areas in which they are not disturbed. Planning of infrastructure should also be based on the opinion of an ornithologist and habitat expert.

10.3.7 Management and Use Unfavourable for Lagoons

Lagoon habitat formation occurs under the influence of sea coast geological processes; therefore, any activities which impact these processes can be considered as unfavourable management and use. Along the Latvian coast, significant disturbances of sediment transport have existed for a long time (external hydro-technical port structures, coastal anti-erosion structures, recreational influence, reduced river sediment loads et al.), which have changed the distribution of erosion and accumulation sections and also the areas of potential distribution of lagoons. The peculiarities of coastal slope development and the development of the Latvian coast (sediment input occurs mainly at the expense of coastal erosion, and long-shore sediment migration is pronounced) determine that various forms of coastal land use can influence coastal habitats in a way that is hard to predict and over long distances.

Use of the lagoon for fishing significantly influences birds during their breeding season. Waterfowl hunting disturbs migratory, also non-game birds, and it is also not compatible to bird watching and other types of land use for nature tourism and recreation.

10.3.8 Conservation and Management Conflicts

Lagoons in Latvia are rare, temporal and only occupy a small area; therefore, there are no certain traditions of their use. In some sites along the Latvian coast, lagoon habitats together with beach habitats (1310 Salicornia *and other annuals colonising mud and sand*, 1640 *Boreal Baltic sandy beaches with perennial vegetation*) are located in a zone of intensive recreation, which makes it difficult to use. The disturbance of lagoon and surrounding beach habitat vegetation (ploughing, mowing etc.) is not acceptable because these activities promote desiccation of the sand subsurface, which may initiate the development of aeolian processes, the filling of the lagoon with wind-blown sand, and overall reduction in width of the beach due to wind-blown sand transport from beach to primary dunes.

Chapter 11. Protected Beach Habitats (B. Laime, J. Lapinskis)

11.1 Beach Habitat Characteristics

11.1.1 Brief Description

This chapter covers four beach habitat types which are designated as threatened and protected habitats in the European Union. These habitats often develop in mosaic, and are closely related to other coastal habitats. Protected beach habitats are characterised by different plant and animal communities. However, their influencing processes, as well as conservation and management methods are similar.

1210 *Annual vegetation of drift lines*
1220 *Perennial vegetation of stony banks*
1310 Salicornia *and other annuals colonising mud and sand*
1640 *Boreal Baltic sandy beaches with perennial vegetation*

All protected beach habitats are very rare in Latvia, and cover only small areas, which may change due to storms and other factors (Table 11.1). These habitats are mainly related to the coast of the Gulf of Riga and the Irbe Strait. The most significant areas of the protected beach habitats are concentrated in the Kolka–Engure section and along the North Vidzeme coast.

Table 11.1. Characteristics of protected beach habitats.

Beach habitat and its main features (Laime 2013a, 2013b; Rove 2013b, 2013c)	Habitat area (ha and % of terrestrial area of Latvia) and distribution in Latvia (Anon. 2013c)
1210 *Annual vegetation of drift lines*	
Dominated by annual plant communities or individual annual or perennial plants, growing on accumulations of drift material and gravel rich in nitrogenous organic matter (Fig. 11.3, 11.4).	26 ha or ~ 0,0004 %
1220 *Perennial vegetation of stony banks*	
Vegetation of the upper beaches, formed by *Crambe maritima*, *Honckenya peploides* and other perennial plant species; beach substrate consists of at least 20% boulders and pebbles or at least 80% pebbles; the total cover of vegetation is at least 10% (Fig. 11.9, 11.18).	41 ha or ~ 0,0006 %
1310 Salicornia *and other annuals colonising mud and sand*	
Plant communities composed mostly or predominantly of annuals, in particular *Juncus* ssp., grasses and *Chenopodiaceae*, colonising periodically flooded low-lying wet sandy beaches or interior salt marshes (Fig. 11.1, 11.2).	40 ha or ~ 0,0006 %
1640 *Boreal Baltic sandy beaches with perennial vegetation*	
Sandy beach that is regularly exposed to severe to moderate wave action, with only minor fluctuations of sea water level, ensuring suitable conditions for perennial plant species. Vegetation is mostly sparse. Large areas of bare sand are common, or with occasional pebbles or boulders (Fig. 11.17). Habitat type 1640 *Boreal Baltic sandy beaches with perennial vegetation* are further referred to below as sandy beaches.	71 ha or ~ 0,0011 %

Fig. 11.1. Continuous vegetation rarely develops on beaches of the open Baltic coast. It can mainly be observed at the Saunags–Kolka section where communities of *Juncus articulatus* and *J. bufonius* develop temporarily. Photo: B. Laime.

Fig. 11.2. Wet beaches of Kurzeme and the North Vidzeme Coast, Gulf of Riga, periodically overgrow in large areas. High diversity of species and their habitat is characteristic here. Photo: B. Laime.

11.1.2 Important Processes and Structures

Beach habitats are located in the beach belt of the active coastal zone, and are subject to the general characteristics of beaches. In a broader sense, the beach is a final product of the transport and sorting of sediments by wave action, and its separate parameters can be found in a very wide range depending on geological, hydrodynamic and other conditions of the location. In general, existence of the beach is possible due to the dissimilar energy of water flow, which can be observed in the swash and surf zone when moving water energy, and hence the transporting ability of incoming waves is greater than that of return flow (Rijn 1998). Since beach formation is the result of wave action, the storm wave run-up limit is considered as the inland border of the coastal slope in gently sloping coasts (Eberhards 2003). Beach morphological borders often cannot be clearly visible, or they exist just temporarily (Sexton 1995). Beach properties directly indicate its forming conditions, and with a slight time delay they reflect the changes in the underwater slope. All changes of the sediment volume of the coastal system, influencing the beach area and composition, can be observed in the beach (Komar 1998).

The difference between beaches in Latvia along the coast of the open Baltic Sea versus the Gulf of Riga

Fig. 11.3. Recently washed drift lines are easily visible. They are concentrated closer to the beach, but are also often located in primary dunes. Photo: B. Laime.

Fig. 11.4. Drift lines covered with windblown sand can be overgrown with embryonic dune grasses, *Salsola kali* and *Cakile baltica*. Photo: B. Laime.

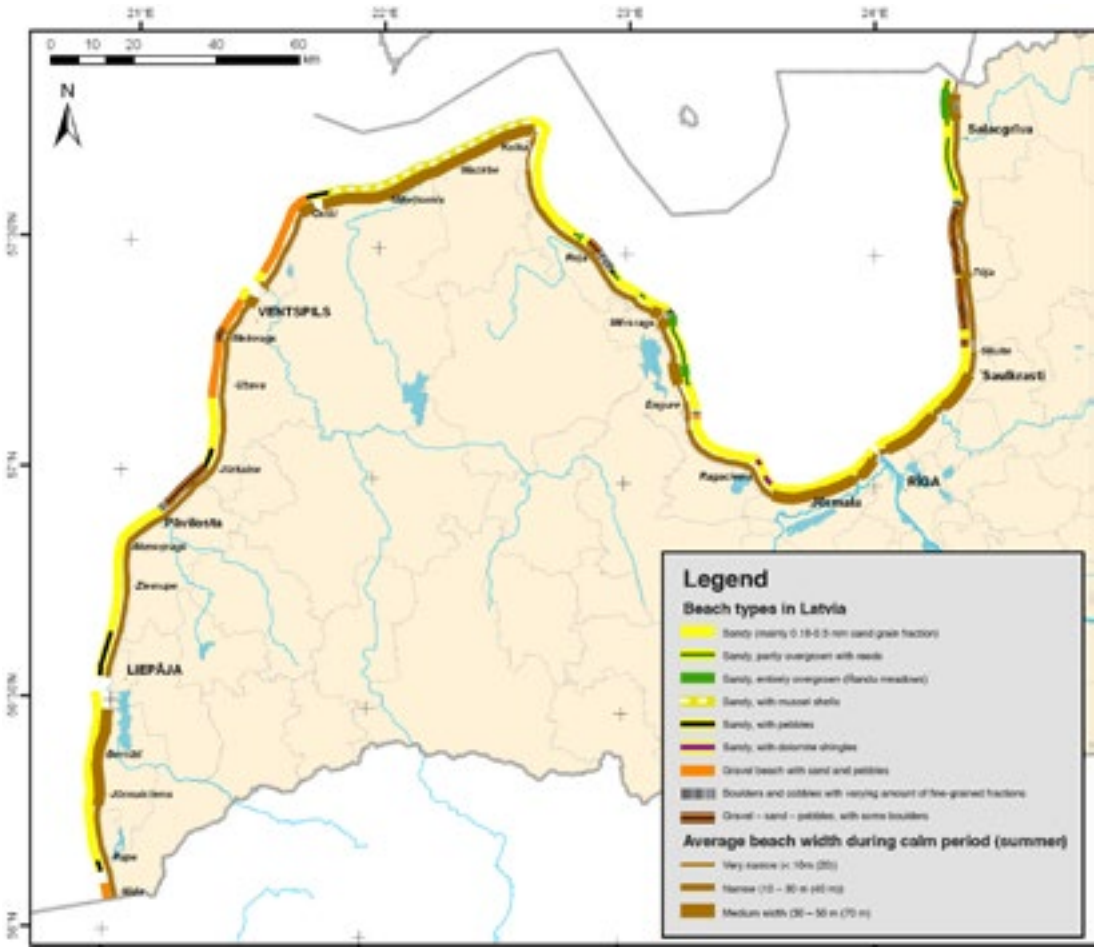


Fig. 11.5. The distribution of seashore beaches in Latvia, depending on beach type and width (data source: Eberhards, Lapinskis 2008). Map prepared by J. Lapinskis.

are mainly determined by local factors – sediment balance, geological structure of the territory and coastline orientation (Fig. 11.5). Wide beach (> 40 m) and large proportion of fine-grained sediments in the beach body usually indicates the predominance of sediment accumulation (Fig. 11.6). Narrow (< 20 m), steep and coarse-sediment formed beaches – the deficit of sediments. Along the open Baltic Sea coast, due to the greater intensity of wave action, beaches are better developed, and their composition – coarser. Along the Gulf of Riga, proper beach development is hindered in pronounced lee sites, and their width may not even reach 10 m (Uši–Aizklāņi, Mērsrags–Bērzciems) (Fig. 11.8). In some places of the Gulf of Riga coast, the volume of fine-grained sediments is very small, and the transitional area between the foreshore and backshore consists of an erosion terrace covered by an array of coarse material (pebbles, cobbles and boulders) (Kaltene–Valgalciems, Mērsrags, many sections between Tūja and Vitrupe) (Fig. 11.9). At the mouth of the River Kurliņupīte, on the Vidzeme coast, a unique concentration of boulders has developed as a result of long-lasting wave activity. Although the Baltic Sea coast is characterised by wider beaches, the majority of protected beach habitat types are related to the Gulf of Riga (Table 11.1).

Lines of washed-up organic debris in the lowest parts of beaches can develop anywhere along the Latvian coast, but after storms those can be found even higher – up to the fore-dune or cliff foot. It should be noted that the composition of drift lines can be very different, although mostly of organic origin. In the Baltic Sea coast, the formation of drift lines occurs less frequently, and their distribution is mainly related to the sections of accumulative coasts. On the coasts of the Gulf of Riga, drift lines develop in the summer and autumn. They often contain plant remains that get into the sea from the large river mouths (Fig. 11.10) or as the plant and algae remains form the foreshore part of the sea.

Fig. 11.6. Coast section where accumulation dominates, with a wide (› 50 m) sand and pebble beach. Lūžņa. Photo: J. Lapinskis.

Fig. 11.7. Coast section where erosion dominates, with a narrow (‹20 m) sand-gravel-pebble beach and boulders. Photo: J. Lapinskis.

Fig. 11.8. Very narrow, poorly developed beach on the west coast of the Gulf of Riga. Aizklāņi. Photo: J. Lapinskis.

Fig. 11.9. Erosion terrace covered by boulders and pebbles. Valgalciems. Photo: J. Lapinskis.

Fig. 11.10. Drift line, the composition of which is dominated by plant remains and tree stumps, which arrived to the sea by the River Gauja. Photo: J. Lapinskis.

Fig. 11.11. Several drift lines of various ages in Mērsrags, summer 2002. The oldest drift line formed in the storm of November 2001 and overgrew during the next summer. Photo: J. Lapinskis.

Fig. 11:12. Foredune and sandy beach with perennial vegetation in Bērzciems. Photo: J. Lapinskis.

Formation of drift lines at a higher rate often occurs simultaneously with beach micro-lagoon formation and with the increase of total intensity of sand sediment accumulation (Anon. 2014). A few years after severe storms, the abundance and total area of lagoons and drift lines, as well as low and wet beaches, increase. Also drift lines in boulders and pebble beaches develop better and last longer due to lower amount of fine-grained sediments on the coastal slope; sediments are not buried and they better become stuck in between boulders.

The formation of perennial vegetation in sand beaches in Latvian conditions occurs more frequently in those sections of the Gulf of Riga coast, the origin of which is accumulative but nowadays their sediment accumulation rate has decreased significantly, and which are presently characterised by a low overall intensity of dynamic processes. Such coastal sections can be found in the surroundings of Bērzciems (Fig. 11.12), between Kuiviži and Ainaži, as well as in several other places along the Vidzeme coast and the Gulf of Riga.

The high intensity of coastal processes is the main criterion, which limits the formation of such habitats along the coast of the open Baltic Sea. In sections of high intensity of coastal processes, after the introduction of vegetation in the upper part of the beach, sand blowing and deposition processes start rather rapidly, small temporary hummocks establish which under favourable conditions can grow into an embryonic dune and foredune. The morphology of sandy beaches, exposed in accumulative parts of the coast, changes very significantly during storms, and the existing vegetation on the beach is usually completely destroyed. One of the essential prerequisites for the persistence of vegetation on the sandy beach is a very gently sloping coastal underwater slope. Such conditions ensure the early breaking of storm waves and that their energy is spent in the coastal underwater slope (surf zone) only, and therefore flooding with little destructive activity of waves occurs in the fore-shore and back-shore area.

11.1.3 Natural Succession

Beach habitats are very diverse and variable. Often it is even difficult to distinguish between the beach habitat types or distinguish them from other coastal habitats. At the same time, a number of common features can be seen. In areas with no vegetation or where it is completely destroyed, succession usually starts with annual plants. In low, wet sandy beaches with organic debris, moisture-demanding plant species like *Juncus bufonius*, *Ranunculus sceleratus*, *Polygonum hydropiper* establish. On drift lines, plant communities of nitrophilic plants develop. In the further development of vegetation, mainly depending on moisture conditions, perennial herbaceous plants establish and start to codominate. On wet beaches, halophytes and

Fig. 11.13. Vegetation with *Sagina nodosa*, on the transition zone between beach and dunes. Photo: B. Laime.

Fig. 11.14. *Agrostis stolonifera* is a common plant species on wet beaches. Photo: B. Laime.

semi-aquatic plants are characteristic. On moderately wet to dry beaches, the proportion of psammophytic grasses increases. After severe storms, followed by a relatively calm growing season, perennial vegetation often rapidly develops in large areas. Often, the dominance of a single species is characteristic. This can be explained by a plentiful reserve of rhizomes and roots in the beach substrate and the volume of drifted diasporas. In small bays where the beach gradually turns into a wide foreshore belt, and is protected from erosion for a long time, lush reed growths, interchanging with willow stands, can develop.

Succession entirely depends on coastal processes. During storms, the sea level is rising, and plants can be washed off due to strong waves; lower plants can be buried in the sand. Thus, the natural development of habitat can be repeatedly discontinued and reestablished. During a period of high temperatures, the beach sand dries up, and succession is followed by the development of embryonic dunes. In this transitional period, abundant species are *Sagina nodosa* (Fig. 11.13.), *Agrostis stolonifera* (Fig. 11.14.), *Cakile baltica* and also *Salsola kali* (Laime 2010).

On boulder beaches, during periods without storms, succession can continue to grassland, heath and shrub communities. In some stable coast sections, atypical vegetation with a high projective cover of mosses and lichens can establish (Rove 2013b).

11.1.4 Indications of Favourable Conservation Status

Most of the Latvian beaches are natural, however, protected habitats develop mainly in sections with a greater diversity of coastal geomorphology and coastal processes. The following characteristics indicate the high quality of protected beach habitats.

- Natural micro-relief is dominating on the beach. No or little visible evidence of excessive vehicle use or trampling.
- No apparent signs of beach modification, of moving boulders or buildings; beach develops under the influence of the sea, wind and other environmental factors.
- Beach periodically overflows with sea water.
- Pools which periodically desiccate and overflow again are characteristic (Fig. 11.15). Some pools remain throughout the summer. Seasonally, depressions may be partially "buried" by sand.
- Abundant algae, wood fragments and other drift on the seacoast. They occur in broad belts, on long sections and/or form rather high heaps (> 10 cm). Drifts are formed continuously. In some places, there still are drift belts of previous years (Fig. 11.11, 11.19, 11.20).
- Alternating belts (groups) of various plant species, which differ in height, growth habit (decumbent, prostrate, and erect), abundance, plant species composition and quantity. Mosaic structure is typical of vegetation (Fig. 11.16).
- Plants of various ecological groups are present: succulents, psammophytes, halophytes, hygrophytes and hydrophytes.
- Low plants (height – from a few to 50 cm) are abundant; large proportion of annual plants (Kabucis 2001; Laime 2010).
- Beaches are rich with littoral plant species,

Fig. 11.15. Depressions, pools and drifts are important structures for beach habitat development. Kolka, Gulf of Riga coast, 2014. Photo: B. Laime.

Fig. 11.16. The mosaic of low beach vegetation: dominating species are *Ranunculus sceleratus, Juncus bufonius, Polygonum hydropiper* and other plants growing in humid habitats. Such beaches represent habitat type 1310 Salicornia *and other annuals colonising mud and sand*. Photo: B. Laime.

Fig. 11.17. Vegetation with *Bolboschoenus maritimus* and *Scirpus tabernaemontani* occurs mostly in small areas, in mosaic with annual plants. Such beaches belong to the habitat type 1640 *Boreal Baltic sandy beaches with perennial vegetation*. Lepste beach, 2014. Photo: B. Laime.

Fig. 11.18. In boulder beaches, vegetation diversity, boulder natural disposition and the amount of sand is important. "Vidzemes Akmeņainā Jūrmala" Nature Reserve. Photo: B. Laime.

Fig. 11.19. On drift lines, rich vegetation of nitrophilic plant species develops. Bērzciems, 2014. Photo: B. Laime.

Fig. 11.20. Annual plant communities on drifts often develop on slopes of the wash-out coasts, which are rich in seaweed, tree branches and roots after the storms. Kolka, 2015. Photo: B. Laime.

of which the majority is related to suboceanic Europe (Fatare 1975, 1992). Rare plant species are present: *Atriplex calotheca* (endemic species of the Baltic Sea and the North Sea coast), *Atriplex glabriuscula* and *Crambe maritima* (Laime 2001; Laime, Tjarve 2012).

High number of various animal species (birds, amphibians, insects, etc.) indicates the naturalness of habitat. Habitat structure favourable for birds:

- wide beaches, both sandy and pebble, are safer as breeding sites;
- river mouths are particularly important, both concerning the wide beach and the feed available for birds (marine invertebrates and small fish) in washed out algae;
- shallow pools with standing water are important

feeding areas for birds;
- uprooted trees fallen over on the beach and in the sea serve as resting places for Mergus merganser, Charadriiformes, and other birds (Priednieks 2015) (Fig. 11.21).

The beach can be a breeding place for *Sterna albifrons*, *Sterna hirundo*, *Sterna paradisaea*, *Charadrius dubius*, rarely for *Charadrius hiaticula* and *Haematopus ostralegus* as well. Drift lines are particularly important feeding sites for *Charadriiformes*, also for gulls and terns (*Larus* spp., *Sterna* spp.) during the migration period, which lasts a long time – for several species, autumn migration begins in July (Priednieks 2015).

Wet beaches with pools are one of the feeding and breeding habitats for the natterjack toad *Bufo calamita*. Several isolated populations of this protected amphibian species have been found along the Latvian coast (Bērziņš 1984, 1987).

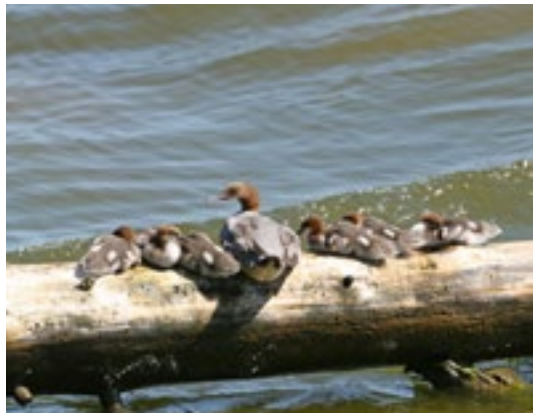


Fig. 11.21. Tree stump on a beach as a resting place for birds, including *Mergus merganser* "family". Photo: I. Priedniece.

The most common invertebrates on the beach are predatory species and those that feed on dead animals or dead parts of plants; herbivorous species are few. Drifts are populated by decomposers –

Fig. 11.22. Higher places of wet beach are important habitats for invertebrates. The pale sandy spots are "diggings" of *Omophron limbatum*. Photo: B. Laime.

Fig. 11.23. Dune tiger beetle *Cicindela maritima*. Photo: V. Spuņģis.

Ephydridae and other dipterous, which in turn is food for coastal birds – both for breeding birds, such as *Motacilla alba*, and migratory birds, such as *Calidris* spp. (Spuņģis 2014). Common species are also *Scatella stagnalis* and *Setacera aurata*; on low beaches, pool shores with absent or low vegetation – *Omophron limbatum* (Fig. 11.22.). Beaches with dry and loose sand are a feeding and overnight resting place for *Cicindela maritima* (Fig. 11.23). Annual plant species *Cakile baltica* plays an important role in invertebrate life because it ensures continuous feeding for pollinators, including butterflies (Jansen 2008). Sea-Rocket is one of the rare coastal plants that also supplies insects with nectar from inland habitats. This is of particular importance in the second half of the summer (Spungis

2002; Spuņģis 2008). The seashore is the only habitat where the spider *Arctosa perita* can be found (Bonte et al. 2000).

11.1.5 Pressures and Threats

11.1.5.1 Intervention in Coastal Geological Processes

The increasing human influence on the Baltic Sea and its coast is increasingly disrupting the balance between the natural erosion and accumulation processes. The most important factors are related to: ports, wharfs, shipping, use of wind and subsoil resources, as well as the establishment of cables, pipelines and other infrastructure and buildings in the sea and on its coast. As explained in *Chapter 11.1.2*, one of the most significant influences concerns the sediment flow. Due to anthropogenically induced sand deficit, in some sections erosion is accelerating and the beach area is decreasing. This has a negative impact on breeding birds such as *Charadrius dubius* and *Sterna* spp. These birds are breeding more successfully on wide beaches, where they can avoid both flooding in the case of strong winds, and predators that threaten birds from the forest edge. On narrow beaches, the recovery of suitable habitats for amphibians and birds occurs poorly and less often, due to more intense erosion and wave activity. In such a situation, the vegetation development cycle is disrupted, and it has a negative impact on the entire habitat structure and functioning.

11.1.5.2 Management cessation

Overgrowth of beaches, usually with common reed and willows, is mostly the case in territories where coastal processes are inactive, and a wide foreshore exists for a long time. Often, such a situation develops in places where the beach is bordered by coastal grasslands where mowing and grazing are discontinued. *Phragmites australis* and other high herbaceous plants and shrubs create lush and dense monodominant stands, reduce the number and abundance of typical beach species, and change environmental conditions (light, substrate etc.). Such stands negatively influence bird breeding and feeding options, and decrease the habitat area for the related insect species.

11.1.5.3 Excessive visitor load

The most significant risk to the specific beach habitat types is excessive recreation load. In territories with the most concentrated visitor influence near Rīga and in other populated areas along the Gulf of Riga coast, trampling depletes beach habitats, reduces the number of plant species. Due to trampling, the drying out of beach substrate increases, and aeolian processes – sand blowing – can start. This is particularly troublesome in sandy beach habitat types with annual and perennial plants (1210 *Annual vegetation of drift lines*, 1310 Salicornia *and other annuals colonising mud and sand*, 1640 *Boreal Baltic sandy beaches with perennial vegetation*). Due to the movement of the windblown sand, wet habitats can be buried. If the movement of windblown sand on the beach increases, sand gets into the backshore and in the water, and the total volume of sand on the beach decreases. Narrowing of the beach can occur, and damage caused by subsequent erosion during storms can be greater and unusual for the particular site.

Exceptionally unfavourable disturbances for bird species are caused by unleashed dogs that accompany people; water motorcycle riding; by people staying for a prolonged time nearby bird breeding sites (Priednieks 2015).

11.1.5.4 Beach relief modification

Excessive vehicle use on beaches causes compaction, does not allow the growth of annual plants, destroys insect shelter places, and scares birds. The worst effects are observed in coastal sections where the beach surface is pushed off by bulldozers. In this way, the micro-relief is disrupted or even the beach habitat is destroyed. The effects are even more pronounced when bulldozed sand (or pebbles and gravel) is gathered and transported away from the coast. Also, the removal of boulders from the beach significantly reduces habitat quality regarding biodiversity conservation at different levels. It degrades the landscape and species diversity. Ecological processes in the surrounding areas are artificially influenced.

11.1.5.5 Removal or relocation of algae and other drift

In some settlements, organic drift material (algae, plant roots, tree branches etc.) are constantly collected and removed from the beach. In this way, habitat type 1210 *Annual vegetation of drift lines* is basically destroyed. This habitat can only develop on the sea coast. By removing organic drift, growing places of several plant species are destroyed as well as living places for important insect species and feeding sites for waders and gulls. Regular removal of algae and other organic drifts in coastal sections of twenty ki-

Fig. 11.24. In intensive recreation areas, washed up seaweed is collected with tractors every morning. In this way, beach habitats are totally destroyed. Moreover, sand that is pushed and transported away creates a sand deficit, also reducing the quality of the recreation site. Photo: B. Laime.

Fig. 11.25. The dumping of gathered sand and algae degrades embryonic dunes and foredunes, in some areas also grey dynes. Dunes overgrow with *Chenopodium* spp., *Urtica dioica, Chelidonium majus, Artemisia vulgaris* and other species uncharacteristic to dune habitats. Photo: B. Laime.

lometres and longer create a fragmentation of beach habitats and species distribution range (*see Chapter 11.3.4*). The most popular public beach recreational areas are also regularly ploughed, thus completely preventing the development of natural habitats (Fig. 11.24, 11.25).

11.1.5.6 Waste

Popular beaches are being polluted with municipal waste. Their volume also increases due to washed out objects. This is especially relevant on accumulative coastal sections where sediment drift habitats develop more often. Mostly, these are products of synthetic polymers (packaging material), which degrade very slowly in the environment and have a negative impact on habitat structure.

11.2 Restoration and Management Objectives for the Conservation of Beach Habitats

- The diversity of annual and beach plant communities is restored and conserved throughout its distribution area along the Latvian coast.
- Suitable breeding, resting and feeding sites are ensured for bird species related to beach habitats.
- Whenever possible, natural geological processes along the Latvian coast are ensured.

11.3 Beach Habitat Restoration and Management

Beach is a very rapidly changing coastal landscape element. It particularly affects habitat types characterised by annual vegetation (1210 *Annual vegetation of drift lines*, 1310 Salicornia *and other annuals colonising mud and sand*). The prerequisite for the existence of these habitats is periodic or episodic beach transformation when it is subject to wave activity. Consequently, specific restoration and management of such habitats is usually not necessary, unless the habitat development disruptions are caused by human economic activities or excessive recreation load. Then, the most appropriate actions are compensation of interference, mimicking of natural processes, and assurance of natural processes.

11.3.1. Non-interference

Like other habitat types related to the active part of a coastal zone, the protected habitat types also depend on undisturbed geological processes of the sea coast. Habitat types 1210 *Annual vegetation of drift lines*, 1310 Salicornia *and other annuals colonising mud and sand* as well as 1150* *Coastal lagoons* represent a temporary phase of coastal slope development. Under favourable conditions, they form naturally and spontaneously. Of primary importance is the maintenance of undisturbed processes of erosion and accumulation (Anon. 2014).

During severe storms, pre-existing beach habitats are washed off or buried in coastal sediments. How-

Fig. 11.26. Beach in Ainaži, overgrown with high herbaceous plants and shrubs. Photo: B. Laime.

Fig. 11.27. Biotechnical measures, restoring beach and dune habitats in Ainaži, 2004. Vegetation of *Salix* spp. and *Phragmites australis* has been removed, the beach is repeatedly ploughed. Photo: B. Laime.

ever, the erosion caused by storm waves is vital for the initiation of a new habitat formation cycle. It creates the preconditions for the formation of habitats with annual vegetation, frees boulder beaches from aeolian sand sediments and "refreshes" them. In sites with perennial vegetation, sand during the storms accumulates over the previously developed plant cover. In most cases, it slows down eutrophication and allows beach typical plant communities to recover.

11.3.2 Removal of Expansive Herbaceous and Woody Plants

The removal of common reed *Phragmites australis* and other expansive herbaceous and woody plant species is relevant in coastal sections where these plants form dense, often monodominant stands, and therefore the regeneration of beach and primary dune habitats is difficult or even impossible. All works must be carried out in accordance with the judgment of experts of coastal habitats and coastal geological processes.

So far, vegetation removal (beach and dune restoration) in Latvia has been carried out in Ainaži, Salacgrīva and Roja, in accordance with the proposals of professor Guntis Eberhards. This experience shows that habitat restoration must be carried out gradually, over several years. It is recommended to start this work experimentally, with a small area, which is gradually extended and expanded. In autumn, vegetation is mown. All biomass is transported to the nearest composting site. Underground plant parts can be removed with a potato harvester or a similar technique, which allows the sifting of sand and gathering of plant roots and sod. Remaining roots should be collected in spring and next autumn. Also, all roots must be transported away from the beach. Work should continue until unwanted growth no longer occurs (Fig. 11.26, 11.27).

During works, all attempts should be invested to preserve the natural coastal ridge, and also to diversify the micro-relief by the creation of small depressions and elevations. This will create different moisture conditions and hence a mosaic structure of vegetation.

This method helps to solve both nature conservation and socio-economic issues. By clearing the area from high, dense growths of reed and shrubs, suitable places are created for recreation and tourism.

11.3.3 Establishment of Tourism Infrastructure

As beach habitats are located in an active part of the coast, exposed to the risk of regular erosion, the development of tourism infrastructure is not necessary. The exception is the habitat type 1640 *Boreal Baltic sandy beaches with perennial vegetation.* Wooden boardwalks that are elevated above the ground must be constructed according to the evaluation of visitor influence. A moderate level of trampling disturbance in this habitat may contribute to the preservation of plant species diversity, but above a certain level of interference, habitat quality may deteriorate. Habitat status can be evaluated by vegetation structure, by present plant species and their vitality.

Infrastructure must be developed outside the breeding sites of birds *Charadriiformes*, *Sterna* spp. and *Haematopus ostralegus*. If the establishment of infrastructure is necessary in these sites, the period of dormancy for bird species must certainly be res-

pected. Usually it is from April to mid-July, but it may vary depending on the species and seasonal characteristics. Construction works should be avoided during this time.

11.3.4 Management and Use Unfavourable for the Habitat Type

Beach habitats develop under the influence of seacoast geological processes. Therefore, any activities which affect the undisturbed coastal processes are considered as undesirable. Examples of such activities are: harbour dredging, beach strengthening (artificial dune planting) with willows, buckthorn and other plants.

Currently there is no impact of unfavourable management on habitats 1220 *Perennial vegetation of stony banks* and 1640 *Boreal Baltic sandy beaches with perennial vegetation*. Direct recreation load is the only significant disturbance in these areas but it does not significantly impair the situation.

In the areas of intensive recreation, where the area is managed by the removal of drift sediments, the persistence of habitat type 1210 *Annual vegetation of drift lines* is endangered. For example, in many parts in the southern part of the Gulf of Riga, organogenic beach sediments are gathered and transported to foredunes, to reduce the erosion risk in related areas. This practice is also considered to be non-compliant because the natural coastal zone evolutionary process includes sediment drift being buried with beach sand or washed back to the sea. Transportation of plant residue to the aeolian accumulation zone contributes to eutrophication and to the establishment of uncharacteristic plant species in habitats next to the beach. Further risks arise from marine litter, solid waste and other objects present in the drifts; released into dunes, they have a negative impact on their quality. Beach surface bulldozing in recreation sites, for example, in Jūrmala City, is also unacceptable. In this way, the persistence of habitat type 1310 Salicornia *and other annuals colonising mud and sand* is endangered in large coastal areas, and a sand deficit is caused. These management types have a negative impact both on habitat condition and recreation resources, and contribute to coastal erosion.

11.3.5 Conservation and Management Conflicts

Conflicts between specific beach management measures and the conservation of other or bordering habitats is not expected. Before a decision is made on the management measures, the specifics of a particular habitat must be evaluated, to reduce the possible risks.

Chapter 12. 1230 *Sea Cliffs* (J. Lapinskis)

12.1 Characteristics of Sea Cliffs

12.1.1 Brief Description

The upper part of a coastal slope, developed as a result of wave-induced erosion, forms habitat type 1230 *Vegetated sea cliffs of the Atlantic and Baltic coasts*, further below referred to as **sea cliffs**. Morphologically expressed sea cliffs along the Latvian coast occur in a total length of 150 km, and their height and geological structure varies greatly (Eberhards 2003). The most common are 6–15 m high cliffs formed of Quaternary sediments; along the coast of the Gulf of Riga – also cliffs formed of Devonian sedimentary rocks. In areas where coastal erosion dominates over accumulation and the sea cliff is moving inland with an average speed > 1 m/year, the establishment of plants is disturbed. In less active sea cliff sections (10–20 years between disturbances), cliff slope overgrowth with vegetation after slope angle reduction occurs for a longer time (KALME 2010). The distribution of plant species also differs because of the different geological structure. Calcareous species, dwarf shrubs, herbaceous plants and shrubs can be found on sea cliffs. On sea cliffs which are inactive for a long time and whose slope is dominated by sandy sediments, *Pinus sylvestris* becomes established. Due to slope processes characteristic for sea cliffs (collapses, soil creep, solifluction) which are acting over several years after the erosion episode, and due to very different humidity conditions at different heights, vegetation which covers the slope is very fragmented, forming a mosaic of various patches and belts of vegetation (Fig. 12.2).

More frequently, sea cliffs are located along the open Baltic Sea coast – north of Liepāja and Ventspils harbours, in the Labrags embayment between Pāvilosta and Užava (KALME 2010) (Fig. 12.1, 12.4, 12.5). Sea cliffs located along the coast of the Gulf of Riga are usually lower, and their retreat episodes occur less frequently (Eberhards 2003) (Fig. 12.3). Sea cliffs at several sections of the Vidzeme coast of the Gulf of Riga are lower, and formed of Devonian sedimentary rocks – sandstone and clay (Eberhards, Lapinskis 2008)

The formation of sea cliffs is highly variable, characterised by the alternation between erosion and stability. The succession of species and their communities is also subject to this aspect. On cliffs with a complex geological structure, conditions may determine a very high diversity of coastal species. However, the persistence of various succession stages is often temporary, and is destroyed by erosion during the next erosion episode.

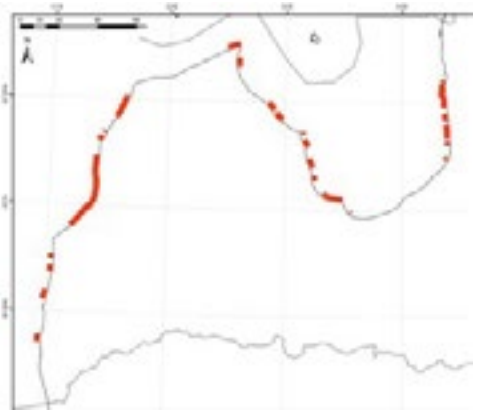


Fig. 12.1. The distribution of sea cliffs in Latvia (red sections) (data source: Eberhards, Lapinskis 2008). Map prepared by J. Lapinskis.

12.1.2 Important Processes and Structures

The functioning of sea cliffs is mainly affected by the frequency of sea coast erosion episodes. Other very important factors are: geological structure (substrate) of the coastal slope; slope height; presence and intensity of groundwater discharges; exposure to the prevailing wind direction; insolation that the slope receives. Habitat can also be significantly influenced by the vegetation of the coastal territory above the cliff and by direct human influences – movement of people on the slope.

There are no sea cliffs in Latvia, the slope of which faces south. Slopes exposed to the west are the most common, east facing slopes are much less (Eberhards, Lapinskis 2008). However, during the summer months, even on the west-facing sandy slopes, specific conditions arise – distinctive drought. In sea cliffs of coarse-grained sediments, moisture remains very temporary, and conditions are unfavourable for the development of any vegetation (Fig. 12.5). Establishment of vegetation is also difficult due to wind influence because sea cliffs along the open Baltic Sea coast are exposed to frequently observed westerly and south-westerly winds (Eberhards 2003).

On slopes, which are rich in fine-grained sediment (glacigenic loam, glacioaquatic clay and aleurites), slope evolution is also influenced by cryogenic processes. Soil freezing – thawing cycles during the winter months contribute to particle movement down the slope and complicate the establishment of

Fig. 12.2. About 8 m high sea cliffs formed of sand, north of Staldzene. Six years after the last erosion episode; pines are establishing. Photo: J. Lapinskis.

Fig. 12.3. About a 5 m high sea cliff formed in glacigenic sediments (moraine loam), soon after the erosion episode (between Kurliņupīte and Ķurmrags). Photo: J. Lapinskis.

vegetation in the first years after the erosion episode (Eberhards 2003) (Fig. 12.6).

Sand blowing from the beach up the cliff slope is only possible in coastal sections which are accordingly exposed, and wholly or partially composed of fine-grained sand, and the height of which does not exceed 3–5 metres. Sea cliffs with the upper part built of sand sediments are found in some places, and aeolian deflation on such cliffs, when sand is moving up over the cliff edge, is possible regardless of their height. Under favourable conditions (bays, sites of the Baltic Sea coast where there is no forest over the cliff and there are interruptions in the cliff front), aeolian deflation can reach very high volumes, creating blowouts tens of metres wide and deep, covering the adjacent terrain with a sand layer several metres thick (Fig. 12.7, 12.8) (Eberhards 2003). Sand movement up the cliff slope and further inland ensures the regeneration of grey dunes in some areas. Wind deflation and secondary accumulation zones provide additional fragmentation of landscape and increase species diversity on cliffs and in bordering habitats.

So, the favourable conservation status of this habitat type is based on natural, sporadic disturbances – storm wave erosion, which is followed by a decline of slope inclination when it stabilises. It is not possible to determine the preferred intensity and repeatability of disturbances for each geological structure type and height, but clearly the disturbances are necessary (Fig. 12.9).

12.1.3 Natural Succession

Vegetation succession is well observed on the slowly retreating sea cliffs. Species composition largely depends on the type of cliff forming sediments and on the presence of groundwater discharge. Usually vegetation development begins with the establishment of annual and perennial species such as the halophytic and succulent species *Cakile baltica* and *Salsola kali*, which are characteristic for beaches and embryonic dunes. Species of sand habitats also occur often, such as *Viola tricolor*, *Cardaminopsis arenosa* and *Jasione montana* (Rēriha 2013). Further succession is significantly influenced by the adjacent habitats. In the bordering zone with grey dunes, abundant species *Carex arenaria*, *Festuca sabulosa*, *Koeleria glauca* often occur. In sites where sand accumulation and rapid development of embryonic dunes or even foredunes has occurred, psammophytic gramineous plants start to dominate in cliff vegetation, such as *Festuca arenaria*, *Leymus arenarius*, *Calamagrostis epigeios*. In coastal sections where the sea cliff borders dune forest, various species of dwarf shrubs, *Lerchenfeldia flexuosa* and mosses quickly spread. On old, inactive sea cliffs, clubmosses and pine saplings are present, which indicates rather stable forest plant communities. On active cliffs, permanent vegetation cannot develop. There, temporary pioneer plant communities are characteristic.

On Devonian sandstone sea cliffs, vegetation only starts to establish after a very long dormancy period when the cliff is covered with fallen and wind brought material.

12.1.4 Indications of Favourable Conservation Status

A sea cliff is a coastal landscape element which is characterised by distinctive dynamism of geological

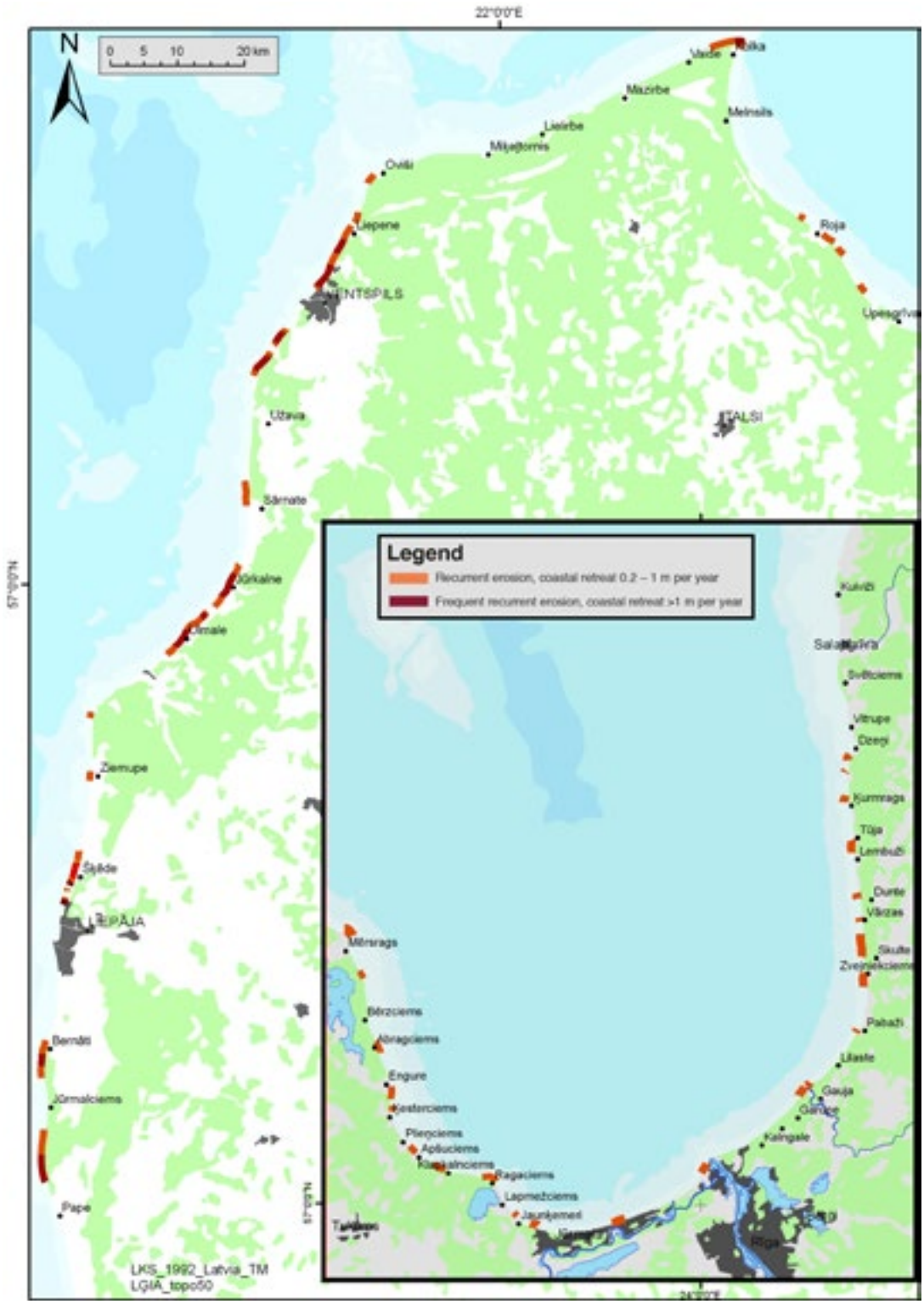


Fig. 12.4. Coastal sections along the Latvian coast where occasional coastal retreat occurs, providing conditions for the habitat 1230 *Vegetated sea cliffs of the Atlantic and Baltic coasts* (Anon. 2014). Map prepared by J. Lapinskis.

Fig. 12.5. Sand-gravel sediments of the Littorina Sea on a sea cliff slope in Staldzene. Photo: J. Lapinskis.

Fig. 12.6. Relatively slow formation of vegetation on a sea cliff slope of fine-grained sediments; north of Jūrkalne (six years since the erosion episode). Photo: J. Lapinskis.

processes; secondary – by dynamism of ecological processes. Sea cliffs as a form of relief can only be formed on the sea coast under a combination of specific conditions, among which the key factor is sediment deficit on the coastal underwater slope (Eberhards 2003; Lapinskis 2010). Coastal erosion episodes are possible throughout the entire Latvian coast if the destruction of backshore relief occurs due to storm waves (Anon. 2014). However, the sea cliff can only be formed if the frequency and intensity of such erosion episodes exceeds a certain, site-specific threshold. This means that the "regeneration" of the coastal slope after storm induced erosion does not take place to the full extent, and coastal slope feature rearrangement occurs in the inland direction. Accumulation intensity between storms is insufficient to create aeolian accumulation forms.

A very important set of processes in the development of sea cliff as a habitat is slope transformation after cliff foot erosion. Depending on the height of the sea cliff and its geological structure, due to cliff collapses and landslides of various sizes and due to erosion caused by groundwater and rainwater, the sediment mass of the upper part of the slope moves down, and usually builds up at the foot of the cliff. This process may continue for a number of decades after wave erosion episodes, until the slope reaches the inclination which is considered as relatively stable (30–45°) (Eberhards 2003). In coastal sections where the beach and the cliff slope are dominated by sandy sediments, significant movement of windblown sand up to the top can occasionally be observed. Sometimes wind erosion forms develop on the cliff slope – blowouts and other depressions. Above the cliff edge (on adjacent area) sand builds up, covering existing soil horizons and vegetation (Eberhards, Lapinskis 2008).

Species diversity is greater in sea cliffs where the retreat occurs relatively slowly and the geological structure is not simple. Also, a greater height of sea cliff usually allows the development of different conditions and a mosaic structure of plant communities. The most valuable slopes are those where erosion occurred more than 5–8 years ago, and afforestation or overgrowth with willows has not started. An additional variety of substrate and vegetation structure is ensured by groundwater discharge sites. According to the duration of succession, growth of low herbaceous plants can occupy the slope, and their area increases over the years after the storm. Plants (including small shrubs) which initially grew behind the edge, on the terrain, often establish on the slope after erosion when the upper part of the edge collapses. They are partially buried and they take root on the slope or at its foot (Fig. 12.2, 12.9). On a long-inactive sea cliff slope, vegetation with a tall and dense sward usually develops. Large fallen trees and their groups that have slipped or fallen from the upper part of the edge on the slope are functionally significant. Around them, special circumstances form – beach debris accumulates, favourable conditions for windblown sand accumulation are created, that are significant for the development of invertebrate species.

For bird species diversity, sea cliffs valuable for breeding are favourable. Sea cliffs are an important breeding habitat for very rare species in Latvia – the European bee-eater *Merops apiaster* as well as for common species – *Motacilla alba*, in some places *Riparia riparia* (Fig. 12.10).

Sea cliff slopes are important habitats for the Bal-

Fig. 12.7. Zone of blowout and aeolian accumulation above the sea cliff slope in Ventspils, 4 km north of the port. Photo: J. Lapinskis.

Fig. 12.8. Soil horizon buried by aeolian sand, sea cliff slope in the northern part of Liepāja. Photo: J. Lapinskis.

tic Sea region's endemic plant species *Linaria loeselii, Tragopogon heterospermus, Anthyllis maritima,* and the Northern Europe species *Cakile baltica* and *Leymus arenarius* (Rēriha 2013). Sea cliffs with springs are especially valuable in terms of biodiversity, around which plant communities similar to that of fens and spring discharges develop with *Carex flacca, Primula farinosa* and *Dactylorhiza baltica* (Fig. 12.11).

12.1.5 Pressures and Threats

Sea cliffs are a unique coastal habitat complex. To ensure favourable conditions, the continuity of natural processes in the context of sea coast erosion must be conserved. The increase of excessive erosion restriction and erosion intensity are considered as threats (EUROSION 2004; Anon. 2014).

12.1.5.1 Intervention in Coastal Geological Processes (Anti-Erosion Measures)

If the wave influence on the coastal slope (due to various coastal protection structures) is restricted, the cliff slope gradually stabilises, its slope angle reduces, slope overgrows with trees and shrubs as a result of natural succession. Consequently, the microclimate changes, the soil is complemented by litter and enriched with nutrients. Vegetation mosaic and species habitats characteristic for a sea cliff disappear on the slope.

12.1.5.2 Coastal Erosion

Research of the last 25 years shows that the coastal erosion intensity and the coastal retreat in Latvia

Fig. 12.9. Sea cliff slope densely overgrown with forest in Uši (40 years since the erosion episode). Photo: J. Lapinskis.

Fig. 12.10. *Riparia riparia* breeding sites on a sea cliff in Ziemupe. Photo: D. Vītola.

Fig. 12.11. Plant community with orchids and *Primula farinosa* on a sea cliff in Ziemupe. Photo: D. Vītola.

is increasing, if compared to the middle of the 20th century (KALME 2010). In coastal cliff sections which are located along the coast of the open Baltic Sea, erosion episodes recur more often. It means that the natural succession characteristic for sea cliff slopes is interrupted in the early stages, while the species diversity is still small. If the sea cliff slope that is significantly eroded in an erosion episode is large in length, localities of rare species can be completely destroyed, and their regeneration is no longer possible. Episodes of catastrophic erosion after which vegetation is fully destroyed on the sea cliff slope in a length of several kilometres, can cause changes in the previously typical succession cycle.

12.1.5.3 Excessive Visitor Load

Road infrastructure has improved in coastal areas, and off-road vehicles have become affordable. This has contributed to an increase in the number of visitors to more remote coastal habitats. In sites of the highest concentration of vacationers and tourists, unplanned trails on the sea cliff slope are developed; vegetation is depleted because of trampling, and wind deflation is promoted.

12.2 Restoration and Management Objectives in the Conservation of Sea Cliff Habitats

- To the extent possible, the continuity of the coastal sea cliff development on the Latvian coast is ensured, conserving the conditions necessary for sea coast erosion.
- The continuity of sea cliff sections is conserved, with periphery (lower erosion intensity) and central (higher erosion intensity) zones characteristic for each coastal section, to guarantee both the highest possible species diversity and the recovery of natural succession after severe storms.
- The conservation of sea cliff landscape scenic value is ensured, preventing both its afforestation and the introduction of invasive species.
- Habitats for plant, lichen and animal species of coastal sea cliffs of various geological structures and height is ensured.

12.3 Habitat Restoration and Management

Sea cliffs belong to rapidly changing natural habitats, so special restoration and management is not usually necessary, unless the disturbances of habitat development are caused by human economic activities or due to recreation overload. Then, disturbance compensatory measures and the restoration of natural process continuity are necessary.

12.3.1 Non-interference

Sea cliff evolution cycle – the foot erosion episode, followed by the collapse of the upper part of the slope and the decrease in the total inclination of the slope, introduction of pioneer species and subsequent rise of vegetation density and height – usually successfully occurs completely without external interference. Such conditions are typical mostly for the coast of the open Baltic Sea where the time span between severe erosion episodes can be from 5 to 10 years, depending on the site. Small-scale erosion, affecting just the sea cliff foot, occurs once every two years on average (Anon. 2014).

Coasts of the Gulf of Riga are isolated from the typical south-westerly winds, and therefore erosion episodes here are observed much less frequently. In some places, reactivation and cycle regeneration occur only 1–3 times a century (Eberhards 2003; KALME 2010).

12.3.2 Trees and Shrub Removal on Artificially Strengthened Sections

The main threat to the sea cliff's stability is artificial intervention in the coastal processes, when coastal erosion is reduced by massive anti-erosion structures. Disturbances which restart the sea cliff evolution no longer exist, and during the ecological succession, the former sea cliff slope overgrows with woodland, usually with *Pinus sylvestris* and various species of *Salix* spp. To conserve the landscape and ecological continuity of sea cliffs, trees and shrubs must be cut in the sections affected by coastal protection structures. A suitable time for felling is during the autumn and winter months, when the adverse impacts on wildlife are lower.

12.3.3 Action after Catastrophic Erosion Episodes

If all the vegetation is destroyed on the sea cliff slope after an erosion episode, and a bare, steep escarpment is created, the usefulness of any restoration measures will be very low. The establishment and restoration of vegetation is expected in places on the slope or at its foot where sod piles or trees have fallen from the top of the cliff (Fig. 12.12).

The restriction of wind deflation on the newly established slope is also not desirable, because windblown sand contributes to the conservation of adjacent grey dune habitats. In wooded areas or in their vicinity, lanes or belts of fallen trees can be formed at the foot of cliffs after episodes of erosion. It is advisable to conserve such concentrated areas of fallen trees because they naturally reduce (but do not exclude) the intensity of further erosion episodes, and ensure the more rapid recovery of biodiversity in their vicinity.

12.3.4 Establishment of Tourism Infrastructure

In areas of increased visitor concentration, the construction of staircases and footbridges on the cliff slope is very desirable. This should be done by using light and simple wooden structures, which can be partially dismantled and moved away at the end of the most active tourist season, or where the eventual destruction risk is already considered in the decision making process. Stairs would reduce the development of concentrated wind deflation zones in sites of spontaneously created trails.

12.3.5 Unacceptable Management and Use

The artificial stabilisation of sea cliff slopes with the aim to "conserve" the current seemingly optimum condition, is considered to be most undesirable because it reduces the overall stability of the system and is dangerous with regard both to the habitat type 1230 *Vegetated sea cliffs of the Atlantic and Baltic coasts* and to other related coastal habitats. Coast fortification with so-called "green" methods is an example of such management measures that are often undesirable but widespread in Latvia (Anon. 2014). So called "green" solutions are practices which include the establishment of beach and dune vegetation plantings, twig and reed bundles coverings, fences and other light sand withholding constructions on the eroded cliff foot or on the slope (Anon. 2014). Usually these methods are shown and perceived in society as the simplest, most "natural", "environmentally friendly" and resource-efficient techniques. Their working principle is to encourage windblown sand accumulation in the area. Secondarily, it reduces the potential threat to the bluff face during erosion episodes. Considerable efficiency is only achieved in coastal sections with large volumes of sandy sediments as well as if the erosion episodes recur very rarely.

"Green" methods in Latvia can only be justified in coastal sections where the coastal slope is gently sloping – no sea cliffs – and where the foredune foot and older dune terrain are not affected by erosion. Modification of the natural development cycle of low and sandy sea cliffs with the methods described can only be allowed in special cases (for example, in sites of very intensive flow of visitors). The establishment of plantations non-compliant to the particular site can promote the overgrowth of cliffs and bordering habitats, contribute to overall environmental eutrophication, or disturb the establishment of plant species characteristic for the particular coastal belt.

However, to meet the various public interests in coastal zone management, the total cessation of coastal erosion restriction works is also not possible. Both the intensification of human induced erosion and its cessation on the former sea cliff sections are considered an undesired influence on the environment, and it must be reduced, and appropriate compensatory mechanisms must be sought. There is a need for long-term monitoring of coastal erosion distribution, and the intensity and degree of human

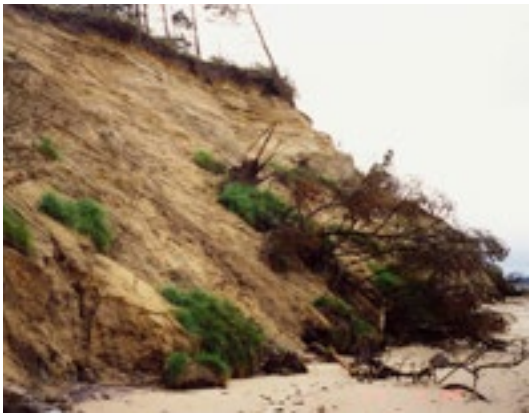


Fig. 12.12. Sod piles and small trees slipped down from the area adjacent to the cliff slope, a few days after the erosion episode. Northern part of Jūrkalne. Photo: J. Lapinskis.

Fig. 12.13. Coastal erosion intensification nearby the coastal section protected by an anti-erosion structure, at Liepāja wastewater treatment plant. Photo: J. Lapinskis.

influence on the coastal system. It would help in responding to environmental changes more effectively, and to prevent habitat degradation.

Sea cliff slope is a morphologically and functionally important element in the wide complex of the coastal environment. For the successful existence and conservation of the habitat of Community importance 1230 *Vegetated sea cliffs of the Atlantic and Baltic coasts*, conditions of other related complex elements, like underwater slope and beach, are of great influence. For sea cliff development, the management and use of other, relatively remote territories may also be important. For example, the intensity of coastal erosion in the Staldzene sea cliff section, north of Ventspils, is largely determined by where the dredged sand from Ventspils Port is dumped. If the sand dumping site were moved from offshore to a depth not exceeding 5 m, the coastal erosion intensity would be gradually reduced (KALME 2010).

Also the quality of other coastal habitats is influenced by the conservation of the sea cliff slope evolution cycle. Sea cliff erosion contributes to the renewal of fine-grained material on the foreshore and the beach. If the sea cliff erosion were reduced at a wider coastal section (> 200 m), the beach erosion would increase, the underwater slope would become steeper, and the degradation of associated grey dunes would occur. An increase of total erosion risk in adjacent coastal sections is also possible (Pranzini, Williams 2013) (Fig. 12.13).

For bird species protection, the most important measure for sea cliffs is not to disturb birds in their breeding season in the most important breeding sites (sand martin *Riparia riparia* colonies, European bee-eater *Merops apiaster* breeding sites). Then, the movement of people should be maximally limited, or at least their long-term stay in the direct vicinity of the colony should be avoided.

12.3.6 Conservation and Management Conflicts

The previously described specificities of sea cliff habitat development determine that the occurrence of conflicts is inevitable. Despite the relatively small population density in the coastal part of Latvia, a large part of the population uses natural resources, which are directly related to the sea coast (Eberhards, Lapinskis 2008). During the last 20 years, coastal retreat (the rearrangement of sea coast in an inland direction) in many sites has occurred at an average rate which is higher than 1 m per year (Anon. 2014) (Fig. 12.4). Due to strong variability, instability and sensitivity to a variety of external factors characteristic for the sea coast and especially for sea cliffs, in many places a kind of confrontation between people and nature has developed. Coastal erosion, which is the prerequisite for the emergence of such habitats, is also one of the most important aspects to be taken into account when planning coastal territory development and the priorities of its use (Anon. 2014). For example, people living in the coastal erosion risk sites want their property to be protected and erosion to be restricted.

Also, there may be a conflict between the conservation requirements of sea cliffs and their bordering habitats. When allowing natural sea cliff development and uninterrupted retreat of the coast, another important habitat area, located just behind the sea cliff edge, such as the habitat type 2130* *Fixed coastal dunes with herbaceous vegetation (grey dunes)* can gradu-

ally be lost. Therefore, priorities should be evaluated for every particular site. A compromise solution or management strategy must be chosen that best suits the various habitats of the coastal complex.

Chapter 13. Embryonic Dunes and Foredunes (J. Lapinskis, B. Laime)

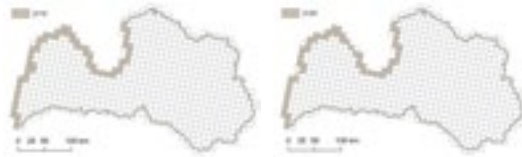
2110 *Embryonic shifting dunes*
2120 *Shifting dunes along the shoreline with* Ammophila arenaria *(white dunes)*

13.1 Characteristics of Embryonic Dune and White Dune Habitats

13.1.1 Brief Description

This chapter analyses habitats belonging to the primary dunes, which are one of the most dynamic in the coastal landscape. Habitat type 2110 *Embryonic shifting dunes*, further below referred to as embryonic dunes, represents the initial stage of dune development, when a wavy or ridge-like surface develops on the upper part of the beach or on the sea-facing foot of the foredune bank. Habitat type 2120 *Shifting dunes along the shoreline with* Ammophila arenaria (*white dunes*), further below referred to as foredunes, where active wind induced sand movement and accumulation occurs, form one or several dune ridges parallel to the coastal belt (Fig. 13.1, 13.2) (Eberhards 2003; Laime 2013c, 2013d).

Both embryonic dunes and foredunes are rare habitat types in Latvia, covering 0.003% and 0.009% of the total area respectively (Fig. 13.3) (Anon. 2013c). The area of this habitat type is also variable in different years. After severe storms the foredune area highly decreases. Embryonic dunes often develop in their place. These primary dune habitats are mainly related to the distribution of sand dominated beaches and with coastal sections which are little influenced by visitors. Since embryonic dunes and foredunes are ecologically similar, their development, related processes and management will be discussed together.



a **b**

Fig. 13.3. The distribution of embryonic dunes (**a**) and foredunes (**b**) in Latvia (Anon. 2013c).

13.1.2 Important Processes and Structures

Foredunes and embryonic dunes develop in the backshore zone. They are accumulative ridge-like forms of coastal relief. Sediment (sand) movement to active aeolian accumulation (sand accumulation zones) occurs mainly under the influence of marine winds.

Particularly intense sand accumulation can occur in coastal sections where large volumes of small-grained sediments are located on the coastal underwater slope and on the beach. And the opposite – if the underwater slope is steep and there is a shortage of sand, wind-induced accumulation does not develop because downward sediment movement to the coastal underwater slope dominates (Ulsts 1998).

The morphodynamic foredune classification scheme is often used, after which foredunes are divided into three simplified types: progressive, regressive and stationary (stable) (Arens, Wiersma 1994). In Latvia, the stable type of dunes is dominating. Progressive foredunes are especially rare; regressive ones

Fig. 13.1. Embryonic dunes with vegetation mosaic, dominated by *Honckenya peploides* and *Leymus arenarius*. Lūžņa, 2013. Photo: B. Laime.

Fig. 13.2. Recently developed foredune, dominated by *Ammophila arenaria*. Lūžņa, 2013. Photo: B. Laime.

occur slightly more often (Eberhards 2003; Eberhards et al. 2009).

Aeolian accumulation is particularly promoted by the introduction of vegetation on the upper part of the beach; it decreases the speed of the wind and hinders the movement of sand carried by the wind. High and massive foredunes only occur on coastal sections dominated by pronounced accumulation, with wide sand beaches (Fig. 13.4). Embryonic dune formation is also possible on beach sections with sediment balance which is neutral in the long term, and sand – gravel beaches. In periods with no storms in the long term (more than five years), embryonic dunes may also develop on erosion dominated coastal sections on the foot of a sea cliff (Fig. 13.5) (Lapinskis 2010).

In coastal sections dominated by erosion, with a large proportion of sand in the coastal sediments and a small height of terrain, an unusual relief form may develop which morphogenetically is not a foredune and may be considered a retreating overblown ridge. It is formed when sand from the beach is blown in large volumes over the low retreating escarpment; a low ridge develops beyond it, and moves in an inland direction over the long term (Fig. 13.6).

Fig. 13.4. High and rapidly growing foredune, south of Ventspils port jetty. Photo: J. Lapinskis.

Foredune forms a transitional zone between the part of the coastal slope influenced by wave action and the upper coastal terrain. However, the morphological borders between embryonic dunes and foredunes often cannot be accurately determined (Sexton 1995; Lapinskis 2010). As the belt of embryonic dunes and foredunes belong to the active and rapidly changing part of the coast, it may temporarily disappear after severe storms due to coastal erosion. According to the observations of the last 25 years, the total length of Latvian coastal sections with foredunes and embryonic dunes is 220–230 km (Anon. 2014). The total length of coastal sections with embryonic dunes only, reaches 100–120 km (mainly the coast of the Gulf of Riga) (Eberhards, Lapinskis 2008) (Fig. 13.7).

An important factor in the development of dunes and their habitats is the orientation of the shoreline to the prevailing winds. The Latvian coast can be divided into five parts, and storms have a different influence in each of them. The Baltic Sea coast from Nida up to Ovīšrags and Vidzeme coast of the Gulf of Riga are exposed to the direct influence of strong south-westerly winds. Kurzeme coast of the Gulf of Riga, from Kolkasrags to Rīga is relatively protected; similarly also the Irbe Strait coast from Ovīšrags to Kolkasrags, because here winds blow parallel to the shore or from the inland. Virtually the entire Latvian coastal zone is exposed to the influence of northwest-

Fig. 13.5. Embryonic dune on the foot of the sea cliff in Staldzene, in a coastal section dominated by erosion. Dune has developed over seven years since the last severe coastal erosion episode. Photo: J. Lapinskis.

Fig. 13.6. Retreating foredune ridge in Nida. Photo: J. Lapinskis.

erly storms, especially the southern part of the Gulf of Riga coast between Jūrmala and Skulte, and in situations when strong northwesterly winds follow the southwesterly and westerly winds, large volumes of water are directed into the gulf (Eberhards 2003; Draveniece 2007).

Meteorological conditions are also associated with processes and structures important for primary dunes and foredunes. Soil moisture and the vegetation season can be directly affected by the persistence of snow cover. Between 1945 and 2004, the snow cover on the western coast lasted an average of 70 days per year, but 95 days on the eastern coast (Draveniece et al. 2007). The activity of aeolian accumulation processes is determined by air temperature and rainfall. In some vegetation seasons, when it rains for longer and the air temperature is generally lower, embryonic dune and foredune formation is less pronounced.

Embryonic dunes and foredunes, located in a habitat complex with beaches, are directly related to wave activity, currents and water level fluctuations. These processes are discussed more in *Chapter 11* on beach habitats.

13.1.3 Natural Succession

Embryonic dunes and foredunes are characterised by plant communities with mostly a low number of species, dominated by psammophytic and salt tolerant grasses. Primary succession associated with dry beaches and primary dunes starts with communities of coastal halophytic and succulent plant species These include communities of annual plants *Cakile baltica* and *Salsola kali*, which in the initial stage of their development (June and July) are only up to a few centimetres tall. Such low, scattered plants are sensitive to any disturbances in their growing site (trampling, sand blowing etc.). The community of *Honckenya peploides* is more resistant to substrate disturbances, coastal processes and human influence. In further succession, the community of *Leymus arenarius* and A*mmophila arenaria* dominates; it is diverse, widely represented on the southern and south-eastern coast of the Baltic Sea, and its primary species is *Ammophila arenaria* (Piotrowska 1988; Isermann 2004a, 2004b; Stankevičiūtė 2000, 2001; Laime 2010). Coastal processes, which are directly related to the amount of sediments, are significant. On the Latvian coast, stands of *Leymus arenarius* develop mainly on the sand deficit coasts which are periodically exposed to wash-out, and the coast even retreats in an inland direction (Laime 2010).

Along the coast of Latvia, several types of succession are identified, determined mainly by contemporary coastal processes. On accumulation shores, like in Pērkone, the most common is primary dune succession, starting from annual plant communities and developing to communities with typical dune grass species and *Hieracium umbellatum*. Distinctive psammophytical plant communities are related mostly to the continuous dune zone or to one continuous foredune. In accumulation shores with periodic wash-out and heavy sand blow, for example, in Daugavgrīva, after the vegetation of *Leymus arenarius* and *Ammophila arenaria*, a community of *Carex arenaria* and *Festuca sabulosa* often develops, with a rather sparse sward (Laime 2010). On sand deficit coasts, for example, in Engure, a mosaic of communities with *Honckenya peploides* and *Leymus arenarius* dominates. In conditions which are highly xerophytic and with sand deficit (moderate sand blowing) vegetation of *Ammophila arenaria* and *Hieracium umbellatum* dominates, which gradually develops to grey dune with herbaceous plants and low shrubs. On low coasts with a dynamic balance and small accumulation of sand, for example, in Ainaži, in the initial stage of succession, sparse vegetation with *Salsola kali, Cakile baltica* and *Honckenya peploides* is typical. With the formation of fragmented foredunes, the communities of *Leymus arenarius* and *Festuca arenaria* mainly develop (Gesinski 1932; Laime 2010). In some places succession towards shrubs can also be observed, with a large proportion of *Salix viminalis* and *Salix daphnoides*. There are cases when *Pinus sylvestris* propagates in the old foredune, and succession develops from foredune to coniferous woodland.

13.1.4 Indications of Favourable Conservation Status

The main prerequisites for the formation of biodiverse embryonic dunes and foredune habitats are high volumes of accumulated sand on the beach and periodically strong wind, which ensures active sand blowing (Fig. 13.8). Accumulation caused by wind is much more pronounced in coastal sections dominated by fine-grained sand. These processes occur more intensively during the warm weather, when sand dries up faster. Plants growing on the sea coast are important because they create a natural barrier and contribute to sand accumulation. The wider and longer the zone of primary dunes where these functionally important processes occur, the more favourable the condition of habitats of these dunes.

Typical embryonic dune and foredune habitats are characterised by predominantly sparse vegetation with a lot of free sand patches between plants

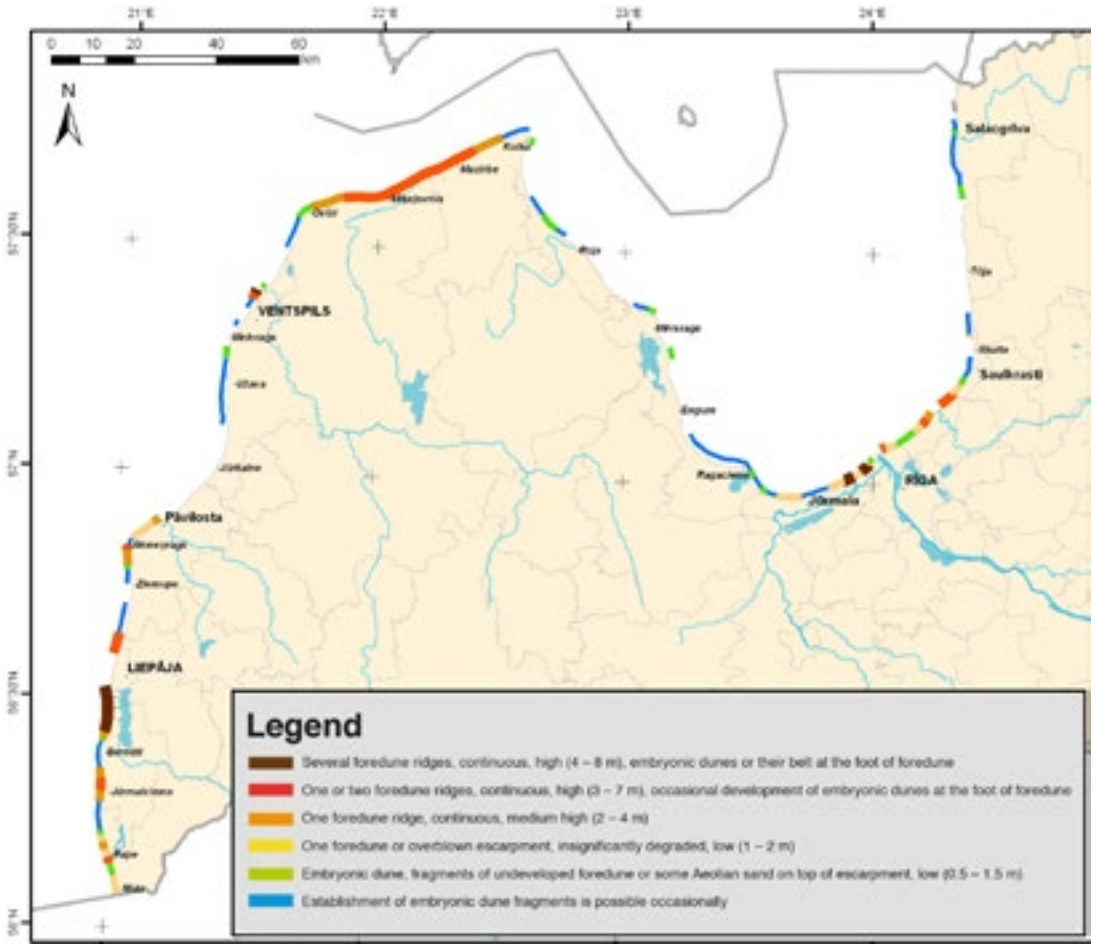


Fig. 13.7. Foredune and embryonic dune types and distribution along the Latvian coast (simplified). Map prepared by J. Lapinskis.

or their groups. In some places, plants can form a continuous plant cover, which is not persistent. Embryonic dunes may be of various forms and heights which further determines the type of habitat vegetation. On the young, small embryonic dunes, annual herbaceous plants often dominate, like *Cakile baltica*, *Salsola kali*, *Corispermum intermedium*. On more stable primary dune formations, the proportion of perennial herbaceous plants is higher. Often, the dominant and almost the only species is *Honckenya peploides*, forming quite densely covered dune hummocks. This is particularly characteristic on shores after storms and also on sea coast sections where periodic washout of foredune or terrain occurs. On sand deficit coasts, vegetation is composed mainly of *Leymus arenarius* and *Festuca arenaria*, often also of *Calamagrostis epigeios*. On continuous periodic accumulation shores where dune hummocks abundantly develop, a great variety of psammophytic grasses is characteristic (Fig. 13.9). All of the mentioned embryonic dune types can be considered as natural and equally important in certain circumstances.

Also foredunes may differ depending on various environmental factors. Excellent foredune habitat has a large variety of plant species: psammophytic dune grasses grow together with dicotyledon herbs *Hieracium umbellatum*, *Anthyllis maritima*, *Petasites spurius*, *Tragopogon heterospermus* (Annex 4). Habitat develops more favourably if the dune is high and it is constantly or at least periodically overblown with sand. Often such habitat is characteristic for old foredunes, especially their lee slopes. In highly dynamic coasts, characterised by intense accumulation and periodic washout and dominated by young foredunes, the number of plant species may be small and *Ammophila arenaria* usually dominates. In a transitional zone with embryonic dunes, often also in young foredunes, one of the most typical species is x *Calammophila baltica*. On natural primary dunes, little influenced by humans, the common insect species are

Fig. 13.8. Sand blowing is the determining process of embryonic and foredune development. Kolka, 2014. Photo: B. Laime.

Fig. 13.9. Embryonic dunes, the vegetation of which is dominated by gramineous plants that are adapted to grow in moving sands. Kolka–Vaide. Annual succulents *Cakile baltica* and *Salsola kali* are often found. Photo: B. Laime.

Fig. 13:10. Fungus characteristic for foredune habitat, *Phallus hadriani*, is included on the list of the protected species of Latvia. Photo: B. Laime.

Cicindela maritima and *Broscus cephalotes* (Spungis 2002; Spuņģis 2008), as well as mushrooms growing in the sand, such as *Phallus hadriani* (Fig. 13.10) Perfect embryonic dune and foredune habitat is dominated by succulent, halophytic and psammophytic plant species. Trees and shrubs, as well as expansive, ruderal and invasive species in such habitats are absent or very rare.

A typical and widespread bird species on embryonic dunes and foredunes is *Motacilla alba.* Here *Charadrius dubius, Charadrius hiaticula*, and rarely *Anthus campestris,* also breed. For birds, primary coastal dunes with mosaic vegetation are important, because they ensure favourable nesting conditions (Priednieks 2015). A suitable habitat for *Motacilla alba* and *Anthus campestris*, is one where a large variety of psammophytic grasses present and vegetation consists mainly of *Leymus arenarius* and *Festuca arenaria* and often *Calamagrostis epigeios* as well. *Charadrius dubius* and *Charadrius hiaticula*, and also *Haematopus ostralegus* can nest on plain areas in embryonic dunes if the area of these dunes is wide enough and is not close to the forest (Priednieks 2015).

Embryonic dunes and foredunes are the basic habitat for litoral species and for species which can only be found on the coast, including endemic species of the Baltic Sea region *Linaria loeselii*, *Anthyllis maritima*, *Tragopogon heterospermus* as well as species that are very rare in Latvia, such as *Eryngium maritimum* (Laime 2000).

13.1.5 Pressures and Threats

13.1.5.1 Intervention in coastal geological processes

One of the most important adverse effects is the artificial disturbance of natural processes contributing to sediment balance. It is caused mainly by various structures in the nearshore and foreshore (port hydrotechnical constructions, jetties, shipping channels, coastal reinforcements, etc.), dredged material disposal in the sea deeper than the sediment exchange zone (Ulsts 1998; Pranzini, Williams 2013). Thereby a sand deficit is created, natural coastal protective barriers decline, and often coastal washout starts instead of previous accumulation processes; also erosion of the coastal underwater part (nearshore) starts, accelerated by processes created by climate change. Along the Latvian coasts, one can observe the consequences of both massive shore reinforcement in the Sambian Peninsula in Russia, and irreversible

Flowering plant species characteristic for embryonic dunes and foredunes. Photo: B. Laime

Ammophila arenaria

Leymus arenarius

x*Calammophila baltica*

Cakile baltica

Petasites spurius

Lathyrus maritimus

Honckenya peploides

Tragopogon heterospermus

Linaria loeselii

Anthyllis maritima

removal of dredged sediments from the drift flow (several hundred thousand cubic metres per year) due to the maintenance of Klaipēda Port in Lithuania. The influence on sediment flow of Liepāja, Ventspils and other, smaller ports, is also constantly increasing. The decrease of sediment volume carried in by rivers is also caused by the construction of hydroelectric power plants on the River Daugava and by the industrial extraction of sand, for example, in Buļļupe and Lielupe rivers. Sand deficit is also increased by dune excavation which occurs during the construction of economic, recreational, tourist and other objects during construction (Anon. 1993; Ulsts 1998). Decreased amount of sediments and the modification of natural processes of the drift flow consequently hinder dune formation, promote the formation of a dead grass layer, especially an increase of the *Ammophila arenaria* dead stem cover, as well as a decrease in the abundance of characteristic species.

13.1.5.2 Inappropriate management

Foredunes and embryonic dunes are among the coastal habitats, the quality of which can be adversely influenced by unsuitable anti-erosion measures, especially – unreasonable creation of willow plantations. Such plantations restrict the influence of storm waves on the foredune front, interfering with its main function – to provide sand material input to the lower parts of the coastal slope during storms. Due to excessive foredune stabilisation, beach erosion can increase and, paradoxically, the overall coastal system stability can worsen (Pranzini, Williams 2013; Anon. 2014). The establishment of willow plantations and other foredune stabilisation measures must be carefully considered in each individual case, because circumstances along the Latvian coast vary widely (Fig. 13.7). Targeted promotion of sediment accumulation in a particular coastal sector may cause a disadvantage in the adjacent coastal habitats (the beach and the terrain beyond the backshore).

In a number of coastal areas, such as Lielirbe, Pape, Ainaži, dense shrub growths have developed, which are constantly expanding, thus reducing the vegetation characteristic for foredunes. These are mostly growths of *Salix viminalis* and *Salix daphnoides*. Shrub litter also increases soil fertility, which further promotes the introduction of expansive herbaceous plants and trees.

13.1.5.3 Climate change

It is forecasted that, in the event of global climate change, the average air temperature will rise, the number of days below freezing and days of snow will decrease, and the frequency and severity of storms will increase. This would promote a decrease in the period with sea ice cover. Coastal erosion processes will intensify, as well as flooding of a wide range of coastal areas during storms (LVĢMC 2016). This would lead to the washout of foredunes, and grey dunes, also wooded dunes, hinder their regeneration and reduce their total area. Along with the rise in air and sea water temperature, a rise in the number of visitors to the Latvian coast is also expected, which would lead to a higher anthropogenic load compared to the current situation. In such circumstances, the decrease of protected dune habitats and their quality is predicted.

13.1.5.4 Excessive visitor load

Excessive recreation load is a very significant threat to the habitats located in the primary dune zone. In most of the Latvian coastline, the sites of highest concentration of visitors also overlap with sites of foredune and embryonic dune distribution, especially along the Gulf of Riga coast, where high-valued recreational resources are located and also the recreational load is one of the highest. While vacationers are moving on the dunes, their habitats are depleted and the number of plants that are crucial to their relief forms are reduced. It is especially important in embryonic dune habitat distribution sites where vegetation destruction can cause the sand to be blown further inland and parallel to the shore. For example, in many parts of the Jūrmala and Saulkrasti coastal sections, natural dune formation does not occur at all (Fig. 13.11). In addition, artificially created bare sand patches and the proportion of trampled and uprooted plants increases, and consequently the area covered with typical plant species decreases.

Under the interaction of specific natural conditions and anthropogenic disturbances, the following may occur in habitats:

- development of human-induced deflation depressions and pits; formation of "blowouts" and depressions in sites where dune vegetation cover is artificially altered and/or the continuity of foredune ridge is disturbed (pedestrian boardwalks and paths, paths/roads cutting through/across primary dune);
- the movement of an existing and actively "growing" foredune onto habitats located behind it;
- periodic deterioration of the beach recreational value (increase of the proportion of coarse sediments), when wind and waves transport the sand

Fig. 13.11. The formation of an embryonic dune is not possible under the conditions of intensive visitor load. Kaugurciems, Jūrmala. Photo: J. Lapinskis.

Fig. 13.12. Deflation depression (blowout) on the foredune and ridge; about 10 m^3 in volume. Photo: J. Lapinskis.

inland;
- on wind erosion development sites, wave activity increases.

Local vegetation disturbance, trackway approximately parallel to the prevailing wind direction, tracks left by vehicle or footbridges cutting through primary dune can create favourable conditions for blowout development (Fig. 12.13) (Anon. 2014). In a typical formation of blowout, wind eroded sand is blown further inland, creating a kind of secondary accumulation body that protrudes beyond the adjacent dune slope and is in the form of a parabola (Eberhards 2003). In the cross-section, blowout is usually in the form of a letter U, and its longitudinal section is characterised by a steeper slope towards the sea. The frontal part of the foredune which is undisturbed but adjacent to the blowout, concentrates wind power and promotes further blowout development. When the blowout is deepened, its side edges collapse.

Adverse effects are caused by the presence or prolonged stay of a large number of people in the same place in primary dunes during the bird breeding season. In such situations, there is no nesting or it ends unsuccessfully Trampling, pit digging and sand compaction adversely affects the habitats of insects, reducing the number of individuals and species survival.

13.1.5.5 Excessive vehicle use

Excessive vehicle use on dunes with quadbike, motorcycles and off-road vehicles is a serious problem. In this way, the dune's natural structure is disturbed, vegetation degraded, as well as birds nesting in embryonic dunes are threatened.

13.1.5.6 Waste

In sites often visited by vacationers, the foredune and embryonic dune belt is polluted with municipal waste. In settlements and their vicinity, weeds, garden compost and branches, in some places even top soil are dumped in dunes. Sometimes compost is even used for coast strengthening. In boundary areas of residential sites (lawn, farmland, flower bed, etc.), dunes constantly receive fertilisers or household waste. In this way, not only does mechanical pollution of the dune occur, but also environmental eutrophication which allows the establishment of *Cirsium* spp., *Urtica* spp. and other plants which are untypical for dunes and undesirable for people.

Waste washed up by the sea also reaches dunes. This is especially relevant along the open Baltic Sea coast, where waste fragments from the beach are blown inland by strong westerly winds (during storms, also washed inland). Mostly, these are products of synthetic polymers (PET bottles and packaging material). Washed up waste visually pollutes the environment; bottles often act as a trap for invertebrate species.

13.1.5.7 Invasive plant species

Over the past 50 years, rapid dune overgrowth with untypical species (synanthropisation) occurs in dunes. It can be explained by sensitive, sparse and undeveloped plant communities in which alien plant species can quickly become established. Natural dune ecosystems are degraded in large areas in Europe and elsewhere in the world by dune strengthening with alien species (Castillo, Moreno-Casasola 1996). Due to these species, areas of natural dune habitats

are rapidly declining, vegetation structure and species composition is changing, rare species and their habitats disappear.

Also on the Latvian coast, especially in villages and towns, coast strengthening works are carried out. In foredunes, *Rosa rugosa*, *Hippophaë rhamnoides*, *Gypsophila paniculata*, *Eleagnus commutata* and other invasive plant species have been planted (Biseniece 2004; Rudzīte 2004). The area occupied by these species is constantly growing. In many places, the local people continue to plant these aggressive plant species in dunes – creating flower beds and decorative plantings over the dunes to the sea or attempting to strengthen the coast against erosion.

13.2 Restoration and Management Objectives for Embryonic Dune and Foredune Habitat Conservation

- Embryonic dune and foredune regeneration on its range is ensured along the Latvian coast.
- Diversity of plant communities and species representing characteristics of the southeastern coast of the Baltic Sea is conserved.
- Area covered with invasive species is decreased and their invasion in primary dunes is stopped.

13.3 Habitat Restoration and Management

Dune management and conservation can only be improved if one goes deep into the detail of ecosystem dynamics, ecology and biology (Packham, Willis 2001). First, it is important to understand the contemporary geological processes of the sea coast, their impact on the coastal dune habitats. Before any habitat restoration and management, the current situation of structures and processes significant for habitats as well as the historical developments and forecasts for different periods of time must be evaluated. Second, the site-specific habitat succession must be understood, using the vegetation structure and composition. Plant communities are among the best ecological indicators, characterising the condition and evolution of coastal habitats (Espejel et al. 2004), and are increasingly used in dune environment and biodiversity monitoring and in management planning.

13.3.1 Non-interference

For the conservation of embryonic dunes and foredunes, it is most important not to interfere with natural processes, because the development of both habitats depends on undisturbed geological process on the coast. Habitat formation and development occurs naturally and spontaneously in the event of favourable environmental conditions. The most important thing is the undisturbed process of erosion and accumulation, and sediment flow. Foredunes and embryonic dunes are the product of coastal sediment accumulation, and their "life cycle" can usually be measured from a few years (embryonic dunes) up to a few decades (foredunes) (Pranzini, Williams 2013). In sections of intensive sediment accumulation, foredune erosion occurs rarely and insignificantly, therefore, while sediment accumulation continues, a new aeolian accumulation zone begins to form, the supply of new sand to the foredune decreases, the "old foredune" stabilises and gradually overgrows in the process of natural succession (Eberhards 2003). On a slope exposed to wind, sand blowing becomes more active, and the embryonic dune grows in size and becomes the "new" foredune. At the same time, movement of other related coastal habitats towards the sea occurs. Such conditions are rare and occur mainly on the coast of the Irbe Strait and south of Liepāja and Ventspils ports. Much more commonly, the dune development cycle includes phases of erosion and subsequent "recovery" phases, during which the windblown sand accumulates in the eroded part of the foredune. Such an alternation of regeneration cycles provides favourable conditions for the development of plant and invertebrate species characteristic for the foredune habitat. Also after severe storms, when embryonic dunes and even foredunes are totally or partially eroded, it is better to ensure self-renewal, without any artificial amplification measures. Under favourable conditions, dunes restore in a few years (Anon. 2014).

While evaluating a specific coastal section, one must take into account that its influencing events can be located several kilometres away and even extend far beyond the borders of Latvia, for example, on the Lithuanian coast. Therefore, for the conservation of primary dunes, preventive measures that often only indirectly affect the habitats under consideration must be considered. These are questions of integrated planning of use of sea coast and aquatorium and of international cooperation in the Baltic Sea region, also including coastal landscape aspects.

Habitat restoration and management must only be carried out in situations where the habitat functioning is threatened by human influence which can reduce the area of habitat, fragment

its distribution range and significantly impair the quality, including populations and habitats of characteristic species. Then disturbances should be compensated and the continuity of natural processes should be restored.

13.3.2 Action after Catastrophic Erosion Episodes

During severe storms, the pre-existing foredune and embryonic dune habitats are significantly disturbed. With extreme erosion episodes, they can be fully washed off for many kilometres of length in total. Storm wave erosion and sand movement from the aeolian accumulation zone downwards is vitally important to start a new cycle of habitat formation and for the successful functioning of coastal habitats, in particular, for embryonic dunes, whose life cycle usually lasts less than 10 years.

Since embryonic dunes and dune habitats are very sensitive to anthropogenic disturbance, habitat resilience thresholds may be exceeded in cases of disturbances caused by erosion and recreation together. Then, natural restoration after the storm may not be possible.

Management, which focuses on the elimination of "emergency" situation consequences, may be in apparent contradiction to the above described non-interference – "best practices" of coastal zone management. Maximum attention should be paid to the restoration of natural integrity (continuity and "naturalness") of coastal relief and vegetation.

13.3.2.1 Fence and mesh systems for dune stabilisation

One of the most widely used methods is the use of fences and meshes. The function of a fence or mesh is to detain windblown sand on both sides of it, because of the drop in wind speed. This method can be used to fill both small (< 5 m^3) and wide blowouts and depressions in cases where mechanical filling is not possible. The most suitable places where this method can be used are blowouts of various sizes in large foredunes.

The main disadvantages of the method are: high cost and complexity; risk of vandalism; temporary negative impact on landscape; and lack of guarantees that the method itself will be entirely successful. Also the period of time that may be necessary to achieve the desired effect is unpredictable and depends on climatic conditions. Since the fence and mesh system is buried in sand, there is a risk that later it will be partly uncovered, possibly endangering vacationers. Fences must be installed after the end of the growing season. When the desired quantity of sand is accumulated, they must be strengthened by plantings (in spring) and/or sand retention material of short-term operation.

Fence or mesh should be manufactured from woven or braided synthetic material with an approximate porosity of 35–45%. Fabric must be attached to galvanised steel wires (vertical distance between the wires – 25–40 cm), which is attached to un-impregnated wooden poles. The distance between the support poles depends on the pole diameter (3–6 m on average). When planning the disposition, one must take into account that the width of the accumulation zone will reach approximately 700% of the mesh height. Furthermore, the denser the mesh, the more sand will accumulate in front of it and less behind. Mesh height should not exceed 1.0–1.5 m, because the burying of higher mesh may take too long. Experience in other countries shows that a better effect can be obtained by sequentially arranging a number of low-mesh systems. When one mesh is "full", a second mesh is mounted above, etc. In order to fill the very large depressions, parallel mesh systems can be used where the distance between them does not exceed 4–5 metres.

Fences made of boards, strips or wicker basketry can be used instead of mesh as a much cheaper and simpler solution. Orientation (vertical / horizontal) of boards or wicker does not matter, but the porosity must be increased to approximately 45–50%. Low fences (0.3–0.5 m high) are widely used for embryonic dune restoration. They are positioned 3–5 m apart from each other, and transverse rows can be installed depending on need. Fences can also be made from twigs or reed. Fresh (alive) willow branches can only be used in situations where the sand blowing is very active because some of willow will grow roots and later develop willow stands, which is not desirable for the protection of open dune habitats (Fig. 13.13).

13.3.2.2 Stabilisation of blowout sides, restored dunes and "shifting" sand

Stabilisation of blowout sides, restored dunes and "shifting" sand is the minimum of activities to avoid greater problems, and to ensure prevention. In places where the filling of blowouts is not possible, but their further development is not permissible, and also where the primary dune ridge is interrupted to accommodate the road or walkway cutting through primary dunes, loose, unstable sand has to be stopped. Stabilisation should also be used in sites where vegetation is exterminated on the dune slope, and erosion has just started, as well as in sites where dune

Fig. 13.13. Low fences for the restoration of primary coastal dunes in Engure, the year 2016. Photo: B. Laime.

Fig. 13.14. Blowout of average size in the frontal side of the foredune, filled with large quantities of willow and birch twigs. Lithuania, the Curonian Spit, 2008 (view from the side of the beach). Photo D. Pupienis.

ridge continuity is restored mechanically through construction machines.

For the highest possible efficiency of stabilisation, it is usually carried out in two stages. Initially, various temporary solutions are used, which are later replaced with permanent ones (vegetation, improved walkways and sites etc.). Temporary sand stabilisation techniques can be used, while the plantations strengthen, and establish sufficient cover:

- twigs, conifer processing residues, mulch, layers of washed out seaweed and pebble (Fig. 13.14);
- coverings of woven or non-woven material (net, geotextile, willow wicker braiding etc.).

The use of twigs, mulch and other local natural materials is the most appropriate in terms of nature conservation, and the costs are the lowest. The main disadvantage of the method is the visual unattractiveness (in most cases) of these materials This type of dune surface coating usually stops the sand blowing very successfully, and also protects newly established plantations against trampling and promotes moderate sand accumulation (Fig. 13.15).

If branches are used, their length should not exceed 0.7–1.0 m, of which approximately 0.2 m need to dug, plugged into or otherwise strengthened in the sand. The total surface of the surface covered with branches in places of intense deflation should exceed 50%. It refers to the front part of the wind exposed site. Covering of the outermost (lee) part of the wind erosion exposed area is not usually necessary. If the width of the deflated area (in the direction of the prevailing wind) exceeds the branch length by more than four times, multiple bands of branches must be established (complete covering is not required). Branches should be located with the top "downwind", with an average slope of 10–25° (depending on the dimensions of the material used). If the branches used are bushy, with leaves or conifer branches, the accumulated amount of sand can be large, and further removal of these branches may be problematic. Dune restoration with branch cover is one of the oldest methods used in Latvia, commonly applied in the beginning and middle of the 20th century, for the strengthening of sandy areas and shifting dunes. Pine branches, *Calluna vulgaris* (it adheres well to the ground) or *Juniperus* spp. were found as the most appropriate materials (Bušs 1960).

The use of woven or non-woven material coating for covering is limited by the relatively high costs. Geotextile and factory made nets are particularly expensive. They are only justified in places with a very high number of visitors. In small areas they can be used very successfully to secure slope surfaces – sides of dune ridge breaks created for trails, or mechanically restored dune slopes (before strengthening vegetation). Method does not ensure the accumulation of sand. Strengthened site acts as a transit area. From an environmental point of view, biodegradable materials are more preferable.

Branch covering, fences, wicker and nets may be combined with dune grass planting (*see Chapter 13.3.4*).

13.3.2.3 Mechanical restoration of foredune ridge

In special cases, the fastest and most effective way to guard against further erosion and prevent damage caused by extreme hydro-meteorological conditions,

Fig. 13.15. Use of dune covering with branches is one of the most cost-efficient methods for dune restoration and coastal sand habitat strengthening. Ķemeri National Park, years 2011 and 2005. Photo K. Lapiņš, B. Laime.

is dune restoration with heavy machines. Dune must be restored before the growing season begins. Not later than one week after the works, comprehensive strengthening of the sand must be performed on the top and frontal part of the dune.

The height and slope of the restored dune fragment must precisely comply with the adjacent "undisturbed" dune.

13.3.3 Establishment of Tourism Infrastructure

Similarly to other protected habitats, in embryonic dunes and foredunes, tourism infrastructure must also be cleverly planned and organised, to maximally redirect people away from the most valuable natural objects. Tourism infrastructure is a tool to purposefully reduce the potentially devastating impact of humans on dune habitats. Tourism infrastructure must not additionally attract visitors and increase anthropogenic load.

Fig. 13.16. Picnic site in an intensively visited territory near Pape lighthouse. Boardwalks are made of recycled plastic. Here, dune restoration by the felling shrubs of invasive plant species is also started, 2015. Photo: I. Mednis.

It is not possible to ensure conditions for undisturbed habitat development in zones of intense recreation. When installing pedestrian trails, waste bins and other objects on dune tops or slopes, the speed of aeolian accumulation of the particular site must be considered. In Latvia, the height of foredunes usually increases by 0.03–0.5 m per year. When choosing a material for the boardwalk, its resistance to environmental influence and to abrasion, human security and aesthetic qualities must be taken into account. Materials must be "environmentally friendly". Timber is the most accessible, and its use and processing capabilities are very broad. Nowadays, for the building of small infrastructure elements (barriers, boardwalks, benches, viewing platforms etc.), recycled plastic is increasingly used. It is relatively expensive, however, it can be used for 15–20 years if properly managed (Fig. 13.16).

When installing pedestrian trails, one must preserve the continuity of the natural dune relief. Materials and technical solutions must be easily adjustable to dune surface changes caused by sand accumulation and erosion. Another solution is trails raised above the earth surface because they do not affect or alter the natural relief formation processes. Also, the orientation of trail centre lines to the prevailing wind and continuous length of the straight trails are of great importance (Fig. 13.17).

The trail at the lower part of the beach is also usually problematic because it can be damaged by storm waves. Nevertheless, the trail must extend across the active part of the foredune, thus preventing trampling of vegetation. In an ideal case, such a trail consists of sections, and its potentially threatened parts can easily be disconnected and removed in autumn, to avoid damage and unnecessary costs.

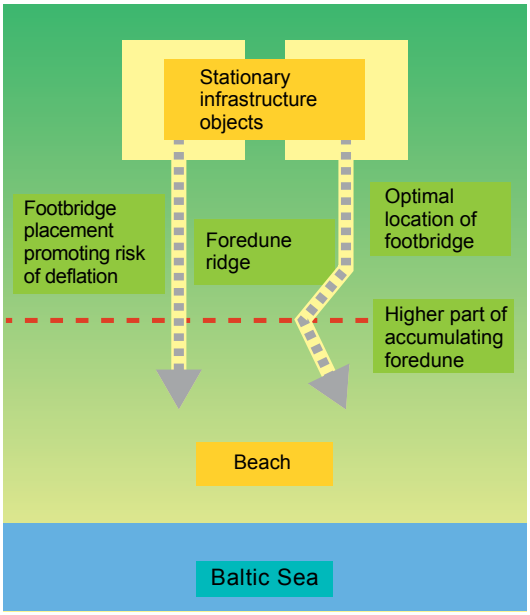


Fig. 13.17. Breaking of the centre line of pedestrian trails, paths or driveways, reducing the risk of deflation development on the frontal part of the dune. Drawing by J. Lapinskis

The trail surface should copy the dune surface but is not possible in the case of a too steep slope. Distance and height ratio of 1:4 is considered the maximum incline for pedestrian trails. On steeper slopes, footsteps or stairs must be installed but this solution is also not optimal because the beach should be open to all groups of people. When planning the infrastructure for people with disabilities, it is important to provide both access roads, parking sites and a passway to the sea.

Trails of chain and board systems. On foredunes with a large visitor load, a system of chains and boards is successfully used (Fig. 13.18, 13.19). The main advantage of such a trail is its flexibility – the trail can be quickly moved or lifted and relieved of accumulated sand. When installing trails on the dune ridge or its sea-facing slope, it is essential to prevent the movement of visitors near the trail, in order to prevent sand movement and deformation of the trail base.

The distance between the trail boards must be chosen with regard to the slope inclination, intensity of aeolian processes and material costs. Trails with very closely arranged boards are more convenient for their users, but they can be burried by sand.

Bridge type trails. From the perspective of nature conservation, ease of management, landscape quality and ease of use, the most appropriate solution is a bridge-type trail which is raised over the dune surface 0.5–1.0 m in height. The main drawback is the high cost and the high expectations of the quality of materials used. Bridge-type trail design must provide the opportunity to modify its height depending on the speed of sand accumulation. Timber is the traditional and most appropriate material (piles, planking and railing). Trails raised above the ground level must be established after the assessment of the number of visitors.

13.3.4 Dune Restoration with Grass Planting

Artificial vegetation restoration is desirable in circumstances when natural embryonic dune and foredune vegetation development process is difficult or even impossible due to natural or anthropogenic factors. The most widely used method is dune grass planting. It accelerates vegetation regeneration, creating habitats for animal species and other plant

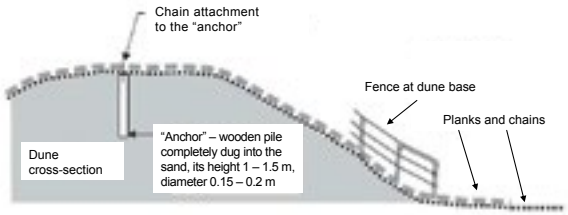


Fig. 13.18. Installation of a chain and board system trail across the dune edge. Drawing by J. Lapinskis.

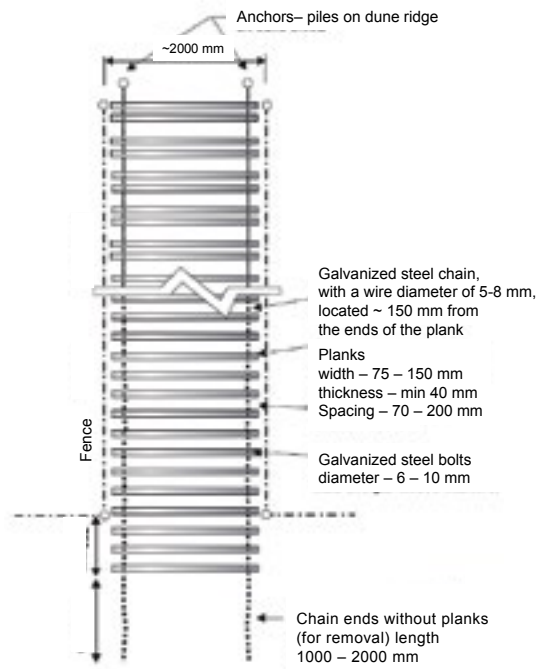


Fig. 13.19. Installation of a chain and board system trail on the frontal part of the dune and edge. Drawing by J. Lapinskis.

Fig. 13.20. Dune sand strengthening with grass planting. Germany, 2010. Photo: K. Vilciņa.

species. The use of native species is a necessary prerequisite. The most effective psammophytic grass species is *Ammophila arenaria* (marram grass). *Leymus arenarius* (especially on sand deficit coasts) and *Carex arenaria* and x *Calammophila baltica* can also be used. When restoring foredunes, the necessary profile can be created by planting gramineous plants of different dispositions and densities, which will determine the amount of sand accumulation.

Planting material should be obtained in the territory which is located as close as possible to the planting site to ensure genetic integrity. Planting material may only be taken in those areas and in such quantities that do not harm the donor population; it must remain viable. Only young, strong plants with a well-developed root system should be taken. To obtain seedlings, plants are cut with a sharp spade, grabbed by the leaves and pulled out of the sand. Planting material should be used as soon as possible, avoiding the drying out of their roots. During transportation, it is recommended to cover them with a damp cloth or film, or put them in plastic bags. To create a planting pit, a spade or special shaft may be used. The recommended planting depth is 0.4 m, spacing – 0.5 m (Fig. 13.20). As mentioned in the literature, in flat sites, furrows can be created with plough. After the placement of seedlings, the furrow is closed again with a plough (Bušs 1960). Distances between the rows depend primarily on relief – the steeper the slope, the closer the rows. *Ammophila arenaria* and *Leymus arenarius* can be planted during all the period of dormancy – from September to April, unless the sand is frozen; preferably in early spring (Bušs 1960; Brook 1979). The planted area is often confined by fencing or other barriers. Fences and barriers must be removed when plants and vegetation are established.

Ammophila arenaria and *Leymus arenarius* can also be reproduced by seeds. For sowing in dunes, it is recommended to establish 8–10cm deep furrows, about 0.5 m from each other. After seed sowing, furrows are closed. To gather seeds of *Ammophila arenaria* and *Leymus arenarius*, grasses must be mown, and ears must be collected by hand, before seed spillage. Then seeds are obtained. It is estimated that 100 m^2 requires two litres of *Ammophila arenaria* seed. A simpler method is to put unthreshed ears in furrows. This technique was widely used in the middle of the 19th century, for example, for the strengthening of the Popes estate sands (Bušs 1960). To promote sand stability, seed germination and the establishment of grasses, the sown area may be temporarily covered with pine branches.

In intensively visited sites, a situation can occur that dune restoration work is being influenced, such as branches are collected and burnt or otherwise disassembled, planted grasses uprooted etc. In such cases, the managed area must be fenced, at least for a time (with poles and net) or delimited with a barrier, at the same time placing informative notices, posters about the management. Once the objective is achieved, fences can be removed and used in other places.

13.3.5 Restoration of Embryonic Dunes and Foredunes with Willow Planting

Willows are expansive plants, therefore their planting for the restoration of embryonic dunes and foredunes is not recommended. **It can only be admissible in exceptional cases** when dune grass planting or a simi-

Fig. 13.21. *Salix daphnoides* row, planted to promote the accumulation of windblown sand. Bigauņciems, summer 2014. Photo J. Lapinskis.

The use of alien plant species is not permissible in dune management and restoration

lar method is not possible. Any planting work must be carried out after the comprehensive evaluation of the situation, taking into account the recommendations of experts of coastal habitats and modern geological processes. Main objectives of willow plantations are: the establishment of barriers, sand accumulation, and facilitating of vegetation natural regeneration.

Willow vegetative propagation by cuttings and poles is widely used. For cuttings, annual or 2–3-year-old sprouts, with cut lateral sprouts cut into about 50 cm long segments, are useful. Cuttings are planted with the heavier end down, around 40–60 cm from each other, with the upper end at the soil surface. Poles are up to 1 m in length, and they are planted into pit holes prepared with a soil auger so that at least 2/3 is buried. In critical situations, a relatively simple technique can be used: approximately 20 cm deep furrows can be established, willow sprouts laid in (first cutting the lateral sprouts and terminal buds), and furrows filled. This should be done in early spring (Bušs 1960). It is not recommended to plant willows in straight rows; slightly winding lanes are more naturally consistent with the coastal landscape.

The most suitable willow species are *Salix daphnoides* and *Salix viminalis*. Planting material must be obtained as close as possible to the managed area (Fig. 13.21).

Willows form a very extensive root system. They can spread rapidly, becoming aggressive, expansive plants, which negatively influence natural processes, characteristic species composition and vegetation structure in embryonic dunes and foredunes.

13.3.6 Removal of Willows and Aggressive Local Herbaceous Plants

In coastal sections where previously planted or self-established stands of willows and expansive herbs, such as *Phragmites australis*, have taken over most of the primary dunes, restoration of the dune vegetation structure is necessary. This problem is particularly acute in places where dunes are gently sloping, often bordering with low beach. For more on vegetation removal, *see Chapter 14*.

13.3.7 Invasive Plant Species Control

For the control of invasive plant species, it is very important to take preventive measures: not to plant invasive alien plant species on the coast. Avoid it for at least a few kilometres in width in the coastal zone.

Invasive plant species restriction must be carried out immediately. It is recommended to use several techniques, combining mechanical, chemical and biological control of these plants. These methods are described in more detail in the chapter on grey dunes. Before the application of these methods, the potential impact on human health and coastal local species must be carefully evaluated.

13.3.8 Management and Use Unfavourable for the Habitat Type

Embryonic dune and foredune habitats are closely related to the conservation and management of the beach and underwater coastal slope. The conditions of these habitats may be influenced by processes many kilometres away. Therefore, it is necessary to analyse each specific situation in a broader context.

The most undesirable management in embryonic dunes and foredunes is too intense recreational load and the establishment of paths/roads cutting through/across the primary dune to ensure the management needs of adjacent territories.

In areas where algae and other beach drift (seaweeds) accumulate in large volumes, the recreational quality of the beach is lowered. Beach drift is often collected and transported to the foredune or embryonic dune zone. **This practice cannot be accepted** because plant residues in foredunes contribute to eutrophication and the introduction of uncharacteristic plant species. Additional risk also arises from municipal waste and other objects in beach drifts.

Establishment of willow plantations can lead to both positive and negative effects on the quality of targeted and adjacent habitats. Willows, as fast-growing plants, suppress typical herbaceous species, create shading, increase the amount of litter and significantly change the vegetation structure. Each specific case must be examined, and, if plantings for dune stabilisation are created, priority must be given to local primary dune herbaceous species (dune grass).

13.3.9 Conservation and Management Conflicts

To avoid conflicts, conservation aims and priorities should be clearly defined for every habitat and territory. The requirements for plant, bird and invertebrate species may differ.

Conflicts, when embryonic dune and foredune management measures create a long-term negative impact on other or adjacent habitats, are not expected. However, in theory, there may be cases where contradictions may arise, if, for example, dune management requires the crossing of a grey dune or dune slack which are very sensitive habitats with rare species. Coastal habitats form a united habitat complex, therefore the requirements of adjacent habitats must also

be taken in account.

Chapter 14. Grey Dune and Open Inland Dune Habitats (B. Laime, J. Lapinskis, D. Tjarve, V. Spuņģis)

2130* *Fixed coastal dunes with herbaceous vegetation (grey dunes)*
2140* *Decalcified fixed dunes with* Empetrum nigrum
2170 *Dunes with* Salix repens *ssp.* argentea (Salicion arenariae)
2330 *Inland dunes with open* Corynephorus *and* Agrostis *grasslands*

14.1 Characteristics of Grey Dunes and Open inland Dunes

14.1.1 Brief Description

The chapter describes the habitat group which includes relatively stable secondary open dunes: Coastal Lowland dunes where a large proportion of vegetation consists of lichens, mosses and vascular plants or dwarf shrubs, or low willows, as well as inland dunes with sparse vegetation (Table 14.1) (Laime 2013e,

Table 14.1 Habitats of grey dunes and open inland dunes

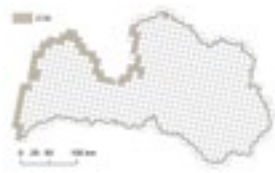
Main features of the secondary open dune habitats (Laime 2013e, 2013f; Rove 2013d, 2013h)	Habitat area (ha and % of total Latvian terrestrial area) and distribution in Latvia (Anon. 2013c)
2130* *Fixed coastal dunes with herbaceous vegetation (grey dunes)*	
Dominated by perennial and annual herbs, mosses, lichens, here are at least three species characteristic for the habitat.	1171 ha or 0,018 %
2140* *Decalcified fixed dunes with* Empetrum nigrum	
Cover of dwarf shrubs at least 25%, proportion of trees and shrubs does not exceed 70%, cover of low willows does not exceed 25%.	66 ha or 0,001 %
2170 *Dunes with* Salix repens *ssp.* argentea (Salicion arenariae)	
Stands of low willows at least 25% of the vegetation cover, cover of Pinus sylvestris does not exceed 50%.	66 ha or 0,001 %
2330 *Inland dunes with open* Corynephorus *and* Agrostis *grasslands*	
An inland dune dominated by pioneer plant communities, abundant annual plants, cover of trees and woody shrubs does not exceed 70%.	427 ha or 0,007%

Fig. 14.1. Habitat type 2330 *Inland dunes with open* Corynephorus *and* Agrostis grasslands, valley of the River Sventāja at Muižkalns. Photo: B. Laime.

Fig. 14.2. Habitat type 2170 *Dunes with* Salix repens *ssp. argentea* (Salicion arenariae), south from Užava. Photo: B. Laime.

Fig. 14.3. Habitat type 2140* *Decalcified fixed dunes with* Empetrum nigrum, north of the River Užava. Ground vegetation dominated by *Arctostaphylos uva-ursi*. Photo: B. Laime.

Fig. 14.4. Habitat type 2130* *Fixed coastal dunes with herbaceous vegetation (grey dunes)*, Plieņciems. Photo: B. Laime.

2013f; Rove 2013d, 2013h). These are xerophytic plant communities, in a coastal and inland dune landscape forming a mosaic of patches of vegetation of differing height, density and species composition as well as patches of bare sand.

Habitat types 2130* *Fixed coastal dunes with herbaceous vegetation (grey dunes)*, 2140* *Decalcified fixed dunes with* Empetrum nigrum and 2170 *Dunes with* Salix repens *ssp.* argentea (Salicion arenariae) further referred to as grey dunes; habitat type 2330 *Inland dunes with open* Corynephorus *and* Agrostis *grasslands* further referred to as open inland dunes.

All grey dune and open inland dune habitats are rare in Latvia. Habitat type 2330 *Inland dunes with open* Corynephorus *and* Agrostis *grasslands* (Fig. 14.1) is located outside the Coastal Lowland and is related to inland sand habitats created by glacial meltwater streams. This habitat type is very rare and distributed in the River Sventāja valley (Rove 2013h). In small areas, open inland dunes may also remain in valleys of the River Daugava and the River Gauja, but their prevalence and the area still needs to be clarified.

The distribution of grey dunes is associated with the Coastal Lowland geobotanical region. Grey dune habitats can be found both at the sea coast and also further from the sea, such as the Ādaži military training area and its surroundings (Tab.14.1). Habitat type 2170 *Dunes with* Salix repens *ssp.* argentea (Salicion arenariae) (Fig. 14.2), is most rarely found, 2140* *Fixed coastal dunes with herbaceous vegetation (grey dunes)* is also rare (Fig. 14.3). Largest areas of both of these habitats are related to the sea coast between Užava and Ventspils (Laime 2013f; Rove 2013d). The most common is habitat 2130* *Fixed coastal dunes with herbaceous vegetation (grey dunes)* (Fig. 14.4), which is distributed on longer and wider coastal sections of the

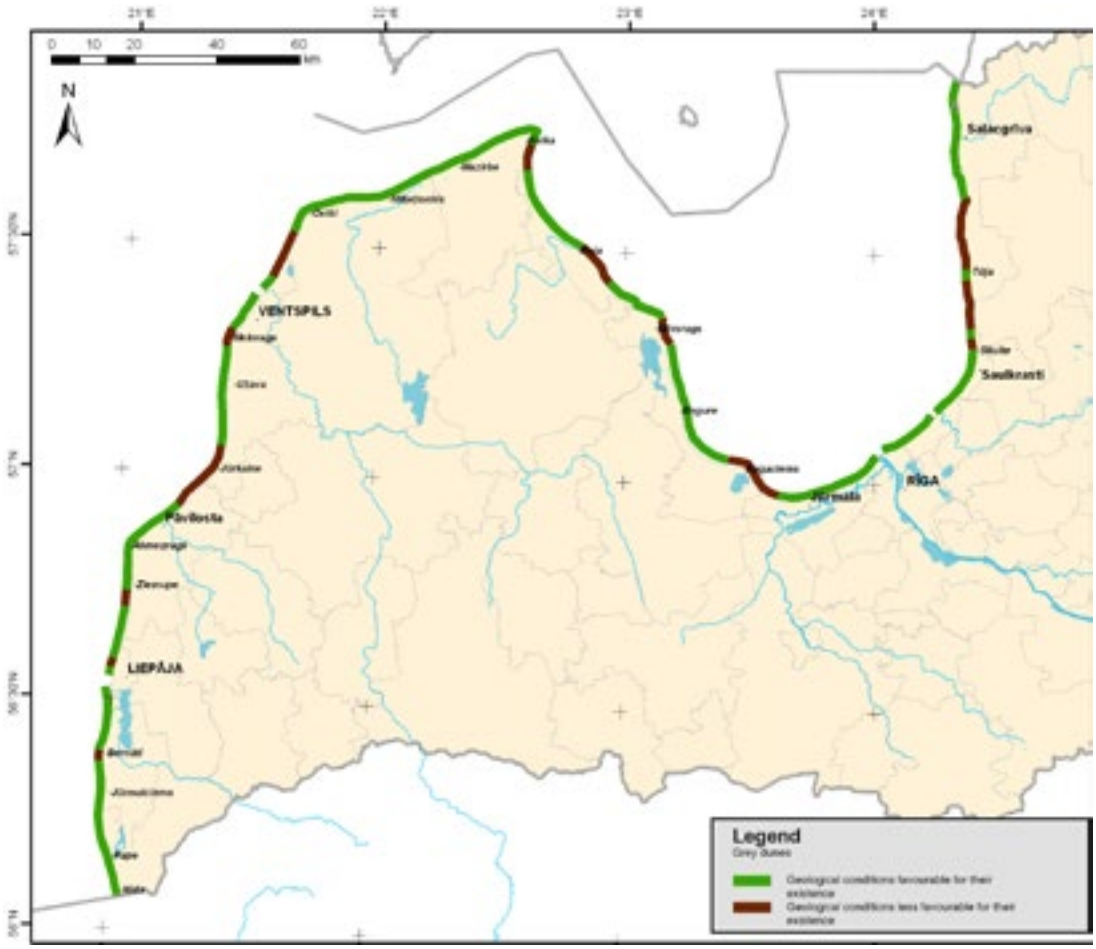


Fig. 14.5. Coastal sections which are more and less favourable for grey dune development in Latvia. Map prepared by J. Lapinskis.

open Baltic Sea and the Irbe Strait coast, and in shorter sections – on the coast of the Gulf of Riga. The largest areas of this habitat are found on the sea coast at Pape, also on the Ziemupe–Pāvilosta, Užava–Vārve, Ovīši–Lielirbe coastal sections. The most significant grey dune areas on the Gulf of Riga coast are located at Daugavgrivas Island, in Lilaste, Ģipka–Žocene and Upesgrīva–Mērsrags.

14.1.2 Important Processes and Structures

Grey dunes in Latvia are mainly located in areas where sediment accumulation in the coastal zone dominates or where it was dominating in the relatively recent past (period of the Littorina Sea stage and after it). Grey dune habitats can also develop on coastal sections dominated by erosion, where earlier accumulative formations are eroded, and sand is blown inland by marine wind (Fig. 14.5). However, most of the grey dunes are considered as secondary dunes – a further stage of primary dune (foredune) development (Eberhards 2003). Compared to foredunes and embryonic dunes, the relief of grey dunes transforms very slowly. Sand blowing only occurs in certain small patches, as well as during storms, when sand is blown from the foredune or from the sea cliff slope. It is assumed that the transition between the belts of primary dunes and grey dunes marks the boundary of the modern coastal active zone (Lapinskis 2010).

Since grey dunes are not located in the actively changing coastal zone, they can naturally exist longer than habitats that are closer to the zone of sea wave activity. Grey dunes which are located further from the sea can regenerate under constant or intermittent anthropogenic influence, such as military training. Open inland dunes can also remain for a long time (Fig. 14.6) when there is poor, neutral or acidic sandy soil with high water permeability (Rove 2013h). However, with the gradual decrease of disturbances created by nature or humans, secondary open dune

Fig. 14.6. Vegetation of inland dune with *Corynephorus canescens* in the River Sventāja valley. Multiple bare sand patches contribute to favourable growing conditions of drought tolerant plant and lichen species. Photo: B. Laime.

Fig. 14.7. Grey dune at the mouth of the River Užava. Habitat is formed on the dynamically neutral coastal section, behind the low, regressing escarpment in older foredune ridge. Its long-term preservation is promoted by natural and anthropogenic disturbances – strong marine winds, large volumes of sand on the foreshore and nearshore, soil surface layer formed by coarse-grained sediments, moderate recreational load. Photo: J. Lapinskis.

Fig. 14.8. Grey dune at Akmeņrags. Habitat is formed on the erosion-dominated coastal section, behind the low escarpment. Its long-term preservation is promoted by coastal erosion (sand blowing from the beach), which also decreases the habitat area (sea encroaches about 0.5 m per year). Photo: J. Lapinskis.

Fig. 14.9. Narrow grey dune belt on the accumulative backshore terrace. Habitat is formed on the coastal area where very active coastal wash-out occurred during the severe storm of the year 1967. After it, the coast regenerated, and now the habitat is delimited from the sea by the embryonic dune. Photo: J. Lapinskis.

habitats convert to forest or heath in the way of ecological succession. Secondary open dune habitats, which are located in areas with a strong influence of prevailing wind and a low groundwater table like in Užava, exist much longer (Fig. 14.7). The functioning of secondary open dunes is significantly influenced by dune relief, micro-relief and compass direction. On leeward slopes, growing conditions are often calmer, but plant survival is complicated due to drought, lack of nutrients, and also high air and soil temperatures during the summer. On steeper slopes, habitats are affected by water erosion, which hinders vegetation development and ensures the possibility for pioneer species to remain for a longer time (Fig. 14.8, 14.9). The burning of vegetation is also a promoting factor. It is associated mostly with forest edges, edges to dwarf shrub stands, as well as the vicinity of roads and trails. Such fires are often caused by people.

14.1.3 Natural Succession

Grey dune and open inland dune begins to develop when there is moderate sand blowing or erosion, and mosses and lichens, as well as land grasses are

Fig. 14.10. Coast of episodic washout, in Užava, with dynamic grey dune. Photo: B. Laime.

Fig. 14.11. Grey dune in the Ādaži military training area is permanently or periodically disturbed by vehicle use or otherwise anthropogenically influenced. These disturbances hinder the dune overgrowing with trees. Photo: A. Priede.

Fig. 14.12. Overgrowing with Scots pine in grey dunes north of Užava started mainly in the 1990s when military polygons ceased to function. Photo: B. Laime.

Fig. 14.13. Removed groundcover (in the foreground) shows that depth of the moss layer is up to 15 centimetres. This hinders the self-regeneration of both open secondary dunes and pine forest. Photo: B. Laime.

establishing. It usually occurs with foredune or embryonic dune stabilisation but grey dune or open inland dune can also develop after the disappearance of vegetation of the forest, grassland or other dune habitat. Although wider grey dunes are associated with shores of marked accumulation, they can also be observed above the washout coasts, as well as in anthropogenically affected areas (Fig. 14.10, 14.11).

The succession of grey dunes may be different. Most often, it starts with a pioneer community. In Latvia, it most often starts with the *Carex arenaria* plant community. This species often already establishes on an old foredune or even an embryonic dune. At the same time, moss species *Brachythecium albicans*, *Tortula ruralis*, *Ceratodon purpureus*, sometimes also *Racomitrium canescens* establish. *Corynephorus canescens* community in Latvia refers mainly to secondary succession (Laime 2010). This species can quickly become established if patches of bare sand develop. It is very resistant to extreme environmental conditions (prolonged drought, high temperature of soil) (Pott 1995; Ketner-Oostra 2001; Blunt 2006). In the initial stage, succession with *Corynephorus canescens* is also characteristic for open inland dunes and dunes in the Coastal Lowland where vegetation is exterminated in large areas, and starts to grow again.

In further succession, the plant community of *Festuca sabulosa* develops which is common on the Baltic Sea coast from Denmark to the south of Finland (Dolnik 2003; Dengler 2004; Boch, Dengler 2006; Löbel, Dengler 2008). This community is very diverse in coastal dunes in Latvia (Laime 2010). Studies on plant communities in various complexes of ecosystems show that there are several vegetation succes-

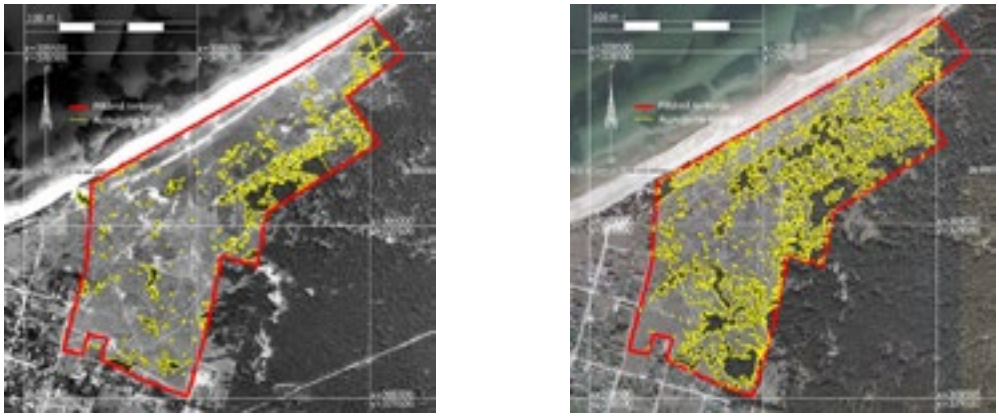


Fig. 14.14. Overgrowing with Scots pine in "Pāvilostas pelēkā kāpa" Nature Reserve is estimated using orthophoto maps of 1995 and 2014 (© Latvian Geospatial Information Agency, kartes.geo.lu.lv). During ecological succession, grey dune turn in to forest. Map prepared by I. Vanaga.

sion types on the Latvian coast associated with the sea coast's historical development, coastal geomorphology, modern coastal processes, plant species distribution, dune management and other factors. The most widely distributed succession type is characterised by a relatively poor plant species composition and uniform vegetation structure. On accumulation shores with periodic wash-out and active sand blow, such as in Daugavgrīva, the community of *Carex arenaria* often dominates in succession.

In very dry conditions with sand deficit (moderate overblowing, partial washout), succession where the grey dune after the pioneer community is represented by a plant community with *Koeleria glauca*, *Astragalus arenarius*, *Alyssum gmelinii* and other xerophytic species, dominates. Often, it continues to vegetation with boreal dwarf shrubs (*Empetrum nigrum*, *Arctostaphylos uva-ursi*) or low willows (*Salix repens*) (Laime 2010).

Disturbances, including those caused by dune management and military training, have been a key factor in the development and continuation of grey dunes and open inland dunes, especially those with *Corynephorus canescens*. Vegetation of these plant communities is found mostly in relatively wide open dunes in coastal villages and in their vicinity, as well as in populated areas outside of the Coastal Lowland where dunes have been grazed and mown for a long time, and succession towards dune grasslands is characteristic. In some areas, even features of xeric moderately fertile and xeric calcareous sand grassland are found.

Coastal succession develops in the following order: habitat type 2130* *Fixed coastal dunes with herbaceous vegetation (grey dunes)*, 2140* *Decalcified fixed dunes with* Empetrum nigrum, and *2170 Dunes with* Salix repens *ssp*. argentea (Salicion arenariae). As habitats with dwarf shrubs and *Salix repen*s are rather rare in Latvia, succession in secondary open dunes mostly starts with vegetation of mosses, lichens and herbs. Overgrowing with trees, it converts to coniferous forest (Fig. 14.12, 14.13, 14.14). The exception is the Ādaži military training area where succession develops mostly in the heath direction.

14.1.4 Indications of Favourable Conservation Status

Grey dunes are a component of a dynamic and changing coastal landscape. Compared to foredunes, wind induced sand movement and reshaping intensity in grey dunes is lower, moderate, but strong sand blowing occurs only episodically. In such circumstances, soil formation starts (humus accumulates, soil podsolisation starts). For the existence of grey dunes, there must be a balance between sand blowing versus dune stabilising (formation of vegetation and soil) (Provoost et al. 2004). Moderate sand overblowing is also important for open inland dunes. It provides sparse vegetation with a high proportion of annual plants.

Wide continuous secondary dune areas with little or no trees and shrubs, with mosaic vegetation structure and patches of bare sand without plants are biologically most valuable (Fig. 14.17). Depending on the progress and stage of succession, there can be stands with low herbs, mosses and lichens, or the dune can be overgrown with dwarf shrubs, or low willow stands can be developed in many places. A fully-functioning grey dune and open inland dune is not dominated by vegetation with a tall and dense sward composed of *Calamagrostis epigeios* or other expansive species,

Fig. 14.15. Pine trees with large crowns and ground-level branches form special microhabitats with lee, more humid and shaded microclimate. Photo: B. Laime.

Fig. 14.16. By moving due to the wind, low tree branches create bare sand patches which are important elements for dune regeneration and for the assurance of the presence of the early successional stage. Photo: B. Laime.

there are no invasive species, and moss species typical for forest do not dominate.

Solitary growing trees and shrubs are of functional importance because specific microhabitats are formed around them, important for invertebrate species development. This applies mostly to slow-growing Scots pines with wide crowns and low lying and creepy ground-level branches (Fig. 14.15, 14.16). Such overgrowth with woody species can be viewed as an integral, functional part of secondary dunes and not as an expansive phase of dune overgrowth. For such landscape development, traditional management methods (grazing, mowing, territory use for repair of fishing nets and boats etc.) have also been of great importance.

The most common species in grey dunes and open inland dunes in Latvia are: *Festuca sabulosa, Carex arenaria, Hieracium umbellatum, Artemisia campestris, Koeleria glauca, Thymus serpyllum*, mosses *Polytrichum juniperinum, P. piliferum, Brachythecium albicans, Tortula ruralis, Racomitrium canescens, Ceratodon purpureus*; lichens *Cetraria* spp. *and Cladonia* spp. For pioneer communities, sparse vegetation with *Corynephorus canescens, Jasione montana, Sedum acre* and *Erophila verna* is characteristic. *Corynephorus canescens* is one of the main indicators denoting the self-regeneration of a grey dune. As individuals and in groups, this species can also be represented in further stages of vegetation development. Although *Corynephorus canescens* is a rare species in Latvia and it is one of its most distant north-eastern distribution localities, it is possible that it could occupy larger areas if more effective management techniques were used. In very dry places, common species are *Epipactis atrorubens* and *Astragalus arenarius* (Laime, Tjarve 2009). In open inland dunes, common species are also *Agrostis tenuis* and *Lerchenfeldia flexuosa*. Under favourable conditions, they do not form monodominant stands, and tend to have a small coverage.

Characteristic species for grey dunes with dwarf shrubs are: *Arctostaphylos uva-ursi, Empetrum nigrum, Calluna vulgaris* and *Vaccinium vitis-idaea*. To be classified as a grey dune with creeping willow, it must contain any of the low willow species in sufficient quantity (*Salix repens, S. rosmarinifolia*).

Insect species indicating favourable conditions for grey dune development are: *Myrmeleotettix maculatus, Sciocoris cursitans, Opatrum sabulosum, Melanimon tibiale, Gronops inaequalis, Barynotus obscurus*. During all the growing season, flowering vascular plants follow each other, providing nectar both for dune inhabitants and for many inland insect species. In the second half of summer, *Hipparchia semele* and other butterfly species are characteristic for grey dunes.

Grey dunes and open inland dunes represent biologically very diverse dune succession stages, characterised by the high diversity of species composition and plant communities. These dunes are the main habitat for: plant species *Dianthus arenarius s. l., Alyssum gmelinii, Pulsatilla pratensis, Eryngium maritimum, Agrostis vinealis, Teesdalia nudicaulis*, insects *Psophus stridulus (Fig. 14.18), Oedipoda coerulescens, Maculinea arion (Fig. 14.19), Bembix rostrata (Fig. 4.20)*, toad *Bufo calamita*, birds *Anthus campestris, Lullula arborea, mushrooms Geastrum schmidelii, Tulostoma brumale* and other rare species (Fig. 14.17, 14.21).

14.1.5 Pressures and Threats

14.1.5.1 Intervention in coastal geological processes

Although grey dune habitats are located outside the

Flowering plant species characteristic for grey dunes and open inland dunes. Photo: B. Laime

Jasione montana

Sedum acre

Epipactis atrorubens

Alyssum gmelinii

Carex arenaria

Corynephorus canescens

Erophila verna

Arctostaphylos uva-ursi

Thymus serpyllum

Pulsatilla pratensis

active coastal zone, their quality can be directly negatively influenced by the installation of various passive anti-erosion measures (seawalls, stone piles, willow plantations, etc.). If the probability of erosion in the foredune or cliff is eliminated, sediment exchange between the different parts of the coastal slope is also arrested, sand blowing in the grey dune zone does not occur anymore, and afforestation can accelerate. Willow plantations contribute to the eutrophication of the dune zone and reduce another desirable disturbance type – moderate trampling. Establishment of coastal anti-erosion structures also negatively affects the stability of grey dunes on adjacent coastal sections – coastal erosion intensifies there, and the number of visitors may increase (Pranzini, Williams 2013).

14.1.5.2 Cessation or suspension of traditional management

Grey dune formation and long-term preservation is determined in many sites by traditional management of coastal areas (grazing, mowing, sea weed drying, fishing net and boat reparation, etc.) (Eberhards 2004; Stūre 2009). With lifestyles changes and subsequent land use changes, the influence of these factors on grey dunes and open inland dunes has been substantially reduced. Consequences – overgrowth of grey dunes with trees and shrubs, formation of a dead grass layer, dominance of invasive and expansive plants, eutrophication, vegetation diversity decrease at a habitat and landscape level (Kondratovičs 2014) (Fig. 14.22, 14.23, 14.24, 14.25).

14.1.5.3 Excessive mowing

With the change in interests, needs and resources, as well as the understanding of environmental processes, landowners are often more and more engaged in excessive landscaping. With frequent and low mowing, flowering plants cannot complete their flowering cycle and ripen seeds. Only a part of the dune plants is able to survive. Habitats for insect and bird species disappear. Thus, in terms of structure and species composition, the very diverse grey dune vegetation, turns into a uniform "dune lawn".

14.1.5.4 Coastal erosion

Grey dune habitats are threatened by the intensification of coastal erosion in coastal sections where it has previously been less expressed. However, undisturbed coastal processes, which also include erosion, are the most important prerequisite for the long persistence, regeneration and formation of coastal habitats, including grey dunes. Only in a small part of the coast, such as Šķēde, is coastal erosion considered to be a threat to grey dune existence (Fig. 14.26). According to the coastal retreat forecast the worst case scenario for the period up to 2060, prepared in 2010 (KALME 2010) (Fig. 14.27), expects erosion intensity which threatens grey dunes on around 30 km total length of the coastline, including the northern part of Liepāja, Kolka, and around the mouth of the River Gauja.

14.1.5.5 Land use change

Urbanisation, settlement expansion, road construction, land transformation, coastal protection measures and other activities directly influence the secondary open dunes, reducing their area. In many places, habitat fragmentation occurs that causes rapid degradation and overgrowth of natural areas. Habitat of a small area is often no longer suitable for habitat-related bird species. By creating artificial barriers, species dispersal capacity decreases, particularly plant and invertebrate species for which dispersal

Fig. 14.17. *Ammophila sabulosa* caves indicate the favourable condition of inland dune sand habitat. Photo: V. Spuņģis, B. Laime.

Fig. 14.18. *Psophus stridulus*. Photo: V. Spuņģis.

Fig. 14.19. *Maculinea arion*. Photo: V. Spuņģis.

Fig. 14.20. *Bembix rostrata*. Photo: V. Spuņģis.

Fig. 14.21. *Peziza ammophila* (right) and *Tulostoma* spp. are found on the foredune – grey dune belt. Photo: E. Vimba.

occurs slowly and which are unable to cross areas without suitable habitat conditions.

Grey dunes are increasingly overgrowing with trees and shrubs due to excessive afforestation of open coastal areas and the lack of control of these plantations (Fig. 14.28). In afforested dunes, insolation on the groundcover level decreases, the microclimate gets colder and wetter, a thick litter layer forms, the soil is enriched. Consequently, grey dune species and their habitats disappear.

14.1.5.6 Excessive visitor load

Nowadays, the number and subsequent influence of vacationers and tourists is rising. In many places, grey dune vegetation is degraded, species number decreases. Rare, protected species predominantly suffer, their localities decrease and abundance and vitality in a locality decreases significantly. Under the influence of recreation and tourism, the dune micro-relief is changed, which is an important structure for the functioning of grey dune habitats. It is mainly caused by excessive trampling and vehicle use. Grey dune habitats are also adversely affected by the fact that coastal tourism and recreation development is concentrated mainly in protected nature areas, including nature reserves and reserve zones which are generally designated to protect endangered species and habitats. In these areas, the construction of main tourism infrastructure objects also occurs (Fig. 14.29).

14.1.5.7 Waste

Dunes, formerly used as military training areas or where there have been buildings, or which were located in closed (inaccessible by civilians) coastal areas, are still contaminated with cables, ruins, building debris etc. Nowadays, similar pollution is possible in the Ādaži military training area.

Dunes in and around the populated areas are pol-

Fig. 14.22. *Festuca sabulosa*, forming a dense, monodominant vegetation, promotes moisture accumulation and humus formation. Photo: B. Laime.

Fig. 14.23. After cessation of grazing in low, flat areas, up to 70-90 cm tall vegetation of *Calamagrostis epigeios* develops. *Leymus arenarius* often has a large proportion in this plant community. Photo: B. Laime.

Fig. 14.24. With the decrease of sand blowing, in some areas a thick layer of dead grass is formed predominantly composed of *Ammophila arenaria*. Photo: B. Laime.

Fig. 14.25. Under the dead grass layer, a favourable environment develops for the expansive moss species, for example, *Hylocomium splendens* and *Pleurozium schreberi*, which outcompete the dune plants. Photo: B. Laime.

Fig. 14.26. Section of intense coastal erosion in Šķēde. Grey dune habitat behind the retreating escarpment is narrowing by 0.5–1.0 m per year. Photo: J. Lapinskis.

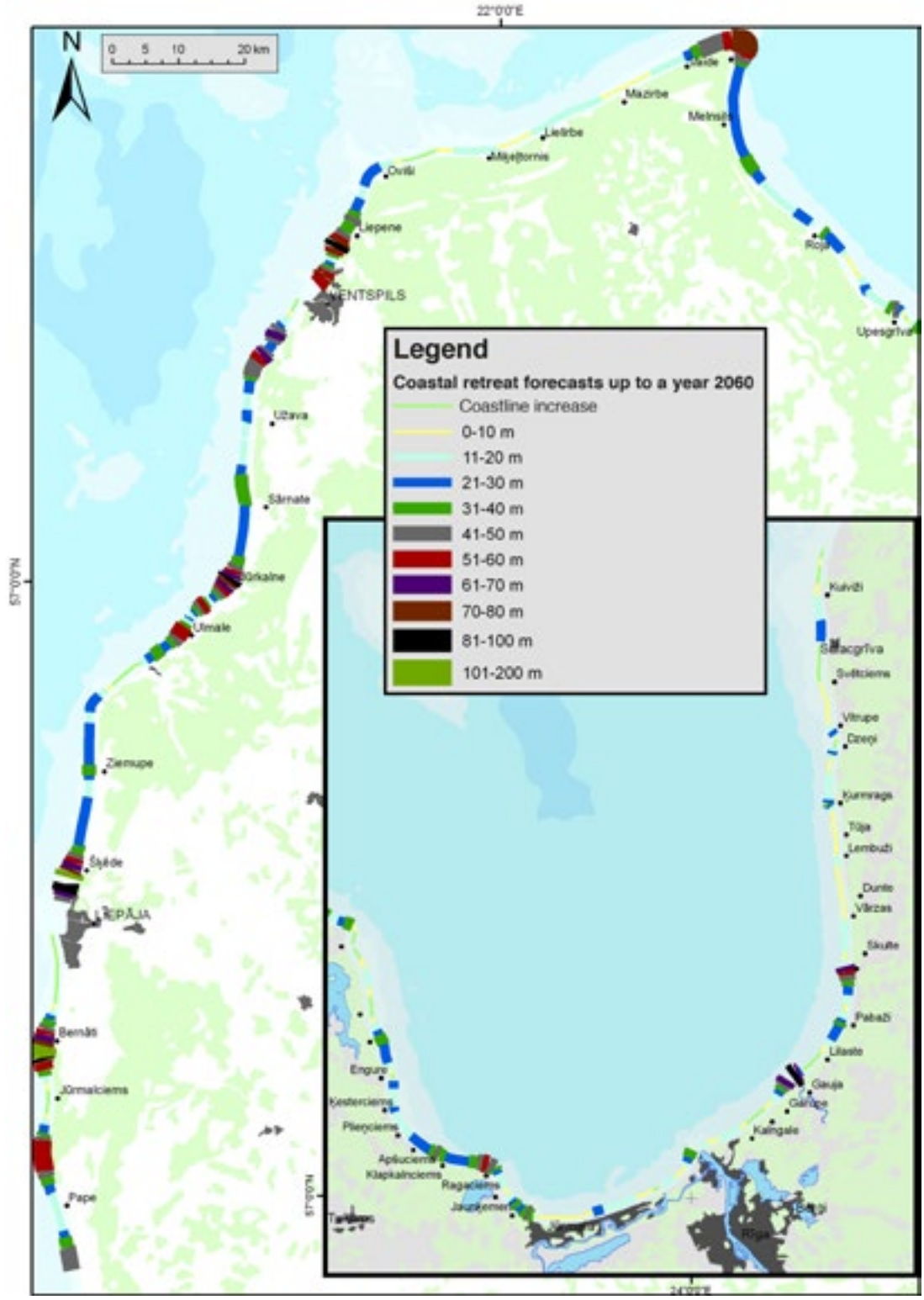


Fig. 14.27. Coastline retreat forecast worst case scenario for the year 2060 (data source: KALME 2010).

Fig. 14.28. In the middle and end of the 20th century, by continuing the open dune afforestation, large areas of grey dunes were planted with forest. Today, many of these plantations form a dense forest stand and can be considered wooded dunes. Photo: B. Laime.

Fig. 14.29. Constant recreational load on Saulkrasti coast does not allow for primary and grey dunes to regenerate. In such areas, at least some sections should be temporarily isolated from visitors. Photo: B. Laime.

luted with municipal waste. In grey dunes, which are located close to the sea, objects washed up from the sea and blown along the beach periodically accumulate. Mostly these are plastic products such as bottles and bags. All of these items negatively affect habitat structure and functions.

14.1.5.8 Eutrophication

Compared to other European countries, there are relatively low levels of nitrogen and phosphorus deposition in grey dune soil in Latvia. However, the accumulation of these compounds and environmental eutrophication can have a very negative impact on dune habitat and species diversity (Remke 2009).

Environmental eutrophication is encouraged by the fact that there are not toilets in many parts of the coast.

14.1.5.9 Invasive plant species

The influence of invasive plant species is one of the most topical problems throughout Europe, and also on the Latvian coast and open inland dunes. Coastal sections polluted most with invasive species are located close to the Lithuanian border (Nida–Priedienгals), between Medze and Ziemupe, around Ventspils, between Jūrmala and Rīga, as well as in the Saulkrasti surrounding (Fig. 14.30, 14.33). These species form monodominant stands, completely or partially destroying the vegetation structure characteristic for grey dunes, changing soil and microclimate conditions, as well as exterminating species' habitats and the most sensitive species.

The most aggressive invasive plant species at the sea coast are: *Rosa rugosa*, *Amelanchier spicata*, *Solidago canadensis*, *Hippophaë rhamnoides*, *Gypsophila paniculata and Eleagnus commutata* (Anon. 2002; Biseniece 2004; Rudzīte 2004; Mizga 2009) (Fig. 14.31, 14.34, 14.35).

In the future, dune habitats can be seriously threatened by moss species *Campylopus introflexus* (Priede, Mežaka 2016). This pioneer species establishes on bare peat of drained bogs after peat extraction and burning, also on fence stakes, stumps, on soil near trails, and in dune habitats (Klinck 2009) (Fig. 14.32).

Part of the grey dunes in the 19th and 20th century were planted with alien tree species like *Pinus mugo*, *P. banksiana* and *P. nigra* (Bušs 1960). In many sites these species form a dense forest stand, and the topsoil is covered by a thick litter layer. In places where plantations are younger and the sea influence is stronger, patches of grey dunes have survived among the pine groups. Species of non-native *Populus* spp., *Robinia* spp., *Quercus* spp. and other tree and shrub species were also planted in dunes. As a large part of grey dunes has developed and been long-preserved in villages and towns, garden escapees such as lilac and apple trees are often observed in the vegetation.

The planting of alien species in dunes is increasing, both creating barriers against sea winds and waves, and introducing ornamental herbaceous and woody plants. The seashore is like an open corridor, where plenty of plant parts are washed out and blown, and so they are introduced to other places. The area occupied by invasive species is increasing, creating a more and more negative influence on natural dune habitats and species.

14.2 Restoration and Management Objectives for Grey Dunes and Open Inland Dune Habitats

- The self regeneration of grey dune and open inland dune habitats is ensured in Latvia, preserving these dunes in all stages of their development.
- Sufficiently large continuous areas of grey dunes with important habitats for birds are ensured.
- Cover of invasive plant species is reduced; their dispersal is limited in grey dunes and open inland dunes.
- Habitats for characteristic plant, lichen and invertebrate species are ensured in grey dunes and open inland dunes.

14.3 Habitat Restoration and Management

14.3.1 Evaluation before Habitat Restoration and Management

Part of the grey dunes and open inland dunes belong to habitats that have persisted for a long time due to their specific management. At the same time, there are also grey dunes whose existence primarily depends on modern sea coastal processes and where optimal conditions have been maintained without human intervention for a long time. However, if disturbances in habitat development are caused by excessive recreation load, intervention is necessary. An adverse influence can be decreased by the prevention of undesirable disturbances. It is topical, for example, in Vecāķi, Daugavgrīva, Saulkrasti.

Grey dunes and open inland dunes are part of the landscape. Therefore, before restoration and management one must assess not only the current situation and pressures of these dunes and surrounding habitats, but also look into the history of use of a particular site and even the wider territory. The earlier use and protection of these dunes must be clarified. The choice of methods depends on the objective and the resources.

When evaluating the conservation status of grey dunes and open inland dunes and deciding on further management needs, it is recommended to use the habitat characteristics (see Indications for the evaluation of grey dune and open inland dune quality

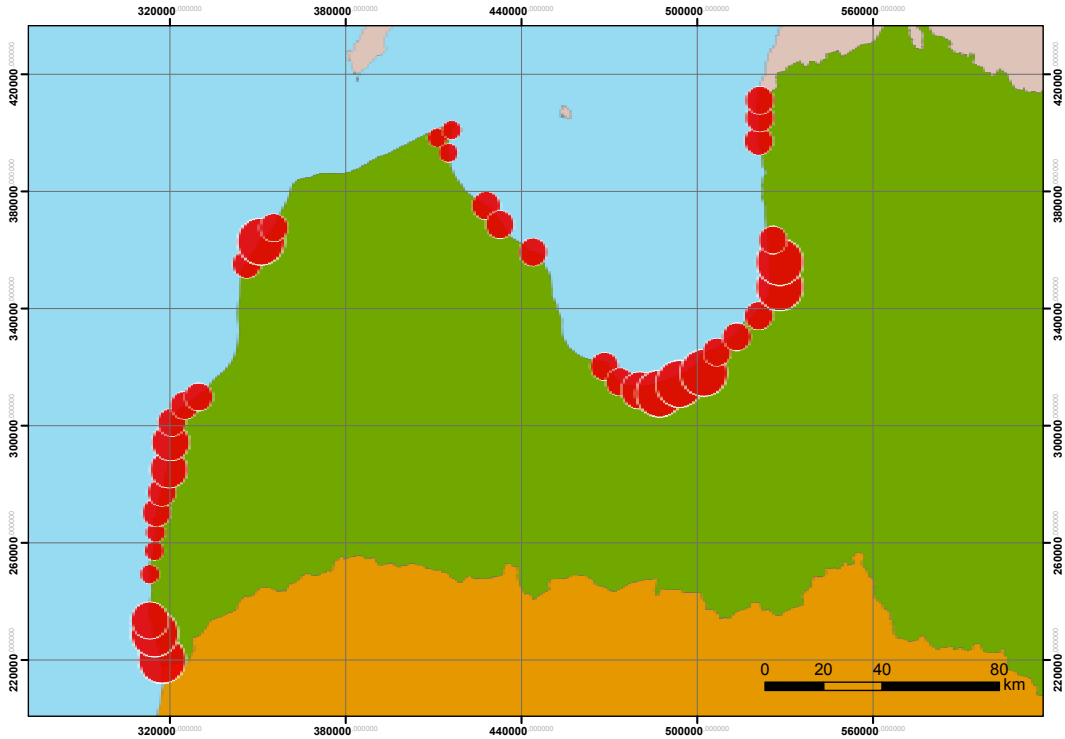


Fig. 14.30. The main sections of invasive species distribution along the Latvian coast. Map prepared by P. Rozenbaks (after Anon. 2002).

Rosa rugosa

Amelanchier spicata

Hippophaë rhamnoides

Solidago canadensis

Fig. 14.31. The most common invasive plant species along the coast. Photo: B. Laime.

assessment, Annex 3), *see Chapter 6*.

14.3.2 Non-interference

Non-interference in natural processes is recommended for those grey dune areas where sand blowing and dune stabilisation are in balance. It is characteristic mainly for coastal sections where grey dunes are exposed to strong marine winds, in some places also to wave influence during storms, which receive sunlight for most of the day, and are xeric. In such dunes, trees and shrubs are few or absent, vegetation is dominated by a mosaic structure and characteristic species, rare and protected species are abundant. Non-intervention is more attributable to grey dune belts bordering the embryonic dunes, foredunes or sea cliffs. Management may differ further in the inland direction where grey dunes are surrounded by forests.

14.3.3 Removal of Tree and Shrub Cover

Overgrowing with trees and shrubs is the main threat to grey dunes and open inland dunes. In Latvia, all habitats of this dune group mainly overgrow with *Pinus sylvestris* and *Salix* spp., in some places also with *Betula pendula* and *Populus tremula*. Scots pine removal is one of the priorities of secondary open dune restoration and management. So far, more experience in Latvia has been accumulated on grey dune management. So below, emphasis is given to activities in grey dunes, though, these also apply on open inland dunes.

In the target area, almost all trees must be cut, leaving only a few, such as 5–8 trees per hectare. Sometimes, all trees must be removed. To decide this, the target area and adjacent areas must be carefully assessed, taking into account the shape of the tree crowns, ecology, age and other characteristics. Slowly growing *Pinus sylvestris* with wide, flat crowns and well-developed ground-level branches are ecologically important (Fig. 14.15). Trees that are chosen to be left can be solitary, dispersed, in small groups or rows. Leaving long, continuous tree rows on the sea side should be avoided because trees detain the wind far too much, hinder sand blowing and other functionally significant processes. Leaving of individual trees is important for the invertebrate habitats. Felled trees and branches must be collected and transported away from the target area, or burnt in places where the humus layer is dense (Fig. 14.36). The best time for tree felling is in August and September, or during the winter, when the impact on birds is the lowest. If there are broken off, uprooted or felled trees of large dimensions, they should be left as suitable habitats for insects (Fig. 14.37).

Exceptions are open dunes for which the integral and functional part are *Pinus sylvestris* growing in

solitary or in groups. In such dunes, pines with low branches, partly buried in sand, must be preserved in larger numbers (Fig. 14.38). Stands of multi-aged fast-growing pines are often located among these slowly growing pines. These must be removed to preserve open dunes and their habitats.

Dune restoration should be carried out at the earliest possible stage of overgrowth. The fewer and lower the trees, the easier it is to implement works at lower costs. Every year for a period of at least three years after tree felling, the managed area must be carefully inspected, and the remaining and newly germinated pines must be pulled out. Further, such pine "weeding" must be carried out every few years. Experience in other countries shows that extensive grazing by sheep or cattle can be used in some areas after tree removal, to maintain grey dune vegetation.

The felling of mature trees can be relatively expensive, while the "weeding" of pine seedlings does not require large financial investment. This work can be done during voluntary joint work with the involvement of local people, after the explanation of the importance of this work, and showing in the nature how the pine stand will influence grey dunes or open inland dunes and their species after a few years. Pulled out pine seedlings should not be dropped right there in the habitat. They must be collected, transported away from the dune area or incinerated in an appropriate place.

In open inland dunes, afforestation must also be

Fig. 14.32. *Campylopus introflexus* is a perennial moss that can quickly spread, forming a dense "carpet". Thus, this moss occupies habitats of local plants. Leaves with a hairy tip are characteristic for *Campylopus introflexus* which, when mosses desiccate, look like a white star. Photo: A. Priede

Fig. 14.33. Pape is one of the Latvian coastal areas where there is the highest number of invasive plant species *Rosa rugosa* and where they occupy the largest area. Photo: B. Laime.

Fig. 14.34. A real problem is the dispersal of invasive species *Rosa rugosa* to coastal cliffs ravines and river valleys, such as Ziemupe. Photo: B. Laime.

Fig. 14.35. Over the past 20 years, planting of *Hippophaë rhamnoides* on coastal dunes is increasing. This woody species is reproducing both with shoots and seeds. Photo: B. Laime.

Fig. 14.36. All felled trees, shrubs and branches must be removed from the restorey grey dune area. Photo: B. Laime.

Fig. 14.38. At least a few slowly-growing pines must be left for each hectare of dune to be restored. They may be of various ages. In this way, landscape values characteristic for a particular coastal section are also preserved. Photo: B. Laime.

Fig. 14.37. Stumps and woody debris of large dimensions must be left, because they are important habitats for insects. Young pine trees growing around the area must be felled. Photo: B. Laime.

Fig. 14.39. When alien pine species plantations grow older, the amount of litter and shading increase, which negatively affects the development of pioneer vegetation and grey dune vegetation in general. Photo: B. Laime.

organised in areas with alien tree species (Fig. 14.39). They must be felled completely, without leaving any trees.

A serious problem is the control of *Populus tremula* in grey dune habitats. In some places, it forms ever greater stands. When a tree is felled, its stump develops stump shoots, and an even denser stand of young trees develops. In this situation, an effective method is ring barking, which destroys the parent plant and stops its vegetative regeneration. For more about this method, *see Chapter 18*. If there are low, dense *Populus tremula* stands, they must be cut. This should be done every year or even twice a year. It is recommended to combine cutting with grazing, preferably with goats.

14.3.4 Litter Removal

In grey dunes overgrown with trees and shrubs, litter (needles and leaves) can form up to a several centimetre thick layer. It hinders the germination of plant seeds, soil drying, sand blowing (Fig. 14.40). After the removal of trees and shrubs, it is recommended to allow the litter and soil surface to dry for at least a few months. Then all the litter including cones must be collected (Fig. 14.41). This should be done with a rake or other suitable tool. The collected material must be incinerated by establishing fires right there in the

managed area. This is best done in places of the most dense woodlands where a thick layer of humus has accumulated. Litter can also be burnt without gathering it in a pile, by burning all over the territory, but it can prove to be more expensive or even impossible. Such management is also relevant for open inland dunes.

14.3.5 Burning of Groundcover

Groundcover burning should be combined with the burning of woody species cover and litter, and with topsoil removal. After the removal of plant cover, the soil surface should be left to dry. Then, in accordance with fire safety regulations, one may try to burn, but experience has shown that, similarly to litter, it can be hard to do or even impossible. In Western Europe, burning as a management measure is often practised in grey dunes with dwarf shrubs. This is more used in places with abundant old dwarf shrubs (heather, crowberry). Thus, dwarf shrubs and the layer of litter catche fire. Later, at least in some places bare sand is exposed, and dwarf shrubs are able to regenerate (Jensen, 2004; Houston 2008a). For more on burning, *see Chapter 18*.

Fig. 14.40. Vegetation recovers very slowly in areas with up to a 1-2 cm or even 5 cm thick layer of pine needles. Photo: B. Laime.

Fig. 14.41. In cleared sites, it becomes drier, bare sand patches are exposed, a favourable environment for characteristic lichen, plant and invertebrate species is created. Photo: B. Laime.

Fig. 14.42. Removed topsoil must be gathered and transported away from the habitat to be restored. Photo: B. Laime.

Fig. 14.43. Sampling plot where groundcover and humus were removed a year ago. In regenerating vegetation, *Anthyllis maritima* dominates. Photo: B. Laime.

14.3.6 Topsoil Removal

Topsoil removal is one of the most important methods for the restoration of open secondary dunes. Often, a humus layer has already been formed below the litter. Under 30–40-year-old pine trees, it can be 10–25 cm and even thicker. There are a lot of roots and other underground parts of trees, shrubs, dwarf shrubs, herbaceous plants. This is one of the biggest problems in the restoration and management of open secondary dune habitats. If the aim is to restore an open dune, the humus layer must be removed completely (Fig. 14.42). This can be done with a rake, a shovel or a hoe, but in this way the mineral soil can only be uncovered in small patches. To restore larger areas, machines must be used by which the topsoil can be pushed away or excavated Whenever possible, it should be done in a continuous area, leaving just small bands or patches as refuge places for species. The collected topsoil must be transported away from the dune to be restored.

When the topsoil is removed, it is preferable to scarify the exposed sand, thus creating smaller and larger patches for sand overblowing (Fig. 14.43). Hand tools can be used, but a tractor with a cultivator, plough or other suitable equipment would be preferable for larger areas.

Management must be planned outside the bird breeding season (*Anthus campestris, Lullula arborea*), which lasts from about April to July (depending on the site).

Topsoil removal is one of the most expensive biotechnical measures. Not only must its technical realisation be planned, but also environmentally friendly disposal or use of the removed material. Removed material cannot be left or transported into adjacent habitats, thus degrading them.

14.3.7 Topsoil Loosening or Covering with Sand

On leeward dunes and other sites where the influence of natural disturbances have diminished, the restoration of open sand areas is one of the tasks. At first, one must assess the possibilities to reduce the barriers of the wind (*see Chapter 14.3.3*). If not, other methods should be used. The simplest method is to scarify the topsoil at around 10–20 cm in depth. Situations may be various – dune areas, vegetation cover, area of bare sand patches etc. may differ. Therefore, each case must be evaluated separately. Loosening must be performed on rows or patches using an appropriate tractor.

One of the methods in open dunes is covering topsoil with sand. In this way, litter and mosses are also covered. Such an experiment was carried out by the LIFE+ NAT-PROGRAMME (LIFE11 NAT/LV/000371) project managed by the Nature Conservation Agency in 2014. The results after one year show that the method is may be effective, because the composition of sand-loving species is recovering, the abundance and germination possibilities of annual plants is increasing (Fig. 14.44) (Biseniece 2015; Tjarve 2015). Sand should be taken from the nearest foredune, beach or grey dune (or inland dune and adjacent area). For example, in the River Sventāja valley it is possible to use the sand of the river bank. Care must be taken to avoid damage to these "donor habitats". Sand should be added on top of the soil in a 0.5–1.0 cm thick layer. Such habitat "nourishment" with sand must only be carried out if it is not possible to provide open sand areas by other means of creating a necessary disturbance, such as ploughing.

Covering topsoil with a 1 cm thick sand layer does not solve the underlying problem – lack of formation of bare sand patches, lack of naturally accruing sand overblowing and necessity for a nutrient-poor environment. There is also a risk that fast-growing grass species will establish, outcompete other dune species and negatively affect habitat microclimate and other conditions.

14.3.8 Grazing and Mowing

Grey dunes and open inland dunes are sensitive habitats, so only extensive grazing can be used for their management. The aim is to maintain species rich, mosaic, low-sward vegetation. While assessing the suitability of the management method, primarily the historical use of the territory and the present habitat condition must be studied. It is possible that grazing can be started without any previous works. However, if a dune is covered by a lot of shrubs as well as tall and dense stands of grasses, first it is recommended to cut these shrubs and mow herbs, and remove them (van Dijk 1992). In bushy areas, it is better to use goats, which eat shrub sprouts and hinder their regeneration. In the past, sheep and cattle have been widely used on the Latvian coast. In areas of open secondary dunes, one must be alert to overgrazing which can cause deterioration of species composition, loss of desired vegetation structure, and also environmental eutrophication. Other signs indicating overgrazing are: total area of bare soil exceeds 30%; bird and insect species characteristic for the habitat cannot be found; plant species which are resistant to trampling like *Plantago major, Trifolium repens, Taraxacum officinale* are abundant as well as plant species which are characteristic for fertile, nitrogen-rich soils.

Fig. 14.44. Sample plot established in grey dunes in Užava. Sand is poured over the topsoil. After one year, annual and perennial species characteristic for grey dunes are found while the surrounding (untreated) habitat is dominated by litter, a dense moss layer and low herbaceous species. Photo: B. Laime.

Fig. 14.45. Removal of *Rosa rugosa* in a recreational area on the grey dunes of Pape. Roses occupy a large area around a footbridge and picnic site. Photo: I. Mednis.

Fig. 14.46. It is recommended to burn cut roses directly in the rose stand, creating the widest possible fire. Photo: I. Mednis.

Fig. 14.47. Sample plot in site of previous fireplace (cut and pulled out roses were burned). Rosa rugosa regrowth is relatively weak. Photo: B. Laime.

In Latvia, the most suitable time for grazing is from May to September. However, in earlier times, grazing was also used beyond the vegetation season. One of the proposed methods in Western Europe is winter or autumn grazing: animals are brought into a particular territory for a certain period only (week, month) (van Dijk 1992; Houston 2008a; Kohyani et al. 2008). In the Latvian dunes, it might be September and October, as well as March and April, because dune vegetation is the most vital during these months. Each situation may differ in various locations and years, and it also depends on weather and other factors. In very dry summers or in the autumn, when the habitat is "dried up" and very sensitive, grazing intensity should be reduced or even discontinued. In warm autumns, the grazing season can be prolonged until December. Along the Kurzeme coast, the duration of the snow-free period is increasing, and grazing is even possible there in winter. Before grazing, all the risks and benefits should be carefully evaluated. Also during the management, both the livestock and managed habitat must be observed. For grey dune grazing, the number of animals should be rather small (0.06–0.3 livestock units/ha), which is, for example, two sheep and a pony per hectare or even up to 3–4 ha (Houston 2008a). It is recommended to use a species and varieties traditionally used in the specific area.

Mowing is less characteristic for dune habitats because of their low and poor vegetation. Nowadays, the number of permanent residents in coastal villages is decreasing and also livestock is held less and less, therefore mowing as a management met-

Fig. 14.48. This *Rosa rugosa* growth in Ziemupe was sprayed with pesticides a year ago. Almost all rose sprouts are withered and dead, bare sand patches are formed, local plant species, including *Dianthus arenarius* and *Tragopogon heterospermus*, recover abundantly. Photo: B. Laime.

hod could become relevant. This refers mainly to dunes, the plant cover of which exceeds 50%, where clump-forming gramineous plants and tall herbaceous plants are rapidly expanding, and a dead grass layer is forming. Mowing is definitely recommended for grey dunes with dwarf shrubs, mainly with *Calluna vulgaris*. Mowing should occur in late June and July, but mowing is also possible in early spring or late autumn (it is preferable to animals). It is recommended to mow once in 2–3 years by a hand scythe or a tractor, and vegetation must be mown very low, otherwise most of the plants will stay unmown. For the protection of species, especially for invertebrates, some unmown patches must be left, which will be mown next time. All the mown biomass must definitely be removed from the managed habitat.

Sandy grasslands are often located nearby open dunes. Traditionally they are more grazed and mown than grey dune habitats. More on mowing and grazing methods: Rūsiņa (ed.) 2017.

14.3.9 Invasive Plant Species Control

The most aggressive invasive plant species in Latvian grey dunes and all coastal areas are *Rosa rugosa, Hippophaë rhamnoides* and *Amelanchier spicata*. These species are also found in inland dunes. Currently, the main method of dune habitat restoration is the mechanical control of invasive plants. Young sprouts may be pulled out by hand or cut off with a shovel. This also applies to small stands of *Rosa rugosa*. The sooner the young sprouts are pulled out, the better the result.

If shrubs are already forming tall and dense stands, they must be cut (Fig.14.45). Experience shows that sprouts develop very rapidly, therefore felling must be repeated for several years, perhaps even twice a year. Cut down or pulled out plants must be removed from the coastal belt or burnt right on the site of the sawn shrub stand (Fig. 14.46, 14.47). In some places in Europe, rose shrubs are eradicated by complete digging up but such an operation is very expensive. If allowed by the dune relief, one can use machines by which shrubs of invasive species are excavated, shaken out, collected in a pile, and then the sand is levelled.

In Denmark and other West European countries, one of the most effective methods is considered to be the treatment of invasive plants, particularly their young sprouts, with herbicides of low doses, to promote the regeneration of local vegetation. This should be done very accurately, spraying only on *Rosa rugosa* leaves, thereby minimising the potential impact on human health and the dune ecosystem. This method can also be used in tall shrub stands, but it is particularly effective for small, low stands. Prior to that, the treated area must be enclosed with warning tape. Herbicides should only be used in windless, sunny but not hot weather. It is recommended to apply herbicides in early summer, when the plants are fully leafed out. In the coming years, newly expanded sprouts and shrubs which are still vital must be sprayed. Work must be continued until sprouts of invasive species are no longer observed. Herbicides should not be used during the time when fruits are ripening. The method was tested in the "Ziemupe" Nature Reserve, where it was found that it was more effective in places where *Rosa rugosa* formed mainly low stands (Fig. 14.48). This situation was known and purposefully used at the beginning of the experiment. Treatment of higher shrubs with herbicides would not have been so effective.

Herbicides should be used very carefully. First, make sure that water will not be polluted in any way. Herbicide use near water – rivers, springs, streams – is prohibited by law. Second, there are land properties in dunes, such as FSC-certified areas (FSC – Forest Stewardship Council – an international wood product trademark), where the use of any chemicals is prohibited. Every time, herbicide use must be coordinated with state institutions responsible for the territory where management is planned.

Rugosa rose may also be limited by grazing. Sheep or goats intensively destroy the young sprouts and also mature plants by trampling. For aggressive species control it is best to combine several methods – mechanical, chemical and biological.

Aggressive plant control should not be delayed.

The immediate response of every landowner and municipality can be much cheaper and more effective than action after the species has spread over a large area.

One of the most dangerous trends is the planting of common sea-buckthorn *Hippophaë rhamnoides* in coastal dunes where this species spreads very rapidly and literally conquers the Latvian sand habitats. The situation has become more complicated because of the need to strengthen the coastal shore and restore sand habitat vegetation. Only local plant species can be used for this purpose. On erosion coasts, wicker-works should be established or pine branches spread, and buckthorns must be cut out.

Particular attention should be paid to the spread of moss species *Campylopus introflexus* because it can become one of the most serious threats. In Latvia, this species is found in more than 30 localities, including Nida–Pape coast, in sites of former peat extraction (Priede, Mežaka 2016). It is recommended to consult a moss expert to verify that any moss found is indeed *Campylopus introflexus*. The Nature Conservation Agency should be informed about every new locality. In countries of Western Europe, *Campylopus introflexus* has rapidly spread since the middle of the 20th century, occupying an increasing number of new areas, including grey dunes (Klinck 2009, 2010). This aggressive moss takes over bare sand patches, forms a dense layer, outcompetes local pioneer species and hinders the development of the desired grey dune structure, species composition and function. This moss species can be restricted by its removal – creating bare sand patches. Collected moss must be immediately put in the bag, removed from the grey dune area, and burnt. Moss can be gathered by hand, a rake or otherwise. Experience in Latvian bogs is that the removal of this moss is ineffective because it regenerates well.

14.3.10 Action after Catastrophic Erosion Episodes

During severe storms, grey dune habitats can be eroded, particularly in sites where they are located over the sea cliff and are not separated from the beach by foredunes or embryonic dunes. There is no need for special intervention in the process of slope "regeneration" after the erosion episode, except in cases when, in combination with storm wave erosion and human impact, wind overblown areas develop particularly actively.

For more on the elimination of these disturbances, *see Chapter 13*.

However, coastal erosion is a necessary prerequisite for the existence and regeneration of sea cliffs, beaches, foredunes and embryonic dunes, therefore the reduction of erosion risks must be evaluated for each individual case, considering the interactions occurring in a particular coastal section.

14.3.11 Establishment of Tourism Infrastructure

To the extent possible, tourism infrastructure should be redirected from the localities of the most valuable dune habitats and species, as well from the protected nature territories. In sites where an excessive flow of visitors cannot be prevented, and there is a risk of decrease in quality and area of protected habitats, purposeful planning and installation of tourism infrastructure is acceptable.

To reduce recreational pressure and limit anthropogenic-induced wind erosion zones, the construction of pedestrian footbridges and demarcated trails is desirable (Fig. 14.49). Footbridges must be raised 0.3–0.5 m above the ground level and constructed out of wooden planks with spaces. For more on tourism infrastructure construction *see Chapter 13*.

Fig. 14.49. Fence construction of twig wickerwork, Nature Reserve "Plieņciema kāpa". Grey dune and foredunes are protected from intense trampling. Year 2011. Photo: K. Lapiņš.

14.3.12 Waste

See Chapter 16

14.3.13 Management and Use Unfavourable for the Habitat Type

The ensuring of favourable conservation status for grey dunes is directly related to the functioning of primary dunes, beaches, cliffs, and also the coastal underwater slope. Ensuring non-interference in these coastal habitats and their natural processes is the most important action, but this is not possible because the largest part of the coast is permanently or periodically exposed to human impact (e. g., coastal strengthening and transformation), which is increasing, as the need to satisfy other interests significant for the society increases. In such circumstances, one must find solutions that most ensure the maintenance of natural process continuity (long-shore and cross-shore sediment exchange).

In order to timely react to changes in the environment, within the framework of coastal monitoring it is necessary to continue to measure nitrogen and phosphorus depositions and their influence on grey dune soil.

Too passive management or even abandonment of secondary open dunes is considered as negative. It is wrong to believe that habitats will be protected by the creation of protected nature territories and setting appropriate restrictions, without any further activity.

14.3.14 Conservation and Management Conflicts

Major conflicts can arise if tourism infrastructure is established within biologically valuable dune habitats. The presence of visitors negatively influences bird and invertebrate species, especially during the bird breeding season. At the same time, the abundance of certain plant species can decrease due to trampling. The condition of adjacent habitats can also be deteriorated due to an increase in visitor numbers.

It is unlikely that other conflicts will arise such as negative influence of open secondary dune management and conservation measures on other habitats located in the active coastal zone. Regarding ensuring the conservation of various plant, bird and invertebrate species, the requirements may differ. To avoid potential conflicts, objectives should be defined for the conservation of every territory in the particular habitat, for example, if there is a question as to whether to restore and maintain grey dune or sandy grassland. In such a case, priorities should be evaluated together, taking into account the distribution, vulnerability and other factors (*see Chapter 6*).

Invasive species control can cause short-term inconvenience because vegetation-free patches are created. However, experience shows that very soon in places where invasive plant species were eradicated, species characteristic for grey dunes establish, and vegetation cover develops.

Conflicts with bird species protection could arise by tree felling in grey dunes, movement of machines, heaps of felled trees, stumps etc. However, these influences are also temporary and insignificant if the measure is professionally organised, according to the characteristics of a particular site, with timely notification of the local population.

Chapter 15. 2180 *Wooded Coastal Dunes of the Atlantic, Continental and Boreal region* (S. Ikauniece, B. Laime)

15.1 Characteristics of Wooded Dunes

15.1.1 Brief Description

Habitat type 2180 *Wooded dunes of the Atlantic, Continental and Boreal region*, further below referred to as **wooded dunes**, includes natural or semi-natural (planted) forests on coastal dunes or dune depressions, with a well developed woodland structure and assemblage of characteristic woodland species (Rove 2013e). Although the tree stand is dominated by *Pinus sylvestris* (Fig. 15.1.), *Picea abies* can also have a large proportion (Fig. 15.2). In the early stages of habitat development, mixed deciduous forests can be observed, mostly with *Betula* spp., *Alnus* spp. and *Salix* spp. Habitat is only located in the Coastal Lowland geobotanical region and includes separate dunes covered with forest and compact dune groups as well as extensive dune systems, where dunes are connected by flat or wavy wind overblown areas of various widths, and with dune depressions of various forms, forming a complex of various woodlands, humid and open areas. It may also include deciduous and mixed forests on dry and wet mineral soils and peat soils, bushes, as well as small areas of wind-throws, burning sites, clearcuts, degraded areas, openings and young forest stands (Rove 2013e).

Fig. 15.1. Wooded dunes, tree stand dominated by *Pinus sylvestris*. Photo: S. Ikauniece.

Fig. 15.2. Slope of wooded dune, dominated by *Picea abies*. Krāču Kalni, Ķemeri National Park. Photo: A. Priede.

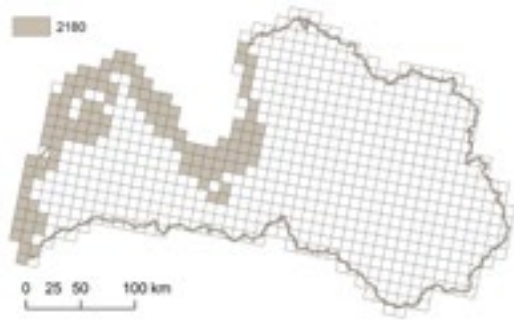


Fig. 15.3. Distribution of habitat type 2180 *Wooded coastal dunes of the Atlantic, Continental and Boreal region* in Latvia (Anon. 2013c).

In Latvia, the ancient slope of the Baltic Ice Lake is considered as the wooded dune distribution range border. Wooded dune habitat type develops on dunes of various ages. The oldest dunes are formed nine thousand years ago. These dunes extend far, in some places even more than 30 km inland. Although the influence of the sea on these old dunes has long declined, their origin is still related to ancient coastal dunes. The question of wooded dune distribution range border is still under discussion.

Nowadays, the largest continuous areas of wooded dunes are related mainly to Priediengalciems–Jūrmalciems, Bernāti, Užava–Ventspils, Ovīši–Kolka, Engure–Ragaciems, Ķemeri National Park, Jūrmala, and Rīga–Saulkrasti coast (Anon. 2013c) (Fig. 15.3). Wooded dunes in Latvia form the largest proportion of this habitat type in the EU (EIONET 2014), which imposes an additional responsibility for conservation of this habitat type.

15.1.2 Important Processes and Structures

The prerequisite for habitat development are dunes formed of wind overblown sand sediments, which

are primarily characterised by the dune complex relief and its condition (unconverted, diverse, without constructions). The amount of light and microclimate are significantly influenced by dune height, width, exposure and arrangement, and they determine various conditions of humidity, temperature and lee, which in turn are important for soil and vegetation development. In typical wooded dunes, growing conditions in general are poor: drought, low nutrient concentration, sandy soil is dominating, humus builds up slowly. Moderate intermittent sand overblowing has a beneficial effect on habitat development. Nowadays, it is predominantly characteristic for dunes nearby the sea, especially in areas bordering foredunes. Also the position of the coast, wind, its force, direction, frequency and duration are of great importance. Close to the sea, severe storms cause disturbances that prevent the accumulation of soil nutrients and ensure poor soil conditions.

Fig. 15.4. Due to disturbance caused by fire, the number of logs and stumps increases, new ecological niches are formed. Photo: B. Laime.

Fig. 15.5. Burnt tree stems and bare sand patches are important structures for the regeneration of species characteristic for the habitat, such as *Dianthus arenarius* and *Melanophila acuminata*. Photo: B. Laime.

For the long-term existence of wooded dunes, periodically occurring natural disturbances characteristic for coniferous forests are necessary – storms and wildfires. After the burning of groundcover, especially of the moss layer, the accumulation of nutrients and humus decreases, and nutrient-poor soil characteristic for the habitat type is maintained. In such circumstances it is less likely that mesophytic plant species (characteristic for moderately humid growing conditions) will establish, and outcompete species characteristic for dunes. On steep slopes, disturbances are also caused by water erosion which washes down the soil surface. Under the influence of these and other environmental factors, bare sand patches are exposed. Natural disturbances are important for the conservation of wooded dune plant communities, creating the opportunity for the development of pioneer communities, for example, with *Corynephorus canescens*, *Jasione montana*, *Polytrichum juniperinum*, *P. piliferum*. In biologically old pine stands, natural self-thinning occurs; canopy gaps and cohorts develop, creating more diverse plant communities and a mosaic of stands of various ages. These natural disturbances are partly limited by moderate anthropogenic disturbances such as trampling.

In the coastal zone, the habitat is significantly affected by wind, especially by storms, during which the cumulative wind speed reaches at least 24 m/s within 10 minutes. Wind speed gusts up to 50 and even 100 metres per second. In Latvia, storms usually affect coastal areas along the coast of the Gulf of Riga and the Baltic Sea, south-westerly and westerly winds are prevailing, the water level is extremely high, coastal dunes and terrain are washed off, and woodlands are directly influenced (Eberhards 2003). Habitats which are located closer to the sea and are not overgrown with trees are most influenced by storms. Although, storms also leave a certain impact on wooded dunes. Wind of a speed up to 24 m/s has a relatively small influence on woodland: it breaks off the large branches. When the wind speed reaches 28–32 m/s, it can cause trees to break or uproot, and can create extensive wind-throws. Wind blows sand from sites of exposed bare soil. In open, sandy sites, *Pinus sylvestris* and other light tolerant plant species can establish. Trees and their parts broken by wind become significant structural elements in a wooded dune habitat and serve as microhabitats for several rare species of invertebrates. Due to wind induced disturbances, the woodland structure and composition become more diverse.

A large part of wooded coastal dune habitat be-

Fig. 15.6. *Monotropa hypopitys*, which is a perennial saprophytic plant without chlorophyll, is a good indicator of the habitat quality in natural pine forests. Photo: B. Laime.

longs to boreal forests. In addition, most of them are dry forests where wildfire is historically a natural disturbance. Wildfire can vary in intensity. After a large fire which totally destroys a forest stand, woodland can regenerate with *Betula* spp. and *Pinus sylvestris*, in some sites also with *Populus tremula*. An even-aged forest stand develops which is characterised by a large amount of dead wood (Shorohova et al. 2011). Nowadays, naturally occurring wildfires in Latvia are very rare, and most of the forest fires are caused by human activity. With wildfire of low intensity, a large proportion of trees are not destroyed, a part of them remains vital, and a multi-aged forest stand develops. Alternatively just the groundcover is incinerated, and the forest stand remains almost fully preserved. Burning improves insolation. It reduces the groundcover and organic layer, thus improving the growing conditions for herbaceous species characteristic for the habitat (Fig. 15.4, 15.5).

An important process is the formation of gaps or gap dynamics in which individual trees or small groups of trees are broken or uprooted due to windthrow, snowthrow or insect outbreak, or reaching biological maturity. While the opening in the canopy cover overgrows with young trees, new gaps emerge in other sites. A mosaic of multi-aged woodlands and gaps as well as the presence of standing and fallen dead trees of the various stages of decomposition is characteristic for these forests. Such a structure changes very slowly, and also the turnover of tree species is very slow. Severe and wide windthrows can also cause wide, continuous disturbances when all trees are uprooted, and the woodland regenerates as an even-aged stand. Main determinants of habitat structure are the shape of relief body,, thickness and location of aeolian sediments. The most common are complexes of various relief forms, with diverse dunes and dune groups. The habitat complex also includes dry or humid dune slacks, as well as flat or wavy sand overblowing plains.

Structure elements of a forest stand serve as a microhabitat for many habitat specialist species which commonly cannot be found in intensively managed forests which lack natural structures. Structural element diversity indicates high ecological value and possible compliance with the criteria of woodland key habitats (Ek et al. 2002).

The presence of characteristic structures, woodland key habitat indicator species and habitat characteristic species in woodland is a significant indicator of quality (Fig. 15.6). The most important structures are trees of large dimensions, coarse woody debris, biologically old trees, gaps, multi-aged stand structure (more – Ikauniece (ed.) 2017). Large areas are occupied by relatively young and middle-aged trees. In these forests, structures which are important for biodiversity, like coarse woody debris or old trees, are usually not found or are very limited.In these cases, the woodland ecological value is lower, but still the geological origin characteristic for habitat and typical groundcover species indicate compliance with wooded dunes. Habitat type 2180 *Wooded coastal dunes of the Atlantic, Continental and Boreal region* can overlap with habitat type 9010* *Western Taiga* but geological origin is the priority for the identification of this habitat type (Rove 2013e). At the same time, old coastal wooded dunes are of particularly high ecological value.

15.1.3 Natural Succession

Wooded dunes naturally develop in a dune complex where active sand overblowing is slowed down. This development can differ on coasts of various types. In most cases, favourable conditions for tree establishment and growth are in grey dunes where the soil surface is strengthened by mosses and lichens (Fig. 15.7). Wooded dunes can develop faster in coastal sections where the grey dune belt is relatively narrow, sur-

Fig. 15.7. On accumulation shores, the establishment of *Pinus sylvestris* and the development of wooded dune are promoted by clusters of shrubs, creating shade, lee and increasing soil humidity. Photo: B. Laime.

Fig. 15.8. Old foredunes and grey dunes overgrowing with Scots pine in a sand deficit shore in the Bērzciems–Lepste coastal stretch. Photo: B. Laime.

rounded by dune forest from one side and by stable foredune of moderate size, from the other side, such as, for example, in Ģipka–Žocene. In sites of open secondary dunes and former dune grasslands, wooded dune development is slower. It is often influenced by a thick layer of dead grass that forms after grassland management cessation and hinders the establishment of *Pinus sylvestris* or other tree species, for example, in dunes at Pape channel.

Along the Latvian coast, the succession from foredune (white dune) to wooded dune is also characteristic. This refers mainly to an old foredune with extensive dead grass, mostly consisting of *Ammophila arenaria* old stems. Such conditions provide shelter from the wind, keep the sand and create niches where Scots pine can establish. The micro-relief is also important: the dune ridge should be low but partially slow down marine wind, water and sand. Succession directly depends on modern coastal geological processes that determine habitat structure and function. If dunes and the beach are not eroded for a long time, there are no severe storms or dunes are bordering a low, periodically wet beach, then even an old foredune provides a favourable environment for the establishment and growth of trees. Such a situation can be observed, for example, in some places between Bērzciems and Lepste during the last 10 years (Fig. 15.8) and on Vaide–Kolka coast during a longer time.

Vegetation development differs, if the species establishing initially in grey dunes are *Betula pendula, Alnus* spp., *Populus tremula* and *Salix* spp. The litter of these species facilitates a rapid increase of nutrient concentration and humus layer development. The micro-relief is also important as groups of trees initially develop in depressions. Further, the shading and enriched sandy soil is a favourable environment for the development of *Pinus sylvestris* plant communities. This succession with deciduous stands as a pioneer stage can be observed, for example, in Daugavgrīva (Fig. 15.9). In all cases, adjacent habitats have a major impact on succession – if the open dune is bordered by pine, birch or other forest, or shrubs.

Succession on sand overblown plains may also differ. It depends mainly on the area of the plain, thickness of aeolian sediments, and intensity of sand overblowing. When sand blowing declines, vegetation of herbaceous plants and mosses develop, in which woody species establish. In more xerophytic sites, the dune mainly overgrows with Scots pine, in more humid – with *Betula pendula*, *Betula pubescens*, *Salix* spp., etc.

In relief depressions of a wooded dune complex, succession from a herbaceous plant community to communities of low willows or other shrubs occurs.

Fig. 15.9. Primary succession by the establishment of deciduous trees and shrubs in an open secondary dune in Daugavgrīva. Photo: B. Laime.

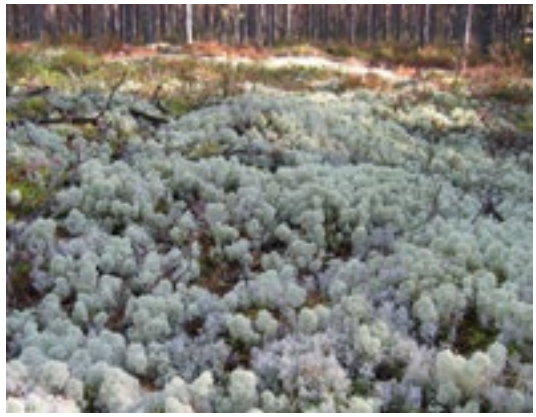


Fig. 15.10. Wooded dune with groundcover of lichens. Kolka. Photo: D. Tjarve.

Fig. 15.11. Wooded dune with dwarf shrub groundcover, Kolka. Photo: B. Laime.

Depending on humidity, these communities develop to humid woodland with pines, birches or alders.

There is interaction in the dunes: the development of established woodlands is significantly influenced by microclimate (temperature, humidity, light), while the microclimate is influenced by woodland. In very dry growing conditions, lichen communities develop and persist for a long time. In shaded forest stands, where the microclimate is more humid, *Pleurozium schreberi, Hylocomium splendens* and other forest mosses establish, and a thick litter layer develops (Biseniece 2015; Tjarve 2015). In the following succession, such conditions promote the development of existing woodland, but arrest the establishment of *Pinus sylvestris* in the long term. With the following decrease of disturbances, the substrate becomes more and more fertile and moist, and the abundance of *Picea abies* increases. This tree species influences the further ecological processes significantly.

The above described wooded dune development refers both to forest located at the sea coast and also to relative stable dune complexes inland, up to the ancient shore of the Baltic Ice Lake. Primary succession of vegetation development is similar in all cases: foredune or grey dune overgrows with trees or shrubs.

After the destruction of woodland of wooded dune (storms, wildfire, burning, felling, overgrazing, etc.), succession may vary. *Pinus sylvestris* regenerates more successfully in woodlands which are closer to the sea coast. Woodlands on sea dunes of older stages are often dominated by communities of *Pinus sylvestris* and *Picea abies*, in mosaic with deciduous woodlands. The succession process is determined by various factors: humus amount in soil, thickness and type of litter layer, micro-relief, soil seed bank, wind, adjacent habitats etc. Wooded dunes in Latvia mostly represent secondary succession.

Every succession stage has its own ecological niches and species composition, differing from other stages. Therefore it is important to study and maintain the diversity of wooded dunes in all the stages of their diversity.

15.1.4 Indications of Favourable Conservation Status

Wooded dune vegetation is characterised by a high diversity of plant communities, determined by a variety of growing conditions. **Wooded dunes where *Pinus sylvestris* dominates** in woodland and in advance growth, are related to the proximity of the sea and relatively young coastal development stages, mainly of the Littorina Sea, when dunes formed 4000–5000 years ago. Such pine stands are also located on dunes further away from the coast, where coastal processes are inactive for a long time. Nowadays, these forests are like "islands of dunes", surrounded by habitats of other types of forests, or mires. On such dunes, substrate is dry and poor, and woodlands with sparse

Fig. 15.12. *Linnaea borealis* indicates the continuity and stability of wooded dune forest. Užava, 2013. Photo: B. Laime.

Fig. 15.13. *Geranium sanguineum* occurs rarely in coastal areas, mainly in old pine forests. Ragakāpa, 2005. Photo: B. Laime.

trees form a mosaic with openings. Patches of bare soil, pine stumps and logs, in some places burnt trees are also characteristic. Stands are multi-aged, and individual old trees of large dimensions are common. In canopy gaps, pines regenerate naturally. Under persisting poor growing conditions, pine forests remain for a long time in woodland. Closer to the sea, sand is overblown periodically during severe storms. The shrub layer is insignificant. Groundcover is dominated by a mosaic of lichens, mosses, dwarf shrubs and herbaceous vegetation. One of the most desirable forms of vegetation of wooded dunes is pine forest on dry, poor soils, with wide growths of lichens (*Cladina* spp., *Cladonia* spp.) and *Arctostaphylos uva-ursi*

Fig. 15.14. *Columba oenas, Aegolius funereus* and *Bucephala clangula* can nest in cavities left by *Dryocopus martius*. Photo: I. Priedniece.

Fig. 15.15. Wooded dune where *Picea abies* is abundant in the subcanopy layer and advance growth. Photo: S. Ikauniece.

Fig. 15.16. Humid mixed forests and shrubs in a dune depression. Buļļu Island, Rīga. Photo: B. Laime.

Fig. 15.17. Periodically humid wooded dune. Groundcover is dominated by *Oxalis acetosella*. Rītabuļļi, Rīga. Photo: B. Laime.

stands (Fig. 15.10). In the longer term, soil is gradually enriched, and dwarf shrubs start to dominate in groundcover – *Vaccinium vitis-idaea* and *Vaccinium myrtillus* (Fig. 15.11).

In such dry conditions, *Pinus sylvestris* dominates in the tree layer, rarely or often *Picea abies* is found, and *Juniperus communis* grows in the understory. The most significant species in the groundcover are the so-called umbrella species which indicate favourable conservation status. These are *Arctostaphylos uva-ursi*, *Festuca ovina*, *F. sabulosa*, *Thymus serpyllum*, *Dianthus arenarius* s. l., *Pulsatilla patens*, *P. pratensis*, *Diphasium complanatum*, *Cladonia* spp., *Cladina* spp., as well as *Linnaea borealis* and *Geranium sanguineum* (Fig. 15.12., 15.13.). Trunks of old pines are habitats for *Nothorhina muricata* (Vilks 2014).

Typical species are: *Vaccinium vitis-idaea*, *Empetrum nigrum*, *Calluna vulgaris*, *Vaccinium myrtillus*, *Chimaphila umbellata*, *Koeleria glauca*, *Silene nutans*, *Trommsdorffia maculata*, *Lerchenfeldia flexuosa*, *Pleurozium schreberi*, *Hylocomium splendens*, *Polytrichum juniperinum*, *Polytrichum piliferum*, *Cetraria islandica*, *Ergates faber*, *Tragosoma depsarium*, *Chalcophora mariana*, *Laphria gibbosa* and *Lacerta agilis* (Kabucis 2001; Rove 2013e). Wooded dunes are an important habitat for the black woodpecker *Dryocopus martius* and other birds which nest in tree cavities created by this woodpecker (Fig. 15.14). In old pine woodlands the breeding of Eurasian eagle-owl *Bubo bubo* is also possible (J. Priednieks, *personal communication*).

If growing conditions in **wooded dunes** are richer, the dominating species in the midstorey layer is *Picea abies* which can also be of large proportion in the canopy layer, together with *Pinus sylvestris*. Deciduous trees are also present in small quantities. Such forests have developed over a long period of time, mainly on the dunes of earlier stages of Baltic Ice Lake development, and they are more humid, shaded, on fertile soils. Groundcover can vary from abundant vegetation of dwarf shrubs, herbaceous plants and mosses to poor and sparse, with bare soil patches (Fig. 15.2, 15.15).

Similar to other forests, the favourable conservation status of wooded dunes is also indicated not only by vegetation typical for this habitat type but also by the presence of natural forest structures (logs, snags, stumps, self-thinning etc.) and the large continuous area of the habitat. In natural wooded dunes, there are no invasive species or species uncharacteristic for coastal habitats. Direct anthropogenic impacts (excessive trampling, vehicle use, etc.) are not characteristic or occur relatively rarely and on a small scale; there are only individual and small paths which do not lead to deterioration of the habitat structure and function.

For biodiversity, wooded dune areas where deciduous trees and shrubs dominate in humid dune depressions are particularly valuable. Such vegetation promotes bird, invertebrate, plant and fungus species diversity, and also increases the diversity of coastal landscapes (Fig. 15.16, 15.17).

15.1.5 Pressures and Threats

15.1.5.1 Relief modification

Although the modification of a dune relief is illegal, dune excavation and bulldozing occurs. When destroying dunes, one of the most important structures for the development of wooded dune habitat is also destroyed – natural relief. This adversely affects functional processes (sand overblowing, wind influ-

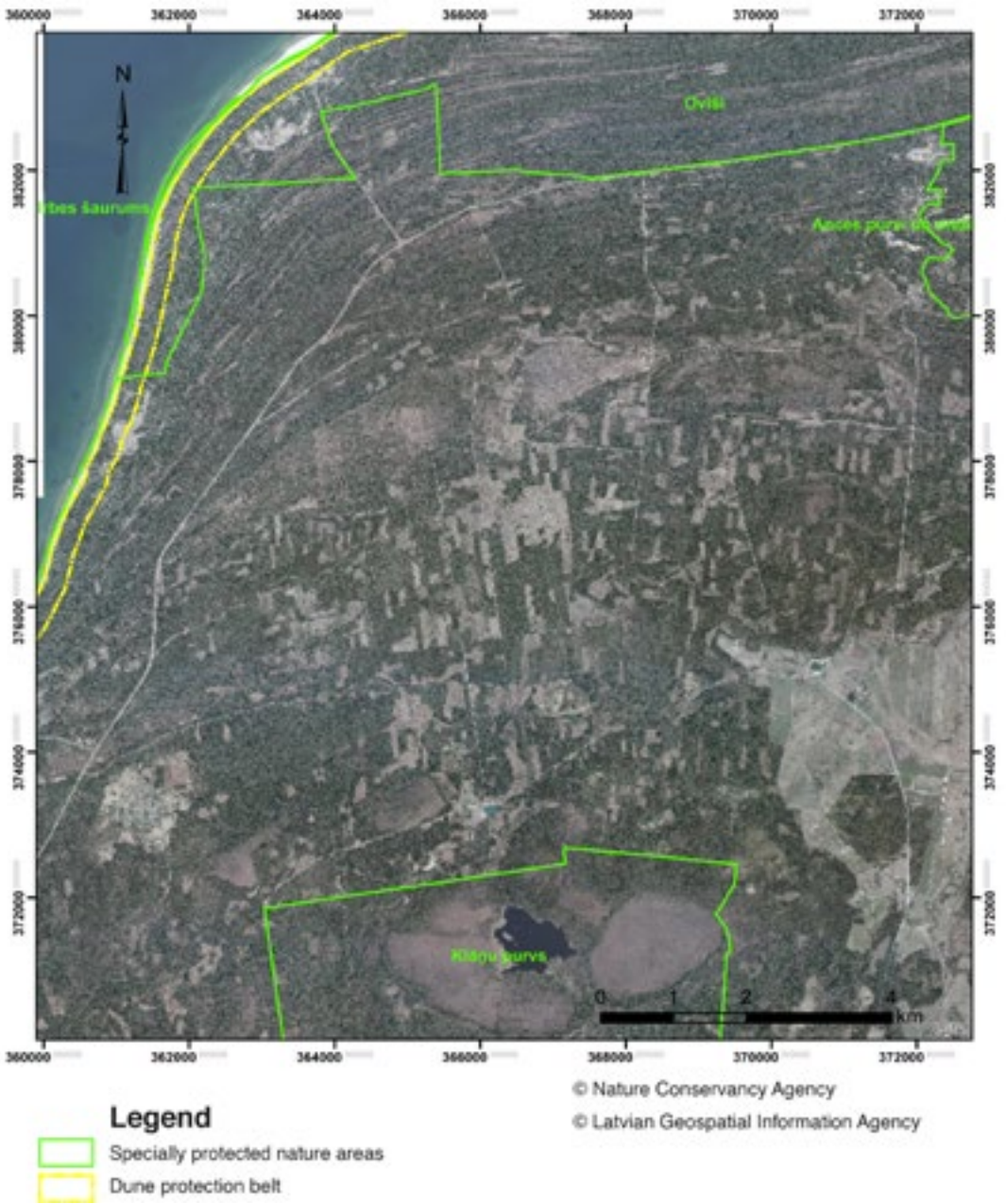


Fig. 15.18. Distribution of clearcuts within the coastal protection belt, in protected nature territories and outside them. Ovišu-Ances surroundings. Map prepared by P. Rozenbaks.

ence, microclimate etc.), and directly decreases or eliminates localities of protected species. Natural relief modification also reduces the landscape values. Relief modification refers both to modern coastal dunes and to ancient dunes in the Coastal Geobotanical Region.

15.1.5.2 Logging

Nowadays, the most negative influence of logging on wooded dunes occurs outside of protected nature territories and the coastal protection belt (Fig. 15.18). Here, dry forests, corresponding to ha-

bitat type 2180 *Wooded coastal dunes of the Atlantic, Continental and Boreal region* are felled, and felled trees are removed. It decreases the quantity of large dimension trees and old trees in the forest stand and their ability to build structures significant for biodiversity. The area of old, natural wooded dunes decreases mostly because of clearcutting. Also selective felling, when mature trees are removed from the woodland, and which also occurs in protected nature territories, leaves adverse effects. Further, forest restoration measures are insufficiently focused on wooded dune diversity conservation – with canopy gaps, multi-aged stands and structures of natural forests. Forest management during the last century has led to artificially created large, even-aged stands in places of previous clearcutting in the habitat distribution area. Young stands are characterised by high density, stumps and logs of small dimensions formed by natural self-thinning. Gradually, canopy gaps develop, and the stand structure becomes more natural.

15.1.5.3 Synanthropisation

Synanthropisation is the human-induced expansion of plant species which are not characteristic for a particular habitat. Since the end part of the 20th century, in the Latvian coastal areas including the habitat type 2180 *Wooded dunes of the Atlantic, Continental and Boreal region* synanthropisation is observed increasingly. Synanthropisation is reinforced by environmental pollution and soil enrichment with nutrients. Ecological processes and plant species composition are changing. The ability of *Pinus sylvestris* to regenerate as well as other species typical to dune forest decreases. The most negative changes occur in dunes which are located in cities, towns and villages, their surroundings, and also in formerly inhabited and now abandoned unmanaged sites and in sites of intense recreation. Dune forests overgrow with various shrub species, or advance growth of deciduous trees develops. A typical species is *Acer platanoides* (Fig. 15.19).

Fig. 15.19. Expansion of *Acer platanoides* on wooded dunes. Jūrmala, 2013. Photo: B. Laime.

Fig. 15.20. Stands of Swida alba in wooded dunes in Jūrmala. Photo: B. Laime.

Fig. 15.21. Stands of *Amelanchier spicata* in a 200 year old dune forest in Jūrmala. Photo: B. Laime.

Fig. 15.22. Degraded forest groundcover at an animal feeder. Photo: A. Priede.

In the shrub layer, dense stands can form *Frangula alnus, Sorbus aucuparia, Corylus avellana* and other species. *Salix* spp., *Lonicera xylosteum, Sambucus racemosa, Cotoneaster lucidum, Ribes* spp. can also be found (Laiviņš 1998). Grasses *Dactylis glomerata, Elytrigia repens* and other species establish in the herb layer. Conditions of insolation and humidity rapidly change, especially in the groundcover.

15.1.5.4 Introduction of invasive plant species

The most common invasive species in wooded dunes in Latvia are: *Amelanchier spicata* and *Rosa rugosa*, in some areas also *Hippophaë rhamnoides, Eleagnus commutata* and *Swida alba* (Fig. 15.20). The species with the most negative impact is *Amelanchier spicata,* which earlier was purposefully planted in dune forests to attract birds (Zviedris 1949). Nowadays, this shrub is spread massively in forests of Jūrmala and Rīga surroundings and in many other places. It transforms the forest structure and environmental conditions. Light conditions change; due to the increase of litter amount, the nutrient amount in the soil also increases (Fig. 15.21). In humid depressions, in the surrounding of rivers and settlements, *Impatiens glandulifera* can be found. In forest edges, clearings and clearcuts – *Solidago canadensis*. The introduction of low juneberry and other invasive species is closely related to the synanthropisation of wooded dunes (*see Chapter 15.1.5.3*).

The naturalness of wooded dunes is also negatively influenced by introduced pine species (*Pinus mugo, P. nigra, P. banksiana*), which were used for sand strengthening on the Latvian coast during the second part of the 20th century (Bušs 1960). Some of these stands have retained their functions. In some places, these pines are withered, in others – are still forming dense stands. In general, these plantations of introduced species reduce the possibility of the development of typical wooded dune communities in Latvia with Scots pine and Norway spruce.

15.1.5.5 Land use change

Over the last 20 years, the volumes of building construction at the sea coast are constantly increasing. Forests, including wooded dunes, are increasingly converted for other uses (land transformation or change of the land-use category). This reduces the area of wooded dunes, and recreational load increases in the remaining areas. Often, the wooded dune deteriorates (rare species, their habitats, characteristics of woodland key habitats disappear), and also their surrounding habitats deteriorate.

15.1.5.6 Forest animal feeding

Habitat 2180 *Wooded coastal dunes of the Atlantic, Continental and Boreal region* covers wide areas of commercial forests which are used for timber extraction and for hunting. Organisation of hunting is also supplemented with the feeding of forest animals. Feeders are installed in locations selected by hunters, on the soil and on elevations. Crops (cereals, sugar beet, potatoes) and feed edible for forest animals are used. Feeders concentrate the animals which come from wide surroundings to feed, and their quantity here is greater than it would be naturally. Staying near the feeder, animals cause soil compaction, destroy vegetation, distribute feed residues, leave manure. Animals also spread the seeds of weeds and enrich the soil with nutrients thus promoting the growth of untypical plant species, and the habitat is being degraded (Fig. 15.22). The influence of feeding on the habitat is long-lasting, and the consequences are difficult to eliminate.

15.1.5.7 Excessive visitor load

In constantly and intensively visited sites, the living groundcover is partially or completely destroyed due to excessive trampling and vehicle use. In these forests, logs and snags are almost or totally absent because they are collected and burnt in camp-fires. Relief of steeper slopes is altered due to erosion and vegetation trampling. In areas with high anthropogenic load, areas of bare soil are formed, and forest restoration may be necessary, although this does not mean that sand should be strengthened in every trampled site. Periodic disturbances can even be necessary for the maintenance of processes and structures characteristic for a dune forest.

15.1.5.8 Waste

Wooded dunes are being polluted with windblown waste from open dunes and the beach and also by municipal waste directly left by people. These are mostly bottles and a variety of plastic packages (bags, cans, etc.). In the surrounding of settlements, household appliances, supplies, waste bins and various other waste is also dumped in the forests. In addition, garden waste (compost) is disposed of at forest margins, for example, in Saulkrasti and Jūrmala. It promotes eutrophication with the subsequent introduction of invasive and atypical species. Mostly, habitats for

wooded dune characteristic species decrease, eutrophication increases, threats to species of plants and wild animals increase.

15.2 Restoration and management objectives for the conservation of wooded dune habitats

- The diversity of growing conditions and plant communities in wooded dunes is maintained, with particular attention to the increase of area and structure quality of dry pine forests, and to the promotion of *Pinus sylvestris* natural regeneration.
- Dynamics of coastal habitats is ensured, including wooded dunes, by the promotion of natural processes (sand overblowing and other disturbances).
- Favourable conservation status is ensured for wooded dune characteristic species and species protected in Latvia and the EU, and for their habitats.

15.3 Restoration and Management of Wooded Dunes

15.3.1 Non-interference

Usually, particular management measures are not necessary for the wooded dune habitat. Unmodified continuation of natural processes is optimal. Without interference, self-thinning occurs in the forest stand; the dune forest is influenced by fire and severe storms, which contributes to accumulation of dead wood which is an important substrate for saprophytic plants. Also for many species of invertebrates, fungi and species of other organism groups (saproxylophages), at least one of their development stages depends on the amount of dead wood. Large fallen branches in woodland are important for the development of particular insect species, including those who have symbiosis with orchids. In dune depression forests, a shaded and humid microclimate remains. In sites where the maintenance of natural processes is desired and it does not come into conflict with ensuring public interests, there is no need to interfere with natural processes.

In Latvia, like in other countries, coastal forests have been used for centuries for timber acquisition, recreation, hunting and other purposes. In the past, excessive use of the dune forests (felling, burning, overgrazing, etc.) caused shifting of the sand dune, thus endangering people's places of residence. This was the reason why open dunes were planted with forests. On the Latvian coast, it was done for more than a 150-year period. Nowadays, there are no shifting dunes in Latvia because all sands areas are afforested. A great part of young and mature dune forests are planted and intensively managed, and they often lack structures characteristic for woodland key habitats.

In such circumstances, management is needed. First, to maintain and restore insolation, poor soil conditions, sand overblowing characteristic for the habitat type. Second, to improve the stand structure for the preservation of species diversity, similarly to in all boreal forest habitats.

15.3.2 Imitation of Natural Disturbances – Prescribed Burning

Prescribed burning is a widely used forest management method in Scandinavia – to improve insolation and to decrease the groundcover and litter layer, thus providing living conditions for rare species. It is used in areas where wildfire has been absent for a long time, the moss layer is dense, characteristic groundcover lichen species have disappeared, and a dense litter layer has formed (Vanha-Majamaa et al. 2007).

In natural conditions, dry pine forests are characterised by woodland with pines of various ages, heights and dimensions, and a relatively open, sparse stand structure, formed under the influence of regular wildfire. In these forests, fires naturally recur once per 50–150 years depending on soil characteristics, topography, stand age and human influence and there are always patches not affected by fire over a long time. Nowadays, fire has been absent in most of the pine stands for more than 120 years – since intense wildfire control was started.

In preparation for prescribed burning it is important to take into account several aspects of fire safety

Prior to habitat restoration and management measures it is important to understand the current condition of the habitat, the main problems, their causes and desirable result. Only after a careful evaluation of the situation and fixing all possible obstacles, can one choose the appropriate methods, and be aware of both their advantages and disadvantages. More on the habitat status evaluation: Ikauniece (ed.) 2017.

in order to prevent an uncontrolled wildfire (Similä, Juuninen 2012):

- stand location – possibility to provide access to fire trucks (roads and passable tracks), possibility to restrict the area to be burnt;
- the location of the nearest water intake (preferably – as close as possible, less than 1 km); temporary water storage can be created in the vicinity of the managed area by excavation of a pit lined with polyethylene foil and filled with water;
- whether the possibility of crown fire ignition is prevented. If the advance growth and midstorey growth of spruces is present in the stand, or if the pine monoculture is too dense, the forest stand must be thinned. Thinning residues must be removed from the stand. If there is an insufficient amount of fuel material in the stand, part of the felling residues may be crushed and scattered on the ground. The mineralised zone should be established around the area to be burnt, and a "wet line" of groundcover along the outermost perimeter of the stand should be created;
- after the burning, continuous monitoring must be ensured for at least three days, and two more days occasionally if needed. More on prescribed burning: Ikauniece (ed.) 2017, *Chapter 10.*

Prescribed burning should be carried out when the organic layer and moss layer is dry enough to be burnt down to the mineral soil. If the fire influence is small, consuming only the moss layer surface (ground fire), burning must be evaluated as failed, and the targets have not been met.

15.3.3 Felling and Removal of Expansive Woody Species

Felling is needed in sites where there is obvious habitat eutrophication (atypically thick humus layer; stand structure uncharacteristic for the habitat: dense advance growth and/or midstory with deciduous trees, dense understory). This type of management is acute in urban areas, such as wooded dunes of Jūrmala City. Expansive woody species must be cut entirely. Felling residues must be removed, or incinerated directly in the habitat. Deciduous trees usually form stump sprouts, therefore at least 1–2 times a year, and later once every few years, sprouts should be removed – until they do not regenerate anymore. To prevent stump re-sprouting, stumps can be treated with herbicides. However, possible risks to the groundcover plant and invertebrate species must be evaluated before this. Deciduous trees must be cut as low as possible. To promote rapid decaying of stumps, they may be cross-notched.

It is recommended that fires that burn the felling residue are set on the stumps of cut shrubs and deciduous trees, and minor and medium-sized piles are burnt in wide fires that influence the widest possible ground area, combusting the moss and litter layer up to the mineral soil. Litter and sod must be removed, and topsoil loosened. Felling of expansive woody species should preferably be combined with the creation of bare sand patches.

15.3.4 Creation of Bare Soil Patches

Bare soil patches are an important prerequisite for the development of wooded coastal dune habitats in dry, nutrient-poor conditions. They are important habitats for plants and animals of pioneer communities. For economic reasons, it is recommended to use this method in areas where the use of prescribed burning is not possible, but it is necessary to uncover the mineral soil. A more beneficial effect on the decrease of individuals of rare species is expected if the habitat to be restored is located near the sites of these species localities, and vital individuals of these species are present, the seeds of which can reach the targeted area; similarly, in the case of invertebrate species.

Before soil scarification, it must be assessed whether it should be done together with creating a more natural stand structure by the creation of gaps and heterogeneous stand density. By hand tools or small tractors, groundcover, including vegetation and topsoil is removed, until the mineral soil is exposed. This work can be carried out in patches or strips. Patches should be of irregular shapes and various sizes, 25 m^2 in average. They can be arranged in mosaic in the forest stand or be concentrated to the habitat part which is closer to the localities of typical or rare species in the adjacent territory. The removed moss and humus layer must be transported away from the stand. It can be transported to the local municipal composting site and used for compost making.

15.3.5 Woodland Thinning and Gap Creation

The main objective is to create a mosaic, including open habitats with predominantly dry, poor, well insolated growing conditions (Fig. 15.23). Woodland would become more sparse and better insolated. This would promote the development of groundcover of lichens. Tree stands should be thinned in sites where prescribed burning is not possible because of various


Fig. 15.23. Gaps in dune forest in Vaide. Year 2016. Photo: Ē. Kļaviņa.

reasons. Thinning and gap creation relates mostly to pine plantations. The objective is to create heterogeneous stands with canopy gaps, with dense and sparse groups of trees, with a structure close to that of naturally developing woodlands. Gaps can be created of various sizes (from 20–100 m^2 or larger) (Viilma 2004). Trees can be cut in different habitat sites and with differing intensity. For example, when thinning of a 20–70 year old pine stand is planned, it is advisable to follow a number of conditions (Ikauniece (ed.) 2017:

- one hectare with two patches of an area of 0.1 ha where the tree number is decreased by 50% compared to the tree stand density, which should be left after commercial thinning, allowed by normative acts;
- one hectare with at least two patches with an area up to 0.05 ha, with an increased density structure;
- one hectare with two gaps with an area up to 0.2 ha, where all the trees are felled;
- patch configuration and arrangement is chosen depending on the specific site conditions;
- if trees of the previous generation are present, they should be preserved by felling younger trees in at least a 3 m radius;
- all logs and snags thicker than 25 cm and remaining from the former forest stand should be preserved;
- individual groups of spruces, birches and junipers should be preserved because they ensure and promote diversity.

In any particular location, felling must be carried out according to the individual management plan, initially identifying conservation objectives for species, habitat and landscape.

Felling residues can be removed or burnt directly in the managed site. If residues are not burnt, they must be removed from the stand, and they should not be left on transportation tracks. If they are burnt, it is recommended to form small to medium-sized piles and burn them in wide fires that influence the widest possible ground area, combusting the moss and litter layer up to the mineral soil. It is recommended to combine stand thinning with the creation of bare sand patches.

15.3.6 Felling of Exotic Tree Plantations

Latvia represents wooded dunes of the Boreal biogeographical region, and it is important to preserve plant communities with *Pinus sylvestris*, with their characteristic species, structures and functions. The question of the preservation of non-native tree species stands is controversial (*see Chapter 15.1.5.4*). They perform the functions of coastal protection, they are decorative, a lot of work is invested in their formation, and they have certain cultural and historical value, but they do not represent wooded dunes typical for Latvia. The question of the preservation or felling of exotic tree plantations is especially topical in protected nature territories. Potential risks which may result from felling or leaving such a stand should be assessed individually for each situation.

If it is decided to reduce exotic tree plantations, their trees must be cut and removed from the managed area or combusted directly in the site. The method of gathering and incineration of felled trees described in *Chapter 15.3.3* must be used. After felling, forest natural regeneration should be promoted or an open habitat suitable for grey dune formation should be maintained. If a dense litter and humus layer is formed, it should be removed, at least in some places, and burnt, or the litter and humus layer should be burnt, exposing bare sand patches to promote the seed dispersal of *Pinus sylvestris*.

15.3.7 Removal of Invasive Woody and Herbaceous Species

15.3.7.1 Removal of tree and shrub cover

Trees and shrubs of invasive species should be removed completely. This is especially topical to the *Amelanchier spicata* and *Rosa rugosa*. Management methods are similar to the methods used to combat local aggressive woody species (*see Chapter 15.3.3*). In places with wide stands, shrubs can be pulled out with the roots, but this is expensive and labour intensive. The removal of invasive woody species should be combined with the creation of bare soil patches.

Taking the high viability of invasive species (sprouts, soil seed bank) into account, management measures should be planned several years in advance. It is also important to evaluate the adjacent areas – to control invasive species dispersal outside the protected habitat. For more on methods – *see Chapter 14*.

15.3.7.2 Removal of invasive herbaceous plants

The most commonly applied method of invasive herbaceous plant control is mowing. It should be done regularly, until the species in the location are no longer present. Invasive herbaceous species must be removed before their seeds are ripe. *Impatiens glandulifera* can be controlled relatively effectively by mowing or hand-pulling. *Solidago canadensis* may be restricted by mowing several times a season. Plant biomass must definitely be removed from the area.

In addition to invasive plant species control it must be ensured that invasive species do not spread into the wild from gardens and greenery. The dispersal of these species in a given area must be controlled, and their planting in dunes and their vicinity must be stopped.

15.3.8 Restoration of Wooded Dunes

Nowadays, the afforestation of coastal dunes is topical only in small areas, mainly in areas of intense recreation or in settlements where wooded dune is degraded or even destroyed. In this situation, it is appropriate to use the research of the Institute of Forestry of the 1950s, on the afforestation of sands (Bušs 1960). To carry out afforestation, the sand movement should be stopped first. Sand strengthening is started from the prevailing wind side. If there are blowouts, it is sufficient to strengthen their sides, while deflation patches must be strengthened entirely. A simple and effective strengthening method is covering the shifting sand with branch cover, *Calluna vulgaris* (they adhere well to the ground) or junipers (persist for a very long time, up to 80 years), or the construction of fences (Bušs 1960). Both branch cover and fences also function as a barrier against excessive trampling. In such a covered area, the best solution is to allow the vegetation to self-regenerate. For more on the arresting of sand overblowing, see the guidelines for embryonic dunes and foredunes.

If it is decided to afforest sands artificially, only local tree species can be used, usually *Pinus sylvestris*. Planting of deciduous trees is not permissible because their litter promotes soil enrichment. Planting of introduced plants is not permissible because they outcompete dune characteristic species. There are various methods of soil preparation prior to planting. To strengthen dunes, sea weed, clay, manure, felling residues (bark, twigs, pine needles, etc.), peat, "mycorrhiza compost", embedded 30–40 cm deep, was also used (Mūrnieks 1951; Bušs 1960). Nowadays, container seedlings are used (Lazdiņa 2008).

15.3.9 Elimination of Animal Feeding Consequences

Animal feeding sites should be abolished by removing all roots, apples, grains or other feed. They must be transported away from wooded dunes. In the feeder site, the topsoil must also be excavated and transported away.

15.3.10 Establishment of Tourism and Recreation Infrastructure

To reduce the impact of coastal visitors to wooded dune habitats in territories with high visitor load, the establishment of tourism infrastructure is permissible and even necessary. Footbridges can be constructed in habitats with especially sensitive groundcover and with intense anthropogenic load, as well as in wetland areas (Fig. 15.24). Viewing platforms, towers and similar constructions are desirable to install because they concentrate vacationers in one place and at the same time redirect them away from other biologically valuable sites. It is also very important to plan and establish picnic sites (benches, tables, fire places, tent sites, etc.). Waste containers must be provided in such places. If a fire place is established, firewood must be provided regularly. Otherwise, logs, branches and trees are collected, thus damaging the dune forest habitat. In dune forests located in towns or other heavily visited sites it is mandatory to provide toilets.

Any infrastructure can only be established in agreement with the responsible national and local government authorities. It is important to assess the

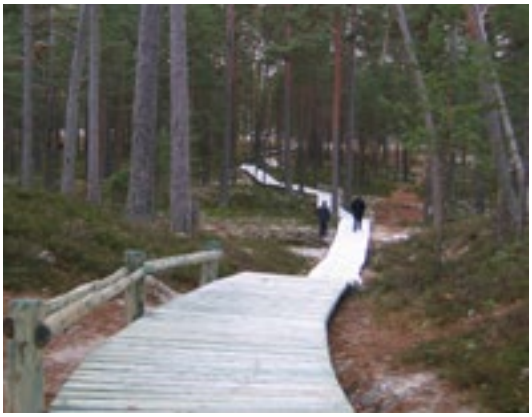


Fig. 15.24. Boardwalks should be adjusted to site topography and landscape, at the same time ensuring visitor safety and the preservation of old trees. Ķemeri National Park, Gausā Jūdze and Lapmežciems at the River Siliņupe, 2005. Photo: B. Laime.

possible benefits and losses in relation to biodiversity conservation and the assurance of people's quality of living.

Information signs, information boards, leaflets and booklets on nature values and the desired behaviour of visitors are necessary. Wherever possible, infrastructure should be established outside of localities of protected habitat or species. In little visited areas, the establishment of tourism infrastructure is not necessary, as it can cause additional load. For more on the construction of trails, *see Chapter 13.*

15.3.11 Conservation and Management Conflicts

Habitat management measures do not contradict the protection requirements of known rare and protected species, which depends on structures characteristic for mature trees or natural forest.

Chapter 16. 2190 *Humid Dune Slacks* (B. Laime, D. Pilāte)

16.1 Characteristics of habitat type 2190 *Humid dune slacks*

16.1.1 Brief Description

In a sea coastal dune complex, humid or wet habitats develop in depressions of dune systems where the groundwater level reaches the ground surface or is close to it. They are characterised by herbaceous or shrub vegetation on mineral and peat soils, and also by vegetation of freshwater water bodies (Houston 2008b; Rove 2013f). **These guidelines apply to habitats of humid dune slacks with pioneer communities, low vegetation and pools (hereinafter collectively referred to as humid dune slacks and humid dune slack habitats).** More on the mire vegetation, which may also occur in dune slacks and belong to the habitat type 2190 *Humid dune slacks*, and their management: Priede (ed.) 2017.

As a whole, habitat type 2190 *Humid dune slacks*, including dune slacks with mire vegetation, is a rare habitat type in Latvia, covering about 1,400 hectares, or 0.022% of the terrestrial part of Latvia (Anon. 2013c). They are only situated in the Coastal Lowland Geobotanical Region, mainly on the Latvian northwest coast and are related to the country's largest dune complexes (Fig. 16.1). The most significant locations of this habitat type are Ovīši–Lielirbe–Kolka surroundings, as well as in separate sections of the Nīca–Liepāja and Ģipka–Roja coast. Nowadays, most of the area of this protected habitat refers to dune slacks with mires, and dune slacks with pioneer communities remain in just a few sites.

Dune slacks may differ in their width, origin and age. They may be completely separated or partially separated from the sea. Due to seasonal fluctuations of humidity, dune slack can go from being waterlogged to dry, and the opposite. Slacks belong to the joint complex of coastal habitats, in which one of the most important factors is relief.

16.1.2 Important Processes and Structures

A key role in the development of humid dune slacks is played by the **hydrological regime, which in turn is closely related to dune relief** (dune height, position, slope gradient and other parameters) (Fig. 16.2). Other coastal processes are also significant: sand overblowing and new dune ridge formation, wave

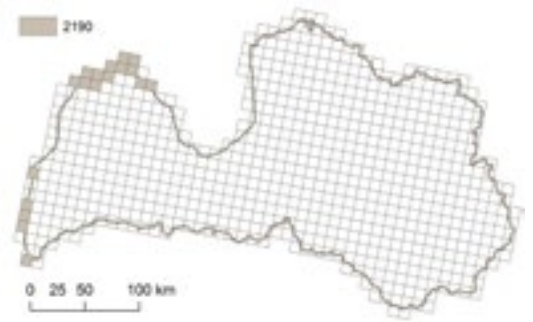


Fig. 16.1. Distribution of habitat type 2190 *Humid dune slacks* in Latvia (Anon. 2013c).

action, beach and dune erosion. In Latvia, it refers mostly to primary dune slacks in the coastal habitat complex consisting of low, poorly formed dunes and a low, wet beach. The connection to the sea is more characteristic for "open" slacks, the endings of which are at least periodically open. Here it is more likely that the slacks will flood more often. Sea water provides not only moisture but also brackish conditions. After severe storms, pools may develop and even persist for a long time. Such habitat development takes place, for example, in the coastal stretch between Roja and Žocene where two or three parallel slacks are formed. For the existence of such habitats it is important that the balance between sand accumulation and erosion is maintained for a long time.

Also, washed out shells are important for slack development. They are important prerequisites for the development of calcium-rich substrate and habitats for related species. Dune slacks rich with shells are formed mainly in coastal sections where large quantities of shells are constantly washed out on the coastal underwater slope and beach. One of the richest "shell sections" in Latvia is related to the Irbe Strait coast (Eberhards, Lapinskis 2008). Moisture regime of dune slacks is largely determined by weather conditions. Years with abundant precipitation and moderate temperatures are the most favourable. Dune slack hydrology is also influenced by its width and micro relief, surface water runoff on surrounding dunes slopes, and all of the catchment area as a whole. Also, the diameter of sand grains is important. The coarser is sand, the faster the water soaks into the substrate. Various humidity conditions, flooding and its duration are important for the development of moisture loving animal species (Anon. 2015a).

For the development of secondary dune slacks,


Fig. 16.2. Humid dune slacks with pioneer communities and humid grassland. Coasts of the North Sea, the Netherlands. Photo: B. Laime.


Fig. 16.3. *Sagina nodosa* can form sparse to quite dense stands in dune slacks in the initial stages of its development. Photo: B. Laime.

wind is of high importance because it takes the sand below the level of the water table. This process is significantly influenced by dune vegetation cover and exposure to prevailing winds. Dune slacks may also form if the groundwater level increases in the dune complex (Rove 2013f).

Annual fluctuations of the groundwater level in a young slack may be 50–100 cm, in an old slack – even up to 200 centimetres. Both meteorological conditions (precipitation, temperature) and coastal processes determine that the maximum humidity is in winter and early spring (Environment Agency 2010). Groundwater level and its fluctuations can be influenced by the vicinity of streams and their hydrological regime.

16.1.3 Natural Succession

Succession of dune slacks is determined mainly by humidity and nutrients in the soil. In early stages of succession, bare sand patches with pioneer communities are characteristic (*see Chapter 16.1.4*). More common are the moisture-demanding species *Sagina nodosa*, *Agrostis stolonifera*, *Centaurium littorale*, *Equisetum variegatum*, *Juncus* spp. (Fig. 16.3, 16.7). If variable, mostly humid growing conditions are maintained, other plant species characteristic for this habitat spread pretty quickly. During the early stages of succession, important habitats for several rare species are created (Rodwell 2000; Houston 2008b). One such species is the orchid *Liparis loeselii* (Fig. 16.18). Bare sand patches are important preconditions for their seed germination (Lammerts, Grootjans 1997; Roze et al. 2015). Such plant communities are sensitive to dropping of groundwater level (Houston 2008b).

Pioneer stages of dune slacks can be preserved for a long time in the presence of sharp fluctuations of groundwater level or disturbances which hinder further succession. When dune slacks become dryer, rather stable herbaceous plant communities

Fig. 16.4. Species-rich humid dune slack habitat. Drawing by D. Segliņa.

develop, dominated by plants characteristic for moderately humid grasslands. In pools of these slacks, humidity-demanding plants remain, such as *Epipactis palustris* and *Dactylorhiza incarnata* (Fig. 16.8). Such depressions gradually overgrow with *Salix* spp. and *Pinus sylvestris* (Laime, Pakalne 2001). Growing conditions become more humid, and the species of tall sedges establish. Such vegetation may persist for a long time. Succession is slow, and its final stage is most commonly humid forest of *Alnus glutinosa*.

16.1.4 Indications of Favourable Conservation Status

Open dune slacks, which are characterised by following indications, are most significant in terms of biodiversity:

- dominated by sparse, low herbaceous plants;
- are continuously or permanently humid or wet, and there are places where permanent or temporary water bodies are formed;
- vegetation is characterised by mosaic structure with a constant presence of pioneer species (Fig. 16.4);
- there are patches with bare mineral soil;
- annual plants are abundant;
- trees and shrubs are absent or few.

The wider and longer the dune slack, and the higher and more fluctuating the groundwater level, the slower the overgrowth of the slack with trees and shrubs, and the habitat conservation status is more favourable (Fig. 16.5, 16.6). There can be dune slacks with stands of low *Salix* spp. or *Myrica gale*.

Dune slacks are important for the conservation of several rare moss species such as of the genus *Bryum* spp. These mosses grow mainly in young slacks on bare, humid, calcium-rich sand (Houston 2008b). As regards flowering plants, characteristic species are *Primula farinosa*, *Carex flacca*, rarely *Schoenus ferrugineus*. Narrow-mouthed whorl snail *Vertigo angustior* can also be found in humid dune slacks. This species is very sensitive to environmental conditions, especially moisture regime changes (Cameron et al. 2003) (Fig. 16.9).

Humid dune slacks are one of the growth locations of *Juncus balticus* where *Centaurium littorale*,

Fig. 16.5 Humid dune slack with bare sand patches and sparse, low vegetation in Ovīši. Still used as a trail in the second half of the 20th century. Nowadays this slack overgrows with Scots pine. 2013. Photo: B. Laime.

Fig. 16.6. Grassland-like humid dune slack between low dunes in Roja. Photo: B. Laime.

Fig. 16.7. *Centaurium littorale*. Photo: A. Opmanis.

Fig. 16.8. *Epipactis palustris*. Photo: A. Opmanis.

orchids such as *Epipactis palustris*, *Cephalanthera rubra* and *Liparis loeselii* are also found in plant communities (Fig. 16.8, 16.18). Brackish dune slacks have a favourable growth environment for halophytic plant species such as *Glaux maritima* and *Trifolium fragiferum* (Fig. 16.10). Dune slacks with freshwater pools are an important habitat for amphibian species – natterjack toad *Bufo calamita* and common spadefoot *Pelobates fuscus* (Bērziņš 2008) (Fig. 16.11).

Dune slacks are significant elements of the natural coastal landscape. The value of dune slacks is higher in sites with characteristic dune habitat diversity and where other habitats of community importance are found such as 2130* *Fixed coastal dunes with herbaceous vegetation (grey dunes)* and 2140* *Decalcified fixed dunes with* Empetrum nigrum.

Fig. 16.9. A whorl snail. Drawing by D. Segliņa.

16.1.5 Pressures and Threats

16.1.5.1 Drainage

Drainage of adjacent dune slack areas causes lowering of the groundwater level. This reduces the proportion of wetland areas in the coastal dune habitat complex, and humid plant communities are replaced by dryer ones. Dune slacks with moderate humid growing conditions are the most influenced by drainage. In permanently or periodically wet dune slacks, vegetation is more persistent: species composition and vegetation structure are changing slowly.

As a consequence of drainage, dune slack overgrowth with *Pinus sylvestris*, *Betula pendula*, *Alnus* spp. and tall *Salix* spp. is accelerated (Fig. 16.12). Litter of woody species has a particularly adverse influence because it increases the nitrogen concentration in the soil. With the decrease of insolation and soil fertility, plant species of nutrient-poor, humid substrates disappear. Such changes adversely influence habitats of *Bufo calamita* and even cause their population extinction. Drainage very significantly influences *Vertigo angustior*. Whorl snails of this species as well as other humid habitat mollusc species disappear together with plant communities of humid habitats. With the development of coastal villages, drainage has been carried out a long time ago, to establish pastures and arable land. Drainage has been and still is an important prerequisite for the maintenance of the living environment of the local population. Therefore, the conservation of humid dune slacks is mainly possible outside of coastal villages – where the high groundwater level does not interfere with economic activities.

16.1.5.2 Land use change

Land use change can affect humid dune slacks in two ways. Direct influence destructs natural ecosystems

Whorl snails *Vertigo* spp. are small snails which are difficult to see in nature without specific soil sampling and laboratory processing. In Latvia, 11 species of genus *Vertigo* can be found. The majority of them (eight species) are found in wetlands (Rudzīte et al. 2010). Four wetland species are protected – *Vertigo angustior, V.moulinsiana, V.genesii* and *V.geyeri.* The size of *Vertigo angustior* is approximately 1.8 mm, it is a wetland species and inhabits not only dune slacks but also fens, periodically flooded calcareous grasslands and lakeshore fens, as well as wet depressions. The species is also found in humid forests on calcareous soils. Habitat humidity regime is very important for this snail species. *Vertigo angustior* also depends on particular plant species and their communities. These plants provide snails with feed.

Vertigo angustior lives in the plant litter layer and in mosses. If the soil surface is waterlogged, they climb onto the plant stems up to 10–15 cm in height. *Vertigo angustior* digs itself into the soil for the drought period; they spend winter in the groundcover. A large proportion of the whorl snails die in spring, when their habitat is waterlogged. *Vertigo angustior* reaches the population maximum in the second part of summer. The main prerequisite for the successful restoration of the population is suitable moisture conditions during the breeding period. *Vertigo angustior* lives for about 18 months. This species is threatened mainly by drainage, intensive grazing, habitat eutrophication and habitat overgrowth with shrubs and trees (Cameron et al. 2003).

Fig. 16.10. *Glaux maritima* is an indicator that characterises the favourable status of brackish dune slacks. Photo: B. Laime.

(construction of buildings, road construction, etc.). Indirect influence transforms the dune slack into another ecosystem, such as a forest or ditch. Land use changes are one of the reasons why open, sunlit sands landscapes suitable for *Bufo calamita* and pioneer vegetation have decreased (Bērziņš 2008) and also habitats of *Vertigo* spp. are being destroyed. In humid dune slacks, similarly to grey dunes, partly also in foredunes, afforestation was carried out in Latvia in the middle and second half of the 20th century. *Pinus sylvestris* were mainly planted, in some places also *Pinus mugo, Betula pendula* and *Alnus glutinosa* (Bušs 1960). This significantly accelerated natural succession and caused the disappearance of the dune slack pioneer species and degraded their habitat.

As relief is one of the most significant prerequisites for dune slack existence, any impact on relief can cause changes in habitat function. Interference also includes shifting of the dune ridge or other transformations. If intense sand overblow is created in a dune slack, humidity conditions change, which speeds up the overgrowth of trees and shrubs.

16.1.5.3 Management reduction or cessation

By the reduction of both traditional management (grazing, mowing) and dune slack use for other traditional purposes (fishing nets and boat repair), dune slacks lack disturbances that hinder their overgrowth. Use of dune slacks nowadays in Latvia has almost disappeared because grazing on coastal dunes including dune slacks has decreased to a few cases. If grazing is decreased, succession leads a species-rich habitat to a habitat much poorer in species (Houston 2008b). Consequences of management cessation also include the formation of a dead grass layer, dominance of expansive and invasive species and environmental eutrophication.

Fig. 16.11. *Bufo calamita*. 2006. Photo: V. Vilnītis.

Fig. 16.12. Lowering of groundwater level accelerates dune slack overgrowth. Trees cause shading and a thick litter layer which adversely affect species diversity of the dune slack. 2013. Photo: B. Laime.

16.1.5.4 Excessive visitor load

Excessive influence of vacationers and tourists hinders the development of pioneer vegetation of humid dune slacks. Persistent or too frequent human presence impacts *Bufo calamita* very negatively by disturbing its spawn and also by walking over its individuals and deteriorating the habitat condition (Bērziņš 2008). For sensitive plant species with small cenopopulations, like *Liparis loeselii*, the number of individuals and viability decreases.

Unfortunately, coastal tourism and recreation are increasingly being developed in protected nature territories, including nature reserves and nature reserve zones which are designated mainly for the conservation of protected habitats and species. For example, "Ovīši" and "Ģipka" nature reserves, and Slītere National Park. Visitor load in protected habitats should be reduced by offering tourist services in other sites.

16.1.5.5 Waste

During the last century dune slacks in many parts of the Latvian coast were used for military purposes. Still today a variety of military construction waste, cables, electric wires and other related objects can be found, causing pollution that can even periodically rise up if cables are unearthed and overspread. Chemical pollution that can be released into the environment from abandoned barrels, tanks and bottles is also dangerous. Waste, litter and related activities reduce the landscape value of dune slacks, and also the vitality of species, especially of characteristic animal species.

In dune slacks located close to the sea, periodically flooded with sea water, a variety of washed up items (glass bottles, bags, shoes, etc.) can be found. Objects windblown from the beach also create pollution. This negative influence is increasing because people visit the coast not only in summer but also in other seasons, like the autumn flounder fishing time.

16.1.5.6 Eutrophication

Compared to other European countries, nitrogen and phosphorus deposition in Latvian coastal dunes is relatively small (Remke 2009). As air pollution, including transboundary air pollution, is growing, nutrient abundance can also have a negative effect on the diversity of dune habitats and species on the Latvian coast. Environmental eutrophication increases due to intense anthropogenic pressure, especially in locations where toilets are absent.

16.1.5.7 Invasive plant species

Dune slacks and enclosing dunes, especially in their early developmental stages, are one of the most appropriate habitats for invasive plant species to become established. In dune slacks, there is more moisture, nutrients, often the interspecific competition is also low, and there are free ecological niches (Biseniece 2004; Rudzīte 2004). Consequently it is expected that invasive plant species expansion can occur very rapidly, destroying vegetation characteristic for dune slacks, and causing the disappearance of *Vertigo* ssp. (Cameron et al. 2003). The most aggressive invasive species in dune slacks are *Amelanchier spicata*, *Rosa rugosa* and *Hippophaë rhamnoides*. For more on the introduction of invasive species, *see Chapter 14*.

16.2 Restoration and Management Objectives for the Conservation of Humid Dune Slack Habitats

- Humid dune slacks with communities of moisture loving and calcareous plant species with a high proportion of annual plants species are preserved.
- Humid dune slacks with hydrological and other conditions suitable for populations of whorl snails *Vertigo* spp. are preserved.
- Humid dune slacks with freshwater pools and shallow water bodies significant for amphibian species are preserved.

16.3 Restoration and Management of Humid Dune Slack Habitats

16.3.1 Activities before Habitat Restoration and Management

Considering the sensitivity to changes of environmental conditions characteristic for humid dune slacks, every situation needs careful assessment. The main attention should be paid to the distribution of moisture loving and calciphilous species, their cenopopulation size and conservation. It is important to record ecological processes because this habitat in Latvia is rare and is relatively little studied.

A humid dune slack is a component of a coastal dune habitat complex. Therefore, restoration and management must be organised in larger areas, including grey dunes and dune depressions, in some places also foredune habitats. This applies, for example to Lielirbe, where *Salix* spp. overgrowth must be reduced in foredunes, trees and shrubs must be removed from grey dunes and humid dune slacks (Fig. 16.13).

Before the start of the works, the consequences

Fig. 16.13. Potential management area in Lielirbe where tree felling in the dune slack and surrounding grey dunes is necessary. 2014. Photo: B. Laime.

Fig. 16.14. In spring, winter and wet summers, pools develop in humid dune slacks. Roja. Photo: B. Laime.

of planned actions on whorl snails and amphibians must be assessed. Breeding and feeding seasons for bird species characteristic for this habitat complex must also be clarified. Expertise of a competent expert is obligatory.

When planning dune slack management, the conservation of adjacent habitats and the interests of the local population must also be taken into account. This applies mainly to coastal villages, where, in order to ensure economic activity, ditches were traditionally dug and special drainage systems were created, pastures and meadows were established alongside arable land. Nowadays, the restoration of the old system of ditches can be the priority in order to restore a traditional cultural landscape and related values. In this situation, the conservation of humid dune slack habitat will be difficult or even impossible.

In Latvia, dune slack restoration and management projects have not yet been implemented. To conserve this habitat, it is desirable to initiate a pilot project to test the experience gained in other countries such as the Netherlands and Denmark. For this purpose, humid dune slacks in Lūžņa could be used. They are partly overgrown but there are still characteristic species. Management must be planned outside the bird breeding season which is from about April to the end of July (depending on the site and year). For management to be successful, it is necessary to carry out research on dune slack characteristic species and their influencing ecological factors.

16.3.2 Non-interference

On coastal sections where low beach and gently sloping foredunes and primary dunes are characteristic and where dune slacks are periodically flooded, natural development of coastal processes must be promoted by avoiding strengthening and modifying coast as well as building construction there. For such coasts in Latvia, dune slacks with *Sagina nodosa* and *Agrostis stolonifera* as well as stable, grassland-like slacks with *Centaurium littorale* and *Juncus articulatus* are characteristic (Fig. 16.14). Also, in continuously wet dune slacks where a high groundwater level remains or where there are sharp annual groundwater level fluctuations, management is generally not necessary, except in dune slacks which is overgrown with trees and shrubs.

The strategy of non-intervention also applies to deflated slacks where humid, bare sand patches develop. Habitats in early successional stages are very important for the conservation of populations of rare mosses and amphibians. In this situation, anthropogenic load is the only factor that should be monitored. If it hinders the favourable development of habitat, management is necessary.

16.3.3 Removal of Trees, Shrubs and their Sprouts

Trees and shrubs must be cut throughout the managed slacks (Fig. 16.15, 16.16). To the extent possible they must also be cut in the surrounding grey dunes and foredunes. In slacks, all trees must be cut, leaving only solitary old, slowly growing *Pinus sylvestris* but only if they do not create a shadow on the dune slack. In some places, low-growing willows must be left, forming a mosaic of low willows, herbaceous plants and bare sand patches. After the felling of trees and shrubs, the managed area must be examined, sprouts and newly sown woody species must be mown. Seedlings can be pulled out. The local population can be involved in this "weeding" by means of joint work.

Felled trees and shrubs, as well as their branches

Fig. 16.15. In a dune slack where characteristic herb and moss species are preserved and overgrowth occurs, all trees and shrubs must be cut. Year 2013. Photo: B. Laime.

Fig. 16.6. In a dune slack where low willows dominate and which overgrows with trees, a vegetation mosaic must be developed by felling all the trees and part of the shrubs. In some places, bare sand patches should be created by groundcover removal. Year 2013. Photo: B. Laime.

and sprouts must be gathered and incinerated outside the managed habitats or transported away from the territory. They can later be used for chippings. If transportation is difficult and may adversely affect the dune relief and vegetation, trees and shrubs must be burnt as far away as possible from the dune slack, such as on the beach.

No chemical treatments can be used because they may contaminate the groundwater and cause a hazard to dune slack animals and plants. When planning habitat management, one should consider that felling of woody species must be repeated every year or every few years. Removal of trees and shrubs should be started in the earliest possible stage of overgrowth. With fewer trees and lower trees, it is easier to carry out works and also the costs are lower. For more on tree and shrub removal, *see Chapter 14.*

16.3.4 Litter Removal

Tree and shrub litter collection applies mainly to dune slopes at the dune slack edges and to the driest places in the slack. Litter, mostly pine needles, are collected with a rake, agricultural machines (small tractor with rake; horse drawn rake) or lawn mower. Litter must be gathered, seized and put in a collecting tank. Collected litter should be transported away from the managed area to a composting site. If this is not possible, litter can be incinerated in dunes or on the beach. Litter should not be burnt on the dune slack or on the surrounding dune from which ash could reach the slack. There is no need to collect litter if sod cutting is planned (*see Chapter 16.3.6*).

16.3.5 Removal of Tall Herb Layer

In sites where dune slacks are occupied by dense stands of tall herbaceous plants, it is recommended to cut these herbs and then start grazing (van Dijk 1992). On the Latvian coast, the mowing of *Phragmites australis* is often necessary (Fig. 16.17). The cut herbs must be gathered, incinerated in dunes or on beach, or transported away from the area (*see also Chapter 16.3.3*). In narrow, small dune slacks it is better to do this by hand, in larger slacks – by tractor. In order to reduce the proportion of tall herbs, their roots and rhizomes must also be collected and the soil surface removed (*see Chapter 16.3.6*). Similarly to sprouts of trees and shrubs (*see Chapter 16.3.3*), herbs also need repeated mowing.

Fig. 16.17. *Phragmites australis* cover removal is one of the priority works for dune slack vegetation restoration. 2014. Photo: B. Laime.

Fig. 16.18. *Liparis loeselii*. Photo: M. Pakalne.

16.3.6 Topsoil Removal

The objective of topsoil removal is to remove the fertile soil layer up to the sand bedrock. It is relevant in sites where bare sand patches do not form anymore, the humus layer increases, resulting in conditions that are unsuitable for the existence of pioneer plant species and *Bufo calamita*. With soil surface removal, dune slack characteristic species will also be excavated. To ensure the continuity of species, the soil surface can be removed in belts by excavating one part of the slack and leaving the other intact, thus serving as a refugee for animals and also preserving plant species. If the dune slack is isolated from the others and relatively small, and works can effectively be implemented throughout all of the slack, one may consider the possibility to restore species from the other closest location. In smaller areas, the soil surface can be removed in patches (0.25–1 m^2). This would give a greater guarantee that species will remain in their habitat. But one must remember that the objective of dune slack management is the formation of pioneer vegetation and not keeping the situation as it was prior to excavation.

Since this method also includes the removal of living groundcover and it can often be combined with dune slack deepening, risks related to the preservation of *Vertigo angustior* must be assessed. Any

Management of *Liparis loeselii* in dune slacks

Liparis loeselii long-term survival depends entirely on its regeneration from seeds, because during the vegetative reproduction the number of specimens remains unchanged – does not increase. *Liparis loeselii* seeds ripen in September and October and its seed spillage begins in March of the next year therefore it is recommended to move perennial herbaceous plants in February and March (Roze et al. 2015). Mowing should be combined with the creation of "regeneration niches" – strips of bare sand (Wheeler et al. 1998).

hydrological regime change in the habitat and its surroundings can only be allowed if no adverse effects on *Vertigo angustior* population can be expected (Pokryszko 1990; Cameron et al. 2003). To provide a favourable habitat for *Bufo calamita*, dune slack edges definitely have to be gently sloping (Bērziņš 2008). An expert must be invited to evaluate how much the slack can be deepened and how it will affect geological processes and the groundwater level.

We recommend using a tractor (mini-tractor) by which the topsoil can be pushed aside and gathered. The gathered soil must be transported away from the slack. Burning or other action that could enrich the soil with nutrients is not desirable. Works should be done by hand, using shovels and other appropriate tools in areas which are difficult to access. Topsoil removal can be difficult because of roots and stumps. To pull out the roots, special tools, equipment and additional resources will probably be necessary.

16.3.7 Invasive Plant Species Control

To eradicate invasive species in dune slacks, only mechanical methods like felling, pulling out or other mechanical destruction can be used. One of the greatest threats can be the aggressive moss species *Campylopus introflexus*, which outcompetes the pioneer species. If this moss species is found, immediate action is necessary: consultation with a moss expert to verify the species, removal of moss with a rake or other tool, transportation away from the protected nature territories, and incineration. For more on invasive plant species management – *see Chapter 14.*

16.3.8 Waste

The removal of waste is a topical issue in former military areas. First, unearthed cables must be removed because they decrease the value of the dune landscape and tourism resources. To collect such scrap (cables, wires, etc.), tools for cutting up scrap and preparing it for transportation are necessary. When collecting scrap, one cannot escape from influencing the habitat, but the related vehicle use is negligible and in some situations even beneficial for the restoration of dynamic dune processes. Household waste must be collected on a regular basis. The work should preferably be done in the autumn, winter or early spring to cause minimum disturbance to plant and animal species.

Fig. 16.19. Footbridges in Roja, along and across dune slacks. Photo: B. Laime.

16.3.9 Tourism Infrastructure Establishment and Management

Construction of recreation infrastructure in dune slacks is not recommended. Exceptions are sites where dune slacks are included in public recreational areas, such as the coast where recreation infrastructure is established by the Roja Municipality. In this case, to reduce the recreational pressure, the construction of boardwalks is advisable. Boardwalks must be raised 0.3–0.5 m above the ground level, and wide enough (1.5–2 m) (Fig. 16.19). Elsewhere, boardwalks made of wood or other materials should not be installed.

If a path across the dune slack is necessary and there are no alternatives for the location of the boardwalk, paths without a deck should be established. This will promote the preservation of the rare *Bryum* spp. species, by creating bare sand patches, reducing interspecific competition and maintaining vegetation in the pioneer stage or close to it (Holyoak 2003). The dune habitat system should be maintained as dynamic as possible (McCorry, Ryles 2009). However, if trampling becomes too intense and the vitality of typical plant species decreases, the established path must be temporarily closed by redirecting people to where a new path is established. The old path can be isolated, for example, by covering it with pine branches. A barrier and information board explaining the situation should be constructed. The redirection of paths is definitely necessary if there are locations of *Bufo calamita* (Bērziņš 2008) or *Vertigo* spp.

16.3.10 Management and Use Unfavourable for the Habitat Type

In planning, implementing and controlling habitat management, care should be taken to avoid adverse management and use of the habitat:

- any activities (road construction, ditch digging etc.), which may alter the groundwater level and influence geological processes including erosion, landslides and cliff collapses of dune slack slopes, thus adversely influencing the dune slack habitat;
- any activities which may lead to eutrophication of the habitat and its surroundings;
- excessive anthropogenic pressure that impairs habitat regeneration;
- construction building in dune slacks, thus reducing the habitat area;
- leaving removed plant cover (herbs, shrubs, trees) in the habitat;
- overgrazing and use of unsuitable livestock species and breeds for grazing;
- installation of wildlife and livestock feeding places in dune slacks or their vicinity;
- application of chemical products;
- any burning in the dune slack habitat;
- planting of trees and shrubs;
- introduction of invasive plant species in the habitat and its surroundings.

16.3.11 Conservation and Management Conflicts

By topsoil removal and slack deepening, locations of some rare plant, whorl snail and amphibian species can be destroyed (*see Chapter 16.3.6*). To avoid potential conflicts, conservation objectives and priorities must be set for every territory in a particular habitat.

Inconvenience could be caused by tree felling: movement of machines, noise, heaps of felled trees, stumps etc., and also scrap gathering. However, these effects can be viewed as temporary and minor, with little influence on nature conservation values of surrounding dune habitats.

Grazing as a method of dune slack management is not described in these guidelines, while in Western Europe it is widely used. Since dune slacks in Latvia are relatively narrow and small, intensive grazing could adversely affect *Vertigo* spp. and other rare dune slack species. However, if grazing is used, it needs to be extensive. The herd should be formed of animals of various ages, sex and breeds (Houston 2008b). In areas where *Vertigo* spp. are found, horses are best suited for grazing (Cameron et al. 2003).

Chapter 17. 4010 *Northern Atlantic Wet Heaths with* Erica tetralix (L. Auniņa)

17.1 Description of wet heaths

17.1.1 Brief Description

Ideally, habitat type 4010 *Northern Atlantic wet heaths with* Erica tetralix includes areas that are open or with individual trees, with overgrown areas dominated by ericaceous dwarf shrubs (Auniņa, Rove 2013). In Latvia, two variants of wet heaths are distinguished: 4010_1 typical variant – wet heaths with *Erica tetralix* (cross-leaved heath) and 4010_2: temperate Atlantic variant – wet heaths without *Erica tetralix* (Auniņa 2013) (Fig. 17.1, 17.2).

Fig. 17.1. Wet heath variant 1 (typical variant) with characteristic species *Calluna vulgaris, Erica tetralix, Trichophorum caespitosum, Molinia caerulea, Juncus bulbosus*, mosses *Sphagnum* spp., *Hypnum jutlandicum*. Photo: L. Auniņa.

Fig. 17.2. Wet heath variant 2 (temperate Atlantic variant): vegetation without *Erica tetralix*. Photo: L. Auniņa.

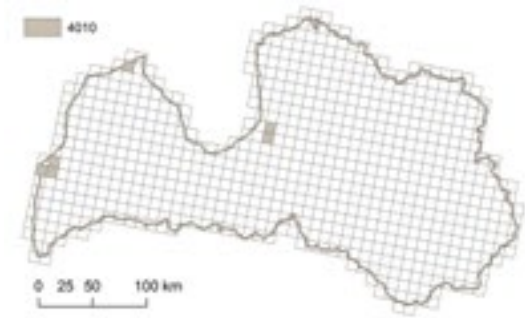


Fig. 17.3. Distribution of habitat type 4010 *Northern Atlantic wet heaths with* Erica tetralix *in Latvia* (Anon. 2013c).

The distribution of wet heaths is mainly related to the Baltic Sea coast, Piemare Plain, southwestern part of the Coastal Lowland (Fig. 17.3, 17.5). The largest areas of wet heaths are located in the Ādaži military training area. Possibly, some of them are bogs heavily affected by drainage and burning, in which a vegetation structure and plant communities similar to wet heaths are developed. Wet heaths in Latvia cover only about 1000 ha or 0.01% of the territory of Latvia (Anon. 2013c; Ķerus (red.) 2015).

Only heaths where the projective cover of fast-growing trees is less than 75% can be determined as habitat type 4010 *Northern Atlantic wet heaths with* Erica tetralix. However, the restoration of more overgrown heaths is also possible if characteristic plant species remain in the groundcover. This will likely be necessary because the most part of wet heaths in Latvia are overgrown with trees and therefore cannot be considered as open landscape, which is one of the main characteristics of wet heaths. Less overgrown wet heaths remain as small, less than 0.5 ha fragments, in complexes of periodically humid forests, bog woodlands or fens. Some of these forests have a history of wet heaths, grasslands or fens. Latvian wet heaths no longer belong to agricultural lands. They do not form a mosaic with semi-natural grasslands and arable lands as it was several hundreds of years ago. At the beginning of the 20th century, wet heaths together with grasslands, fens and sparse, periodically humid pine forests, formed a typical landscape of the Piemare Plain (Fig. 17.4).

According to the national soil classification of Latvia (Kārkliņš 2009), within the historical distribution area of wet heaths in Piemare Plain, soil can be classified as mucky – humus podsolic gley soil in most humid sites and humi-podzolic gley soil in drier

Fig. 17.4. Mosaic of wet heath and semi-natural grasslands in the Piemare Plain. Ziemupe, beginning of the 20th century. Topographic map of the Latvian Army General Staff, 1929.

Fig. 17.5. Nowadays, the same area (Fig. 17.4) is a mosaic of small, partly overgrown wet heaths, forests and fens. Topographic map of Latvia, LGIA, 2008.

sites (according to FAO – Spodic Histic Gleysol). In most humid sites, around a 10–25 cm thick peat layer is formed. A distinctive ortstein (hardpan) horizon is frequent. These soils are acidic, low in nitrogen and phosphorus, periodically waterlogged (Salmiņa (red.) 2007). Deeper layers of sand contain a lot of lime, because there are dolomites below the sea sediments (Gailis 1958). Therefore in lower locations, such as fens, where the groundwater level is close to the soil surface, species characteristic to calcareous substrates can also be found.

17.1.2 Processes and Structures Important for Wet Heaths

17.1.2.1 Processes

Together with wet grasslands, fens and sparse woodlands, wet heaths often form an ecologically joint habitat complex the existence of which depends on management of these habitats, as well as on climate change and human activity outside the habitat. At the beginning of the 20th century, management in Ziemupe and Saka surroundings mainly included grazing, mowing and controlled burning. Its aim was to improve pasture quality (Gailis 1958). Unmanaged wet heaths gradually overgrow with trees and shrubs, and their characteristic species disappear.

Another important process in wet heaths is perio-

Grīnis is a 5–10 km wide and about 12 km long zone along the Baltic Sea coast between Pāvilosta, Saka and Ziemupe (Gailis 1958), as local inhabitants call it. In poor *Pinus sylvestris* forest, fragments of wet heaths are mostly preserved. Although this term originated as the name for the landscape, nowadays poor *Pinus sylvestris* forest is generally understood as one of the forest types of Latvia, which can be found on periodically humid, highly podsolic gley and sandy soils. Such soils frequently have indications of ortstein in illuvial horizon. In poor *Pinus sylvestris* forest, sparse *Pinus* spp. and *Betula* spp. prevail in the tree layer, the understory is composed of junipers (Bušs 1981).

Fig. 17.6. Vegetation of wet heath with old pines. Photo: L. Auniņa.

dic rising of water table that alternates with periods of drought, and therefore peat formation in heaths is hindered. The peat layer in wet heaths does not exceed 30 centimetres. In sites where the peat layer is thicker, species characteristic for constantly waterlogged conditions dominate. There is no pronounced groundwater level decrease in the driest months, and mire develops. With the drainage of mires, heaths and adjacent areas, groundwater level fluctuations increase, causing a decrease in cover of *Sphagnum* ssp. and other species of humid substrates. In such circumstances, the cover of brown mosses and *Molinia caerulea* increases.

17.1.2.2 Structures

Wet heaths in Latvia are dominated by various dwarf shrubs, mainly *Calluna vulgaris*, *Erica tetralix*, *Empetrum nigrum*. Common herbaceous plants are *Molinia caerulea*, *Eriophorum vaginatum*, *Carex nigra*. A moss layer is moderately to well developed, formed by *Sphagnum* spp. and brown mosses. In most wet sites, bare peat patches are sometimes formed. The layer of trees and shrubs in Latvian wet heaths is usually distinctive (50–70%), and should be reduced. Open wet heaths and heaths with a low cover of trees and shrubs are rare in Latvia (Fig. 17.6). Ideally, *Erica tetralix* and *Calluna vulgaris* should be present in wet heaths in all stages of their development, but such a situation cannot be found in Latvia. In Great Britain, the aim of wet heath favourable conservation status includes: cover of dwarf shrubs 25–90%; dwarf shrubs in all stages of their development; bare soil cover 1–10%; bare soil with signs of disturbances <1%, *Molinia caerulea* is not present, sphagnum cover > 10%. At least one herbaceous species must be abundant, and one – found in several places. If there are lichens, they must cover more than 5%. At least two dwarf shrub species must be frequent (Hewin et al. 2007). To set objectives for wet heath structures in Latvia, most of the wet heaths must be surveyed, and these criteria must be evaluated.

17.1.3 Natural Succession

Habitat type 4010 *Northern Atlantic wet heaths with* Erica tetralix has developed secondarily, mostly under the influence of human activities – felling or burning woodlands in sandy areas, with subsequent grazing or keeping them open by other methods. Heather formation and existence are equally affected by abiotic, biotic and anthropogenic (human influen-

Fig. 17.7. *Erica tetralix* is a rare species in Latvia, found only in the western part of the country, in a belt of a few kilometres along the Baltic Sea. It grows in wet heaths, periodically humid coniferous forests, fens, as well as in nutrient-poor moderately humid semi-natural grasslands. In the Atlantic Europe, especially in Great Britain, it is a common plant species in appropriate habitats. Photo: Ē. Kļaviņa, L. Auniņa.

ce) factors. Wet heaths in Latvia develop in periodically humid, acidic to slightly alkaline, nutrient-poor sandy soils. In the climatic conditions of Latvia, the anthropogenic factor is most important for the existence of heaths. In the process of natural succession, wet heaths overgrow with shrubs and trees. Possibly, some of the periodically waterlogged forests (woodlands of poor *Pinus sylvestris* forest type) of Saka and Ziemupe surroundings are the former wet heaths. Some of them could meet the criteria of habitat types 91D0* *Bog woodland* (Bambe 2013), some – 9070 *Fennoscandian wooded pastures* (Lārmanis 2017).

17.1.4 Indications of Favourable Conservation Status

Ideally, wet heaths are characterised by a mosaic of dwarf shrubs, grasses and sedges as well as bare peat patches, without a significant cover of trees and shrubs. Characteristic plant species are *Calluna vulgaris*, *Erica tetralix*, *Molinia caerulea*, *Trichophorum caespitosum*, *Myrica gale*, mosses *Sphagnum compactum*, *Sphagnum capillifolium*, *Sphagnum contortum*, *Sphagnum subsecundum*, *Sphagnum papillosum*, *Hypnum jutlandicum*, lichens *Cladonia* spp. Other common species are *Salix rosmarinifolia*, *Vaccinium vitis-idaea*, *Vaccinium uliginosum*, *Juncus bulbosus*, *Eriophorum vaginatum*, *Carex panicea*, *Carex nigra*, *Potentilla erecta*, mosses *Leucobryum glaucum*, *Lophozia ventricosa*, *Ptilidium ciliare*, *Cephaloziella* spp., *Fossombronia* spp., *Calypogeia* spp.

There are butterfly species related to *Calluna vulgaris* or to heath species, which are found in Grīņi Strict Nature Reserve. These species could be considered as wet heath characteristic species. They are *Plebejus argus*, *Plebejus optilete*, *Lycophotia porphyrea*, *Xestia castanea*, *Eupithecia goossensiata* (Salmiņa (red.) 2009). Species of other organism groups characteristic to wet heaths in Latvia have not been studied.

Indications on the favourable conservation status of wet heaths are:

- habitat area is increasing or at least not decreasing;
- vegetation is mosaic-like without a marked dominance of a single species;
- *Calluna vulgaris* in all stages of its development can be found;
- there is *Erica tetralix* of various ages present;
- there are bare soil patches of a few square metres;
- *Molinia caerulea* is absent or its cover is low;
- habitat characteristic species are present;
- open landscape prevail;
- optimal hydrological regime is characteristic for habitat – groundwater level with minor seasonal fluctuations.

17.1.5 Pressures and Threats

17.1.5.1 Cessation of extensive management

With the cessation of extensive management of poor *Pinus sylvestris* forests, wet heaths gradually convert into woodlands. Heaths mostly overgrow with *Pinus sylvestris* and *Betula* spp. The age structure of *Calluna vulgaris* and *Erica tetralix* becomes uniform. Vegetation becomes homogeneous, without a mosaic structure.

17.1.5.2 Land use change

Significant areas of previous wet heaths in Latvia are afforested (Gailis 1958). It was even continued up to the late 1980s, after management cessation or after wildfires. Part of the wet heaths was likely transformed into arable land. Possibly, such areas are located in Ziemupe, besides woodlands with fragments of wet heaths.

17.1.5.3 Drainage

Drainage causes alteration of the wet heath moisture regime. Wet heaths in Latvia are characterised by a moderately high groundwater level, which ranges from 0 to 1 m in depth, depending on rainfall and the influence of drainage. Groundwater level fluctuations in drained wet heaths are significantly higher than in undrained wet heaths. In well-drained wet heaths, the water level never exceeds the soil surface, remaining at least 5–6 cm below the soil surface even in spring, autumn and winter, when water is abundant. In the dry period of summer – July and August – the groundwater level is about 1 m in depth. In undrained heaths, even in the driest months of the year, a water table above or at ground level can be observed. In the case of a stagnant water table which is up to 5 cm above the ground level, groundcover is continuously wet and waterlogged. During long periods without precipitation, the water table even goes down to 40–50 cm below the ground surface, and the heath dries up. After the first severe rainfall in summer, the soil surface and groundcover rapidly become waterlogged (Auniņa (red.) 2014).

Due to drainage, species uncharacteristic to wet heaths become established, while the abundance and cover of characteristic species decrease. The cover

of herbaceous plants, especially *Molinia caerulea*, increases, *Sphagnum* spp. cover decreases, brown moss cover increases. Trees and shrubs become established. If grazing or other management is ceased in such heath, it rapidly converts to woodland.

17.1.5.4 Eutrophication

Similarly to mires (Priede (ed.) 2017), wet heaths can also be influenced by eutrophication, which causes the extinction of wet heath characteristic species and excessive dispersal of grasses. For example, a significant decrease of *Erica tetralix* cover in wet heaths in Denmark is explained by an increase of atmospheric nitrogen deposition over a 50 year period (Damgard et al. 2014). In contrast to many other European countries, during the last 35 years in Latvia, a very high concentration of atmospheric nitrogen deposition has not been observed. Atmospheric nitrogen deposition in Latvia has no significant impact on sensitive habitats (European Environment Agency 2016).

17.1.5.5 Herbivores and pathogenic organisms

In heaths, *Lochmaea suturalis* can be found. In years of its outbreak, it can destroy the majority of heather, because its larvae feed upon leaves and small twigs of heather, eating them up completely. Sometimes larvae also feed upon *Erica tetralix* (Pakeman et al. 2002). Most of the heather is later unable to withstand drought or frost, and withers. In addition, their further regrowth is weak (Pinder et al. 2015). So far, outbreaks of *Lochmaea suturalis* have not been observed in Latvia while it is a regular occurrence elsewhere in Europe. Following beetle attacks, the heath can transform into grassland, because *Calluna vulgaris* regeneration is sometimes slow, and it is outcompeted by gramineous plants (Berdowski, Zeilinga 1987).

In European plant nurseries, pathogens *Phytophthora ramorum, P. kernoviae* and others are detected. They can infect plants of the heather family and cause their die-back (Potter et al. 2011). Leaves of the infected plant turn brown, and plants wither (CSL 2006). *P. ramorum* was detected for the first time in Latvia in a plant nursery assortment in 2007 (Freipiča 2007). These pathogens have not been found outside of plant nurseries in Latvia. It is believed that only plants with injuries are sensitive to this pathogen (CSL 2006).

Fig. 17.8. *Withered Calluna* vulgaris in wet heaths of "Sakas grīņi" Nature Reserve, August 2008. Photo: L. Auniņa.

17.1.5.6 Low winter temperatures and frost without snow cover

Climatic factors are important for heath development because *Calluna vulgaris* and also *Erica tetralix* often die off under low air temperatures if they are not covered by snow. *Erica tetralix* is able to withstand temperatures up to -22°C (Bannister, Polwart 2001) or even lower, as may occur in Latvia.

Also, prolonged drought adversely affects the development and germination of these species (Symes, Day 2003). *Calluna vulgaris* can wither extensively in the winter in conditions of long-term frost without snow cover. Most likely, this is the reason why patches of dead *Calluna vulgaris* were found in the western part of Latvia in 2008, including in "Sakas grīņi" Nature Reserve and Grīņi Strict Nature Reserve. In "Sakas grīņi" Nature Reserve *Calluna vulgaris* recovery has not occurred during seven years. Their place is occupied by abundant *Molinia caerulea* (Fig. 17.8). It is possible that *Calluna vulgaris* will not dominate here anymore because there are no free niches for the dispersal of these species. At the same time, the *Erica tetralix* population in this nature reserve is not affected by frost.

17.2 RESTORATION AND MANAGEMENT OBJECTIVES IN WET HEATH CONSERVATION

- Mosaic landscape of wet heaths, fens and sparse woodlands with vital populations of respective habitat characteristic species and with good habitat structure and area of habitat type 4010 *Northern Atlantic wet heaths with* Erica

tetralix especially typical variant is increased in Latvia, compared to the year 2013.
- The hydrological regime in wet heaths is optimal for their management by conserving nature values, and for their long-term existence.
- Wet heath landscapes have become a valuable tourist attraction and are used in beekeeping.

17.3 Restoration and management of wet heaths

17.3.1 Restoration of Significantly Degraded Wet Heaths

In Latvia, wet heath restoration is very topical. They must be protected from extinction, and even highly degraded wet heaths are included, because high-quality wet heaths no longer exist in this country. To ensure the conservation of habitat type 4010 *Northern Atlantic wet heaths with* Erica tetralix, all the landscape elements characteristic for Piemare Plain must be restored because due to the natural conditions, wet heaths have likely never occupied large continuous areas. When evaluating the abundance and quality of habitat type 4010 *Northern Atlantic wet heaths with* Erica tetralix in all the protected nature territories where this habitat is still present, "Ziemupe" Nature Reserve is the most appropriate place to restore the landscape complex. Here, fragments of wet heaths are interspersed with fens and poor *Pinus sylvestris* forest type woodlands. Compared to other areas, in "Ziemupe" Nature Reserve they cover the largest area. Moreover, all the wet heath characteristic species are abundant here.

First, it is necessary to clarify the historical management of poor *Pinus sylvestris* forests in Ziemupe and Saka surroundings. Then the most suitable areas for habitat restoration must be selected and a management plan elaborated, which includes the assessment of potential risks and alternatives. A specific management objective must be set for every site.

17.3.2 Rewetting

In well-drained sites, the necessity for rewetting must be evaluated. Is it necessary to preserve or even restore small, shallow ditches which were created a hundred or more years ago with the aim to create conditions suitable for heath grazing? It must also be assessed if the restoration of these ditches impairs the conditions of adjacent humid habitats, such as bog woodlands and bogs. Nature conservation priorities and management objectives must be set for every particular site. More on the rewetting and decision-making: Priede (ed.) (2017).

For the restoration of the wet heath hydrological regime, the same methods are used as for bogs and bog woodlands – dam construction on ditches and ditch infilling (Priede (ed.) 2017). Ditch infilling is a more effective method because its result stays for a long time, compared to dams which will most likely need to be repaired in the coming years.

17.3.3 Felling of Trees and Shrubs

Selective felling of trees and shrubs, in order to establish open landscape or landscape with sparse trees, is one of the first measures for wet heath restoration. If the overgrown heath is woodland, then its felling is permitted for the restoration of wet heaths with *Erica tetralix* (*see Chapter 6.3*).

Fig. 17.9. In "Ziemupe" Nature Reserve trees and shrubs were selectively cut, creating a park-like landscape. Photo: L. Auniņa.

Fig. 17.10. Felled trees are stacked in a pile and left in the woodland. Photo: L. Auniņa.

According to studies carried out in Latvia, felling of trees and shrubs without the further resumption of grazing can only be accepted in sites dominated by *Calluna vulgaris, Erica tetralix,* and *Sphagnum* spp. in the moss layer, with low cover of *Molinia caerulea* (Fig. 17.9). In sites with a prevailing cover of *Molinia caerulea*, its cover further increases after the trees and shrubs are cut down. Moreover, shrubs and deciduous trees regrow. The increase of wet heath characteristic species increases or is stable only in sites with distinctive *Sphagnum* spp. cover (Auniņa (red.) 2014). Ideally, grazing should be started after the felling of trees and shrubs.

Habitat management experts from Great Britain recommend to pull out shrubs with a winch, using a tractor, quadbike or other machines, thus creating bare ground patches (Symes, Day 2003), because bare, periodically waterlogged soil is suitable for wet heath plant species such as *Juncus bulbosus*, *Drosera* spp., *Lycopodiella inundata* and others. It is not recommended to use heavy machines, because it can create deep tracks, which serve as drainage ditches. Felled trees and shrubs must be transported away from heaths or incinerated directly in the managed site because they bring additional nutrients to the heath. They can be stacked and transported away gradually (Fig. 17.10).

For more on the felling of trees and shrubs, *see Chapter 18.3.3*, Priede (ed.) 2017, Chapter 15.3.7).

17.3.4 Topsoil Removal

Topsoil removal diversifies the habitat structure and creates ecological niches for species richness. In Latvia, topsoil removal is only necessary in heaths with a pronounced effect of drainage where the soil surface is heavily mineralised, the cover of *Molinia caerulea* is high and the cover of other wet heath characteristic species is low.

Some authors recommend removing all the mineralised peat layer, leaving only a 1–2 cm thick layer of peat. This reduces the nitrogen concentration in soil and creates niches for plant species characteristic for wet heaths, such as *Lycopodiella inundata* and *Juncus squarrosus* (Jacquermart et al. 2003).

Most often, topsoil is removed in small, for example 15 x 10 m patches. Topsoil can be removed by hand, cutting it out with a shovel. However, it is labour intensive and hence expensive. Work carried out with an excavator is more effective. In small areas where it is possible to enter with heavy machines, a mini-excavator is efficient. It does not influence vegetation significantly, does not create deep tracks and other adverse effects. When uncovered patches overgrow, new patches are created elsewhere in the heath.

If topsoil is removed in larger areas, it should be planned in advance where to put the removed layer. In earlier times it was used for field fertilisation but nowadays it is difficult to find a practical use for it. Transportation of removed topsoil away from the area requires additional costs. It is possible to desiccate topsoil directly in the habitat and incinerate it later. Topsoil can also be dispersedly arranged in an adjacent habitat, but it will lead to an additional input of nutrients to the site.

Topsoil removal in Latvia must be complemented with rewetting to promote the establishment of wet heath species because there is a risk that gramineous plants and dwarf shrubs (like *Vaccinium vitis-idaea*) will spread on dry peat, and the habitat situation will not improve.

17.3.5 Prescribed Burning

Prescribed burning is used to restore wet heaths before the restarting of grazing if the area is dominated by old and woody *Calluna vulgaris*. However, some studies have shown that burning of old *Calluna vulgaris* does not encourage heather vegetative regrowth because their dormant buds are already woody (Allchin et al. 1996).

It is not recommended to burn wet heaths with marked *Sphagnum* cover because it can be destroyed. In Great Britain, heaths are usually burnt in late winter, when the soil and moss layer are still wet. Then only the thick layer of heather twigs is burnt, but roots and seeds in the soil seed bank are unaffected (Symes, Day 2003). If the heath is dominated by dwarf shrubs, vegetation succession after burning includes a temporary stage with grasses. Most often, *Molinia caerulea* dominates a few years after wet heath burning. Then dwarf shrubs should dominate again (Aerts 1993). It is recommended to burn in strips, and to avoid grazing there for some time (a few years), to promote vegetation regeneration (Sedlakova, Chytrý 1999). Small, for example, 5 × 5 m or 10 × 10 m squares, can also be burnt, thus creating a mosaic of bare soil patches.

However, even prescribed burning has a number of risks. Part of the wet heath species, like *Calluna vulgaris* and *Erica tetralix*, have adapted to burning. They both regenerate successfully and also propagate by seeds. Other species, like *Sphagnum* spp., may die during a strong fire, and their recovery may be slow (Symes, Day 2003). After burning, *Betula* ssp. can spread.

In dry heaths, the recommended interval between burning is 15–30 years, until *Calluna vulgaris* reaches the end of the maturity phase, and it depends on the *Calluna vulgaris* growth rate in a given place. In wet heaths, a shorter interval is recommended because of the faster accumulation of plant litter, especially if *Molinia caerulea* is abundant (Symes, Day 2003). Other authors recommend avoiding prescribed burning if the *Molinia caerulea* cover exceeds 20–30% (Backshall 2001).

In Latvia, fragments of wet heaths located outside the Ādaži military training area are characterised by moderate cover of *Calluna vulgaris*. Therefore, careful examination of whether prescribed burning is optimal in a particular site, is necessary. Such burning would preferably be done in sites with vital stands of *Erica tetralix* because burning promotes its propagation by seeds, thus creating suitable conditions for germination (Bannister 1966).

In the climatic conditions of Latvia, the preferred time for burning would be early spring, late April or May, or even early summer because in winter the ground is covered with snow. Wet heath burning should be started with a small-scale experiment. Vegetation changes after burning depend on many factors – fire intensity, vegetation composition, season, substrate humidity, wind strength and direction, size of burnt area etc. However, if burning is not followed by grazing, there is risk that *Molinia caerulea* will become abundant, and it will outcompete wet heath characteristic species. For more on prescribed burning, *see Chapter 18.3.2*.

17.3.6 Traditional Management

17.3.6.1 Heaths as agricultural land

Until the early 20th century, heaths in Europe were a significant part of the agricultural land. Their management was closely linked to the management of adjacent areas, which were mostly grasslands, woodlands and arable land. Heather management slightly differed in various regions but the main type of use was grazing. Heaths were burnt occasionally and in mosaic, to promote the development of young sprouts which animals ate more willingly than old heather. The surface of the peat layer was cut and later used as manure for adjacent arable land, together with animal dung. Heather was mown and used for roofing and bedding. Such management contributed to the establishment of diverse microhabitats (Gimingham 1978; Webb 1998). It is estimated that in heath areas, 2 hectares of grasslands and 9 hectares of heaths were needed to maintain 1 ha of arable land. With the use of fertilisers, the need for heaths decreased and their area gradually decreased (Jeannette 1999). Nowadays in Europe heaths are surrounded by wide areas of intensively managed agricultural land, and such complex traditional management is rare. Therefore, it is difficult to restore and maintain all microhabitats and the species diversity of heaths.

Below, the most common methods for wet heath management, restoration and conservation will be listed, and the possible use of these methods in Latvia will be evaluated. Whichever method is selected for wet heath management, it is important to observe vegetation changes and revise management if vegetation does not develop as desired.

17.3.6.2 Grazing

Grazing is still considered the main and most important heath management method because it creates various microhabitats and arrests heath overgrowth with trees and shrubs. In the planning of grazing, the following must be taken in account: (1) quality of heath, (2) other necessary management such as prescribed burning, (3) population size of wild herbivores, (4) animal species most suitable for grazing and their number per hectare, (5) duration of grazing period (Symes, Day 2003).

Nowadays, when heaths are most often managed for their nature value conservation and not for agricultural purposes, it is recommended to use several animal species in one area because each of them creates another effect on the heath vegetation structure (Rūsiņa (ed.) 2017, *Chapter 22.3.1*). Although it is believed that heather grazing with a small number of animals (0.2 livestock units per hectare) is better, there are studies that show that such grazing, even if heaths are grazed throughout the year and without fencing, does not give the desired result, as sometimes it cannot arrest establishment and growth of woody species in heaths. In this study, grazing intensity in summer was 30% higher than in winter (Bokdam, Gleichman 2000). Parallel to grazing, it is recommended to use prescribed burning, thus creating microhabitats (Gimingham 1981), and also the felling of young trees or mowing their sprouts. Grazing can be started with a smaller number of animals per hectare, and increased gradually if necessary (English Nature 2005), or vice versa – start with a larger number of animals and then reduce it (Symes, Day 2003). It is very difficult to know in advance how many animals and which species would be used for wet heath grazing, and for how long. Therefore, the approach

should be flexible, and additional costs should be taken into account. Most likely, grazing intensity should be higher in sites with high cover of *Molinia caerulea* than in sites where the plant species composition is already close to that which is desired. Pastures are traditionally enclosed. It is not always necessary to enclose a large area. Small enclosures can also be used, and moved if necessary. Thus, vegetation can be grazed to the necessary structure. Later, animals can be moved to another pasture area (English Nature 2005). Red deer can also be used for heath and grassland grazing (Virtanen et al. 2002), but the high fences are an obstacle to wildlife.

In Latvia, grazing renewal in heaths is hindered by the fact that fragments of wet heaths are located in woodlands, far away from farmland, and the species composition of wet heath, fens and woodlands is unlikely to provide sufficient resources for livestock feed. Adjacent fens are dominated by a variety of sedges, mainly *Carex lasiocarpa* and *Carex hostiana* that are not rich in nutrients. In woodlands, a dominant grass species that animals could eat is *Molinia caerulea,* which cattle eat mainly in the spring and early summer (English Nature 2005). However, there are cattle breeds which, if grazing all year round, eat *Molinia caerulea* in winter as well, thus successfully reducing its cover (Symes, Day 2003).

For more on grazing also see the Chapters on dry heaths (*see Chapter 18.3.6*) and on mire habitats (Priede (ed.) 2017, *Chapter 15*).

17.3.6.3 Mowing

To facilitate *Calluna vulgaris* regeneration, mowing is recommended in wet heaths where *Calluna vulgaris* has reached the maturity (Symes, Day 2003). At the same time it is emphasised that *Calluna vulgaris* over 6–10 years old does not recover well after mowing (Miller, Miles 1970; Sedlakova, Chytrý 1999). In turn, there is no need to mow *Calluna vulgaris* which regenerates well vegetatively. For the reduction of *Molinia caerulea* cover in heaths, the efficiency of mowing is low (Jacquermart et al. 2003).

So far, the study in "Sakas Grīņi" Nature Reserve in Latvia, shows that *Calluna vulgaris* in wet heaths regenerates poorly, and its place is taken by *Molinia caerulea*, *Vaccinium vitis-idaea* and *Vaccinium uliginosum* (Fig. 17.11, 12.17, 17:13) (Auniņa (red.) 2014). Similar results are observed in the Czech Republic, where *Calluna vulgaris* in dry heaths recovered poorly after mowing (Sedlakova, Chytry 1999). In 2015, even *Calluna* spp. which had regenerated wilted due to unknown reasons. So, old heather mowing in wet heaths is not advisable. However, if this method is used, it is recom-

Fig. 17.11. Wet heath before mowing (2004), "Sakas Grīņi" Nature Reserve. Dominated by *Calluna vulgaris*; abundance of gramineous plants is low; small *Betula* spp. and *Pinus* spp. are abundant. Photo: L. Auniņa.

Fig. 17.12. Vegetation development in a wet heath two years after mowing (2008), "Sakas Grīņi" Nature Reserve. Dominated by *Molinia caerulea, Vaccinium vitis-idaea, Vaccinium uliginosum*. Photo: L. Auniņa.

Fig. 17.13. Development of wet heaths seven years after mowing (2013), "Sakas Grīņi" Nature Reserve. *Molinia caerulea, Vaccinium vitis-idaea, Vaccinium uliginosum* still dominate. Just a few *Calluna vulgaris* are present. Photo: L. Auniņa.

mended to mow in strips and in spring, since *Calluna vulgaris* mown in autumn is more susceptible to pathogens, frost and desiccation (Miller, Miles 1970). Cut *Calluna vulgaris* must always be removed to avoid soil enrichment with nutrients. When mowing, 5–10 cm tall stems should be left.

In Latvia, there are very few such wet heaths where it would be necessary to reduce *Calluna Vulgaris* coverage. Management measures should reduce the cover of *Molinia caerulea*, trees and shrubs, as well as create bare peat patches where less competitive heath species like *Drosera rotundifolia* and *Juncus bulbosus* can establish.

17.3.7 Other Management Measures Favourable for Habitat Conservation

Restoration of Piemare Plain traditional landscapes would also contribute to the improvement of the conservation status of habitat types 7230 *Alkaline fens* and 9070 *Fennoscandian wooded pastures*. Ideally, mosaic landscapes should be established as a diverse habitat complex.

17.3.8 Management and use Unfavourable for the Habitat Type

Management unfavourable to the habitat is the following:

- activities that may artificially change the water table (digging of new ditches and ditch cleaning in heaths and their adjacent areas, rising of water table caused by beaver dams, etc.) in a direction which is unfavourable for the habitat;
- chopping of mown grass and/or dwarf shrubs and leaving of mown material;
- movement of heavy machines in wet heaths when the ground is not frozen (except tractors with wide tyres);
- fertilisation, including organic fertiliser use;
- herbicide application (to combat shrub sprouts, expansive and invasive plant species);
- installation of inadequate, habitat degrading tourism infrastructure (not redirecting visitors away from sensitive habitats, creating additional pressure, attracting too many visitors, etc.);
- feeding of forest animals (promoting groundcover eutrophication and the introduction of untypical, ruderal and invasive species);
- afforestation;
- inappropriate grazing intensity (too high or too low for a particular site).

17.3.9 Conservation and Management Conflicts

So far, there are no known conservation and management conflicts in wet heaths in Latvia. In the future, possible conflicts may arise when deciding if wet heath fragments should be left for natural succession, thus promoting the development of habitat type 91D0* *Bog woodland*, or wet heaths should be restored including drainage impact reduction, which can also promote the restoration of a raised bog habitat. For example, the best solution in the Ādaži military training area is probably to promote wet heath paludification by constructing dams on ditches. Such decision would be logical because these wet heaths are formed under the influence of raised bog drainage and burning.

Chapter 18. Dry Heaths (I. Mārdega)

2320 *Dry sand heaths with* Calluna *and* Empetrum nigrum
4030 *European dry heaths*

18.1 Habitat Characteristics

18.1.1 Brief Description of Habitats

Dry heath habitat management guidelines apply to heaths under dry growing conditions, located in the Coastal Lowland or outside it. Both habitats are surveyed together because they are characterised by similar ecological conditions, and a similar plant and animal species composition.

Habitat type 2320 *Dry sand heaths with* Calluna *and* Empetrum nigrum includes heaths which are located in sandy plains of the Coastal Lowland, also on coastal dunes and dune ridges as well as inclusions with a variable or humid hydrological regime (continuous area up to 0.1 ha) if they are part of an integrated complex of dry heaths (Rove 2013g). **Habitat type 4030 *European dry heaths*** is located outside the Coastal Lowland, mainly on aeolian sediments (Rove 2013i).

Dry heath vegetation can be very diverse depending on the development stages of *Calluna vulgaris* growth. Vegetation consists mainly of dwarf shrubs. *Calluna vulgaris* is usually dominating or grows in combination with *Arctostaphylos uva-ursi*, *Empetrum nigrum* and *Vaccinium vitis-idaea*. Heath vegetation varies from heterogeneous with sparse cover and patches of bare sand, xerophytic pioneer vegetation or *Nardus stricta* grasslands, to monodominant, even-aged heath. There can be groups of trees and shrubs. In relief depressions, *Molinia caerulea* is often found, which is resistant to burning and can become expansive (Rove 2013g, 2013i).

Habitat types 2320 *Dry sand heaths with* Calluna *and* Empetrum nigrum and 4030 *European dry heaths* (further in the text – dry heaths) are among the rarest habitat types in Latvia; together they cover not more than 0.02% of the territory of the country (Rove 2013g, 2013i). During the last 100 years, the area of dry heaths in Latvia has fallen sharply (Auniņa, Rove 2013). The largest areas of dry heaths are located in Ādaži, Sēja and Garkalne municipalities where these habitats are primarily maintained under the influence of disturbances caused by military training (Fig. 18.1, 18.2) (Rove 2013g; Rove 2013i).

18.1.2 Important Processes and Structures

18.1.2.1 Processes

- **Drought and nutrient poor sandy soils** are the most significant environmental factors determining heath formation. Furthermore, regular disturbances (fire, erosion, grazing, etc.) are necessary which arrests the heath overgrowth with trees and shrubs and promotes heathland restoration. Heaths cannot persist without disturbances in the climatic conditions of Latvia because they turn into woodland or bushes in the process of natural succession (Rove 2013g).
- **Burning.** Heathland species have adapted to the regular influence of fire. With high intensity fires, vegetation changes completely. With fires of lower intensity, vegetation perishes only partly. *Calluna vulgaris* (dominant plant species) regenerates vegetatively, and also the cover of the other species (woody species, lichens, gramineous plants) remains.

Fig. 18.1. Distribution of habitat type 2320 *Dry sand heaths with* Calluna *and* Empetrum nigrum in Latvia (Anon. 2013c).

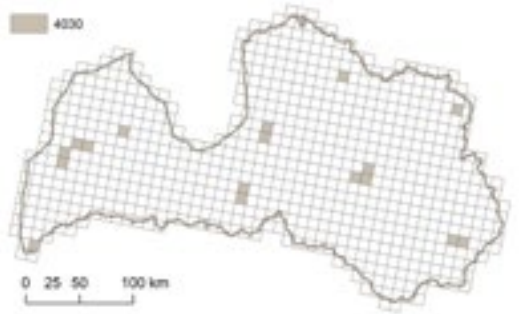


Fig. 18.2. Distribution of habitat type 4030 *European dry heaths* in Latvia (Anon. 2013c).

Fig. 18.3. *Oedipoda coerulescens* in Ādaži military training area. Photo: I. Mārdega.

Fig. 18.4. Heath fire in Ādaži military training area. Photo: I. Mārdega.

- **Influence of large herbivores.** In earlier times, heaths in Latvia were used for grazing. Arable lands were usually not established in poor soils. In addition, heaths could also be grazed in winter, after the plant growing season. Grazing prevented heath overgrowth with shrubs, maintained its mosaic structure and promoted the vegetative regeneration of the heather.
- **Other disturbances.** Nowadays, a large proportion of the dry heaths are located in the Ādaži military training area and are exposed to a variety of disturbances of military origin – driving with heavy military vehicles, soil scarification (digging, blasting), burning. Disturbances of moderate intensity maintain the mosaic structure of the habitat.

18.1.2.2 Structures

The main criterion for dry heath habitat identification is dwarf shrub (mainly *Calluna vulgaris*) cover which is at least 25%. Cover of trees and shrubs should not exceed 70% (Rove 2013g, 2013i). The number of the habitat characteristic species as well as the proportion of area with at least one of the characteristic species are also significant indicators. There can be grass-covered patches if they do not exceed 25% (Rove 2013g, 2013i). In order to maintain the habitat, bare soil patches are especially important. Lichens, mosses and also rare species of vascular plants can establish there. These patches are an important habitat for many animal species (ants, Orthoptera, reptiles, birds). One such characteristic species of the heath is *Oedipoda coerulescens* (Fig. 18.3).

18.1.3 Natural Succession

The formation of the dry heaths is determined by a sandy substrate on the ground surface and relief as well as by long-term grazing, fires or other disturbances such as military training.

Dry heath habitat may develop after the vegetation development of sands and nutrient poor grasslands, mainly *Nardus stricta* grasslands (Rove 2013g, 2013i). Dry heath can also develop after the burning of the dry forest, and also after the "ageing" of grey dunes. A large part of the dry heaths in Europe was formed after forest clearance followed by grazing.

Each type of succession is characterised by regional and local differences determined by substrate, succession phase, substrate humidity, rainfall and intensity of use. Important factors for the long-term existence of heath habitat are a lack of nutrients and regular disturbances including fire (Fig. 18.4). In the

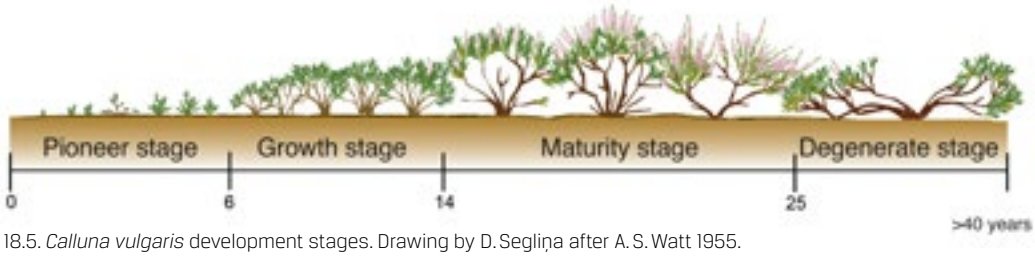


Fig. 18.5. *Calluna vulgaris* development stages. Drawing by D. Segliņa after A. S. Watt 1955.

presence of regular burning and other disturbances which directly affect the substrate and reduce nutrient accumulation, extreme dry conditions develop, which slow down heather overgrowth with trees and shrubs. Under natural conditions without disturbances, monodominant even-aged heather stands develop; the habitat gradually overgrows and usually converts into dry pine forest. On the contrary, regular burning ensures the mosaic structure of the habitat, suitable for the characteristic plant and animal species (Rove 2013g).

Since *Calluna vulgaris* is a dominating species in heaths, the habitat structure is influenced by the heather development stages (Fig. 18.5) and their proportion in a given area.

The age when these stages are changing depends on the growing conditions. *Calluna vulgaris* is one of the key elements determining the structure, soil formation and ecology for the entire habitat (Rayner 1921).

18.1.4 Indications of Favourable Conservation Status

Dry heath habitats are characterised by the nutrient-poor soils dominated by *Calluna vulgaris*. Ideally, *Calluna vulgaris* is multi-aged, the area is species-rich, trees and shrubs are few and they are not the main producers of organic matter, they grow scattered or in groups, their total cover does not exceed 10–20% (Fig. 18.6).

In dry heaths, rare and protected species in Latvia such as *Dianthus arenarius*, *Pulsatilla patens*, *Oedipoda coerulescens*, *Psophus stridulus*, *Bembix rostrata* can be found. They are among the best indicators proving that the conditions are beneficial for dry heath habitat development and its favourable conservation status.

18.1.5 Pressures and Threats

18.1.5.1 Management cessation

Management cessation is the main factor that threatens dry heath habitats. With the decrease of necessary disturbances (burning, groundcover mechanical damage) and in the absence of moderate grazing, the habitat overgrows. Heaths overgrow mostly with *Pinus* spp., *Betula* spp. and *Populus* spp. (Fig. 18.7). The overgrowth rate depends on the soil conditions (very dry places overgrow slower than wet sites) and soil composition (overgrowing is faster in nutrient-rich soil). If the heath is overgrown, plant species for which insolation is one of the main limiting factors development disappear, as well as animal species which need bare soil patches and open landscape (Orthoptera characteristic for heaths and sands such as *Oedipoda coerulescens*, or birds such as *Anthus campestris*). By resuming management, the heath habitat may recover and its characteristic species can return to the restored area, if it is not completely isolated from nearest populations.

18.1.5.2 Eutrophication

Adjacent farmland fertilisation can have a negative impact on the heath habitats because additional nutrients, especially nitrogen and phosphorus, can reach heath habitats by surface runoff and groundwater, thus promoting its overgrowth with trees and shrubs. Eutrophication can also be caused by atmospheric deposition via rainfall (if nitrogen concentration is high in precipitation, heaths overgrow more rapidly).

***Calluna vulgaris* development stages**

- Pioneer stage (0-6 years) – heather develops from seed into small pyramid shaped plants. Short (mown, burnt or grazed) swards can be included as "pseudo-pioneer". Grasses characteristic for this stage are *Corynephorus canescens, Agrostis tenuis, Lerchenfeldia flexuosa, Poa angustifolia*. Pioneer stage is of great importance for the biodiversity as it is characteristic with the largest number and diversity of Orthoptera (Fig. 18.3).
- Growth stage (6-14 years) – heather forms a closed canopy. It grows up to 40 cm.
- Maturity stage (14-25 years) – heath vegetation consists mainly of branched heather, stems become less vigorous, openings develop, other species, mainly mosses, establish on soil.
- Degenerate stage (after 25 years) – heather gradually dies off, central branches wither, brown leafless branches occur, bush centre becomes open, stems lie flat on the ground, leaves and blossom are more common on outer stems; number of leaves and flowers usually decreases (Watt 1955; Auniņa, Rove 2013).

Fig. 18.6. The habitat 2320 *Dry sand heaths with* Calluna *and* Empetrum nigrum in Ādaži military training area. Photo: I. Mārdega.

Fig. 18.7. Dry heath overgrowing with *Pinus sylvestris*. Ādaži military training area. Photo: I. Mārdega.

Fig. 18.8. Bare sand patches in heaths are favourable for the diversity of sand loving plants and animals. However, too frequent driving and other excessive disturbances may cause adverse effects. Photo: I. Mārdega.

18.1.5.3 Overexploitation

Heath overexploitation including too intense grazing and too frequent burning is a serious threat. There are no data on dry heath grazing in Latvia but we can use the experience from other countries. According to the British recommendations (Symes, Day 2003), the preferred number of grazing animals for heaths is: 1–2.5 cows on 10 hectares or 10–25 sheep on 10 hectares. If the number of animals exceeds the "capacity" of a given habitat, it can lead to vegetation destruction by trampling, heath transformation into grassland, extinction of protected species (plants, invertebrates, reptiles). Too frequent fires (more than once every five years) may cause heath degradation and reduce species diversity.

18.1.5.4 Excessive vehicle use

Dry heaths, especially in military training areas, can be threatened by too intense vehicle use (Fig. 18.8). Due to the continuous and regular disturbances, especially if disturbances occur during the bird breeding season, species of birds breeding in heaths can disappear (*Anthus campestris, Tetrao tetrix, Lullula arborea,* etc.). If the heath habitat area is too small (each animal requires its minimum area) and bordering habitats are not suitable for a particular species, the species will become extinct even though the habitat quality is good. Therefore it is very important to maintain heath areas which are as large as possible, arranged close to each other, to preserve the value of the habitat for various species.

18.2 Restoration and Management Objectives in the Conservation of Dry Heath Habitats

Heath areas across Europe have sharply decreased over the last 100 years, therefore habitat conservation and appropriate management are of great importance for biodiversity conservation. Dry heath conservation objectives are as follows:

- nutrient poor dry heath habitats dominated by stands of multi-aged heathers with a large number of characteristic species are maintained;
- habitats for species specific for dry heaths including rare and protected species such as *Anthus campestris, Lullula arborea, Oedipoda coerulescens* and *Bembix rostrata* are conserved and maintained.

18.3 Habitat Restoration and Management

18.3.1 Basic Principles of Heath Conservation

To conserve heaths as disturbance-dependent habitat, active management is definitely required. Its type, frequency and intensity must be specified for each site individually, taking into account its ecological conditions. To maintain open heath habitats in the long term, they should be grazed, or the necessary disturbance must be created by prescribed burning or vehicle use. Grazing and burning can be combined with mowing and removal of mown material or incineration. If heath is overgrown with trees and shrubs, they should be thinned first. This activity must be followed with the prevention of sprout regrowth. In overgrown and monodominant heather stands, topsoil removal may be applied. All cut and mown material must always be incinerated or transported away. Often, heather management methods should be combined, to achieve the desired result.

18.3.2 Prescribed Burning

Prescribed burning is widely used in Scandinavia and elsewhere in Europe to maintain open heath habitats, encourage *Calluna vulgaris* regeneration and improve conditions for protected species (Inger et al. 2010). It is used in areas where fire has been absent for a long time, *Calluna vulgaris* form monodominant stands, *Calluna vulgaris* individuals are old and start to wither, thick layers of mosses and litter have accumulated. Burning is essential for the establishment and maintenance of high-quality heath because it promotes the formation of multi-aged *Calluna vulgaris* populations (Fig. 18.9). If the heath is burnt in a mosaic, it promotes plant propagation by seeds and also creates microhabitats for annual plant species such as *Filago minima* and *Teesdalia nudicaulis*. Also, many animal species depend on bare soil patches in heaths. For example, they are important for a variety of Orthoptera (Fig. 18.10).

In preparation for prescribed burning, fire safety aspects must be taken into account:

- habitat location – whether it is possible to provide access to fire-engine (roads, tracks); whether the burnt area can be localised;
- distance to the nearest water intake (preferably – as close as possible, no more than 1 km); if there is no water, temporary water storage may be established in the vicinity of the managed area, by digging a pit and lining it with a durable polyethylene layer, and filling it with water;

Fig. 18.9. Heath which was burnt (prescribed burning) two years ago. Some of the young *Pinus* spp. have died, some survived, there are patches with *Arctostaphylos uva-ursi*. *Calluna vulgaris* regenerates both vegetatively and by seeds. Photo: I. Mārdega.

- establishment of mineralised strips – ploughed firebreaks (about 3 m wide) around the area of planned burning (Fig. 18.11). If an area of just a few square metres is burnt, it can be localised by digging with a shovel around the site.

During prescribed burning, groundcover at the outer perimeter should be made wet. If it is not possible to establish mineralised firebreaks, mown strips can also be used (at least 6 m wide if there are no other restrictive elements such as ditches and roads) and those should be intensively watered during the burning. If the burning of only *Calluna vulgaris* is necessary, prescribed burning can be carried out when the groundcover and moss layer are moist. If there is a thick layer of mosses and groundcover, and burning down to the mineral soil is necessary, burning must be carried out in dry weather conditions.

The best time for this activity is April (before bird breeding) or from mid-July to mid-August, which is usually a high fire risk period. If burning is carried out in April, it should be done in the first half of the day, after the dew has dried and when the day has become warm. If burning is carried out in late summer, the best time for prescribed burning is the afternoon.

18.3.3 Felling and Removal of Trees and Shrubs

Trees and shrubs should be cut in sites where the habitat starts to overgrow and where trees are too large to get rid of them by other methods. This can also be done in places where prescribed burning is not possible due to various reasons. The method gives

Fig. 18.10. *Psophus stridulus* in a recently burnt heath. Photo: I. Mārdega.

Fig. 18.11. Ploughed firebreak around the area which is planned to be burnt. Photo: I. Mārdega.

Fig. 18.12. Pile of felled trees and branches which *Lanius collurio* can use for nesting. Photo: I. Mārdega.

Fig. 18.13. Heath with bare soil patches. Photo: I. Mārdega.

instant results because open conditions in the habitat are restored. Works must be carried out outside the bird breeding season (1 August to 15 March).

The method and its result depend on the age and species of trees and shrubs:

- only *Pinus* spp.;
- various species (including *Betula* spp., *Populus* spp. and other deciduous trees and shrubs).

Felled trees and branches should be removed from the area or burnt. They cannot be left in the heath. If wood is burnt directly in the heath, it is recommended to burn medium-sized piles and create wide fires, thus ensuring that mosses and litter are burnt up to the mineral soil in the widest possible area. If felled trees are at least 25 cm in diameter or larger, if possible, it is recommended to leave the trunks in the heath area (with a few or several together in small piles) to ensure living and feeding possibilities for various protected species (jewel beetles Buprestidae, long-horn beetles Cerambycidae, *Lacerta agilis*, *Coronella austriaca*, *Coracias garrulus*, *Lanius collurio*, etc.). Piles (at least 2 × 2 m, no more than one pile for 4 ha) of felled trees and branches can also be arranged in the restored habitat for the nesting of *Lanius collurio* (Fig. 18.12).

Felling of trees and shrubs is recommended as the first activity if the habitat is highly degraded. After this, other management methods should be used – prescribed burning, mowing, topsoil removal and grazing.

18.3.3.1 Felling of pines

For heath restoration, pines must usually be cut. To ensure landscape diversity and habitats for birds (such as *Tetrao tetrix*, *Lullula arborea*) and invertebrates, it is desirable to leave solitary pines with low, wide branches to the ground. Depending on the habitat area and overgrowth rate, up to 20% of trees can be

Fig. 18.14. *Betula* spp. stump sprouts re-growing from felled birches. Photo: I. Mārdega.

Fig. 18.15. After ring-barking, *Betula* spp. trees wither and form less offshoots. Photo: I. Mārdega.

left, but this must be assessed individually in each situation. The pine felling machines can also be used for soil scarification, except for places where there is already plenty of bare soil (Fig. 18.13).

18.3.3.2 Felling of deciduous trees

In places where the heath is also overgrown with deciduous trees, they must be cut, but the growth of the offshoots (*Betula* spp., *Salix* spp., *Populus* spp., Fig. 18.14) can be expected. For trees such as aspen, offshoots also develop several metres around the stump.

To decrease the soil eutrophication it is not desirable to leave deciduous trees and shrubs in the habitat except for a few solitary trees if they have already reached an older age, as well as low *Salix* spp. (such as *Salix rosmarinifolia*). *Betula* spp. which have already reached at least 10 cm in diameter can be ring-barked, thus reducing the possibility of offshoot growth (Fig. 18.15). For ring-barking, a drawknife should be used as it allows one to work accurately, without damaging the wooden part of the trunk. Dead *Betula* spp. (on average, they will wither after three years) can be removed from the area or left there, depending on their number and arrangement. If they are not many, trunks should be left as habitats for insects and feeding sites for birds (as perching poles).

In sites of felled trees, offshoots grow rapidly in the subsequent years. In such cases, offshoots must be cut on a regular basis until they do not regrow (it can require a long time and additional funding). If *Populus* spp. are ring-barked, they often do not wither, and in the following years they form offshoots in a wide area around the ring-barked tree. It is possible that regrowth may be reduced by offshoot felling at a certain time (waning moon, middle of summer or late summer). Stumps and roots of felled trees may possibly be milled. However, groundcover plants including *Calluna vulgaris* can be damaged if there are many stumps. Offshoot regrowth can be stopped with herbicide injection in the stump just after felling, but the application of such substances may adversely affect other species (invertebrates, reptiles, birds) of heath habitats.

18.3.4 Mowing

To encourage heather regeneration in dry heaths, they can be mown, but the plant mass definitely must be collected, thus reducing the nutrients in the environment (Symes, Day 2003; Rove 2013g, 2013i). After cutting, *Calluna vulgaris* regenerates vegetatively from lateral buds. This does not promote heath genetic diversity. Mowing should occur outside the bird breeding season because many protected species such as *Caprimulgus europaeus, Lullula arborea* and *Anthus campestris* nest on the ground. It should be assessed if mowing in late summer, after 15 July, will eliminate other protected species – invertebrates, reptiles. If this may occur, mowing should only be performed in the autumn, starting in September or October, especially in habitats with small areas where species movement between suitable habitats may be difficult or impossible.

18.3.5 Topsoil Removal and Soil Scarification

Topsoil removal and soil scarification are recommended in sites without bare soil patches in the habitat. Thus nutrients are removed from the habitat and the vegetation returns to the early succession stage. Works can be carried out either with hand

Fig. 18.16. Topsoil removal with front loader and bucket. Ādaži military training area. Photo: I. Mārdega.

tools or with specialised equipment (Fig. 18.16) and supplemented by soil scarification.

Removed soil can be transported away from the habitat or used in several ways directly at the site, creating suitable habitats for various species, especially invertebrates and reptiles (Symes, Day 2003; Rove 2008) (Fig. 18.17).

- A small rampart is formed from the removed soil, along the north edge of the open sand area, to avoid shading and to protect the mineral soil area from the north wind.
- Small ramparts and piles are established on the bare soil patch to diversify the micro-relief of the territory.
- The removed soil can be put on tree and shrub piles which can be left after tree and shrub felling, thus creating shelters for animals. In all cases, this type of heather habitat restoration must be planned together with an expert of a particular animal species group.

Topsoil removal and soil scarification can be done in patches or in strips. Patches should be of irregular shape and of various sizes, depending on the habitat area and structures. It should be clarified if removed soil can be used in plant nurseries (such as rhododendron) or for household purposes.

18.3.6 Grazing

It is possible that in the past dry heaths in Latvia were used for grazing but there is no documented information on grazing intensity, time and type of livestock. British experience (Symes, Day 2003) shows that grazing prevents heath overgrowth with trees and shrubs, maintains a diverse habitat structure, and forms bare soil patches which are important for a number of protected species. With grazing, low levels of nutrients in the habitat are maintained. However grazing could also have unwanted side effects – trampling, eutrophication (if the number of animals is too large). A negative impact on invertebrates is also possible both by eating flowering plants they need and by destroying their larvae (eating together with plants, trampling), and on reptiles which need mature heather as hiding places.

Elsewhere in Europe, where heath has been used for centuries as pasture, the habitat has adapted to the impacts of grazing. When starting grazing in areas which have not been previously grazed, one should be very cautious – grazing should be started with a small number of animals and their impact on the species and habitat as a whole must be continuously monitored. In areas smaller than 25 ha grazing is not recommended (Symes, Day 2003). However, in Latvia the minimum grazing area could be lower.

In very dry heath with few trees and shrubs, grazing is not necessary. In heath with trees, shrubs and grass patches, sheep are suitable grazing animals (only in summer, to limit offshoot growth and to promote the preservation of grass

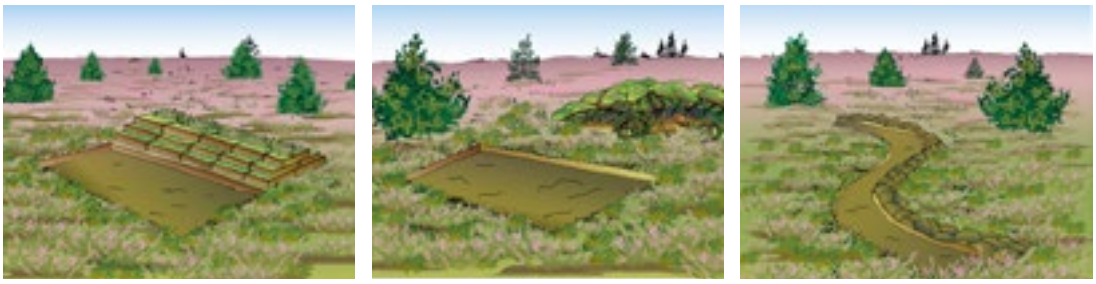


Fig. 18.17. Use of the removed soil by creating habitats for reptiles and other species in the managed heath. Drawing by D. Segliņa.

patches). In dry heath with acidic soils, sheep, horses and cattle can be used.

18.3.7 Restoration of Heavily Degraded Dry Heath Habitats

The restoration and improvement of dry heath habitats which meet the minimum requirements of habitat quality (*see Chapters 18.1.2, 18.1.4*) is possible, but the resources necessary depends on the level of degradation. If the area is overgrown for more than 30 years, but patches of open heath remain, habitat restoration is still possible.

In long overgrown heath habitats, first trees must be thinned, and then regular management must be started (prescribed burning, mowing, offshoot cutting, grazing, topsoil removal).

Fig. 18.18. Mowing of heath and collection of the mown material in the Ādaži military training area. Photo: I. Mārdega.

18.3.8 Management and Use Unfavourable for Dry Heath

Habitat quality may deteriorate if concentrations of the nutrients increase (or do not decrease) due to the management. For example, if cut trees and shrubs or mown materials are not removed, or the number of grazing animals is too high.

Prolonged non-interference promotes nutrient accumulation and heath habitat natural succession to woodland.

If the use of the most appropriate management in the particular site is not possible, for example, prescribed burning cannot be used because of fire safety problems, at least the trees and shrubs must be cut and removed from the habitat.

However, most of the dry heath characteristic plant and animal species are closely related to the influence of burning or the bare mineral soil, therefore it is hard to ensure their favourable conservation status without prescribed burning. By just felling trees and shrubs, appropriate conditions for protected, fire-dependent (pyrophylic) and epigeic invertebrate species are not ensured, and the humus layer is not decreased.

Prescribed burning can also be performed in an area of a few square metres (especially in monodominant heather stands, depending on habitat area) aimed at creating a mosaic-like habitat structure.

18.3.9 Experience of Heath Restoration and Management in the Ādaži Military Training Area

Targeted management of dry heath in Latvia was started in 2007, in the Ādaži military training area, in land under the possession of the Ministry of Defence, which is also "Ādaži" Protected Landscape Area. Between 2007 and 2009, approximately 1,000 hectares of heath were managed by the LIFE project "Restoration of Biological Diversity in the Military Training Area and Natura 2000 site "Ādaži"" (LIFE06 NAT/LV/000110). The main management method was felling of trees and shrubs. Cut material was usually transported away from the area, but a small part was left in piles in heath, thus providing hiding and living places for a variety of species. Heath was also restored by mowing (with a tractor and mower, leaving the cut material on the ground). In 2008, species and habitat monitoring was started, to evaluate the management influence on protected habitats (including dry heath) and species.

In 2009, prescribed burning was carried out for the first time in relatively small areas (territories of 1 ha, 5 ha and 12 ha). Further on, this management was continued every year.

Between 2010 and 2013, the State Centre for Defence Military Sites and Procurement of the Republic of Latvia continued to maintain restored heath (by cutting and mowing offshoots and by prescribed burning) and also restored and maintained other heath areas (by tree and shrub felling and by prescribed burning). In 2013, the State Defence Military Objects and Procurement Centre launched a new LIFE+ project "Improving of the conservation status of specially protected bird species in the Natura 2000 site "Adazi"" which plans to restore additional 1,000 hectares of heath. Methods used are tree felling, heath mowing, prescribed burning and topsoil removal. Topsoil re-

moval has been widely used in Western Europe but has so far not been tested in Latvia.

Heath mowing was started in 2015 with new mowing equipment which allows collecting the mown material. In this way, the eutrophication of heaths is reduced (Fig. 18.18).

In 2014 and 2015, prescribed burning was carried out in late summer, after the bird breeding season, to encourage groundcover incineration up to the mineral soil (in spring, the groundcover is usually too wet). Also in subsequent years, burning is planned in late summer if possible.

Due to large areas and their diversity, grazing would probably be an appropriate management method in the military training area. However, for the time being, it cannot be applied due to safety regulations.

18.3.10 Conservation and Management Conflicts

Species of dry heath are adapted to their specific conditions (drought, insolation, regular fire). Therefore, conflicts between species conservation and management are not expected if the habitat is properly managed. While performing various management measures, it is important to respect the specific requirements of a variety of species (reptiles, invertebrates, birds) to avoid the destruction of individuals, their hiding places and bird nests. For example, *Lullula arborea* requires the presence of *Pinus* spp., while *Anthus campestris* needs a more open area. For each case, the priorities for the conservation of various species must be set, especially if the habitat area is small. Management should be avoided during the bird breeding season. Grazing intensity should be kept to minimum, its influence must be carefully observed, to immediately notice negative consequences and eliminate them.

Glossary

Abiotic – non-living condition or thing, influencing the ecosystem structure and function.
Aeolian processes – wind-caused deflation, transport and accumulation of fine-grained particles, creating negative and positive relief forms.
Amelioration – (= *Land amelioration*) – land improvement, reducing the adverse effects of climatic conditions and ensuring long-term use of natural resources.
Anthropogenic pressure –direct or indirect impact of humans and their economic activities on the environment as a whole or on its individual components and elements (landscapes, nature resources, etc.). Due to excessive anthropogenic pressure, the territory may lose its natural properties.
Backshore – highest part of a modern coastal slope, formed by aggregates of windblown sand (dunes) or a slope created under the influence of erosion (sea cliff).
Baltic Ice Lake – cold freshwater watercourse in the southern and central part of the present Baltic Sea basin, formed at the end of the last ice age by North European glacial melt water (about 13,000 to 10,300 years ago).
Biocoenosis – a set of living organisms, characterised by certain environmental conditions.
Biotechnical measures – active measures to maintain a habitat in a certain condition. Examples of biotechnical measures are felling of shrubs, mowing and removal of grass. See also *Habitat management*, *Habitat restoration* and *Habitat creation*.
Biotic – conditions of the living environmental that occur and are transformed in mutual relations of living organisms.
Biotope – natural or semi-natural terrestrial or aquatic area characterised by certain abiotic and biotic conditions including biocoenosis, and is in continuous interaction. See also *Habitat*. Biotope is almost synonymous with the term "habitat".
Blowouts – sandy depressions in the frontal part (exposed to prevailing wind) of a sand dune caused by the removal of sediments by wind.
Brackish environment – an environment that has more salinity than fresh water but not as much as salt water. Inland seas such as the Baltic Sea contain brackish water.
Coastal erosion – removal of ground (sand, gravel, clay, etc.) by wave and wind action from the upper part of the coast (terrestrial) and lower part of the terrain coastal slope or deep water part of the basin.
Coastal Lowland – in this edition – Coastal Lowland geobotanical region in Latvia, characterised by similar soil conditions, vegetation and plant species.
Coastal pool – here – shallow water body on the beach or in an interdune depression, which dries up periodically.
Coastal retreat – movement of coastline and terrain border towards inland due to chronic coastal erosion.
Coastal sediment deficit – conditions in which sediment input (sand, gravel, pebble) is less than sediment output (washout).
Coastal slope "regeneration" – movement of slope forming sediments on a slope upwards to the top due to wave and wind activity, thus restoring the terrain characteristic before erosion episodes.
Deflation – dune fragmentation and relief transformation occurred due to wind erosion.
Devonian sediments – sediments formed and accumulated during the fourth geological period of the Paleozoic Era; in the largest part of Latvia, located directly beneath the Quaternary sediments.
Drainage – here – artificial removal of surface and sub-surface water from an area.
Ecosystem services – various types of ecosystem benefits provided to society.
Erosion episode – downward movement of coast-forming material along the slope, caused by wave activity.
Eutrophic – rich in plant nutrients.
Eutrophication – environmental enrichment with plant nutrients, caused by natural processes or human activities.
Expansive species – native species that are able to quickly spread and dominate over the other species. These species only become expansive in certain circumstances (such as management practice change or cessation, rapid increase of nutrients, etc.).
Foredune ridge – low ridge on accumulative coastal sediments formed during the erosion episode (e. g. in the foredune frontal area).
Foreshore – the most variable part of the coastal slope, which includes the zone from the shoreline to about 2 m in depth.
Fragmentation – fragmentation of territory (habitat, landscape, species range) into smaller, mutually isolated patches.
Glacigenic sediments – unsorted sediments (moraine) formed and accumulated by geological processes of a glacier.
Ground-cover – herbaceous plants, dwarf shrubs, mosses and lichens growing on soil.
Groundwater – upper permanent horizon of water found underground located above the first impervious surface. Non-pressure waters, the regime (level, resources, composition, etc.) of which is determined mainly by climatic conditions.

Habitat – living environment of species characterised by specific abiotic and biotic factors, and in which the species lives at any stage of its biological cycle. See also: Biotope.

Habitat management – set of biotechnical measures aimed at maintaining habitats in a favourable conservation status.

Habitat restoration – set of biotechnical measures aimed at the restoration of environmental conditions, vegetation structure (species composition, age structure, etc.) and species in a site where the habitat existed earlier or still exists but in an unfavourable conservation status.

Habitat type of European Union interest (also habitat of Community importance) – habitat type listed in Annex I of the Habitats Directive (see the Habitats directive).

Habitats Directive – Council Directive 92/43/EEC of 21.05.1992 on the Conservation of natural habitats and of wild fauna and flora.

Halophytes – plants that grow in substrates with high salinity.

Hydrophytes – plants that grow partially or fully submerged in water.

Hygrophytes – plants that grow in humid areas.

Invasive species – species that is not native to a specific location and which has a tendency to spread over large areas and outcompete local species. Typically, the spread of invasive species in natural or semi-natural ecosystems is associated with biodiversity decrease, economic loss or human health risks.

Land amelioration – see *Amelioration*.

Litho-morphodynamics – relief transformation and sediment movement in a geological process.

Littoral species – species, the habitat of which is only the sea coast or close to it.

Littorina Sea – a geological stage of the Baltic Sea which existed around 7,500–4,500 years ago.

Long-shore sediment drift (also long-shore drift flow) – transportation of fine-grained sediments (mainly sand) along a coast at an angle to the shoreline (ensured by the kinetic energy of the moving mass of water – waves and currents).

Marine regression – geological process occurring when areas of submerged seafloor are exposed above the sea level; opposite to transgression.

Marine transgression – geological process which occurs when flooding from the sea covers previously exposed land.

Marine wind – wind blowing from land toward sea.

Massive anti-erosion structures/coastal defences/defence structures – defence against coastal erosion – measures/constructions which reduce wave energy or strengthen/cover sediments which form the upper part of the coastal slope thus significantly changing the conditions of the coastal system.

Oligotrophic – relatively poor in plant nutrients especially nitrogen and phosphorus (soils, water).

Organic drift (beach debris) – here – materials washed onto the beach by waves or transported by rivers. Such materials may include tree trunks or branches, macroalgae, plant roots and seaweed. It usually forms after storms and spring floods.

Pathogen – an organism that causes disease, such as viruses, fungi, bacteria.

Podsolisation of soil – leaching of bedrock mineral decomposition products from soil upper horizons, leaching and deposition in deeper soil layers.

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 – endangered habitat, the conservation of which is regulated by national regulations. In Latvia, specially protected habitats are listed in the Regulation of the Cabinet of Ministers of the Republic of Latvia.

Protected species – endangered species, the conservation of which is regulated by national regulations. In Latvia, species that are specially protected and the use of which is limited, are listed in the Regulation of the Cabinet of Ministers of the Republic of Latvia.

Psammophytes – plants that are adapted to grow in shifting sands or sandy soils.

Quaternary sediments – sediments (sand, clay, gravel, loam etc.) formed and accumulated during the most recent geological period, which builds up the upper part of the geological formation almost all over the territory of Latvia.

Sandy depression – aeolian deformation shape.

Saprophytic – microorganisms, fungi, plants that derive their nourishment from dead or decaying organic matter.

Semi-aquatic plants – plants that can grow in water and on land.

Spit/sandspit – a long shoreline sediment bar that separates a lagoon from the main part of the sea basin.

Succession – ecosystem formation process in which habitat types replace each other, such as foredune transforming to grey dunes, which further develop into wooded dunes. Primary succession occurs when there is a new substrate with no existing vegetation, for example, on beach debris or a washed off sea cliff. Secondary succession is a process started in sites of preexisting soil and vegetation which is totally or partly destroyed but abiotic conditions and also part of the species (seeds or vegetative propagules) is

preserved. Both during primary and secondary succession, several stages can be observed when environmental conditions change due to biocoenosis development which in turn contributes to the gradual formation of new biocoenosis.

Succulents – plants that have some parts that are thicker than normal and fleshy. This allows them to adapt to long-term xeric conditions and to sandy soils. Succulents store water in their fleshy stems and leaves.

Synanthropisation – the process of change in plant cover (also in the fauna and the abiotic elements of the environment) brought about by human impact.

Vascular plants – seed plants (Spermatophyta) and ferns (Pteridophyta); plants having vascular tissue.

Xerophytes – plants which are adapted to dry soils.

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ANNEXES

Annex 1. Indicative Costs of the Frequently Used Restoration and Management Methods of Coastal, Open Inland Dune and Heath Habitats

Costs were calculated using recent (2010–2015) data, interviewing the project implementers and practitioners. These costs are approximate and can vary depending on the geographical location, interest of the contractors and other factors. Costs for some of the methods recommended in the guidelines cannot be determined at present. This applies mainly to those methods that have not been implemented in Latvia so far or have been tested only experimentally.

Total costs can be influenced by several factors, including

- availability of the executer in the region (skills, knowledge of the executer, etc.);
- possibilities or transportation, i. e., location of the management area (distance from the road, road condition);
- the availability of equipment in the region (transportation of the equipment over long distances can significantly increase the costs);
- the amount of work, such as volume and height of trees and bushes, density of groves;
- terrain features (dune height, slope);
- additional research and/or the scope of the preparation of the expert opinion;
- preparation of technical projects;
- possibilities of use of harvested biomass (trees, shrubs, grass);
- public information on planned works;
- coordination of works with the responsible national and/or local institutions.

Method	Approximate costs EUR/ha
Cutting of trees and shrubs (sparse stands), collection, transportation from the area or burning on site in dry conditions. Small pines can be hand-pulled.	150…300
Cutting of trees and shrubs (moderately sparse to sparse stands), collection, transportation from the area or burning on site in dry conditions. Small pines can be hand-pulled.	500…700
Cutting of trees and shrubs with collection, transporting from wet conditions or otherwise challenging conditions. Small pines can be hand-pulled.	600…800
Cutting of shrubs and stump sprouts, collecting and transporting from the territory.	100…200
Cutting/mowing and transporting or burning on site of invasive shrubs (*Rosa rugosa*, etc.).	500…700
Pulling out invasive shrubs with roots, transporting or burning on site.	1000
Treatment of invasive shrubs (separately growing, separate groups of shrubs) with herbicides.	200
Treatment of invasive shrubs (many, everywhere or partially dense stands) with herbicides.	300…500
Topsoil removal, litter collection and disposal.	2000
Deepening the lagoon, removal of sediments.	4000
Burning of reeds.	30…50
Reed mowing (without costs of transporting the mowing equipment), collection and removal from the territory or burning on site.	200–300
Reed mowing (including costs of transportation of the mowing equipment), collection and removal from the territory or burning on site, in difficult circumstances.	350…500
Mowing of reed etc. grasses with a trimmer, collecting in difficult circumstances.	700
Specialised pre-commercial thinning. Creation of dead wood, if trees are of sufficient dimension.	2200…2400

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Method	Approximate costs EUR/ha
Mowing with tractor equipment, gathering of grass.	200…250
Manual mowing with a trimmer or scythe, gathering of grass.	500…700
Removal, composting, burning, etc. of the mown grass or hay.	40…50

Annex 2. The factors affecting natural habitats and the species

Pressures and Threats	European Union Protected Habitat code *							
	1150*	1210	1220	1230	1310	1640	2110	2120
Intervention in coastal geological processes	■	■	■	■	■	■	■	■
Change of hydrological regime	■							
Management reduction or cessation	■	■	■		■	■		
Inappropriate management							■	■
Excessive visitor load	■	■		■	■	■	■	■
Pollution and scrapping	■	■	■		■	■	■	■
Invasive plant species	■						■	■
Excessive vehicle use or sand bulldozing		■	■		■	■	■	■
Drift removal		■						
Coastal erosion				■				
Land use change								
Eutrophication								
Relief modification								
Logging								
Forest animal feeding								
Phytophages and pathogens								
Low temperatures and frost								

*** European Union Protected Habitat code**

1150* *Coastal lagoons,* 1210 *Annual vegetation of drift lines,* 1220 *Perennial vegetation of stony banks,* 1230 *Vegetated sea cliffs of the Atlantic and Baltic coasts,* 1310 Salicornia *and other annuals colonising mud and sand,* *1640 Boreal Baltic sandy beaches with perennial vegetation, 2110 Embryonic shifting dunes, 2120 Foredunes,*

Pressures and Threats	European Union Protected Habitat code *								
	2130*	2140*	2170	2180	2190	2320	2330	4010	4030
Intervention in coastal geological processes	■	■	■						
Change of hydrological regime					■			■	
Management reduction or cessation	■	■	■		■	■	■	■	■
Inappropriate management	■	■	■			■	■		■
Excessive visitor load	■	■	■	■	■				
Pollution and scrapping	■	■	■	■	■		■		
Invasive plant species	■	■	■	■	■		■		
Excessive vehicle use or sand bulldozing						■			■
Drift removal									
Coastal erosion	■	■	■						
Land use change	■	■	■	■		■	■	■	
Eutrophication	■	■	■	■	■	■	■	■	■
Relief modification				■					
Logging				■					
Forest animal feeding				■					
Phytophages and pathogens								■	
Low temperatures and frost								■	

2130* *Fixed coastal dunes with herbaceous vegetation (grey dunes),* 2140* *Decalcified fixed dunes with* Empetrum nigrum, 2170 *Dunes with* Salix repens *ssp.* argentea (Salicion arenariae), 2180 *Wooded coastal dunes of the Atlantic, Continental and Boreal region,* 2190 *Humid dune slacks,* 2320 *Dry sand heaths with* Calluna *and* Empetrum nigrum, 2330 *Inland dunes with open* Corynephorus *and* Agrostis *grasslands;* 4010 *Northern Atlantic wet heaths with* Erica tetralix, 4030 *European dry heaths.*

Annex 3. Characteristics of habitat quality evaluation

Characteristics for the evaluation of the quality of beach habitats

1210 *Annual vegetation of drift lines,* 1220 *Perennial vegetation of stony banks,* 1310 Salicornia *and other annuals colonising mud and sand,* 1640 *Boreal Baltic sandy beaches with perennial vegetation*

Indications	Evaluation
Beach connection with backshore area	
	The beach naturally continues up to the backshore area (aeolian relief or sea cliff). During storms, backshore erosion can occur uninterrupted. Sand overblowing from the beach in the direction of inland can occur uninterrupted.
	Barriers for sand crosshore exchange are minimal, including lines of willow plantings and temporary infrastructure objects on the beach.
	Backshore is delimited by permanent anti-erosion structure (boulder revetments, concrete wall, gabions, etc.).
Drift material and gravel rich in nitrogenous organic matter	
	The sea washes up a lot of seaweed, wood and sediments rich in nitrogenous organic matter (further – drift material). It is concentrated in broad belts, on long sections and/or form rather high heaps (> 10 cm). Permanently formed, persisting in the long term. Drift material from the previous years is still present in some places.
	Amount of drift material is low, in narrow, low bands. In some places drift materials are removed. Rarely formed.
	Drift material is absent. Drift material accumulation does not occur or it is regularly fully removed. Perhaps, drift material is gathered and left in upper part of the beach or transported to dunes.
Depressions, pools	
	Every year elongated depressions or pools are created on the beach that are parallel to the shore, and that periodically dry out and overflow again. Some remain throughout the summer. In other seasons depressions may be partially "buried" by sand. Plants are abundant.
	No pools on the beach, some depressions are present, beach is generally low and flat. Temporary shallow depressions or even wide pools can periodically appear. Small amount of plants.
	Some/rarely small (<10 m^2) depressions on the beach that are temporarily filled with water. No plants or very sparse.
Cover of low plants	
	Low plants in the beach are abundant (their height from a few cm to 50 cm). Great proportion of annual plants, succulents as well. Plants form dense, sparse or even very sparse beds, or single individuals between tall herbage.
	In open beaches low plants can only be seen in some places (mainly in the high part of the beach), they generally form small groups or grow separately. In the growth of tall herbage, there is no low herbage.
	There are no low plants on the beach and they are absent over the last few years.
Herbaceous plant vegetation mosaic — diversity	
	Alternating belts (groups) of various plant species: in height, growth habit (decumbent, prostrate, and erect), abundance, plant species and quantity.
	Vegetation mosaic is poorly expressed, number of species is small (1-2).
	No mosaic. Vegetation is poorly developed in general.

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Indications	Evaluation
Characteristic species	
	Characteristic species are found in most of the territory and more than other species.
	Number of habitat specific species is still higher than number of other species, in at least half of the territory.
	The number of characteristic species is small, their viability — low. Other species prevail.
Diversity of animal species	
	Various animals (birds, amphibians, etc.) or their trails are observed often.
	Animals are observed rarely, their diversity — low.
	The animals are observed very rarely.
Excessive vehicle use, trampling	
	No or little visible evidence of excessive vehicle use or trampling on the beach.
	Few trails are present (for boat transportation etc.). Several places are intensively and constantly trampled, but the rest of the area is only slightly disturbed, or the land cover has been trampled in many places.
	The beach is excessively used by vehicles, compacted, constantly trampled, destroying plants and beach micro-relief.
The quantity of waste on the beach	
	Waste is absent or rare and occurs periodically.
	Waste in separate/isolated places. Periodically a lot of it.
	A lot of waste every year, it appears in most of the territory.

Indications for the evaluation of the quality of habitats of embryonic dunes and foredunes

2110 *Embryonic shifting dunes* and/or *2120 Shifting dunes along the shoreline with* Ammophila arenaria *(white dunes)* (complex)

Indications	Evaluation
Windblown hills of sand (the accumulation of aeolian formations) (0.3-1.5 m relative height)	
	All over the habitat, at various heights.
	Only in some places, of various heights or all very low through.
	No or very low (<0.5 m relative height). Signs of deflation expressed very well.
Dune ridge	
	Dispersed or in groups all over the habitat.
	In some places, in low numbers.
	Absent, or few individually growing plants.
Characteristic annual plants, including succulents	
	Dispersed or in groups all over the habitat.
	In some places, in low numbers.
	Absent, or few individually growing plants.
Characteristic perennial sand loving plants (psammophytes).	
	Many young (current year) sprouts, dominating throughout the habitat.
	Dominates only partially.
	Psammophytes are absent or their old shoots dominate.
Diversity of animals	
	Various animals or their traces can often be observed (insects, amphibians, reptiles, birds etc.).
	Animals are observed rarely, their diversity – low.
	The animals are observed very rarely.
Ammophila arenaria	
	Young sprouts dominate, they occur throughout the habitat.
	Many young sprouts, but in some places old stems as well.
	Mostly old stems.

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Indications	Evaluation
Invasive plants: *Hippophaë rhamnoides, Rosa rugosa*, etc.	
	No invasive species have been found.
	Invasive species are found in some places.
	Invasive species are dominating.
Tree and shrub cover and abundance (any age)	
	Trees and shrubs absent or their cover up to 10%.
	Trees and shrubs in some places (cover more than 10, less than 30%).
	Large number of trees/shrubs (cover > 30%).
Vegetation mosaic (various species, vegetation height, density, colour, etc.)	
	In most of the habitat various plant groups alternate with one another.
	Mosaic is characteristic to less than 50% of the habitat area.
	No mosaic.
Excessive vehicle use in the dunes or in the upper part of the beach	
	No or only slightly (few separate signs of vehicle use can be seen).
	Periodically intense excessive use of vehicles.
	Constant excessive use of vehicles, destroying the dune relief and interfering with dune development. Accelerated dune deflation.
Quantity of waste	
	Wastes is absent or rare and occurs periodically.
	Wastes in separate/isolated places. Periodically a lot of it.
	A lot of waste every year, it appears in most of the territory.
Artificially created barriers (roads, buildings, structures), except those relating to fisheries	
	None.
	Few (<1 on every shore km).
	Many (>1 on every shore km), especially in the summer season.

Indications for evaluation of the quality of grey dune and inland dune habitats
2130* *Fixed coastal dunes with herbaceous vegetation (grey dunes),* 2140* *Decalcified fixed dunes with* Empetrum nigrum*, 2170 Dunes with* Salix repens *ssp.* argentea (Salicion arenariae), 2330 *Inland dunes with open* Corynephorus *and* Agrostis *grasslands*

Indications	Evaluation
Bare soil patches (sand, gravel, pebbles) free of plants, dead grass layer and litter; also vegetated patches with signs of accumulation of wind carried sands	
☺	Bare soil patches are dispersed in most of the territory, their total area is at least 10% (approximately up to 30%) of all of the area of the dune habitat.
😐	Bare soil patches are few, dispersed unevenly, in less than half of the territory their total area is approximately up to 30%.
☹	Bare soil areas dominate or are absent (all covered with vegetation or dead grass).
Cover of trees and shrubs (any age), not including low willows)	
☺	No trees/shrubs or cover up to 10%.
😐	Tree/shrub cover greater than 10%, less than 50%.
☹	Tree/shrub cover greater than 50%.
Lichens	
☺	Lichens abundant, their cover and species diversity is high.
😐	Lichens can be found in most part of territory, but species number is low and cover is mostly low.
☹	Lichens are absent or can be found in small patches in few places.
Invasive plants: *Rosa rugosa, Hippophaë rhamnoides, Amelanchier spicata*, etc.	
☺	Invasive species are absent.
😐	Invasive species are found in some places, cover is small.
☹	Invasive species dominate in one part of the habitat or are dispersed over the entire habitat.
Mowing and pasturing	
☺	The dune has been pastured or mown for a long time, with removal of the cut grass. No other use for at least 30 years (cropland, etc.). Or such management is not necessary.
😐	Formerly mown and grazed, but not managed in the last few years, or mown but grass not removed.
☹	Not mown or grazed for a long time, overgrowing with shrubs and trees.
Dead grass layer (dead parts of aboveground parts of plants, not yet decayed, including mown grass that is not removed)	
☺	Dead grass absent or a very thin layer, in just a few places.
😐	Dead grass in the most part of the territory (up to a 3 cm thick layer).
☹	A lot of dead grass, all over the territory, thick and dense layer (more than 3 cm).

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Indications	Evaluation
Characteristic species	
	Characteristic species are found in most of the territory and are more common than other species.
	Number of habitat characteristic species is still higher than the number of other species in at least half of the territory.
	Small number of characteristic species, their high viability in a small part of the territory only. Other species prevail.
Tree and shrub litter	
	No litter or a very small amount in just a few places.
	Litter forms thin layer in the biggest part of territory, or very thick layer in several places.
	Litter is abundant in all of the territory; in many places, it forms a thick layer and its direct influence on the humus layer can be observed.
Ant nests	
	Ant nests are abundant, dispersed over the habitat or concentrated in one area.
	Ant nests are few.
	Ant nests are absent.
Aggressiveness of local plant species (expansive species): *Calamagrostis epigeios, Carex arenaria, Leymus arenarius*, etc. are dominating.	
	No marked dominance of one local species that would form dense stands and a dead grass layer or in any other way hinder the development of other local plant species.
	There is a local plant species that forms dense stands which cover no more than 30% of the total area of the habitat.
	There is a local plant species that forms dense stands which cover more than 30% of the total area of the habitat.
Herbaceous vegetation density and height	
	Herbaceous plants form sparse plant cover, bare soil patches, mosses and lichens can be observed, low plants (approx. 20-30 cm)dominate in between herbs.
	Vegetation is mainly formed of low herbs, which form dense stands and/or in some places tall herbaceous plants dominate (mostly gramineous plants).
	Dominated by tall, dense stands of gramineous plants, dead grass is characteristic, low number of plant species.
Vegetation mosaic	
	Patches of herbaceous plants (dwarf shrubs, low shrubs), moss, lichen and bare ground. Mosaic is typical for the most part of the dune.
	Mosaic is characteristic for less than half of the territory, or mosaic is poorly expressed throughout the dune.
	No mosaic or in a very small area (10%).
Moss layer thickness	
	Dominated by mosses, which above ground form a layer up to 2 cm.
	Partially dominated by mosses that form a layer of more than 5 cm.
	Mosses that form a layer of five or more cm are found in at least one fifth of the dune. Mostly these are moss species not characteristic to the habitat.

Indications for heath habitat quality evaluation

2320 Dry sand heaths with Calluna *and* Empetrum nigrum*, 4010 Northern Atlantic wet heaths with* Erica tetralix*, 4030 European dry heaths*

Indications	Evaluation
Bare soil patches, free of vegetation, dead grass and litter	
	Bare soil patches are dispersed, in the larger part or the territory, their total area is at least 10% (approx. up to 30%) of all the area of habitat.
	Total area of bare soil patches is between approximately 30-50% of all the habitat area.
	Bare soil patches are more than 50% or absent (all covered with vegetation or dead grass).
Dwarf shrubs	
	Dwarf shrubs, mainly *Calluna vulgaris*, dominate.
	Dwarf shrubs, mainly *Calluna vulgaris*, cover only 25% to 50% of the area.
	Dwarf shrubs cover less than 25% of the area.
Age structure of *Calluna vulgaris* and other dwarf shrubs	
	*Calluna vulgaris* and/or other dwarf shrubs can be found in all development stages.
	Dominated by *Calluna vulgaris* and/or other dwarf shrubs in mature stage, stems of part of dwarf shrubs become less vigorous.
	Dominated by old dwarf shrubs, including of degenerate stage.
Characteristic pioneer species	
	At least 2 characteristic pioneer species found.
	At least 1 characteristic pioneer species found.
	Characteristic pioneer species are absent.
Characteristic species	
	Characteristic species are found in most of the territory and more than other species.
	The number of characteristic species is larger than the number of other species in at least half of the territory.
	Small number of characteristic species, their vitality is only high in a small part of the territory. Other species prevail.
Vegetation mosaic	
	Patches of dwarf shrubs/herbaceous plants/lichens/mosses. Mosaic is characteristic for the most part of the habitat.
	Mosaic is in less than half of the territory or the mosaic is poorly expressed throughout the habitat.
	No mosaic or in a very small area (10%).

(continued)

(continued)

Indications	Evaluation
Lichens (habitats: 2320 *Dry sand heaths with* Calluna *and* Empetrum nigrum, 4030 *European dry heaths*)	
	A lot of lichen cover and the variety of species is vast.
	Lichens are found in most areas, but species number and cover are low.
	Lichens are absent or only in small areas in few places.
Tree and shrub litter	
	No litter or a very small amount in just a few places.
	Litter forms a thin layer in the biggest part of the territory, or a very thick layer in several places.
	Litter is abundant in all of the territory; in many places, it forms a thick layer and its direct influence on the humus layer can be observed.
Invasive plants: *Rosa rugosa, Hippophaë rhamnoides, Amelanchier spicata*., etc.	
	Invasive species are absent.
	Invasive species are found in some places, their cover is small.
	Invasive species dominate in one part of the habitat or are dispersed over the entire habitat.
Cover of trees and shrubs (any age), not including low willows)	
	No trees/shrubs or cover up to 10%.
	Tree/shrub cover greater than 10%, less than 50%.
	Tree/shrub cover greater than 50%.
Diversity of insect, reptile and bird species	
	Throughout the habitat: animals of various species or their traces are present.
	Animals can be observed very rarely.
	Animals are absent.
Aggressiveness of local plant species (expansive species): *Calamagrostis epigeios, Molinia caerulea*, etc. dominate.	
	No marked dominance of one local species that would form dense stands and a dead grass layer or in any other way hinder the development of other local plant species.
	There is a local plant species that forms dense stands which cover no more than 30% of the total area of the habitat.
	There is a local plant species that forms dense stands which cover more than 30% of the total area of the habitat.

Indications for habitat 2190 *Humid dune slacks quality evaluation*

Indications	Evaluation
Pools, water bodies	
☺	Pools are constant or form at least once every few years and persist during the vegetation season.
😐	Pools form rarely, are temporary. Mostly, pools are absent during the vegetation season.
☹	Pools do not form.
Bare patches of soil, free of plant cover, dead grass and litter	
☺	Bare soil patches are dispersed, in the larger part of the territory, their total area is at least 10% (approx. up to 30%) of all the area of habitat. They can be periodical.
😐	Bare soil patches are few (total area <10%), located unevenly, or their area is 30-50%.
☹	Bare soil patches are more than 50% or absent (all covered with vegetation or dead grass).
Cover of trees and shrubs (any age), not including low willows	
☺	No trees/shrubs or cover less than 10%.
😐	Tree/shrub cover greater than 10%, less than 50%.
☹	Tree/shrub cover greater than 50%.
Invasive plants: Rosa rugosa, *Hippophaë rhamnoides, Amelanchier spicata*., etc.	
☺	Invasive species are absent.
😐	Invasive species are found in some places, their cover is small.
☹	Invasive species dominate in one part of the habitat or are dispersed over the entire habitat.
Dead grass (dead aboveground parts of plants, not yet decayed)	
☺	Dead grass absent or a very thin layer, in just a few places.
😐	Dead grass in the most part of the territory (up to a 3 cm thick layer).
☹	A lot of dead grass, all over the territory, thick and dense layer (more than 3 cm).
Characteristic species (*Juncus* spp., *Equisetum variegatum, Sagina nodosa, Centaurium* spp., *orchids* etc.)	
☺	Characteristic species are found in most of the territory and more than other species.
😐	Number of habitat characteristic species is still higher than number of other species in at least half of the territory.
☹	Low number of characteristic species, their vitality is only high in a small part of the territory. Other species prevail.

(continued)

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Indications	Evaluation
Tree and shrub litter	
	No litter or a very small amount in just a few places.
	Litter forms a thin layer in the biggest part of the territory, or a very thick layer in several places.
	Litter is abundant in all of the territory; in many places, it forms a thick layer and its direct influence on humus layer development can be observed.
Aggressiveness of local plant species (expansive species): dominated by *Phragmites australis*, etc.	
	No marked dominance of one local species that would form dense stands and a dead grass layer or in any other way hinder the development of other local plant species.
	There is a local plant species that forms dense stands which cover no more than 30% of the total area of the habitat.
	There is a local plant species that forms dense stands which cover more than 30% of the total area of the habitat.
Mosaic in plant cover	
	Patches of herbaceous plants (also dwarf shrubs, low shrubs), moss and bare ground. Mosaic is characteristic for the most part of the habitat.
	Mosaic is in less than half of the territory or the mosaic is poorly expressed throughout the habitat.
	No mosaic or in a very small area (10%).
Moss layer thickness	
	Dominated by mosses, which above ground form a layer up to 2 cm.
	Partially dominated by mosses that form a layer of more than 5 cm.
	Mosses are found in at least one fifth of the dune, they form a layer of five or more cm. Mostly they are moss species not characteristic to the habitat.
Characteristic animal species	
	At least one species. Dominate habitats suitable for them.
	Species are absent, but habitats suitable for them are present.
	Both species and habitats suitable for them are absent.

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