Protected Habitat Management
Guidelines for Latvia

Rivers and Lakes

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Protected Habitat Management Guidelines for Latvia

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Foreword

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

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

General Director of the Nature Conservation Agency
Juris Jātnieks

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Contents

Introduction

(A. Priede)

Guidelines for the conservation, management and restoration of protected habitats have been developed during the period from 2013 to 2016 within the framework of the European Commission programme LIFE+ funded project "National Conservation and Management Programme for Natura 2000 Sites" (NAT-PROGRAMME, LIFE11 NAT/LV/000371) implemented by the Nature Conservation Agency. The purpose of the guidelines is to provide recommendations for the conservation, management and restoration of land and freshwater habitats that are included in Annex I of the Habitats Directive in Latvia. The guidelines are intended for the planning and implementation of habitat protection, conservation and restoration in Latvia, and are one of the key tools for the conservation of the European Union's (EU) protected habitats. The guidelines and resulting activities are one of the ways of promoting the introduction of the Habitats Directive and Birds Directive in Latvia. The guidelines are issued in six books. This volume provides recommendations for the conservation of the diverse nature of rivers, lakes and dolines.

The guidelines were developed by involving a leading expert for each group of habitats (coast, sands and heaths, rivers and lakes, meadows and pastures, mires, springs, and seep springs, rock outcrops and lodges, forests), who organised the compilation of the guidelines. Most of the chapters of the guidelines have been developed by the project's experts, while the other part of the guidelines has been elaborated through the attraction of other specialists. The development of the guidelines was an open process – they were available to all interested parties in various development stages – published on the project website, giving the possibility for everybody to participate with suggestions. At the beginning of the project, working groups were established, allowing for the involved parties to follow the development of the guidelines and to participate with opinions and recommendations throughout the process. Representatives of various fields took part in the working groups – experts of species and habitat conservation, researchers from scientific institutions, representatives of several governmental and non-governmental organisations – professionals of nature conservation, forestry, agriculture and other industries. Development of the guidelines included 25 seminars that combined both work groups and excursions to investigate the problem situations, as well as discussions among representatives of various fields about possible solutions. The suggestions received were assessed carefully and used in the development of the guidelines. During the development of the guidelines the leading experts met and consulted with practitioners and researchers in Latvia and abroad, thus the best available experience has been gathered. So, the guidelines have to be considered a result of team work which would not be possible without a wide range of expert involvement, which has helped to create the most voluminous edition of such type in the Latvian language so far.

The recommendations provided for in the guidelines have been tested in practice in Latvia or geographically similar conditions, their efficiency was assessed and recognised as applicable. The project also carried out experimental habitat management and restoration by using less known or even never used methods in Latvia, to assess their usage and result. The experience gained was used in the preparation of the guidelines.

For habitat management, restoration and creation, it is not possible to establish one recipe for all cases, and it is not likely to be possible in the future either. The diversity of conditions makes every case unique. So any attempt of restoration of a degraded ecosystem, even using well-known techniques and applying thorough feasibility studies, does not always guarantee success. One should be creative in the restoration of degraded habitat and willing to adapt to the conditions, to experiment and use additional solutions – including those not proposed by these guidelines. If the reader expects universal recommendations from this publication that always guarantee success, this is not possible. The approach should always be flexible when trying to restore changed, degraded or even extinguished ecosystems. Sometimes, even having done everything possible according to the best recommendations and practice, adjustments are necessary to correct the mistakes or unexpected deviations from that which was planned. Each ecosystem restoration attempt is in a way an experiment, no matter how well-designed it is. Its success or failure in the longer term can only be affirmed by systematically made observations and careful analysis of results, including errors.

The target audience of the guidelines is primarily practitioners – habitat managers and restorers – owners of the land possessing important natural values, as well as those whose duty or call it is to promote the conservation of natural values – representatives of public administration, local governments, and non-governmental organisations. This edition can be used as a guide for practical action – including both the planning and implementation of works. It will be useful for nature conservation professionals who create and develop a regulations framework or plan and implement nature conservation and biodiversity preservation measures. 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 applicable and useful – a step towards a deeper understanding of ecosystems and an integrated approach in the conservation of natural values of Latvia. As time goes on, this knowledge will improve, the techniques and abilities will change, yet these guidelines will remain as the most complete reflection of experience of nature conservation of the last 25 years, forming the basis for future problem solving. 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. A Brief Description of Groups of Water Habitats

In Latvian waters, there are seven types of protected habitats of the European (EU) level. Four of them are lake habitats, while two are river habitats. The group of water habitats also includes the habitat types that occur rarely and cover small areas in Latvia, namely, Lakes of gypsum karst and muddy riverbanks with nitrogen loving vegetation of pioneering species.

This publication covers seven types of protected habitats of EU importance:

- 3130 *Oligotrophic to mesotrophic standing waters with vegetation of Littorelletea uniflorae and/or Isoeto- Nanojuncetea*[1], 3140 *Hard oligo-mesotrophic waters with benthic vegetation of Chara spp.*,
- 3150 *Natural eutrophic lakes with Magnopotamion or Hydrocharition - type vegetation*,
- 3160 *Natural dystrophic lakes and ponds*,
- 3190* *Lakes of gypsum karst*,
- 3260 *Water courses of plain to montane levels with Ranunculion fluitantis and Callitricho-Batrachion vegetation*,
- 3270 *Rivers with muddy banks with Chenopodion rubri p.p. and Bidention p.p. vegetation.*

The existence of river and lake habitats is determined by many factors that characterise waters and their adjacent land. The most important ones are physical and chemical indicators of water, morphometric indices of a water course, bedrocks in a water catchment area, land use type and intensity in the water catchment, as well as the placement of water bodies (Cimdiņš 2001).

Lakes. For those lakes, which from a geological point of view are temporary objects that evolve during their existence turning into a marsh, morphometric parameters are very important – the lake's depth, width of the coastal shallow-water zone, sinuosity of shores and openness to dominating winds, as well as hydrological parameters such as rate of water exchange, intake from ground water and surface runoff. The type and intensity of economic activity in a lake's catchment in interaction with the morphometric and hydrological parameters, determine the course and speed of lake development (Leinerte 1985). Lake development is characterised by two opposing processes – **eutrophication**, which is enrichment with easily degradable nutrients, and **dystrophication** – which is enrichment with humic substances and absorption of nutrients. During such enrichment process, when the environmental conditions and species composition are changing, oligotrophic and mesotrophic lakes become eutrophic. While accumulating humic substances, lakes become dystrophic. The general relation between protected lake habitats and lake development is shown in Fig. 1.1. In the management of lake habitats, it is important to understand that the presence of the habitats in the lake is related to a certain development stage of that lake. Therefore, the management should provide for the lake staying at this stage of development the longest possible time.

Explanation of Terms and Processes.

Rivers and lakes significantly differ according to specific features of ecosystem functioning.

- The key function of lakes is the accumulation of substances and energy.
- The key function of rivers is the transport of substances and energy.

Figures and Facts.

There are 2,256 lakes and about 12,000 watercourses exceeding the length of 10 kilometres in Latvia. Approximately 35 % of the rivers, which are longer than 10 km, are partially or completely regulated, and the total length of artificial channels and drainage ditches exceeds 65,000 kilometres. In Latvia, waters such as rivers, lakes, ponds, springs and drainage systems take up around 3.7 % of the country's territory. Each year, the rivers of Latvia transport 34.7 km^3 of water to the sea, and 15.3 cubic kilometres originate in the Latvian territory.

[1] The code that has been assigned to habitat types in Annex I of the Habitats Directive. These codes added to names of habitat types will be used throughout the book without further specific explanations.

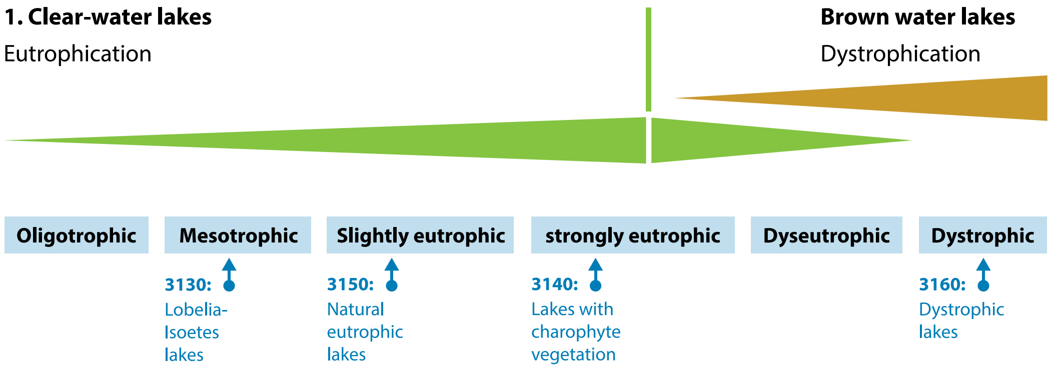
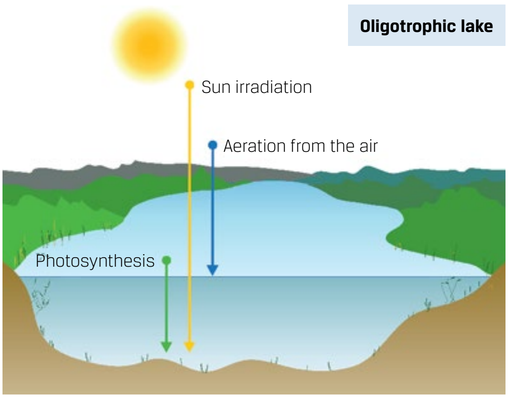


Fig. 1.1. Change of eutrophication and dystrophication processes during lake development and their relation to protected lake habitats.

Lake development and ageing are closely associated with the accumulation of nutrients or eutrophication, and it is a natural and irreversible process of lake development. At their final development stage, lakes turn into mires. When planning lake management and choosing the management methods, the following patterns of processes that happen in lakes should be taken into account:

- **in deep lakes** (> 9 m), eutrophication is basically seen as an increasing amount of algae plankton;
- **in shallow lakes**, eutrophication is basically seen as an increased development of aquatic plants that first develop in zones of submerged and floating-leaved plants and then in zone of emergent plants. As emergent vegetation develops, open shore parts disappear and open water zone gradually decreases (Urtāne 2014).

As the nutrients accumulate, their circulation in lakes also becomes faster, and more and more dead organisms accumulate in the lake's bottom. The decomposition of sunken aquatic plants and animals consumes oxygen. In the bottom water layer, reserves of dissolved oxygen start to deplete. In anoxic conditions, sediment-bound phosphorus starts to release back into the water. It increases the internal load of the lake with nutrients and causes secondary enrichment of the water body (Fig. 1.2).

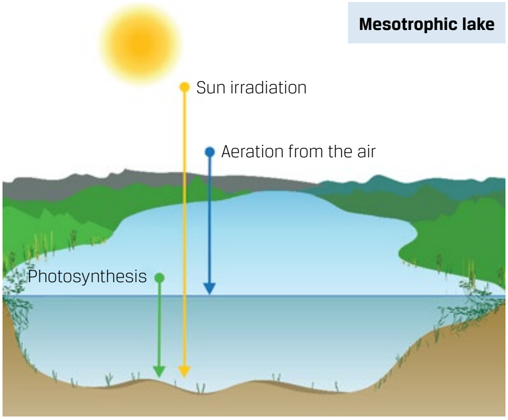


Processes taking part in the lake

Oxygen is mostly produced.
There is practically no surplus of organic substances.
Life cycle is closed.
P is bound to sediment and removed from circulation.

Lake type specific characteristics

O_2 in water: Plenty.
O_2 in bottom layer: Encountered.
Biogenes in water: Few.
Biogenes in sediments: Binded and withdrawed from turnover.
Production: Small.
Number of planktonic species: Small.
Number of planktonic organisms: Small.
Emergent macrophyte zone: Poorly developed or lacking. Plants scattered.
Submerged macrophyte zone: Separate growths *of Isoetes spp., Lobelia dortmanna, Littorella uniflora.*
Zone of floating – leaved macrophytes: Lacking.

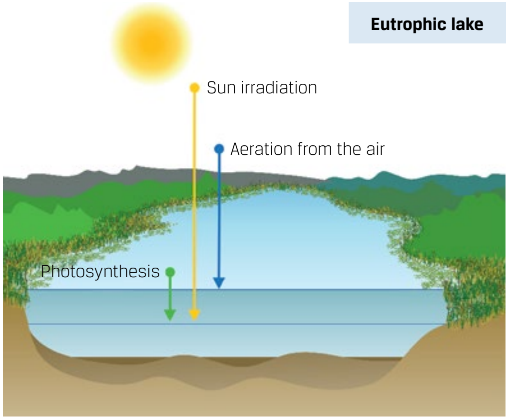


Processes taking part in the lake

Oxygen is mostly produced.
The surplus of organic matter is beginning to develop. Circulation is not closed.
P is slowly being released and returning to circulation.
The amount of precipitated organic matter is increasing.

Lake type specific characteristics

O_2 in water: Plenty.
O_2 in bottom layer: Decreases. Sometimes deficient.
Biogenes in water: Few.
Biogenes in sediments: Sometimes releases back to the lake.
Production: Average.
Number of planktonic species: High.
Number of planktonic organisms: Small.
Emerged macrophyte zone: Moderately developed, not exceeding 10–15 meters. Consists of *Phragmites australis*, *Schoenoplectus lacustris*, *Sparganium spp.*, *Typha angustifolia*.
Submerged macrophyte zone: Separate stands of *Isoetes spp.*, *Lobelia dortmanna*, *Littorella uniflora*. Shallow lakes sometimes rich in Charophytes stands
Zone of floating – leaved macrophytes: Consists of single stands of *Nuphar lutea*, *Potamogeton natans*.
Zone of free floating macrophytes: Seldom.



Processes taking part in the lake

Oxygen is mostly consumed.
A great amount of organic material is formed. Increasing amounts of unused organic matter.
A thick layer of sludge is formed in the lake.
P is actively liberated from sediment and returns to circulation.

Lake type specific characteristics

O_2 in water: Moderately to few.
O_2 in bottom layer: Absent.
Biogenes in water: Plenty.
Biogenes in sediments: Plenty. Sometimes dissolutes and returns to the lake.
Production: High.
Number of planktonic species: Low.
Number of planktonic organisms: High.
Emerged macrophyte zone: Developed and expanding, width exceeds 10–15 meters. Number of species small. Dominates *Phragmites australis*, *Typha latifolia*.
Submerged macrophyte zone: Moderately rich. Frequently replaced with floating – leaved plants.
Zone of floating – leaved macrophytes: Well developed. Frequently with development of eutrophication processes wide and vital stands of *Nuphar lutea*, *Nymphaea* sp develops.
Zone of free floating macrophytes: Well developed.

Fig. 1.2. Processes in the lakes in different stages of lake development: Oligotrophic lake **(1)**, Mesotrophic lake **(2)**, Eutrophic lake **(3)**. Drawing by D. Segliņa (according to Urtāne 2014).

Lake enrichment with nutrients causes major changes to the composition of groups of water organisms that inhabit the lake's bottom, as well as to the entire food chain. Research shows that the greatest diversity of aquatic invertebrate species can just be found in the shore part with a depth of up to 2 m (Kačalova, Laganovska, 1961). High biomass of water organisms can also be found in deeper layers, however, it consists of only a few species (Fig. 1.3).

In sandy and washed over lake littoral parts, species diversity is moderate. The most diverse set of organisms in terms of species develops in a moderately overgrown (< 30 %) shore part with submerged and floating-leaved aquatic plants (Kačalova, Laganovska 1961) (Fig. 1.4).

As the lake develops, it accumulates the dead parts of aquatic plants and animals, and thus organic substances are created. In their decomposition, oxygen is consumed and carbon dioxide is formed, and this encumbers the respiration of aquatic organisms. A mud layer develops, and the number of its species is low, while their representatives – *Chironomidae* and *Oligochaeta* – can sometimes be found in large numbers. Some molluscs are present but their number is not high (Fig. 1.4).

The water masses of rivers and lakes are inhabited by various planktonic organisms. Zooplankton (animal plankton) and phytoplankton (an algae plant plankton) play an important role in the aquatic ecosystem by creating primary production of organic substances (in algae) from inorganic substances; aquatic animals form secondary production by consuming and transforming into their species specific biomass (Cimdiņš 2001).

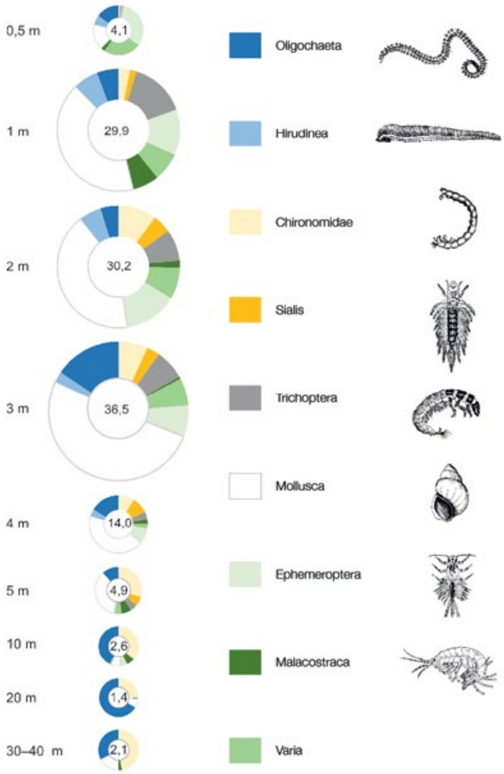


Fig. 1.3. Changes to groups of water organisms and their biomass (g/m^2) at different depths of a eutrophic lake Dridzis. Drawing by D. Segliņa (according to Kačalova, Laganovska 1961).

Fig. 1.4. Fauna of sandy **(1)**, moderately overgrown **(2)** and muddy **(3)** lake littoral part Drawing by D. Segliņa (according to Kačalova, Laganovska (1961).

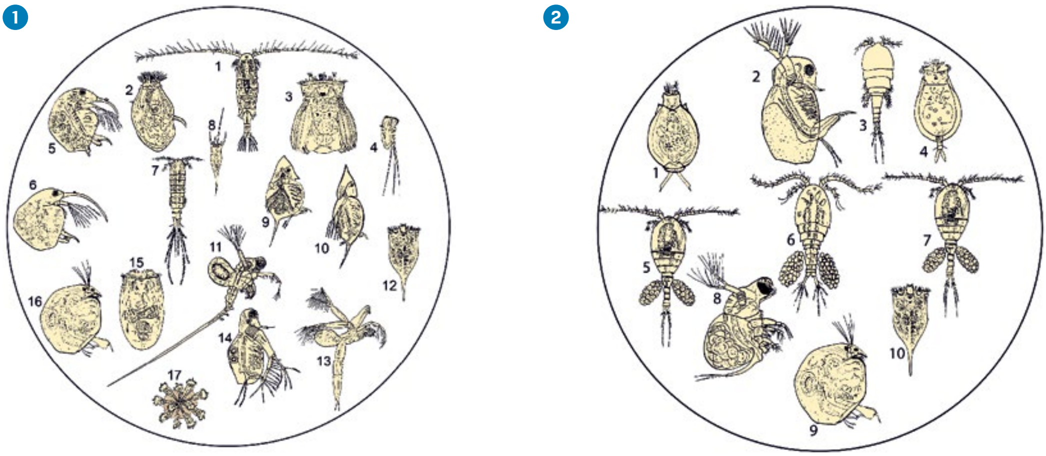


Fig. 1.5. Main zooplankton taxonomic groups inhabiting littoral and central part of a lake. Littoral zooplankton **(1)** consists of Rotifers: 1– *Lecane* spp., 4– *Euchlanis* spp., 10– *Keratella* spp.; Cladocera (water fleas): 2– *Sida* spp., 8– *Polyphemus* spp., 9– *Chydorus* spp.; Copepods: 3– *Paracyclops* spp., 5– *Ectocyclops* spp., 6– *Acanthocyclops* spp., 7– *Paracyclops* spp.
(2) Zooplankton of the central lake part: rotifers: 2– *Gastropus* spp., 3– *Polyarthra* spp., 4– *Filinia* spp., 8– *Kellicotia* spp., 12– *Keratella* spp., 15– *Asplanchna* spp., 17– *Conochilus* spp.; Cladocera (water fleas): 5– *Bosmina longirostris*, 6– *Bosmina coregoni*, 9– *Daphnia cristata*, 10– *Daphnia cuculata*, 11– *Bythotrephes* spp., 13– *Leptodora* spp., 14– *Diaphanosoma* spp., 16– *Chydorus* spp.; copepods (oar feet): 1– *Diaptomus* spp., 7– *Mesocyclops* spp. Drawing by D. Segliņa (according to Kačalova, Laganovska 1961).

Zooplankton is the main consumer of plankton algae, as well as the main feedstock for juvenile fish and fish that feed on plankton. The composition of the zooplankton species inhabiting the lake and the lake's open areas is different. This is determined both by the available feed resources and the environmental properties of the watertemperature, dissolved substances in the water and associated transparency, the effects of waves (Fig. 1.5). Therefore, in managing habitats, it is important to ensure diverse habitat conservation and to maintain the open and partly overgrown parts of the lake suitable for different groups of organisms.

Rivers are natural water streams, which collect waters from their drainage basins and follow self-formed channels. They are open ecosystems, where substances and energy are being transported. For practical reasons, running waters are divided into groups and classified by several criteria, for example:

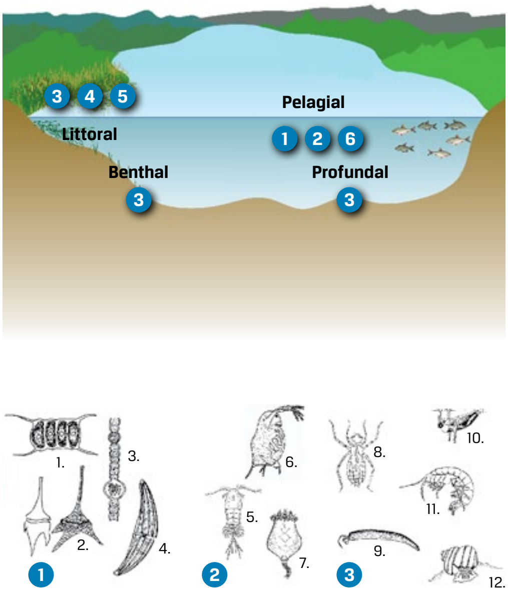
- hydrological criteria – velocity, discharge, river length, the size of the catchment area, etc.;
- ecological longitudinal profile or zoning according to fish or other water organisms;
- water chemical composition;
- types of their use and the quality objectives – recreational waters, fishery waters, waters for the extraction of drinking water, etc. (Cimdiņš 2001).

The rivers are divided into two groups according to their processes and habitats, which develop in rhithral – type and potamal rivers. The rapid (rhithral – type) rivers are characterised by a bed, which is covered by rocks, pebbles, and gravel, by high stream velocity, water temperature in the summer months below 20° C; their gradient is >1 m/km. According to the theory, the rapid (rhithral – type) rivers are typical for upper reaches of the rivers and highland areas. The potamal rivers have low stream velocity and the gradient < 1 m/km, while the water temperature in the summer months exceeds 25° C. This principle can only partially be applied to Latvia which is a geologically new formation, and often the rivers are of mixed type – riffles can be found not only in the upper reaches, but also in the lower reaches of rivers.

As rivers are open ecosystems, their flow interacts with their catchment areas. Mutual relationship mechanisms of the rivers and their banks are explained by a number of concepts:

- the concept of the river continuum describes the processes that take place in the river's longitudinal direction from the upper reach of the river to its mouth;
- The concept of flood pulse explains the processes that take place on land areas that are adjacent to plain rivers, in so-called zones of a river corridor, as they interact with the rivers.

Both concepts do not exclude but rather complement each other, and each of them explains the two major processes in rivers. For more information on the concepts of river continuum and of flood pulse concept, *see Chapter 17.* Rivers and lakes are inhabited by the same groups of organisms. The number of species and specimens of these groups in rivers and lakes greatly differs and is determined by functions of transporting or accumulating of substances and energy, stream velocity, morphometric parameters of water bodies, physical conditions and chemical parameters of the water environment. An overview of the major groups of water organisms is shown in Figure 1.6. All of these organism groups are closely related and form a food chain.



1. **Phytoplankton:** also known as microalgae, unicellular plant species which exist individually, or in chains or group.
2. **Zooplankton:** animal plankton, living in the water mass and feeding on algae; there are species that feed on organic substances or other zooplankton organisms.
3. **Benthos:** aquatic organisms that live in the upper layer of the waterbody bottom, or amidst the macrophytes.
4. **Macrophytes:** vascular plants, sporophytes, macroscopic algae and aquatic moss plants that have completely or partially adapted to life in water and are visible to the naked eye.
5. **Periphyton:** overgrowing algae and bacteria that cover the substrate as a glutinous film.
6. **Nekton:** fish, water bugs and other bigger insects, free floating macrophytes.

Fig. 1.6. Groups of plants and animals inhabiting the rivers and lakes (source: Urtāne 2014).

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

After the glacial retreat, the first people that entered the territory of Latvia settled near waters where they could obtain food and things for the household (fish, bivalves, root-stocks of water-lily and bullrush for food, common club-rush and reeds for construction, otters, beavers and other animals for food and clothing). Next to the outlet of the River Salaca of the Lake Burtnieks, there was a Stone Age settlement on Riņņi hill 5000 years ago. There, a layer of shells and fish bones was found, being up to 0,75 m thick, and composed of shells of bivalve – *Unio tumidus* (Rudzite et al., 2012). The importance of water abundance in the everyday lives of humans is evidenced by findings of harpoons and hooks, made of bone and later also of metal, in ancient settlements and in ancient grave fields, where they were donated as grave goods.

Rivers and lakes have been of importance not only in terms of food acquisition, but also as an opportunity to travel and as a landmark in the landscape; besides, they also provided protection from the forays of strangers. Most of the Latvian castle mounds (54 % or 256 castle mounds out of a total of 472) are located near watercourses, and for approximately one third (147 of 472) of the castle mounds, a short distance to the lake was important. 5 % or 22 castle mounds have been near both a river and a lake (Sietiņsone 2006). The location of the castle mounds near waters in Latvia is shown in Figure 2.1. Currently on Latvian lakes there are 11 known ancient settlements, which have been created right in the lakes. The best-known is the Āraiši ezerpils (Lake Āraiši dwelling site).

In ancient Latvia, the use and protection of waters was ensured by an old customary law that stated, even in the oldest law of the Livonian (14th century) knights, “two or more people may have common land, pasture, forest and fish, which means that everyone who settles there, can use all of this by putting his or her own efforts therein. While no one can use all of this by the help of strangers” (Švābe 1941). Also, in times of Baltic German dominance (12th–19th century), the issue of use of water resources was so important that for several lakes in Kurzeme the status of a free access lake was obtained, with every person having fishing rights. These rights have changed over time, and now the historically old idea of free

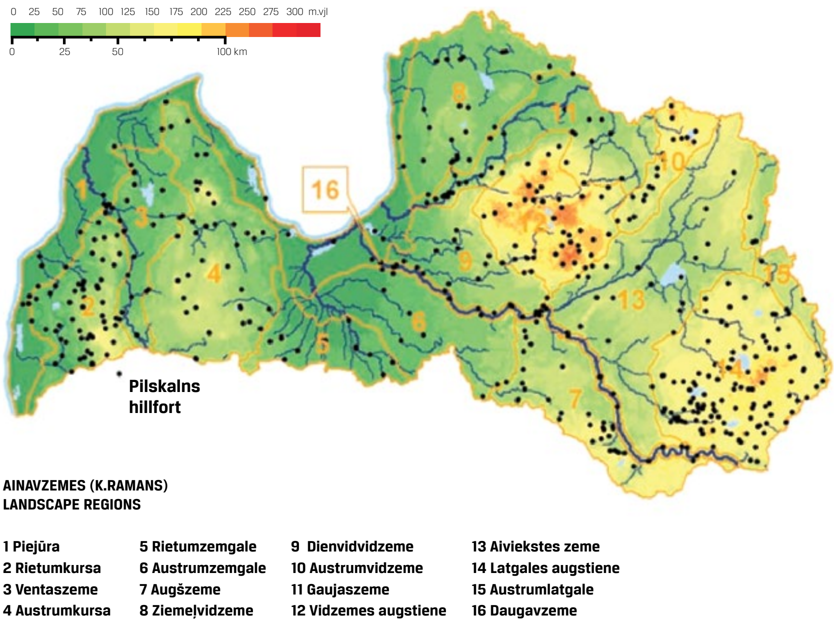


Fig. 2.1 Placement of castle mounds near waters in landscape regions of Latvia (source: Sietiņsone 2006).

access lakes as a water territory where everyone is allowed, is incorporated into laws in the concept of public lakes.

Since the 13th century, the energy of water has been used for grinding grain and later also for sawing wood. In the early 20th century, there were about 700 mill ponds in Latvia, and the energy of their water was used for grain grinding, woodworking, wool processing, and even for the production of gunpowder. In the 19th century people started to use water energy for the generation of electricity. In 1876, the Bille felt factory on the River Amata started to produce electricity, and in 1878 – a paper factory of Šablovskis in Augstpriedes started to produce electricity on the River Mazā Jugla. In 1901, the landlord of Smiltene Manor, Paul von Lieven built the first power plant on Lake Teperis (Anon. 2015).

Currently, there are three large hydro-electric power stations operating on the River Daugava, which ensure about 50 % of the electricity produced in the country. There are a total of 146 small hydro-electric power stations on Latvian rivers, and their total contribution to the national electricity balance is around 1 %. Hydro-electric power stations are often built on river reaches with a major gradient. By using water power, national energy independence is being strengthened; however, at the same time outstanding river reaches with their natural and cultural and historical values, such as the part of the Daugava between Koknese and Pļaviņas, are lost now and forever.

As the number of the population grew in the early 19th century, there was a greater wish to obtain land at the expense of drained lakes. Thus, for example, in 1842, when a channel of Lake Engure was dug in the length of 1.2 km, the water level of the lake decreased by about 2 metres and a grassland zone with a width of about 1 km was obtained on the western shore of the lake. Around the same time, Lake Vidāle was drained in Kurzeme in the middle of the 19th century in order to acquire additional land for agriculture (Penēze et al. 2013).

The largest water transformation project in Latvia involved Lake Lubāns and its surroundings. Before the transformation work, during flooding, the lake flooded even up to 80,000 ha of land, causing extensive losses to surrounding households. Lake Lubāns gained its current look in 1982 after the construction of the Northern dam. The former landscape was transformed to a great extent when six polders with pumping stations, which protect 40,000 ha of land from the flood, were built on the lowland of Lubāns. 38,000 ha of drained agricultural land and 10,000 ha of drained forests were obtained and fish ponds covering about 3000 ha were created (Bielis 1974).

The waters have always been important landscape elements, embraced by tales and stories. Old maps show that even in the 17th century, the land area for agriculture was small and scattered. So the large areas of the lakes were visually impressive and definitely caught people's attention. This is one of the explanations as to why there are so many tales and stories about the waters. The place and role of lakes were also outlined by the fact that their depth was not available to people, they were full of secrets and possibly included a variety of mythological beings (Urtāns 2008). The rivers have also had sacred importance both as a boundary and provider of fertility and prosperity. This is evidenced by the hydronyms – for instance, 15 rivers in Latvia are called *Svētupes* (Sacred river). A lake's sacred significance is also recorded in several hydronyms that indicate Latvian gods, such as Lake Dievezers (God's lake), Lake Māra (Māra is a goddess in Latvian mythology, Mother Earth), Lake Svēte, Lake Svētezers (Urtāns 2016).

The rivers still serve as a natural boundary between people and regions, for instance, the River Daugava has been a border between the Selonian and Latgalian lands, as well as a natural border with our neighbouring countries.

Chapter 3. Water Ecosystem Services

3.1 Classification of Ecosystem Services

Planning of water habitat management is closely linked with an increasing approach of ecosystem services used worldwide. The approach is based on a conclusion that the existence of humans on Earth is possible thanks to the ongoing natural processes and to those processes that ensure human existence, also called ecosystem services. When any of these services is absent, human existence on the Earth becomes difficult or even impossible.

The ecosystem services can be grouped and classified according to various criteria, however, the most commonly used is the international classification of ecosystem services, or Millennium Ecosystem Assessment (MEA 2003). This classification divides all the ecosystem services into four main categories: supporting services, provisioning services, regulating services and cultural services.

The so-called **supporting services** are essential ecosystem services – ecosystems create the environment and conditions required by living organisms by ensuring the circulation of water and substances, oxygen provision, a habitat for species in its broadest sense, a place for living, breeding, as well as feeding and migration paths. The value of the basic services is difficult or even impossible to measure and convert into monetary terms.

Water bodies and watercourses have a great role in the provision of **regulating and maintenance services**, in particular in the regulation of climate and water circulation. For example, river floodplains intercept and accumulate melting waters and flooding water, which actively participates in flooding regulation and flood prevention. At the same time, water bodies complement the ground water with their waters. Evaporation from water bodies creates a microclimate favourable to plant development, preventing or reducing the adverse impact of spring frost on agriculture.

Provisioning services of ecosystems are received by society directly from nature, including in the form of materials and energy. The importance of water as a life provider is difficult to overestimate.

Cultural services are nonmaterial benefits that society obtains from nature. The natural environment may provide people with spiritual, religious, aesthetic experiences, may serve as a source of inspiration; it also ensures recreational services, eco-tourism, and services in relation to cultural heritage and education. Rivers and lakes are an integral part of the landscape, and they often unconsciously serve as a background, which fosters thinking and work in our everyday life. Historically, settlements have concentrated near waters, and many historical events are related to the use of the waters. Life and recreation by waters is still an important part of human existence and an element in regaining human energy.

Each individual service of ecosystems can be expressed in economically measurable categories. Therefore, this approach is actually being used even more when planning the development of certain areas. There are different summaries about the monetary value of ecosystem services of the rivers and lakes (Table 3.1). The value of ecosystem services is high, and they can be very important for the local economy.

Table 3.1. The monetary value of ecosystem services per hectare in a year (Russi 2013), in US dollars in 2007.

Rivers and Lakes	Minimum value (USD/ha/year)	Maximum value (USD/ha/year)
Supporting services		
Food	27	196
Fresh water supply	1141	5580
Regulating services		
Natural purification of waters, post-purification of incoming sewage waters	305	4978
Cultural services		
Recreational and tourism opportunities	305	2733
Total	1779	13,487

3.2 Specific Water Ecosystem Services

Watercourses and water bodies provide many specific ecosystem services.

Self-purification of surface waters. Rivers, and to a lesser extent also lakes, have a unique self-purification ability. Their organisms use organic substances to maintain life processes. In this way, pollution of organic origin that reaches a river is reduced and the river purifies itself. This naturally reduces the water pollution, which is caused by agricultural and forestry activities, and this also reduces the organic pollution, which enters the water bodies with sewage waters.

Restoration of quality of groundwater. Groundwater provides people with high-quality water resources. They are in constant interaction with surface waters. Ground water affects the thermal and chemical properties of water bodies to a great extent. At the same time, surface waters supplement ground water supplies that are a source of drinking water.

Reduction of flood risk and its consequences. Properly managed water bodies and their terrestrial parts catch and accumulate flooding waters, balancing and reducing their rapid outflow and reducing the risks of damage in the territories that are located downstream. In contrast, unmanaged and overgrown shore areas promote the formation of groups of fallen trees (large woody debris) in rivers and block the rivers making the negative effect of flooding even greater and enhancing the erosion of the bank.

Sediment transportation, precipitation and neutralisation. Water bodies from their catchment areas receive minerals and particles of soil and dead organisms, called detritus. A part of them is neutralised by the water self-purification process. The remaining part precipitates on the river and lake bottom. If sediment precipitation exceeds the critical limit necessary for water bodies to function, negative consequences of precipitation appear. They among others include the blocking of water bodies, increased overgrowth, covering the river riffles with sediments, destruction of fish spawning grounds and decreasing the variety of habitats for aquatic invertebrates.

3.3 Green Infrastructure

In 2013 the Council of Europe adopted a strategy of green infrastructure, "Green Infrastructure – Enhancement of Europe's Natural Capital". The strategy is based on the preposition that green infrastructure includes natural and human-made formations, which, using the laws of nature, facilitate ecological stability and economic and social well-being. According to this approach, the green infrastructure is a strategically planned network of natural or semi-natural territories combined with other environmental objects, which are created and are managed to ensure the conservation and exchange of genetic diversity of species and their populations,even in intensively managed areas, and to provide a wide range of ecosystem services. The green infrastructure zone (or blue, when referring to aquatic ecosystems) is based on a principle that protection and improvement of nature and natural processes, as well as many benefits gained by the society from nature are integrated in the spatial planning and territorial improvement in places that are actively managed and used by people. Small rivers, streams, and even drainage ditches in managed territories serve not only as a water draining-channels, but at the same time they and their shore zones are essential as corridors for the living and migration of water organisms and species, which live on shore zones,

Blue infrastructure

In Sint-Truiden, Belgium, measures were taken to protect the village from flooding and the resulting soil erosion and sediment precipitation. Watercourse overgrowth was limited and protective zones settling basins were created in the river's catchment area. The total costs of these measures were low (126 euros per hectare for 20 years), compared to the costs of the prevention of the damage caused by sedimentation and flood and improvement costs in the managed territory (54 euros per hectare in a year). Furthermore, there were many additional benefits, including water of a higher quality, lower costs of water post-purification, lower psychological stress for the population when flood frequency decreased, and greater biodiversity in the river reach downstream. The greater biodiversity and more beautiful landscape opened new opportunities for agricultural and ecological tourism.

and as accumulators and transformers of nutrients that naturally reach the waters.

Inclusion of considerations of the green infrastructure in the management of river basins may significantly contribute to the provision of water quality and reduction of the consequences of hydro-morphologic load, as well as of the impact of flood and drought.

3.4 Role of Freshwater Habitats in the Mitigation of Climate Change

There are many ecosystem services that are related to water and wetlands. Analysis of long – term river runoffs shows that, when affected by climate change, there will be a significant increase in the cost of ecosystem water – related services (Kļaviņš, Zaļoksnis (ed.) 2016).

When implementing the Latvian National research programme "Impact of Climate Change on the Latvian Water Environment" (KALME), in the period from 2006 to 2009, the impact of long-, medium-, and short-term environmental variability on quality and ecosystems of Latvian inland waters and environment of the Baltic Sea was assessed. The studies provided significant conclusions on the impact of climate variability: it is expected that by 2100 the average annual temperature in Latvia will increase by 2.6–4.0 °C, while the total annual rainfall will increase by 8–12 % (KALME 2010).

It is expected that weather, according to the future climate models, will be characterised by (1) significantly shorter winters, even for three months that will come to an end in February, (2) spring starting half a month earlier, (3) a summer, which will last for two months longer (May–September), (4) nice and relatively dry and warm October, early November, (5) a rainier and longer autumn (including January).

Seasonal and regional changes of river runoffs will be more crucial than the annual average changes: (1) significant reduction of spring flood and its occurrence at least one month earlier; (2) significant increase in the flow rate through the winter; (3) significant extension of summer low water period and reduction of the runoff at the same time.

As winters become warmer and the maximum rainfall increases, the surface runoff during the vegetation-free period will also increase. This phenomenon will also encourage increased erosion during the leafless period, leading to changes in the chemical composition of surface waters and respectively changing the functioning of water ecosystems. To ensure the quality of Latvian water objects, the reduction of leaching soil particles and chemical elements in the winter period will need to be addressed.

The major part of agricultural runoff occurs in vegetation-free and winter periods. Only 27 % of the nitrogen leakage from fields reaches the water during the vegetation period. The remaining 73 % leaks in the period from November to March. Winter months – December, January, and February – have a special role, since leakage of nitrogen compounds forms 43 % of the total annual leakage, as suggested by the average long-term runoff data. Under intense farming conditions, around 75 % of the nitrogen fertiliser, which is cultivated in soil, is used by crops to harvest, while 15 % forms leakage in local drainage, and about 10 % reaches the river (Jansons 2013).

It shows that in the case of insignificant changes or even the reduction of the river flow rate, agricultural pollution may increase significantly in the future. **Therefore, year-round functioning grassland buffer zones with buffer lines of trees and shrubs along watercourses and water bodies should be planned and established in advance, as well as sedimentation ponds for the settling out of soil particles and for binding nutrients, before they enter water bodies, should be formed on intensively-managed areas and on areas that are subject to erosion processes.** When the climate changes, environment-friendly drainage systems, such as two-stage drainage ditches, which will be able to ensure both the accumulation of water during flooding and conservation of organism – friendly conditions during low-water summer periods, will be more important for organism conservation.

The expected structural and functional changes to fish fauna will also affect Latvian fish resources. The studies on the changes to the composition of inland water fish species (ichthyocoenosis), their distribution and incidence, migration and growth of fish species allows one to predict the impact of climate changes on fish resources as a whole and on related issues – fishing, angling and aquaculture. During the next 50–70 years, the composition of ichthyocoenosis will change significantly as a result of the decreasing amount of cold-water fish and increasing number of warm-water fish. As the temperature and discharge rate change, the food base of salmonids might be affected (Fig. 3.1). River restoration measures will have a primary role in the conservation of spawning grounds for salmonids, and they should be taken into account in the national environmental policy (KALME 2010).

It is expected that as a result of climate change, the annual average water temperature will rise, oxygen saturation will decrease, soil leaching processes under increased run-off conditions will increase during a vegetation – free season, as well as water colouration will increase due to the process of humic substance leaching. These factors will reinforce the overgrowth of water bodies. New conditions will form for interspecific competition.

One of the most significant manifestations of interspecific competition will be associated with an increasing availability of leaked nutrients that will promote the mass growth of algae on the upper layers of water. As the algae shading increases, the water colouration related to the leaching of humic substances will also increase, while the distribution depth available to submerged plants will decrease and their development will be limited. Initially, there will be better conditions for floating-leaved plants and freely floating lemnids, the photosynthetic parts of which are located in the upper layers of the water body. The conditions will be most favourable for emergent vegetation (*Phragmites australis, Typha* spp., *Scirpus lacustris*) with their main producing mass above the water, as well due to fact that they are not affected by the reduction of water transparency. Considering the distribution of emergent plants by up to 2.5 m in depth, floating – leaved plants will be partly eliminated from the littoral zone. All of this will lead to major changes to the composition of benthic organisms and thus also to the food base, which is available to fish and water birds. These changes will take place over several decades.

However, when we understand the processes, it is possible to create the conditions, by the use of corresponding management measures, that enable long – term conservation of functions and biological diversity of waterbodies.

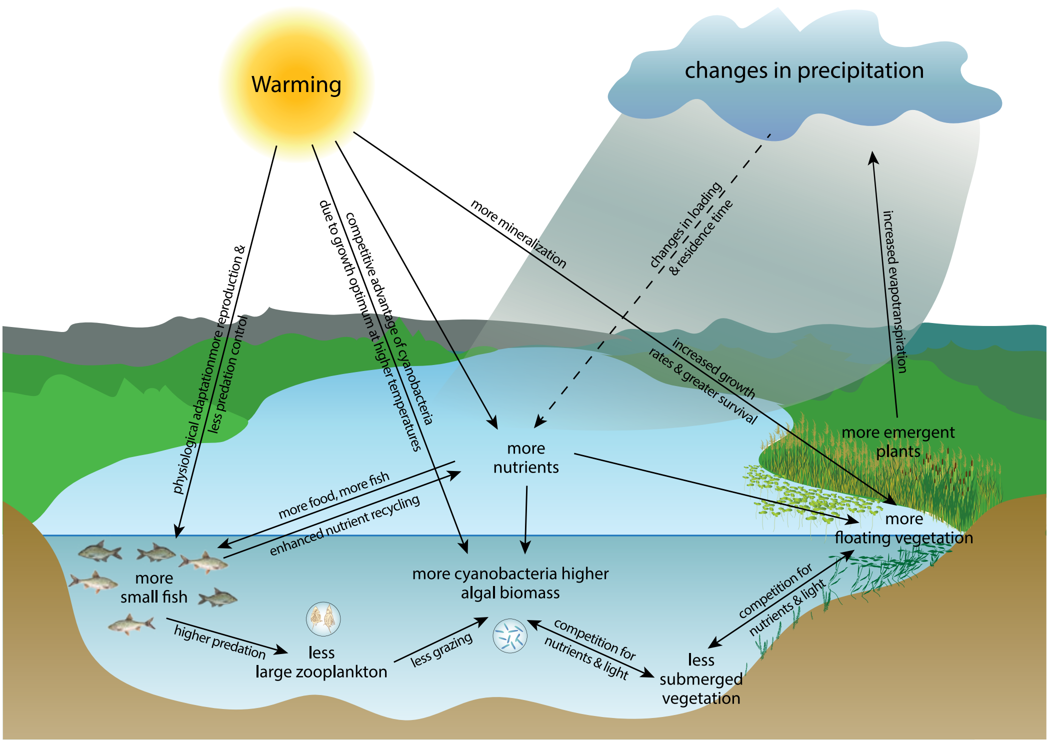


Fig. 3.1. Impacts of climate change on water organisms and processes in water bodies. Adapted and expanded according to Moss (2012). Drawing by D. Segliņa.

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

Different terms for the activities that focus on the provision of favourable conservation status of the habitat are used in the guidelines. **Habitat conservation** includes various actions – both the establishment of protected nature territories and micro-reserves, prohibitions and restrictions of various kinds, and planning and implementation of species' and habitats' management measures. More and more often the term **"conservation"** is used as an alternative term for habitat protection. In these guidelines both have been used as synonyms.

During the last decades, water bodies as open systems have received large quantities of nutrients in the form of phosphorus compounds, which cause eutrophication and which do not originate in Latvia. Therefore, protection and conservation encompass targeted actions, approaches, and techniques that are focused on the conservation of species and habitats. Passive management or non-intervention as a method applies only to dystrophic lakes that are related to mires, the development of which is still not affected by external conditions, and which receive their nutrients mainly from precipitation.

In these guidelines, **habitat restoration** is considered to be a set of biotechnical measures aimed at restoring the environmental conditions, composition of structures and typical species in the place where the habitat has once existed or still exists, but is in a poor conservation status. Habitat restoration in waters for the purpose of these guidelines includes, for example, removal of beaver dams from river riffles, removal of excessive overgrowth or fallen trees, and restoration of water flow.

Habitat restoration, management, and maintenance within the meaning of these guidelines are often used as synonyms, since water habitats, when they are not managed as open systems for a long period of time, also change their functionality. After resuming habitat management, the habitat-specific functions are also improving and being restored. For example, when aquatic plants are mown, the former sandy, gravel or pebble-covered bed structure and its related groups of previously disappeared organisms are restored under the impact of flow or wave activity (in lakes). Maintenance for the purpose of these guidelines means regular activities that ensure the diverse and habitat-specific functions and possibly the comprehensive sustainable existence of the species in a particular habitat.

Activities described further, except D2.1, D2.2, D2.3, had been tested and adapted for particular conditions in Latvia.

Table 4.1. Aquatic habitat restoration, management, maintenance and their objectives

Activity code	Habitat management activity	Habitat management activity objective			
		Renewal of Function	Renewal of structure	Renewal of typical species	Decrease of visitor load
A1:	Removal of fallen trees (large woody debris) and control of "catchers"				
A2:	Demolition of beaver dams				
A3.1:	Mowing of aquatic plants				
A3.2:	Mowing of aquatic plants with loosening and removal of roots.				
A4.1:	Improvement of the shore vegetation structure – shrub cutting and establishment of natural grassland zone.				
A4.2:	Improvement of the shore vegetation structure - regulation of river shading.				
A5:	Stabilisation of the shores				

Activity code	Habitat management activity	Habitat management activity objective			
		Renewal of Function	Renewal of structure	Renewal of typical species	Decrease of visitor load
A6:	Formation of riffle areas				
A7:	Maintenance of natural spawning grounds and establishment of artificial spawning grounds.				
A8:	Establishment of fishways				
A9:	Demolition of mill dam remains and obstacles				
A10:	Removal of sand deposits from mouths of rivers flowing into the sea.				
A11:	Invasive plant species control				
B1:	Diversification of structures of the regulated river reaches				
B2:	Construction of sedimentation ponds				
B3:	Construction of surface flow constructed wetlands				
B4:	Restoration of straightened rivers				
B5:	Environmentally friendly management of drainage ditches				
C1.1:	Mowing of aquatic vegetation in different lake depth zones and breaking of roots.				
C1.2:	Mowing of emergent aquatic plants and root breaking.				
C1.3:	Establishment of migration channels				
C2:	Mowing of emergent vegetation of shore areas – reinforcement of wave activity				
C3.1:	Change of structure of shore vegetation – felling of shrubs				
C3.2:	Change of structure of shore vegetation – grazing of shore grasslands				
C3.3:	Change of structure of shore vegetation – creation of wind corridors				
C4.1:	Reed burning – in winter and spring period				
C4.2:	Reed burning – in the second half of summer				
C5:	Mowing of emergent vegetation residues in autumn and winter				
D1:	Lake deepening and gyttja extraction				
D2.1:	Limitation of the circulation of plant nutrients – chemical settling of phosphorus				
D2.2:	Limitation of the circulation of plant nutrients –deep layer aeration of the lake				
D2.3:	Limitation of the circulation of plant nutrients – use of algaecides				
D3.1:	Prevention of fish suffocation – ice holes				
D3.2:	Prevention of fish suffocation – aeration				
D3.3:	Prevention of fish suffocation – mowing of emergent vegetation in river mouths and fish wintering depressions				
D4:	Food chain change – biomanipulation				
D5:	Development of infrastructure to decrease recreation pressure				
D6:	Establishment of artificial islets for water birds				

Chapter 5. Habitat Conservation and Management Objectives

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

(J. Jātnieks, A. V. Urtāns, A. Priede)

The major nature conservation legislation in the EU is Council Directive 92/43/EEC of 21 May 1992 on the conservation of natural habitats and of wild fauna and flora (hereinafter – the Habitats Directive) and 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 for the implementation of the "nature directives".

The most important law in the field of the protection of waters, which also includes the aspect of nature conservation, is Directive 2000/60/EC of the European Parliament and of the Council of 23 October 2000 – Water Framework Directive. It defines the action of the European community in the field of water protection policy. Its objective is to ensure the **achievement of at least good ecological status** in all EU waters, as well as to facilitate their sustainable and well-considered management and use. It, and the Habitats Directive, have a common aim.

Directive 2007/60/EC of the European Parliament and of the Council of 23 October 2007 on the assessment and management of flood risks requires the drawing up of flood risk management plans for each river basin district. These plans should include measures for protecting flood-prone territories, as well as for reducing the consequences of flooding by the restoration of floodplain meadows or wetlands. The provision of water ecological quality, which also includes sustainable management of water habitats, as well as a reduction of flood risk, are mutually related measures, and therefore, a special conceptual plan to protect European water resources (Water Blueprint 2012) has been elaborated.

The Birds Directive is intended to protect all species of wild birds and their habitats in the EU. The Directive provides for the protection of threatened bird species in the EU, protects feeding and resting sites most important for the migratory birds, particularly emphasising wetlands of international importance. **The Habitats Directive** is intended to promote biodiversity by protecting natural habitats, wildlife and plant species within the territory of the EU Member States. The Habitats Directive defines the necessity of protecting rare, endangered and endemic species, in total approximately 450 animal and 500 plant species, in the EU. Annex I to the Directive includes 231 habitat types, out of which 71 are recognised as priority protected at the EU level. Of those, 58 habitat types are found in Latvia, 19 of which are priority protected at the EU level[2].

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

The Habitats Directive provides for the implementation of nature conservation in a way so as to maintain or restore the favourable conservation status of natural and semi-natural habitats, wildlife and plant species[3]. In this edition the proposed guidelines include a set of techniques and methods to facilitate the achievement of favourable conservation status of the EU protected habitats found in Latvia. However, it is only a part of the activities encompassed in nature conservation *(see Chapter 4)*.

According to the Habitats Directive, one of the ways of how to save the habitats of Annex I and species of Annex II, is the designation of protected areas. Together with the areas established in accordance with the Birds Directive,

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[2] Currently three more forest habitat types, which can be found in Latvia, are being discussed to be included in the list of the EU protected habitat types. They have already been included in Volume 3 of these guidelines (grasslands) and Volume 6 (forests).

[3] A favourable conservation status is defined in Article 1 of the Habitats Directive, which in Latvia has been incorporated into the Law on the Conservation of Species and Biotopes (favourable conservation status is defined in Section 7 of the above law).

they create the EU **protected areas network Natura 2000.** Protected areas are established based on scientific criteria provided in Annex III. Upon planning and implementing the nature conservation measures in accordance with the Habitats Directive, for example, when 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, including seven protected marine areas. In total, Natura 2000 sites occupy around 11.5 % of the country's territory. Latvia is pro rate the third smallest area of protected natural areas in the country out of 28 EU Member States (compared to ten EU Member States, Natura 2000 territory occupies >20 % of the country).

Natura 2000 sites of Latvia are both small (up to 1 ha) and also may reach more than 50,000 ha, depending on the species inhabiting them or habitat features and conservation objectives. The area of Natura 2000 sites in Latvia on average varies from 100 to 1000 hectares. Many of them are known as public and well-respected natural heritage sites – national parks, nature parks, and nature reserves, as well as the areas, which create and maintain our agricultural, forest, mire, water, and sea shore landscapes – a significant part of natural and cultural history heritage.

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

According to the Habitats Directive, a task of habitat protection is to provide a set of factors that favourably affect the habitat and its characteristic species and promote the natural distribution, structure, and functions of the habitat, as well as the long-term survival of its characteristic species. Habitat conservation in the range of its distribution or – in a narrower sense – at a national level, is considered as favourable if its natural distribution range and areas where it can be found, are stable or increasing, it has characteristic structure and functions necessary for the long-term existence of the habitat, and it is expected that they will exist in the near future, as well as if the conservation of the characteristic species is provided for.

The EU Biodiversity Strategy to 2020 sets that by 2020, the Member States in their territories must restore at least 15 % of the degraded ecosystems (European Commission, *no date*). The criterion of restoration includes both the total area of the restored habitats, and the conservation status – improvement of biotic and abiotic environmental conditions. However, taking into account the extent of possible impacts on ecosystems in modern Europe, restoration is considered to be a condition where a considerable improvement has been reached in the main functions, processes, and structures of the habitats, as well as in the restoration of species populations and their suitable conditions. The reference point is believed to be the year 2006, when the first report on the conservation status and areas of habitat types included in Annex I of the Habitats Directive was prepared for the European Commission (Lammerant et al. 2013). Just like in other EU Member States, this objective should also be implemented in Latvia.

In order to achieve the biodiversity conservation goal, in 2013 Latvia, like other EU Member States, prepared *A Prioritised Action Framework for Natura 2000* – a document, which provides for the action on how to preserve species and habitats, taking into account the threats and problems related to their conservation. This guideline book provides for the instructions on restoring and managing the habitats and related species by performing (or in some cases – on the contrary – using the non-interference regime) certain activities.

5.2 Freshwater Habitat Conservation and Management Objectives in Latvia

The objectives of water habitat conservation and management in Latvia correspond to the common European Union's objectives for the conservation of waters, as well as of species and habitats inhabiting them – to achieve good ecological status in all waters by ensuring favourable conservation status to specially protected freshwater habitats and their protected species. The objectives for the conservation and management of freshwater habitats in Latvia are significantly expanded according to growing knowledge about the importance and various opportunities for the use of water resources by providing ecosystem services, acting as green infrastructure, as well as adapting to Climate change.

In the Latvian National Programme on Biological Diversity (Anon. 2002a), the following tasks were set for the conservation of water habitats and species:

- to conserve river riffle areas;
- according to a beaver protection plan, elaborate and introduce a programme for restoration of the most significant river riffle areas flooded by beavers;
- to ensure the function of ecological river corridors;
- to assess the necessity and opportunities for restoring the straightened river reaches;
- to implement a concept for planning the management of river basins.

To achieve these objectives, tools of different levels and methods on different scales are used — from cleaning up small reaches of rivers and lakes, developing and maintaining protective belts, sedimentation ponds, artificial wetlands, purification structures, creating new protected territories or micro-reserves to even planning an individual lake management plan, as well as to developing and implementing management plans for river basin areas.

The objectives for the conservation and management of water habitats in Latvia are in line with the objective of the Water Framework Directive – to reach high ecological quality status in all EU waters by 2015 (and, if it is not possible, in a longer period).

Therefore, before implementing the proposed activities, it is necessary to also know more about the river basin management plan. The common management goals for lakes and watercourses are summarised in Table 5.1.

Facts and Figures

For water resource management four river basin areas (RBA) are distinguished in Latvia – Daugava, Gauja, Lielupe, Venta RBAs. The smallest management unit is "water object", which embraces lakes and rivers with similar qualitative indices.

176 river, 250 lake, 3 transitional, 6 shore and 23 groundwater objects are distinguished (Urtane 2008).

For water resource management the interaction of different environmental, economic and social factors is taken into account and 6 year river basin management plans are elaborated for each of them. Each water object within the river basin area has specific management measures for reaching high ecological quality.

Table 5.1. Common goals of water habitat management in lakes and watercourses defined in River Basin District Management Plans (RBDMP) .

Lakes	**Rivers**
To prolong the development of the lake: • reduce the leakage of nutrients to the lake; • reduce the previously accumulated amount of nutrients. To improve the functionality of the lake: • create opportunities in the lake to effectively use the existing nutrient supplies, so that surplus forms at a slower rate; • create opportunities to withdraw nutrients that exist in the water environment from circulation.	To ensure good flow rate and living conditions for water organisms in rivers: • improve the ability of the river to effectively use the existing nutrient stocks, by assimilating them into the biomass of aquatic organisms; • promote the removal of the nutrients from the water environment that have accumulated in water organisms, mainly in aquatic plants; • reduce the nutrient leakage from the catchment area; • reduce sedimentation processes in watercourses; • reduce flood risks.
To ensure favourable conservation status to habitats	

5.3 General Principles of Planning Habitat Restoration and Management

When planning management of a river or lake, setting an aim is the most important thing to do – *what* do we want to achieve with our action? Management desires and their scale may be very diverse – from a local swimming place or creation of a river riffle to the restoration of the whole lake or several kilometre-long river stretch. This requires knowledge not only about the natural condition of the habitat, its current processes and ecological requirements of species residing there, but also information about the structure (morphology) of the managed water body and its relation to the higher hierarchical elements of the catchment area.

Various hierarchical levels of a river as a system are shown in Figure 5.1. Similarly, various hierarchical levels can also be determined for lakes, when planning and implementing their management. Management measures will vary significantly if restoration and improvement of habitat quality will be associated with the activities in the whole catchment area of a lake or if the activities will cover only a separate part of a lake, such as mowing of the emergent plants to promote restoration of a shore zone, which is more suitable to wading birds, fish and aquatic invertebrates.

It is just as important to realise that a wish to restore a part of a water ecosystem will always be relative, since it is not possible to accurately restore "the lake from my granny's childhood" when knowing that agricultural land is cultivated with mineral fertilisers that have not originated in Latvia.

Before starting to restore the habitats, it is important to also assess the aspects of water resource use and their intensity in a catchment area because the condition of aquatic habitats is mainly a consequence of economic activities in the catchment area. Therefore, in each separate case, it is necessary to understand the real situation, taking into account the impacts and obstacles. Without preventing the degrading impact of water habitats in catchment areas, for instance, without improving the operation of wastewater treatment systems or functionality of shore protection zones, management will only give temporary positive results. For example, mowing of the aquatic plants will be less effective, and it must be repeated more often if nutrient rich waters from nearby intensively used agricultural areas or misoperated wastewater treatment plants continuously discharge or leak into the nearby upstream. This does not mean that it is not worth starting to clean up a small territory in a huge

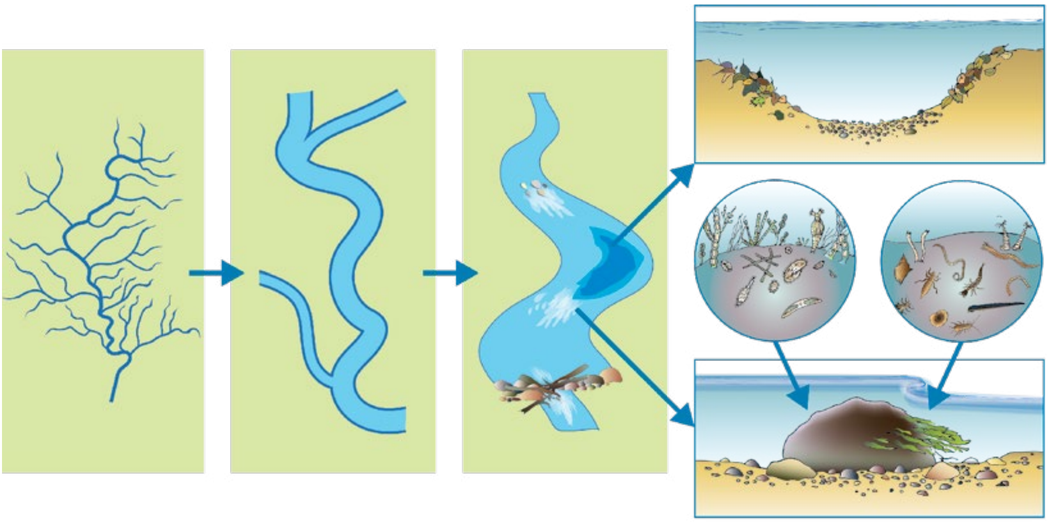

Fig. 5.1. Planned management activity scale in relation to the river as a joint ecological system and its microhabitats. Drawing by D. Segliņa.

lake before the inflow of nutrients is prevented from the whole lake's catchment, which covers hundreds of square kilometres. A perfect, still, in practice rare solution is integrated management, which includes activities both in the catchment area, avoiding the possibility of the occurrence of pollution or eliminating the consequences of pollution in the particular water body.

In many cases, only maintenance and prevention of worsening the condition in aquatic ecosystems as open systems are possible – it is a sort of compromise, which is still better than doing nothing.

To achieve good results, cooperation and planning not only among the neighbouring households, but also among interest groups, local partnerships, and even cooperation at the level of parishes and regions is also of great importance. An effective management solution for medium-size and large public lakes, which are more often controlled by local municipalities, is the development and implementation of a lake management plan and of lake zoning. Such lake zonings are elaborated, taking into account the various resources of the lake, their potential use, historical use of the lake, and preferences of the population (Urtāne, Urtāns 2011). During the elaboration process, different interests of use of the lake are harmonised.

Chapter 6. Preparation Before Management or Restoration

Waters are a place where the interests of different water users and managers meet. Before planning the management or restoration measures, all of these interests must be identified and agreed upon (*see Chapter 8*). The following information should be clarified about each particular water body:

- whether the water body, which is intended for management, is private or public water – this determines the further course of measure harmonisation;
- quality criteria set for a water body – whether it is priority Salmonid or Cyprinid water;
- identification of wastewater discharges and pollution loads allows an assessment to be made as to whether the expected action can provide the long-term improvement of habitat quality;
- proportion of land use in the catchment area (forests, wetlands, agricultural land, built-up areas) –this allows one to evaluate the potential of diffuse pollution loads, as well as further eutrophication and sedimentation processes, and the success of the measures taken.

One should find out whether the water body – a lake or river (a river reach) – is located in a flood-prone territory and what measures for the reduction of flood risks and its consequences are included in the flood risk management plan of the relevant river basin area. Before planning the management measures, we should become familiar with the spatial planning of local governments and the planned development of future activities. Provisions that refer to habitat management and the need for harmonisation of the measures are established by a legal framework, therefore requirements of law should be explored before planning the management measures (*see Chapter 8*).

If the objective is clear, the next step is to figure out how to achieve it – with which actions the idea can be implemented. This requires exploring the situation in detail, a survey of site conditions, clarification, comparison, and selection of the potential habitat restoration and management techniques, assessing how suitable they are for the particular situation with regard to the available resources.

Already in the idea stage, it is necessary to be able to assess the extent to which the objective is achievable, and anticipate the obstacles. This will help to decide whether the investment is commensurate to the expected result. If not, then, most likely, it is better to invest efforts where they are more worthwhile.

Establishment of lake and river management priorities is shown in Annexes 1 and 2.

Chapter 7. Landscape Ecological Aspects of River and Lake Biodiversity Conservation

Historically, people first settled in river valleys and shore parts of lakes. Water landscapes formed through the permanent interaction of human and nature, and they served not only as distribution corridors of plants and animals, but also as a path of movement for people. Not only medium-size and large rivers, but also lakes have always been important and diverse landscape elements. The waters, which were clearly visible in nature, served as borders of property and of national borders. Waters and their shores in many cases form a central part of the landscape. Watercourses and their shore zones are often the only relatively natural corridors for plant distribution and animal movement in arrays of agricultural lands, for example, Zemgale Lowland. A similar situation exists in many parts of Europe, and by using the knowledge about animal migration patterns, residence and migration opportunities in intensively farmed landscapes can also be ensured (Fig. 7.1).

Lakes are also important landscape elements, and their shore floodplains have historically been used in agriculture. The lakes by themselves have provided the human population with fish resources. This model of use in many places has created a mosaic-type landscape structure, adapted to the shore parts of rivers and lakes (Melluma, Leinerte 1992). As a result of the lasting interaction of humans and nature, the landscape mosaic also ensures the greatest diversity of species and micro-habitats. In recent decades, in connection with the extensive decline of agricultural production, Latvian rural landscapes have become more and more closed (Fig. 7.2), and we can observe a reduction of territories with high-value cultural landscapes (Lakovskis 2013).

From the point of view of landscape ecology, more problems in rural areas are currently caused by overgrowth of river and lake floodplains, and it leads not only to the disappearance of many species, which are characteristic for semi-natural grasslands (Nikodemus et al. 2007), but also to a rapid decrease in the possibilities of visual perception of the landscapes (Lakovskis 2013). Management decline has resulted in vast emergent plant zones in shore parts of lakes that significantly reduce not only the openness of the water bodies and their scenic attractiveness, but also their biological diversity (Fig. 7.3).

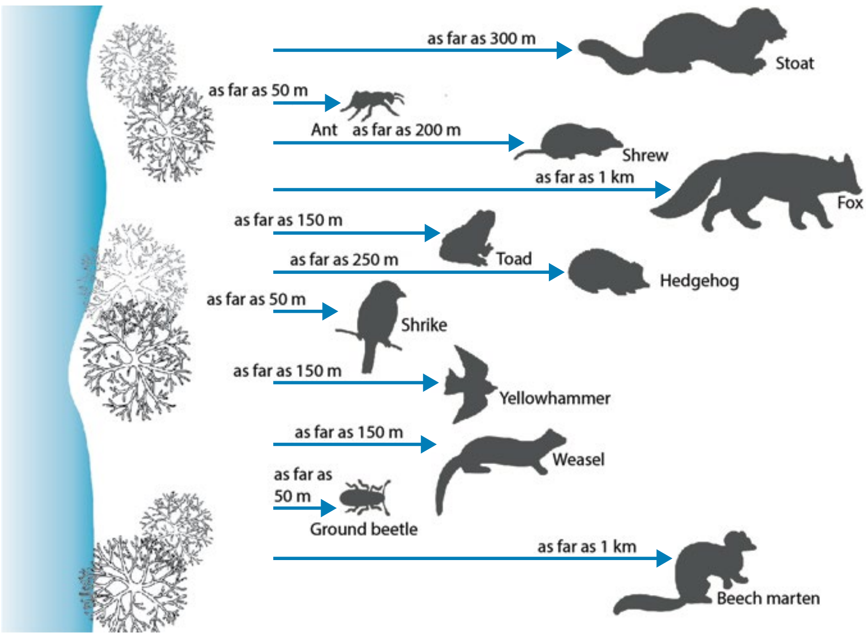

Fig. 7.1. Waterfronts as migration corridors. Animal migration distances in water shore parts. Drawing by Z. Rubene. (according to Lange, Lecher 1989).

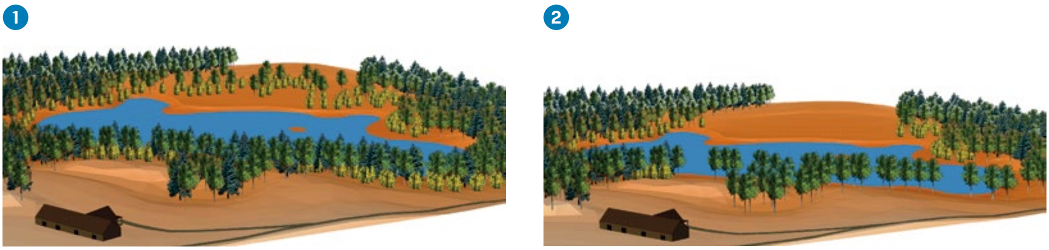

Fig. 7.2. A three-dimensional model for the visualisation of landscape management: a close view of a lake **(1)**, a wide view of the lake **(2)** (according to Lakovskis 2013).

Conservation and creation of the traditional landscape structure has been identified as one of four strategic aims of the Latvian National Programme on Biological Diversity (Anon. 2000). It is very important to reach this objective for the ecological planning of landscapes. Nowadays the concept "landscape ecology" refers to science that explores the ecosystem complexes in broader areas (Lakovskis 2013).

Landscape ecological planning in Latvia is a relatively new approach to spatial planning and focuses on the conservation of viable populations of species in a long-term perspective. It includes the assessment of various factors and their mutual impacts, which is a much more complex task than the passive short-term conservation of species and habitats that is based on restrictions. It must ensure the conservation of biodiversity, protection of cultural and historical landscape and its elements, conservation of the aesthetic quality of landscapes as an important resource for territory development, with the simultaneous facilitating of sustainable territory development (Nikodemus et al. 2007). The ecological planning of landscapes includes identifying and creating landscape corridors, which at the level of the entire region or at the local level connect different natural elements and structures that serve as habitats for many living organisms. This planning approach gives a special role to waters, since the waters and their shore landscapes form an ecosystem (an ecotone), where impacts of land and water environments are expressed at the same time.

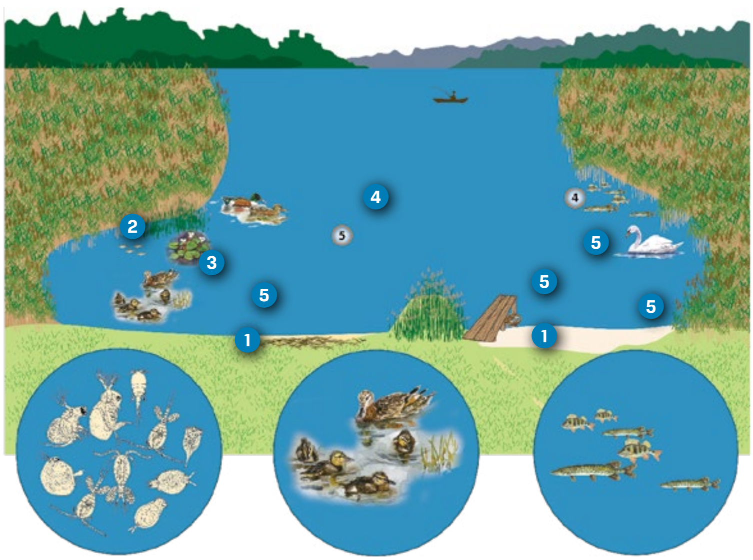

Fig. 7.3. Importance of open shore area for the maintenance of lake functionality and biodiversity. 1– plant residues washed ashore; 2– shallow water zone where fish juvenile feeds on zooplankton; 3– submerged and floating-leaved plants; 4– hideout zone where predator fish stay; 5– warmed up shallow water zone with massively evolving zooplanktic communities. Drawing by D. Segliņa (supplemented according to the materials of SYKE (SYKE no date)).

Chapter 8. Legal Framework of Restoration and Management of Water Habitats

(L. Urtāne, Ē. Kļaviņa)

Water and related resources are widely used in various sectors of the economy. In order to know what you can do on the water and on its shores, which management measures are allowed and where, whether and how they need to be coordinated, what the responsibility and duties are when managing specially protected water habitats and its species, one should explore the legal provisions or consult the responsible public authorities.

8.1 Legal Framework for Water Resource Use and Management

Protection and management of water resources. Unlike other habitat groups, freshwater habitats and species cannot be viewed without a component of water environmental quality. To ensure the conservation of EU water quality, habitats and species, a number of directives have been issued, and their requirements have been incorporated into the national legal framework. In Latvia, the main water-related law or the so-called "umbrella" law is **the Water Management Law**[4]. The purpose of this law is to establish a system for the protection and management of surface water and groundwater which: facilitates sustainable and rational use of water resources, ensuring the long-term protection thereof and sufficient supply to inhabitants with good quality surface water and groundwater; prevents the deterioration of water and the state of the terrestrial ecosystems and wetlands directly dependant on water, protects such ecosystems and improves the condition thereof.

The Water Management Law has been elaborated in order to transpose the requirements set by the Water Framework Directive of the European Parliament and the Council in national legislation. The law establishes a system to implement Directive and to achieve the objective of at least good ecological condition for all surface waters and groundwaters of the EU Member States by 2015. To achieve these objectives, four river basin districts have been identified in Latvia. For each of the districts, **a River Basin District Management Plan** has been elaborated, to establish the programme of measures. In order to target the management measures needed, all natural waters according to their typology and degree of physical alterations by human activity have been divided into water bodies. At the time of publishing these guidelines, the objective of the Water Framework Directive is not achieved to the full extent in any of the EU Member States.

The Water Framework Directive

Water Framework Directive 2000/60/EC of the European Parliament and of the Council was approved on 22 December 2000 with an aim to protect and improve the condition of inland surface waters and groundwater and facilitate the sustainable use of waters. This directive substantially changed the approach to water quality assessment. Previously, water quality was evaluated by chemical parameters, while now, with the implementation of the Water Framework Directive, the ecological status is being assessed. This means that the ecological quality of a water body is evaluated by the composition and number of species that correspond to the particular type of surface water and parameters characterising the natural ecosystem. Thus, the objective of the Water Framework Directive directly echoes the aim of the conservation of species and habitats.

With the implementation of the Water Management Law, there is a new concept used in practice, namely, "water body". Water body, within the meaning of this law, is the smallest management unit of river basin districts, which is a discrete and significant element of surface water including both water and the catchment area. Thus in practice the ecological quality of the water body is assessed and then the management measures are addressed to all the territory of the water body (Urtāne etc. 2012).

With regard to protected areas, it is important to understand that according to the Water Management Law, not only protected nature territories but also drinking water abstraction sites and bathing water areas are designated as protected areas.

Flood risk management. When planning the management or restoration of water habitats, it is also necessary to take into account the aspects of flood risk management, which is also regulated by

[4] Adopted 12.09.2002.

the Water Management Law. **Flood risk management plans** are one of the planning documents for the water management system. These plans list the measures for the reduction of the likelihood of floods and their consequences. These actions should be taken into account when planning water habitat management. For example, the restoration of floodplain grasslands or wetlands as a habitat management measure also reduces the flood risk at a larger scale. At a local scale, flood risk may occur under the conditions of a hindered river flow due to beaver dams or large accumulations of large wooden debris (LWD). Therefore, when planning habitat restoration or management in a flood-threatened territory, the requirements and restrictions, which are set in the flood risk management plan, are considered to be a priority, since habitat management measures should not reduce the water flow rate or endanger the safety of people and infrastructure.

Water use. When planning the management or restoration of water habitats, the **regulations for the exploitation (management) of water objects** must also be taken into account, since they, in compliance with the legal framework, are elaborated for public waters – public lakes and rivers, waters where fishing rights belong to the state[5], as well as for water objects with hydro-technical constructions for the regulation of the water regime[6].

Water quality objectives. With regard to the management of water habitats, the most important regulatory enactment for water quality objectives is **"Regulations Regarding the Quality of Surface Waters and Groundwaters"**[7], which define the quality requirements of priority fish waters and list the rivers and lakes where these requirements are attainable. In Latvia, 123 rivers or their separate reaches and 45 lakes have been recognised to beas priority fish waters.

These regulations of the Cabinet of Ministers state that "priority fish waters are freshwater, in which water protection or measures for improving water quality are necessary in order to ensure favourable living conditions for the fish population". According to these provisions, priority fish waters are divided into:

- **Salmonid fish waters**, in which salmon (*Salmo salar*), sea trout and brook trout (Salmo trutta), grayling (*Thymallus thymallus*) and whitefish (*Coregonus*) live or where it is possible to ensure the existence thereof;
- **Cyprinid fish waters**, in which fish of the carp family (*Cyprinidae*), as well as pike (*Esox lucius*), perch (*Perca fluviatilis*) and eel (*Anguilla anguilla*) live or where it is possible to ensure the existence thereof.

From the perspective of habitat management, the priority Salmonid water category includes rivers, which are particularly sensitive to the reduction of flow rate and intensification of sedimentation. Therefore, priority should be given to habitat management measures, which can prevent these threats. In Salmonid lakes, priority is granted to the management measures that ensure the improvement of lake functionality. For example, intensification of wave movement, which is achieved by emergent aquatic plant mowing to open the lake shore.

The necessity to ensure a river's flow rate is also indirectly set by the regulations of the Cabinet of Ministers **"Regulations on Rivers (Parts of Rivers) where, for the Purpose of Fish Resource Protection, Construction and Renovation of Hydropower Plant Dams and Building of any Artificial Dams is Prohibited"**[8]. The annex to these Regulations in-

Flood risk management system

Necessity of flood risk management is defined by Directive 2007/60/EC of the European Parliament and of the Council of 23 October 2007 on requirements for the assessment and management of flood risks. According to the requirements of the Directive, a flood risk is assessed over the entire threatened territory throughout the country. For each river basin district, a flood risk management plan, which sets out measures to reduce the likelihood of floods and their consequences, has been elaborated. Flood-prone territories in Latvia cover 200,000 ha, which represents approximately 3 % of the country's area.

[5] Regulation of the Cabinet of Ministers No. 918 of 11.08.2009, Regulation on the lease of water bodies and commercial fishing rights and use of fishing rights.

[6] Regulation of the Cabinet of Ministers No. 1014 of 27.12.2005, order for the elaboration of regulations for the exploitation (management) of water objects.

[7] Regulation of the Cabinet of Ministers No. 118 of 12.03.2002, Regulations Regarding the Quality of Surface Waters and Groundwaters.

[8] Regulation of the Cabinet of Ministers No. 27 of 15.01.2002, Regulations on rivers (parts of rivers) where Building and Restoration of Hydropower Plant Dams and Building of any Artificial Dams is Prohibited for Fish Conservation Purposes.

cludes a list of rivers (their reaches) where, for the purpose of the protection of fish resources, it is prohibited to build and restore any hydro-power plant dams and create any other mechanical obstacles. The list includes the most significant fast flowing river reaches with riffle habitats where unimpeded water flow rate is necessary for the provision of fish migration. When managing these river habitats, the priority measures are those that can improve the conditions of the river flow and reduce the negative impact of sedimentation (*see Chapter 17.2*).

8.2 Legal Framework for the Protection of Aquatic Habitats

8.2.1 Protected Habitat Types and Species

Law on the Conservation of Species and Biotopes[9] defines that the conservation of species and habitats is a set of measures necessary for the preservation or restoration of populations and habitats in a favourable conservation status. The subordinated regulations of the Cabinet of Ministers provides a list of habitat types[10] and species[11] that are specially protected in Latvia, a list of plant and animal species of EU importance[12], and a list of the species and habitats in Latvia of EU priority[13]. The list of specially protected habitats of Latvian and EU importance are not the same. For example, rare and specially protected lake habitats in Latvia, "Lakes with *Trapa natans*" (three lakes) and "Lakes with *Najas spp.*" (14 lakes), as well as the river habitat "Riffles and waterfalls" are not included in the list of the Habitats Directive[14]. The same also applies to protected species of aquatic organisms in Latvia and the EU.

Separate regulations of the Cabinet of Ministers[15] provides a list of bird species whose habitats are subject to a specific conservation measures. These regulations enlist a total of 96 bird species. Of them, 41 bird species are breeding or staying during their migration in the water habitats.

8.2.2 Protected Nature Territories and Micro-reserves

Law on Protected Nature Territories[16] defines the key principles for the establishment of protected nature territories in Latvia. Categories of specially protected nature territories – strict nature reserves, nature reserves, protected landscape areas, and a biosphere reserve – are established and managed to protect and conserve nature diversity, including habitats of protected plant and animal species, and landscape elements which are necessary for the provision of ecological functions of protected species and habitats. All specially protected nature territories in Latvia are included in the network of protected nature territories of European significance, Natura 2000.

Micro-reserves (protected nature territories of small area (0.1–30 ha), in compliance with the provisions of the **Law on the Conservation of Species and Biotopes**[17], are established to protect certain protected species or habitats. The subordinated regulations of the Cabinet of Ministers[18] define that micro-reserves in aquatic areas can be established for the conservation of four fish species, one *Cyclostomata* species, three amphibian species, seven aquatic invertebrate species, seven aquatic vascular plant species, and one charophyte species.

Boundaries of the protected nature territories are set by regulations of the Cabinet of Ministers. Boundaries of micro-reserves are set in decisions on the establishment of the microreserves. Digitally they can be viewed in the national information system – nature data management system "Ozols" (http://ozols.daba.gov.lv/).

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[9] Adopted on 16.03.2000, with the amendments of 01.01.2016.
[10] Regulation of the Cabinet of Ministers No. 421 of 05.12.2000, on the list of especially protected biotopes.
[11] Regulation of the Cabinet of Ministers No. 396 of 14.11.2000, on the list of especially protected species and species with restricted use.
[12] Regulation of the Cabinet of Ministers No. 1055 of 15.09.2009, List of animals and plants species essential in European Community which need to be protected and for which hunting and gathering in the wild can be restricted.
[13] Regulation of the Cabinet of Ministers No. 153 of 21.02.2006, on the list of priority species and biotopes of the European Union encountered in Latvia.
[14] Council Directive 92/43/EEC of 21 May 1992, on the conservation of natural habitats and of wild fauna and flora.
[15] Regulation of the Cabinet of Ministers No. 211 of 27.03.2007, on the list of those bird species, to which special measures for the protection of habitats are to be applied in order to ensure the survival and reproduction of species in the natural range.
[16] Adopted 02.03.1993, with the amendments as of 11.01.2014.
[17] Adopted 16.03. 2000, with the amendments as of 01.01.2016.
[18] Regulation of the Cabinet of Ministers No. 940 of 18.12.2012, Procedures for the Establishment of Micro-reserves and their Management, Conservation, as well as the Interpretation of Micro-reserves and Buffer Zone.

8.2.3 Provisions for the Protection and Use of Protected Nature Territories

Protection and management of protected nature territories are defined in **General regulations on the protection and use of specially protected territories** or **regulations on their individual protection and use.** In order to harmonise the interests of nature conservation, use of natural resources and sustainable development of the region by maintaining the natural values, a nature conservation plan[19] can be elaborated for a protected nature territory. The nature conservation plan determines nature conservation and protection objectives, as well as measures for the management of specially protected species and habitats.

General Regulations on the Protection and Use of Specially Protected Nature Territories[20] define general permitted and prohibited activities in protected nature territories of each category, as well as activities and measures that may be carried out with permission of the Nature Conservation Agency. The general regulations must be followed unless individual regulations on protection and use are elaborated for the particular territory, defining specific restrictions for its habitats and species.

8.2.4 Provisions on the Protection and Use of Micro-reserves

Nature conservation and management measures in micro-reserves are subject to the regulations of the Cabinet of Ministers[21] determining (1) activities that are prohibited in the territory including its waters, (2) activities that are allowed according to an opinion of an expert, as well as (3) activities that may be implemented with written permission of the Nature Conservation Agency.

8.2.5 Environmental Impact Assessment

Law on Environmental Impact Assessment[22] determines actions requiring an initial environmental impact assessment[23] or environmental impact[24] assessment. With regard to the management and restoration measures of the water habitats described in these guidelines, a procedure of initial environmental impact assessment is applied in cases where deepening of a lake is related to the extraction of gyttja and the planned volume exceeds 1000 cubic metres.

The proposed activities, which require technical regulations issued by the State Environmental Service, are defined in subordinated regulations of the Cabinet of Ministers[25]. They include the following management measures of water habitats:

- restoration and reconstruction of channelised watercourses of national importance – refer to management measures dealing with the improvement of functionality of regulated river reaches (Table 8.1);
- construction and reconstruction of hydro-technical constructions – refer to the construction of fishways (Table 8.1);
- maintenance and deepening of surface water bodies if technical regulations are required in compliance with the regulatory enactments regarding maintenance and deepening of surface water bodies – refer to measures dealing with flow rate improvement (Table 8.1).

In Natura 2000 territories, in addition to activities that need a preliminary environmental impact assessment or environmental impact assessment according to the law, the State Environmental Service can decide that the proposed activity[26] can significantly affect a protected nature territory of European importance (Natura 2000), and request a preliminary environmental impact assessment. Based on this assessment, the State Environmental Service either issues the technical regulations or applies the environmental impact assessment procedure in accordance with the regulations of the Cabinet of Ministers[27].

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[19] Regulation No. 686 of 09 October 2007, Regulations on the Content of and Procedure Regarding the Elaboration of a Nature Protection Plan for a Specially Protected Nature Territory.
[20] Regulation No. 26264 of 16 March 2010, General Regulations on the Protection and Use of Specially Protected Nature Territories.
[21] Regulation of the Cabinet of Ministers No. 940 of 18.12.2012, Procedures for the Establishment of Micro-reserves and their Management, Conservation, as well as Interpretation of Micro-reserves and Buffer Zone.
[22] Adopted 14.10.1998, with the amendments as of 01.01.2016.
[23] Annex 2.
[24] Annex 1.
[25] Regulation of the Cabinet of Ministers No. 30 of 27.01.2015, Procedures by which the State Environmental Service shall issue technical regulations for the intended activity.
[26] A planned activity – implementation of a project, construction, extraction or use of natural resources, influencing of areas and landscapes not affected or little transformed by human activities, as well as other activities, the performance or result of which may significantly affect the environment.
[27] Regulation of the Cabinet of Ministers No. 300 of 19.04.2011, on the procedures for the assessment of the impact on European specially protected nature territories (Natura 2000).

8.2.6 Ownership of Waters

The legal framework provides that water management measures must be coordinated with the land owner or possessor[28], [29]. Therefore, ownership of waters and their adjacent land should already be clarified during the planning of the management measures. Unlike other habitat types, there are two more ownership forms in waters – public waters and waters for which the fishing rights belong to the State. In Latvia, public waters is a type of property, set by the **Civil Law**[30] in order to provide the population of the country with the right to waters. The public waters are owned by the state, thus by all of its residents, and, in compliance with the rights which are established by Civil Law, they may be used by every person for everyday needs. The current legal framework defines seven types of using property and fish resources, which in practice complicates the management of water habitats. They are:

- public lake;
- private lake with fishing rights belonging to the state;
- private lake;
- public river;
- public river with fishing rights belonging to the state;
- private river with fishing rights belonging to the state;
- private river.

In Latvia, for 207 lakes and 42 rivers (their reaches)[31] there is a status of public waters. The state owns fishing rights in 208 lakes[32] and 17 rivers (their reaches)[33]. The list of public lakes includes all the biggest lakes in populated areas or nearby areas, as well as lakes located in protected nature territories or lakes that cross the Latvian border into other countries. The list of public rivers includes the major and most important Latvian rivers from the fish and nature conservation point of view, as well rivers on borders with Estonia, Russia, Belarus and Lithuania. About 40 % of all public lakes are located in protected nature territories.

As the **Land Management Law**[34] entered into force, the public waters are transferred into the possession of the local municipality in whose administrative territory they are located.

The Ministry of Environmental Protection and Regional Development is in possession of all public waters in strict nature reserves, national parks and nature reserves. The habitat management measures, which are planned in public waters, must be coordinated with the responsible possessor. If the public waters or waters with their fishing rights belonging to the state are leased, a management measure must also be agreed on with a water tenant.

8.2.7 Type of Use of Land and Immovable Property

A **type of land use** is set for every land property, which is defined in compliance with **the Land Survey Law** and its underlying regulations of the Cabinet of Ministers[35], as well as an **aim of use of immovable property** defined in **the National Real Estate Cadastre Law**[36] and its subordinate regulations[37]. Concerning the type of use of waters, the law in Latvia identifies two types of use – *051: The land under the water* (includes all natural waters and water bodies that are not used for fish breeding) and *052: The land under fish ponds* (the water objects that are artificially installed for fish farming). Depending on the aim of use, waters are divided into three groups – *0301: Public waters, 0302: Water territories that are owned or used by natural and legal persons,* and *0303: Pond management.* The State Land Service maintains the State Cadastre System of Immovable Property, for which local municipalities and the State Forest Service provide up-to-date information, according to the established procedure.

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[28] Cabinet Regulation No. 475 of 13 June 2006, Order for the Maintenance and Deepening of Surface Water Bodies and Water Areas of Ports, Paragraph 27.
[29] Protection Zone law, with amendments as of 22.12.2015, Paragraph two, Section 35.
[30] Adopted: 28.01.1937; Renewed: 01.09.1992, with the amendments as of 03.12.2015.
[31] Civil Law, Annex 1.
[32] Civil Law, Annex 2.
[33] Civil Law, Annex 3.
[34] Adopted 30.10.2014; come into force: 01.01.2015, with the amendments as of 01.01.2015.
[35] Regulation of the Cabinet of Ministers No. 562 of 21.08.2007, Procedure for the classification of the types of use of land and their definition criteria.
[36] With the amendments as of 09.06.2016.
[37] Regulation of the Cabinet of Ministers No. 496 of 20.06.2006 Classification of the purposes of use of real estate and the procedures for specification of the purposes of use of immovable property and changing thereof.

With regard to a change in the type of land use, **the Land Management Law** determines that for the implementation of the planned activities, the category of land use may be changed according to the requirements of territorial development plans of the local municipality and requirements of other laws and regulations. When implementing the management measures of water habitats and their shore zones referred to in these guidelines, there is no need to change the type of land use and aim of use of the immovable property. Re-meandering of regulated rivers is an exception.

8.2.8 Permission and Approval of Habitat Management Measures

In the planning stage of water habitat and species management measures, permission or approval (further in the text – agreements) of the measure must be received from the responsible public authorities, local municipality, land owner or manager, and in some cases also from a water tenant. Sometimes, an opinion of a certified expert will also be required.

These permits depend not only on the type of the planned management, but also on whether the managed habitat is located in a protected nature territory or micro-reserve, as well as on its aim of use. This chapter gives an overview of the necessary agreements depending on the territory protection status, while further chapters give an overview of the necessary agreements according to the planned activity type and form of ownership. All agreements that refer to the aquatic habitat management measures are summarised in Table 8.1.

Agreements necessary for the activities in protected nature territories. According to the legal framework[38], a written permit is required from the Nature Conservation Agency:

for all the planned management measures, including management of water habitats, when they are planned in nature reserves or territories of national parks designated as a functional zone of the regulated regime;

- *for measures of re-meandering regulated rivers,* when they are planned in nature reserves, nature parks or territories of national parks and biosphere reserves designated as a functional zone of the nature reserve;
- *for measures to ensure the functionality of regulated rivers,* when they are planned in nature reserves, nature parks or territories of national parks and biosphere reserves designated as a functional zone of the nature reserve;
- *for reed burning,* when they are planned in nature reserves, nature parks, areas of protected landscapes or territories of national parks and biosphere reserves designated as a functional zone of the nature reserve, territories of national parks and biosphere reserves designated as a functional zone of areas of protected landscapes.

If reed burning is used for lake management, in addition to an agreement with the Nature Conservation Agency, **fire safety authorities** must be informed in writing. The activities that are to be coordinated with **the State Environmental Service** are set out in the Law on Environmental Impact Assessment and its subordinated Cabinet regulation (*see Chap. 8.2.5*).

Agreements for activities in microreserves. According to the regulatory framework[39], for the management of water habitats, depending on the type of management, an official written opinion of a certified bird expert and in certain cases the written permission of the Nature Conservation Agency is also necessary.

In micro-reserves which are located in water habitats and created for the conservation of protected breeding birds, an official written opinion of a certified bird expert is required to restore the functionality of the regulated river reaches, while written permission is required from the Nature Conservation Agency for aquatic habitat management if it can cause a change of surface and/or groundwater level.

In micro-reserves that are created for the protection of species that live in aquatic habitats, aquatic plants can only be burnt in cases when this is necessary for the management of the micro-reserve. Other management measures may be implemented, if they do not contradict the protection objectives of micro-reserve target species. If the reduction of shore overgrowth and increase of exposure of the shore is combined with the establishment of a swimming place, this should only be done in places specified by the certified water habitats expert.

[38] Regulation of the Cabinet of Ministers No. 264 of 16.03.2010, General regulations on the protection and use of specially protected nature territories.

[39] Regulation of the Cabinet of Ministers No. 940 of 18.12.2012, Procedures for the Establishment of Micro-reserves and their Management, Conservation, as well as Interpretation of Micro-reserves and the Buffer Zones.

Agreements necessary for an activity outside protected nature territories and micro-reserves. Several types of freshwater habitat management described in these guidelines must be coordinated with the State Environmental Service, as well as with land owners or managers and tenants. The activities that must be coordinated with the State Environmental Service are set out in the Law on Environmental Impact Assessment and its subordinated Cabinet regulation (see Chapter 8.2.5). Other specific agreements related to certain management types are defined in the legal acts of the specific areas of activities.

8.2.9 Maintenance of Rivers and Lakes

The procedures for the maintenance[40] of lakes and rivers are set by the regulation *Order for the Maintenance and Deepening of Surface Water Bodies and Water Areas of Ports*[41]. The following surface water habitat management measures of these guidelines are defined by Cabinet of Ministers Regulations:

- measures to ensure the functionality of reaches of natural rivers – A1, A2, A3, A6, A7 (Table 8.1);
- measures to ensure the functionality of reaches of a regulated river – B1, B5 (Table 8.1);
- lake management measures – C1, C2, D1 (Table 8.1).

All of the above management measures must be coordinated with the **land owner** or **legal governor** with their written consent. To manage public waters, written consent must also be received from the **local municipality** or **governor of public waters** located in strict nature reserves, nature reserves, or national parks[42]. The written consent of the local municipality is also necessary when water fishing rights belong to the state. If the management measures are planned for waters located next to objects of national defence importance, a written permit must also be obtained from **the Ministry of Defence.**

For management measures which are to be classified as surface water maintenance, in addition to the consent of the land owner (legal governor), technical regulations from the **Regional Environmental Board** of the State Environmental Service must also be obtained. Technical regulations are not necessary in the following cases:

- habitat is managed in a protected nature territory, which has an elaborated and approved nature conservation plan and management is carried out according to this plan;
- mowing of aquatic vegetation in private rivers or lakes is carried out from 1 July to 31 March.

The requirements for the permission or approval of management measures also depends on the size of a river or lake. If the catchment area of the watercourseriver exceeds 25 km^2, or the open surface area of the lake is at least 10 ha, the official written opinion of **a certified water habitats and species expert** on the following issues is necessary (1) the potential impact of cleaning on fish resources, (2) the potential impact of management measures on specially protected nature territories, specially protected species and habitats, as well as on surrounding water objects.

Regarding the maintenance measures in rivers and lakes, not only the procedure of permitting, but also the its implementation, determining that:management technique, is determined as follows:

- the maintenance of a river shall commence and shall be performed against the flowin an upstream direction;
- aquatic plants shall be cut first in areas, where the sludge layer forms intensively, as well as in sandy shallow water areas, which are characterised by intensive overgrowth;
- the cutting of aquatic plants in lakes shall be performed by making passageways in order to ensure water exchange between shallow water and deep water zones;
- the aquatic plants, which are cut, shall be removed, in order to prevent a repeated pollution of the water body with organic substances of easy degradation and the accumulation of sediment.

8.2.10 Management Measures for Regulated Watercourses

Requirements for the management of drainage systems are set by the **Amelioration Law**[43] and its subordinated regulations of the Cabinet of Ministers. **Regulations regarding the operation and**

[40] Surface water maintenance – removal of floating waste, removal of herbaceous and woody plants, removal of fallen trees, removal of sunken items, and other works including bed deepening in order to prevent a reduction of water flow rate.

[41] Cabinet Regulation No. 475 of 13 June 2006, Order for the Maintenance and Deepening of Surface Water Bodies and Water Areas of Ports.

[42] Land Management Law (wording of 01.01.2015).

[43] Adopted: 14.01.2010, with the amendments as of 01.01.2015.

maintenance of land drainage systems[44] apply not only to various elements of drainage systems, but also to channelised rivers[45] – natural watercourses, which are regulated (usually straightened) in order to increase the water flow rate. In channelised river ecosystems, protected habitats can be found. The channelised rivers as parts of the drainage system are included in the **Amelioration Cadastre**[46]. Therefore, during the planning of management measures it is necessary to clarify the status of the watercourse and level of significance (channelised watercourse of State, municipal, or a single property's importance). A digital form of the Amelioration cadastre is available on the website of the State LTD "Immovable properties of the Ministry of Agriculture" (VSIA "Zemkopības ministrijas nekustamie īpašumi")[47].

The development of the Amelioration Cadastre is currently under development. It primarily contains information on drainage systems on agricultural land (channelised watercourses of State importance, open and internal drainage ditches), while information about forest drainage systems is currently limited. Amelioration cadastre is supplemented by the list of municipalities where information is not yet complete. In cases when the watercourse is located in the listed municipalities, during management planning it is necessary to contact the corresponding department of the State Ltd. department "Immovable properties of the Ministry of Agriculture" and clarify the status of the watercourse.

According to the existing legal framework[48], drainage systems, including reaches of regulated watercourses, must be maintained by cutting shrubs, trees and their shoots which impede the free movement of water, as well as from domestic waste, fallen trees, scraps, sediments, beaver dams. **Regulations regarding the operation and maintenance of land drainage systems** must be addressed to management measures dealing with the improvement of the functionality of regulated river reaches (B1 and B2 – Table 8.1). The establishment of environmentally friendly elements of drainage systems, intended to reduce the negative impacts on the quality of surface waters from the drainage system (B3 and B4 – Table 8.1), as well as measures for re-meandering the rivers (B5 – Table 8.1) are subjected to the Latvian construction standard LBN 224-15 **"Amelioration systems and hydrotechnical constructions"**[49].

It must be taken into account that even after re-meandering, the river will keep the status of a channelised watercourse as an element of the drainage system. Therefore, the **environmental protection requirements** set by Chapter 9 of this regulation must be followed to harmonise habitat protection and land drainage needs. The above mentioned regulations specify that: when designing the course, slope and profile of the regulated or reconstructed water course, if it is possible to ensure the necessary hydraulic conditions and, if it is possible due to the structure of the bottom material, the following requirements have to be taken into account:

- to preserve unaltered channel sections with particular landscape characteristics;
- to adapt to the natural channel course as much as possible and refrain from the creation of long straight sections;
- to create eddies, pools, fish wintering depressions and spawning grounds;
- to vary the deepest sections of the channel with shallower, wider and narrower stretches; to leave large stones or create riffles;
- to reconnect active oxbows with the main course, etc.[50]

When these environmental requirements are complied with, it is also possible to ensure the conservation of the protected habitats of EU importance in the regulated rivers having the status of channelised watercourses. It is very important to pay attention to compliance with these requirements when certified experts give an official written opinion on maintenance of the channelised watercourses.

A channelised watercourse is managed (maintained) by the land owner or governor. In the case of drainage systems of state importance[51], the manager is State Ltd. "Immovable properties of the Ministry of

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[44] Regulation of the Cabinet of Ministers No. 272 of 03.08.2004, Regulations regarding the operation and maintenance of land drainage systems.

[45] Channelised river — a natural or regulated watercourse (river, spring), including artificially developed river bed, which drains the water from several drainage systems or surface water objects.

[46] Regulation of the Cabinet of Ministers No. 623 of 13.07.2010, Regulation on the Amelioration Cadastre".

[47] https://www.melioracija.lv.

[48] Regulation of the Cabinet of Ministers No. 272 of 03.08.2004, Regulations regarding the operation and maintenance of land drainage systems, Paragraph 7.1.

[49] Regulation of the Cabinet of Ministers No. 329 of 30.06.2015, Regulations on the Latvian construction standard LBN 224-15 "Amelioration systems and hydrotechnical constructions.

[50] Sub-paragraphs of Paragraph 264.

[51] The drainage systems of State importance – a drainage system that complies with the criteria and parameters set by legislation, and that is used and maintained by the state.

Agriculture". The drainage systems that are on the land of the state forests are respectively managed by their governor – AS JSC "Latvia's State Forests", State Forest Service, or Nature Conservation Agency. Management of the systems of common use are mutually agreed upon by their owners. If a third party (such as a non–governmental organisation, for the purpose of improving habitat quality and biodiversity) wants to carry out the habitat management measures, then, according to the property rights established by the Civil Law, activities should be coordinated with the land owner or governor.

It is defined by the legislation that the maintenance of channelised watercourses means the removal of trees, shrubs and their shoots from the channel, so that the water flow is not impeded[52]. The regulations of the Cabinet of Ministers also define the criteria according to which the water flow is assessed as being in a bad or unacceptable condition[53]. For instance, the condition of a channelised watercourse is bad "when its bed is heavily overgrown with woody or herbaceous plants, there are fallen trees or domestic waste, beaver dams are frequent". The technical condition of a channelised watercourse is inadmissible in the following cases: "beaver dams or unauthorised blockages of the channel change the required water regime, alter channel stability, and create new deformations". In order to carry out daily maintenance work, except for in the cases when the channelised watercourses are in protected nature territories, agreements with the responsible public authorities are not necessary. According to the legal framework, the State Environmental Service issues technical regulations if the restoration and reconstruction of channelised watercourses of State drainage systems and drainage systems of State significance are required[54].

Criteria for the assessment of the drainage system's condition and activities required for its maintenance are also necessary in order to ensure the functionality of the river habitat, and they are not in conflict with the habitat management techniques described in these guidelines – ensuring the functionality of regulated river reaches (except for river re–meandering) and measures to ensure the flow rate of the rivers – regulation of aquatic plant overgrowth (A3) and demolition of beaver dams (A2), as well as sometimes the removal of large woody debris (A1 – Table 8.1). As the legal framework does not define what activities are to be classified as restoration of a water drain, the relevant Regional Environmental Board of the State Environmental Service should be informed about the expected activities at the management planning stage.

8.2.11 Management Measures in the Protection Belt of Rivers and Lakes

The **Protection Belt Law**[55] defines the minimum width of protection belts of lakes and rivers, with wider protection belts in rural areas and narrower ones in village and urban territories. The size of the protection belts, which refers to the particular water object, is determined in the territorial planning of the relevant municipality according to the administrative division.

The Protection Belt Law applies to a number of management measures described in these guidelines. Such activities are: regulating of overgrowth and shading of river shores; measures for the improvement of lake shore vegetation structure (Table 8.1). If the type of land use of the territory of the water protection belt is not forest, according to the legal framework[56] tree felling must be coordinated with the local municipality (*see Chapter 8.2.12*). If the territory of the protection belt area is forest land, management activities must comply with the legal framework of the forestry. If the clear–felling of grey alder (*Alnus incana*) is planned as permitted by regulatory enactments[57], the following conditions must be met:

- *Quercus robur, Tilia cordata, Ulmus spp., Acer spp., Pinus spp., Alnus glutinosa, Salix spp., and Malus sylvestris* must be kept;
- felling of trees is prohibited on slopes with a gradient exceeding 30 degrees;
- felling of trees is prohibited from 1 April to 30 June;
- a clear-felled area in the protection zone of a surface water body may not exceed one hectare.

[52] Regulation of the Cabinet of Ministers No. 714 of 03.08.2010, on the use and maintenance of amelioration systems, Paragraph 7.1.1.

[53] Regulation of the Cabinet of Ministers No. 272 of 03.08.2004, Regulations regarding the operation and maintenance of land amelioration systems, Annex 5.

[54] Regulation of the Cabinet of Ministers No. 30 of 27.05.2015, Procedures by which the state environmental service shall issue technical regulations for the intended activity, Paragraph 1.4 of Annex 1.

[55] Adopted 05.02.1997.

[56] Regulations of the Cabinet of Ministers No. 309 of 02.05.2012, on felling of trees outside forest.

[57] A forest where the prevailing tree species is Alnus incana.

8.2.12 Felling of Trees Outside Forest

The procedure for the the cuttingfelling of trees outside forest land is set by the **Regulations on the felling of trees outside forest**[58]. Measures regarding regulating river shore shading and vegetation structure, and lakeshore vegetation structure improvement described in these guidelines, refer to this regulation (Table 8.1). All of the above must be coordinated with the land owner or legal governor. As the shore part of rivers and lakes is located in the protection belt, a permit must also be received from the local municipality must also be received for the felling of trees. A permit of the local is not required for the felling of trees with a stump diameter less than 20 centimetres.

8.2.13 Deforestation for the Restoration of Habitats

Regulations regarding the restoration of specially protected species and protected species habitats in forest refer specifically to habitat management[59]. They establish the procedure for deforestation if it is necessary for the restoration of a protected habitat or species habitat which is located in forest. For the purpose of this normative regulation, the restoration of a habitat in a forest is a planned activity of the forest owner (legal governor or a person authorised by the legal governor), which restores a specially protected habitat.

With regard to the management of freshwater habitats, these regulations only apply to the re–meandering of rivers. To apply deforestation when it is necessary for the establishment of new river bed, there must be a valid forest inventory of the relevant territory. A permit of the **Nature Conservation Agency** is required if the activity is planned in a protected nature territory or micro–reserve. The permit is issued based on an **official written opinion of a certified habitats expert,** which, in the format defined by regulation[60] gives an assessment of the justification for the restoration of a protected habitat. If the planned measure includes a change of terrain or surface water level, the planned activity must be coordinated with the regulatory enactments regulating construction and drainage, and it must not conflict with the planning documents of the local municipality.

8.2.14 Control of Invasive Plant Species

Several invasive plant species can be found on the banks of rivers and lakes, – *Heracleum sosnowskyi, Impatiens glandulifera, Echinocystis lobata, Helianthus tuberosus,* etc. *Heracleum sosnowskyi* is the species that is most dangerous to natural habitats. This is also the only invasive plant species, the combating procedures of which are regulated by laws[61].

The Plant Protection Law[62] and its subordinated Cabinet regulations[63] determine the establishment of a list of invasive plant species, how these species are monitored and controlled by the state, etc. From the point of view of habitat management, the most important of them are **Regulations regarding the use of plant protection products**[64], which determine requirements for the use and storage of plant protection products, including the special measures for the protection of the aquatic environment and drinking water resources.

According to the general legal framework of protected nature territories[65], the use of chemical plant protection products is prohibited in forests and in agricultural land of strict nature reserves. Other requirements may be specified in their individual protection and use regulations. Use of plant protection products — pesticides – is prohibited in micro–reserves[66]. In these cases, other methods must be used to combat the invasive species.

Combating of invasive animal species in Latvia is not regulated by legislation.

[58] Regulations of the Cabinet of Ministers No. 309 of 02.05.2012, on felling of trees outside forest.

[59] Regulation of the Cabinet of Ministers No. 325 of 08.06.2013, Regulations regarding the restoration of specially protected habitats and species habitats in forest.

[60] Regulation of the Cabinet of Ministers No. 925 of 30.09.2010, Content and minimum requirements of an opinion by an expert in species and habitat conservation.

[61] Regulation of the Cabinet of Ministers No. 468 of 30.06.2008, List of invasive plant species and Regulation of the Cabinet of Ministers No. 559 of 14.06.2008, Regulations regarding restricting the spread of invasive plant species — Heracleum sosnowskyi.

[62] Adopted: 17.12.1998

[63] Regulation of the Cabinet of Ministers No. 467 of 30.06.2008, Regulations regarding restricting the spread of invasive plant species.

[64] Regulation of the Cabinet of Ministers No. 950 of 13.12.2011, on the use of plant protection products.

[65] Regulation of the Cabinet of Ministers No. 264 of 16.03.2010, on the conservation and use of the specially protected natural areas, Paragraph 4.4.

[66] Regulation of the Cabinet of Ministers No. 940 of 18.12.2012, Procedures for the Establishment of Micro-reserves and their Management, Conservation, as well as Interpretation of Micro-reserves and the Buffer Zone, Paragraph 45.9.

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

8.1. att. Activities when planning the habitat management.

8.2.15 Permits and Approvals Required for the Management of Aquatic Habitats

Management measure	Permits and approvals for all watercourses and lakes			
	Technical instructions issued by the State Environmental Service	**A written agreement with the land owner (governor)**	**A permit of the local municipality for tree felling outside forest**	**A permit of the State Forest Service for tree felling in forest**
Natural rivers (river reaches)				
A1: Removal of fallen trees (large woody debris) and control of "catchers"	X	X (4)		
A2: Demolition of beaver dams	X	X (4)		
A3: Regulation of aquatic plant over-growth by cutting	X (1)	X (4)		
A4.1: Improvement of the shore vegeta-tion structure – shrub cutting and establishment of natural grassland zone	X (2)	X (4)	X	X
A4.2: Improvement of the shore vegetation structure - regulation of river shading		X (4)	X	X
A5: Stabilisation of the shores		X (4)		
A6: Formation of riffle areas	X (1)	X (4)		
A7: Maintenance of natural spawning grounds and establishment of artifi-cial spawning grounds.	X (1)	X (4)		
A8: Establishment of fishways	X	X (4)		
A9: Demolition of mill dam remains and obstacles	X	X (4)		
A10: Removal of sand deposits from mouths of rivers flowing into the sea.	X	X (4)		
A11: Invasive plant species control		X (4)		

Management measure	Permits and approvals for all watercourses and lakes			
	An official written opinion of a certified expert* on the possible impact of maintenance on fish resources (6)	**An official written opinion of a certified expert* on the possible impact of maintenance on protected nature territories, protected habitats and, and on surrounding water objects (6)**	**Informing the fire safety authority**	**Coordination with the Nature Conservation Agency, if the water object is located in a protected nature area**
Natural rivers (river reaches)				
A1: Removal of fallen trees (large woody debris) and control of "catchers"	X	X		(7)
A2: Demolition of beaver dams	X	X		(7)
A3: Regulation of aquatic plant over-growth by cutting	X	X		(7)
A4.1: Improvement of the shore vegetation structure – shrub cutting and establishment of natural grassland zone				(7)
A4.2: Improvement of the shore vegetation structure - regulation of river shading				(7)
A5: Stabilisation of the shores				(7)
A6: Formation of riffle areas	X	X		(7)
A7: Maintenance of natural spawning grounds and establishment of artificial spawning grounds.	X	X		(7)
A8: Establishment of fishways				(7)
A9: Demolition of mill dam remains and obstacles				(7)
A10: Removal of sand deposits from mouths of rivers flowing into the sea.	X	X		(7)
A11: Invasive plant species control				(7)

* Certified expert — an expert in the protection of species and habitats who has been certified according to Regulation of the Cabinet of Ministers No. 267 of 16.03.2010, Procedures for the Certification of Experts in the Field of the Conservation of Species and Biotopes and Supervision of the Activities Thereof.

Management measure	Permits and approvals for all watercourses and lakes			
	Technical instructions issued by the State Environmental Service	A written agreement with the land owner (governor)	A permit of the local municipality for tree felling outside forest	A permit of the State Forest Service for tree felling in forest
Regulated rivers (river reaches)				
B1: Diversification of structures of the regulated river reaches	X (2)	X (5)		
B2: Construction of sedimentation ponds	X (2)	X (5)		
B3: Construction of surface flow constructed wetlands	X (2)	X (5)		
B4: Restoration of straightened rivers	X (2)	X (5)		
B5: Environmentally friendly management of drainage ditches	X	X (5)		
Lakes				
C1: Reduction of aquatic vegetation	X (1)	X (4), (5)		
C2: Mowing of emergent vegetation of shore areas – reinforcement of wave activity	X (1)	X (4), (5)		
C3.1: Change of structure of shore vegetation – felling of shrubs		X (4), (5)		
C3.2: Change of structure of shore vegetation – grazing of shore grasslands		X (4), (5)		
C3.3: Change of structure of shore vegetation – creation of wind corridors		X (4), (5)	X	x
C4.1: Reed burning – in winter		X (4), (5)		
C4.2: Reed burning – in the second half of summer		X (4), (5)		
C5: Mowing of emergent vegetation in autumn and winter		X (4), (5)		

Management measure	Permits and approvals for all watercourses and lakes			
	An official written opinion of a certified expert* on the possible impact of maintenance on fish resources (6)	An official written opinion of a certified expert* on the possible impact of maintenance on protected nature territories, protected habitats and, and on surrounding water objects (6)	Informing the fire safety authority	Coordination with the Nature Conservation Agency, if the water object is located in a protected nature area
Regulated rivers (river reaches)				
B1: Diversification of structures of the regulated river reaches	X	X		(7), (8)
B2: Construction of sedimentation ponds	X	X		(7), (8)
B3: Construction of surface flow con-structed wetlands	X	X		(7), (8)
B4: Restoration of straightened rivers	X	X		(7), (8)
B5: Environmentally friendly manage-ment of drainage ditches				(7), (8)
Lakes				
C1: Reduction of aquatic vegetation				(7)
C2: Mowing of emergent vegetation of shore areas – reinforcement of wave activity				(7)
C3.1: Change of structure of shore vege-tation – felling of shrubs				(7)
C3.2: Change of structure of shore vege-tation – grazing of shore grasslands				(7)
C3.3: Change of structure of shore vege-tation – creation of wind corridors				(7)
C4.1: Reed burning – in winter			x	(7), (9)
C4.2: Reed burning – in the second half of summer			x	(7), (9)
C5: Mowing of emergent vegeta-tion in autumn and winter				

Management measure	Permits and approvals for all watercourses and lakes			
	Technical instructions issued by the State Environmental Service	**A written agreement with the land owner (governor)**	**A permit of the local municipality for tree felling outside forest**	**A permit of the State Forest Service for tree felling in forest**
Specific techniques that are mainly used to recover highly eutrophic lakes, but which under certain circumstances can also be applied to naturally eutrophic lakes				
D1: Lake deepening and gyttja extraction	x	X (4), (5)		
D2.1: Limitation of the circulation of plant nutrients – chemical settling of phosphorus	(3)	X (4), (5)		
D2.2: Limitation of the circulation of plant nutrients –deep layer aeration of the lake	(3)	X (4), (5)		
D2.3: Limitation of the circulation of plant nutrients – use of algaecides	(3)	X (4), (5)		
D3.1: Prevention of fish suffocation – ice holes	(3)	X (4), (5)		
D3.2: Prevention of fish suffocation – aeration	(3)	X (4), (5)		
D3.3: Prevention of fish suffocation – mowing of emergent vegetation in river mouths and fish wintering depressions	x	X (4), (5)		
D4: Food chain change – biomanipulation	(3)	X (4), (5)		
D5: Development of infrastructure to decrease recreation pressure	X	X (4), (5)		
D6: Establishment of artificial islets for water birds	X	X (4), (5)		
D7: Raising of water level to limit emergent vegetation expansion.	X	X (4), (5)		

Management measure	Permits and approvals for all watercourses and lakes			
	An official written opinion of a certified expert* on the possible impact of maintenance on fish resources (6)	An official written opinion of a certified expert* on the possible impact of maintenance on protected nature territories, protected habitats and, and on surrounding water objects (6)	Informing the fire safety authority	Coordination with the Nature Conservation Agency, if the water object is located in a protected nature area
Specific techniques that are mainly used to recover highly eutrophic lakes, but which under certain circumstances can also be applied to naturally eutrophic lakes				
D1: Lake deepening and gyttja extraction	X	X		(7)
D2.1: Limitation of the circulation of plant nutrients – chemical settling of phosphorus				(7)
D2.2: Limitation of the circulation of plant nutrients –deep layer aeration of the lake				(7)
D2.3: Limitation of the circulation of plant nutrients – use of algaecides				(7)
D3.1: Prevention of fish suffocation – ice holes				(7)
D3.2: Prevention of fish suffocation – aeration				(7)
D3.3: Prevention of fish suffocation – mowing of emergent vegetation in river mouths and fish wintering depressions	X	X		(7)
D4: Food chain change – biomanipulation				(7)
D5: Development of infrastructure to decrease recreation pressure				(7)
D6: Establishment of artificial islets for water birds				(7)
D7: Raising of water level to limit emergent vegetation expansion.	X	X		(7)

Notes (1) If it is planned outside the period from 1 July to 31 March; (2) If it is planned to restore and rebuild a water drain of state importance. A permit is not necessary for daily maintenance works; (3) Although the coordination of activities is not regulated by law, the Regional Environmental Board of the State Environmental Service must be consulted before the start of work; (4) For public waters – with the local municipality or governor of the public waters located in a strict nature reserve, nature reserve, or national park; for waters with fishing rights belonging to the state – with the local municipality; for objects of national defence importance – with the Ministry of Defence; (5) for water drains of State importance – with State LTD "Immovable properties of the Ministry of Agriculture"; (6) If it is planned in a watercourse with a catchment area exceeding 25 km² or in a water object with an open water area exceeding 10 ha; (7) If it is planned in a strict nature reserve, nature reserve or in a territory of a national park designated as a regulatory regime zone; (8) If it is planned to be performed in a nature reserve, nature park, or in a territory of a national park or biosphere reserve designated as a nature reserve zone.

Chapter 9. Main Methods of River and Lake Management and Habitat Restoration

When choosing the most appropriate habitat restoration or management method, a general principle must always be followed: it is cheaper to identify and duly prevent the causes of habitat degradation than to restore it later. This means, as far as possible, to prevent the introduction of plant nutrients and other contaminants into rivers and lakes and to reduce the adverse effects of humans (sometimes beavers). From the point of view of lake development, habitats represent one of the natural stages of lake development (*see Chapter 1*). However, the concept of "natural processes" should be treated critically, as it creates a misleading notion that lake management is forceful interference with ongoing processes in the lake (Table 9.1).

In Latvia, starting from 1960s, human activities provided lakes and rivers with nutrients in the form of fertiliszers, whose origin was outside of the country, promoting anthropogenic eutrophication and ageing of lakes. Therefore, except for in the case of raised bog areas, lakes and rivers cannot be considered as unaffected by human economic activity.

The main protected water habitat restoration and management methods, which focus on solving specific issues, are summarised in Table 9.2. A more detailed description of the factors and threats that affect habitats, as well as a description of management methods is given by describing the specific river and lake habitats.

Table 9.1. Advantages and disadvantages of the Non-interference method in natural processes in lakes.

Method	Advantages	Disadvantages
Non-interference in natural processes	Management activities are not needed. The development of the lake is as follows: • Initially, when nutrient inputs are low, the diversity of aquatic plant species and the associated aquatic organisms increases, and the fishery's productivity in the lake increases. • Initially, submerged and floating-leaved plants dominate. In further development they become appropriate for duck and *Chlidonias niger* breeding. • When replacing submerged and floating-leaved vegetation with emergent vegetation, there are possibilities to attract new species of emergent vegetation, such as *Panurus biarmicus.*	There is a very small number of lakes that are not influenced by economic activity, which changes the speed of natural development of the lake. Therefore: • Under non-intervention conditions the accumulation of dead plant material increases, expansion of emergent vegetation increases, especially reed *Phragmites australis*, which further replace and outcompete floating-leaved and submerged aquatic plants. • Open and shallow shore area that warms up, with its crustacean complex, disappears. It becomes a limiting factor for the development of benthic aquatic organisms, fish larvae and juveniles. • With the increased development of emergent vegetation, conditions suitable for the successful breeding of waders and dabbling ducks disappear. • Without taking out leached and stored nutrients more intense filling of the volume of the lake occurs. • Intensive macrophyte development results in residues promoting possible oxygen deficiency and fish suffocation below the ice cover. • Increase of potentially toxic cyanobacteria. • In the long term, general deterioration of the habitat quality.

Table 9.2. Main methods of watercourse and lake habitat restoration and management.

Restoration of habitat function		
Problem	**Solutions**	**Habitats**
Beaver dams and fallen trees (large woody debris) impede the water flow. Sedimentation processes increase, the river riffle area becomes silted and disappears, and this results in a reduction of the natural self-purification ability of watercourses	A1: Removal of fallen trees and restoration of water flow. A2: Removal of beaver dams. A5: Stabilisation of the shores.	Watercourses.
Restoration and improvement of habitat structure		
Problem	**Solutions**	**Habitats**
Enrichment in nutrients and excessive develop-ment of aquatic plants – eutrophication	A3.1: Mowing of aquatic plants. A3.2: Mowing of aquatic plants with loosening and removal of roots. A6: Formation of riffle areas. B1: Diversification of structures of the regulated river reaches.	Watercourses.
	C1.1: Mowing of aquatic vegetation in different depth zones and breaking of roots. C1.2: Mowing of emergent aquatic plants and root breaking. C2: Mowing of emergent vegetation of shore areas – reinforcement of wave activity. C3.3: Change of structure of shore vegetation – creation of wind corridors. C4.1: Reed burning – in winter. C4.2: Reed burning – in second part of summer. C5: Mowing of emergent vegetation in autumn and winter.	All lake habitats, except at bog (secondary) lakes that are included in the habitat type *3160 Natural dystrophic lakes and ponds*.
Excessively large wood-en debris contributes to bank erosion and the accumulation of sed-iments	A1: Removal of part of fallen trees (large woody debris) and control of "catchers".	Watercourses.
Beaver dams and floods contribute to sedimenta-tion and the loss of the biologically most valuable river riffles. Migration of water organisms is interrupted	A2: Demolition of beaver dams.	Watercourses.
Productive shallow water area of the lake overgrows with emergent vegetation. Paludification, extinction of previously dominant habitats, sedi-ment accumulation in the shore part	C2: Mowing of shore emergent vegetation zones. Rein-forcement of wave effect. C4.1: Reed burning in the autumn and winter. C4.2: Reed burning – in second part of summer. C5: Mowing of emergent vegetation in autumn and winter.	All lake habitats, except for bog (secondary) lakes that are included in the habitat type *3160 Natural dystrophic lakes and ponds*.

Restoration and improvement of habitat structure		
Problem	**Solutions**	**Habitats**
Extinction and replacement of submerged and floating-leaved plants with emergent vegetation	C1.1: Mowing of aquatic vegetation in different depth zones and breaking of roots. C2: Mowing of shore emergent vegetation zones. Reinforcement of wave effect. C3.1: Change of structure of shore vegetation – felling of shrubs. C5: Mowing of emergent vegetation in autumn and winter.	All lake habitats, except for bog lakes that are included in the habitat *3160 Natural dystrophic lakes and ponds.*
Fish suffocation	D3.1: Prevention of fish suffocation –drilling ice holes. D3.2: Prevention of fish suffocation – aeration. D3.3: Prevention of fish suffocation – mowing of emergent vegetation in river mouths and fish wintering depressions.	All lake habitats, except for bog lakes that are included in the habitat type *3160 Natural dystrophic lakes and ponds.*

Restoration of populations of habitat-characteristic species		
Problem	**Solutions**	**Habitats**
Overgrowth of salmonid and lamprey spawning site with aquatic plants, covered with sediments	A10: Removal of sand deposits from mouths of rivers flowing into the sea. A8: Establishment of fishway. A9: Demolition of mill dam remains and obstacles. B4: Restoration of straightened rivers. B5: Environmentally friendly management of drainage ditches.	Watercourses.
Migration of fish, lampreys and invertebrates due to man-made insurmountable obstacles or rivermouth clogging	A8: Establishment of fishway. A9: Demolition of mill dam remains and obstacles. A10: Removal of sand deposits from mouths of rivers flowing into the sea. B4: Restoration of straightened rivers. B5: Environmentally friendly management of drainage ditches.	Watercourses.
Overgrowth and clogging up of *Margaritifera margaritifera* and *Unio crassus* habitats	A3.1: Regulation of aquatic plant overgrowth by cutting. A2: Demolition of beaver dams. A4.1: Improvement of the shore vegetation structure – shrub cutting and establishment of natural grassland zone. A4.2: Improvement of the shore vegetation structure - regulation of river shading. A6: Formation of riffle areas. B2: Construction of sedimentation ponds on ditches entering the rivers. B3: Construction of surface flow constructed wetlands. B5: Environmentally friendly management of drainage ditches.	Watercourses.
Extinction of habitat typical plant communities due to overgrowth or sediment accumulation on the lake bottom	B2: Construction of sedimentation ponds on ditches entering the lakes. B3: Construction of surface flow constructed wetlands in ditches entering the lakes. C1.1: Mowing of aquatic vegetation in different depth zones and breaking of roots. C2: Mowing of emergent vegetation of littoral areas – reinforcement of wave activity. C5: Mowing of emergent vegetation in autumn and winter.	3150 Natural eutrophic lakes with *Magnopotamion* or *Hydrocharition* - type vegetation.

Restoration of populations of habitat-characteristic species		
Problem	**Solutions**	**Habitats**
Extinction of the plant communities typical for the habitat due to the expansion and shading of emergent vegetation	C2: Mowing of emergent vegetation of littoral areas – reinforcement of wave activity. C2: Mowing of littoral emergent vegetation zones - reinforcement of wave effect. C3.1: Change of structure of shore vegetation – felling of shrubs. C5: Mowing of emergent vegetation in autumn and winter.	3130 Lobelia-Isoetes lakes; 3140 Hard oligo-mesotrophic waters with benthic vegetation of *Chara* spp.
Extinction of water bird species typical to the habitat due to overgrowing of lakes	Partition of emergent vegetation massives and increasing of the indentation of external edges, mowing of emergent vegetation, restoration of water exchange and an open shore zone, creation of artificial nesting islets for birds. C1.1: Mowing of aquatic vegetation in different depth zones and breaking of roots. C1.2: Mowing of emergent aquatic plants and root breaking. C1.3: Establishment of migration channels. C3.1: Change of structure of shore vegetation – felling of shrubs. C3.2: Change of structure of shore vegetation – grazing of coastal grasslands. C4.1: Reed burning in the autumn and winter. C4.2: Reed burning – in second part of summer. C5: Mowing of emergent vegetation in autumn and winter. D6: Establishment of artificial islets for waterbirds.	3150 Natural eutrophic lakes with *Magnopotamion* or *Hydrocharition* - type vegetation; 3140 Hard oligo-mesotrophic waters with benthic vegetation of *Chara* spp.

Prevention and Reduction of Visitor Load		
Problem	**Solutions**	**Habitats**
Adverse, degrading effect on the ecosystem and the inhabiting species related to visitor load (such as trampling of underwater isoetids, waste, undesirable disturbance — noise, physical presence, aesthetic damage, etc.)	D5: Development of infrastructure to decrease recreation pressure. Creation of plank-ways, floating platforms, delimiting and distracting barriers, and toilets. Creation of redirecting infrastructure (shifting the load to less sensitive areas or other areas). Placement of educational information (information boards, demonstrative objects, educational playgrounds, etc.).	All lake habitats, especially lakes with oligotrophic to mesotrophic vegetation.

Chapter 10. Cost Estimation

(J. Jātnieks)

Cost estimation is one of the most important steps in the preparatory process. Cost varies over time and can rarely be generalised for specific types of work or a set of actions required to improve habitat condition. The difference in costs can be great for similar works – depending on the geographic location, complexity of works, executors and availability of special equipment, and other factors. These guidelines are to be used over a longer period of time, thus we do not offer exact costs for all types of works, and only the indicative costs are given (Table 17.3). 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 the developers of nature conservation plans, LIFE and other large projects in order to estimate the costs of habitat management and restoration activities for a period of 2 – 5 years, in one large or several Natura 2000 sites. In small areas (up to 1 ha), as well as in cases where management is regular or certain parameters are known (for example, annual mowing of aquatic plants), costs can generally be equated to the works performed elsewhere or interviewing the potential executors and agreeing on the total cost of all works. Here, the key principles to determine the reasonable cost of the planned actions are given.

- After monitoring of the managed site the most appropriate actions, methods and technical means are chosen. It is advised to divide the works by stages, timing and type of work. For example, manual work, use of one or another type of equipment, in order to determine the pricing of each job separately and summing up to obtain a more objective assessment. The cost and efficiency of the work to be done often depends on the season; for instance, it is best to mow aquatic plants when the water level is low, as it is easier to access deeper places and those places that are inaccessible when the water table is high. If these conditions are not taken into account, the costs can grow unpredictably, while 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 appropriate units – in man-hours, person-days, the cost of equipment per hour, cost of materials depending on the area or volume of nature of works (m3, km, kg, t). The number of units required for all the works, should be assessed and summed up. Experience shows that these calculation errors happen the most, thus it is always advisable to use both the experience of similar, already implemented works, such as reports on the projects, specific works, and the experience of the institutions (Nature Conservation Agency, JSC "Latvijas Valsts meži", municipal and non-governmental organisations). If the set of activities to be carried out consists of various different works not performed before or their pricing is not available, at least three potential executors can be surveyed. In this case, the result can be obtained faster, however the risk increases that unforeseen costs may arise during the works that can complicate the achievement of the aim.
- The indirect preparatory costs of habitat management and restoration works should be assessed – site survey, expert opinions, technical projects, permits and agreements set in regulatory enactments (*see Chapter 8*). It involves working time, transport and administrative costs, which are often inadequately assessed. The time and means to inform the public and explain the necessary steps must be scheduled in complex work projects.
- The regional cost differences in Latvia should be taken into account as well as the availability of the executors in the given region up to 30 km from the planned place of activity. The costs may rise significantly if the executors and/or equipment must come from a greater distance. For this reason, the specific activities that require special equipment or skills (for instance, mowing of aquatic plants and destruction of their root system) will always be more expensive than simple activities (manual mowing, removal of trees from a watercourse).
- It is desirable to entrust cost assessment to professionals – managers, managing specialists, practitioners, entrepreneurs – and sche-

dule this job and adequate funding.

- The planning should also include potential income related to wood removed from water and mown biomass of aquatic plants obtained during habitat restoration and management. Ideally, at least in part, they may be transported from the area and used elsewhere (for example, they can be used for wood chips or firewood, mown reeds can be used for roofs, cogeneration). However, it is usually difficult to find a practical use for these materials, if the volumes are small and management 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 and possible.
- Table 17.3 shows the indicative costs for various types of works referred to in the guidelines. The costs have been studied in the form of surveys (project implementers, managers, practitioners, public price lists) and are approximate – refer to an approximate period from 2010 to 2016. The costs vary in each case, determined by the factors mentioned above.

Chapter 11. Evaluation of the Success of Management and Restoration

When restoring and managing habitats, it is important to assess the result, including success and failure not only during the process but also over a longer period of time after the completion of works. Evaluation of success means systematic documentation of changes or at least comparing the situation before and after the restoration measures. Reliable results will only be possible if the changes are documented according to a certain method and on a regular basis. This approach is called monitoring. The monitoring results should answer the questions as to whether restoration and management have reached the initial target, to what extent, as well as why the target has not been reached in some cases. Such assessment of success of the implemented activities is also needed in order to be able to improve the restoration and management. If the objective has not been reached, one should understand the reasons and take the necessary steps to improve the result and eliminate the mistakes at least partially. Evaluation should be carried out according to the methods used in scientific practice allowing one to compare the results with the monitoring or research carried out somewhere else. When assessing the success of water habitat restoration and management, the following indicators are used most often: changes in vegetation, changes in the composition of aquatic invertebrates, changes in fish species and changes in the materials (substrate) that form the bottom of the water body.

Vegetation monitoring is a relatively simple and cheap way of assessing the nature of the changes, thus it is considered to be the minimum programme of monitoring. Macrophytes in lakes are assessed according to the Latvian macrophyte assessment method that is taken from Estonia and adapted to be used in Latvian conditions. A method conforming to the requirements of the Water Framework Directive for rivers concerning the composition and abundance of Macrophytes has not been elaborated in Latvia yet. Currently, the most suitable method for Latvian conditions is that which is used in Poland, namely, the MIR index (*Polish Macrophyte Index for Rivers*) (Szoszkiewicz et al. 2010). Improvement of the situation of waters and development of conditions that are favourable to species are also indicated by changes in water invertebrate species composition.

Valuable additional information on changes to the habitat is provided by photos that have been systematically taken before the management activities, during the management measures, and after the management activities. Understanding of development of the territory over a longer period of time is also given by historical pictures and photos, for example, from the portal "Zudusī Latvija" or "Lost Latvia" (www.zudusilatvija.lv), which is maintained by the Latvian National Library.

Part II

Chapter 12. 3130 *Oligotrophic to mesotrophic standing waters with vegetation of Littorelletea uniflorae and/or Isoeto-Nanojuncetea*

(A. V. Urtāns, U. Suško, L.Urtāne)

12.1 Characteristics

12.1.1 Brief Description

Distribution of habitat type. Habitat type 3130 *Oligotrophic to mesotrophic standing waters with vegetation of Littorelletea uniflorae and/or Isoeto-Nanojuncetea* (further referred to as *Lobelia-Isoetes* lakes) are very rare in Latvia. This lake type is particularly sensitive to eutrophication and pollution. The habitat is represented by clear-water (oligohumic) and brown-water (polyhumic) lakes. Species of the *Lobelia-Isoetes* complex are usually important for the ecosystem. In Latvia, this habitat type includes mesotrophic, oligodystrophic, slightly eutrophic and eutrophic lakes with typical vegetation of the *Lobelia-Isoetes* species complex. Periodically drying out water bodies with possible *Lobelia–Isoetes (Isoeto-Nanojuncetea)* plant communities are not considered as this habitat type. Lakes with mesotrophic plant communities in Latvia are rare and mainly found in the Vidzeme region –the lakes Ummis, Mazuika, Ungurs – a few lakes in the Kurzeme region, such as Lake Pinkas, and the lakes Laukezers, Ārdavs, Drīdzis and Svātava in the Latgale region (Eņģele, Sniedze-Kretalova 2013, Suško 2013).

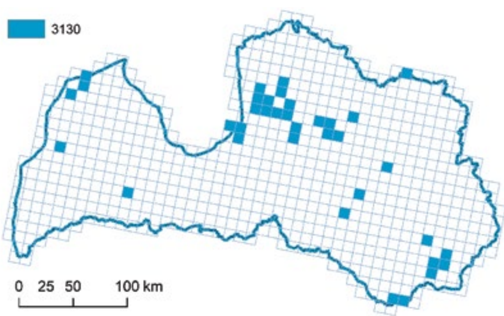

Fig. 12.1. Distribution of habitat type 3130 Oligotrophic to mesotrophic standing waters with vegetation of Littorelletea uniflorae and/or Isoeto-Nanojuncetea in Latvia (Anon. 2013).

The vulnerability of *Lobelia-Isoetes* lakes is illustrated by fact that 64 lakes with the *Isoetes* complex were known in Latvia in the early 19th century. Lake surveys at the end of the 20th century (Suško 1999) revealed that, in less than one hundred years, the complex of *Lobelia-Isoetes* and its accompanying species have almost or completely disappeared in 39 lakes (61 % of the total number of mesotrophic lakes) and their populations in 15 lakes are severely endangered or small in numbers. There are now only 14 lakes in Latvia that are still rich in communities of *Lobelia-Isoetes*, and five of them are located in the vicinity of Riga (Suško 1999).

Characteristics. *Lobelia-Isoetes* lakes are divided into two groups according to their origin.

The first group includes lakes that are poor to moderately rich in nutrients (mesotrophic to slightly eutrophic). Typical oligotrophic lakes in the Baltic Sea region, including Latvia, have disappeared. In clear-water lakes of Latvia, the vegetation of the *Lobelia-Isoetes* complex is present in mesotrophic lakes where nutrient enrichment has already begun, as well as in slightly eutrophic and eutrophic lakes, where enrichment with nutrients is characteristic, but which still have retained high-quality waters with appropriate vegetation due to various specific circumstances — a small catchment area, slow water exchange, remarkable depth.

The second group of *Lobelia-Isoetes* lakes represents brown-water (polyhumic) lakes rich in nutrients which are compounded in complex, water-insoluble humic substances and are therefore unavailable to water organisms (Urtāne 2014). These are oligo-dystrophic lakes, which developed when receiving raised bog waters, as well as separate eutrophic lakes with small catchment areas, insignificant anthropogenic activity and slow water exchange, which are sometimes also very deep. The *Lobelia-Isoetes* complex in Latvian lakes is composed of aquatic plant species, almost all of which are endangered not only in our country but also in other countries of the Baltic Sea region. Usually the species of the *Lobelia-Isoetes* complex in Latvian lakes can be found in a set of 2–3 species, while in outstanding lakes of this type, there can even be a complex of 9 species. The *Lobelia-Isoetes* complex includes ten vascular plant species — *Eleocharis multicaulis, Isoetes echinospora, I. lacustris, Juncus bulbosus, Littorella uniflora, Lobelia dortmanna, Myriophyllum alterniflorum, Sparganium angustifolium, S. gramineum, and Subularia aquatica* – and two moss species – *Fontinalis dalecarlica* and *Sphagnum auriculatum* (Āboliņa 1968; Suško 1990, 2015). Due to their specific ecological requirements, the locality of just one of these species in any of our lakes should be regarded as an important ecological quality indicator of the lake (Suško 1990, 1996).

In clear-water lakes with *Lobelia-Isoetes*, there is usually a relatively high number of aquatic organisms, while each species is represented by a small number of individuals (Urtāne 2014). In brown-water lakes, the number of species and their individuals is also low.

In deep *Lobelia-Isoetes* lakes with a large volume of water and slow water exchange, there can also be relict species of Najas – *Najas flexilis* and *N. tenuissima*, as well as a number of invertebrates that live in deep-water zones, such as *Eurytemora lacustris* and *Pallaseopsis quadrispinosa* (Stepanova et al. 2012). Populations of cold water species *vendace Coregonus albula* can also be found in such lakes. Nowadays vendace are recorded in about 15 lakes, including six lakes located in Natura 2000 territories (Aleksejevs et al. 2012; Birzaks 2013b). To a great extent, a freshwater form of smelt, *Osmerus eperlanus spirinchus*, can also be included in this group. This fish was recorded in about 30 Latvian (mainly in the Latgale region) deep lakes in the 1930s, while in the 1950s it was found in seven lakes; but in 1989 – only in four lakes including Dridzis and Sivers (Mansfelds 1936; Spuris 1954; Plikšs, Aleksejevs 1998; Aleksejevs, Birzaks 2012).

In *Lobelia-Isoetes* lakes several rare and protected vascular plant species can also be found that belong to habitat type 3150 *Natural eutrophic lakes with Magnopotamion* or *Hydrocharition* - type vegetation. Such species are *Callitriche hermaphroditica, Elatine hydropiper, Limosella aquatica, Nuphar pumila, Potamogeton filiformis, P. pusillus, P. rutilus, Scolochloa festucacea, Chara* spp. – *Chara filiformis, Ch. aspera, Nitella flexilis*, as well as mosses – *Calliergon megalophyllum, Fontinalis hypnoides*, and *Warnstorfia trichophylla* (Āboliņa 1968; Suško, Āboliņa 2010; Suško 2015). The presence of these plants indicates the lake's succession and transition to the habitat type 3150 *Natural eutrophic lakes with Magnopotamion* or *Hydrocharitio*n – type vegetation.

The vegetation of these lakes is sparse, and often vegetation-free shore sections of mineral ground are also can be observed. Communities of the *Lobelia-Isoetes* complex and its accompanying species develop in the littoral zone. is no zone of emergent vegetation, or it consists of sparse stands of *Phragmites australis, Eleocharis* spp., *Carex* spp., and other species. Typical plants of floating-leaved vegetation are *Sparganium angustifolium, S. gramineum, Potamogeton natans*, or sometimes this zone is absent. The development stage of the submerged plant zone may be different depending of on the water transparency, and species of the *Lobelia-Isoetes* complex can also be found here. In brown-water lakes with *Lobelia-Isoetes* complex, quaking mires can develop in some shore sections. Transitional mires or raised bogs are located in lake drainage basin or adjacent to such lakes (Lake Ilzenieki, Ungurs, Augstroze).

12.1.2 Indications of Favourable Conservation Status

Favourable conservation status of this habitat is characterised by a set of several interdependent factors, which is primarily a low concentration of nutrients and low conductivity. It limits the growth of periphytic algae and other competing aquatic plants, as well as it slows down "ageing" of a water body.

High water transparency also ensures the conservation of isoetids at depths that are no longer available to other submerged and floating-leaved plants. In certain lakes (Ārdavs, Dridzis, Sivers) the water transparency during the summer reaches 4–7 m (Suško 1990, 1996, 2013, 2015).

Favourable conservation status is also characterised by a thin layer of dead aquatic plant parts and fallen-off leaves on the bottom, or by this layer being absent. Most of the species characteristic to the habitat are small, with rosette leaves (*Isoete* spp., *Lobelia*), and sensitive to being buried by parts of dead plants and fine sediments. Under the impact of slow water exchange, there are negligible water level fluctuations ensuring relatively stable environmental conditions that do not contribute to nutrients entering the lake. The slow water exchange also reduces leaching of nutrients into the lakes.

Due to the low nutrient concentration, the vegetation is sparse, and there are vegetation-free littoral sections with a mineral bottom. There are very few floating-leaved plants or they absent. Although the upper irradiated water layer, in which photosynthesis takes place, is larger than the lower un-irradiated layer, the total productivity of the lake is low. In mesotrophic *Lobelia-Isoetes* lakes, the number of species, but the total number of organisms is low (Cimdiņš 2001). Usually, there is no dominant species (Urtāne 2014). The concentration of organic substances and nutrients is low, but the concentration of dissolved oxygen is high. Oxygen saturation in the bottom water layer is 40–80%. The indicatorsions of a favourable condition are summarised in Figure 12.2.

Isoetids – submerged aquatic plants with rosette leaves, often long and thin. This group of aquatic plants was named after the most well-known representative – *Isoetes* spp.

12.1.3 Important Processes and Structures

12.1.3.1 Nutrients

Low concentration of dissolved nutrients in water is the most significant factor for the existence of *Lobelia-Isoetes* habitat. The circulation of nutrients is nearly closed, i.e., excess nutrients are not produced (Kļaviņš, Cimdiņš 2004). In brown-water lakes of *Lobelia-Isoetes* type, phosphorus released from the dead organisms is bound in insoluble complexes of humic substances (Kļaviņš, Zicmanis 1998). These phosphorus binding processes determine the slow development of nutrient enrichment in nutrients and ensure the preservation of the minerogenic bottom in a shore part of a lake (littoral zone), necessary for the existence of characteristic species of this type of lakes. Sediments of mesotrophic *Lobelia-Isoetes* lakes mainly consist of insoluble silica shells of diatom algae.

The amount of phosphorus compounds in the bottom water layer is low. In addition, when reach sediments, they turn into an insoluble form, since because there is enough oxygen in the layer. Slow leaching of nutrients into the lake is also promoted by nutrient poor soils in the lake's catchment area, small catchment area, and slow water exchange in the lake.

The life processes in lakes are determined not only by the amount of nutrients, but also by their accessibility. Depending on the chemical properties of the lake water, nitrogen and phosphorus compounds may be present in water in insoluble forms, which cannot be used by living organisms. The chemical characteristics of the lake's water also depend on the types of soil and bedrock in the lake's catchment area.

Phosphorus is the limiting factor for the stability of a *Lobelia-Isoetes* lake ecosystem (Cimdiņš 2001), therefore any discharge of wastewater containing phosphorus in the lakes causes a rapid increase of algae population and productivity, and the lake can soon pass on to the next development stage – a eutrophic lake.

12.1.3.2 Shape and Depth of Lakes

The speed of a lake's ageing is also affected by the width of its shore part and its depth. In lakes with a narrow shore zone, parts of dead plants and water organisms and fallen-off leaves are transported by the wind and waves to the deepest part of the lake where they settle. High transparency promotes photosynthetic and microbial activity at depth and ensures that the phosphorus in the sediments reacts with oxygen of the bottom water layer, and settles in an insoluble form, and thus is removed from the nutrient circulation. Due to a low concentration of nutrients, the mesotrophic lakes have wide sandy shorelines with sparse stands of emergent aquatic plants. There is a low concentration of organic substances and nutrients and a high concentration of dissolved oxygen. Oxygen saturation in the bottom water layer is 40–80 % (Cimdiņš 2001).

12.1.3.3 Water Exchange Rate

The water exchange rate in the lake is determined by how much water flows into the lake and how much flows out of it. This parameter is directly related to the impact of incoming nutrients on the quality of the lake. For example, the water exchange period of the mesotrophic Lake Laukezers (Krustpils region, Kūkas Municipality) is very long – 9 % per year. This means that all the water in the lake exchanges in 4058 days or in about 11 years (Urtāne 2014). Consequently, nutrients that are brought into the lake, stay there and are consumed. The smaller the catchment area, the smaller the potential amount of nutrients brought to the lake. At the same time, any form of pollution can significantly affect the quality of the lake.

12.1.3.4 Water Level

The water level of a lake depends on rainfall, temperature, evaporation from the open part of the lake, as well as on the volume of water inflow and outflow. Slow water exchange also ensures small annual natural and seasonal fluctuations of the water level, which further promotes the existence of a characteristic of the habitat-specific and stable littoral zone. The existence of such a shore zone with sparse vegetation is also promoted by prevailing poor soils in the catchment area and pine forests which are growing on them, as they produce a small quantity of litter and thus reduce the accumulation of organic substances and their leaching into the lake. If any of the external factors changes, for example, new drainage ditches enter the lake or beaver dams are established on outlets of the lake, then water level fluctuations and the leaching of nutrients and plant residues (leaves, twigs), which have accumulated in the terrestrial part of the shoreline, becomes more intense. Leaching of nutrients and plant dead plant parts into a lake puts an additional load on the lake's ecosystem and promotes more rapid transition to a eutrophic state with its characteristic floating and emergent vegetation.

12.1.4 Habitat-specific Species of Macrophytes

Based on botanical studies of Latvian lakes (Āboliņa 1968, 1994; Gavrilova 1985; Tabaka, Gavrilova, Fatare 1988; Gavrilova, Šulcs 1999; Suško 1990, 1999, 2014, 2015a, 2015b; Suško, Bambe 2002; Suško, Āboliņa 2010), a list of macrophyte species of this habitat type was compiled (Table 12.1). The list consists of 75 vascular plant species, 10 species of charophytes, and 14 moss species. Of them, 22 are habitat-characteristic species.

Table 12.1. Macrophyte species in Lobelia-Isoetes lakes

Vascular plants		
Acorus calamus	*Lemna minor*	*Potamogeton obtusifolius*
Alisma plantago-aquatica	*Lemna trisulca*	*Potamogeton pectinatus*
Batrachium circinatum	***Limosella aquatica***	*Potamogeton perfoliatus*
Butomus umbellatus	***Littorella uniflora***	*Potamogeton praelongus*
Callitriche cophocarpa	***Lobelia dortmannaa***	***Potamogeton pusillus***
Callitriche hermaphroditica	*Menyanthes trifoliata*	***Potamogeton rutilus***
Callitriche palustris	***Myriophyllum alterniflorum***	***Potamogeton sturrockii***
Carex elata	*Myriophyllum spicatum*	*Ranunculus lingua*

Vascular plants		
Carex lasiocarpa	*Myriophyllum verticillatum*	*Ranunculus reptans*
Carex rostrata	***Najas flexilis***	*Rorippa amphibia*
Ceratophyllum demersum	***Najas tenuissima***	*Sagittaria sagittifolia*
Crassula aquatica	*Naumburgia thyrsiflora*	*Scirpus lacustris*
Elatine hydropiper	*Nuphar lutea*	***Scolochloa festucacea***
Eleocharis acicularis	***Nuphar pumila***	***Sparganium angustifolium***
Eleocharis multicaulis	*Nymphaea alba*	*Sparganium emersum*
Eleocharis palustris	*Nymphaea candida*	*Sparganium erectum*
Eleocharis uniglumis	*Phragmites australis*	***Sparganium gramineum***
Elodea canadensis	*Polygonum amphibium*	*Sparganium microcarpum*
Equisetum fluviatile	*Potamogeton compressus*	*Sparganium minimum*
Hottonia palustris	*Potamogeton crispus*	*Spirodela polyrhiza*
Hydrilla verticillata	***Potamogeton filiformis***	*Stratiotes aloides*
Hydrocharis morsus-ranae	*Potamogeton friesii*	***Subularia aquatica***
Isoetes echinospora	*Potamogeton gramineus*	*Typha angustifolia*
Isoetes lacustris	*Potamogeton lucens*	*Typha latifolia*
Juncus bulbosus	*Potamogeton natans*	*Utricularia vulgaris*
Charophytes		
Chara aspera	*Chara rudis*	*Chara virgata*
Chara contraria	***Chara strigosa***	***Nitella flexilis***
Chara filiformis	*Chara tomentosa*	*Nitellopsis obtusa*
Chara globularis		
Mosses		
Calliergon megalophyllum	***Drepanocladus sordidus***	*Scorpidium scorpioides*
Calliergonella cuspidata	*Fontinalis antipyretica*	***Sphagnum auriculatum***
Chiloscyphus pallescens	***Fontinalis dalecarlica***	*Warnstorfia exannulata*
Drepanocladus aduncus	***Fontinalis hypnoides***	***Warnstorfia trichophylla***
Drepanocladus sendtneri	***Platyhypnidium riparioides***	

Note: Rare and protected species are highlighted in color, habitat characteristic species, whose presence and sufficient distribution in a particular lake distinguishes this habitat from other lake habitats, have background imprinting.

12.1.5 Natural Development of a Habitat

When there is a stable water level and of nutrients, the lake's ecosystem can remain in a stable state for a long period of time. When the leaching of nutrients in lakes of this type is changing and increasing, conditions become favourable for the growth of algae and vascular plants. The increase of reduces the water transparency in an open lake. Floating-leaved plants and emergent plants increase the shade and their dead parts "bury" the *Lobelia-Isoetes* species, which are small in size. Such waters enriched with nutrients and detritus rapidly transform into the next stage – a eutrophic lake (*See Chapter 14*), and species of the *Lobelia-Isoetes* complex, which are characteristic for mesotrophic lakes, disappear. Transformation into the eutrophic stage is a natural lake development process, which is sped up by human activities in the lake catchment. Therefore the habitat management goal is to lessen the impact of human activity and preserve the lake in the given development stage for as long as possible.

In brown-water lakes, dystrophication processes dominate, characterised by slow nutrient turnover. Natural development of a brown-water lake differs from clear-water lakes, bypassing the eutrophication phase in most cases. Therefore, if enrichment of a lake by nutrients is avoided, such lakes can stay intact for a long time and turn into dystrophic lakes long period (See Chapter 16).

12.1.6 Pressures and Threats

12.1.6.1 Increased Input of Nutrients

Lobelia-Isoetes lakes are threatened by a high concentration of nutrients from small rivers and ditches that flow into the lakes. The origin of nutrients is an economic activity in the lake's catchment area, such as the ploughing of grassland and creation of new agricultural areas, increasing the areas sown with rape and corn, logging, which can also be distant from the lake. Due to nutrient input, periphytic algae cover develops in the shoreline and water transparency decreases (Fig. 12.2).

12.1.6.2 Recreation

About a third of Latvian *Lobelia-Isoetes* lakes can be reached within an hour when driving from Rīga or regional centres, and they are popular swimming places. The water of *Lobelia-Isoetes* lakes is clear and transparent, however, most plant species are sensitive to sediment resuspension and mechanical trampling, caused by the increasing number of swimmers and lack of adequate infrastructure. If the bathing area of the lake is not equipped with toilets, visitor load can also significantly increase the concentrations of biogenes, especially phosphorus, in the water. It manifests as fast-growing green algae that covers the lake bottom and *Lobelia-Isoetes* complex, suppressing and destroying it.

Personal watercraft ("jet skis") has become popular in recent years. They can significantly damage *Lobelia-Isoetes* lakes, since they use a water pump rather than propellers to move through the water. To speed up, the water flow through the watercraft turbines in the water environment must be much greater than the speed of the watercraft at a given moment. Maximum engine power is used to generate the initial acceleration. The water environment is much denser than the air environment, and such movement of water in the water environment, especially in shallow waters, has a much greater impact. The turbulence produced by jet propulsion disturbs plants and sediments, plants are uprooted and washed away from bottom. Organogenic sediments are resuspended and mobilised, and there are more opportunities for these elements to be involved in nutrient circulation

Fig. 12.2. In the littoral zone, lobelias are suppressed by fast-growing green algae. Lake Mazuika, 2013. Photo: A. V. Urtāns.

(eutrophication). Due to sediment resuspension, water transparency decreases, rosettes of *Lobelia-Isoetes* are buried and their vitality decreases. Water jet engines of watercraft, depending on their power, can mobilise sediments at a depth of 5 m and deeper, (Asplund 2000), i.e. up to the lower depth limit of isoetids.

12.1.6.3 Impact of Dead Plant Material

A significant negative impact is created by the growth and death of emergent vegetation. In most cases, this vegetation is composed of *Phragmites australis*. In autumn, when the emergent vegetation dies, organic residues of large dimensions are formed – detritus with a slow decomposition rate. A loose layer of dead *Phragmites australis* and *Scirpus lacustris* develops. Beneath this layer, the plants of Lobelia-Isoetes are shaded and die. Such a loose layer does not affect the development of reed shoots. In subsequent seasons, conditions favourable for the distribution of *Phragmites australis* and *Scirpus lacustris* develop.

Lobelia-Isoetes lakes are also negatively affected by the overgrowth of previously open shores with shrubs and trees. Shrubs and trees becomes a pollution source – autumn leaves fall into the water, where over time, a layer of organogenic sediments several centimetres thick forms. To decompose this layer, oxygen, which is needed for other living processes, is consumed, and the total amount of oxygen in the lake decreases. In addition, the mass of fallen leaves covers *Isoetes*, *Lobelia*, and other low plants, and creates a substrate for the development of emergent vegetation. In this way, the development of emergent plants is promoted and conditions unfavourable for the further existence of *Lobelia-Isoetes* complex are created.

12.1.6.4 Rise in Water Level

With a rise in water level, shore zone floods and shore mineral nutrients are leached, leading to rapid growth of algae. They cover the vegetation of the *Lobelia-Isoetes* complex, suppressing and destroying it. When building dams on ditches or on small rivers that flow out of the lake, beavers can raise the water level. In sandy areas of Coastal Lowland, water flow can change, even influencing water levels far from *Lobelia-Isoetes* lakes. Such effects have been observed, for example, in Lake Buļļezers which is an endorheic (no outflow) lake (Fig. 12.3). After deepening the nearby River Krievupe, the water level decreased by about 50 cm (Suško 1996) but later raised again, leaching nutrients into lake and causing mass algal growth in summers; water transparency suddenly worsened, and the *Lobelia-Isoetes* complex disappeared.

Fig. 12.3. Signs of degradation of Buļļezers – the former Lobelia-Isoetes lake – rise in water level of lake enriched with nutrients, lake has started to overgrow with floating pondweed. Intensive reproduction of algae has significantly decreased water transparency, 2014. Photo: A. V. Urtāns.

12.1.6.5 Input of Humic Substances

Humic substances are high molecular complex compounds of organic origin, which form either through the activity of living organisms, or their biodegradation. The complex of these substances causes the yellow colour of the water. Their concentration in rivers and lakes ranges from 1 to 30 mg/l, while in bog waters it can reach 300 mg/l.

Humic substances have a high content of functional groups that can create complexes with metal and phosphorus ions. Humic substances in natural waters are one of the main factors affecting the impact and forms of pollutants (Kļaviņš, Zicmanis 1998). Humic substances with phosphorus compounds form complex, only slightly soluble compounds, and thus limiting the development of algae and macrophytes. Humic substances reach water bodies by leaching through the soil or via drainage ditches. Such natural washing ininput of humic substances may be long term and come from a large territory, without a significant decrease in vitality of *Lobelia-Isoetes* vegetation. For example, in Lake Augstrozes Lielezers, the *Lobelia-Isoetes* complex is represented by *Lobelia dortmanna, Littorella uniflora, Sparganium angustifolium*, and *I. lacustris*. The total length of the shoreline of the lake is 9,5 km. Of them, 3.5 km or 37 % directly border a raised bog or bog woodland. Lakes with Lobelia-Isoetes vegetation can be significantly affected if large-sized aggregates of humic substances – peat particles are discharged from peat extraction fields in lake catchment. Peat particles mixed with water decrease the water transparency, cover the bare minerogenic bottom and physically bury the rosettes of *Lobelia-Isoetes* vegetation.

12.2 Management Objectives for the Conservation of *Lobelia-Isoetes* Lakes

Since there are only 20–30 lakes of this type in Latvia and they are sensitive to even a small increase in biogenes, the conservation of these lakes is one of the most topical priorities in the conservation of Latvian waters.

The conservation and management objective of *Lobelia-Isoetes* lakes is to maintain a water resource of high chemical and physical quality, while providing a suitable living environment for those organisms with a weak ability to adapt.

12.3 Restoration and Management of *Lobelia–Isoetes* Habitats

12.3.1 Planning the Conservation of *Lobelia–Isoetes* Lakes

If the input of biogenes to a lake does not increase, lakes that are poor in nutrients can remain stable for a long period of time. Enrichment with nutrients causes a rapid replacement or disappearance of previously dominating species. Restoration of such modified and degraded lake habitats is almost impossible or can only be implemented over a longer period of time, and it requires a large investment. Some of these lakes have slow water exchange or a large volume of water. Therefore, the most important task of lake management is to ensure that the nutrient input does not increase. This can be achieved by careful planning of economic activities and by introducing a drainage area management plan and control, which is accepted by all the economic operators that live in the catchment area.

In Latvia, there are only 20–30 lakes of this type, and they constitute the "golden fund" of our waters. Only a portion of them have the status of a protected nature area. In the future, we should develop and implement a conservation and management programme for all of these lakes, regardless of their current conservation status. The issue of granting conservation status for Lake Sivers (Fig. 12.4) must be solved urgently, as this is the richest and largest lake of *Lobelia–Isoetes* complex in the Baltic states; this also refers to Lake Ārdavs (Suško 2013, 2015).

Fig. 12.4. Lake Sivers has the largest area occupied with the Lobelia-Isoetes complex in the Baltic states. Photo: U. Suško.

It is most important to ensure that such lakes are not exposed to an adverse impact. To achieve the above, cooperation and mutually-coordinated planning among various institutions is needed. It includes conservation of the natural hydrological regime and ensuring that drained areas in the lake's catchment area do not increase; extensive management of the catchment area; observance of regulations in protection belts; restriction of recreation; prevention of of any untreated waste waters and other waters containing elements of biogenes, as well as a reduction of beaver impact.

To reduce the inflow of biogenes, actions should also be taken in the lake and on its shores – limiting of habitat-degrading and expansive species (such as reeds), improvement of shoreline vegetation structure (for example, tree and shrub felling). The potential impact of these activities on the lake's ecosystem must be carefully assessed in advance. A review of the management methods is given in Table 12.1.

12.3.2 Reduction of Recreation Load (D5)

Conservation of *Lobelia-Isoetes* lakes should be planned in the context of the wider surroundings, by also planning the recreational load. It is important to ensure that the pollution load and the load of direct human presence do not increase, as they cause degradation, which is difficult to prevent or which is even irreversible for this rare type of lake.

At most of the *Lobelia-Isoetes* lakes, visitor infrastructure is minimal or lacking. There are no toilets with a closed container for faeces, waste is not removed on a regular basis. Current experience shows that prohibitions may only solve recreational issues in closed territories, such as Ādaži military training area where recreation on the Lieluika and Mazuika is not allowed. For other mesotrophic lakes, the only solution is the improvement of current recreational infrastructure, without its further expansion. The redirection of vacationers to adjacent lakes with appropriate infrastructure is also a solution which would decrease the pressure on *Lobelia-Isoetes* lakes. It is also important to inform the visitors about the natural values of the lakes and their sensitivity in different and simple ways.

Recreational load is also increased by the wider use of easily transported personal watercraft. The impact of the use of watercraft is described in detail *in Chapter 14.1.6.9*. Taking into account the small number of preserved *Lobelia-Isoetes* lakes and their increased sensitivity to phosphorus, the sediment resuspension caused by watercraft results in the return of phosphorus into the water layer and poses a serious threat to the entire lake ecosystem. From this perspective, the use of personal watercraft in small mesotrophic lakes, only a few tens of hectares in size, must not be allowed.

12.3.3 Shore Zone Management (C3.1)

Agricultural activity on the shores of some lakes has significantly decreased in recent years; therefore, the lake shores and floodplains overgrow with shrubs, reeds or trees. Consequently, leaves and parts of dead plants reach the lakes in autumn, enriching the water with phosphorus compounds. To reduce the amount of phosphorus that enters the water body, various management methods and their possible implications must be evaluated based on the location of *Lobelia-Isoetes* localities in relation to the terrain forms of the lake's shore and directions of prevailing winds. With regard to the small number of mesotrophic lakes with *Lobelia-Isoetes* vegetation, their management should be based on the precautionary principle.

Over time, a stand of shrubs often develops on the shores of the lake, forming a dense screen that blocks wind and at the same time promotes the input of phosphorus into the lake by leaf litter. In these cases, shrub removal is recommended to remove shrubs, at least to extent that the leaves may not directly reach the water. Shrubs should be removed gradually, in parts, as the cutting of trees and shrubs on the shoreline will improve light conditions and promote the growth of shoots.

If in addition to the shrub layer there are large trees on the shores of such lakes, their shade affects the shore zone to a greater extent; mass development of reedbeds in the shore zone of shallow water is restricted, not allowing them to outgrow the *Lobelia-Isoetes* stands. Although the amount of leaf litter from large trees is equal to or even exceeds the amount of organic substances accumulated in reedbeds, these trees must be preserved, taking into account their importance in strengthening the shore and creating the landscape. Active management of natural forests with woodland key habitats, old growth forests on lake shores are not necessary because their interaction with the lake ecosystem have become stable over time.

Shore management in endorheic (no outflow) lakes must be assessed with particular care, as the felling of trees there can lower the evapotranspiration rate and thus promote the rise in water level. If the water level in mesotrophic lakes rises, flooding the shore zone of shrubs and trees, the trees that have been in the water for a long time must be removed to prevent them from falling into the lake, because if trees are uprooted then nutrient-rich soil also enters the lake from the place where they grow. To avoid the enrichment of mesotrophic lakes with nutrients, the management measures should be carried out regularly, at least every five years.

12.3.4 Reduction of Mass Development of Emergent Macrophytes (C2)

Emergent vegetation – reeds – must be mown if previously sparse reed stands with underneath vegetation of Lobelia-Isoetes complex becomes too dense and accumulates the particles of dead reeds, thus promoting the physical burying of vegetation of *Lobelia-Isoetes* complex. As *Lobelia, Isoetes, Littorella uniflora*, and *Subularia* are very small, the emergent vegetation should be mown with a portable internal combustion mower mounted on a boat, and mown around 15 cm above the bottom of the lake. Mown reeds must be taken to the shore at a distance where the waves cannot carry them to the lake again.

The emergent vegetation should be mown in separate 10–15 m wide belts, perpendicular to the shore. Mowing should be continued for at least two years. If an increase of washed ashore *Lobelia-Isoetes* complex plants, including uprooted plants, is observed in the second year, reed cutting must be stopped.

In Latvia, in compliance with the effective legal framework[67], plant mowing can be started from 1 July. Mowing in early July is more efficient than mowing in August because the aquatic plants start their preparation for winter and accumulate nutrients in the roots, therefore along with the aquatic plant mass, only a small part of the nutrients will be removed from the lake.

12.3.5 Constructed Wetlands and Sedimentation Ponds on Inflows to the Lake (B2, B3)

The eutrophication-causing nutrients can be intercepted if sedimentation ponds or artificial wetlands are established on rivers and drainage ditches that flow into the lake. They can significantly reduce nutrient inflow, and can be used as additional solutions in cases if there are inflowing waters from agricultural land or from individual objects such as saunas, guest houses and other objects that consume a lot of water.

The two main types of constructed wetlands are subsurface flow and surface flow constructed wetlands. Surface flow constructed wetlands are used for the reduction of pollution caused by agricultural runoff, while subsurface flow constructed wetlands are used for the treatment of municipal wastewater in separate objects or in small settlements. Surface flow constructed wetland and sedimentation pond construction is similar, but their functions are different: sedimentation ponds precipitate soil particles, thus reducing the intensity of sedimentation process, while constructed wetlands intercepts nutrients from water. For more information about constructed wetlands: *see Chapter 17.3.4.3*.

In some lakes, specific solutions are necessary. Lake Ungurs has rich *Isoetes* vegetation but it borders with peat extraction areas. Peat particles from these areas enter the lake, physically burying and destroying *Isoetes* individuals. To intercept the peat particles, a deepening is created in a ditch before its inflow to a lake. As the water flow speeds down, peat particles settle down in the deepening of such ditch. The efficiency of such mechanical construction depends on the frequency of cleaning.

12.3.6 Chemical Methods of Nutrient Binding (D2.1)

Chemical methods can theoretically be used in *Lobelia-Isoetes* lakes for binding the phosphorus compounds, which are dissolved in the water environment and which are otherwise difficult to separate. To reduce the concentration of phosphorus in water, aluminium or iron compounds are introduced into the lake. They react with phosphorus ions dissolved in water, forming insoluble compounds that settle down as sediments (*see Chapter 14*).

Compared to macrophyte mowing, the advantage if this method is the opportunity to manage large areas of water without the use of expensive equipment and the related infrastructure. However, when working with these compounds, it must be remembered that in the case of a drop in pH value, phosphorus in an acidic environment is released in the water mass. Potential benefits and risks should be carefully evaluated in relation to other groups of organisms and to human health:

- this method is easy to implement, the positive result is immediate and obvious. However, the result is quite temporary, and this procedure must be repeated in 1–3 years;
- a negative impact is posed by the fact that the content of aluminium and iron in the lake is increasing, however, in natural conditions it should not be so; the aluminium compounds in the water body's acid environment can become toxic (Kļaviņš 1998).

[67] Cabinet Regulation No. 475 of 13 June 2006, the Order for the Maintenance and Deepening of Surface Water Bodies and Water Areas of Ports.

12.3.7 A Comparison of the Management Methods to be Used in Lobelia-Isoetes Lakes

Table 12.2. Review of the management methods.

General management measures		
Method	**Advantages**	**Disadvantages**
C3.1: Shore zone management. Felling of shrubs on lake shores	Reduced input of leaf litter as a source of phosphorus.	Every 3–5 years.
C2: Mowing of emergent vegetation of shore areas – reinforcement of wave activity	Reduced accumulation of coarse detritus produced by emergent macrophytes.	The mown areas become available to visitors, and localities of *Isoetes* are subjected to a risk of mechanical trampling.
Specific management measures		
Method	**Advantages**	**Disadvantages**
B2: Construction of sedimentation ponds or peat particle interception filters on ditches inflowing from peat extraction areas	Reduced input of peaty sediments.	Regular servicing, cleaning, or replacement of filters and cleaning of ditches is necessary.
B3: Construction of surface flow wetlands	Direct input of nutrients into the lake is reduced.	Regular cleaning of wetland and withdrawal of excessive vegetation.
D2.1: Limitation of the circulation of plant nutrients – chemical settling of phosphorus	Reduction of bioavailable phosphorus available in water.	Can be used in small lakes only. Has negative side effects on aquatic organisms and human health.
D5: Construction of the infrastructure to reduce the recreation load	Possibility to control and limit the flow of vacationers.	Regular maintenance of infrastructure is necessary.

12.4 Management and Use Unfavourable for *Lobelia-Isoetes* Lakes

Unorganised or unauthorised recreation and nutrient leakage is the main factor that has a negative impact on small *Lobelia-Isoetes* lakes. Here, periphytic algae cover can rapidly increase, making such places visually unattractive. As explained in previous chapters, phosphorus is the main limiting factor in lakes of this type. Large lakes with a large volume of water (Lake Sīvers) can be destructively and irreversibly affected by changes in land use and by the introduction of intense agricultural practices in the lake's catchment areas. Devastating consequences can also be caused by the development of pond farming on the shores of the lakes. In autumn such ponds are drained and large volumes of phosphorus compounds and organic substances inflow into lakes causing rapid growth of emergent vegetation and suppressing the *Lobelia-Isoetes* complex. *Lobelia* and *Isoetes* are also suppressed by the filamentous algae cover, which rapidly develops in the presence of phosphorus in the shallow shore zone. Input of slowly decomposing organic compounds into lakes also contributes to the accumulation of the mud layer and destroys the minerogenic bottoms suitable for *Lobelia-Isoetes* vegetation.

Additional load is caused by the use of personal watercraft and motorboats. There are even irresponsible people who use motorised watercraft for a short period of time in lakes which are included in protected nature areas, causing significant sediment resuspension and destruction of *Lobelia-Isoetes* vegetation. The impact of watercraft is much greater than the impact of swimmers, who trample *Lobelia* and *Isoetes* that grow in shallow zones.

Brown-water lakes with Lobelia-Isoetes vegetation can border directly with raised bogs (Lake Augstroze). In some of these bogs, peat is also being extracted (Lake Ungurs). Then, it must be assessed whether the lake only receives natural surface runoff that does not significantly affect *Lobelia-Isoetes* vegetation. The situation is considered as unfavourable if peat particles from peat extraction sites cover the minerogenic bottom and destroy habitats that are suitable for *Lobelia-Isoetes* vegetation (Lake Ungurs).

12.5 Contradictions of Conservation and Management

The main conflict in conservation and management is highly valued water resources of lakes and their active use for recreation, without an understanding that the removal or neutralisation of all phosphorus compounds reaching the water due to activities of visitors and the returning of lakes to their initial, nutrient-poor condition, is only possible theoretically. Additional recreation load and risks of degradation are caused by the fact that five of the 30 identified lakes of this type are located in the vicinity of Rīga. The small number of these lakes and their location close to major urban areas make the reduction of visitor load very problematic. Due to the vicinity of the city, the development of impact mitigating infrastructure can attract even more visitors, causing even higher pressure on the lake. A similar contradiction arises when dealing with the removal of shore shrub overgrowth to promote the establishment of a grassed lane, preventing nutrient inflow, which at the same time becomes attractive for visitors. An additional contradiction arises from mowing shading reeds in areas with Lobelia and *Isoetes* stands. The very activity of mowing itself can destroy Lobelia and *Isoetes*. The preferred form of mowing in winter conditions on the stable ice becomes inapplicable due to the shift in climate.

Chapter 13. 3140 *Hard Oligo-Mesotrophic Waters with Benthic Vegetation of Chara spp.*

(A. V. Urtāns, L.Urtāne, U. Suško)

13.1 Characterisation of Hard Oligo-mesotrophic Waters with Benthic Vegetation of Chara spp.

13.1.1 Brief Description

Distribution of habitat type. Habitat is mostly recorded in waters rich in compounds of calcium and magnesium, with the dominance of *Charophyta* (*Chara* spp.) communities in their ecosystem. Most lakes of this habitat are shallow, and their depth does not exceed 2–5 metres. Distribution of the habitat is determined by the chemical composition of waters and sediments. Ions of bicarbonates (HCO^{3-}) and of calcium dominate in waters of such lakes, and their concentration is mainly determined by the weathering of carbonate bedrock (limestone, dolomite) (Kļaviņš, Kokorīte 2013).

The habitat occurs very rarely in Latvia (Fig. 13.1), and it covers a total of 8810 ha or 0.1 % of the country's territory (Anon. 2013). More than half of their total area is occupied by shallow coastal lagoon-type lakes – Engure and Kaņieris. Baltiņš, Zvirgzdu, Kurjanova, Silabebri, and Dreimaņi lakes situated in Latvia also belong to this habitat type (Fig. 13.1). It is still possible to discover new small lakes that belong to this habitat type.

Characteristics. *Chara* spp. is quite often found in flooded quarries at a depth of up to 5–8 m. Water bodies of an artificial origin (flooded quarries of carbonate rocks) where *Chara* spp. vegetation can also be found, are not considered to be protected as EU habitat type 3140 *Hard oligo-mesotrophic waters with benthic vegetation of Chara spp*. (further referred to as charophyte lakes).

In charophyte lakes, great Fen-sedge *Cladium mariscus* can be found. According to the methodology for defining protected habitats of EU importance (Auniņš (ed.) 2013), such stands can be classified as a protected habitat type if the projected coverage of stands of *Cladium mariscus* in a lake's quaking bog (habitat 7140 Transitional mires and quaking bogs) is at least 50 % of the total coverage of the herbaceous layer, as well as the habitat occupies at least 4 m^2, it should be classified as habitat 7210 Stands of *Cladium mariscus* in lakes and bogs.

Of other rare and protected species found in charophyte lakes, the most common is *Najas marina*, and these lakes are the richest habitat for this species in Latvia. Other rare and protected aquatic plant species are found rarely in charophyte lakes – *Ceratophyllum submersum, Potamogeton pusillus, P. rutilus, and Zannichellia palustris, Chara polyacantha,* and *Ricciocarpos natans* (Gavrilova et al. 2005; Zviedre, Grīnberga 2012).

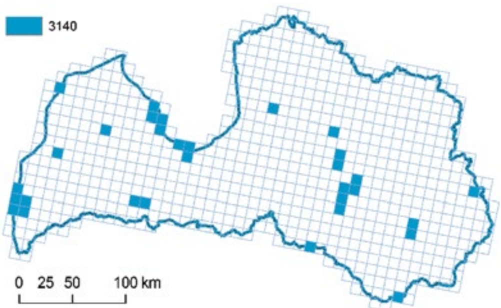

Fig. 13.1. Distribution of habitat type 3140 *Hard oligo-mesotrophic waters with benthic vegetation of Chara spp*. in Latvia (Anon. 2013).

Fig. 13.2. In late summer, in the shallowest areas of the lake dense charophyte stands rise above the surface. Lake Silabebri. Photo: L. Urtāne.

13.1.2 Indications of Favourable Conservation Status

The first indication of favourable conservation of this habitat type is the vitality of charophyte communities. This means that vast continuous charophyte stands are present throughout the lake. Floating-leaved or emergent plants forms only separate clusters among these stands. Individual charophytes have good vitality, their lateral branches overlap and create a complex spacious network (Fig. 13.3) attracting water organisms and providing shelter. Charophytes are not covered by dead parts of macrophytes.

Charophyte stands in shallow 1–3 m deep lakes cover more than 30 % of the lake bottom. In the central part of the lake, wide closed stands of emergent plants and quaking vegetation do not develop. Emergent vegetation that faces the open part of the lake is heavily indented and looks like a mosaic. High diversity of charophyte species is characteristic. For instance, in Lake Engure, nine *Charophyta* species have been found (Zviedre, Grinberga 2012). Some lake shore parts of the lake are open, not closed by emergent vegetation.

Charophyte stands are a good substrate for the development of various water organisms. Charophytes are productive and important with regard to fish resources. The shallow depth of the shore zone and free access to the shore provide favourable conditions for waders *Charadriiformes* and dabbling ducks *Anatinae,* as well as favourable spawning conditions for pike *Esox lucius*. One of the key factors that determines the number of water birds in lakes of this type, is the optimal structure of emergent vegetation – a mosaic of relatively low cottontails (*Typha* spp.) and reeds, as well as open water (Vīksne 2013). Water of the lake is not turbid and is transparent down to the bottom.

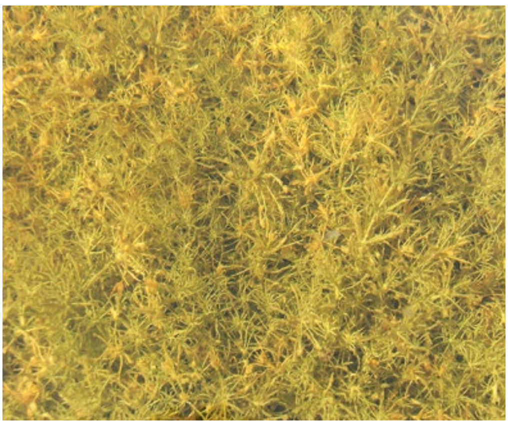

Fig. 13.3. Spatial structure of *Charophyte* stand in Lake Silabebri. Photo: L. Urtāne.

13.1.3 Important Processes and Structures

13.1.3.1 Charophytes and Water Chemical Composition

The formation and existence of this habitat is facilitated by lake sediments that contain dissolved calcium and magnesium carbonates – so called "hard water". Charophytes can also indirectly affect the nutrient circulation in lakes. Under the conditions of intensive photosynthesis, bicarbonates are attracted and calcite is precipitated. This promotes immobilisation of phosphorus, by it binding in crystalline structures or settling on particles of the lake bottom (Kļaviņš et al. 2013). Intensive photosynthesis and high carbonate and hydrogen carbonate ion concentration allow a highly alkaline environment to establish in summer seasons, and it remains for the entire year (Kļaviņš, Kokorīte 2013).

Charophytes can transport oxygen to the lake's sediments, reinforcing the nitrification and denitrification and preventing the return of phosphorus, which is bound to iron compounds in the lake's sediments, to the water environment (Blindow 1991).

Dense charophyte stands prevent sediment resuspension by blocking phosphorus as a nutrient source for plankton algae. In shallow lakes, charophyte stands are effective in nutrient binding ("nutrient trap"). Massive charophyte development and intense assimilation of biogenes suppress the growth of other algal species. Lakes of this type often have clear water and are transparent to the bottom.

13.1.3.2 Fish

Charophyte lakes ensure a diverse food base to animals and belong to a group of the lakes that are productive in terms of fisheries. Fluctuations of water level in spring are highly important for spawning fish. Pikes spawn in relatively shallow flooded bottoms, as well as in flooded grasslands, where they lay their eggs. Eggs initially stick to grass or other substrate (Plikšs, Aleksejevs 1998). If the water level decreases rapidly or flooded shore grasslands are separated from the lake by a zone of emergent vegetation or a rampart of dead aquatic plants and grasses, the pike larvae cannot return to the lake and all of their mass dies due to the decrease in water level (Birzaks 2014).

Their spawning efficiency largely depends on spring floods. The most effective spawning takes place in the lake's littoral zone, which is free of dense emergent vegetation, and in adjacent grasslands. After hatching, larvae feed on reserves of the yolk-sac. But they are insufficient for a long period of time, and the pike die if food (plankton organisms) is not available. Until reaching the length of 6 cm, pike feed on zooplankton, while the food for pike from 6 to 10 cm mainly consists of insects at various developmental stages and later on the share of fish in their diet grows. When reaching the length of 30 cm, the pike mainly feed on fish.

13.1.3.3 Water Level

The water table depends on rainfall, temperature, evaporation from the open parts of the lake and from those parts that are covered by plants, as well as on the volume of water that enters the lake. Annual and seasonal fluctuations in water level affect the development of aquatic plants and conditions for fish spawning. Life processes of all water birds of the particular lake depend on water level fluctuations, as it changes their breeding opportunities. As the water level rises, foraging opportunities become more critical for dabbling ducks that do not dive when feeding, but just immerse the front part of their body in water, at a depth of up to 45 cm (Vīksne, Mednis 1978).

Rapid changes in water level in spring flooding and in summer after long rain also significantly affect the bird population. If the water level is high, the area suitable for foraging of water birds is smaller, and this can reduce the breeding population of dabbling ducks. Such changes also decrease the number of males (especially *Anas platyrhynchos*) who gather for moulting and the number of *Anatinae* after breeding and during the autumn migration. Changes in water level also significantly affect the number of *Charadriiformes* both during and after breeding. To obtain food, they need moist soil, shallow water and muddy banks.

For other water birds, the water level is not a critical factor from the point of view of foraging, however, it becomes critical from the point of view of breeding. A high water level during the breeding season does not cause a problem to *Podiceps* spp. and *Fulica atra* that build floating or partially floating nests.

For all other water birds that nest on a solid substrate – in grasslands of lake islets, on the shore – or in relatively dry quagmires or fens, the level of spring flooding is crucial. A slow drop in the water level delays the beginning of breeding or forces the birds to move from flooded nesting grounds to higher non-flooded grounds (if any), or even makes nesting impossible (Vīksne 2013).

In several charophyte lakes (such as the Engure and Kaņieris lakes), the water level is lowered in order to obtain agricultural land. A decrease of inflowing water volume promotes a shift of the water turnover balance to more active evaporation processes. A change in water level also promotes more rapid overgrowth of charophyte lakes. Due to drainage, watercourses that once flowed into some lakes are now directed to other water bodies. With decreased water circulation, sedimentation and evaporation increase and the water level drops. Thus, conditions for the more rapid development of emergent vegetation and quagmires are established in Lake Silabebri.

13.1.4 Habitat-specific Species of Macrophytes

Based on botanical studies of Latvian lakes (Āboliņa 1994; Gavrilova 1985; Tabaka, Gavrilova, Fatare 1988; Gavrilova, Šulcs 1999; Gavrilova u.c. 2005; Suško 1994, 2002; Suško, Āboliņa 2010; Zviedre, Grīnberga 2012), a list of macrophyte species of charophyte lakes has been compiled by researcher U. Suško. The list consists of 60 vascular plant species, 12 species of Chara spp., and 6 moss species, including 15 habitat-characteristic species (Table 13.1).

Table 13.1. Species of macrophytes in charophyte lakes.

Vascular Plants		
Acorus calamus	*Lemna minor*	***Potamogeton pusillus***
Alisma plantago-aquatica	*Lemna trisulca*	***Potamogeton rutilus***
Batrachium circinatum	*Myriophyllum spicatum*	*Ranunculus lingua*
Batrachium trichophyllum	*Myriophyllum verticillatum*	*Ranunculus reptans*
Butomus umbellatus	***Najas marina***	*Rorippa amphibia*
Callitriche cophocarpa	*Nuphar lutea*	*Sagittaria sagittifolia*
Callitriche palustris	*Nymphaea alba*	*Scirpus lacustris*
Carex elata	*Nymphaea candida*	***Scirpus tabernaemontani***
Carex rostrata	*Phragmites australis*	*Sium latifoliumre*
Ceratophyllum demersum	*Polygonum amphibium*	*Sparganium emersum*
Ceratophyllum submersum	*Potamogeton berchtoldii*	*Sparganium microcarpum*
Cladium mariscus	*Potamogeton compressus*	*Sparganium minimum*
Eleocharis acicularis	*Potamogeton crispus*	*Spirodela polyrhiza*
Eleocharis palustris	*Potamogeton friesii*	*Stratiotes aloides*
Eleocharis uniglumis	*Potamogeton gramineus*	*Typha angustifolia*
Elodea canadensis	*Potamogeton lucens*	*Typha latifolia*
Glyceria maxima	*Potamogeton natans*	*Utricularia australis*
Hippuris vulgaris	*Potamogeton pectinatus*	*Utricularia intermedia*
Hottonia palustris	*Potamogeton perfoliatus*	*Utricularia vulgaris*
Hydrocharis morsus-ranae	*Potamogeton praelongus*	***Zannichellia palustris***
Charophyres		
Chara aspera	*Chara intermedia*	Chara tomentosa
Chara contraria	***Chara polyacantha***	Chara virgata
Chara globularis	*Chara rudis*	Chara vulgaris
Charophyres		
Chara hispida	***Chara strigosa***	*Nitellopsis obtusa*
Mosses		
Calliergonella cuspidata	*Fontinalis antipyretica*	*Scorpidium scorpioides*
Drepanocladus aduncus	***Ricciocarpos natans***	*Warnstorfia exannulata*

Note: Rare and protected species are highlighted in color, the habitat characteristic species, whose presence and sufficient distribution in a particular lake distinguishes this habitat from other lake habitats, have background imprinting.

13.1.5 Natural Development of a Habitat

With a stable water level and nutrient-poor water inflow, lakes can remain stable for a long period of time, which is characterised by phosphorus immobilisation and oxygen transportation mechanisms described in *Chapter 13.1.3.1.* Ecosystem stability is also ensured by the density and complex vertical structures of *Charophyte* stands. They limit the opportunities for other plant seeds or rhizomes to establish.

With nutrient enrichment and the accumulation of dead organic particles, vegetation development can be divided into a number of stages that are characterised by different structures. Cover of submerged and floating plants decreases, and they are replaced by emergent vegetation. The area of *Charophyte* carpets, decreases. As the vegetation structure changes, so does the composition of waterbird species. The changes of the composition of aquatic vegetation and related water birds that are described below have been observed on Lake Engure for several decades (Vīksne 2013).

Stage 1. Mosaic of small aquatic plants (monodominant or composed of several species) – and open water where the open water area is larger than the area covered by the vegetation. Wide areas are occupied by charophytes, which cover most of the lake bottom. Emergent vegetation is formed by *Phragmites australis, Typha angustifolia,* also *Sparganium* spp., *Equisetum* spp., and *Scirpus lacustris*. Birds that build floating or semi-floating nests are characteristic for such places – *Podiceps cristatus, P. grisagena, P. auritus, Fulica atra, Chlidonias nigra, Larus minutus*, and *L. ridibundus*. Some shore sections of the lake are open, with a belt of sparse emergent vegetation or without it.

Stage 2. *Chara* spp. carpet area of algae slightly decreases, the mosaic of emergent vegetation and open water remains the same, while the open water area decreases. Small stands of emergent vegetation slowly interlock, and emergent marshes of *Typha angustifolia* with small inclusions of reed, Typha latifolia, *Carex* spp., and *Solanum dulcamara* often form. These emergent marshes create a dry enough substrate, which is suitable for the nesting of *Larus ridibundus* and various ducks (*Aythya fuligula, Aythya ferina, Anas platyrhynchos, Anas clypeata, Anas strepera, Anas querquedula,* and *Anas acuta*). Ducks, *Fulica atra, Larus,* and *Sterna* prefer to nest near open water – along the edge of a quaking bog or in an internal lagoon. The number of breeding water birds reaches its maximum, when the border between the open water and the relatively dry is the longest (Vīksne 2013). Grebes *Podiceps sp.* and *Fulica atra* continue to nest in sites where plants are sparse. Still there are some shore sections with sparse emergent vegetation.

Stage 3. Emergent marshes expand and interlock, thus creating huge massifs (even several hundred of metres in diameter) dominated by reeds, while *Typha angustifolia* remains only occasionally, usually in a narrow lane along the outer edge of the stand. The length of the border between the relatively dry substrate and open water significantly decreases. The emergent marsh becomes drier, residues of aquatic plants mineralise, and the substrate becomes suitable for the growth of *Salix* spp., *Betula* spp., and *Alnus* spp. It also becomes suitable for *Mustela vison* and *Nyctereutes procyonoides*. In this succession stage, waterbird species that are characteristic of emergent vegetation, namely, *Podiceps* sp., *Fulica atra*, ducks, *Larus* sp. and *Sterna* sp. only nest in a small number in the outer edge of the huge massifs. *Larus ridibundus* and other *Larus* move to sparse *Typha angustifolia* stands, where they make nests from risen rhizomes of *Typha* spp. For ducks, there is a limited possibility to find dry ground for nesting.

13.1.6 Pressures and Threats

13.1.6.1 Input of Biogenes

The small or scattered input of biogenes in lakes of this type is intercepted in the charophyte vegetation and does not have a significant impact on the lake's ecosystem. Due to the increase of nutrients, charophyte vegetation die-off is characteristic, creating muddy areas without vegetation (Kokorīte et al. 2013). As time passes, the introduction of separate floating-leaved plants and later also the growth of emergent vegetation can be observed in such areas.

13.1.6.2 Accumulation of Detritus and Development of Competing Plant Species

Formation of coarse detritus produced by emergent macrophytes is a significant factor in the development of the shore zone. Dead emergent plants cover charophytes and shade them. A substrate is created for the establishment of roots of other aquatic plants and for seed germination. In subsequent seasons, the floating leaves of established aquatic plants shade the growth of charophytes and arrest their development.

Due to mechanical damage, open areas without charophyte vegetation can develop. Charophyte vegetation can be shaded or destroyed by emergent vegetation. In the further development, nutrient demanding plant species such as *Potamogeton pectinatus, Ceratophyllum demersum, Stratiotes aloides* can establish here. These plants also contribute to increased shade, weakening and even eliminating charophyte vegetation.

Concentration of melting ice blocks and wind interaction in a part of the lake can also mechanically damage charophyte stands. In such areas, the establishment of macrophytes and further fragmentation of charophyte vegetation is possible.

13.1.6.3 Vegetation Succession and Predator Impact on Water Birds

A large proportion of charophyte lakes are located within bird migration routes, which have traditionally been a place for birds to rest, breed and moult their feathers. The bird population is significantly affected by predators. For example, in Lake Engure, within the period of 1958–2012, predation of 17 species of the lake's breeding birds, killing old birds, juveniles or eating their eggs, has been observed. Of these 17 species, 11 have been recognised as insignificant (six species of birds and five species of mammals). Six species – *Vulpes vulpes, Nyctereutes procyonoide, Circus aeruginosus, Corvus corone cornix*, and *Corvus corax corax* – have been recognised as significant species whose activities can negatively affect breeding success and the population size of breeding water birds. (Vīksne 2013). Predation structure is also affected by changes of emergent vegetation development. When vegetation stands merge in large arrays and become drier, *Nyctereutes procyonoide* and *Vulpes vulpes* can enter the nesting grounds of water birds. Drier places become their permanent residence. One *Mustela vison* or *Nyctereutes procyonoides* can destroy several tens of waterbird nests within a few days (Vīksne 2013). For ducks and gulls to be able to nest further in drier places, the grounds should be delimited by at least a 100 m wide zone of open water (Blums, Mednis 1991).

13.1.6.4 Impact of Bird Colonies on Water Quality

Several lagoon-type charophyte lakes are internationally important bird stopover sites during their migration, as well as important breeding sites of water birds. In multi-annual observations of Lake Engure it is observed that bird excrement inevitably ends up in the water and over a longer period of time also affects the water quality and the quality of the charophyte stands near breeding sites. The largest concentration of excrement can be found near gull and duck colonies, where charophyte extinction has been observed in a zone of several tens or even hundreds of metres around long-term large (thousands of pairs) bird colonies (Vīksne 2013). Such an impact is considered characteristic of the biotope and regulation of bird numbers is not necessary.

Fig. 13.4. A layer of macrophyte residues has started to mineralise, and *Alnus glutinosa* starts to establish in the central part of Lake Pape. Photo: A. Urtāns.

13.1.6.5 Oxygen Deficiency and Fish Suffocation

Most lakes with charophyte vegetation are shallow. At the end of the vegetation season, a major part of emergent and floating-leaved vegetation dies off and sinks to the lake bottom. Additionally, organic materials that flow into the lake from its catchment area also accumulate in the lake. To break them down, oxygen is needed. The origin of organic pollution may be organic substances that have accumulated in the lake over time and input of organic substances to the water body from its catchment area. As oxygen stocks in the lake come to an end, fish start to suffocate.

In the lakes of this type, fish mainly suffocate in late summer and late winter. During the winter, when the lakes freeze over, natural wind aeration stops. The only source of oxygen is often from rivers that inflow lake. When there is no snow, slight photosynthesis activity also takes place using the light that penetrates the water through the ice. Still, this is not enough to maintain all of the living processes in the lake. In the second half of the summer, fish suffocation is related to the maximum development stage of vegetation where, during the day, aquatic plants produce oxygen through photosynthesis, while during the night it is consumed for respiration and for the breakdown of residues of plants which start to die-off at the end of the vegetation season. For example, regular fish suffocation has been observed in Lake Engure since 1925 (Aleksejevs, Birzaks 2013).

13.1.6.6 Decrease in Water Level

With a decreasing water level, better conditions are created for the development of emergent vegetation. When emergent marshes form, they cover and destroy charophyte vegetation. Development of emergent vegetation has a domino effect because the enlargement of macrophyte stands in a vegetation season facilitates evapotranspiration and further lowering of the water level. Calculations reveals that during the vegetation period each square metre of a reed stand can evapotranspirate up to 0.5 m^3 water (Bernatowiez et al. 1976), causing significant water losses, which is still an underestimated problem in Latvia.

13.2. Management Objectives in the Conservation of Charophyte Lakes

The lakes of this habitat are a specific living place for charophyte algae. At the same time, the existence of fish and water birds in the lakes is also ensured by charophytes and by other aquatic plants, as well as by organisms living in the bottom of the lake. Therefore, conservation and management objectives must be well balanced and respect the needs of all groups of organisms. In lakes of this type, the main conservation and management objectives that ensure the needs of all of these organism groups are as follows:

- to prevent reduction of charophyte areas by overgrowth with emergent vegetation;
- to ensure favourable breeding and moulting conditions for water birds;
- to promote water circulation during the ice-covered period and prevent the formation of an anoxic environment, ensuring the preservation of fish resources;
- to restrict the development of the emergent vegetation by fragmenting it and maintaining an open shore strip.

13.3. Restoration and Management of Charophyte Habitats

13.3.1. Reduction of Overgrowth with Aquatic Macrophytes (C1.1, C1.2, C2, C5)

Charophyte lakes are not usually very deep, and conditions favourable for emergent vegetation growth prevail in all of the lake's territory, threatening charophyte stands. Therefore, the most important management measures for this habitat are the conservation or expansion of the areas covered by the habitat-characteristic charophyte stands by mowing the aquatic plants that hinder or threaten charophyte growth and existence of *Chara* spp. (Fig. 13.5). At the same time, shallow charophyte lakes are important sites for waterbird breeding resting and moulting. Charophyte stands provide a great diversity of aquatic invertebrates, thus also preserving the fishery productivity of lakes of this type. By mowing the aquatic plants and restoring and managing the habitat, environmental requirements of charophyte, waterbird and fish species must be in balance.

There may be various objectives for the mowing of macrophytes in charophyte lakes. In many cases, mowing allows one to achieve several objectives simultaneously:

- preservation of growth ability of charophyte stands and their areas is achieved with repeated mowing of emergent vegetation in the summer vegetation season, combined with mowing in winter;
- removal of biogenes accumulated in plants is achieved by mowing of emergent vegetation in the summer vegetation season;
- creation of shallow zone that warms up, to increase the production of zooplankton, benthic invertebrates and fish larvae and juveniles;

Fig. 13.5. Fragmentation of reed stands with a specialised cutter in Lake Engure. Photo: J. Reihmanis.

- maintenance of shore zones and shallow water parts suitable for ducks and waders is achieved by repeated mowing of emergent vegetation;
- fragmentation of emergent plant stands and emergent marshes;
- increase of the proportion and indentation of emergent plant stand outer margin to promote their suitability for various breeding waterbird species;
- facilitation of water circulation and aeration, which also provides fish migration through repeated mowing channels in the summer vegetation season;
- maintenance of boat transportation routes in very overgrown lakes with repeated mowing of vegetation in the summer vegetation season.

The mowing of aquatic plants shading charophyte vegetation is necessary in lakes where emergent vegetation has established at a depth which is suitable for charophytes (up to 2 m), and where emergent or floating-leaved vegetation is dominating but charophyte vegetation still remains in small localities. As charophyte lakes are often very shallow, it is best to mow the aquatic plants with specialised equipment, such as mowers, that are attached to boats. To mow the areas which have been left unmanaged for a long period of time, a more powerful machine is necessary. Equipment of TRUXOR and Seiga type is used in Lake Engure (Fig. 13.6 –13.9).

Fig. 13.6. Floatable machinery Big Float for reopening of water circulation and fish migration channels in dense mineralised reed masses. L. Engure. Photo: J. Reihmanis.

Fig. 13.7. Floatable machinery can be equipped with reed cutter, an excavator, sediment sucking equipment as well other tools facilitating diverse activities. Photo: Ē. Kļaviņa.

During management, the plant parts above the lake's bottom are mown, while the roots remain in water. This contributes to a faster regrowth of aquatic plants. Aquatic plants can be removed with the entire root system with a floating excavator. However, such measures are expensive, and they can be implemented in small areas.

For a measure to be effective, the plants should be mown 3–4 times per year 2–3 years in a row (Urtāne 2014). Aquatic plants' regrowth ability is lower when the first mowing is performed at the earliest possible stage of development. From the point of view of the physiology of aquatic plants, mowing must be started in June, since already at the end of July and in August, the aquatic plants start their preparation for the winter season, and accumulate the nutrients in their roots. Therefore, only a small amount of nutrients will be taken out of the lake with the mown mass of aquatic plants. To balance management effectiveness and demands of different species, mowing of aquatic plants is now allowed from 1 July.

The first step of mowing is the removal of emergent (for example, *Phragmites australis* and *Typha latifolia*) and floating (such as *Nuphar lutea*) aquatic plants, while trying not to damage charophyte stands. Mown aquatic plants float to the water surface. Depending on the distance of the mown site to the shore, they are removed by the use of a rake-type assembly that is attached to the mowing equipment. Aquatic plants can also be removed by using old nets – the mown aquatic plants are collected with a net and towed to a previously determined mown site. Aquatic plants are saturated with water at the time of mowing, therefore their transportation to the shore is physically demanding. The mass of aquatic plants that are towed to the shore are unloaded by pitchfork. Plant mass can also be unloaded by a wheeled tractor with a loader. The removal of aquatic plants often consumes more time and is more expensive than mowing. Therefore, the aquatic plants are often left at the mowing site, thus reducing the effectiveness of the work done, as the biogenes that were accumulated in the plant biomass, are not removed.

In the removal of continuous emergent vegetation from the lake's shores, shallow shore zones that warm up are created, which are suitable for the development of zooplankton and benthic invertebrate organisms. Such shore zones, which are rich in food, attract not only waders and dabbling ducks, but also fish juveniles and predatory fish that are hunting them.

Mowing of all aquatic plants is not recommended, and it must be done so that separate and at least a few to 5 hectare large areas of reeds also remain in the perimeter of the lake's shore that attract passerine birds which inhabit reedbeds, namely, *Acrocephalus arundinaceus*, various species of *Locustella* spp., *Emberiza schoeniclus*, and *Botaurus stellaris*. When leaving some emergent vegetation stands, it should be assessed whether they will serve as cover for birds of prey, *Mustela vison*, *Nyctereutes procyonoide* and *Vulpes vulpes* to secretly reach and attack the nests.

Fig. 13.8. Floatable TRUXOR equipped for mowing of macrophytes suitable for management of larger areas. Photo: L. Urtāne.

Fig. 13.9. Reed rake for moving cutted macrophytes ashore. Photo L. Urtāne.

Fig. 13.10. Removal of cut reeds with TRUXOR equipped with a specialised rake.
Photo: L. Urtāne.

Fig. 13.11. Deepening of a channel to renew water circulation and organism migration. L. Engure.
Photo: J. Reihmanis.

Even in large overgrown stands of emergent plants, small overgrown channels frequently remain, which secure the migration of organisms between mutually demarcated massifs and serves for lake manager and fishermen communication (Fig. 13.11). If they are not managed, such channels are filled with sediments, water exchange and migration stops, and separate emergent plant stands consolidate. Renewal of water circulation is only possible after reopening and deepening such natural channels, preferably outside of the nesting period.

13.3.2 Provision of Waterbird Breeding Persistence in the Lake (C1.3, C2, C5)

Shallow charophyte lakes are important sites for waterbird breeding, resting and moulting. In different development stages of aquatic plant vegetation, each particular part of a lake can only be suitable for the breeding and development of some bird species or even groups of bird species. Therefore, it is necessary to evaluate the area which is covered by charophytes as well as the arrangement of emergent marshes and their development stage and to decide which particular waterbird species or their groups should be targeted in the management.

Birds that build floating or partially floating nests in aquatic plant stands far from a shore, such as *Podiceps cristatus, P. grisagena, P. auritus, Fulica atra, Chlidonias nigra, Larus minutus*, need a mosaic of small stands with one or several aquatic plant species, where the area of open water exceeds the vegetation-covered area. By using the above techniques for mowing the aquatic plants, it is possible to create such emergent marshes far from the shore that cannot be accessed by predators, mainly for *Mustela vison*. To create such areas, a part of the mown plants can be left in the water, where they form a substrate for floating or partially floating nests.

For the nesting of Larus, mainly *Larus ridibundus* and various ducks – *Aythya ferina, A. fuligula, Anas platyrhynchos, A. clypeata, A. strepera, A. querquedula*, and *A. acuta*, emergent marshes with relatively dry substrate are necessary. They consist of *Typha angustifolia* with small inclusions of reed, *Typha latifolia*, *Carex* spp., and *Solanum dulcamara*. Aquatic plants in such emergent marshes are mown, possibly creating an indented edge of aquatic plant vegetation, where internal bays and lagoons are also formed if allowed by the area and mineralisation level of the emergent marsh. In such marshes, ducks – *Fulica atra, Larus*, and *Sterna* – prefer to nest near open water – along the edge of the emergent marsh or in an internal lagoon. The number of breeding water birds reaches its maximum when the proportion of border between the open water and the relatively dry emergent marsh is the longest (Vīksne 2013). When creating relatively dry emergent marshes which are suitable for *Larus ridibundus* and a variety of ducks, it should be understood that after a while, the aquatic plants that were mown and left in the emergent marsh will form a layer of litter, which is suitable for predators, mainly *Mustela vison*. To prevent the formation of such dry litter layers, in the second half of summer – in August and September – this dry substrate can possibly be reduced by burning it down after the young birds have left the site. To prevent huge and uncontrollable wildfires, such method can only be used in small arrays at least 50–100 m from dry reedbeds and only if the emergent marsh is isolated, and when the wind blows lakewards from the dry emergent marsh (*see Chapter. 13.3.5*).

13.3.3 Prevention of Fish Suffocation (D3.1, D3.2, D3.3)

When water bodies freeze over, oxygen uptake from the atmosphere stops. The only oxygen reserves of the lake are those that have accumulated before the ice formed. Fish start to suffocate when the concentration of dissolved oxygen falls below 2 mg/l. Methods to prevent fish suffocation are explained in more detail in *Chapter 14.3.7*.

13.3.4 Management of Islet and Shore Grasslands to Support the Waterbird Population (C3.1, C.3.2, D6)

Natural or artificially-created islets and open parts of shore are one of the most important nesting sites for water birds (Fig. 13.12, 13.13) if these areas are managed and their overgrowth with trees and shrubs is prevented. However, the number of bird nests per area of various species, especially of ducks, *Charadriiformes*, and *Lariformes*, on islets is much greater than in shore grasslands of similar habitats, because water birds on islets are less threatened by predators.

For an islet to be attractive to water birds, it must meet several criteria. Firstly, the islet may not be included in a continuous reedbed. It is important for the islet shores to be gently sloping, and open water areas should be at least partially adjacent to them (Mednis 2002). In Lake Engure, the largest increase in the number of nests of *Anatinae* (*Anas platyrhynchos*) was observed in managed islets located in archipelago parts far from continuous open water areas, while both species of *Aythyinae* (*Aythya ferina, Aythya fuligula*) prefer nesting in the periphery of an archipelago near open water areas (Mednis 2002).

Secondly, the islet should not be overgrown with trees, shrubs and reeds. Dabbling ducks need a dead grass layer and a belt of tall vascular plants in order to hide their nests. The depth of the shore water part is significant, since they get food at a depth of 15–45 cm.

Water birds prefer vegetation of *Carex* spp., *Poacea*, and *Urtica dioica* (Blūms, Mednis 1991; Mednis 2002). Artificial islets should be built as far away as possible from the shore, and if the size of the lake allows it, even up to 200 m from the shore. Islets should be 0.01–0.5 ha 0.5–1 m above the water level (Janaus 2002), and their construction should prevent them from being flooded in spring (Vīksne, Mednis 1984).

Fig. 13.12. A high number of nests of ground-nesting birds is present in islets which are far from shore and inaccessible to *Mustela vison*. Photo: A. Soms.

Fig. 13.13. Nests, located on open ground frequently are minimally improved. Photo: A. Soms.

Grassland birds are also related to the water environment, and they are mainly represented by waders – *Limosa limosa, Philomachus pugnax, Tringa totanus, Numenius arquata, Gallinago gallinago*. These birds have fairly similar requirements: a habitat area that exceeds 10 ha, moisture can be vary (with both dry and wet ground), low vegetation (5 to 20 cm) until the middle of June. Access to open water is also preferable.

Open shore areas can be created by grazing by cattle, when the number of livestock does not exceed 1,5 animals per hectare. Large herbivores willingly eat shoots of reeds in the spring, restricting their development in the shallow shore zone (Fig. 13.14).

For the management of islets and shore grasslands of Lake Engure, which is an important bird area, it is recommended (Mednis 2002; Šiliņš, Mednis 2013):

- before mowing, to mow down the old reeds during the ice-cover period;
- in the first year of management, to mow reedbeds adjacent to islets and shore grasslands three times per vegetation season, starting with 15 July (after duck and gull chicks have left their nests);
- in the second year of management, to mow reedbeds adjacent to islets and shore meadows twice per vegetation season, starting with 15 July;
- in subsequent years, to mow these reedbeds, if necessary, once per vegetation season, around 15 August;
- to remove all trees and shrubs from islets and shore meadows, and burn them down before the breeding season; if possible, islets should be grazed or mown after the end of the breeding season (Šiliņš, Mednis 2013).

13.3.5 Prescribed Burning (C4.1, C4.2)

In dense reedbeds unmanaged for a long period of time, mowing is difficult or even impossible due to a thick layer of dead reeds. Ornithological research (Šiliņš, Mednis 2013) shows that waterbird species diversity in such continuous reedbeds is low. In such conditions, habitats can be managed effectively with fire. Experiments in Lake Engure (Mednis 2002) show that prescribed burning in reedbeds can be carried out in years with a low water level in the second half of the summer – in early August (Fig. 13.15). After burning, small open water areas are created, which persist for several years, and this positively affects the number of waterbird (Šiliņš, Mednis 2013). In the first year after experimental burning (Reinvalds 2002), burnt reeds were significantly lower than unburnt reeds. The effect of reed burning disappears in about five years (Fig. 13.15).

Reed burning on ice has a relatively short-term positive effect because it only creates an open water area in the following spring (Šiliņš, Mednis 2013). Meanwhile it is an effective method of getting rid of large dead plant matter volume. If the reedbed is not burnt, died-off reed stalks sink into the water, decompose slowly, and are

Fig. 13.14. Grazed shore grassland at Lake Engure. Photo: E. Zviedre

Fig. 13.15. Prescribed reed burning. Photo: I. Mednis.

a feeding place for a low number of water organisms (mainly *Oligochaeta* spp.). Such areas are also not suitable for fish. In the case of burning, the volume of dead stalks of reeds is significantly reduced, but additional inorganic substances are released which contribute to the regrowth of reeds. As observed in Lake Hornborga, Sweden, the dead reed layer can even reach the thickness of 75 cm (Björk 1994).

Burning can also be performed to increase the diversity of populations and species of birds that inhabit coastal grasslands. To meet the differing needs of waders and dabbling ducks, burning should be performed in 30–50 m wide belts that alternate with unburnt belts. In such a case, ducks can create their nesting sites in intact vegetation, and waders in the burnt shore section (Opermanis 2002). Prescribed burning in breeding sites of water birds is permitted before the return of migratory birds in March, often at the beginning of April, when burning can improve the quality of the habitat of ducks and waders for at least one season (Opermanis 2002).

If the objective is to prevent reedbed expansion, burning can be done at the end of summer, when most of the animals have ended breeding. Burning in autumn is best for the restriction of reedbed development (Opermanis 2002). It is only recommended in the shore parts which are suitable for wading bird breeding and fish spawning, and when the wind blows lakewards. It is also recommended to initially burn a fire line around the target area. If burning is not possible within the above terms due to weather conditions (rain, wind blowing shorewards), burning should be postponed until the next year (Opermanis 2002). Before burning, the State Fire and Rescue Service and the State Forest Service must be informed.

13.3.6 Comparison of Methods Used in Charophyte Lakes

Table 13.2. Management methods of charophyte lakes.

Method	Advantages	Disadvantages
C1.1: Reduction of aquatic vegetation – mowing of emergent vegetation in different parts of the lake	Growing ability of charophyte stands is maintained. Conditions for bird breeding and foraging, and fish foraging, are improved.	The effect is short term and management must be repeated. If the mown plants are left in the lake, plant dead parts accumulate and cover charophyte stands, destroying them.
C1.2: Reduction of aquatic vegetation – shredding the emergent plants and their roots	Long-term effect. Emergent vegetation is replaced by floating-leaved or charophyte vegetation.	Only possible if the water level is low. At low depth cleaning works can threaten charophyte stands.
C1.3: Reduction of aquatic vegetation – opening of passageways	Long-term effect. Ensures water circulation, wintering holes for fish, suitable conditions for the rare and protected bird species *Botaurus stellaris*.	High cost of transporting equipment and digging channels.
C2: Mowing of emergent vegetation of shore areas – reinforcement of wave activity	Improved fish spawning conditions. Territory becomes more suitable for waders and dabbling ducks. Mown vegetation mass is more easily collected and taken away. In open shore parts dead plants and organic particles are washed ashore and taken out of lake.	The effect disappears quickly – regular repetition is needed.
C3.1: Change of structure of shore vegetation – felling of shrubs	Reduced influence of birds of prey on wading birds and *Anatidae*.	Regular maintenance (management) is necessary.

Method	Advantages	Disadvantages
C3.2: Change of structure of shore vegetation – grazing of shore grasslands	Attraction of *Charadriiformes* and ducks. Fish spawning becomes more successful.	Requires the provision of a constant number of livestock in grasslands.
C4.1: Reed burning – in winter	Increase in open water areas available to birds and fish. Charophyte stands recover. Decreased volume of dead plant parts, which cover and destroy charophyte stands.	Released nutrients are actively involved in the formation of new biomass. Only the plant mass above the ice is destroyed. Must be repeated every 5–6 years.
C4.2: Reed burning – in the second half of summer	Compared to burning in winter a larger number of dead plant parts, as well as some of the new sprouts are destroyed if burnt in the low-water period in summer.	Killing of terrestrial invertebrates. Must be repeated every 5 – 6 years.
C5: Mowing of emergent macrophytes in autumn and winter season	Less threatening to water birds and insects attracted to emergent macrophytes.	Only some of the nutrients are taken out due to the fact that most of the nutrients are already stored in the roots.
D3.1: Prevention of fish suffocation – ice holes	Active involvement of motivated fishermen. Labour intensive activity.	Only possible on stable ice cover.
D3.2: Prevention of fish suffocation – aeration	Evident increase of oxygen saturation.	Hardly possible in lakes that are remote from settlements and electricity supply.
D3.3: Prevention of fish suffocation – mowing of emergent vegetation in river mouths and deepening of fish wintering depressions	Increase in aerated water volume and space for fish.	Due to fragile and unstable ice in areas with water circulation, activity must already be undertaken in summer or autumn.
D6: Creation of artificial islets for water birds	Gulls and ducks are attracted; high number of nests and successful hatching expected.	High cost of equipment transportation and exploitation. Regular maintenance (management) of islets is necessary.

13.3.7 Unfavourable Use and Management of Charophyte Lakes

Charophyte lakes are not usually deep and a rapid accumulation of organic substances occurs here. Under these circumstances, the most negative management is non-intervention both in the part of the lake which is covered by emergent vegetation, and in the terrestrial part of the lake shore.

The management of Lake Engure has been well-documented for at least the last 50 years (Vīksne 2013). Termination of haymaking and grazing, with an aim to ensure better breeding success of water birds, caused overgrowth of grasslands and a reduction of habitats suitable for *Anatidae* and waders, and thus a decrease in their populations. In some cases, certain groups of birds, such as wading birds, even disappeared (Vīksne 2013). Expansion of reedbeds and scrublands facilitates the introduction of *Nyctereutes procyonoides* and *Mustela vison*. They destroy the nests and drastically reduce the number of breeding water birds or even cause their extinction (Mednis 2002).

13.4 Contradictions of Conservation and Management

The main conflict regarding conservation and management is based on the lack of a joint systematic approach, which is based on an understanding of how the ecosystem functions, and therefore conservation measures are only orientated towards groups of separate organisms.

The conflict of management and conservation in shallow charophyte lakes which are important for birds, is reed mowing after 1 July in accordance with the regulatory framework, which is substantiated by the requirements of breeding birds. However, in the middle of summer, reeds have accumulated their maximum biomass and a part of the nutrients is transported to their roots to ensure the next vegetation period. When mowing the reeds in the middle and second half of the summer, only the nutrients that have accumulated in stems and leaves are removed, not those accumulated in roots. Such action is inefficient and needs to be regularly repeated.

An old conflict which is now solved, but the consequences of which will be felt for a long time, is the termination of the law of 1987 regarding cattle grazing and hay yield in shore grasslands of Lake Engure and on the island of Lielrova, in order to ensure the better success of waterbird breeding, completely excluding the factor of human disturbance. The prohibition provided a temporary increase in the number of *Charadriiformes* and gulls (Vīksne, Mednis 1978), however, in 2012, breeding of these birds in these sites was not observed anymore, since the prohibition of economic activity resulted in overgrowth of the territory with reeds and shrubs, and the area became inappropriate for its former inhabitants – species of gulls (Vīksne 2013). The well-intended reduction of disturbance to the bird population over a longer period of time has given the opposite result. Now, in order to restore the abandoned grasslands and to purchase cattle, large resources are necessary. Local residents still remember the negative experience, therefore an invitation to resume management of the lakeshore grasslands was received with scepticism. Consequently, only a small part of the potentially significant shore part of the lake is being managed.

The management and research project carried out in Lake Engure in the 1980s also illustrates the conflict of conservation and management in those days. The objective of the project was to ensure the breeding of *Larus ridibundus*, a long-term research objective of the Ornithological Station of Lake Engure, by decreasing the numbers of its natural enemy *Circus aeruginosus*, by shooting or catching them in traps and relocating them to other suitable habitats far from Lake Engure. Elsewhere in Europe, Circus *aeruginosus* is a rare bird of prey, therefore, in 2002, it was included in Annex I of the Birds Directive as a rare and protected species of EU importance (Opermanis 2005). Thus there was a conflict between the implementation of Europe's longest study project of *Larus ridibundus* and the requirements of conserving a bird of prey that is rare and protected in Europe.

Chapter 14. 3150 *Natural Eutrophic Lakes with Magnopotamion or Hydrocharition - Type Vegetation*

(A. V. Urtāns, L. Urtāne, U. Suško)

14.1 Characterisation

14.1.1 Brief description

Distribution. In Latvia, 3150 *Natural eutrophic lakes with Magnopotamion* or *Hydrocharition* - type vegetation (further referred to as natural eutrophic lakes) can be found relatively often, except for in Zemgale Plain (Fig. 14.1). The total area covered by this habitat type is 66,330 ha, which corresponds to approximately 1 % of the country's territory. This is the most common of all protected water habitat types of EU importance in Latvia, in terms of both the number and the total area (Anon. 2013). Most lakes of this habitat type are rather shallow, and their depth does not exceed 2–9 metres.

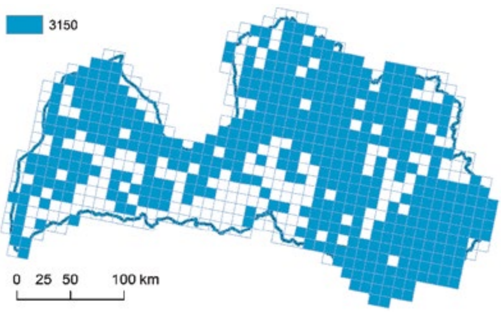

Fig. 14.1. Distribution of habitat type 3150 Natural eutrophic lakes with Magnopotamion or Hydrocharition - type vegetation in Latvia (source: Anon. 2013).

Fig. 14.2. Naiad *Najas tenuissima*. Lake Ārdavas. Photo: U. Suško.

Characteristics. Lakes of this habitat type may have different origins and morphometrical differences (lake area, depth, shore indentation, exposure to the prevailing winds), as well as different land use in the lake's catchment area. In natural conditions, lakes with a small catchment area and slow water exchange experience a slower eutrophication process, while lakes with fast water exchange depend on the concentration of the biogenes, humic substances, and other compounds of inflowing waters (Leinerte 1988).

There are three variants of the habitat:

- **Variant 1:** clear-water (oligo-humic) lakes with submerged vegetation;
- **Variant 2:** brown-water (poly-humic) lakes with diverse vegetation;
- **Variant 3:** oxbow lakes with diverse vegetation typical to eutrophic lakes.

The inclusion of oxbow lakes in this habitat type is associated with the character of biogene circulation. In oxbow lakes, unlike in watercourses, biogenes are not transported, but rather they accumulate corresponding to processes taking place taking place in lakes.

Water bodies of artificial origin (flooded, excavated) in Latvia are not considered to be a protected EU habitat type 3150 *Natural eutrophic lakes with Magnopotamion or Hydrocharition - type vegetation.*

Natural eutrophic lakes, depending on their depth are usually characterised by a narrower or wider species-rich belt of submerged plants, sparse or continuous zone of floating-leaved plants; often, also a fragmentary sparse or continuous zone of emergent plants. Sometimes the shoreline is open and not overgrown with aquatic plants. Very wide zones of emergent plants are characteristic for shallow (2–9 m) and very shallow lakes (< 2 m), as well as for highly eutrophic lakes.

Due to a lake's morphometrical features and available nutrients, nowadays a habitat supports diverse fish and water invertebrate fauna. At the same time, lakes of this habitat are significant sites for bird breeding and foraging. Floating-leaved and submerged vegetation zones are home to several rare and protected dragonfly species and other species of water invertebrates (Kalniņš 2013).

The habitat is often an important site for rare and protected species of vascular plants, charophytes and mosses (an overview of these species is presented in Table 14.2). Special attention should be paid to three relict species – *Najas flexilis*, which is highly endangered in Europe and which, in the continental part of the EU together with Norway and Switzerland, has been preserved in just about 25 lakes, N. tenuissima with only about 54 localities in the modern world, as well as *Hamatocaulis lapponicus*, which is rare throughout the EU[68].

For these species, slightly eutrophic clear-water lakes or small and overgrowing lakes are particularly important. Often very small lakes, with their area covering less than 1 hectare, are also rich in rare aquatic plant species. From the point of view of economics, such lakes are left almost unattended, while in terms of nature diversity they are very important to a number of rare and protected species, and thus must be correspondingly managed. Emergent marshes of different size are also often found on shores of many lakes, and they usually correspond to a protected mire habitat type of EU importance, namely, the habitat type 7140 Transitional mires and quaking bogs. Such shore marshes (a contact zone of water and emergent marsh) of lakes in Latvia are an important habitat for *Liparis loeselii*, which is included in Annex II of the Habitats Directive.

In natural eutrophic lakes, a number of macrophyte species, which have remained from previous lake development stages or are characteristic for other protected fresh-water habitats, can be found. For example:

- *Berula erecta* is characteristic to clean rivers corresponding to habitat type 3260 *River riffles and natural reaches of rivers* and are also found in clean forest lakes adjacent to the mouths of spring fed river inflows, like in Lake Šilovka. *Potamogeton alpinus* can be found in clean lakes or by the spring-fed stream inflow (L. Dūneklis);
- *Cladium mariscus* and *Najas marina* can be found in habitat type 3140 *Hard oligo-mesotrophic waters with benthic vegetation of Chara* spp (L. Beļaukas and L. Ješa) as well as many Charophytes, like in Lakes Meduma, Riču, Sventes;
- Several species characteristic for habitat type 3130 *Oligotrophic to mesotrophic standing waters with vegetation of Littorelletea uniflorae and/or Isoeto-Nanojuncetea* can also be found, such as *Fontinalis dalecarlica, Isoetes lacustris, Littorella uniflora, Lobelia dortmanna, Sparganium angustifolium, S. gramineum*, and *Subularia aquatic* (Lakes Cārmins, Jazinks, Lejs, Ots and Kadagas).

Relict fish species like vendace *Coregonus albula* and introduced populations of European whitefish *C. lavaretus*, as well as a number of relict, cold-loving deep-water species, such as *Eurytemora lacustris, Limnocalamus macrurus, Mysis relicta, Pallaseopsis quadrispinosa*, and *Pontoporeia affinis,* which inhabit the deep poorly eutrophic and eutrophic lakes in Latvia, have special value. Another important relict species is a freshwater form of smelt, *Osmerus eperlanus spirinchus*, which was recorded in about 30 Latvian (mainly in the Latgale region) deep lakes in the 1930s, while in the 1950s, it was recorded in 7 lakes, and in 1989 – in 4 lakes, currently including Lake Svente (Mansfelds 1936; Spuris 1954; Plikšs, Aleksejevs 1998).

14.1.2 Indications of favourable conservation status

Favourable conservation status of the habitat is indicated by the following features:

- overgrowth of the lake with emergent, floating-leaved and submerged vegetation does not exceed 30 % of the lake's area during the vegetation season, a clearwater phase is typical to the lake;
- lake water contains negligible nutrient amount, which all is consumed, during vegetation season clear water phase is characteristic, oxygen is detectable up to the lake bottom;
- a large number of habitat characteristic species of aquatic plants (> 15) is present;
- occurrence of *Najas* species, as well as small numbers of species belonging to the Lobelia – Isoetes complex;
- presence of European crayfish *Astacus astacus;*
- there is no mass development of algae in the peak of the vegetation season;
- a continuous shore-delimiting zone of emergent vegetation has not developed along the shoreline;
- there are openings in the emergent vegetation zone, there are also open beaches and open access to water;
- mineral bottom is found in more than a third of the lake's littoral area;
- there are open and shallow shore zones that warm up with a mineral bottom or sparse vegetation of submerged aquatic plants, juvenile fish are consistently found there;

[68] Council Directive on the conservation of natural habitats and of wild fauna and flora 92/43/EEC

- if there are lake floodplains, there are transitions between the lake and its floodplain, unhindered by continuous emergent vegetation;
- in the edge zone between the lake and open floodplain, there are no drift lines with plant residues that hinder the passage for spawning fish, fish larvae and juveniles;
- fish suffocation is not observed during winter.

These indications may be more difficult to observe in some seasons. When evaluating the conservation status of a lake's habitat, one should not rely on one indicator only, but should rather assess various parameters and their possible seasonal fluctuations and mutual interference. Chemical parameters even undergo cyclical and significant changes even during a day. In summer, the oxygen concentration in water is different in the early morning and at noon. Concentration of dissolved phosphorus is close to zero during the vegetation season. If the total cover with aquatic plants exceeds 30 % of the lake's surface and there is a low concentration of phosphorus, this rather indicates that phosphorus is incorporated in the green mass of plants. In autumn, when aquatic plants die off, a part of the phosphorus returns to the water, and its concentration can significantly increase.

14.1.3 Important Processes and Structures

14.1.3.1 Provision of Oxygen to the Lake

Oxygen in water plays a crucial role in the maintenance of living processes and in the provision of the stability of chemical compounds. Algae and aquatic vascular plants both produce and consume oxygen, while other water organisms only consume oxygen. Therefore, to a large extent the amount of oxygen in the lake is determined by the distribution of algae and aquatic vascular plants. Usually, aquatic plants in the lake can only be found at a depth of up to 6 m, while in transparent lakes, algae can also be found at a depth of 20 m.

Oxygen enters the water environment through diffusion from the atmosphere and through photosynthesis in aquatic plants. The larger the surface of the lake, the greater its contact zone with the air. Thus, the amount of oxygen in the lake also depends on the lake's size. During one day, an average of about 5 g of oxygen dissolves on 1 m2 of the lake surface (Cimdins 2001), but its diffusion in deeper layers is very slow. Therefore, natural aeration of lake water by wind is very important. In Latvia, particularly in small lakes and lakes surrounded by forests, water aeration during storms in autumn and spring is the only significant mechanism of oxygen supply and of complete mixing of water layers (Table 14.1). Such an approach to water ventilation is traditionally used in pond management, when planning pond placement parallel to prevailing winds (Sprūžs 2013).

Table 14.1. Impact of wind speed on the depth of water mixing (Cimdiņš 2001).

Wind speed		Mixed layer depth (m)
m/s	km/h	
2	7.2	1–2
5	18.0	4–7
10	36.0	6–12

Oxygen distributes in a water mass through changes in temperature. When the water temperature falls below 4 °C its density increases and it settles in deeper layers of the lake. In this way, oxygen rich waters from the surface reach the lake bottom. In spring, this trend is reversed (Cimdiņš 2001). Most lakes in Latvia are dimictic, i.e., their water layers mix twice a year – both in spring and autumn (Glazačeva 2004).

Oxygen levels in the lake determine not only the presence and distribution of organisms, but also nutrient circulation. If there is a sufficient level of oxygen in the bottom water layer, i.e., it exceeds 50 % of the theoretically possible saturation in the given temperature, phosphorus that has reached the bottom water layer is bound in an insoluble compound – iron hydrophosphate. Thus, the stock of dissolved nutrients is reduced. When the concentration of oxygen decreases to 1 mg/l, anoxic conditions develop in the bottom water layer; sediment-bound phosphate dissolves and returns to the water environment, thus facilitating the eutrophication and ageing of the lake (Cimdiņš 2001).

14.1.3.2 Lake Morphometry

Life processes in lakes are determined not only by the volumes of nutrients, but also their availability. Depending on water characteristics, eutrophication-causing nitrogen and phosphorus compounds may be in insoluble forms and cannot be used by living organisms. Properties of lake water also depend on the soil types and bedrock in the lake's catchment area.

To a very large extent, the nutrient accumulation rate and lake development rate are dependent on the **lake's depth**. Lakes are divided into deep (> 9 m), shallow (2–9 m), and very shallow (< 2 m) lakes according to their depth[69].

Eutrophication and ageing occurs faster in shallow and very shallow lakes because the development of aquatic plants, die-off, accumulation of detritus and filling up of lake volume occurs in a higher proportion of the lake. Deeper lakes have a larger volume and often a narrower shore part where aquatic plants can develop. Enrichment with nutrients is slower, and the volume fills up with organic material more slowly. Therefore shallower lakes overgrow and disappear first. The depth and oxygen volumes of a lake directly determine the nutrient utilisation rate. If there are sufficient oxygen levels in the bottom layer of the lake, phosphorus is bound into insoluble compounds and thus is removed from circulation. As soon as oxygen levels in the deepest layers of the lake reduce and anaerobic conditions develop in the bottom water layer, sediment-bound phosphorus becomes soluble and enters the water column. This process is followed by an increase in algae and zooplankton populations, decrease in water transparency, reduction of oxygen-producing layer, and other processes.

The shape of a lake can be round or stretched, while the shoreline can form bays and peninsulas. Lake shore characteristics determine the extent to which the economic activity, which is performed in the lake's directly adjacent area, affects the lake quality. The longer the shoreline of the lake, the greater its connection to the terrestrial part and also the greater the potential leakage of nutrients into the lake.

14.1.3.3 Water Level Fluctuations

The water level of a lake depends on precipitation, temperature, evaporation from open parts of the lake and parts covered by vegetation, and on the volume of water that enters the lake. In small lakes, the water level is also affected by beavers, when they build dams on river outlets from lakes.

Annual and seasonal fluctuations of water level affect the development of aquatic plants and changes in zones occupied by various groups of aquatic plants (submerged, floating-leaved, emergent plants). Water level changes also affect the zooplankton species composition and biomass, as well as fish spawning conditions. Water level fluctuations significantly affect breeding and foraging opportunities of water birds. Impacts of human and beaver induced water level fluctuation processes are more explained in *Chapter 14.1.6.6* of these guidelines.

14.1.3.4 Overgrowth with Aquatic Plants

As the amount of dissolved nutrients in water increases, the development of aquatic plants in eutrophic lakes becomes more intense. To some extent, the development of aquatic plants has a positive impact on living sites, hiding sites and foraging of water organisms. In nutrient-poor lakes, overgrowth with aquatic plants is usually low, with a dominance of submerged and floating-leaved aquatic plants.

Increase in nutrient levels causes increased growth of emergent plants which are more efficient at light absorption and photosynthesis. Submerged and floating-leaved aquatic plants are suppressed both by shade and by being buried under a layer of dead plant parts (Fig. 14.3).

Fig. 14.3. Reed residues prevent the development of other plants. The number of groups of other water organisms in these bottom-covering sediments is very low. Photo: A. V. Urtāns.

[69] Cabinet Regulation No. 858 of 19 October 2004, regarding the characterisation of the types, classification, quality criteria of surface water bodies and the procedures for the determination of anthropogenic loads.

When emergent vegetation occupies the shallow shore zone, which is better at warming-up and therefore the most productive, the available water volume for the growth of zooplankton and fish larvae and juveniles which consume the zooplankton, decreases. The part of the lake bottom shaded by emergent vegetation, mainly by reeds, becomes covered by a thick layer of coarse dead parts of plants, inhabited by only a few benthic species of water organisms, compared to the zone of submerged and floating-leaved plants. The replacement of submerged and floating-leaved aquatic plants with dominant emergent vegetation can also significantly modify the composition of other species of dominant organism groups and the entire food chain of the lake.

Floating-leaved plants have better development opportunities behind the zone of emergent vegetation (Fig.14.4). However, when floating-leaved plants cover large continuous areas, wave activity here decreases, light conditions worsen, submerged plants die off, the accumulation of dead organic particles (detritus) increases, and also the composition of bottom inhabiting species simplifies (Fig.14.5).

If the vegetation structure in natural eutrophic lakes is optimal, all zones of aquatic plants are represented, and submerged and floating-leaved plants dominate.

Also, thick blanket-like mats of *Spirodela polyrhiza* and *Lemna minor* can create shade in shallow, wind-protected bays of lakes. A lake is considered significantly affected, if overgrowth with emergent vegetation occupies more than 30 % of the littoral zone at a depth of up to 2 m (a relative line of distribution of emergent vegetation) or where a continuous zone of emergent

Fig.14.4. Behind the emergent vegetation zone dense stand of water lilies facilitates cessation of water circulation and promote sediment accumulation. Lake Burtnieks, 2014. Photo: A. V. Urtāns.

Fig. 14.5. When developing *en masse* free floating plants shade out submerged macrophytes. Photo: A. V. Urtāns.

Fig.14.6. The length of *Nymphae* spp. roots indicates the thickness of the sediment layer. Photo: A. V. Urtāns.

Fig. 14.7. The continuous development of the float-leaved vegetation zone has contributed to the formation of a thick organic sediment layer. L. Burtnieks. Photo: A. V. Urtāns.

vegetation forms around the whole lake. Such continuous zone hinder washout of organic debris, thus promoting increase of sediment amount (Fig. 14.7) and paludification of littoral zone.

The composition and structure of aquatic plant species determine not only the occurrence of certain groups of water birds – ducks, waders and gulls, but also their breeding opportunities and success in a given site (Vīksne, Mednis 1978). These processes are explained in further detail in *Chapter 13* of these guidelines.

14.1.4 Habitat-specific Species of Macrophytes

Based on botanical studies of Latvian lakes (Āboliņa 1994; Tabaka, Gavrilova, Fatare 1988; Gavrilova 1985; Gavrilova, Šulcs 1999; Suško 2002; Suško, Bambe 2002; Suško, Āboliņa 2010), a list of macrophyte species of this habitat type was compiled (Table 14.2). The list consists of 104 vascular plant species, 20 charophyte species, and 22 moss species. Of them, 53 are habitat characteristic species.

Table 14.2. Macrophyte species in naturally eutrophic lakes.

Vascular plants		
Acorus calamus	***Leersia oryzoides* – parastais parīss**	*Potamogeton perfoliatus*
Alisma gramineum	*Lemna minor*	*Potamogeton praelongus*
Alisma plantago-aquatica	*Lemna trisulca*	***Potamogeton pusillus***
Batrachium circinatum	***Littorella uniflora***	***Potamogeton rutilus***
Batrachium eradicatum	***Lobelia dortmanna***	***Potamogeton sturrockii***
Batrachium trichophyllum	*Menyanthes trifoliata*	***Potamogeton trichoides***
Berula erecta	***Myriophyllum alterniflorum***	*Ranunculus lingua*
Butomus umbellatus	*Myriophyllum spicatum*	*Ranunculus reptans*
Callitriche cophocarpa	*Myriophyllum verticillatum*	*Rorippa amphibia*
Callitriche hermaphroditica	***Najas flexilis***	*Sagittaria sagittifolia*
Callitriche palustris	***Najas major***	*Scirpus lacustris*
Carex acuta	***Najas marina***	***Scirpus radicans***
Carex acutiformis	***Najas minor***	***Scirpus tabernaemontani***
Carex elata	***Najas tenuissima***	***Scolochloa festucacea***
Carex lasiocarpa	*Naumburgia thyrsiflora*	*Sium latifolium*
Carex riparia	*Nuphar lutea*	***Sparganium angustifolium***
Carex rostrata	***Nuphar pumila***	*Sparganium emersum*
Carex vesicaria	*Nymphaea alba*	*Sparganium erectum*
Ceratophyllum demersum	*Nymphaea candida*	***Sparganium gramineum***
Ceratophyllum submersum	*Oenanthe aquatica*	*Sparganium microcarpum*
Cladium mariscus	*Phalaroides arundinacea*	*Sparganium minimum*
Elatine hydropiper	*Phragmites australis*	***Sparganium neglectum***
Eleocharis acicularis	*Polygonum amphibium*	***Sparganium oocarpum***

Vascular plants		
Eleocharis mamillata	***Potamogeton acutifolius***	*Spirodela polyrhiza*
Eleocharis palustris	***Potamogeton alpinus***	*Stratiotes aloides*
Eleocharis uniglumis	*Potamogeton berchtoldii*	***Subularia aquatica***
Elodea canadensis	*Potamogeton compressus*	***Trapa natans***
Equisetum fluviatile	*Potamogeton crispus*	*Typha angustifolia*
Glyceria fluitans	***Potamogeton filiformis***	*Typha latifolia*
Glyceria maxima	*Potamogeton friesii*	*Utricularia australis*
Hippuris vulgaris	*Potamogeton gramineus*	*Utricularia intermedia*
Hottonia palustris	*Potamogeton lucens*	*Utricularia minor*
Hydrilla verticillata	*Potamogeton natans*	*Utricularia vulgaris*
Hydrocharis morsus-ranae	*Potamogeton obtusifolius*	***Zannichellia palustris***
Isoetes lacustris	*Potamogeton pectinatus*	
Charophytes		
Chara aspera	***Chara strigosa***	*Nitella mucronata*
Chara contraria	*Chara tomentosa*	***Nitella opaca***
Chara filiformis	*Chara virgata*	***Nitella syncarpa***
Chara globularis	*Chara vulgaris*	***Nitella tenuissima***
Chara hispida	***Nitella confervacea***	*Nitellopsis obtusa*
Chara intermedia	***Nitella flexilis***	***Tolypella prolifera***
Chara rudis	***Nitella gracilis***	
Mosses		
Calliergon giganteum	*Drepanocladus sendtneri*	***Pseudocalliergon trifarium***
Calliergon megalophyllum	***Fissidens fontanus***	***Riccardia chamaedryfolia***
Calliergon richardsonii	*Fontinalis antipyretica*	*Riccia fluitans*
Calliergonella cuspidata	***Fontinalis dalecarlica***	***Ricciocarpos natans***
Chiloscyphus pallescens	***Fontinalis hypnoides***	*Scorpidium scorpioides*
Drepanocladus aduncus	***Hamatocaulis lapponicus***	*Warnstorfia exannulata*
Drepanocladus longifolius	*Leptodictyum riparium*	
Drepanocladus polygamus	***Platyhypnidium riparioides***	

Note: Rare and protected species are highlighted in color, while the habitat characteristic species, whose presence and sufficient distribution in a particular lake distinguishes this habitat from other lake habitats, have background imprinting.

14.1.5 Natural Development of a Habitat

Natural development of a habitat is related to nutrient circulation and accumulation in the lake. A eutrophic lake can develop when a lake with oligotrophic to mesotrophic vegetation (EU protected habitat type 3130 *Oligotrophic to mesotrophic standing waters with vegetation of Littorelletea uniflorae and/or Isoeto-Nanojuncetea*) overgrows. A mesotrophic lake also develops into a eutrophic lake through the accumulation of nutrients and sediments from the catchment basin. In areas where the lake's catchment basins are rich with wetlands or peaty substrates, nutrients accumulated during the natural course of development can form complex compounds – humic substances. In such cases, the lake naturally develops towards a dyseutrophic lake – the concentration of phosphorus compounds here is high but they are bound in insoluble compounds. With continuing enrichment with phosphorus and nitrogen compounds, the lake can completely overgrow with marsh and disappear. In this way, about 70 km^2 of open water areas disappeared in Latvia in the second half of the 20^{th} century.

Initially, diverse stands of submerged and floating-leaved plants develop in the course of natural succession. In these cases, the increase in the proportion of emergent vegetation and in the width of emergent vegetation zones can be considered as an indication of eutrophication and gradual deterioration of habitat quality.

Nutrient enrichment and circulation also changes other parts of the food chain. Salmonids are replaced by cyprinids. Several lake vegetation development stages that form different structures can be distinguished in a lake's development, with increasing nutrient enrichment and the accumulation of dead plant particles. They also differ in the composition of breeding water bird species (*see Chapter 13*). In eutrophic lakes, deterioration in quality can be seen as a reduction of the area suitable for habitat characteristic organisms: plankton abundance increases in deep lakes, overgrowth starting from shores occurs in shallow lakes, followed by the expansion of an emergent vegetation zone and the disappearance of an open shore zone.

Oxbow lakes, which are included in this habitat type even though they have a different origin, should be viewed individually. For oxbow lakes, there can be irregular water exchange with a river that is only active during spring flooding. Some oxbow lakes receive spring waters or soil filtration waters from adjacent rivers. Such diversity of origin and function also continues during the further development of oxbow lakes. If oxbow lake waters are not supplemented, the lake dries out and turns into a wet depression. If filtration waters still circulate or if it receives spring waters, an oxbow lake can persist for a long period of time.

Fig.14.8. Oxbow lake next to the River Iecava.
Photo: A. V. Urtāns

If oxbow lakes still retain their connection with the river, during spring flooding they exchange not only waters, but also their organisms. Oxbow lakes can have rich vegetation. For example, in oxbow lakes of Gauja National Park, 150 species of vascular plants, mosses, and charophytes have been found (Salmiņa 2000). Over a longer period of time, oxbow lakes, just like other lakes, clog up with silt and plant detritus and turn into wet grasslands or small fens.

14.1.6 Pressures and Threats

14.1.6.1 Nutrient Enrichment

Increasing economic activity in the lake catchment area contributes to enrichment with nutrients both in the form of dispersed runoff when waters are filtered from surrounding territories and from point sources, such as waste waters that directly enter the lake. Increased nutrient concentration creates favourable conditions for the mass development of microscopic algae, filamentous green algae, and aquatic vascular plants, as well as for the rapid replacement of former organisms characteristic to the lake and their food chains. Enrichment with plant nutrients (eutrophication) can irreversibly change the lake in just a few decades. All of this promotes much faster ageing of the lake's ecosystem.

Due to the nutrient inflow, dense emergent vegetation develops. It creates continuous shading and outcompetes rosette-leaved aquatic plants, which grow at a small depth (*Juncus* spp., *Isoëtes* spp.), and species of *Potamogeton* with low stems (*Potamogeton friesii, P. gramineus, P. berchtoldii, P. obtusifolius*).

The open parts of the shore zone, as well as the shore zone of floating-leaved and submerged plants have the most diversity of zooplanktic and benthic invertebrates. These organisms are an important fish food base, and their inhibited zone is an important site for juvenile fish. It is also the main zone for ducks, which obtain food at a depth of 15–50 cm. When they are replaced with emergent vegetation, both the previously established diversity of species and areas that are available to birds, fish and their juveniles, are significantly reduced. When waters, the phosphorus concentration of which exceeds 0.02 mg/l inflow in a lake, mass development of cyanobacteria can begin.

14.1.6.2 Mass Reproduction of Algae

The presence of algae is important for the provision of a water body and its organisms with oxygen, particularly in large, deep lakes (Leinerte 1988). However, the mass growth of algae can also have a negative impact on the lake's development. A mass of algae of 1.0 to 9.9 mg/l is considered as favourable for the water habitat. With excessive increase, the mass can even reach 100 mg per litre and more (Cukurs 1980). Rapid increase in algal growth is promoted by warm water (> 16^{o}C), calm weather, and a sufficient concentration of nutrients (Balode 2007). It can also significantly affect light penetration in the water mass. Thus water transparency and light penetration significantly decrease, submerged plants can disappear and the oxygen level in the bottom layer can reduce in a short period of time. Living conditions for fish that identify the prey by sight, such as pike, deteriorate. When the food base and insolation conditions change, the composition of bottom-inhabiting organisms becomes homogeneous and poor. It mostly consists of *Oligochaeta* and *Tubificidae*, which can live in conditions of oxygen shortage (Kačalova et al. 1962).

Most algae species are not toxic and serve as food for other water organisms. Only around 6 % of the world's algae species can cause so-called "algal bloom" (Fig. 14.9.) and only around 2 % of algae species may be toxic (Balode 2007). In Latvia, the mass growth of algae in summer is caused by toxic *cyanobacteria Microcystis aeruginosa, Anabaena* spp., *Aphanizomenon* spp., *Nodularia* spp., *Lyngbia* spp., *Planktothrix* spp. (Balode 2007).

14.1.6.3 Pollution

There are various definitions for and explanations of pollution. The term "pollution" is understood to refer to chemical compounds that cannot naturally occur in water, or where their concentration is much greater than what would occur naturally (Leinerte 1985). Pollution of various types affects the processes and food chains in eutrophic lakes differently. Enrichment of the lake with nutrients can also be considered as pollution. Pollution influencing the structure and processes of habitats in eutrophic lakes can be divided into several groups.

- *Oxygen-consuming substances* – organic substances of natural origin used by aerobic microorganisms which consume oxygen. If there is an insufficient concentration of oxygen in water, other groups of oxygen-consuming organisms can perish.

Fig. 14.9. Mass growth of cyanobacteria in Lake Burtnieks, 2014. Photo: A. V. Urtāns.

- *Inorganic nutrients* – nitrates and phosphates soluble in water. Enrichment with nutrients causes eutrophication – increased overgrowth of water bodies and the following reduction of species diversity.
- *Modified organic compounds* – oil products, gasoline, high-molecular compounds, plastics, pesticides, solvents, detergents, etc. Many of them decompose in the water environment slowly and can cause congenital defects and reproduction abnormalities for organisms. Oil products on the water surface can form a layer several microns thick, which can stop the diffusion of oxygen in the water mass and cause the death of water organisms.
- *Suspended substances – insoluble in water particles of soil, or other organic and inorganic substances that cause turbidity of the water and thus:*
- *decrease the opportunities for the photosynthesis of aquatic plants;*
- *fill the lakes with sediments,*
- *destroy fish feeding and spawning areas;*
- *make it difficult for water organisms to find food and affect food chains;*
- *absorb on the surface and transport the pesticides, bacteria and toxic substances.*

14.1.6.4 Cease of Shore Management

Eutrophic lakes are threatened by the cessation of management of the open parts of the shore zone and overgrowth of the protection belt with trees, shrubs and reeds. During the development of trees and shrubs, a vertical shield, which reduces the air circulation develops around the lake. When there is no wind, the dead parts of plants in the shore zone are not washed into the deepest part of the lake – the profundal zone. Together with the dead leaves of trees and shrubs, they accumulate in the shore zone and promote the development of emergent vegetation. This is seen in small lakes in particular.

Overgrowth of the partially exposed shore zone and its replacement with trees and shrubs close to the lake reduces the diversity species living at the shore, such as dragonflies that need low bank and shore vegetation in order to move to the land and undergo the transition from larva to adult. The sparse shore vegetation zone is also a living environment for a number of rare plant species such as *Lycopodiella inundata,* and several species of orchids.

14.1.6.5 Expansion of Emergent Macrophyte Zone

The visual manifestation of deterioration attributable to all protected lake habitats is the mass development of reeds and the formation of a large monodominant reed massives (Fig. 14.10). Spreading, they occupy the shallow littoral zone, which is of particular importance for the development of aquatic organisms. If the lake has a dense reed and other emergent macrophyte belt, it brakes the wave action and holds out the part of the dead macrophyte and organic debris to become washed ashore. With the accumulation of dead macrophyte parts on the outer edge of the reed massifs, an appropriate substrate for expansion of reed stands arises. Reed stand investigations in the Hornborg Lake (Bjork 1994) revealed that, the undisturbed reed layer can reach even a thickness of 75 cm (Fig. 14.11). It promotes not only the expansion of the upper roots of reeds, but also the rapid filling of the lake, the disappearance of the open part of the lake and the ageing of the lake itself. The dead parts of the reeds have a low nutritional value, only a small number of *Oligochaeta* spp. and water beetles *Coleoptera* spp. occur there.

Fig.14.10. Accumulation of reed residues promotes the quick disappearance of shore shallow water zones. L. Durbe. Photo: L. Urtāne.

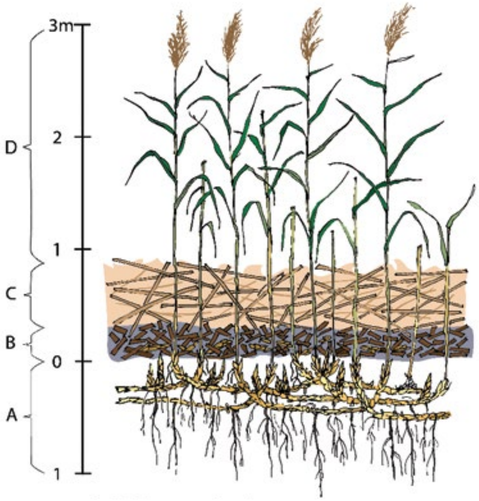

Fig.14.11. Distribution of living and dead material in the reed stand. The thickness of B and C layers amounts to 75 cm. A – roots and rhizomes; B – very coarse reed detritus; C – horizontally deposited stems of several generations of shoots together with basal parts of broken stems; D – vertical living stems and several generations of dead stems. Drawing by D. Segliņa (according to Bjork 1994).

14.1.6.6 Lowering the Water Level

In prolonged periods of low water level, rapid and irreversible overgrowth of the littoral part which is shallow or becomes dry, occurs. It overgrows with emergent mire vegetation, which shades or outcompetes the former vegetation of submerged or floating-leaved plants. Monodominant emergent plant stands (mainly reeds and bulrush *Typha* spp.) develop, and they cover places that were previously too deep for them. Emergent vegetation promotes increased water evaporation (*see Chapter 13*), worsening the situation even more.

Like in mesotrophic lakes (*see Chapter 12.1.6*) a raise in water level promotes wetting of soil horizons, nutrient leakage with the following algal mass development and a decrease in water transparency. Lowering of the water level promotes a decrease in lake volume and the development of emergent vegetation at a depth that was previously unaccessible. The processes are similar to those described in Chapter 13.1.5.6.

14.1.6.7 Intensive Recreation

A distinction should be made between intensive and extensive recreation. Due to intensive recreation, nutrients and in some cases synthetic detergents reach the littoral zone of lake. Mechanical pollution, such as food packaging is also left near the shore. Excessive load – human presence, noise, floating devices – create inappropriate conditions for dabbling ducks and waders that potentially live there.

Two metres of shore per one visitor can be considered as the acceptable threshold of visitor load in a swimming place (Rungule 1982).

14.1.6.8 The Use of Watercraft

The use of watercraft, especially jet skis in shallow (2–9 m) and very shallow (< 2 m) eutrophic lakes should be carefully considered according to their quality criteria[70]. A summary of the depth of water mixing caused by jet-skis is given in Table 14.3. Watercraft up to 75 horsepower are popular in Latvia.

Table 14.3. Depth of mixing water layers when using jet-skis (source: Lakeline 1991).

Engine power in horsepower	Mixing depth (m)
10	1.8
28	3.0
50	4.5
100	5.4

The majority of Latvian lakes are 6–10 m deep (Glazačeva 2004). At a smaller depth, water flows caused by watercraft turbines loosen and resuspend the deepest layers of the lake bottom and bring deposited compounds of phosphorus into circulation again. At the same time, the root system of floating-leaved and submerged plants is washed out and destroyed, and emergent stands only remain in sites where they are dense enough to reduce the power of wave activity. The ability of watercraft to reach the cen-

[70] Cabinet Regulation No. 858 of 19 October 2004, regarding the characterisation of the types, classification, quality criteria of surface water bodies and the procedures for the determination of anthropogenic loads.

tral part of the lake, without causing turbidity in the shallow shore area, should also be taken into account. In theory, the use of watercraft should only be permitted in the central part of shallow (2–9 m deep) eutrophic lakes and in deep eutrophic lakes.

14.2 Management Objectives in the Conservation of Eutrophic Lakes

From the point of view of lake development and biodiversity, the main conservation and management objective is to reduce or prevent an increasing quantity of nutrients getting into the habitat from the lake's catchment area and returning of the nutrients into the water environment from the lake's deposits, in order to slow down ageing of the lake and its transition to a hyper-eutrophic condition. Ageing is expressed as an accumulation of nutrients, reduction of lake volume, lake overgrowth and disappearance. If this ecosystem disappears, species diversity also decreases in this territory. In the course of such succession, transition bogs develop, as well as raised bog in the coming thousands of years.

14.3 Restoration and Management of Eutrophic Habitats

14.3.1 Reduction of Overgrowth with Aquatic Plants (C1.1, C1.2, C2, C.5)

It is necessary to reduce aquatic plant overgrowth in lakes where continuous stands of emergent or floating-leaved plants have developed and if these plants occupy more than 30% of the lake surface. It does not apply to the rare and protected aquatic stands described in *Chapter 12*.

The threshold – 30% overgrowth - is considered a criterion of high and good ecological quality of lakes from the perspective of improvement of lake functionality.

There can be different objectives for the reduction of aquatic vegetation growth:

Overgrowth with macrophytes is reduced to improve lake functions and processes and to lessen the negative effects of economic activities:

- to prevent the replacement of submerged and floating-leaved vegetation with emergent vegetation as far as possible;
- to promote the preservation or restoration of open shore parts;
- to create shallow water areas that warm up for increasing zooplankton and fish larvae production and for the maintenance of dabbling duck and wader populations;
- to slow down eutrophication processes, ensuring that the dead plant parts in the shallow water area are carried ashore by the wind and waves;
- to decrease nutrient amount through mowing and withdrawing macrophytes;
- to promote an indented zone of aquatic vegetation in the overgrown lake parts and the formation of islets separated from the shore;
- to promote the diversity of shore aquatic plants and the existence of mosaic-type stands;
- to improve recreation possibilities;
- to maintain boat transportation routes in heavily overgrown lakes, to cut and remove aquatic plants, thus removing biogenes accumulated in these plants.

In many cases, several objectives can be achieved simultaneously by mowing. Lakes with floating-leaved and submerged vegetation are a significant bird and fish habitat.

To ensure the protection of both bird and fish species, an open and shallow shore water area is necessary. By creating openings in the emergent vegetation in the littoral part of the lake, conditions for dabbling ducks to access open water are improved. Open shoreline allows the attraction of the 18 species of wading birds found in Latvia, which have been included in the Birds Directive[71]. Mown openings with free access to water in reedbeds reduce dabbling duck mortality due to attacks by American mink.

Mown open and shallow shore parts warm up better, and they are important areas for fish spawning as well as productive fish larvae and juvenile feeding (Fig. 14.12, 14.13). When mowing aquatic plants, the precaution principle must be followed. If emergent plants (the main accumulators of phosphorus) are mown entirely, favourable conditions for the increased growth of algae are

[71] Bird Directive 2009/147/EC

created. In a lake dominated by algae, water turbidity of the upper water layers increases. The turbid water impedes light accessing the bottom layers, and during the summer stagnation and winter ice-cover period it can cause the transformation of phosphorus, which is deposited in the bottom of a lake, into a soluble form, and further increase algal growth and turbidity. Therefore mowing must be performed as carefully as possible. The first step of mowing is the removal of emergent (for example, *Phragmites australis* and *Typha* spp.) and floating-leaved (such as *Nuphar lutea*) aquatic plants, while trying to preserve submerged aquatic plants. At least a third of the original aquatic vegetation of a lake must be left.

Fig. 14.12. In large lakes with high wave energy, apart from the shore, a line of emergent plants should be left to lessen effects of erosion and maintain warmed areas for zooplankton and fish juveniles. Photo: U. Suško

There is a variety of technical possibilities for the mowing of aquatic plants. They are described in *Chapter 13.3.1.* The most effective method to reduce aquatic plant overgrowth is weakening of the aquatic plant roots by regular mowing or, ideally, shredding and destroying the root system with rotor cutters. In lakes unmanaged for a long period large emergent vegetation massifs sometimes develop, hindering or even halting water circulation between different parts of the lake (Fig. 14.14).

In such cases water circulation channels in emergent vegetation stands are created to restore or create new junctions between separate parts of the lake (Fig. 14.15).

Mowing of aquatic plants should be started in early July, because at the end of July and at the beginning of August aquatic plants already start preparing for the winter season and nutrients are accumulated in roots, therefore along with the aquatic plant mass only a small portion of nutrients will get removed from the lake. Legislation allows the mowing of aquatic plants starting from 1 July (CM Regulation No. 475). In the first season, mowing is recommended 2–3 times (*see Chapter 13.3.5*). The objective of mowing is to reduce the amount of nutrients accumulated by aquatic plants, therefore it is important to bring the cut plant material ashore. This often takes more time and work than the mowing itself. To facilitate transportation of the cut plants, mowing should be carried out while the wind is blowing shoreward (Fig.14.16).

Fig. 14.13. Shallow shore areas that warm up, protected from wave activity, with favourable conditions for the development of zooplankton and other aquatic invertebrates. Lake Svente. Photo: A. V. Urtāns.

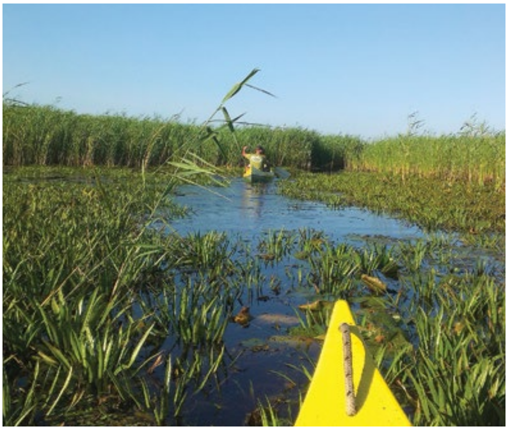

Fig. 14.14. Overgrown hardly surpassable channel in a dense reed stand. Lake Pape. Photo: A. V. Urtāns

First, a vegetation free zone must be mown. During harvesting, reeds should be directed by rake to the cut zone, so the wind can move them shoreward. It is best to use special equipment for cutting. For example, for small mowing works (water bodies up to 2000 m^2) reed cutters "Elis", "Dorocutter", and others are useful. For bigger areas and for work at greater depths we recommend using TRUXOR, "Wattenmaster", RS200 and other commercially available aquatic mowers. In Latvia these services are provided by companies specialising in this field. Aquatic plants can also be mown by a scythe or special hand tools (*See Amendment 3*), by wading along the shore or using a boat.

Plants must be cut below the water surface and as close as possible to the lake bottom. If plants are mown above the water surface, they grow back rapidly, reducing the efficiency of mowing. Along with plants, the nutrients stored in them are also removed from the lake, so cut aquatic plants must be removed, placed in temporary storage sites and later transferred to a composting site.

14.3.2 Changing Depths of a Lake (D7)

A lake is a place where organic matter of plant or animal origin is produced, which deposits in the bottom of a lake after die off. Over time, the sediment layer can reach a large volume, fill and lift the lake volume to the extent that light rea-

Fig. 14.15. Renewal of overgrown channel **(1)** and renewed channel **(2)**. Lake Pape.
Photo: I. Mednis

Fig.14.16. Transportation of mown emergent plants with the help of a suitable wind direction **(1)**. Withdrawal of mown macrophytes from the lake using floating equipment **(2)**. Photo: Ē. Kļaviņa.

ches the bottom of the whole area of the lake, promoting rapid overgrowth with aquatic plants. The development of aquatic plants that take over the entire lake bed can be very rapid. Through the development and die off of aquatic plants, the volume of a lake gets filled rapidly, and during the summer and winter, an anoxic environment develops in the bottom water layer, promoting the transition of phosphorus into a soluble form and it re-entering the food chain. In such cases, the distribution of aquatic plants in shallow lakes can be limited in two ways:

- by raising the water level to the extent that light may no longer reach the lake bottom; this prevents the development of plants growing on the lake bottom;
- by removing sediments from the lake bottom and by deepening the bottom so that the photosynthetic activity and development of aquatic plants is limited at the new depth.

Both methods have advantages and disadvantages.

Water level in a lake is raised either by constructing an adjustable dam or by installing a free overflow threshold. Depending on shore morphology, significant raising of the water level can reduce the shallow water shore zone, and the development of aquatic plants is limited, or the relationship between groups of aquatic plants is changed. The previously dominant emergent plants are replaced by submerged plants and floating-leaved plants that are able to establish at a greater depth. This effect of aquatic plant group replacement is long term (Björk 1994). Increase of the water level in lakes has a number of negative side effects. During flooding, nutrients from terrestrial areas are leached into the water body. Due to flooding, trees wither not only at the shore but also further from it. As the terrestrial part of the shore is flooded, the land area of the property owners in the shore area is reduced.

Another method of lake deepening that decreases mud and sediment volume is described in *Chapter 14.3.3.*

14.3.3 Lake Deepening and Gyttja Extraction (D1)

Accumulation of organic sediments facilitates a decrease in depth and the active development of aquatic plants, while reducing the number of groups of aquatic organisms inhabiting a lake. Accumulation of organic sediments also reduces the productivity of lake fisheries. The volumes of accumulated sediments can be very large. For example, in the Czech Republic, while restoring the eutrophic fish pond Vajgar, roughly 330 000 m^3 of sediments were pumped out of a 40 ha large area (Pokorny, Hauser 1994). In some cases, improvement of the general condition of a lake is possible by extracting gyttja. Gyttja extraction also increases the depth of water bodies. This, in turn, can contribute to better water exchange and formation of fish wintering holes with sufficient levels of oxygen. Aquatic plant development is limited in such deep sites.

Gyttja is a type of organogenic lake sediment, originating from aquatic animal and plant residue, mixed with mineral particles (sand, clay, calcium carbonate and other compounds). It is a brown, black, grey, greenish or yellowish, gelled mass with a colloidal structure, found in the majority of Latvian lakes and in more than a third of Latvian bogs. Gyttja sediments vary in thickness in various lakes from a few centimetres to around 20 metres. In the 1990s geologists systematically surveyed gyttja sediments in Latvian lakes, which were larger than 3 hectares.

There are 1327 lakes in Latvia that contain gyttja. Gyttja sediments are dispersed unevenly in the territory of Latvia. The major part of gyttja sediment locations can be found in upland areas (particularly in the Latgale Upland). Mostly, these lakes are small. However, the largest lakes with gyttja sediments are mainly located in lowland areas (Lācis *without date*).

Experience of the Nordic countries (Björk 1994) has demonstrated that two basic requirements must be followed during gyttja extraction. First, sediment resuspension should be as little as possible. Second, water content in the sludge layer, which is to be pumped out, must be as low as possible – only sufficient to ensure the operation of the pump. The upper sludge layer, which is richest with nutrients, should be pumped out without mixing it with additional water.

In order to reduce sediment resuspension, several methods have been developed that allow the extraction of gyttja without mixing the top sediment layer. Gyttja can be put in portable bags – containers, and transported directly to the shore on floating pontoons.

Often, shallow lakes scheduled for deepening are densely overgrown by emergent and floating-leaved vegetation. The dense root system obstructs mud pump inlet nozzles and makes sediment extraction difficult or even impossible. In order to ensure the effectiveness of the work, preparation is necessary. As shown by the experience of Lake Hornborga, it must be performed a year before gyttja extraction (Björk 1994). First, floating-leaved and emergent vegetation must be cut as low as possible. Then, using a rotator, aquatic plant roots must be shredded. A large part of the roots then float up. The mass of shredded and floating roots must be surrounded by large mesh nets and pulled by a motorboat to the open (or mown) shore part of the lake, which is exposed to the wind. Root parts remaining at the bottom start decomposing until the next year and don't create any problems for operation of the sediment pump. The best time for mowing reeds and other aquatic plants is from June to September (Björk 1994).

Some experts believe that lake deepening is an efficient but aggressive method, because of its substantial intervention in the ongoing processes of a lake. It is therefore only recommended when other actions cannot give the desired effect. This applies to lakes with a depth of up to 3 m, and which have accumulated a more than 3 m thick sludge layer (Balecičius, Ciūnys 2013). For such lakes, deepening is the only lake restoration method that can be used. At the same time it must be taken into account that shallow lakes, if they have transparent water, can be an important habitat for rare and protected mosses, charophytes and vascular plants. Therefore, before making a decision on gyttja extraction as a lake restoration method, a comprehensive study of the lake must be carried out.

When planning for deepening the lake bottom, several conditions must be taken into account:

- it is possible to achieve good results, if the depth in the deepened part of a lake is at least 4.5–5 m, or if the mineral bottom has been reached;
- it is only possible to achieve good results if a sufficiently large lake area is cleared - around 60–70% of the total lake area (Urtāne 2014).

14.3.4 Development of Extensive Bathing Sites (C2)

Extensive recreation, by creating or managing small, around 50 m wide, open beaches, is beneficial for the habitat from the point of view of the lake functioning (Fig. 14.17). Such openings in the lake shore parts that are overgrown with emergent vegetation facilitate the formation of shallow water areas that warm up. Such sites also facilitate the faster development of zooplankton organisms, which serve as the basic feed for several juvenile fish species. Zooplankton is the major food for juvenile pike, until they reach 6 cm in length (Birzaks 2013). In deeper places behind the emergent vegetation area, the water temperature is lower and the amount of zooplankton organisms is smaller and their development – slower. Open shore recreational areas also often provide access to water for water birds during nights and early mornings. Active swimming also contributes to turbidity of the sludge sediment layer accumulated in the shore part, which is brought to the shore by waves, where it oxidises and mineralises.

Fig. 14.17. The open bathing site in the shore part of Lake Zāģezers provides access to the water for ducks and facilitates the better survival of broods **(1)**. The open shore bathing site that warms up provides good conditions for juvenile fish **(2)**. Photo: A. V. Urtāns.

14.3.5 Chemical Methods of Nutrient Binding (D2.1, D2.2, D2.3)

Chemical methods are used for the binding of phosphorus compounds which are dissolved in water and are otherwise difficult to separate. The benefit of using chemical methods in comparison with mechanical techniques (aquatic plant mowing, sediment removal) is the opportunity to effectively manage large areas of water without the use of expensive equipment and related infrastructure. Phosphate ions can be precipitated with trivalent iron Fe^{3+} or aluminium Al^{3+} saline solutions, as together with phosphate ions they create insoluble compounds. However, when working with these compounds, it must be remembered that due to a drop of pH value or due to oxygen deficiency in the bottom layer, in an acidic environment phosphorus is released in the water mass. Aluminium compounds in the water body can become toxic in an acidic environment (Kļaviņš 1998). In this case the benefits and risks must be assessed. This method is easy to implement, the positive result is immediate and obvious. However, the effect is quite temporary, and this procedure must be repeated in 1–3 years. It is undesirable that the aluminium and iron content in a lake increases above the level of natural conditions.

The use of algaecides. To prevent massive growth of algae, the application of algaecides is recommended as an effective method. However, the possible negative effects are rarely explained. Algaecides destroy the algal cells, and their contents, including toxins, are released into the environment. After the use of algaecides it is forbidden to swim in the water for several weeks, and fishing is also advised against. After the repeated use of algaecides, cyanobacteria can develop a resistance to the given algaecide. Many algaecides degrade slowly, they accumulate in the sediments of water bodies, polluting the environment (Balode 2007).

Aeration of the lake's bottom water layer. Aeration of the lake's bottom layer and enrichment of the water environment with oxygen, in order to prevent the release of linked phosphorus compounds, may be considered as a sort of chemical method.

14.3.6 Prevention of Fish Suffocation (D3.1, D3.2, D3.3)

A major part of the shallow lakes, where the water depth does not exceed 4–5 m and where the cover of aquatic plants exceeds 30 % of the lake's surface, is potentially subjected to oxygen deficiency and the resulting fish suffocation. There can be several causes of oxygen deficiency in water. Most often it is caused by organic pollution, the origin of which can be both organic substances accumulated in the lake over time and the input of organic substances from the catchment area.

Fish suffocation during winter, during the ice-cover period, is a process that accompanies increasing eutrophication. The layer of ice and snow prevents the water from getting a sufficient amount of oxygen from the atmosphere, and photosynthesis also cannot take place. Plants start to decompose and rot, consuming a large part of the oxygen dissolved in water. The only oxygen reserves of a lake or a pond are those that have accumulated before the formation of ice.

Ice holes. It is recommended to cut out or drill holes in the ice cover, and to watch if fish gather around them. If fish start to concentrate around the ice holes, it may be an indication that the water body already has a problem with the necessary oxygen. A critical oxygen concentration in water is considered to be below 3 mg/l (Sprūžs 2013). Fish start to suffocate when the concentration of dissolved oxygen falls below 2 mg/l.

It is recommended to cut out 4–6 ice holes in a timely manner. To prevent holes from freezing over, they must be covered with reeds or straw. It is the most efficient method. Good results can also be achieved by pouring water from one hole into another. It is also recommended to clear snow from the ice in several locations. Sunrays destroy the ice, and under the ice oxygen is produced through photosynthesis. In the ditches and watercourses that flow into water bodies, it is recommended to break out and open places for water flow. They can be identified by the darker colour of ice and ice washouts. When working on ice, safety measures must be followed.

Some natural aid is provided by air pockets between the ice layer and water surface that form in autumn – they are mostly used by crucian carp *Carassius carrasius* and tench *Tinca tinca*. Sometimes wooden piles with wooden crosses on their ends, are frozen inside small lakes and ponds to create air pockets between the ice and water surface. Such pockets also form in reedbeds, when ice freezes over reed stands. Unfortunately, the incoming oxygen in reedbeds is only consumed to break up the mass of dead plants.

Mechanical aeration devices. Nowadays methods using wind or solar energy are used to get oxygen into a water body (Fig. 14.18). With the help of wind rotors, air is entered into a water body through diffuser nozzles and, by rising up, it facilitates both water circulation and oxygen dissolution in the water. There is also a method which, with the help of a wind rotor, allows water to be mechanically poured from one ice hole into another or to continuously aerate one ice hole.

Management of inflowing, outflowing ditches and watercourses, and mowing of aquatic plants. Complete mowing of aquatic plants is recommended in places where watercourses flow out of a lake. In such overgrown places, sediments are accumulated and outflow areas are often paludified, and sometimes completely overgrown with marsh. Mouths of ditches that flow into a lake should be mown in a way that water movement becomes visible. Such water flow during winter months will provide oxygen-rich

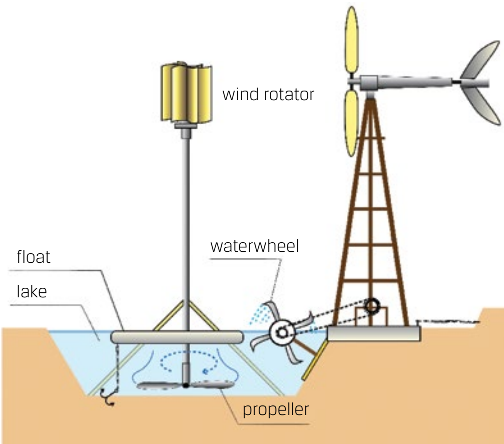

Fig. 14.18. Water aeration using wind power. In Latvia's conditions, when pouring water from one ice hole to another, the aerator must be placed on floats. Drawing by D. Segliņa.

water. Wherever possible, the mouth part needs to be cleaned from debris and deepened once in a couple of years. This is important in shallow and overgrown lakes.

14.3.7 Creation of wind corridors (C3.3)

As mentioned in *Chapter 14.1.3.1*, natural aeration of lake water with the help of wind, particularly in small lakes and lakes surrounded by forests, during storms in autumn and spring, is the only notable way of achieving complete mixing of water layers and water enrichment with oxygen in Latvia (Cimdiņš 2001). Wind corridors are openings that are free of trees in the lake shore zone, creating a flow of air masses and inducing wave activity. The purpose of this method is:

- to promote lake aeration and water enrichment with oxygen;
- to promote mechanical washing of the lake's shore zone and drifting of dead plant and animal material ashore;
- to increase oxygen saturation in the bottom layer to ensure that the phosphorus accumulated in sediments is not brought back to the water column;
- to create an observation space and to improve the scenic value of the territory.

Wind corridors are necessary for lakes previously located in landscapes, which have only overgrown with trees and shrubs in recent decades due to changes in the type and intensity of economic activity. For lakes surrounded by forest, the establishment of wind corridors is not necessary because there is usually a natural surface runoff, and the development of such lakes in most cases reflects their natural eutrophication process. The creation of wind corridors is efficient for small, tree-surrounded lakes. In larger lakes, a belt of trees and shrubs does not significantly slow down the wind. The efficiency of this method is low for lakes located in valleys.

As a result of wind-induced wave activity, the open water surface area increases and oxygen from the air dissolves more efficiently in the water mass. Thus oxygen is supplied not only to the upper layers, but also to deeper layers. In big lakes, the depth of which exceeds 15–20 m, wind-induced waves do not affect the deeper layers of the lake. Small lakes are protected from waves and mixing of the water layer by woodland growing on the shores. This is demonstrated by measurements of lake temperature. During summer, temperature stratification occurs in small, tree-surrounded lakes – the formation of water layers with different temperatures that do not mix with each other. No waves occur at the shore part of a lake, the water is stagnant and warms up quickly. In productive, nutrient-rich lakes, a large mass of dead organisms develops. If oxygen that is necessary for breaking down this mass decreases in the bottom layer, sediment-bound phosphorus is released into the water environment. Lake aeration and enrichment of water with oxygen not only facilitates life processes of aquatic organisms, but, by enriching the deepest layers of lake water, keeps the phosphorus bound in the lake sediments in an insoluble and inert form.

Wind corridors are established by creating up to 10 m wide openings in the direction of the prevailing wind. The following must be observed:

- openings are created by decreasing the number of trees, but leaving scenically impressive, large and old trees;
- the width of the openings, according to the shape of the lake and other morphological characteristics, as well its placement in the landscape, can vary;
- initially, the width of openings should not exceed 10 m; width and placement of any further openings shall be determined on the basis of the assessment of the effectiveness of the measures taken;
- black alder *Alnus glutinosa* and their groups should be preserved in the landscape.

14.3.8 Food Chain Manipulation or Biomanipulation

Biomanipulation is an efficient method to balance the nutrient cycles in water bodies, however, in-depth knowledge of the functioning of the lake's ecosystem is necessary in order to use it. Biomanipulation is implemented to change the food chain, thus changing processes in the lake, and to improve water quality.

Basically, biomanipulation is selective fishing. To change the food chain, certain fish species are caught, or even just some of their age groups. Basically these are the cyprinids or the so-called "white fish" that feed on zooplankton or benthic aquatic organisms by loosening the surface of the bottom and causing the release of bound phosphorus. Prior to biomanipulation, comprehensive research of the water body and its catchment area must be carried out. As observed by Finnish experts, biomanipulation often causes problems that could not be foreseen prior to the works (Sammalkorpi 2013).

Biomanipulation can only be used, if phosphorus concentrations are from about 50 to 150 µg/l. If the phosphorus concentration is initially low, zooplankton organisms consume algae and are able to maintain a relatively low amount and biomass of algae. Also, predatory fish are able to regulate and maintain low numbers of plankton-eating fish. It simultaneously provides for the relatively low elimination of zooplankton. If the phosphorus concentration is high (120–150 µg/l), zooplankton can no longer control the massive development of algae (phytoplankton). Algal bloom causes increasing water turbidity, reduces its transparency, and reduces foraging opportunities for predatory fish, for example, perch and pike, which use vision when hunting. This promotes an increase in the numbers of zooplankton-eating fish. In this situation, improvement of lake quality is reduced by decreasing the number of fish that consume zooplankton. As the number of zooplankton organisms grows, the volume of algae is reduced and water transparency increases. In biomanipulation measures carried out in Finland, the proportion of cyprinids in catches ranged from 63% to 97%. The largest part of the caught fish was *Rutilus rutilus* and *Abramis brama*. In less eutrophic lakes, small perch *Perca fluviatilis* and *Alburnus alburnus* dominated among the fish caught (Sammalkorpi 2013).

Biomanipulation experience in the lakes of Finland

As a method of lake quality improvement biomanipulation has been used in Finland for several decades. According to the Finnish Environment Institute (SYKE) Fresh Water Centre, more than 150 lakes in Finland have been recovered (Sammalkorpi 2013).

Experience shows: in order for biomanipulation to give the desired result, fishing in the entire lake is necessary. The effect is not always achieved after the first time of fishing. Also, after replacing the dominant fish species and decreasing the algal bloom, monitoring of the lake is still necessary. After 3-4 years, a massive increase in populations of cyprinids is possible and fishing must be repeated. The method is only effective if accompanied with nutrient inflow reduction in the catchment area. Biomanipulation is often very important in lake management, especially if the nutrient concentration is low, but cyanobacterial blooms can still be observed (Samallkorpi 2013).

With biomanipulation it is possible to reduce the amount of nutrients (phosphorus) in the lake water by 20% to 30% and the amount of phytoplankton (measured as chlorophyll-a) by 30% to 50%. Calculations presume that 1 kg of cyprinids contain 0.8 g of phosphorus.

14.3.9 Comparison of eutrophic lake management methods

Table 14.4. Management methods.

General lake management measures		
Method	**Advantages**	**Disadvantages**
C1.1: Reduction of aquatic vegetation – mowing of emergent vegetation in different parts of the lake	• Growing ability for submerged macrophytes is not impacted. • Waterbird nesting and feeding as well fish feeding conditions improves.	• Effect is not long lasting. Necessary to repeat the activity. • If mown macrophytes are left in the lake, they can cover submerged macrophyte stands and shade them out.
C1.2: Reduction of aquatic vegetation – shredding of emergent plants and their roots	• Long-lasting effect. • Submerged and floating-leaved vegetation replaces monodominant emergent vegetation.	• Only possible at low water level and small depth. • Activity can threaten submerged macrophyte habitats.
C2: Mowing of emergent vegetation of shore areas – reinforcement of wave activity	• Shallow shore zones that warm up are created, which are suitable for zooplankton development, ensuring important spawning and feeding areas for fish. • Access for waders and ducks is created. • Areas suitable for recreation are created.	• Removal of mown material is time and resource consuming. • Must be repeated regularly, if the territory is not located in a zone of direct wind impact.
C3.3: Change of structure of shore vegetation – creation of wind corridors	• Littoral part of the lake is cleared mechanically from sludge and debris by waves. It becomes biologically more diverse and attracts water birds and juvenile fish. • The lake's nutrient load reduces. • The amount of dissolved oxygen necessary for the degradation of organic substances decreases. • Openings allow viewing of the lake, landscape is diversified.	• Due to the mechanical impact of wind, lake turbidity can increase for several years and a part of the submerged vegetation can die off. • In big lakes the removal of large shore emergent macrophyte stands can initiate bank erosion due to wave activity.

General lake management measures		
Method	**Advantages**	**Disadvantages**
D2.2, D3.1, D3.2: Water aeration	• Increase of oxygen concentration in the lake. • Fish suffocation and phosphorus release are prevented.	• Difficult to use in large water bodies.
D3.3: Prevention of fish suffocation – mowing of emergent vegetation in river mouths and fish wintering depressions	• Ensures the conservation of fish resources in places where oxygen deficiency occurs regularly.	• High costs. Under the impact of wind and waves, treated areas can quickly fill up with sediments from adjacent areas.
Specific lake management measure		
Method	**Advantages**	**Disadvantages**
D1: Lake deepening and gyttja extraction	• Lake ageing is interrupted for several hundreds of years depending on the extracted sediment. • Management activity can be combined with gyttja extraction. • Creation of added value for fisheries and recreation.	• Requires special technology. Needs substantial financial resources. Not all methods are environmentally sound. Qualitative labour and competence needed. • Difficult to perform in deep lakes. • Hard to allocate an area for initial sediment storage.
D2.1: Limitation of the circulation of plant nutrients – chemical settling of phosphorus	• Decrease in the amount of phosphorus available for macrophyte and algae growth.	• Only possible in small lakes. • Has a negative and cumulative effect on aquatic organisms and human health.
D2.3: Limitation of the circulation of plant nutrients – use of algaecides	• Immediate effect.	• Temporarily effective. Effect is achieved when algaecides destroy algal cells, and their contents, including toxins, are released into the environment. • Algaecides break down slowly. After the use of algaecides, there are prolonged restrictions on fish harvesting and recreation. • After the repeated use of algaecides, cyanobacteria can develop a tolerance to the particular algaecide.
D4: Food chain change – biomanipulation	• Efficient stabilisation of a lake's ecosystem. • Reduction of massive growth of algae and the impact of low-value zooplankton-eating species. • Strengthens predatory fish populations. Increase of lake fishery value.	• Before the activity, data sampling and monitoring over many years is necessary. • Results are temporary if there is no reduction of pollution loads. • Independent external factors limit the achieving of planned fish harvest and the desired results (meteorological conditions change fish behaviour, location and fishing success). • Management activity is only successful if all of the lake is treated.

14.3.10 Unfavourable Use and Management of eutrophic lakes

Unfavourable use for all types of lake habitat is mostly associated with nutrient discharge in the lake both from point sources and from non-point sources from agricultural lands and forests.

Non-intervention in the case of increasing eutrophication can also be considered as unfavourable, as well ignorance of eutrophication causes and their prevention. Eutrophic lakes are adversely affected by extensive aquatic plant mowing in the entire water area (such cases have not been registered in Latvia). If the majority of the stands of aquatic plants are removed, the potential diversity of aquatic invertebrate, fish and bird species reduces. Conditions suitable for lake turbidity can increase for several years and a part of the submerged vegetation can die off. In big lakes, the removal of large shore emergent macrophyte stands can initiate bank erosion due to wave activity. The habitat is also adversely impacted by extensive development of emergent vegetation in the shallow shore water area. Routes to spawning grounds for pike and feeding areas for fish larvae and juvenile fish are destroyed. In general, due to inappropriate feeding sites and a lack of food, up to 50% of the fish larvae die during the primary fish developmental stage (Birzaks 2013a).

An adverse impact on lake habitats, including eutrophic lakes, is caused by uncoordinated management of hydro-technical structures on lake outflows, causing adverse conditions for the recovery of fish stocks and increased overgrowth of the shallow shore water areas. Just like for other lake types, eutrophic lakes are also negatively affected by unbalanced economic activity in their shore area.

Many residential areas have historically formed at lake shores and, with regular management over the centuries they have prevented shore overgrowth and lake ageing. It can be seen in many images from years ago, showing shore construction and the condition of the shore area. During the Soviet times (1945–1991), due to the temporary cost benefits (distance to water supply for animal drinking, water supply for dung removal from cattle sheds with water), stock farms and manure storage facilities were built close to lake shores in many places (Figure 14.19). While many of these farms no longer exist, nutrient-rich waters from the former manure storage facilities are still entering lakes from nutrient-rich soils.

Population equivalent is the ratio of the sum of pollution load, which is equivalent to the household sewage produced by a single person in 24 hours.
One unit is equal to organic pollution in wastewaters produced by one person in 24 hours, which corresponds to the biochemical oxygen demand (BOD). It is assumed that the amount of organic wastewater pollutants produced daily by one person equals 60-65 g BOD_5 (it equals, for example, 0.5 l of milk or 1-5 kg of laundry water).

Fig. 14.19. Livestock shed at Lake Aulejas **(1)** and abandoned chicken complex at Lake Vilgāles **(2)**. Photo: A. V. Urtāns.

Unfavourable lake use refers to wastewater discharge without phosphorus treatment. This is promoted by the existing legal framework, which only requires the construction of treatment facilities in residential areas with the population equivalent of 2000. Nowadays, potential hazards are caused by discharging wastewater containing phosphorus compounds from single farms, lakeside residential buildings and recreation facilities. Most of the former manors, Soviet farms and collective farms do not meet this criterion, and they often operate treatment facilities that are noncompliant with the current population and specifics of the settlement (Figure 14.19). The amount of phosphorus in water is often a limiting factor. It is known that nutrients for the mass production of green algae are used when the ratio of phosphorus to nitrogen in the water is similar to that in algae cells. (Lee, Jones 1986; Polprasert 1996). If phosphorus-containing effluents are discharged into the lake, there is an increased macrophyte green mass build-up, which promotes filling up of the lake with sediments and ageing.

14.4 Contradictions of Conservation and Management

Similarly to in charophyte lakes (habitat type 3140 *Hard oligo-mesotrophic waters with benthic vegetation of Chara* spp.), the main contradictions of conservation and management are caused by the lack of an ecosystem-based, unified systematic approach to lake conservation and management (*see Chapter 13*).

Environmental legislation in Latvia in the late 1980s was based on the general prohibition of economic activities in a lake and its shore area. In many cases it was determined by the presence of rare or otherwise protected species in a lake, and not an understanding of the general requirements of the species and ecosystem processes in the long term. The inefficiency of such approaches and the devastating impact on the water bird population was even recognised by the promoters of this legislation themselves (Vīksne, 2013). The management prohibition, for example, caused the massive development of emergent vegetation and the disappearance of breeding sites suitable for Latvia's largest colony of *Larus ridibundus* birds in Lake Dūņezers in Limbaži (Anon. 1988).

Eutrophic lakes simultaneously provide the living environment for aquatic invertebrates, fish and aquatic plants and also serve as a feeding and breeding site for water birds. Contradictions of habitat conservation and management arise if the functioning of the whole water ecosystem, as well as the relationship between different groups of organisms is not taken into account. By only focusing on the needs of some individual groups of organisms or even species, over a longer period of time the condition in the whole lake's ecosystem and the adjacent shore area can significantly worsen. In 1977, a nature reserve was established in Lake Dūņezers in Limbaži for the protection of a *Larus ridibundus* colony. Management regulations set non-intervention. Thus the marshes available for gull breeding overgrew and became unsuitable for further use. Also, the previously open lake shore overgrew, reducing the number of habitats suitable for ducks and waders.

In some cases a conflict of conservation and management may be caused by the prohibition of aquatic plant mowing in private watercourses or water bodies in any time other than during the period from 1 July to 31 March, which is mentioned in Cabinet Regulation No. 475 of 13 June, 2006 *"Order for the Maintenance and Deepening of Surface Water Bodies and Water Areas of Ports"*. Such a requirement is based on the water bird breeding period and is applicable to the whole water body. In July aquatic plants start to prepare for the next growing season, and a part of the nutrients accumulated in plants is transported to the roots. In such circumstances, mowing of aquatic plants is of low efficiency. Experience and studies show that the mowing of aquatic plants is most efficient if repeated several times - the first time must be in the beginning of the growing season, before the development of large plant biomass, as mowing will weaken the regeneration abilities of plants, thus improving the efficiency of the second mowing, by facilitating the further thinning or even extinction of plants (Björk 1994).

The solution should be long-term planning of mowing aquatic vegetation in a mosaic pattern, considering requirements of all organism groups of the given habitat.

Chapter 15. 3160 Natural Dystrophic Lakes and Pools

(A. V. Urtāns, L.Urtāne, U. Suško)

15.1 Characteristics

15.1.1 Brief Description

Distribution. Habitat type 3160 *Natural dystrophic lakes and ponds* (further referred to as *dystrophic lakes*) is a rare lake type in Latvia (Eņģele, Sniedze-Kretalova, 2013). The total known area occupied by the habitat is 3140 ha or 0,05% of the territory of the country (Anon. 2013). Dystrophic lakes are the final stage of lake development. This is why they can only be found in raised bog massifs. This type of lake includes lakes in Teiči bog – Lake Murmastienes, Lake Pieslaista, Lake Tolkovas, Lake Vējgranta, and lakes in Olļa bog – Ramatas Lielezers, Ramatas Mazezers, as well as Lake Sokas in Soka bog (Fig. 15.1). According to the habitat size criterion, bog pools that are larger than 0.1 ha also belong to the dystrophic lake habitat (Fig. 15.1). Abandoned and flooded peat extraction sites are not currently considered to be this habitat type.

Characteristics. The water in dystrophic lakes is acidic – pH ranges from 3 to 6 (Kļaviņš et al. 2003). The brown to red-brown water colour typical for these lakes is caused by the large concentration of humic substances (humin, humic acids, fulvic acid and their salts). The ability of humic substances to form stable complexes with non-organic and organic components defines the low species diversity and productivity (Kļaviņš, 1998). Compared to other lake types, the number of bacteria, algae, zooplankton and benthic organisms is much lower (Urtāne, Kļaviņš 1995; Urtāne 2014). Aquatic plant vegetation is species-poor or absent. Macrophytes are only found in lakes, which have contact with the minerogenic bottom or that have groundwater inflow. Also fish species diversity and productivity is low. Water acidity in these lakes very often exceeds the threshold limit for fish survival (pH < 5,5).

The low productivity of dystrophic lakes is determined by a set of characteristic factors – low mineralisation rate, high acidity in the environment, plant nutrients bound in the macromolecular humic substance complexes (Cimdiņš, 2001; Hagman et al. 2015).

Dystrophic lakes belong to the brown-water (poly-humic) lake type. However, water colour is not the key feature of the habitat, since dark brown humic water can also be a feature of lakes of other types. A lake's belonging to a particular habitat type is determined by the stage of lake development characterised by the lake type and processes. Characteristics of brown-water lakes that belong to different habitat types are summarised in table 15.1.

Fig.15.2. A bog pool in Olļa (Saklaura) bog that corresponds to a dystrophic lake habitat. Photo: L. Urtane.

Fig. 15.1. The dystrophic Lake Ramatas Lielezers. Photo: I. Druvietis.

Table 15.1. Characteristic parameters of brown-water lakes belonging to different lake habitats.

Habitat, its characteristic parameters	**3160 *Natural dystrophic lakes and ponds***	**3150 *Natural eutrophic lakes with* Magnopotamion *or* Hydrocharition *type vegetation*, 2nd variant (brown-water lakes with diverse vegetation, dyseutrophic lakes)**
Chemical and physical parameters		
Plant nutrients (biogenes)	Abundant, but hardly bioavailable, as they are bound in humic substances.	High concentration nutrients (total phosphorus) both in water and sediments, but are also bound in insoluble humic substances.
Lake processes related to plant nutrients	Mostly Dystrophication (nutrient linking) processes dominate.	Eutrophication (nutrient accumulation) and dystrophication (nutrient linking) processes take place.
Origin of the humic substances in lake water	Mostly of autochthonous origin - are created in the water body itself as the organic substances of living organisms decompose. Are leached from peat layers of lake shores.	Mostly of allochthonous origin - occurs by leaching of mineral soils of lake shores.
Environmental acidity (pH value)	High, pH value – acid (< 6,0).	Low, pH value – alkaline (> 6,0).
Biological parameters		
Macrophytes	Few or absent. Only few species of floating-leaved vegetation are represented - *Nuphar lutea*, *Nuphar pumila*. In lakes with groundwater discharges, rare stands of *Schoenoplectus lacustris* can be present. Bog vegetation at lake shores.	Abundant. Rather biodiverse. Belt rich in floated-leaved and emergent plants. Submerged plants can also be found.
Zooplankton	Species-poor. Their number and taxonomic group depends on the origin of the lake. Zooplankton in bog lakes (secondary lakes) consists of *Cladocera* (Water fleas) and *Copepoda* (Copepods) species. Species number rarely exceeds five. The number of zooplankton species in primary lakes is bigger, it also contains *Rotatoria* (Rotifers) species.	Species-rich. It consists of species that are characteristic to nutrient-rich waters and belong to all three taxonomic groups – *Rotatoria (Rotifers)*, *Cladocera (Water flees)* and *Copepoda (Copepods)*.
Phytoplankton	Species-poor, dominated by *Gonyostomum semen* characteristic of brown-waters, next – *Chlorophyta*, also dominated by *Desmidiales* (*Staurodesmus* spp., *Staurastrum* spp., *Desmidium* spp., *Cosmarium* spp., *Micrasterias* spp.), *Chrysophyta* (*Dynobryon* spp.).	Species composition is relatively rich, dominated by *Gonyostomum semen*, followed by *Chlorophyta*, *Bacillariophyta*, *Dynophyta* and *Cryptophyta* (*Cryptomonas* spp. and *Rhodomonas* spp.), small number of *Cyanophyta*, as well as *Flagellata*.

15.1.2 Indications of Favourable Conservation Status

Although dystrophic lakes are located in raised bog massifs and mostly far away from sites of ongoing economic activity, they can also be negatively impacted. Good quality of a habitat and favourable conservation status are indicated by several features:

- bog vegetation on lake shores;
- no ditches that drain drain lakes or adjacent bog areas;
- no rapid water level fluctuations in the lake.

15.1.3 Important Processes and Structures

15.1.3.1 Lake Origin

By their origin, dystrophic lakes can be divided into two groups – primary lakes and secondary lakes. Primary lakes are primary succession lakes. They are the remains of relict lakes that have maintained contact with the mineral ground. The bog surrounding the lake has formed by overgrowing of the lake. This is a very special type of lake. The set of organisms inhabiting these lakes (biocenotic structure) differs from secondary lakes.

Bog lakes are secondary succession lakes. They form when a peat layer sinks under the impact of gravity and the formed depression fills up with water. Lakes of this group do not have contact with the mineral ground, and they only receive water from precipitation. Lakes of both groups cannot be distinguished by their visual characteristics – depth, size, shore vegetation structure, water colour, etc. A lake's belonging to either the remnant lake or bog lake group is indicated by the composition of aquatic organism species (Table 15.2). The origin of a lake can most accurately be determined through geological research.

15.1.3.2 Nutrient Cycling

Processes occurring in the brown-water lakes of the dystrophic lake type are significantly different from clear-water (oligo-humic) lakes. This is due to lakes being in various stages of development. In clear-water lakes, which, depending on the amount of nutrients and their cycling rate, are in one of the early lake development stages, the nutrient accumulation or eutrophication processes prevail. In dystrophic lakes, which are at the end stage of lake development, the nutrient-binding or dystrophication processes prevail (Urtāne 1998).

Although the concentration of plant nutrients or biogene elements in dystrophic lakes is relatively high, compared to clear-water lakes, they have a very low amount of plankton, since biogene elements in water are bound in humic substances, and in this way they are hardly accessible to living organisms. For this reason, nutrient cycling

Table 15.2. Characteristics of primary and secondary dystrophic lakes.

Dystrophic lake origins	Characteristics
Primary lakes (relict lakes) – final stage of oligo-eutrophic succession	• Located in raised bogs. • Contact with mineral ground has been maintained. • Macrophytes can be found. • Zooplankton is relatively species rich, rare species are present.
Secondary lakes (bog lakes) – secondary succession lakes, that have formed by the sinking of a peat layer	• Located in raised bogs. • No contact with mineral ground. • No macrophytes. • Zooplankton is very species poor, only five *Cladocera* species.

in dystrophic lakes is slow.

Humic substances are macromolecular compounds. The phosphorus ions in the water deposits or joins on the surface of humic substances. Thus the phosphorus ions are not usable for building the primary production (Kļaviņš et al. 2003).

Dystrophic lakes have a high concentration of humic substances – 300 mg/l (Cimdiņš, 2001). They are found in a lake as insoluble humin fractions and in the form of dissolved humic acids and fulvic acids. Humic substance particles that are deposited on the lake bottom, together with the dead planktonic organisms form peaty mud. Each year about 20%–30% of newly formed organic substances turn into humus, around 0,4%–1,4% deposit in sediments (Cimdiņš, 2001). This is how nutrient binding or dystrophication is expressed. Humic substances are resistant to microbial degradation. Oxygen deficiency often develops in the layers of lake bottom. It is caused not by the decomposition of humic substances, but by their oxidation, because bacterial activity in dystrophic lakes is low (Cimdiņš, 2001). Bacteria plays a very important role in brown-water lakes, because they, in order to ensure their life processes, are able to use humic substances as a source of carbon.

The low nutrient cycling that is characteristic of dystrophic lakes is determined not only by the non-availability of nutrients, but also by the colour of the water. The dissolved humic acids and fulvic acids are brown to dark yellow in colour. The presence of humic substances in the water not only slows down the cycling of nutrients, but also makes the water less transparent, thus affecting the depth of light penetration and the algal photosynthetic activity.

By the degree of solubility in water there are three fractions of humic substances:

- *humin* – the fraction of humic substances that is insoluble in water at any pH;
- *humic acid* – the fraction of humic substances insoluble in water under acidic conditions (pH $<$ 2), but soluble at a greater pH;
- *fulvic acids* – the fraction of humic substances that are soluble in water at all pH values (Klavins, Sire 2010).

15.1.3.3 The Formation of the Structure of Biocoenosis

The structure of aquatic animals and aquatic plants living in dystrophic lakes is specific. In addition, the species composition of aquatic organisms inhabiting primary (relict) lakes and secondary (bog) lakes is also different.

Zooplankton. Although dystrophic lakes have a small amount of phytoplankton due to the low transparency and the high concentration of humic substances, they can develop rich zooplankton – tiny animals, passively floating in the water mass. Unlike in the food chains characteristic for clear-water lakes, the zooplankton in dystrophic lakes feed on the humic substances in the water and not on algae. Algae, which cannot assimilate the nutrients bound with the humic substances, use nutrients that have been processed by the zooplankton. So the high ratio of zooplankton and phytoplankton is considered a typical characteristic of bog (secondary) lakes (Druvietis et al. 2010).

There are two types of zooplankton associations in dystrophic lakes. Their structure is determined by the origin of the lake. Zooplankton in primary lakes, which have contact with the mineral ground, is richer with species. It consists of species that belong to all three taxonomic groups of zooplankton – *Rotatoria, Cladocera* and *Copepoda*. The largest and richest with species is the group *Cladocera*, consisting of both the zooplankton species characteristic of the lake's free-water zone – *Diaphanosoma brachyurum, Ceriodaphnia quadrangula, Bosmina coregoni obtusirostris*, and the bottom water layer and phytophilous species – *Acroperus harpae, Alona gutatta, Alanopsis elongata, Polynemus pediculus etc.*

Secondary (bog) lakes that have originated by the sinking of the peat layer have very simplified zooplankton associations. The zooplankton consists of only five species of *Cladocera*, but *Copepoda* are only represented by the *Calanoida* species (Urtāne, Kļaviņš 1995).

The number of zooplankton species is also affected by the environmental acidity. However, it depends more on the lake origin. Primary lakes, with a few exceptions, also have a relatively high number of zooplankton species at low pH conditions (Fig. 15.3).

Phytoplankton. Dystrophic lakes usually have a low number of algal species. It usually consists of *Dinobryon divergens, Mallomonas* spp., *Bacillariophyta* (*Asterionella formosa*), *Botrococcus braunii, Euastrum* spp., *Staurastrum* spp. and *Micrasterias* spp. Only in recent years has it been found that *Gonyostom semen* of the Raphiophyta group is often abundant in the plankton, but until now this species was often not detected because it is dissolved by using the usual sample preparation methods. Benthic and periphytic algae in dystrophic algae are represented by *Mougeotia* spp., *Ulotrix* spp., and *Batrachospermum* spp., which are characteristic of this type of lake.

Various phytoplankton species dominate in dystrophic lakes on a seasonal basis. During spring, the plankton is dominated by *Dinobryon* spp., which in early summer is replaced by *Flagellates* spp. (Druvietis et al. 2010).

The composition of phytoplankton species is also affected by the origin of the lake. Secondary lakes, which have originated by the sinking of the peat layer, and have no contact with the mineral ground, have a small number of algal species. The number has a clear correlation with the environmental response (Fig. 15.4).

Zoobenthos. Due to the monotomous lake bottom substrate and lack of higher aquatic plants, zoobenthos consisting of aquatic invertebrates inhabiting the surface layer and the substrate of the lake bottom, is also poor. It is represented by 20–80 species of 9–15 taxonomic groups. At the shore parts of dystrophic lakes, the most common organisms are *Chironomidae larvae, Trichoptera, Ephemeroptera, Odonata, Culicoides, Sialis, Assellus, Hirudinea, Oligochaeta, Coleoptera* and *Mollusca*. The lake bottom below the open water surface is inhabited by organisms belonging to only 1–3 taxonomic groups dominated by *Diptera*, mainly *Chironomidae* and *Chaoborus flavicans*.

In dystrophic lakes, rather abundant water-bug fauna are present. For example, in Lake Sokas and in the lakes within Oļļa bog – Ramatas Lielezers and Ramatas Mazezers, eight species of water-bug have been found. Several specially protected insect species can be found in dystrophic lakes and bogs, as well as in nearby areas. These lakes are home to *Dytiscus lapponicus* and several dragonfly species - *Leucorrhinia albifrons, Sympetrum danae* and *Somatochlora arctica*. Most often, dragonflies have been observed as flying insects, because they are easier to observe at this stage of development.

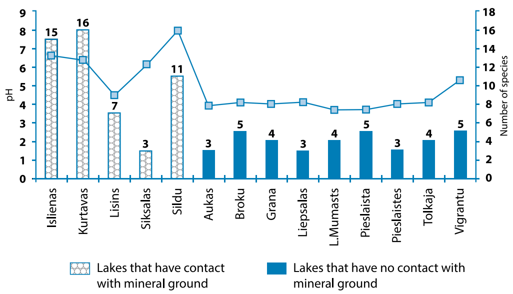

Fig. 15.3. The number of zooplankton species in dystrophic lakes of various origins and their relation to the acidity of the environment (source: Druvietis et al. (2010)).

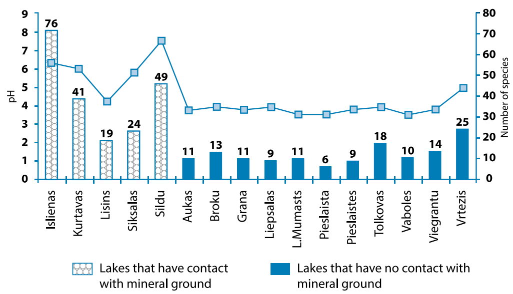

Fig. 15.4. The number of phytoplankton species in dystrophic lakes of various origins and their relation to the acidity of the environment. Data on *Gonyostomum semen* are not included (source: Druvietis et al. (2010)).

Figure 15.5. Eastern White-faced Darter *Leucorrhinia albifrons* turning into a flying insect **(1)** and an adult insect **(2)**. Photo: M. Kalniņš.

Macrophytes. Typical aquatic plants are only found in primary (relict) lakes (Fig. 15.6), for example, in the floating vegetation zone – *Nuphar lutea,* as well as the rare *N. pumila* that is protected throughout the Baltic region (Fig. 15.6); sometimes also *Nymphaea* spp. If there is groundwater discharge in the lake, there can be sparse stands of *Schoenoplectus lacustris* (for example, in Ramata Lielezers).

A total of seven species of vascular plants and seven species of moss can be found in dystrophic lakes in Latvia (table 15.3) (Suško, Āboliņa 2010; Suško 2010). Charophytes are absent in dystrophic lakes. Secondary lakes are poor in macrophytes, but this is not considered a sign of lake degradation.

Fish. Due to the specific living conditions, fish productivity and species diversity in dystrophic lakes are low. Water acidity in these lakes very often exceeds the threshold limit for fish survival (pH < 4.5). In primary lakes, which have contact with the mineral ground and contain sparse floating-leaved vegetation, the diversity of fish species is higher. For example, in Ramatas Lielezers, which is located in the northern bog protected area, *Esox lucius, Perca fluviatilis, Rutilus rutilus, Scardinius erythrophthalmus, Tinca tinca* and *Cyprinus carpio* have been found. In Lake Islienas, which is located in the Teiči bog nature reserve - *Perca fluviatilis, Esox lucius,*

Fig. 15.6. Lake's contact with the mineral ground or groundwater discharge is indicated by floating-leaved vegetation **(1)**. Lake Sokas. Photo: L. Urtāne. *Nuphar pumila* can be found in brown-water lakes which correspond to a habitat type protected in Latvia – *Lakes with stands of Nuphar pumila* **(2)**. Photo: L. Urtāne.

Table 15.3. Macrophyte species in dystrophic lakes.

Vascular plants		
Carex lasiocarpa	*Nuphar lutea*	*Scheuchzeria palustris*
Carex Limosa	***Nuphar pumila***	*Utricularia minor*
Carex rostrata		
Moss		
Sphagnum cuspidatum	***Sphagnum pulchrum***	*Warnstorfia exannulata*
Sphagnum fallax	*Sphagnum riparium*	*Warnstorfia fluitans*
Sphagnum magellanicum		

Note: Rare and protected species are highlighted in color, while the habitat characteristic species, whose presence and sufficient distribution in a particular lake distinguishes this habitat from other lake habitats, have background imprinting.

Tinca tinca, Rutilus rutilus, Cyprinus carpio and Gymnocephalus cernua have been found. Small, dark coloured perch are most commonly found in secondary lakes. Pike and crucian carp have also been found in some secondary lakes.

Water birds. Due to the specificity of dystrophic lakes, there is a relatively low number of bird species. Typical birds here are the gulls *Larus argentatus, Larus canus* (Fig. 15.7), ducks *Bucephala clangula, Aythya fuligula, Anas crecca, Anas platyrhynchos*, as well as the specially protected species - *Cygnus cygnus etc*. The specially protected *Gavia arctica* nests in lakes in large raised bogs.

During bird migration, these lakes can have a large number (15 thousand and more) of the protected *Anser fabalis, Anser albifrons* and *Branta leucopsis*. Large open bog areas with large lakes are important bird migration sites. Therefore these dystrophic lakes, that cover dozens or even hundreds of hectares, are very important for birds.

Fig. 15.7. The common gull *Larus canus* chick **(1)** and a nest **(2)** in the area of the nature reserve "Ziemeļu purvi" in the surrounding of Lake Sokas. Photo: M. Kalniņš.

15.1.4 Natural Development of a Habitat

According to several lake classification systems, lakes that are located in raised bogs are considered to be the final stage of lake development (Wetzel 2001). The habitat develops with the accumulation of nutrients in the lake. Since the productivity of organisms is low, filling the lake also occurs in small quantities, and lakes can retain their externally unaffected status for longer. In primary lakes, productivity is higher, but the amount of biomass produced is too small to fill up the lake rapidly.

15.1.5 Pressures and Threats

Dystrophic lakes, irrespective of their origin, are hydrologically very closely linked to the surrounding raised bogs. Therefore, the main threatening factor is the hydrological regime change caused by the drainage of bogs in the catchment area. Some lakes have been completely destroyed by draining bogs for peat extraction. In drained bogs, peat mineralisation starts – nitrogen compounds in peat are oxidised, nitrogen oxide is released into the atmosphere, creating gasses that contribute to the greenhouse effect. Water ecosystems are significantly affected both if the water level in the drained bog areas is raised and if they are permanently flooded. Flooding creates a new water area, which initially, is not considered as a dystrophic lake.

The example of Ramatas Lielezers

The hydrological regime of Ramatas Lielezers has been changed several times. The first time it occurred was about 120 years ago - in the time period between 1877 and 1885 – when the outflowing stream Ezergrāvis was modified. This was done in order to use water power to operate the watermill on the River Ramata. For this purpose a dam with wooden floodgates was built on the river outlet. Later, when the wooden floodgates became out of order and stopped functioning (1970s), the lake's hydrological regime was affected again, because the runoff was no longer regulated, and the amount of water flowing away through the river, which had been deepened in the preceding years, increased. This has affected the condition of lake shores, where a layer of mineralised peat about 70 cm thick was exposed.

Rivers outflowing from primary lakes with groundwater discharges, were historically used to support local, small watermills. Economic use and the adjustment of these rivers have historically affected the hydrological regime of these lakes. The water level in lakes has dropped, exposing shores where the peat has mineralised over time. By raising the water level, moistening of the mineralised peat layer may have a significant effect on the hydrochemical regime of a dystrophic lake to the degree that the lake type may change. Research and monitoring results obtained in Latvia and elsewhere in the world show that the increase in the concentration of the dissolved organic carbon in the water multiplies the primary production (Reynolds, Fenner 2001; Freeman et al. 2004; Kļaviņš et al. 2012). Unusually high primary production occurs in a dystrophic lake in the final development stage, causing changes in the bioceonosis structure.

At the end of the 20th century, *Gonyostomum semen* was first found in dystrophic lakes in Latvia. Perhaps, it had been there before but was not detected. Earlier finding of this algal species was delayed by the fact that it can only be detected in a fresh sample without added phytoplankton fixation. The rapid spread of this species is also observed in neighbouring countries and across Europe. It can proliferate massively and can cause allergic skin reactions for humans. It is believed that this algae is mixotrophic and even consumes humic substances. A biomass of 12 mg/l has been found in the bog lake Islienas, which, in comparison with the background condition (0,01–0,15 mg/l) indicates an almost hundredfold increase in the algae mass (Druvietis et al. 2010). Factors that contribute to the spread of this species are not yet clearly understood (Hagman et al. 2015).

15.2 Management Objectives for the Protection of Dystrophic Lakes

Since the habitat of a lake is formed in an open ecosystem related with wide surrounding areas, its protection is not just important for habitat conservation and the protection of species. Dystrophic lakes that are located in bog massifs play an important role as water reservoirs. The water accumulated in raised bogs and dystrophic lakes influences the microclimate of the surrounding areas. In river basin area management plans, lakes with an area above 50 ha are distinguished as separate water objects and have specific management measures, if it is found that they are not at least of good ecological quality.

Specific, habitat management-related objectives are set on the basis of the conservation value of the habitat, their typical and protected aquatic species, as well as on the basis of terrestrial species that use the lake as their habitat.

The origin of a dystrophic lake – primary (relict) or secondary (bog) lake – also determines its conservation value. Secondary lakes are geologically new, and must be conserved as a natural raised bog structure. Primary lakes, which are the remains of ancient lakes are very important for the maintenance of biodiversity and the preservation of the relict species found in these lakes.

Bog areas with dystrophic lakes are an important place for water birds to stay during migration, and one of the management objectives is the protection of the integrity of such territories.

15.3. Restoration and Management of Dystrophic Lake Habitats

15.3.1 Non-intervention in Natural Development Processes

The aim of non-intervention is to ensure the preservation of an intact dystrophic lake and its undisturbed natural development. In clear-water (oligohumic) lakes, in which active nutrient accumulation processes take place, the objective of habitat restoration and management is to reduce the input of nutrients into lakes and to improve lake functionality, in order to slow down lake development. In dystrophic lakes where nutrient binding processes or dystrophication processes occur naturally, this type of management is not necessary. For dystrophic lakes, as for lakes that have reached the final stage of development in raised bogs, the optimum management type is non-intervention.

15.3.2 Stabilisation of the Hydrological Regime

The aim of hydrological regime stabilisation is to maintain a high moisture level characteristic for bogs in natural conditions, preventing the mineralisation of bog peat.

In raised bogs with rich groundwater discharges, natural watercourses have developed. Due to economic reasons, many of them were modified, thus increasing the water runoff rate, causing lowering of the water level in the lake. Water level can also be lowered due to bog drainage.

In dystrophic lakes, if the water level has been artificially lowered for a prolonged period of time, any attempt to restore the previous water level of the lake by building dams in ditches or by backfilling ditches should be evaluated very carefully. After the water level has dropped, the lake's shore peat layer gets exposed. Over time, oxygen-saturated (aerobic) precipitation water infiltrates into the peat layer causing the oxidation of organic substances and peat compaction. Therefore, it is not possible to restore the previous condition. When moistening a compacted and oxidised peat layer anew, the oxidised organic carbon compounds transform into the form of dissolved organic carbon (DOC). In water they contribute to bacterial activity, the break-up of macromolecules of humic substances and release of bound phosphorus and nitrogen compounds, which is considered as polluting (Kļaviņš et al. 2012). Increase of the concentration of the dissolved organic carbon in the water causes a multifold increase in primary production (Reynolds, Fenner, 2001; Freeman et al. 2004; Kļaviņš et al. 2012). In this way, the release of phosphorus and nitrogen compounds promotes eutrophication, which is opposite to dystrophication. During this process, a dystrophic lake transforms into a dyseutrophic state, and this contradicts natural lake development. Increasing of the water level in such circumstances degrades the habitat.

Artificial increasing of water level may only be permitted in secondary succession lakes in which shore areas there are still marshes. This facilitates the development of *Sphagnum* and prevents peat compaction.

15.3.3 Waste Removal

The goal of waste removal is to prevent contamination of the dystrophic lake habitat and the adjacent area. Although dystrophic lakes are located in raised bog massifs and are hardly accessible, some of them are popular fishing spots. This can be seen by the boats locked up at lake shores far away from the nearest settlements. Visitors leave waste in the territory. Waste collection in bogs is difficult due to the difficult accessibility. The most effective method of waste management is to prevent waste production by placing waste bins with invitations to use them in easily visible locations next to trails that lead to the bog lakes.

15.4 Contradictions of Conservation and Management

One of the contradictions between lake habitat conservation and management is caused by the public status of lakes determined under the Civil code, guaranteeing the right to reside in lakes and use their resources for fishing. Due to the large number of visitors, the upper *Sphagnum* layer gets trampled and muddy trails are developed with a tendency to expand. To prevent this, load-reducing infrastructure (footbridges) has been constructed, however, it increases the interest in the territory from tourists, berry pickers and hunters, which, in turn, increases disturbance for nesting birds.

Contradictions arise if the mineralisation of secondary (bog) lake shores is considered to be an indication of degradation, and hydrological regime restoration by the filling of outflowing ditches is planned. However, the formation of lake shores with a firm and dense peat layer is determined by physical processes, which are more pronounced in bigger lakes. Water evaporation from an open water surface is higher than from a bog area, which is covered with *Sphagnum*. Increased water evaporation from the lake surface facilitates lowering of the water level and the formation of high shores, where growing conditions are drier. Such naturally drained shores of lakes and watercourses are natural bog structures, and their rewetting is not necessary.

It is different, if there are excavated drainage ditches. In this case, ditches can be filled and dams constructed taking into account the fact that the dams should not be higher than the level of the previous, long-term existing water level in the lake. If a dystrophic lake has high shores with exposed and mineralised peat, its water level should not be raised, in order to prevent leaching of the dissolved organic carbon (DOC).

Chapter 16. 3190 *Lakes of gypsum karst*

16.1 Characteristics of Lakes of Gypsum Karst

16.1.1 Brief Description

The habitat includes small permanent lakes, which, as a result of rock weathering and dissolution (karst) processes, have developed in carbonate and sulphate bedrock. Rock weathering is determined by the fact that minerals, which have formed under the conditions of high temperature and pressure, may be unstable in contact with water, especially if saturated with carbon dioxide and oxygen (Eiduks, Kalniņš 1961). Depending on the rock, two types of karst are distinguished – processes in carbonates (dolomite, limestone) and sulphates (gypsum) (Zelčs 1995).

Over the course of karst processes - chemical dissolution of soluble rocks or suffusion processes – sinkholes of various forms appear on the surface – chains of funnel-shaped sinkholes and small hollows. They usually accumulate water. The oldest and shallowest sinkholes can fill up and develop into a mire. Sometimes the bottom part of sinkholes is linked with permeable underlying rocks, therefore the accumulation of water in them is not possible. The depth of dry sinkholes in Latvia can reach 18 m, but karstic lakes, such as Lake Liliju in the vicinity of Baldone, is up to 12 m deep (Vītiņš, Cukermanis 1940). Water level fluctuations (Fig. 16.2), high calcium and sulphate ion content in the water is characteristic for the majority of water bodies that have formed in sinkholes. In the territory between Pļaviņas and Koknese, due to complex geological processes, karstic manifestation can be observed in Sinking Korkuļi karst stream.

Lakes of karst greatly differ in shape, size, age and origin. Therefore, their vegetation can also be quite diverse. Older sinkholes can develop in mires or waterbodies of various types, whereas the newest sinkholes can have no vegetation at all. Karst lakes are usually small, and have very poor vegetation. It consists primarily of plant species well adapted to fluctuating water levels. Free-floating and submerged aquatic plant communities can also be present. Also, terrestrial plant communities can be found in older sinkholes. There are no characteristic plant or animal species in karst

Fig. 16.1. Korkuļu stream – as a result of karst processes the river regularly vanishes, leaving a dry riverbed. Photo: Ē. Kļaviņa.

Fig. 16.2. Lake Allažu Linezers in August, 1982 – water level dropped **(1)**. Photo: G. Eniņš. Allažu Linezers in August, 2015 – the lake has filled up with water **(2)**. Photo: A. V. Urtāns.

lakes in Latvia, and no species that would be related to karstic processes have been found (Eņģele 2013). The habitat in Latvia is found very rarely, mostly in the surroundings of Allaži, Skaistkalne and Saldus, where surface karst processes is observed (Fig. 16.3).

The habitat has formed anew in a gypsum extraction site in Saurieši, where the former gypsum extraction quarries fill up with water, continuing to dissolve the gypsum layers. The total identified area of the habitat in Latvia is 47 ha, which equals 0.0007% of the territory of the country (Anon. 2013). There are older sinkholes that are paludified or filled with organic materials or soil. Karst lakes usually have a very variable water level. The existence of such diverse forms and their identification in nature makes the determination of the total habitat area difficult.

16.1.2 Indications of Favourable Conservation Status

The progress of karst processes is unpredictable – sinkholes and associated karst lakes can form suddenly, in a matter of a few hours or days (Fig. 16.4), or the process can occur very slowly, as a gradual "sinking" and flooding of a larger territory. An essential prerequisite for sinkhole formation is intense underground water streams into soluble gypsum, dolomite and limestone bedrocks with a corresponding structure (cracks, etc.). Consequently, a favourable conservation status is characterised by unchanged groundwater circulation and the existence of sinkholes that are visible in nature.

16.1.3 Natural Development of a Habitat

The natural development of the habitat is influenced by many factors. The intensity of the karst process is affected not only by the original accumulation features of gypsum, but also by the gypsum structures, admixtures and water-proofing properties of clays (Kuršs, Stinkule 1997). When comparing the intensity of karst processes in different areas with gypsum sediments, it is much less observed in places with more clay layers and in places where those layers are thicker. Such regions include Mālpils-Allaži, Saurieši-Salaspils, Nāvessala and Baldone. In contrast, in the southern areas of the country and in the border areas (Skaistkalne, Birži in Lithuania), where the thickness of the clay layer is smaller and gypsum is more mixed with carbonates, karst processes are more pronounced (Kuršs, Stinkule 1997). The development of the habitat is determined by the continuous active water circulation even after the establishment of the sinkhole.

16.1.4 Pressures and Threats

One of the affecting factors and threats is groundwater circulation changes that alter the intensity of karst processes. Economic activity can also have an impact. The manifestation of karst processes often interferes with intensive land management, therefore on agricultural lands, sinkholes are sometimes filled with the surrounding ground or with the organic residues - shrubs etc. brought from fields. Gypsum and dolomite is extracted

Fig. 16.3. The distribution of karst areas in Latvia (source: V. Venska, amended Ģ. Stinkulis 2017).

Fig. 16.4. Newly formed karst sinkhole in the surroundings of Allaži, 16 June, 1992. Photo: G. Eniņš.

for the production of building material. The establishment of quarries contributes to changes in groundwater flow. They can intensify and reinforce the manifestation of karst processes or, on the contrary, redirect the water flow and dry out the existing karst water bodies, arresting their further development.

16.2 Management Objectives in the Protection of Karst Lakes

Karst is the manifestation of geological processes. There are no plant and animal species which are characteristic only to this habitat type. Therefore the protection and conservation of natural groundwater circulation is the objective of both conservation and management of the habitat.

16.3 Restoration and Management of Karst Habitats

Restoration of this habitat type is not necessary or is even impossible. For example, it is known that in Lake Linezers in the vicinity of Allaži, the water level lowered significantly and almost disappeared in around 1939, 1976, 1982, 1996, 2003, and 2014, thus naturally limiting or stopping the existence of aquatic organisms previously inhabiting the lake. As the water level of the lake renewed, some aquatic organisms became established in the lake again.

Karst lakes have become a favourite tourism destination. They are advertised on regional portals and tourism websites. In various karst areas their improvement and maintenance has been undertaken by JSC "Latvian State Forests", local authorities and landowners. Areas are maintained, there are information boards informing people of the areas and the ongoing processes, and picnic and campfire sites have been established.

16.3.2 Unfavourable Use Management of Karst Habitats

The main unfavourable management for this habitat is the filling up of sinkholes, in order to ensure intensive farming. So far, this practice is not widespread, because it is expensive. In the past waste was arbitrarily stored in some sinkholes. In the current economic situation, the removal of waste from such areas and transportation to a landfill is not considered a priority.

To use the habitat for economic purposes – gypsum or dolomite extraction – large investment is necessary. Prior to starting the work, preliminary research and an environmental impact assessment must be carried out. Site investigation, application of the initial environmental impact assessment for the proposed activity and setting of specific conditions for the extraction of rocks by responsible authorities basically does not allow unfavourable management of the habitat.

16.4 Contradictions of Conservation and Management

The main conflict between the conservation and the management of the habitat is the development of intensive agriculture and filling up of the existing sinkholes.

Chapter 17. 3260 *Water Courses of Plain to Montane Levels with Ranunculion Fluitantis and Callitricho-Batrachion Vegetation*

(A. V. Urtāns, L. Urtāne)

17.1 Characteristics

17.1.1 Brief Description

Distribution. The total area of the habitat in Latvia is 17 620 ha, which equals 0.3% of the territory of the country (Anon. 2013). The habitat can be found over almost all of the country (Fig. 17.1).

Facts and Figures.
The total number of rivers is around 12 400, their total length – approximately 37 950 kilometres. 11 500 of them are small rivers, shorter than 10 km; 880 rivers are longer than 10 km, and only 17 rivers are longer than 100 kilometres. The density of rivers is higher in Zemgale Plain and on slopes of uplands. The average density of rivers in the country is 590 m/km² (Eipurs, Zīverts 1998). Approximately a third of the total river length is regulated - 13 690,4 km.

Characteristics. Habitat type 3260 *Water courses of plain to montane levels with Ranunculion fluitantis and Callitricho-Batrachion vegetation* (further referred to as *River riffles and natural river reaches*) includes two variants of the habitat:

1st variant: rivers or river reaches with the riverbed covered with boulders or pebbles, with the stream velocity > 0.2 m/s;

2nd variant: all natural rivers and river reaches, in which the stream velocity is < 0.2 m/s; the naturalness is indicated by an unmodified riverbed.

Dammed, straightened, deepened river reaches, where the average stream velocity is less than 0.2 m/s, are not considered as this habitat type (Eņģele, Sniedze-Kretalova 2013)[72].

[72] Order of the Ministry of Agriculture No. 168, 16.12.2016 "State amelioration system 2016. Data"

In comparison with lake habitats, there are much less rare and specially protected vascular plant and moss species in rivers in Latvia.

River stretches, where the sequence of riffles and pools ensures the coexistence of diverse microhabitats in a small area, are biologically the most diverse river habitats. The river riffle reaches, due to the gravitational potential energy of the water, have a high capacity of hydroenergetic resources. However, by installing water reservoirs and watermill ponds, the riffle habitat in many places has been significantly affected or even destroyed.

The 2nd variant also includes watercourses flowing out of raised bog lakes, where the bed consists of peat. This is a special type of watercourse, since the riverbed structure and the bank vegetation differs from the riverbed structure and bank composition in a river stretch flowing outside the bog massifs. Therefore their conservation priorities and management methods are also different. In the future it would be advisable to divide it as a separate variant of habitat.

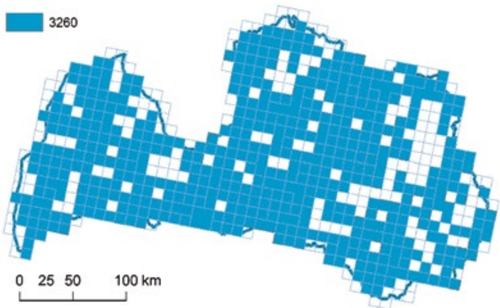

Fig. 17.1. Distribution of habitat type 3260 *River riffles and natural river reaches* in Latvia (source: Anon. 2013).

17.1.2 Indications of Favourable Conservation Status

Watercourses are open systems, which, by collecting the waters of their catchment area, are related with wide surrounding areas. Thus, the condition of the river habitat is affected by the processes in both the river itself, and in its catchment area. The processes in the river most often cause hydromorphological (stream or riverbed parameter, and shore vegetation structure related) changes. Water pollution by organic substances and plant nutrients is related to the processes in the catchment area and depends on economic activity. Depending on the main river characteristics, two types of river are distinguished – fast flowing rivers and slow flowing rivers[73]. The fast (rhithral-type) rivers are mostly dominated by reaches of river, in which the stream velocity exceeds 0,2 m/s, the river gradient is >1 m/km and the riverbed structure consists mainly of coarse gravel, cobbles and boulders; sand covered areas can be found in eddy sections and the shore part of the river. The flow of a river of this type is turbulent, and different water layers can have a very different stream velocity. The occurrence of small fine-grained and silt fractions in the riverbed indicates the activation of sedimentation processes and hydromorphological changes.

The average stream velocity in slow rivers characteristic for lowlands and belonging to the potamal river type, is usually less than 0,2 m/s. The stream flow is laminar, more aligned and even in different water layers. The structure of the riverbed is composed of fine sand or clay that is covered with mud and detritus - dead plant material in various stages of decay.

According to the average river gradient per kilometre, stream velocity and the dominant riverbed composition, the fast and slow rivers are divided into Salmonid and Cyprinid waters. In the conditions of Latvia, typical salmonid streams are the lower reaches of rivers flowing into the sea, uplands, as well as the lower reaches of the tributaries of large rivers. Rivers that are considered as Cyprinid waters, are typical in Zemgale Plain and the East-Latvian Lowland. According to the dominant characteristics (stream velocity, channel composition) a river, in different reaches, can match the criteria of both a fast river (Salmonid waters) and a slow river (Cyprinid waters).

The fast rivers, inhabited by salmonid fish, correspond to the 1st variant of the habitat – river riffles – rivers or river reaches with the riverbed covered with boulders, cobbles or pebbles, with a stream velocity > 0,2 m/s. The slow rivers, inhabited by cyprinids, correspond to the 2nd variant of the habitat – all natural rivers and river reaches, in which the stream velocity is less than 0,2 metres per second.

1st variant. Under favourable conservation status, the characteristics of this habitat variant include the sequence of riffles and pools, a diverse riverbed-forming substrate mosaic - coarse gravel and stones in the fast flowing sections, and sand in eddy sections and shore parts. In many cases such watercourses have characteristic groundwater discharges and feeding from springs. The water temperature in July and August is < 18 °C (Birzaks 2013). The overgrowth of the river with macrophytes does not exceed 30%. There are no large volumes of fallen trees in the river, and bank erosion does not exceed 5% (EVS-EN 15843:2010; Urtāne 2015). River banks are moderately shaded. The sunlit and the shaded shore sections form a mosaic with a ratio of 30:70 (Urtāns 1989; Anon. 2002b).

2nd variant. Under favourable conservation status, this variant of the habitat is characterised by a larger proportion of naturally sunlit river reaches. The sunlit and the shaded shore sections form a mosaic with a ratio of 50:50 (Urtāns 1989; Cowx, Welcomme (eds.) 1998). In river habitats under favourable conservation status, the water temperature in the summer months varies around 18 °C and only temporarily exceeds 20–22 °C. Although the dominant riverbed substrate in these habitats is fine sand, covered with mud and detritus of various coarseness, they also have reaches where the riverbed is covered in stones and gravel. Such river parts are biologically more diverse.

For both variants, favourable conservation status of the habitats is characterised by:

- conditions, when optimal river bank sun-lighting allows the formation of a narrow herbaceous plant belt;
- the number of trees fallen into rivers (diameter > 10 cm) does not exceed 12 trees per 100 m in agricultural land, or 20–27 trees per 100 m in forest land (Degerman 2008);
- sediment accumulation in the river does not exceed 5% of the riverbed area (EVS–EN 15843:2010; Urtāne 2015);

[73] This division of rivers is set in Cabinet Regulation No. 858 of 19 October 2004, regarding the Characterisation of the Types, Classification, Quality Criteria of Surface Water Bodies and the Procedures for the Determination of Anthropogenic Loads.

- in the sunlit river reaches, filamentous green algal stands are not observed in more than 5% of the river surface; cyanobacteria are found only in the form of separate micro-scale film on surfaces (near the internal drainage and wastewater inlet places); rivers flowing in raised bogs have no shading on the banks; the overgrowth of the riverbed consists of aquatic *Sphagnum* species and the rare *Batrachospermum* spp. – a protected species and indicator species of the water habitats in Latvia.

17.1.3 Important Processes and Structures

17.1.3.1 Mechanisms of Water and Substance Transport

The mechanisms of substance and water transport in rivers are affected by the surrounding ongoing economic activity (logging, agricultural activity), which contributes to soil erosion and entry of sediments into the water, as well as to the reduction of water throughflow capacity due to sedimentation of the material carried by the stream.

Under the force of gravity, water flow forms in rivers and it transports substances and chemical compounds that have leaked or dissolved in the water. Water is a universal solvent, and the water flow also transports the substances dissolved in the water (Fig. 17.2). The amount of these substances can be very large. According to the stream velocity, the water stream also transports particles of a particular size. Therefore, riverbeds in the fast flowing rivers are covered with coarse gravel and stones of different sizes, but the accumulation of sand indicates the activation of sedimentation processes and changes in the natural riverbed structure. If the composition of the riverbed changes, the habitat becomes unsuitable for various organism groups that are characteristic for fast flowing river habitats. For example, if the sand fraction in the riffle is > 15%, it becomes unsuitable for the spawning of salmonids (Madsen 1995). If the sand fraction is > 25%, bivalves die out – *Unio crassus* and *Margaritifera margaritifera* (Madsen 1995).

The interdependent mechanisms of rivers and their shore area are described and explained by the **River Continuum Concept** and the **Flood Pulse Concept**. Both of these concepts, complementing each other, describe the two major processes in rivers: processes, which take place in the longitudinal direction of a river - starting from the outlet to the mouth, and processes that occur in the terrestrial areas adjacent to lowland rivers - river corridor areas, as they interact with rivers.

River Continuum Concept. According to this concept, a river as an open ecosystem, interacting with its shore area, accumulates, transforms and transports energy in the form of organic matter from the upper reaches to the mouth of the river (Vannote 1980). Through natural processes the energy reaches the river ecosystem and is created in the form of various organic substances:

- shore vegetation, like tree leaves, needles, branches, dead aquatic plants, etc.;
- production from the river itself (phytoplankton, zooplankton, zoobenthos, algal, bacterial and protozoan periphyton, macrophytes, etc.;
- with transport of organic substances from the upper reaches to the lower reaches.

As a result of human economic activities, energy also reaches rivers in the form of pollution - with wastewaters and the diffuse runoff from agricultural areas.

The type of energy source changes in the downstream direction (from the outlet to the mouth). In the upper reaches of a river, organic substances mostly reach the water from the terrestrial ecosystem in the form of litter from trees and terrestrial vegetation. In a river they can be found in the form of detritus of various coarse-

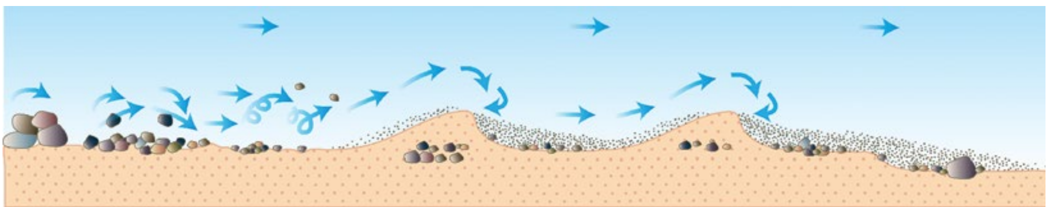

Fig. 17.2. Sediment movement and settling as the stream velocity in the bottom water layer decreases. Drawing by D. Segliņa.

ness or periphyton (periphytic algae that grows on stones on the riverbed). At the middle reaches of a river, rich aquatic vegetation usually develops by using the substrate with organic substances carried down from the upper reaches and those washed in from the banks. It consists of submerged, floating-leaved and emergent plant stands, which, in turn, create habitats and feeding areas for many aquatic organism groups. At the lower reaches of a river, the impact of organic substance input from terrestrial ecosystems is lowest, because the river width versus shoreline length ratio changes. The role of periphytic organisms (periphyton) decreases, but the importance of the organisms inhabiting the water mass increases. The lower reaches of a river have a higher number of algal and zooplankton communities.

The River Continuum Concept is best illustrated by the changes in the proportion of the functional groups of invertebrates. Aquatic organisms, depending on the type of food base, are divided into four functional feeding groups: shredders, collectors (including collector-filterers), scrapers, and predators. The numerical ratio of these groups differs at the upper and lower reaches of a river (Fig. 17.3). Therefore, the upper and lower reaches of each river differ significantly. In the direction from the outlet to the mouth, not only does the composition and number of various hydrobiont groups in the river change, but also varies other parameters characteristic for the quality of river. Biological and chemical oxygen demand, water temperature, thickness of the mud layer, the total number of organisms and the biomass, as well as other parameters increase, while flow velocity, atmospheric aeration intensity, water clarity, and other parameters decrease (Cimdiņš 2001).

Latvian rivers are new geological formations, so the classic longitudinal profiles - high gradient at the upper reaches and low gradient at the lower reaches - have not yet formed for them. Many rivers in Latvia have high gradients not only in the upper reaches, but also in the middle and lower reaches. Organism groups that are traditionally characteristic for the upper reaches of a river, are also present at the middle and lower reaches in Latvia.

Flood Pulse Concept. The concept was developed at the end of the 20th century (Anon. 2001). It explains the unity of rivers and floodplain ecosystems in time and in space (Fig. 17.4). According to the Flood Pulse Concept, a river and its floodplain form a joint system with a unified balance of water and sediments, as well as exchange organisms and energy. The main factor that determines the existence, structure, productivity and metabolic processes of such systems, is "flood pulse", which incorporates periodic flooding and the subsequent low water periods. According to the concept, a floodplain, in which the terrestrial and underwater conditions vary periodically, is called the aquatic/terrestrial transition zone (ATTZ). The time period during which a portion of this zone is in terrestrial or underwater conditions, is called the terrestrial phase or the aquatic phase (Anon. 2001). The Flood Pulse Concept provides the theoretical justification for various river floodplain rewetting projects (Gruberts 2006).

During the first half of the flooding period, the lowest part of the floodplain forms under conditions that are at first characteristic for wet grassland and a wetland, then - a shallow water body, and later – a deep, stratified lake or a riverbed. As the water level falls, conditions in the floodplain change in the opposite order.

The majority of primary and secondary production is generated in the floodplain, while the riverbed provides for the transport of water and substances. The riverbed serves as a migration route for aquatic organisms and a retreat during low-water periods (Anon. 2001).

After receding of the flood, terrestrial and freshwater bioceonosis develop in a floodplain, regardless of the river which was flowing into the floodplain earlier. During flooding the seasonal development is interrupted and resumes again later. In the lower floodplain sectors it occurs every year. In the highest sectors it can only occur if there is a very high floodwater level (Anon. 2001). The regularity of flooding determines the development of distinctive microhabitats and plant and animal communities inhabiting them along the watercourses. Unlike flooding, which is natural, floods are a critical form of flooding, which in most cases occur as a result of human activity. Floods are occasional. In Latvian conditions, the Flood Pulse Concept fits medium and large plain rivers better. Processes in the shore area of these rivers complement the changes in productivity described in the River Continuum Concept, by comparing the productivity of the upper and lower reaches of a river.

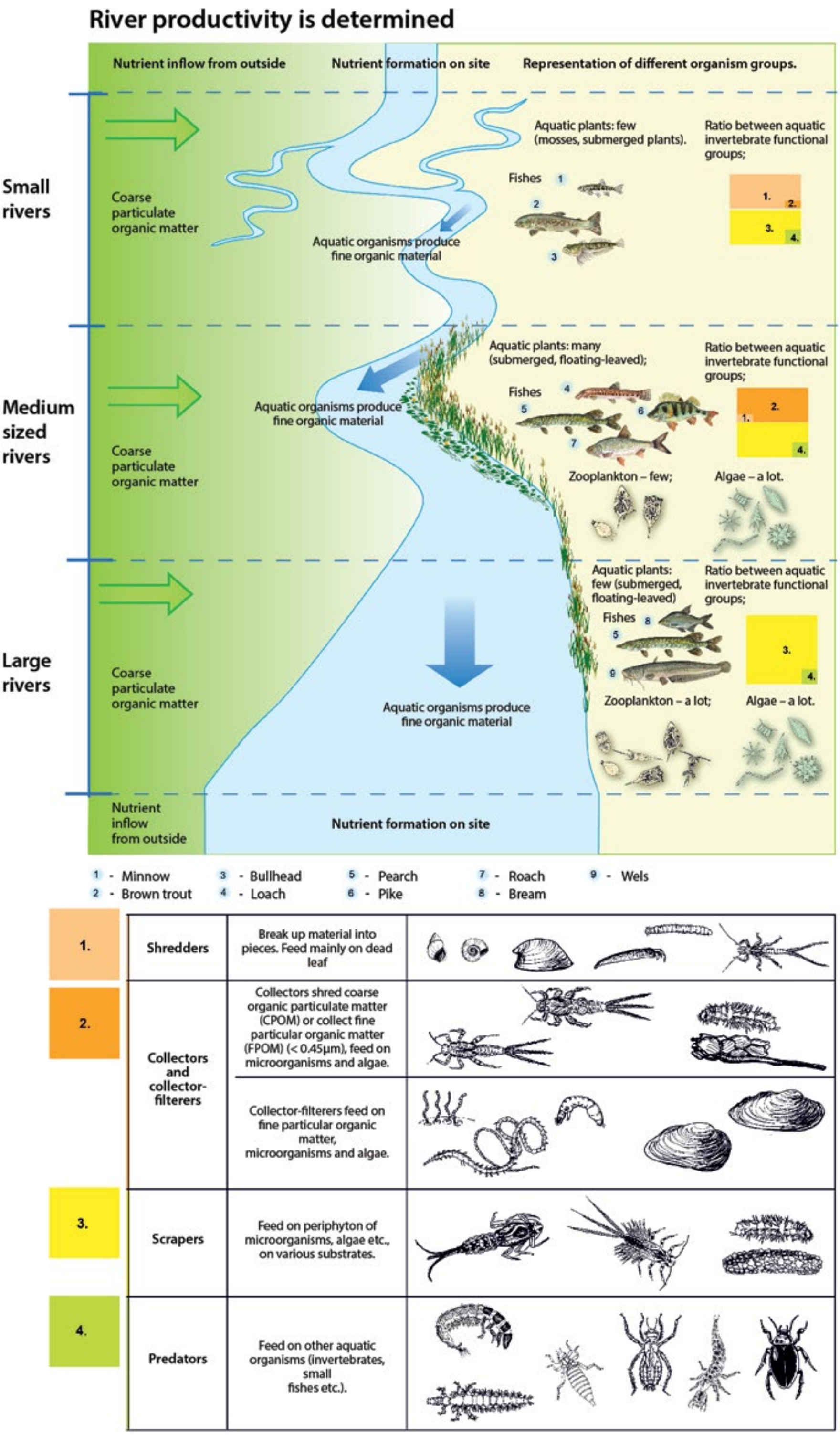

Fig. 17.3. River Continuum Concept. Drawing by L. Urtāne (explanation of the concept, drawings of invertebrates), D. Segliņa (drawing).

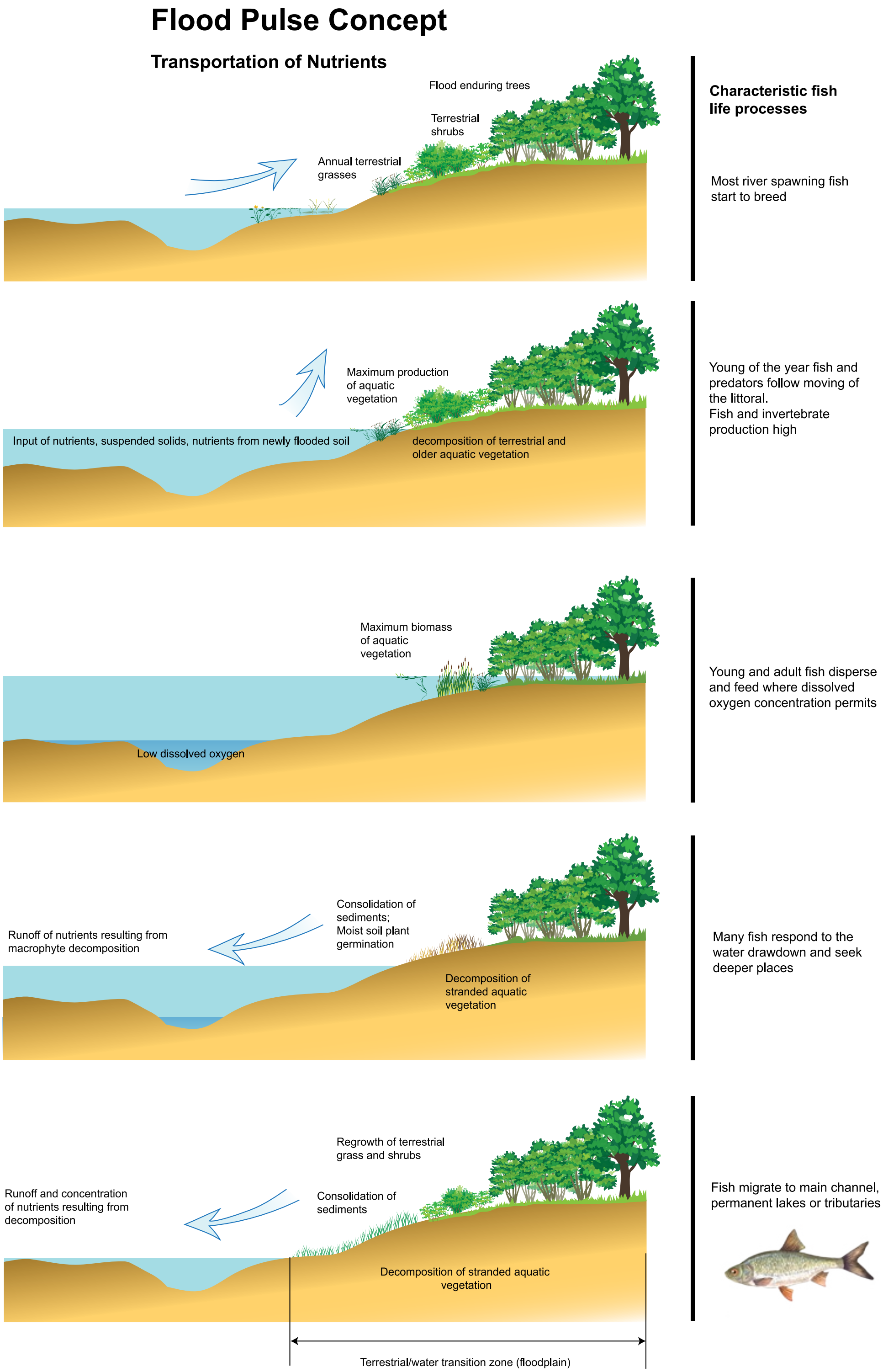

Fig. 17.4. Flood Pulse Concept. Drawing by D. Segliņa (according to Anon. 2001).

17.1.3.2 Self-purification

Rivers have the unique ability to reduce the amount of organic substances entering them. Organic substances (dead plant and animal particles) and plant nutrients (biogenic elements) that are discharged into or formed in rivers, or drained along with wastewaters during the biochemical and physical processes occurring in the river, are transformed into compounds, which can be used by plants or animals, or settle down as sediments. In this way the river reduces its pollution levels.

The size and efficiency of a river's self-purification capacity is determined by the stream velocity, the flow rate of the river, the characteristics of the riverbed and the structure of the shore vegetation (Wetzel 2001; Cimdiņš 2001; Degerman 2008). Fast flowing rivers (stream velocity > 0.2 m/s) have the highest self-purification ability. Degradation of organic matter in rivers is at least four times faster than in standing waters, since the periphytic bacteria and algae here have perfect contact with the thin layer of waters flowing over them. In small rivers, around 10 000 m^3 of water per hour comes into contact with a 1000 kg periphyton layer or biofilm, consisting of various groups of microorganisms (Cimdiņš 2001). During the contact, microorganisms break down the organic substances in the water and absorb them in their biomass, and through this process the self-purification of the water takes place. In riffles, due to the stony riverbed and the turbulent water flow, the amount of dissolved oxygen increases. It allows diverse habitats – the biofilm, to form on the stones of a riffle riverbed (Sand-Jensen (ed.) 2005; O'Grady 2006). The biofilm consists of bacteria, algae, protozoa, which, in order to maintain their own life processes, utilise organic matter, thus reducing its total amount in water. Such "covered" stone surface provides many other aquatic organisms with an adequate food base too (Fig. 17.5).

The previously described principle of the functioning of the biofilm and its ability to break down and consume organic compounds is also used in wastewater treatment plants. It is estimated that a 5–10 m^2 wide riffle area can reduce the organic pollution made by one person, known as Population Equivalent (PE).

17.1.3.3 Protection belts

Protection belts are established to reduce the negative impacts of pollution on aquatic ecosystems – watercourses, lakes and artificial water bodies, to prevent the development of erosion processes, to limit economic activity in potentially flooded areas and to preserve the characteristic landscape of the region. It is determined by the Protection Zone Law (*see Chapter 8*). A well-functioning protection zone not only reduces the amount of pollution discharged in water, by intercepting and accumulating the dissolved plant nutrients, but it is also crucial for the reduction of the sediment flow (Eberstaller-Fleischanderl et al. 2010) (Fig. 17.6).

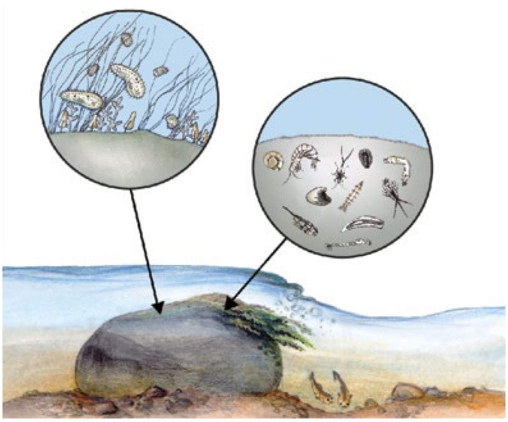

Fig. 17.5 Microorganisms forming periphyton on the hard surfaces in the water – the biofilm, and microorganisms and invertebrates consuming them. Drawing by Z. Rubene (according to Beuschold 1984). Photo: J. Urtāns.

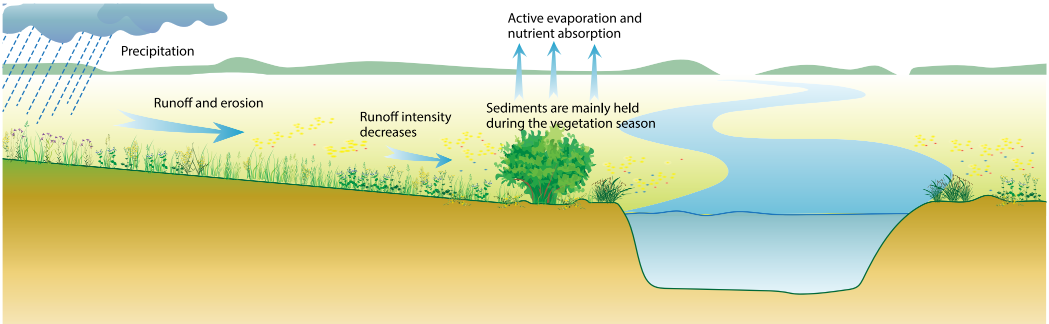

Fig. 17.6 Basic principles for functioning of the protection zone. Drawing by D. Segliņa (according to Anon. 2001).

Phosphorus compounds are leached out of any type of soil in small amounts. They are leached out in large quantities from intensively farmed agricultural lands. Discharge of the dissolved phosphorus compounds into waters is mostly related to the surface runoff, less – with drainage runoff. Higher amount of phosphorus compounds is bound in heavy clay soils with a low filtration coefficient; lower phosphorus content is observed in light soils with a high content of sand fractions (Jansons 2013).

The observation of long-term agricultural runoff shows that around 65% of the soil losses caused by erosion have been recorded from January to March, and only 6% – from April to August, when fields are covered in stable vegetation (Jansons 2013) (Fig. 17.7). This confirms the significance of herbaceous plant vegetation and stable groundcover in the delay of erosion processes and the related limitation of sedimentation processes. It is especially important during the winter months and spring flooding. The measurements show that an up to 2 m wide vegetation belt along the drainage ditch or a river bank, serves as a good protection zone and may hold 50–60% of soil particles and erosion products (Jansons 2013).

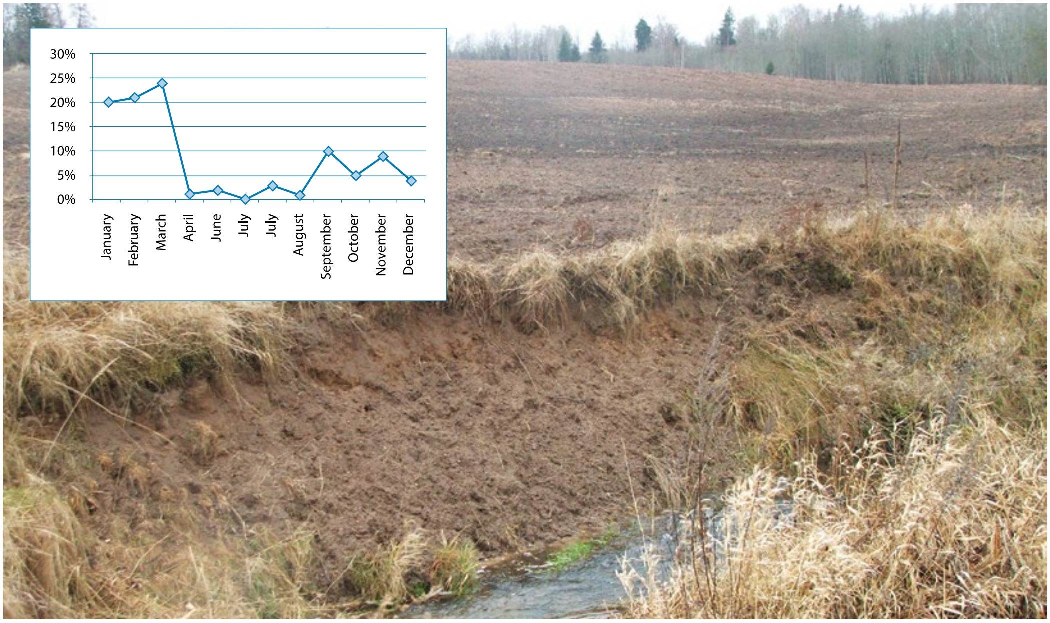

Fig. 17.7. Non-compliance with the requirements of the protection zone and field cultivation up to the upper bluff of watercourses, leads to washing out of soil material, thus contributing to the increase of sedimentation processes. In the photo – River Jādekša. The soil loss graph was prepared using the monitoring station data of the River Mellupīte (2001–2012). Photo: A. V. Urtāns (source: Jansons 2013).

17.1.3.4 River Shoreline as an Overlay Area of the Biological System

The river shoreline is the location of the transition and overlay (ecotone) of two biological systems – water and terrestrial area. It involves processes that are relevant to both systems, and it has high biological diversity. The width of the overlay zone of both systems varies from a few to up to dozens of metres, and depends on the size of the river. The shore area is a hiding place and migration corridor for terrestrial organisms. Its use for this purpose depends on the composition and quality of the shore area vegetation. The shore zone provides the maintenance of the water temperature regime (cooling or heating), regulates the intensity of photosynthetic processes taking place in the water (facilitates or hinders) and provides the river with organic matter. The overlay zone is a place of stay and a feeding place for water-related organisms – here the larvae of aquatic insects change into flying specimens, adult aquatic insects – beetles and dragonflies – reside and feed. The shore zone plays an important role in the strengthening of the banks and the limiting of erosion processes (Fig. 17.8).

In large areas intensively used for agriculture, riverbank zones are important hiding and residing places, as well as movement corridors for animals, ensuring species dispersal, breeding and population stability (Madsen 1995).

17.1.4 Habitat-specific Species of Macrophytes

Based on botanical studies of Latvian lakes (Āboliņa 1968, 1994; Tabaka, Gavrilova, Fatare 1988; Gavrilova 1985; Gavrilova, Šulcs 1999; Grīnberga 2011; Priedītis 2014; Urtāns 1995; Uzule 2015; Vizule-Kahovska; Uzule 2016), a list of macrophyte species of charophyte lakes has been compiled (Table 17.1). It consists of 94 vascular plant species, 18 moss species and four charophyte species, of which 36 are habitat-characteristic species.

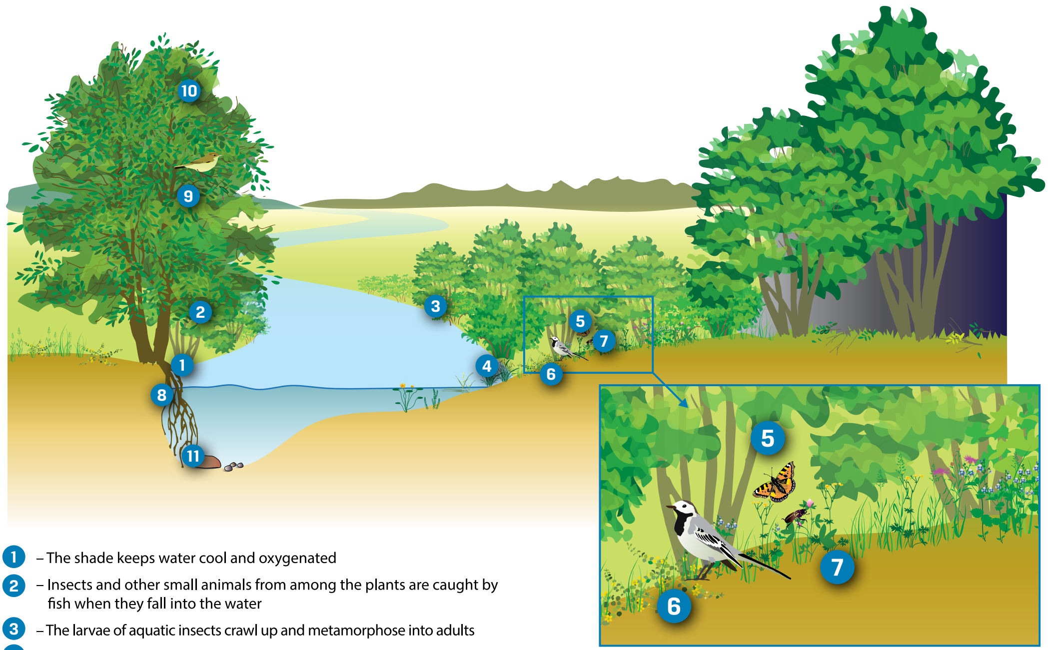

Fig. 17.8. Processes taking place in the river shore area: Drawing by D. Segliņa (according to Madsen 1995).

Table 17.1. Macrophyte species found in riffles and natural river reaches.

Vascular plants		
Acorus calamus	*Glyceria maxima*	*Potamogeton lucens*
Alisma gramineum	*Hippuris vulgaris*	*Potamogeton natans*
Alisma lanceolatum	*Hottonia palustris*	***Potamogeton x nitens***
Alisma plantago-aquatica	*Hydrocharis morsus-ranae*	*Potamogeton obtusifolius*
Batrachium aquatile	*Iris pseudacorus*	*Potamogeton pectinatus*
Batrachium baudotii	***Leersia oryzoides***	*Potamogeton perfoliatus*
Batrachium circinatum	***Lemna gibba***	*Potamogeton praelongus*
Batrachium eradicatum	*Lemna minor*	***Potamogeton pusillus***
Batrachium hederaceum	*Lemna trisulca*	***Potamogeton x salicifolius***
Batrachium peltatum	***Limosella aquatica***	***Potamogeton x sparganifolius***
Batrachium trichophyllum	*Mentha aquatica*	***Potamogeton x suecicus***
Berula erecta	*Menyanthes trifoliata*	*Ranunculus lingua*
Butomus umbellatus	*Myriophyllum spicatum*	*Ranunculus reptans*
Callitriche cophocarpa	*Myriophyllum verticillatum*	*Rorippa amphibiaa*
Callitriche hermaphroditica	*Naumburgia thyrsiflora*	*Rumex hydrolapathum*
Callitriche palustris	*Nuphar lutea*	*Sagittaria sagittifolia*
Callitriche stagnalis	*Nymphaea alba*	*Scirpus lacustris*
Carex acuta	*Nymphaea candida*	***Scirpus tabernaemontani***
Carex acutiformis	*Oenan the aquatica*	***Scolochloa festucacea***
Carex lasiocarpa	*Phalaroides arundinaceae*	*Sium latifolium*
Carex riparia	*Phragmites australis*	*Sparganium emersum*
Carex rostrata	*Polygonum amphibium*	*Sparganium erectum*
Carex vesicaria	***Potamogeton alpinus***	*Sparganium microcarpum*
Catabrosa aquatica	***Potamogeton x angustifolius***	*Sparganium minimum*
Ceratophyllum demersum	*Potamogeton berchtoldii*	*Spirodela polyrhiza*
Crassula aquatica	*Potamogeton compressus*	*Stratiotes aloides*
Elatine hydropiper	*Potamogeton crispus*	*Typha angustifolia*
Eleocharis acicularis	***Potamogeton x fennicus***	*Typha latifolia*
Eleocharis palustris	***Potamogeton x fluitans***	*Veronica anagallis-aquatica*

Vascular plants		
Elodea canadensis	*Potamogeton friesii*	*Veronica beccabunga*
Equisetum fluviatile	*Potamogeton gramineus*	*Utricularia vulgaris*
Glyceria fluitans	***Potamogeton lacunatus***	***Zannichellia palustris***
Charophytes		
Chara globularis	*Chara vulgaris*	***Tolypella prolifera***
Mosses		
Chiloscyphus polyanthos	***Fissidens fontanus***	***Platyhypnidium riparioides***
Cinclidotus danubicus	*Fontinalis antipyretica*	*Riccia fluitans*
Dichelyma falcatum	***Fontinalis hypnoides***	***Ricciocarpos natans***
Dichodontium pellucidum	***Hygroamblystegium fluviatile***	*Sphagnum magellanicum*
Drepanocladus aduncus	***Hygroamblystegium tenax***	*Sphagnum riparium*
Fissidens arnoldii	***Hygrohypnum luridum***	
Fissidens crassipes	*Leptodictyum riparium*	

Note: Rare and protected species are highlighted in color, the habitat characteristic species, whose presence and sufficient distribution in a particular lake distinguishes this habitat from other lake habitats, have background imprinting.

17.1.5 Natural Development of a Habitat

The natural development of the habitat is closely related to the processes in the river catchment area and the river itself. Natural river habitat development is described by the River Continiuum and Flood Pulse concepts (*see Chapter 17.1.3.1*)

In Latvia, there are no territories in which no economic activity takes place or has not taken place in the recent past. In those circumstances natural development could be considered a situation, in which the nutrient inflow from the catchment area of the river reach and the upstream river reach corresponds to the natural one and does not significantly exceed the background level.

Natural development is indicated by a situation where:

- the river type corresponds to the natural gradient and, due to physical clogging (large wooden debris, beaver dams, stone dams), it has not changed from a rhithral (fast flowing) river to a potamal (slow) river;
- the river has a bottom substrate structure corresponding to its type;
- aquatic plant overgrowth does not exceed 30% of the river.

If the state of the river does not comply with above, the habitat is affected by human activities and its development cannot be considered natural.

17.1.6 Pressures and Threats

17.1.6.1 Eutrophication

Process characterisation. Eutrophication is the process of water enrichment with plant nutrients, mostly with soluble phosphorus and nitrogen compounds. The most visible manifestation of eutrophication is an increased development of algae and aquatic plants. Aquatic plants have always been an important group of aquatic organisms. They are essential as food for other aquatic organisms, as a habitat or hiding place for aquatic organisms, and as sediment flow interceptors and depositors. The presence of aquatic plants in a river depends on the geomorphological features of the river – the size of particles forming on the riverbed, and on the hydrological regime of the river – the minimum and maximum stream velocity, the frequency and rate of flooding. It is also affected by the river surface shading caused by the bank vegetation. All of the listed parameters can vary considerably, for example, in the rivers of the Plains of Zemgale and the hillside rivers of the Vidzeme Upland. Through experiments (Madsen 1995) it has been proven that, if the aquatic plant overgrowth exceeds 20–30% of the river surface, negative side effects start to appear - bank erosion, enhanced leakage of plant nutrients and related increase of deposit sedimentation (Fig. 17.9).

Characterisation of the impact. In surface water management practice, aquatic plant overgrowth of 20–30% is considered as the threshold of good ecological quality (Urtāns 1989; Cowx, Welcomme (eds.) 1998; O'Grady 2006; Buisson et al. 2008; Degerman 2008).

At the end of the vegetation season, the green aquatic vegetation mass dies off, and the nutrients that were used for its formation are stored in the root system, so they can create a new green mass the next year. From the dead aquatic plants, particularly of the emergent plants, a coarse detritus is formed in rivers, which decomposes slowly and is increased at the end of each vegetation season. The most intense detrital accumulation occurs in the slow rivers (stream velocity < 0.1 m/s) and sometimes in the deepest places – pools – of fast flowing watercourses. A riverbed covered with coarse detritus is a specific microhabitat, which can only be inhabited by certain species of aquatic organisms, therefore the diversity of microhabitats and the related biodiversity in the river decreases (Urtāns, Urtāne 2012). The amount of macrophytes and degree of overgrowth affects the water throughflow and plays a role in building riverbed substrate.

The degree of overgrowth of the river also has an impact on the structure of fish communities. The total number of fish is significantly smaller in river reaches without aquatic plant overgrowth. As the overgrowth increases to 30%, the number of fish belonging to the group of ecologically tolerant fish species - *Esox lucius, Rutilus rutilus, Leuciscus cephalus, Alburnus alburnus, Perca fluviatilis* increases significantly. As the overgrowth of the river increases, the total number of fish species increases, but the ratio between ecological groups of fish changes. The number of fish that are characteristic of fast flowing and oxygen-rich rivers – trouts and minnows, decreases, but the number of *Gobio gobio, Alburnoides bipunctatus* increases (Birzaks 2013).

17.1.6.2 Large Woody Debris

Process characterisation. Due to changes in the form of economic activity, in many places along rivers the existing former agricultural land is overgrown with tree and shrub pioneer species - *Alnus incana, Salix* spp., *Padus avium*, more rarely with *Betula* spp. and *Populus tremula*. As a result of bank overgrowth and its caused shading, the herbaceous plants, which had previously grown on the shore part, disappear, and former semi-natural grasslands are occupied by woodlands with their characteristic groundcover. This is particularly critical for *Alnus incana* stands, where stable groundcover does not develop due to dense shading.

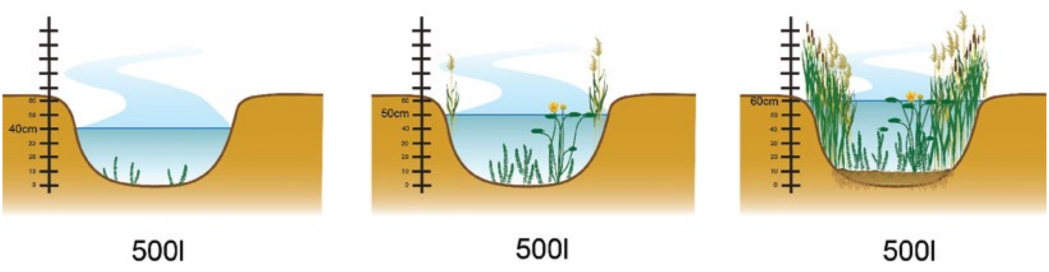

Fig. 17.9. Water level changes due to the increase of the overgrowth. As the water level rises, the shore soil gets rewetted, and nutrients migrate from soil into water, causing additional eutrophication. Drawing by D. Segliņa (with amendments according to Madsen 1995).

Due to bank overgrowth, wide-crowned oaks that prefer open space and well-insolated conditions, start to grow among hazels and grey alders. It promotes the faster death of trees and increases the potential of a tree falling into the river. Also, in forest stands that have been growing under natural conditions for a long time period, falling into the river is observed over time. However, it happens over a much longer period of time, and this applies to natural ageing of the forest stand and gap formation at the shore area of the river. Therefore, trees (their parts) that have fallen into the river, mostly have greater dimensions and form permanent structures in the water, which serve as habitats for different aquatic organisms. The fallen tree structures, defined as large woody debris (LWD) in the rivers, at the banks of which forest stands have been growing for a prolonged period of time, significantly differ from the litter of fallen twigs and small trees, which form in river reaches, and which flow through overgrown former agricultural land.

A new problem in Latvia and Estonia – relevant only in recent decades – is the decay of *Alnus incana* stands (Mander 1995; Arhipova et al. 2011), which worsens the condition of both types of rivers (is relevant for both types of habitat). This occurs because the stands have reached the age of maturity (around 30 years). The *Alnus incana* infection with root rot also contributes to the decay of younger trees. *Alnus incana* is one of the most common tree species, which establishes in the former agricultural lands, including the previously open bank parts of rivers. Over the course of the last 70 years, areas in Latvia occupied by *Alnus incana* have increased by 18 times (Daugaviete, Ūsīte 2006). As the root rot of *Alnus incana* has developed, the falling of trees into rivers has intensified (Fig. 17.10).

Fig. 17.10 Rot infected grey Alder *Alnus incana* on the riverbank of R. Vēždūka. Photo: L. Urtāne.

Characterisation of the impact. In many small and medium-sized rivers, the amount of fallen wood significantly exceeds the optimum amount of wood (supporting the river with the necessary organic matter resources, but not affecting the through flow). The optimum number of trees in a river is 6–12 trees (> 10 cm in diameter) per around a 100 m long river reach, which flows through agricultural land, and up to 20 - 27 trees per 100m long river reach, which flows through forest (Degerman, 2008). By mass, the natural amount of wood in a small river is 3–14 kg/m^2. The amount of wood that is atypical for a river is 16–62 kg/m^2 (SEPA 1994).

Large woody debris significantly changes the functioning of the river and its natural processes. Some of the fallen trees are used by fish (S*almo trutta fario, Leuciscus cephalus, Salmo trutta*) as hiding places. They also serve as substrate and food for aquatic invertebrates. As the number of fallen trees increases, the stream velocity significantly decreases, and often the riverbed changes too. As the stream velocity decreases, the water energy decreases and the particles of soil and organic sediments carried by the stream settle down. Thus, unstable and varying sand bars form behind the fallen-tree structures. Former gravel, pebble or stone microhabitats characteristic of fast flowing rivers are covered with sediments and becomes less biodiverse. Excess large woody debris redirects water flow, the water erodes riverbanks, and rivers become wider and shallower.

The newly formed shore parts of the shallow and wide rivers consist of weakly cohesive soil – sand bar and shoals, which, due to their instability, are not productive; they can only be inhabited by a small number of aquatic organisms. Furthermore, the water in wide and shallow rivers heats up faster and evaporates more intensely. Therefore, during the low-water period in the summer, rivers often partly dry out (Fig. 17.11).

17.1.6.3 Beaver Activity

Characterisation of the situation. The beaver (*Castor fiber*) population assessment carried out in the 1980s, showed that the optimum (formation of a healthy population and non-deterioration of the river quality) size of the beaver population in Latvia is 50 000 specimens (Balodis, 1990). Currently

Fig. 17.11. Due to shading and wooden debris accumulation, a former trout streambed has become wide and partly dried out during the low water period. Vēždūka. Photo: L. Urtāne.

the number of beavers in Latvia is more than 71 000 (VMD 2015). The number of beavers has also significantly increased in other Baltic countries, reaching quantities, which cause deterioration of the quality of rivers and their aquatic habitats (Järvet 2014; Urtāne 2015).

In 2006, the beaver population in Lithuania was around 36 000 specimens. Now the number has grown to 85 000, and unofficially the number is estimated at up to 121 000 specimens. The average density of beaver dams in Lithuania is 0,81 pcs./km in rivers with a rate of flow > 0,5 m3/s, and up to 1,1 pcs./km in drainage ditches (Pliuraite, Kesminas 2012).

In Estonia, according to data from 2013, there are 18 000 beavers that live in 4500 beaver families, and have built 11 000–12 000 dams on rivers (Lanetuu, Lode 2013).

Characterisation of the impact. The impact of beaver dam (Fig. 17.12) construction on the change of river quality depends on several factors – the type of the river, number of dams per river length unit, the location of the dam (upper, lower, or middle reaches), as well as on the condition of the river banks. In slow flowing rivers, with less water force and more intensive formation of sludge, the beaver-caused impoundment initially facilitates sedimentation of the material carried by the river, heating up the water and creating living conditions suitable for cyprinids. Initially these impounded areas also attract bats (Vintulis, *priv. comm.*), which gather food above the warmed up waters. However, the impoundment also contributes to nutrient leaching from the bank part of the flooded river stretch. Thus, along with soil particles, additional nutrients enter the stream, which in this case is regarded as pollution. Beaver dams interrupt the continuity of the river, because the upstream and downstream migration of aquatic organisms, as well as the transport of energy and substances, as described in the River Continuum Concept, is interrupted. By flooding river riffles, beavers not only interrupt the continuity of the river and significantly reduce the river's self-purification abilities, but also destroy the riffle habitats, which, due to their biological diversity and the function of maintaining oxygen-loving species, are important protected habitats.

In Estonia, beaver activity at the current level is considered a factor influencing the deterioration of water quality. A watercourse is considered hydromorphologically heavily affected, if there is on average one beaver dam per a 2 km long reach in fast flowing rivers, and very heavily affected, if the density of beaver dams is one dam per kilometre. Slow rivers are considered heavily affected, if there are one or more beaver dams per 1 km long river reach (Jarvet 2014). To reduce the impact of beavers on the deterioration of the quality of aquatic habitats, a reduction of the number and activity of beavers as a national management measure has been implemented in Estonia since 2006 (Anon. 2010).

Research in Estonia shows that fish are not able to overcome dams above 30 cm in height, and the diversity of microhabitats in rivers is smaller due to the sedimentation processes dominant in the beaver impoundments (Järvekülg et al. 2003).

Lithuanian research in three different rivers shows that the taxonomic diversity of macrozoobenthos in beaver impoundments is lower than in the river reaches above and below them (Pliuraite, Kesminas, 2012), confirming that beaver dams affect the structure of aquatic invertebrate communities by replacing the organism groups of flowing waters with the organism groups characteristic for stagnant waters. In the sections flooded by beavers, the number of organisms of the collector/gatherer functional group – *Chironomus* and *Oligochaeta* – increased. The number of organisms of shredder (detritophagous) and scraper functional groups decreased, although the organic matter that can be used as their food was abundant in the water. Such a decrease in the quantity of shredder organisms was explained by changes in stream velocity and the disappearance of substrates suitable for them (Pliuraite, Kesminas 2012).

The study found that by maintaining 4500–5000 beaver lodges, the total amount of sediments washed into Estonian rivers is 30 000–50 000 m^3 per year. If the characteristic values of beaver activity obtained in Estonia are transferred to Latvia, it can be concluded that the yearly volume of sediments washed into rivers due to beaver activity is from 118 000 to 197 000 m^3. In comparison, the River Venta in the second largest Latvia's harbour – Ventspils port district, brings in on average around 115 000 m^3 of sand per year, which is taken out to maintain port activity (Anon. 2001).

A comprehensive study on the impact of beavers, surveying 3189 beaver families, was carried out in Estonia (Lanetuu, Lode, 2013). The criteria developed can be used to evaluate the impact of beaver activities on the quality of rivers. They showed that:

- in 19% of cases (n = 609) the beaver populated areas were not impounded, but lodges were built on river banks, in burrows, etc.;
- in order to ensure the needs of one beaver family, in most cases 1–4 dams were built, five dams were built in 8% of the cases, six and more dams – in 10% of the cases;
- one beaver family uses a yearly average of 1 m^3 of wood for food (assuming that such volume of the trees is damaged by flooding the area);
- the total yearly wood loss caused by 18 000 beavers is 35 000–40 000 m^3 of flooded and dead wood, and 4500 m^3 of branches (about 1 m^3 per year per one beaver family);
- one beaver family during a year restores and builds approximately 30–35 m of lodges and channels, and for the construction of 1 m of a lodge or a channel, 0.2 (maximum 0,5–0,7) m^3 of soil is brought into the watercourse;
- approximately a 6–7 m^3 large volume of sediments are discharged in the watercourse from one beaver family per year, if beavers inhabit lodges in mineral soils, and respectively a 10–15 m^3 large volume of sediments if beavers live in organic (peaty) soils.

Fig. 17.12. Single beaver dams frequently transform into a dam cascade. R. Vašleja. Photo: A. V. Urtāns.

17.1.6.4 Shading

Process characterisation. Optimal shading ensures the necessary temperature regime and regulates the intensity of the photosynthetic processes taking place in the water. In fast flowing rivers (1st variant of the habitat), there is a low water temperature under natural conditions (during the summer vegetation season < 18 °C) and low volumes of primary production (algae, aquatic plants). Therefore their banks must be moderately shaded, the insolated and shaded shore sections form a mosaic with a ratio of 30:70 (Anon. 2002b; Urtāne 2015). Slow rivers (2nd variant of the habitat) under natural conditions have a higher water temperature (during the summer vegetation season > 18 °C) and large amounts of primary production (algae, aquatic plants). Therefore their banks have a greater proportion of insolated sections - the illuminated and shaded shore sections form a mosaic with a ratio of 50:50 (Cowx, Welcomme (eds.) 1998; Urtāne 2015).

Since large areas of former agricultural lands are overgrown with shrubs and tree pioneer species, most of the small and medium-sized Latvian rivers currently have higher shading than optimal. This mainly applies to areas, in which intensive agricultural activity does not take place. In areas with intensive agricultural activity, mainly in the Zemgale region, rivers are excessively illuminated.

Characterisation of the impact. Shading by woody species is essential for the maintenance of the temperature regime (Fig. 17.13). It also affects the oxygen regime. Temperature difference in the same, up to 1 km long unshaded and shaded river reaches can be up to 3.5 °C (Eipurs 1984; Armstrong et al. 2010). In shaded river reaches, more oxygen dissolves due to the lower water temperature. The

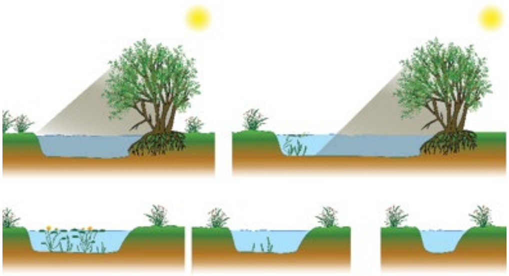

Fig. 17.13. The influence of shading depending on the shore overgrowth and the width of the watercourse. Drawing by D. Segliņa (according to Buisson et al. 2006).

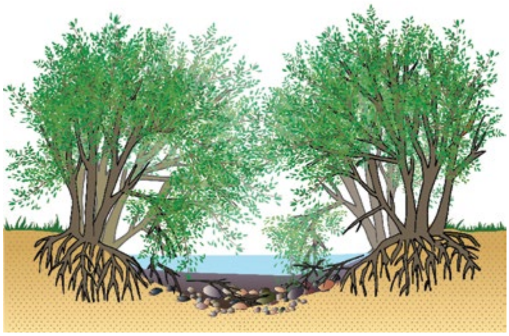

Fig. 17.14. Excessive shading causes riverbank instability and facilitates erosional processes. Drawing by D. Segliņa.

primary production and the water's self-purification ability in such river reaches is lower, because, due to insufficient insolation, algae, bacteria and consequently protozoa which by overgrowing stone surfaces are actively involved in breakdown of organic substances do not develop in them. The lack of biofilm as food for aquatic invertebrates reduces the diversity of fish species, and the total fish biomass in these waters is low (O'Grady 2006).

Fish species respond to the intensity of shading in the habitat in different ways. Less shaded river reaches have a significantly higher number of fish species and their specimens (Birzaks 2013). Fish species *Rutilus rutilus, Leuciscus cephalus, Alburnus bipunctatus, Alburnus alburnus, Gobio gobio, Cobitis taenia* and *Perca fluviatilis* are found in places with less shading. As the shading increases, the number of these species decreases. No *Alburnus bipunctatus* and *Cobitis taenia* can be found in completely shaded places (Birzaks 2013a). The only species, the number of specimens of which increases as the shading increases, are *Phoxinus phoxinus* and *Salmo trutta fario*. The highest number of specimens of these species are in rivers with moderate shading. There are 2.5 times less juvenile salmonids in up to 100 m long, evenly shaded river reaches than in adjacent river reaches with a mosaic of insolated and shaded sections (O'Grady 2006).

17.1.6.5 Decline of Riverbank Stability

Process characterisation. Shore area vegetation directly affects the water ecosystem, not only by shading, but also by creating an additional food supply with leaf litter (Forestry Commission 2011). Root systems of woody and herbaceous species play an important role in stabilising the riverbanks. Good riverbank stability and resistance to erosion is provided by *Alnus glutinosa*. Their root strands also create good hiding places for fish, crayfish and aquatic invertebrates. Some tree species on the riverbanks can also affect the river adversely. Such tree species include *Picea abies* and *Alnus incana*.

Picea abies creates dense shading on the riverbanks and prevents the formation of a stabilising herbaceous plant turf under them. Needle litter from *Picea abies* causes soil and water acidification. Shading and acidification contribute to the disappearance of many aquatic organisms. *Alnus incana* is classified as a softwood broadleaf tree with a short life span. Its impact on river quality and the changes of the natural shoreline structure significantly differ in primary and secondary *Alnus incana* forests. The primary *Alnus incana* forests in Latvia develop naturally. They grow naturally in river valley floodplains, on slopes and in brook ravines. These forests are classified under the European Broadleaf Forest Class, and correspond to habitat type 91E0* *Alluvial forests with Alnus glutinosa and Fraxinus excelsior* (Alno-Padion, Alnion incanae, Salicion).

Characterisation of the impact. *Alnus incana* forests are only undesirable for the river ecosystem when secondary *Alnus incana* stands form on the riverbanks as a result of overgrowth of former agricultural areas. Such stands have developed in Latvia during the last few decades. Primary and secondary *Alnus incana* stands can be distinguished by groundcover vegetation. Primary *Alnus incana* stands have natural, well-developed herbaceous plant vegetation that has formed over a long period of time. If groundcover vegetation is open, composed of unconsolidated clusters of individual herbaceous plant species, then the woodland is considered a secondary *Alnus incana* stand. Under trees in secondary A*lnus incana* stands, only shade-tolerant herbaceous plants and mosses are able to establish (Daugaviete, Ūsīte 2006). Shade-tolerant herbaceous plants and mosses do not form a continuous turf. Therefore in snowless conditions during the dormancy period in autumn and spring, after thaw and rain periods the open turf cannot prevent the flow of soil particles into the river, especially if the watercourse is located in a valley. Furthermore, *Alnus incana* has a shallow root system. Without the stabilisation provided by turf of herbaceous plants, the root system of *Alnus incana* that grows on open and often sedimentary soil, quickly gets washed away and loosened. This is why an *Alnus incana* that doesn't reach the age of maturity falls down. Having fallen into the river, they form large wood debris, thus contributing to a local water level rise and the activation of erosion processes (Fig. 17.15). This phenomenon has a domino effect, since the rise in water level contributes to the moistening and following erosion of the fragile riverbanks, which further facilitates even more intense tree falling.

The necessity for management of the secondary Alnus incana stands located on riverbanks is also determined by the fact that *Alnus incana* – a species that quickly reaches the age of maturity – can only actively intercept phosphorus until the age of 10–15 years old. This means that they only perform the river's protection zone function for 10–15 years, and in the following years their phosphorus accumulation abilities significantly reduce (Mander 2008).

17.1.6.6 Intensification of sedimentation processes

Process characterisation. Sedimentation is a natural process in watercourses. Soil particles that have entered the river through the surface runoff are deposited. A part of the soil particles that have entered the watercourse, are transported by the water stream down the river to a receiving water body (lake or sea). The higher the stream velocity and the easier it is to erode the bedrock forming the riverbed, the greater the amount of sediment transported. Therefore the natural riverbed in fast flowing rivers is basically formed by coarse gravel and stones.

As the intensity of agricultural activity and logging increases, the volume of soil particles brought into watercourses increases. Discharge of sediments from agricultural lands increases, if buffer zones are not respected and the arable land is cultivated up to the upper edge of the watercourse. The introduction of forestry-related sediments increases from logged areas, especially from clear-felled areas. During the first years felling areas are open areas with sparse herbaceous vegetation, so the precipitation previously intercepted by tree crowns now freely reaches the sparsely covered surfaces, from which, due to increased surface runoff, they end up in rivers and lakes. Along with the surface water flow, the soil material, which is not covered with the groundcover, is also transported.

The total volume of washed-out sediments depends on the type of land use, landscape structure, shape of river valley, soil type and other factors. More intense sedimentation occurs in rivers with a larger proportion of drained lands in the catchment area. The total length of the drainage systems built in Latvia is 63 500 km, and it is approximately 1,6 times the total length of rivers in Latvia (Urtāns 1989). From one square kilometre of the catchment area, up to 23 tonnes of sediments and deposits can be transported into a river (Sand-Jensen (ed.) 2006).

Characterisation of the impact. Due to the intensification of sedimentation processes the structure of the riverbed changes – the deposited sediments fill the spaces between gravel and pebbles on the riverbed. As the riverbed clogs up, the river throughflow capacity decreases.

Following the modification of life conditions, the composition of species inhabiting the riverbed changes, and species characteristic for natural rivers disappear. 14% sediment addition to the riverbed substrate already makes it unsuitable for Salmonid spawning (Madsen 1995; Cowx, Welcomme

Fig. 17.15. Shading prevents the development of herbaceous plant turf. The lack of turf contributes to the washout of soil particles located between tree roots and the intensification of shore erosion. Photo: A. V. Urtāns.

(eds.) 1998) (Fig. 17.16). A 20–25% sediment addition is the threshold when *Margarita margaritifera* and *Unio crassus* disappear from rivers (Rudzīte 2010).

As sedimentation intensifies, the amount of suspended solids also increases, thus reducing the survival abilities of filtering organisms, because their filtering organs needed for consuming nutrition are blocked. For feeding, aquatic organisms better use those sections of the biofilm, which don't have sediment additions (Degerman 2008), thus the number of sites suitable for invertebrate foraging is reduced. As the sediment depositing rate increases, the total area of biofilm formed on hard surfaces decreases, which reduces the efficiency of the river's self-purification.

The filling of mouths of rivers that flow into the sea with sand is a separate case. As a result, the mouths become shallow, narrow and hard to pass for migrating fish. Such barriers also facilitate the flooding of the lower reaches and promote favourable conditions for illegal fishing. In the past, the mouth areas of the rivers that flow into the sea were often a landing place for fishing boats. Fishermen, by deepening river mouths and maintaining the depths necessary for the movement of boats, at the same time ensured that migrating fish and lampreys reached their spawning grounds. From the point of view of river functionality, such mechanical human intervention should not be considered as deteriorating the quality of the habitat.

17.1.6.7 Watercourse Regulation

Process characterisation. Climatic conditions in Latvia determine that the amount of precipitation in the country exceeds the amount of evaporation and runoff, therefore excessive moisture accumulates in the soil. In these circumstances, the aeration of plant root systems is encumbered, and soil paludification starts, which complicates its economic use. Excessive soil moisture can be decreased by increasing runoff. For this purpose, drainage systems are established. Natural rivers are regulated by reducing their sinuosity, thus achieving faster water runoff. More than 60% of the agricultural land and about 40% of the forest land in Latvia has been drained, the total length of regulated river reaches is 13690,4 km (Ministry of Agriculture Decree No. 168 of 16 December, 2016), which is 35,7% of the total river length.

The aim of river regulation is to achieve faster runoff. Therefore rivers' longitudinal and cross sectional parameters are modified. Although the existing legal framework, when defining environmental requirements (Chapter 9 of Cabinet Regulation No. 329 of 30 June 2015, *Regulations Regarding the Latvian Construction Standard LBN 224-15 "Amelioration Systems and Hydro-technical Structures")*, describe the preconditions for the conservation of the biodiversity of rivers; regulated riverbeds do not always ensure good biological functioning of the river (Fig. 17.17).

Many rivers are regulated solely from the point of view of ensuring the lowest costs for excavation works, without taking into account the biological functions of watercourses. Bad agricultural practices – ignorance of protection belts (for rivers) and buffer zones (for drainage ditches) and field cultivation up to the upper bluff of watercourses – contributes to the increase of sedimentation processes

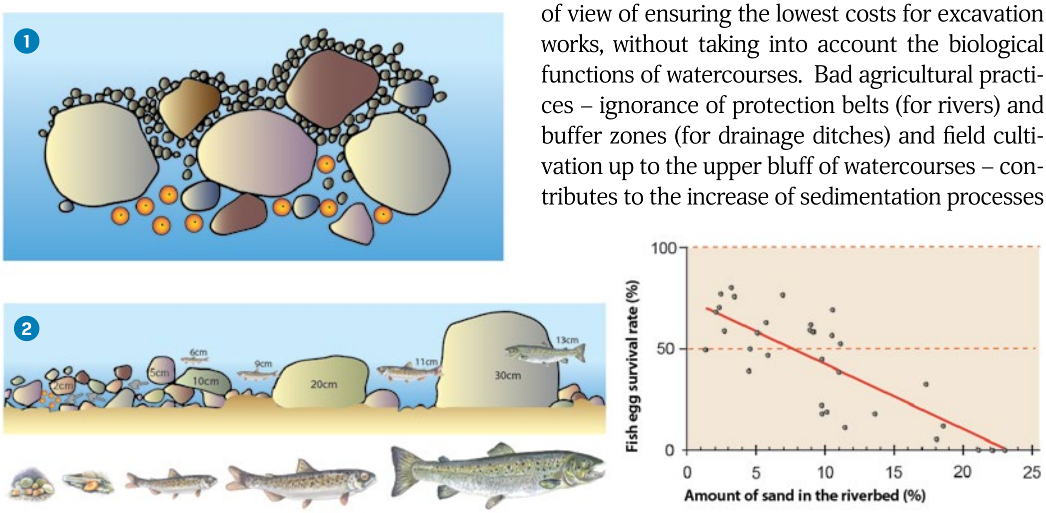

Fig. 17.16. Sediments covering salmonid spawning grounds **(1)**. Dependence of the survival of salmonids on the amount of sand accumulation in the riverbed **(2)**. Drawing by D. Segliņa (according to Cowx, Welcomme (eds.) 1998).

Fig. 17.17. A regulated reach of a fast flowing river with a uniform riverbed. The microhabitat diversity on the riverbed is low. The stone left on the riverbed is used by organisms as a hideout. Photo: A. V. Urtāns.

and rapid clogging up of channels, and results in the need for more regular stream cleaning and sediment excavation.

Characterisation of the impact. When regulating watercourses, in most cases a uniform channel bed is established. As the diversity of living conditions and the number of microhabitats decrease, the biological diversity of the river also decreases. Small morphological alteration of the river (up to 25%) does not affect the structure of the fish community. As the proportion of morphologically altered river reaches increases, the biomass of ecologically tolerant and predatory fish increases, but the biomass of ecologically sensitive fish decreases more than threefold (Birzaks 2013). In heavily altered rivers the number of fish that spawn on hard substrates (lithophils) decreases, as well as the number of specimens of insectivorous and long distance migrating species, but the number of plant spawners (phytophils) and predatory fish increases, the most common representative of which in Latvia is pike (Birzaks 2013a). As the riverbed diversity decreases, large fish lose their hideouts, and species with small specimens start dominating fish communities (Madsen 1995; Cowx, Welcomme (eds.) 1998).

Due to the altered cross section profile of the riverbed, simplified aquatic plant vegetation develops in the straightened rivers. They have no floating-leaved plants, have a small number of submerged plants, emergent plants (most often reeds) form wide and uniform stands. The lack of diverse aquatic vegetation also determines the development of simplified and species-poor invertebrate fauna (Urtāne 1992; Urtāne et al. 2012). In regulated rivers there are few or no larvae and beetle species characteristic for slow rivers (2nd variant of the habitat). Even greater differences in the composition of species can be observed in natural and regulated reaches of fast flowing rivers (1st variant of the habitat).

17.1.6.8 Dams on Rivers

Characterisation of the situation. The force of river water has been used as an energy resource for many centuries. There is historical evidence that already at the beginning of the 13th century, a mill was installed between Lake Ķīšezers and Lake Jugla, the use of which had become the subject of dispute between the Livonian Order and the city of Riga. In the early 20th century approximately 700 watermills were operating on Latvian rivers. They were constructed in places, where rivers have the highest gradient. Also nowadays, small hydroelectric power stations are often built in areas, where there have been mill dams in the past. Currently there are 146 small hydroelectric power stations on Latvian rivers. Their contribution does not exceed 1 percent of the total electricity generation in Latvia.

Characterisation of the impact Since rivers with the highest gradient are also important fish spawning grounds and a living environment for aquatic invertebrates sensitive to oxygen deficiency, the interests of the use of the river and of riffle habitat conservation are opposed when small hydroelectric power station (HPS) dams are established. Furthermore, riffles have high self-purification efficiency, which significantly decreases when a water reservoir is established on the river. Dams interrupt the movement of migratory fish. The impact of dams on the composition of fish species in the river is particularly high, if the dam is set up in the lower reaches of the river. This creates conflicts between energy producers and other groups of users – anglers, water tourists, environmental protection and water management sectors. In order to protect important riffles or fast flowing reaches of rivers and to protect fish resources, Cabinet regulations have been issued, which include a list of rivers, on the reaches of which it is prohibited to build and restore HPS dams and create any mechanical obstacles (Cabinet Regulation No. 27 of 15 January 2002, *Regulations regarding the rivers (sections of rivers) in which, with a view to the protection of fish stocks, the construction and reconstruction of* *hydroelectric power station dams and creation of any mechanical obstacle shall be prohibited*). The more than 200 rivers (their reaches) included in this list, are high-quality riffles that correspond to the 1st variant of the habitat.

Without denying the potential of the small hydro-power sector, it must be stressed that, with a few exceptions, turbine models that are currently in use in Latvia are out-dated from the point of view of hydro-power technology development, and require the establishment of impoundments on the river, thus changing the natural river flow. In addition, fishways are established in only a few small hydroelectric power stations, and the existing fish facilities almost never ensure fish protection (ZM LZPI, 2003; Environmental projects 2004). There is still no solution for how to balance the use of water energy and the conservation of riffle habitats. In addition, in many places, water power is no longer used but the remains of the old dams are not removed and continue to have a negative impact on the quality of rivers. There have only been a few cases of dismantling of dam remains (Fig. 17.18). For example, the removal of the concrete bridge and the concrete weir in the River Vikmeste (Sigulda; 2002; volume of the reinforced concrete constructions is approximately 20 m^3) and the removal of the former mill dam on the River Noriņa (rural area of Ainaži; 2015; volume of wooden constructions is approximately 5 m^3).

17.1.6.9 Invasive Species

Characterisation of the situation and the impact. Nowadays, the spread of invasive species is considered as one of the major factors affecting the quality of river habitats, and it has been facilitated by the introduction of species non-characteristic for the local conditions, and the development of trade and transport routes. Not all species imported or introduced in Latvia from abroad are considered as invasive. An invasive (from Latin *invasus* - invade, conquer) species is one that can be found outside its natural range and which causes harm to the local ecosystems. Species that are considered invasive can reproduce quickly, spread successfully and outcompete the local species.

The most often noticeable invasive plant species on riverbanks are *Heracleum sosnowskyi* and *Impatiens glandulifera*. Less frequently observed species are *Echinocystis lobata* and *Helianthus tuberosus*. In some places *Petasites hybridus* and *Impatiens parviflora* have been planted and have spread.

Heracleum sosnowskyi is the most invasive species and the most dangerous to ecosystems. It forms a sunlight-intercepting canopy, thus suppressing other plants and significantly depleting the herbaceous plant habitats. One plant can develop 3–20 thousand seeds and more, the ability to germinate of which remains for 4–6 years. Thus, after sowing a single seed, 1500–2000 seedlings per 1 m^2 develop (Lejiņš, 2007). In shore areas that are occupied by *Heracleum sosnowskyi*, bare soil is excessively washed away, promoting bank erosion.

Due to the transport function of rivers, invasive species growing on riverbanks spread more rapidly and occupy new territories much faster (Fig. 17.19). The seeds of both *Heracleum sosnowskyi* and *Impatiens glandulifera* mature in August and

Fig. 17.18. The dismantled former mill dam on the River Noriņa. Photo: A. V. Urtāns.

Fig. 17.19. Due to the transport function of rivers invasive *Heracleum sosnowskyi* growing on riverbanks spread more rapidly and take up new territories much faster. Photo: A. V. Urtāns.

early September, i.e., in the period before the autumn rainfall and the rise of the water level, which helps the seeds to spread. The seeds of *Heracleum sosnowskyi* maintain germinating ability in water for about three days. After that about 90% of the seeds sink. The banks of small rivers, where flooding waters remain for a short time, are threatened most. There *Heracleum sosnowskyi* and *Impatiens glandulifera* can be found above the line of the annual flooding level (Lejiņš 2007).

Fig. 17.20. *Pacifastacus leniusculus.* A very characteristic feature is that there is a large whitish to purple base on the joint of the claws, which is not present in any other crayfish in Latvia, and is clearly visible to young and adult specimens. Photo: A. Soms

In recent decades three crayfish species uncharacteristic of the local fauna have spread into Latvian rivers and lakes, including riffle habitats – *Astacus leptodactylus, Pacifastacus leniusculus* and *Orconectes limosus*. They create competition and a threat to the only local crayfish species – *Astacus astacus*.

Astacus leptodactylus is an invasive species that is found in some watercourses near Daugavpils, Madona, Dobele and Rīga. It inhabits various habitats – shallow and deep lakes, rivers and brooks, and it can be found on different substrates. This crayfish species can also live in brackish and acidic waters. In addition, its temperature tolerance is wider than that of *Astacus astacus*.

Pacifastacus leniusculus is an invasive species, introduced in Latvia from Lithuania, originating in the western part of North America. Its distribution has been facilitated by the competition ability of the specimen, its resistance to crayfish plague *Aphanomyces astaci* and other diseases that threaten the local species. It inhabits brooks, rivers and lakes with high water quality. This species is sensitive to environmental pollution and physical degradation of the environment.

Orconectes limosus is also an invasive species, possibly introduced to Latvia from Lithuania, originating in the eastern part of North America. It inhabits waters of various quality and has also adapted to polluted water. Similar to *Pacifastacus leniusculus*, it is resistant to crayfish plague, which threatens the local *Astacus astacus* population.

Eriocheir sinensis has been found in the Latvian shore waters and in the lower reaches of the rivers flowing into the sea. This invasive species is omnivorous, feeding on plants, algae, invertebrates, small fish, as well as bivalves. The crab itself is food for predatory fish, wading birds, otters and raccoon dogs. *Eriocheir sinensis* spend the greatest part of their lives in rivers where they can migrate upstream for several hundreds of kilometres.

17.2 Management Objectives for the Conservation of River Riffles and Natural River Reaches

Good functionality of a river not only ensures high quality of the habitat, but also the maintenance of good ecological quality in the sense of the Water Framework Directive. It means maintenance of an unchanged habitat for all habitat type characteristic species. In the case of riffle areas, it also has high economic potential. Therefore the management objective is to renew or reinforce river functions, which provide:

- Throughflow in natural conditions;
- Self-purification potential;
- Living conditions for species characteristic for the given river type;
- Unaffected organism migration upstream and downstream.

Especially protected species in riffle areas:
River Nerite *Theodoxus fluviatilis*, River *Limpet Ancylus fluviatilis*, Thick shelld river *mussel Unio crassus*, River *Clubtail Gomphus flavipes*, Snaketail *Ophiogomphus cecilia*, Freshwater Pearl Mussel *Margaritifera margaritifera*, Grayling *Thymallus thymallus*, Brook lamprey *Lampetra planeri*, River lamprey *Lampetra fluviatilis*, Salmon *Salmo salar*, Brown trout *Salmo trutta*, Spined loach *Cobitis taenia*, Bullhead *Cotus gobio.*

Conservation goal and management objective is defined by the river type, size and geographical location of the river.

Maintenance of the 1st variant of the habitat (rivers or river reaches with the riverbed covered with boulders or pebbles, with the stream velocity > 0.2 m/s) provides for the survival of riffle specific organisms as well a state in which salmonid spawning places are not disappearing.

Therefore the habitat-specific management and conservation goal is to stop water drainage detention (excessive large wooden debris accumulation, beaver dams, overgrowth with aquatic plants) and decrease the negative manifestation of sedimentation through improved riverbank structure and the creation of an optimal illumination and shading mosaic, thus ensuring the natural flow of the river and preserving the riverbed structure corresponding to the type of river.

Rivers that flow into the Baltic Sea and the Gulf of Riga belong to the 1st variant of the habitat and are economically important due to the spawning of the migratory fish – salmonids, *Vimba vimba* and *Lampetra fluviatilis*. Concerning the quality of the habitat, these species are indicators of good water quality and a significant component of the river's biodiversity.

During flooding, the sediment material carried by the river settles in floodplains, thus decreasing the amount of nutrients in the water and enriching the floodplains, where characteristic and rich terrestrial vegetation develops. This phase of the hydrological regime of the river is economically essential for the prevention of flood risk and the accumulation of flood waters. Therefore, it is important to maintain a floodplain which is not overgrown with trees and shrubs, which can be flooded during the spring flooding. An exception is the historically developed alluvial forests that are a protected habitat type of EU interest - they must be conserved as forests.

Small rivers are more threatened due to their dimensions, if their banks are overgrown with trees and shrubs, or if excessive fallen trees jam the channel. Therefore it is important to maintain optimal bank overgrowth structure to create appropriate illumination for the river type, stable bank coverage with a grassland and shrub/tree mixture, with longer biological age expectancy, which is more stable and resistant to disease.

Regardless of the specific characteristics of each watercourse, the goal of conservation and management of each river must be to ensure that the self-purification capacity is used fully. A river's self-purification capacity is maintained by the composition of species corresponding to the type of river, ensured by the optimal stream velocity, temperature regime, shading conditions, and the riverbed structure (*see Chapter 17.1.2*).

17.3 Restoration and Management of River Habitats

17.3.1 Preparation for River Habitat Management

Considering various water balance components (precipitation, runoff, evaporation, river network density), 17 hydrological districts have been identified in Latvia (Pastors 1995). The differences between various characteristic parameters of hydrological districts are remarkable – differences in precipitation can be up to 200 mm/year, evaporation differences – up to 140 mm/year, runoff differences – up to 126 mm/year. Water supply significantly affects the quality of watercourse habitats, especially in the summer's low-water period. So it is important that management ensures that the whole potential of waters of the watercourse is used effectively.

Due to unsustainable land use and due to changes in climate, flood risk has also significantly increased. Since floods often influence territories of several countries, their mitigation and prevention measures require coordinated action. On 23 October 2007, to reduce and manage the floods, the European Parliament and Council approved Directive 2007/60/EC on the assessment and management of flood risks. In Latvia, areas at risk of flooding comprise 200 000 ha, which make up 3% of the national territory. In order to reduce flood risks, the National Programme of Flood Risk Assessment and Management has been developed, and within each river basin district, areas of flood risk have been identified, as well as river basin flood risk management plans have been developed, which include measures to reduce the likelihood of floods and their effects.

Factors affecting the quality of habitats listed in Chapter 17.1.6 depend on the size of the river. It is important to assess whether these factors affect a large, a small or a medium-sized river; which are the predominant land use types in the adjacent areas and throughout the river's catchment area; whether there is a point source pollution load, etc. (Table 17.2). Therefore, it is necessary to obtain the following information before planning management for a particular river:

- the size of the river (large river: length > 100 km, catchment area > 1000 km^2; medium-sized river: length 10–100 km, catchment area 100–1000 km^2, small river: length < 10 km, catchment area < 100 km^2), which can be assessed using the national classifier of the Latvian Environment, Geology and Meteorology Centre (classifier of water management districts);
- the gradient of the river – fast flowing river (1st version of the habitat): > 1 m/km; slow river (2nd version of the habitat): < 1 m/km;
- seasonal average water supply of the river;
- whether the river (or river reach) is located in an area at risk of flood and what measures for the reduction of flood likelihood and its consequences are included in the flood risk management plan of the relevant river basin area for 2016-2021.
- land use in the river's adjacent areas (forest or agricultural land; overgrown abandoned farm land);
- proportion of types of land use in the catchment area (forests, mires, agricultural land, urban areas), which allows the potential of diffuse pollution loads, as well as the risk of intensification of sedimentation processes to be evaluated;

Conditions related to habitat management and the need for the coordination of actions are defined in legislation (*see Chapter 8*). Therefore, before the planning of river management activities, the following requirements of legislation must be referred to:

- Requirements under the Protection Zone Law, applicable to protection belts of surface water objects;
- Cabinet Regulation No. 475 of 13 June 2006, *Order for the Maintenance and Deepening of Surface Water Bodies and Water Areas of Ports.*
- Regulation of the Cabinet of Ministers No. 329 of 30 June 2015, *Regulations regarding Latvian Construction Standard LBN 224-15 "Amelioration Systems and Hydro-technical Structures"*.

Table 17.2 Factors affecting habitat quality and the relation of their potential indications to the size of the river.

Factors affecting the quality of the habitat	Group of rivers		
	Small rivers	**Medium-sized rivers**	**Large rivers**
Manifestation of eutrophication – massive aquatic plant overgrowth	x	x	The impact is small.
Manifestation of eutrophication - excessive growth of algae	Mainly filamentous green algae found on the riverbed.	Mainly filamentous green algae found on the riverbed.	Mainly planktonic algae of the water mass.
Large woody debris	x	x	The impact is small.
Beaver activity	x	x	The impact is small.
Shading	x	x	The impact is small.
Decline of riverbank stability (bank erosion)	x	x	The impact is small (except the River Gauja).
Intensification of sedimentation	x	x	The impact is small.
Regulation (straightening) of watercourses	x	x	Not applicable.
Dams on rivers	Fast flowing streams.	Fast flowing streams.	Large hydroelectric power stations.
Invasive species	x	x	x

17.3.2 Maintenance and Increasing of the Biological Diversity of Rivers

The maintenance and increasing of biodiversity can be attributed both to natural rivers and their particular reaches, and regulated rivers. The biodiversity of aquatic organisms can be maintained and increased by different combinations of the functionality improvement methods described below, which can be implemented both in the river and on its banks. For example, strengthening of the riverbanks not only restricts the sedimentation processes, but also creates living places for various aquatic organisms. By mowing and limiting the spread of *Phragmites australis*, preconditions for the development of more diverse emergent and submerged plant vegetation are created. The formation of more diverse emergent plant stands - bur-reed *Sparganium* spp., flowering rush Butomus umbellatus, iris *Iris pseudacorus*, calamus *Acorus calamus* creates a diversity of microhabitats, which ensures larger diversity of aquatic organisms (Buisson et al. 2008).

In regulated rivers with long, straight reaches and a uniform riverbed, wooden logs (diameter > 10 cm), fastened by poles that are driven into the riverbed, can be installed on the riverbanks parallel to the stream, strengthening the riverbanks. Cavities washed-out around them create microhabitats for aquatic organisms and serve as hiding places for fish.

17.3.3 Ensuring the Functionality of Natural River Reaches

17.3.3.1 Removal of Excess Fallen Trees and Control of "Catchers" (A1)

The aim of the removal of excess fallen trees (Large wooden debris – LWD) is to restore the natural river flow, in order to (1) limit the development of sedimentation processes; (2) increase the river's self-purification capacity (3) reduce the risk of floods, due to the accumulation of an even greater amount of LWD.

In unmanaged river banks, especially in steep slopes, tree litter forms regularly, and trees are washed out, or, as it happens in the secondary *Alnus incana* stands, trees decay due to age or rot. As the decayed trees fall into the river and block it, structures of large woody debris start to form. Larger clusters of fallen trees most often form in spring or in periods of intense rainfall, when tree litter material of different origin and in varying sizes is washed down with the stream from the upper reaches of the river. Leaves and small branches from trees tilted over the river also fall in the river. Small twigs, which fill the space between the fallen trees, form a compact blockage, which holds off the water runoff, facilitates the rise of the water level and bank erosion.

In addition, if the fallen trees are not timely removed from the river, they reduce the river's self-purification capacity under the conditions of high rainfall, increase the risk of flood, make the use of the river for water tourism purposes more difficult.

Fig. 17.21. A reach of the River Vaive before (1) and after (2) the removal of fallen *Alnus incana*. After the removal of the fallen *Alnus incana* formation, a more diverse water flow established in the river, and the former microhabitats are restored. This is indicated by the visible flow and water ripples, the disappearance of sand sediments and the exposure of a pebbly, gravelly riverbed. Photo: L.Urtāne.

Therefore, taking into account the interests of habitat conservation, the provision of water flow, flood risk reduction and water tourism, the volume of fallen trees in the river must be controlled. The most appropriate tree removal solution should be chosen according to the type of large woody debris and its total volume (Fig. 17.21). General principles that apply in all cases are:

- the total volume of large woody debris left in the river does not exceed the volume characteristic for good habitat quality (*see Chapter 17.1.2*);
- in the central part of the river there is at least a 1 m wide, obstruction-free water area that provides free migration of aquatic organisms, free flow of sediments and deposits and is suitable for safe boating (Urtāns, Urtāne 2011).

Depending on the total amount of woody debris in the river, the fallen trees are either removed manually or by special machinery. It is important to place the removed trees on the riverbank in a way that does not allow them to be washed back into the river by flooding waters. Depending on the amount of dead wood in the woodland, small amounts of removed woody debris are distributed sparsely.

Large amounts of removed trees are taken away, but, if that is not possible, they are left in big piles on the riverbanks or burnt on top of dry bars on the riverbed.

Wooden dam type, structure and volume:
Large volume of large fallen trees has accumulated in the river. River throughflow is hindered. Due to the limited flow, sediment transport has been delayed. As a result, the structure of the river-type characteristic structure has changed to sandy sediments unsuitable for *Unio crassus* and salmonids spawning here. R. Rauza.
Management method:
To renew river flow and improve the structure of the riverbed, excessive wooden debris is taken out of the river.

Fallen tree type, structure and volume:
Fallen trees are located across the river and block the stream, acting as "catchers", attracting new wooden debris brought by the stream. R. Kauliņa.
Management method:
Taking into account the excessive volume of wooden debris in river stretches upstream and downstream, all accumulated trunks must be taken out of the river, leaving a few logs located along the bank parallel to the stream. All mechanical waste – plastic bottles must be collected from the river.

Fallen tree type, structure and volume:
Fallen trees in the river are orientated along the direction of flow. R. Kauliņa.
Management method:
Fallen trees must be taken out of the central part of the river. Logs, that are located parallel and close to the banks, are left as hides for fishes and invertebrates. Logs are fastened to the bottom with poles.

Fallen tree type, structure and volume:
Fallen trees are located across the river and used as bridges for small rodents. In an elevated water level they can act as "catchers" and promote the development of wooden dams and bank erosion. R. Kauliņa.
Management method:
One of three wooden "bridges" across the river seen in the background of the photo should be left. Fallen trees must be taken out of the central part of the river. Logs, that are located parallel and close to the banks, are left as hides for fishes and invertebrates. Logs are fastened to the bottom with poles.

Fig.17.22. Choice of appropriate management method for fallen tree type, structure and volume.

17.3.3.2 Demolition of Beaver Dams (A2)

The aim of the demolition of beaver dams is: (1) to restore the natural river flow, restore flooded riffle reaches: (2) increase the river's self-purification capacity: (3) limit the development of sedimentation processes and reduce flood risk.

Depending on the size, quantity, location and accessibility, beaver dams are either demolished manually or mechanically. In practice, various demolition techniques are used. Information on the best available practice can be found on various websites. General principles for beaver dam demolition are:

- Since a beaver dam is built in a certain order, the following parts are distinguished: (1) a base, fixed to supporting wooden poles, positioned perpendicular to the stream, and (2) a pile-up on top of the base, made of interconnected wooden poles, twigs and branches, with a filling of leaves, grass and soil that may contain stones;
- the order of dam demolition works is the reverse order of its construction – it is recommended to start demolishing downstream from the dam, by first removing the largest supporting trees that are perpendicular to the dam; the trees forming the dam must be removed by gradually reducing the width of the dam so that the dam is as narrow ("thin") as possible, but the water level is not lowered;
- When the dam has become sufficiently "thin", a small opening (Fig. 17.21) must be created, in order for the water flow to wash away the leaf and mud sediments, which will facilitate further removal of the largest trees. If the principle of gradual dam removal is not followed and a large part of a dam is destroyed at once, materials from the demolished dam might form a new blockage a few dozens of metres downstream from the demolished dam.

In order to maintain the water flow in cases of large dams that are difficult to demolish, pipes with different diameters are inserted into the dams. However, this technique only delays implementing a real solution, because keeping the beaver dam will create the further accumulation of sediments and debris (leaves, twigs) carried in the stream, thus clogging up the river. The demolition of beaver dams is effective if it is accompanied by regulating the number of beavers (hunting) in the given river reach and in a wider area.

This action also applies to regulated watercourses and drainage ditches. In rivers that flow through managed agricultural land, dams are often built only from plant litter, mostly reeds and their rhizomes, as well as sand and stones (Fig. 17.23). Removal of such dams is relatively simple, and agricultural machinery can be used for this purpose.

Fig. 17.23. Beaver dams in agricultural land are often built only from macrophyte litter and soil. R. Slocene. Photo: L. Urtāne.

Fig. 17.24. In rivers unmanaged for a long time the root system of macrophytes develop an up to 30 cm thick turf over the mineral ground. River Venta. Photo: A. V. Urtāns.

17.3.3.3 Regulation of Macrophyte Overgrowth (A3)

According to the river pollution level, the type of river (fast flowing or slow) and the degree of overgrowth, the aim of management is to restore the natural level of the river's overgrowth, in order to:

- reduce a monotonous emergent vegetation, thus creating an opportunity for diverse emergent and submerged vegetation to develop;
- reduce the amount of plant nutrients accumulated in the system;
- destroy the turf created by the emergent plant root system and to restore the gravelly/sandy ground (in the fast flowing rivers);
- restore the natural flow of the river, and the transport of energy and substances.

Aquatic plants are an important group of aquatic organisms. They are not just habitats and shelters for other aquatic organisms, but also their food. By accumulating the dissolved plant nutrients and creating a green mass of plants, aquatic plants participate in the river's self-purification processes. However, if they grow excessively, the basic functions of the river are hindered – the transport of energy and substances.

In rivers that are rich in plant nutrients and unmanaged for a long time, the root system of *Phragmites australis, Scirpus lacustris, Phalaris arundinacea, Typha* spp. and *Sparganium* spp. develop an up to 30 cm thick turf over the mineral ground (Fig. 17.24, 17.25). It covers riffle areas, thus destroying the pebble and gravel habitats and spawning grounds of *Salmonidae* fish and river lamprey *Lampetra fluviatilis*.

Natural aquatic plant overgrowth in an undisturbed river never exceeds 30%. When the phosphorus and nitrogen compounds from the soil reach the water environment, they increase the nutrient load and contribute to the enhanced development of aquatic plants. If the riverbed is too overgrown with aquatic plants, the water flow is hindered, the water level rises, and, as the lower bank parts become moistened, the leakage of plant nutrients into the river is enhanced. If the aquatic plant overgrowth in a river is > 30% of the open water surface the aquatic plants must be removed.

Reduction of aquatic plant overgrowth involves several successive activities:

- establishing temporary storage places for the removed aquatic plants;
- reducing aquatic plant overgrowth;
- removing the mass of mown aquatic plants from the river;

Fig. 17.25. After macrophyte mowing and shearing their root system, sediments are scoured, opening substrate typical for fast flowing rivers. Venta. Photo: A. V. Urtāns.

- placing the removed green mass in the composting site.

Depending on the depth and degree of the overgrowth of the river, aquatic plants can be mown with a scythe or with devices mounted on a tractor or boat. In areas where it is difficult for a tractor to access or where the amount of work is small, aquatic plants can be mown with a hand scythe (Fig. 17.26) or with cutter mounted to a boat (Fig. 17.27). However, in this case the work efficiency is lower, because roots of aquatic plants remain in the river. In the next vegetation season, although in smaller amounts, aquatic plants will regenerate, and the mowing has a shorter effect. In order to achieve greater management efficiency and prevent the regeneration of aquatic plants, plants must be mown several times during one vegetation season.

Mowing of aquatic plants is much more efficient, and serves more for the long term, if it is combined with removal of the roots. It is performed with an appropriately equipped tractor (Fig. 17.28, 17.29). If a tractor is used to reduce the overgrowth of the river, manual work will be needed in some parts of the renewable river reach. Aquatic plants are usually removed by hand in places, where due to the river depth or the shape of the riverbed, it is not possible to gain access with a tractor, for example, in areas with alternating pools and stone assemblages that are not possible to be overcome with machinery.

When working with a wheeled tractor, the elimination of aquatic plant overgrowth and improvement of the riverbed structure is carried out by multiple and sequential scarifying of the river bottom and by removing the aquatic root system (Fig. 17.28). The experience gained in the River Jaunupe, the River Salaca, the River Gauja and the River Venta showed that wheeled tractors equipped with auxiliary devices for ploughing forest clearings are effective in the elimination of aquatic plant overgrowth. A tractor with this kind of equipment is able to work at depths of up to 1.5 m.

In order to destroy the aquatic root system, reduce the accumulated sediment layer and ensure its gradual wash-out, the riverbed must be repeatedly scarified at specified intervals. After each such scarification, when the stream has washed away the loosened sediments, the deeper sediment layers which were previously strengthened by plant roots can now be accessed by the stream.

If aquatic plant development has taken place for a long period, a sandy sediment layer accumulates on the turf of aquatic plant roots, and species characteristic of river floodplains and wet meadows, starts to develop here – reeds, along with various species of sedge *Carex* spp. and bur-reed *Sparganium* spp. To eliminate such islet deposits on a formerly stony or pebbly riverbed, actions must be gradual. Initially, when working with a forest plough, it is only possible to partially split the root system and the ground layer. Therefore the ground has to be cleared gradually. At first, only edges of the turf are torn off from the riverbed and lifted up so that they are exposed to the stream of the river. The lifted turf must be inspected after a couple of days and, using a hoe or fork, must be upturned so that the root system faces the stream. When the inversed root aggregations are rinsed with water, they must be removed from the river. A part of the washed out roots are transported

Fig. 17.26. Manual macrophyte mowing using a trimmer. Photo: L. Urtāne.

Fig. 17.27. Macrophyte cutter mounted to a boat. Suitable for deeper rivers and lakes. Photo: L. Urtāne.

Fig. 17.28. In the River Venta, a wheeled tractor is used in order to reduce the aquatic plant overgrowth and to scarify the root system. To provide additional grip, the tractor is equipped with metallic wheel wrappers. Photo: A. Lācis.

Fig. 17.29. In the River Mūsa, in order to reduce the aquatic plant overgrowth and to scarify the root system, a caterpillar tractor is used.
Photo: A. V. Urtāns.

downstream, where they accumulate in the lower slow-flowing reaches of the river. The plant roots that were carried away by the stream in the River Jaunupe and in the River Venta, lost their regeneration abilities and rarely rooted again (Urtāns, Urtāne 2011).

Working methods are different when working with a caterpillar tractor (Fig. 17.29). The experience gained in Latvia shows that in order to reduce aquatic plant overgrowth, **a caterpillar tractor** can only be used at a depth of 0.6–0.8 m. Overgrowth and the root system is eliminated and the composition of the riverbed is improved by bulldozing. In this way, relatively large amounts of bottom material can be displaced, significantly affecting the upper – around 10 cm thick – layer of the river bottom, which is inhabited by the majority of bottom-dwelling invertebrates. This method is regarded as traumatic to bottom inhabiting invertebrates.

Regardless of the methods for the reduction of aquatic plants (mowing by hand or using machinery), prior to the start of work, an appropriate temporary storage place for the mass of mown aquatic plants must be prepared in the shore zone of the river. The planned area of work must be surveyed in detail, the movement route of the tractor must be selected, the owner of the land adjacent to the river must be found and informed, temporary deposit sites for aquatic plants must be selected and their use coordinated.

When the temporary storage place for aquatic plants is selected – usually an about 10–25 m^2 large area in the shore area, as high as possible above the flooding level, it must be mown and cleared from shrubs, in order to have free movement and to follow work safety. The established temporary storage site must be as close to the riverbank as possible, to allow aquatic organisms hiding among the plants to return to the river with the runoff water (*see Chapter 17.3.3*). A few hours after placing the plants in the temporary storage location, it must be surveyed and larger aquatic organisms must be removed to the water – bivalves, lamprey juveniles and others.

Along with the green mass of aquatic plants, a part of the nutrients is also removed. Thus, after the mowing of aquatic plants, not only is the river flow improved, but the total amount of nutrients is reduced. Aquatic plants of a river reach should not be mown completely. Separate aggregations must be left to maintain hiding, feeding and living places for aquatic organisms that live among the aquatic plants. As large as possible mass of the cut aquatic plants must be removed from the river and taken ashore. Aquatic plants that are mown and are not removed from the river can create obstructions in the lower reaches of the river, thus raising the water level and causing mechanical pollution.

In the temporary storage place, the volume of the green mass significantly reduces due to evaporation. Therefore aquatic plants should be stored there before transporting them to a composting site for as long as possible. If it is planned to keep the cut water plants in the temporary storage place for longer, it should be above the flooding level. It must be easy to access and collect the mown material and transport it to a composting site.

Legislation proposes to mow aquatic plants in the upstream direction, thus ensuring runoff of resuspended sediments and transparency of the riverbed. By mowing upstream, plants form a dispersed mass. To collect such mass in the water environment, additional manpower is necessary. Sometimes, in short river reaches, a few dozens of metres long, it is more efficient to mow aquatic plants in the downstream direction. When mowing down the stream, the mown aquatic plants float above the water surface, get trapped in the yet unmown plants, and can be collected and removed more easily.

17.3.3.4 Improvement of shore vegetation structure (A4.1)

> The shore vegetation structure is improved in order to: (1) reduce soil leaching from areas with no vegetation; (2) enhance plant nutrient detention capacity, thus reducing their discharge in the river from the adjacent terrestrial areas.

This action refers to the bank part of a river. It is considered a priority in the former agricultural lands, which overgrow with tree pioneer species – *Alnus incana, Salix* spp., *Padus avium*. Over the course of the improvement of the shore growth structures, the forest stand is maintained – the structure of the stand is improved, by gradually replacing the secondary *Alnus incana* stands with more valuable and more enduring broadleaf tree species – *Fraxinus excelsior, Ulmus laevis, Ulmus glabra*. This action may be combined with the planting of *Alnus glutinosa*, which, from the point of view of riverbank stability and hiding places for aquatic organisms, is a very valuable tree species (Fig. 17.30). The preferable distance between the *Alnus glutinosa* to be planted is 1,5 metres. In the area between the river and the tree line a herbaceous plant zone at least 1 m wide must be created.

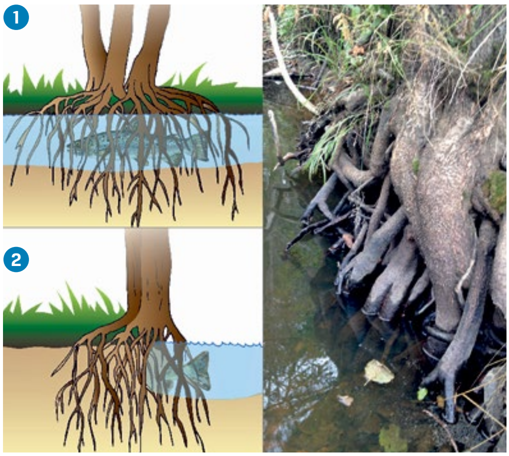

Fig. 17.30. Improvement of the shore vegetation structure *with Alnus glutinosa*. In riverbanks with *Alnus glutinosa*, groundcover with herbaceous plants develops. Their roots strengthen the riverbank and: **(1)** provide hiding places for fish and crayfish; **(2)** aquatic organisms inhabits roots and shoots. Drawing by D. Segliņa (according to Lange, Lecher 1989). Photo: L. Urtāne.

To effectively strengthen the riverbank, herbaceous plants must have a well-developed and deep root system that can detain the soil (Wenger, 1999). The development of a belt of herbaceous plants is necessary for all natural rivers, the shore areas of which are overgrown with trees and shrubs all the way to the river. Research shows that a 6 m wide grass belt and a 13 m wide combined belt of grass and forest hold up 20–50% of ammonium, 50% of the total nitrogen and 50% of nitrates (NIWA Client Report 1997; Wenger, 1999). In younger woodlands phosphorus and nitrogen compound uptake occurs more actively than in old woodlands (Mander et al. 1999). It has also been found, that over time soils in unmanaged shore areas become saturated with the accumulated phosphorus and phosphorus compounds that start to leach out from the soil, thus causing additional nutrient enrichment of the water (Wenger 1999). To maintain a high nutrient accumulation ability in the shore zone, it must be regularly managed by mowing and cutting shrubs which overshade the herbaceous ground cover. In order to ensure the efficient nutrient interception function of a protection zone, management of *Alnus incana* is recommended in the former protection zones of watercourses in agricultural lands – 10–20 year old *Alnus incana* stands are the most effective in accumulating nutrients and do not allow them to enter watercourses (Arhipova et al. 2011).

17.3.3.5 Strengthening of the riverbanks (A4.2)

Riverbanks are strengthened in order to: (1) reduce bank erosion and the intensity of sedimentation processes; (2) to narrow ("compress") the riverbed, so that the riverbed, which has been extended due to various influences, returns back to its original width.

Bank fastening to limit erosion is preventive activity. In everyday praxis much frequently it is applied not for habitat protection and increase of biodiversity, but rather for economical reasons. Restricting bank erosion intensity of sedimentation process is decreased and protection of fast flowing river stretches ensured. In urban areas bank fastening includes as well environmental or so called blue structures. (Fig. 17.31).

Riverbank strengthening to eliminate erosional impacts. Riverbank strengthening is carried out in areas where bank erosion has occurred due to the hindered water flow or the operation of small hydroelectric power stations. To stabilise the riverbanks, stones or tree trunks that have fallen in the river, stay in the water and are placed parallel to the bank and fixed. When reinforcing a riverbank, it must be taken into account that the water flow will hit it and will be redirected to the opposite bank of the watercourse. Therefore, downstream from the reinforced area, the opposite riverbank must be strengthened, too. This technique is also used for remediation and "extending" the eroded riverbanks. In this case, the eroded riverbank is completely confined with stones or tree trunks, thus redirecting the water stream (Fig. 17.32).

Riverbed narrowing. A river channel is narrowed in places, if, due to various influences, it has widened, has become shallower and partly dries out in the dry period (Fig. 17.33). To restore the natural width of a riverbed, the riverbank strengthening techniques described above are applied. To create a new shoreline, stones or trees that have fallen in the river are placed parallel to the bank and fixed.

ig. 17.31. Stones strengthen the riverbank against erosion, while also creating suitable habitats for aquatic and shore animals **(1)**. The River Lazdupe in Ranka. Photo: L. Urtāne. Strengthening of riverbanks for rivers located in an urban environment River Stulpa in Lithuania is also used as a landscape design element and blue infrastructure. The amount of stones placed on the riverbank is greater than is needed for its strengthening **(2)**. Photo: A. V. Urtāns.

Fig. 17.32 Bank stabilisation undertaken to halt bank erosion and falling of an oak into the river **(1)**. Eroded bank stabilised with stone riprap and additionally wooden trunks to promote bank revegetation **(2)**. R. Kauliņa. Photo: A. V. Urtāns.


Fig 17.33. Channel narrowing. Sediment filled shallow channel stretch with negligible flow **(1)** is narrowed using stone riprap. Renewed flow scours sediments and re-creates diverse microhabitats suitable for salmonids **(2)**. Kārļi fish hatchery. Photo: A. V. Urtans

To keep the river channel from widening, stones or trees are placed along the riverbank in several rows. Gaps and cavities must be left between them to keep hides for fishes, diversify the riverbed and to allow the development of microhabitats over time. Living places for species that are sensitive to oxygen deficiency develop in such "compressed" rivers, as well as spawning grounds for salmonids (Fig. 17.33). In settlements such structures make the riverscape more scenic and serve as blue infrastructure (*see Chapter 3.3*).

17.3.3.6 Establishment of Riffles

The aim is to enrich the river water with oxygen, in order to increase the river's self-purification ability, maintain the diversity of oxygen sensitive aquatic invertebrates and to reduce the impact of climate change on water quality.

Stones in rivers have several functions. A stone in a river is a substrate for various aquatic organisms. Stones in a river create a turbulent stream – they make the water flowing over them swirl. Thus the surface of the water significantly increases and facilitates the dissolving of oxygen from the air.

Stones that are placed in a river properly, increase the riffle areas and contribute to the processes mentioned above. When placed in a watercourse, stones quickly overgrow with a layer of microscopic aquatic bacteria, fungi and algae (biofilm). The dissolved oxygen activates this biofilm, thus speeding up the interception and breaking down organic and mineral substances. Bacteria, fungi and algae become food for the river's aquatic organisms, which, in turn, are used as food by fish. In such oxygen-rich river reaches plant nutrients mineralise much faster and the quality of the water improves. Stones as a substrate become a home for oxygen-sensitive species, thus contributing to the increase of biodiversity. Eddies behind stones serve as hiding places for fish and crayfish.

Increased riffle areas are also crucial to mitigate the effects of climate change. As water heats up, oxygen dissolution in water decreases, therefore during hot summers the suffocating of fish and other aquatic organisms can begin. Stones placed in a river, diversify the flow and promote mechanical aeration. Thus, the survival of aquatic organisms is also ensured under the conditions of increased air temperature. Unlike trees that have fallen in a river, stones are chemically stable (they don't decompose over time) and become a permanent substrate.

Only fast flowing rivers (river reaches) with a stream velocity above 0,20 m/s are suitable for the installation of riffles. The stream flow in such rivers is visible, rippling or with standing waves. Stones cause water to swirl in small and shallow medium-sized rivers. In the large rivers and in slow-flowing river reaches, where the riverbed is covered with a thick layer of mud, a stone put in a river will "sink" and will not be able to swirl the surface of the water, therefore the mechanical dilution of oxygen into the water will not occur.

When installing riffles, patterns related to the functioning of the river must be taken into account:

- stones placed in the river should not rise above the water surface too much, thus becoming catchers of the materials carried by the stream and creating a blockage in the river;
- in order for the stones not to have the effect of a dam, the pile of stones must be established in the central part of the river, so that it does not take up more than 20% of the cross-section of the river (Fig. 17.34);
- a stone placed in the river is an obstacle, which changes the direction of the stream, therefore, in order to avoid bank erosion, after creating the riffle, the direction of the stream must be observed and the riverbank below the created riffle must be stabilised with a row of stones (Fig. 17.34). If it is not done, sediment deposition will increase, and the planned improving effect of the habitat quality will only be achieved partially.

This management method can also be used in regulated watercourse stretches with a stream velocity > 0.2 m/s. Unlike in natural rivers, in regulated rivers stones are placed not only to enrich the water with oxygen and produce habitats suited for aquatic organisms, but also to facilitate the naturalisation of the riverbed. In such cases, riverbank fixing below the installed stone riffles is not performed. The altered stream gradually washes out the opposite riverbank and in the straightened reach a small sinuosity starts to develop.

This is an environmentally friendly method of restoration of the straightened river, where with the help of structures placed on the river bottom, the naturalisation of the riverbed is facilitated. This method is more time-consuming, but more natural and economically more beneficial than excavating a new sinuous riverbed.

17.3.3.7 Maintenance of Natural Spawning Grounds Suitable for Salmonids and Lampreys and the Creation of Artificial Spawning Grounds (A7)

> The aim of activity is to maintain a good quality riverbed structure for specific fish species to: (1) maintain or increase the spawning ground area; (2) ensure good spawning success.

Creating spawning grounds. Creation and maintenance of spawning grounds suitable for salmonids is a specific form of management, applicable to certain species. salmonids – *Salmo trutta fario, S. trutta* and *S. salar* – are indicators of good water quality. They have become a kind of symbol of clean and oxygen-saturated rivers. In many places around the world (for example, in Denmark) the creation and maintenance of spawning grounds for salmonids have become a significant form of cooperation between anglers, local residents and municipalities (Madsen 1995). In Latvia, through the engagement of angler's clubs, non-governmental organisations,

Fig. 17.34. River reach before **(1)** and after **(2)** removal of fallen trees. River Kauliņa. **(A)** After the removal of large woody debris, a riffle is created – stones are located in a central part of the river in a way that they do not become "catchers" of debris and do not block more than 1/3 of the river width. **(B)** Downstream of the newly created river riffle, the river bank is reinforced with stones to avoid bank erosion. **(C)** Downstream from the riffle, a spawning ground shall develop. Photo: L. Urtāne. Explanation of the process: A. V. Urtāns.

environmental authorities and municipalities, several spawning ground establishment projects for salmonids have been implemented.

Each salmonid species have specific needs in relation to the selection of spawning grounds (Cowx, Welcomme (eds.) 1998).

- Optimal conditions for **Salmo salar spawning are:** stream velocity 0.6-1.0 m/s, soil structure - stones in different sizes (51-150 mm in diameter), pebbles (12-50 mm in diameter), gravel (3-11 mm). Under optimal spawning conditions, the sand and sediment fraction does not exceed 10%. The total proportions of the riverbed substrate for the spawning ground – stones (30%), pebbles (40%), gravel (20%), sand (10%). The depth of the spawning ground is at least 0.5 m (Mitāns 2004).
- For **Salmo trutta spawning** shallow riffles with a depth of 0.3-0.6 m, and stream velocity of 0.3-1.10 m/s (0.5 m/s on average) are more appropriate. These spawning grounds are dominated by coarse gravel and small pebbles. The size of pebbles in 70% of the cases is 2-63 mm, 16 mm on average (Madsen, 1994).

Since pebbles in the salmonid spawning grounds are irregularly shaped, spaces form between them. There the laid roe are constantly supplied with oxygen and the resulting metabolic products - washed away (Fig. 17.35).

Experiments carried out in the River Bjerge in Denmark showed that even a 14% sand and sediment fraction in the spaces between pebbles destroyed all of the roe laid by *Salmo trutta* (Madsen 1995). The Danish experience in the creation of artificial spawning grounds ("spawning nests", "redds") show that their functioning is successful, if the following conditions are fulfilled:

- riverbed gradient at the spawning ground locations is 2–17 cm per a 100 m long reach;
- the average thickness of the pebble layer is 10–50 cm, 25 cm thick on average;
- the length of spawning nests depends on the width of the river and the volume of water; in larger rivers, their length could even be 10–15 m. In small rivers, their length should not exceed 4–5 m (Madsen 1995).

Creating spawning grounds for lampreys. In Latvia, two species of lampreys are found – *Lampetra fluviatilis* and *Lampetra planeri*. Environmental requirements of both species are similar, but their life cycles are different. *Lampetra fluviatilis* is a migrating species, the spawning of which takes place in river riffles, larval development – in the slower river reaches, while the adult specimens feed in the sea. *Lampetra planeri* in its larval stage is morphologically similar to *Lampetra fluviatilis*. Unlike *Lampetra fluviatilis, Lampetra planeri* has no sea phase in its life cycle.

Lampreys spend the autumn and winter period until their spawning period from February – July, in the upper or lower reaches of riffles, where the stream velocity does not exceed 0.5 m/s and larger stones can be found (> 256 mm), which serve as hiding places (Aronsuu 2015). Lampreys spawn in fast flowing river sections where the river bottom is composed of coarse (16–32 mm) gravel or pebbles (32–64 mm) (Nika, Verbickas 2010).

In 2015, employees of the Nature Conservation Agency, in cooperation with the angler's club "Salmo" established spawning grounds in the River Raķupe. In an approximately 30 m long river reach, 60 m³ of coarse gravel and stones of varying sizes were put in the river, thus creating a pebble riffle. Already during the first year, several dozens of spawning *Lampetra fluviatilis* and *Lampetra*

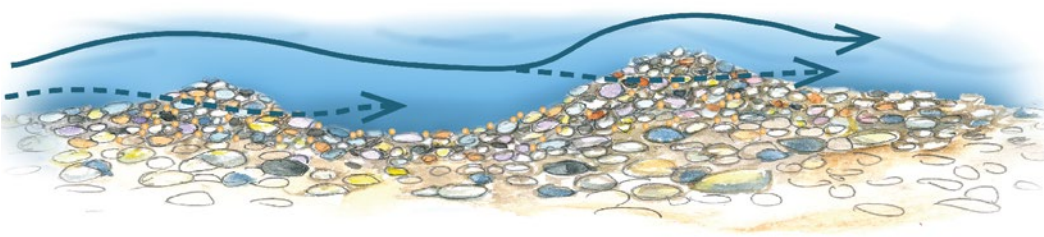

Fig. 17.35. Water flow in the potential salmonid spawning ground. Drawing by D. Segliņa (according to Madsen 1995).

planeri were found in the newly established spawning grounds.

Maintenance of spawning grounds. Since the quality of rivers is affected by the economic activity of humans, over time the structure of the riverbed changes – pebbles and gravel become compacted, and the spaces in-between fills with sediments. It is therefore necessary to maintain the spawning grounds of *Salmonidae* fish. In autumn, before the spawning period, it is recommended to scarify the long-known spawning grounds with hoes or garden cultivators at a depth of at least 10 cm. This will facilitate water movement through the spaces between pebbles and removal of sediments, thus increasing the chance of successful spawning.

17.3.3.8 Regulation of River Shading (A4.2)

> The aim is to create (1) optimal shading conditions, to create living conditions suitable for organism groups characteristic to each type of watercourses, and (2) maintain the biodiversity of the watercourse.

Regulation of shading applies to small and medium-sized rivers, which run through overgrown and abandoned agricultural land. They can be both natural and regulated rivers, as well as drainage ditches. According to the structure of the shore vegetation, regulation of the shading of a river is both the reduction of the shading (brush cutting, thinning or felling of *Alnus incana* stands in former agricultural lands) and creation of shading (creating shore landscaping).

Optimal shading of a river is important for the primary production (algae, aquatic plants) and thus the development of the rest of the food chain. The experience of Ireland (O'Grady 2006) shows that in 100 m long, evenly shaded reaches with an adequate riverbed, the number of salmonid juveniles only account for up to 40% compared to the number of fish found in the adjacent, moderately shaded river reaches. It is explained by the shading limited insufficient food base for fish and the fact that the critical factor of survival during the first weeks of larvae of many fish species is related to algae and zooplankton that is only available in the unshaded river reaches.

Depending on the type of river (fast flowing or slow), its geographical location and climatic conditions, the optimal ratio of illuminated/shaded river reaches is considered to be 30:70 (Cowx, Welcomme 1998), or 50:50 (Mander 1995; Cowx, Welcomme 1998; Buisson et al. 2008). In Latvian rivers the optimal proportion is when at least 30 m are illuminated per every 100 m of a river (Urtāns 1989).

Depending on the width of the river, the shading is provided by trees and shrubs, as well as by tall herbaceous plants growing on the riverbanks. Herbaceous plants that have been preserved on the banks of up to 2 m wide watercourses are able to provide mosaic-type shading and also limit the development of aquatic plants without the presence of trees and bushes (Buisson et al. 2008).

Optimal shading of a river is maintained by regular management of the riverbanks so that natural grassland zones or openings in the tree canopies form. It also reduces the possibility of fallen trees creating obstructions and prevents increased bank erosion. If the shore vegetation consists of monotonous spruce stands, the management of riverbanks also improves the chemical composition of the water. Needle litter increases the acidity of the water, which is unfavourable to the development of aquatic organisms, so the development of monodominant spruce stands on the riverbanks should not be allowed (O'Grady 2006).

17.3.3.9 Construction of Fishways

> The aim is to ensure the continuity of the river, ensuring not only the transport of substances and energy, but also the genetic material exchange among aquatic organisms and survival of a healthy and viable population.

Construction of fishways is a specific technique. In order to implement this, a Building design developed by a qualified engineer is necessary. The majority of fish species inhabiting Latvian waters locally migrate between spawning, wintering and feeding areas. The watermill pond impoundments and small hydroelectric power station dams in rivers create obstacles that fish and other aquatic organisms are not able to overcome. The decline of migration limits the genetic material exchange among aquatic organisms and survival of a healthy and viable population. Around the world sufficient experience has been gained in the formation of fishways, ensuring fish migration with various technical solutions.

A fishway is a construction that helps fish to overcome obstacles in the river. According to the technical solution, fishways are divided into three groups: step cascades, ramps (slopes) and elevators (lifts). In practice, when looking for the best solution for a specific situation, combinations of these basic groups are often used (Cowx, Welcomme (eds.) 1998, Armstrong et al. 2010). Each watercourse is different by the nature of the riverbed, chemical parameters of the water and the composition of inhabiting organisms. Any fish pass must be designed and operated in accordance with the biological characteristics and behavioural patterns of the migrating species concerned. For example, when creating a cascade-type fishway (Fig. 17.36) for salmonids, the height difference between two steps should not exceed 30 cm, the gradient should not exceed 7 cm/m. Cyprinids in fishways are only able to overcome 0,1–0,2 m high, successive steps (Armstrong et al. 2010). In Venta Rapid it has been observed that *Vimba vimba*, belonging to *Cyprinidae* species, can overcome up to 0,8 m high single-step obstacles.

The location of the fishway entrance is also very important. The most effective fishways are those, in which the entrance is close to the obstacle (dam) and at the same time close to the bank, i.e. those, which comply with the flow of migratory fish. In order to attract all fish species, stream volume at the fishway entrance must be around 1 m^3/s. In rivers with migrating salmon, the water flow rate must be around 2 m^3/s. In rivers in England and Wales the precondition for a functional fishway is considered the flow rate, which must account for 5% of the average flow rate of the river concerned (Armstrong et al. 2010). Although many fishways have been constructed all over the world, the most efficient solutions for the migration of juvenile fish down the fishways are still being sought (Cowx, Welcomme (eds.) 1998).

In rivers of Latvia only a few functioning fishways have been created, for example, at the Kārļi hydroelectric power station in the River Amata, at the hydroelectric power station in the River Aiviekste, in the River Līgatne.

Fig. 17.36. Cascade-type fishway in the River Līgatne. Photo: A. V. Urtāns.

17.3.4 Ensuring of the Functionality of Regulated River Reaches

Another approach to ensure the biodiversity of a watercourse is the formation or preservation of natural structures characteristic for the watercourses, which are regulated (straightened) in order to discharge waters faster by draining the adjacent land areas. Such management aims to balance the human economic interests and the ecological interests of the river. Experience shows that even under conditions of intensive economic activity, it is possible to preserve the ecological functioning of the watercourse and its shore zone. The regulatory framework in force in Latvia regarding straightened rivers determines that the diversification of structures of regulated (straightened) rivers is ensured, respecting the environmental requirements – keeping larger stones, pools and separate natural, unregulated reaches, etc. This approach determines that structures characteristic for natural rivers are also created in regulated rivers and drainage ditches, and that they are managed in a similar manner to that of natural rivers. Unfortunately in daily practice the most often used approach is that of the lowest expenditure and the principles of environmentally friendly amelioration are not always followed.

17.3.4.1 Construction of Settling Ponds (B2)

Aim of settling ponds is to settle down soil particles that have been transported with drainage waters of agricultural lands and logging territories, thereby reducing the introduction of sediments and plant nutrients into rivers.

Enhanced formation of unnatural amount of sediments occurs in watercourses with intensive agricultural and logging activities in their catchment areas. Discharge of sediments of agricultural origin into watercourses is reduced and delayed by establishing and maintaining river protection zones and buffer zones of drainage ditches. In addition, it is recommended to build settling ponds in intensively used agricultural areas in main drainage ditches near to where they flow into the recipient watercourse. A settling pond is an engineer-designed expansion of a drainage ditch, in which, due to the reduced stream velocity, the soil material carried by the stream is deposited. This environment-friendly drainage system element effectively reduces the introduction of sediments, delaying hydromorphological changes in the bed of the watercourse channel.

Settling ponds of similar construction are also applied on drainage ditches that are located in forests. In Latvia the efficiency of such settling ponds is assessed by the researchers of the Latvian State Forest Research Institute "Silava" (Lībiete-Zālīte, 2012). For the effective functioning of a settling pond, it must be 2–3 times wider than the width of the channel in which it is installed; the deep section must be at least 0,5–1 m deeper than the natural bed of the channel, the length of the sediment interceptor must be 10 times longer than the width of the channel (Anon. 2002b).

Settling ponds that have been created in forest drainage ditches not only deposit sediments – they can also be used as a drinking place for forest animals or for fire-fighting purposes. Since the main function of a settling pond is the depositing of soil particles of various origins, they must be managed on a regular basis – the accumulated sediment must be removed. Finnish experts recommend cleaning a settling pond at least once a year (Lībiete-Zālīte 2012).

17.3.4.2 Construction of Surface Flow Constructed Wetlands (B3)

> The aim of surface flow constructed wetlands is to deposit plant nutrients from the agricultural drainage as well household waters, thus reducing their introduction into rivers.

The operation principle of surface flow constructed wetlands is similar to that of sedimentation ponds. Only the construction objective is different. The objective of a settling pond is to deposit sediments in the form of sand and soil particles. The objective of a surface flow constructed wetlands is to accumulate plant nutrients from water, thus purifying the waters collected by the amelioration system before they reach rivers or lakes. It is achieved by depositing nutrient-rich soil particles and transforming nutrients contained in the water into a green mass of aquatic plants.

According to the construction type, surface flow constructed wetlands and subsurface flow constructed wetlands are distinguished. For the treatment of agricultural runoff waters, surface flow constructed wetlands are used, visually resembling ponds overgrown with reeds. Its size depends on the amount of the surface runoff and the concentration of plant nutrients in the water. In order to effectively hold up the nutrients from the agricultural runoff waters, wetland areas must be large enough in relation to the catchment area. If the wetland area is not large enough, it quickly gets clogged up by suspended soil particles and is not able to effectively accumulate plant nutrients (Briedis (ed.) 2013).

When creating surface flow constructed wetlands, soil properties should also be taken into account. The finer the mechanical composition of the soil, the more depositing time is needed for soil particles containing phosphorus. Thus, wetland areas, where the catchment area is dominated by soils with a fine mechanical composition, must be large enough. A settling pond should hold the through-flowing water for at least five minutes, in order for sediments and biogenic elements to deposit. If the catchment area is greater than 30 ha, hydrological calculations are performed using 1% probability of exceeding the flow rate (Grinberga, Jansons 2012).

17.3.4.3 Restoration of Straightened Rivers (B4)

> The goal of straightened river restoration is to improve the physical environment of degraded rivers, regain their former biodiversity and self-purification capacity.

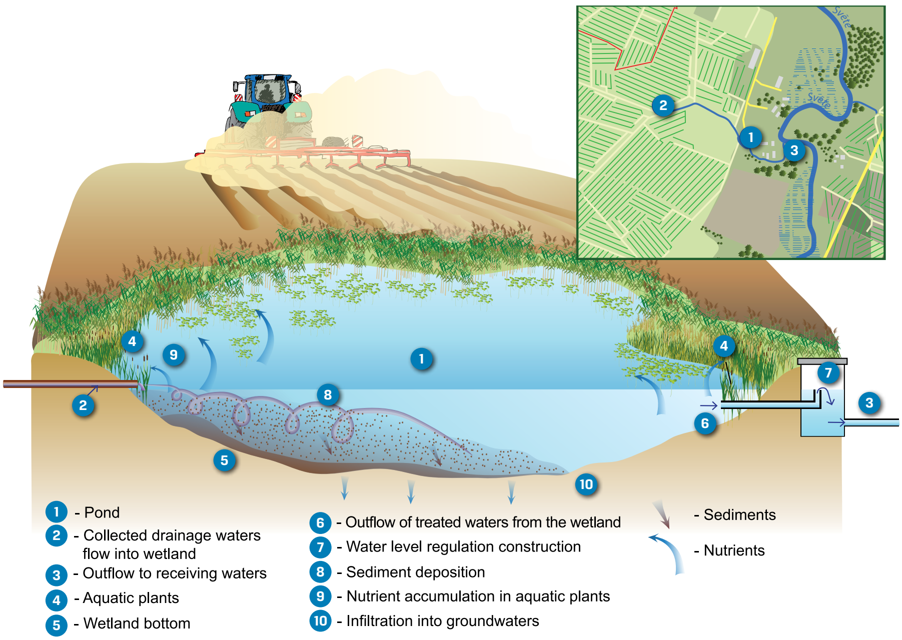

Fig. 17.37. Construction of surface flow constructed wetlands. Drawing by D. Segliņa (with additions according to Grinberga, Jansons 2012).

It is achieved by creating various riverbed structures in order to enhance the formation of the pool – riffle sequence and small sinuosity of the riverbed. In order to increase agricultural productivity, the river regulation (straightening) carried out in many European countries has significantly reduced the proportion of natural rivers. In an attempt to correct the previous mistakes, many projects for river recultivation have been developed. Different methods can be used for riverbed restoration. The most environmentally friendly method is the establishment of riverbed structures (placement of single stones or groups of them in the riverbed, spreading of coarse gravel and small stones, etc.), which, by reinforcing bank erosion, would facilitate the formation of small sinuosity and natural cross-section profile of the riverbed. Restoration, by excavating a new riverbed, is the most radical and expensive method of renaturalising a watercourse. In addition, it requires specific knowledge (Cramer (ed.) 2012).

River recultivation was started in Denmark, where an integrated approach is used in the restoration of watercourses, planning the restoration of hydrological and hydrobiological values of rivers, as well as the improvement of their functionality (Sand-Jensen (ed.) 2006). In the Netherlands, the method of new riverbed development is commonly used. A process-orientated approach is used to reduce the risk of flooding at the lower reaches of the river, maintain the existing groundwater level in the adjacent agricultural land and improve the condition of the aquatic ecosystem. Designing the cross-section shape of a new riverbed, most commonly a one-dimensional flow model is used, taking into account all three requirements for the functioning of the new riverbeds listed above. The summary and analysis of the experience in the Netherlands show that, in practice, it is too complicated to ensure all the needs, so unfortunately the ecological requirements are the ones that are partially disregarded (Reeze et al. 2015).

Taking into account the experience gathered in Latvia, re-meandering of regulated (straightened) rivers (Fig. 17.38), is the most expensive and most radical management method from the perspective of nature that, in addition, requires the greatest expertise, and is only worth choosing if it is possible to fulfil all the requirements related to the functioning of the river. In this case, when designing the new riverbed, as well calculating the flow rate values, not only should the water runoff rate be taken into account, but also the typological and functional characteristics of the river, environmental requirements of aquatic organisms and the flood pulse concept. In the development phase of the river renaturalisation project, when calculating the required flow rate values of the river, terrestrial habitat experts must define the humidity requirements of the terrestrial ecosystem (Priede et al. 2015).

When restoring the watercourse-adjacent floodplain grassland habitats and habitats suitable for the protected, floodplain grassland-related bird species *Gallinago media*, as well as spawning grounds suitable for *Esox lucius* that spawn in floodplains, water flow rate (with different probabilities of exceeding the flow rate) values must be such that the floodplain would only be flooded in the spring's flooding season. To ensure proper functioning of the restored water flow, it is necessary to form a riverbed profile that is similar to a natural river, with different riverbank slope variations. The planned riverbank slope must be such so as to facilitate the formation of a shallow shore area in the river, and in the meanders a cross-section of the channel bed must be designed in such a way that the depth in the outer side of the bend must be greater than in the inner side of the bend (Priede, et al. 2015). A riverbed profile that is designed in this way will facilitate the development of aquatic vegetation, occurrence of phytophilous aquatic invertebrates and will ensure faster stabilisation of the bioceonosis (Urtāne, 1992; Ķuze et al. 2008). During re-meandering, when forming a new riverbed or clearing a former riverbed that is visible in the landscape, it is necessary to leave all stones with a diameter above 30 centimetres. Such stones are resistant to the impacts of stream and ice movement, as well as form micro-habitats and small natural sinuosity.

17.3.4.4 Environmentally Friendly Management of Drainage Ditches (B5)

The goal of environmentally friendly drainage ditch management is diversification of a channel's basic functions to provide water drainage and flood risk reduction, at the same time integrating the requirements for biodiversity conservation.

Drainage ditches are artificially constructed channels intended for water drainage from agricultural lands and forest areas. Ditches are usually created in trapezoidal or V type cross section profiles that are rarely seen in natural rivers. However, human-made drainage ditches may be important habitats for rare and specially protected species, such as *Misgurnus fossilis*. Drainage ditches are feeding areas for various bird species, such as *Ciconia nigra*, and clogging of these ditches causes adverse effects on the feeding possibilities of these species (Strazds 2005).

Although drainage ditches are not included in habitat type 3260 *Water courses of plain to montane levels with Ranunculion fluitantis and Callitricho-Batrachion vegetation*, in agricultural lands and forest areas they often have a similar function to natural rivers because they provide living places and migration corridors for aquatic organisms. Therefore, for species conservation purposes, they must be managed.

Management, according to its target, can be divided into two groups: (1) ensuring of biodiversity and (2) mitigation of impacts of flooding and flood. Measures that provide biological diversity:

- *in the channel* – mowing of aquatic vegetation, demolition of beaver dams, formation of sinuosity of the ditch course, excavation and cleaning of settling ponds, placement of stones or groups of them in the drainage ditch, clearing of roots of trees and bushes penetrating the ditch bottom;
- *construction of two-stage drainage ditches;*
- *mowing of riverbanks and bank slopes* – cutting of tree and bush sprouts.

Fig. 17.38. Re-meandering of regulated river Dviete
Photo: K. Goba.

Depending on the regularity of conducting, all management works are divided into annual works and works that need to be carried out over a longer time period (Buisson 2008). Works that need to be carried out over a longer time period include the formation of sinuosity of the course of the channel, which is achieved by facilitating guided bank erosion of the uniform ditch, excavation and cleaning of settling ponds, etc. Clearing of the ditch from bushes and their root systems penetrating the ditch bottom is also management that needs to be continued over a longer time period in regular intervals. In Great Britain, in a three-year management cycle, either one of the slopes of the ditch, or the channel-bed of the ditch is alternately managed. By following this management pattern, aquatic habitats are impacted less and the function of migration corridors is ensured (Buisson 2008).

Due to agricultural intensity characteristic for Latvia, many parts of the landscape are dominated by a mosaic of agricultural land and natural habitats. In such areas the three-year management cycle applied in Great Britain is not necessary. It is important to apply this cycle in areas dozens of hectares of size, where strips separating fields, buffer zones of drainage ditches and protection zones of watercourses are the only hiding places and migration corridors for organisms.

Biodiversity is ensured by all management activities that make the channel-bed of a drainage ditch more diverse. Such activities include, for example, the establishment of riffle areas by placing individual stones or their groups on the drainage ditch channel-bed, thus diversifying the substrate inhabited by aquatic invertebrate species –*Ephemeroptera, Odonata, Trichoptera* (Urtāns 2011; Kalniņš 2014).

Another way to ensure biodiversity in flood prone areas, that has been introduced and tested in other countries, is the installation of two-stage drainage ditches (Fig. 35). The goal of creating such ditches is to not only collect flooding waters and reduce the risks of flood, but also to limit soil erosion, reduce nutrient leaching, maintain water flow in the summer low-water period and create diverse habitats (Briedis (ed.) 2013). In the summer low-water period, when the water is concentrated in the narrowest and deepest part of the ditch, a constant water flow is ensured, the ditch does not dry out and serves as a living environment for aquatic organisms. It also prevents clogging of the channel. The terrace created in the watercourse slope facilitates the formation of additional shading and prevents the ditch from overgrowing with aquatic plants. The created flooding terraces extend the ecological corridor area. Vegetation growing in the ditches can also be used as animal feed. The main disadvantage of two-stage ditches is that their area is larger than that of the trapezoidal or V profile ditches.

17.3.5 General Management Measures in Watercourses

17.3.5.1 Removal of Household Waste

Items of anthropogenic origin can often be found in watercourses - bottles, plastic bags, boards, metal items, etc. They are foreign objects for the river and the ditch, and their presence decreases the visual appeal of the river (Fig. 17.40). Household waste management can only be directly related to habitat management in cases when the amount of such items causes hydromorphological alterations and impedes the flow rate of the river. In such cases, the waste can be collected, most often, with the use of machinery. In other cases rubbish is collected during the course of other habitat management works. However, the most effective way to manage waste is to prevent it from entering the water.

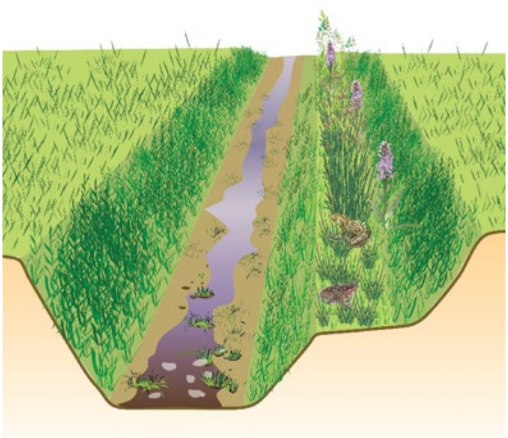

Fig. 17.39. Two-stage ditch. Drawing by D. Segliņa (according to Briedis (ed.) 2013).

Fig. 17.40. Outsource items in the River Kauliņa. Photo: L. Urtāne.

Fig. 17.41. *Heracleum sosnowskyi* can be eliminated most efficiently in spring, when the plant has not yet reached a large size **(1)**, and it can be easily removed with the roots **(2)**. Photo: A. V. Urtāns (1), M. Poikāne (2).

17.3.5.2 Landscaping

Rivers and their valleys are often the main connecting points of various landscape elements. Even regulated rivers on intensively farmed lands make a pleasant change in an otherwise monotonous landscape. Riverine landscape (Riverscape) elements have disappeared in many places in Latvia and are not noticeable behind the continuous shore vegetation. A well-functioning and biologically diverse watercourse is also a natural and scenic river. Therefore most of these guidelines, management methods of natural rivers described in *Chapter 17.3*, are also landscaping activities, which ensure the maintenance of migration corridors for organisms, formation of living places and hiding places, riverbank stabilisation, regulation of shading, reduction of wind and water erosion impacts, etc.

17.3.5.3 Control of invasive species

Methods of invasive species control depend on the physiology and growth characteristics of the species. In Latvia, the majority of invasive plant species are found on riverbanks, rather than in the water, therefore management is needed on the riverbanks. Given that these species grow in the protection zones of rivers, the use of herbicides on any of these species is prohibited. They can only be combated with mechanical techniques.

Combating invasive plant species found on riverbanks. The most common invasive species on riverbanks are *Heracleum sosnowskyi* and *Impatiens glandulifera*. The spread of *Heracleum sosnowskyi* may be limited, by not allowing it to bloom and ripen seeds. Therefore territories that are overgrown with *Heracleum sosnowskyi* must be mown 2–3 times during a season. *Heracleum sosnowskyi* that grows near rivers is combated by digging it out. It is recommended to do it in spring, when the plants are small in size and can be dug out with the roots (Fig. 17.41). The dug-out rhizomes must be wrapped in rubbish bags with thick, preferably lightproof film and stored until they are fully decomposed. During one vegetation season, the digging of rhizomes should be repeated 2–3 times, because plants can recover from the root fragments remaining in the soil (Anon. 2007). For the same reason, riverbanks invaded by *Heracleum sosnowskyi* must be surveyed in their management locations for several years in a row, also after the seemingly successful destruction of invasive plants.

Mowing, even if it is performed several times in a season, has low efficiency. With mowing the plant can be weakened and its further spread can be limited, but it cannot be completely destroyed. Good results can only be achieved by regular and long-term management and collaboration of all land owners of the land on the riverbanks. In small invaded areas, grazing by sheep or cattle is applicable.

When combating *Heracleum sosnowskyi,* safety requirements must be met – the plant's sap may cause burns through a photochemical reaction, therefore the person performing mowing must use thick, preferably waterproof clothing, rubber gloves or other waterproof material and protective goggles. If the skin has come into contact with the sap of the plant, the area of the skin should be rinsed off with water immediately.

Impatiens glandulifera spreads on riverbanks and slopes (Fig. 17.42). If it spreads massively, it outcompetes lower herbaceous plants, causing increased erosion and washing of the soil from the riverbanks. The most efficient method to limit *Impatiens glandulifera* is weeding the plant before it blooms. If the plant is weeded during bloom, sowing of seeds is possible, because during bloom the majority of the seeds are already ripe. If mowing is used, it is necessary to mow as close to the ground as possible, because new shoots can develop if the remaining stems are too high (Priede 2007).

Eradication and control of invasive species of aquatic animals is much more complex, and it is more difficult to link it with economic interests. Experimental control of the invasive species *Pacifastacus leniusculus* (Fig. 17.43) population has been implemented in Salacgrīva Municipality.

In order to involve the public in invasive species control, licences for the catching of *Pacifastacus leniusculus* were sold, with the condition that all *Astacus astacus* that have been caught must be released. Over a three-year period (2008–2011), during the catching season of invasive *Pacifastacus leniusculus* (from 20 July to 30 September) each year 7167–16 000 *Pacifastacus leniusculus* were caught in the River Salaca. Unfortunately, no *Astacus astacus*, characteristic for the local fauna, were found among them. This means that the population of *Astacus astacus* has either disappeared or is minor. Control and complete eradication of the numerically large invasive populations of *Pacifastacus leniusculus*, in order for the *Astacus astacus* to return to its former living place, takes much more time.

17.3.6 Comparison of Methods Used for the Management of River Riffle and Natural River Habitats

Management and restoration of rivers and regulated watercourses is becoming increasingly popular. Not only do individual people, angler's clubs and non-governmental organisations engage in management and restoration activities, but such activities become regular annual events on a municipal and even regional level. The most active municipalities in this field are Jelgava, as well as Bauska and Kuldīga.

An overview of the applied habitat management and restoration methods is provided in table 17.3. An overview of the selection of optional river management activities is given in Appendix 1, the selection of optional lake management activities is represented in Appendix 2.

Fig. 17.42. *Impatiens glandulifera.*
Photo: L. Urtane.

Fig. 17.43. *Pacifastacus leniusculus.*
Photo: A. Soms.

Table 17.3. Habitat restoration and management methods.

Method	Advantages	Disadvantages	Costs	Necessity to repeat
A.1: Removal of large woody debris	Restored water flow and migration routes to promote: • prevention of degradation of riffle area; • washouts and bank erosion; • increased self-purification capacity; • renewed aquatic organism migration; • decreased flooding risk.	Significant increase in cost, if there are steep riverbanks or if trees need to be floated to a suitable removal site.	30–50 EUR/ m^3 of woody debris removed from the river.	The cleared river reach must be reviewed annually, in the case if clearing must be repeated.
A2: Demolition of beaver dams	Restored water flow and migration routes to promote: • prevention of degradation of riffle area; • increased river self-purification capacity; • renewed aquatic organism migration possibilities; • decreased flooding risks.	Needs to be repeated often if beavers are not eliminated.	Depends on the size and location of the dam, availability of machinery and manual labour. Average 80 EUR/m^3.	Regularly, each year (0,5 to 8 hours per dam).
A3.1: Mowing of aquatic plants	Improved water flow to promote: • increased river self-purification capacity; • reduction of degradation of riffle area; • reduced nutrient amount stored in macrophytes.	Regular repetition is needed, usually every year.	85–500 EUR/ ha (mowing and removal).	Every 1–3 years.
A3.2: Aquatic plant mowing with scarifying/ removal of the root system	Improved water flow to promote: • river self-purification capacity; • reduction of degradation of riffle area; • reduced nutrient amount stored in macrophytes; • diverse microhabitats development on an open riverbed.	Available machinery working only to the depth of 0,6–0,8 m.	1700–2500 EUR/ha + tractor transportation costs.	Every 3–5 years.

Method	Advantages	Disadvantages	Costs	Necessity to repeat
A4.1, 4.2: Improvement of the shore vegetation structure and shading regulation	Reduced soil leaching from areas with no vegetation to promote decreased sedimentation process intensity. Reduced nutrient discharge in the river from the adjacent terrestrial areas to promote pollution limitation and diverse microhabitats development on an open riverbed.	Once started, needs regular maintenance, especially in the case of open grassed bank.	300 EUR/ha.	Once a year.
A5: Bank stabilisation	Prevention of bank erosion to promote decreased sedimentation process intensity or renewal of former river width.	Use of unnatural elements, riverscape becomes less attractive.	Expenditure depends on the material used.	One-time.
A6: Creation of riffles	River is inriched with oxygen to promote increased river self-purification ability and mitigation climate changes impacts to water quality. Creates microhabitats to promote increased biodiversity.	If inadequately designed and positioned in the river, riffles can facilitate bank erosion.	1700 EUR/ha.	Once every five years.
A7: Creation of spawning grounds	Maintains area and quality for reproduction of particular fish species, while also providing living conditions necessary for many aquatic invertebrates.	If inadequately designed and placed in the river, spawning grounds can facilitate bank erosion.	1700 EUR/ha.	Cleaning once every 1–3 years.
A8: Construction of fishways	Created for fish, also provide migration possibilities for many aquatic invertebrates, maintaining a diverse genetic pool.	The functionality of fishways is determined by the amount of water available, the length and positioning of the fishway. Fishways are not always effective.	Costs depend on the material used and the size of the construction, 7000–700 000 EUR.	One-time.

Method	Advantages	Disadvantages	Costs	Necessity to repeat
A9: Demolition of mill dam remains and obstacles	Restores migration of fish and other aquatic organisms, maintaining diverse genetic pool and healthy population.	Temporary load in the lower courses of the river from the sediment accumulated in the dams.	2130 EUR (20 m^3) (example of the River Vikmeste – costs in 2002).	One-time.
A10: Removal of sand deposits from mouths of rivers flowing into the sea	Provides a larger number of fish arriving to spawn.	The sea often fills up river mouths, and the activity must be repeated regularly.	Costs depend on the complexity of access.	As needed. Cleaning once every 1–3 years.
A11: Invasive plant species control	Restores riverbank stability. Prevents the further spread of invasive plants in terrestrial habitats.	Only effective through the cooperation of landowners.	Depends on the availability of machinery or manual labour, as well as on the invaded area. Manual mowing – 200 EUR/ha, manual digging – 300–500 EUR/ha.	Digging must be carried out at least 2–3 years in a row. In the coming years individual plants must be eliminated.

17.3.7 Unfavourable Use and Management of riffles and natural river reaches

17.3.7.1 Inappropriate Use

In previous chapters, threats for riffle and natural river habitats and the factors influencing them are described. The majority of them are attributable to the lack of appropriate management, which can be resolved by using the management techniques described in these guidelines. Inappropriate management of riffle and natural river habitats is:

- constructions and impoundments built for electricity production purposes;
- regulation of natural watercourses;
- increased pollution loads that include wastewater (domestic, industrial wastewater, stormwater and waters collected in drainage systems) runoff and diffuse runoff from agricultural lands and forests;
- introduction of invasive species in riverbanks, unauthorised dumping of garden waste on riverbanks and in their vicinity.

The threats listed above may be at least partially reduced with the regulatory framework and sustainable land-use planning, as well as by introducing environmentally friendly technologies and using the management techniques described in these guidelines (table 17.4).

17.3.7.2 Unfavourable management

Unfavourable management of riffle habitats and natural river habitats can sometimes be seen as the maintenance of an individual river function or ensuring favourable conditions for an individual species, which is often even unrelated to the river. For example, to ensure the water flow rate, the cleaning works in rivers over the previous decades have often been carried out without paying sufficient attention to the structure of the river-

Table 17.4 Techniques that minimise adverse effects on the habitat.

Use unfavourable to the habitat	Management techniques to reduce the impact
Increased pollution loads	• Ensuring functionality of protection zones. • Limiting aquatic plant overgrowth. • Establishment of riffles. • Environmentally friendly management of drainage ditches. • Establishment of artificial wetlands on the inflowing ditches. • Establishment of settling ponds on the inflowing ditches. • Maintenance of natural spawning grounds suitable for salmonids and lampreys and the establishment of artificial spawning grounds.
Regulation of watercourses	• Improvement of the functionality of straightened rivers (sinuosity, establishment of pool – riffle sequence, etc.). • Re-meandering of straightened rivers.
Man-made constructions in the river and uncontrolled formation of dams	• Establishment of fishways. • Demolition of dam remains. • Removal of excessive large woody debris.
Inappropriate management of the shore area	• Improvement of the shore vegetation structure. • Limitation of the number of beavers. • Regulation of river shading. • Riverbank strengthening.
The introduction of invasive species, garden waste disposal on the riverbanks and near them	• Preventive measures, precluding planting or other type of spreading of invasive species in the vicinity of rivers; education of people. • Limiting the distribution of invasive foreign plant species.

bed to be cleaned – maintaining pools, stones, pebbly and gravelly river reaches. Such microhabitats can provide a diversity of aquatic organisms even in long, regulated river reaches. By focusing only on the ensuring of water flow, species diversity in the regularly cleaned drainage ditches, significantly decreased.

Watercourses are open systems, and their enrichment with plant nutrients (mostly nitrogen and phosphorus compounds) that have discharged into them in the form of fertilisers, detergents and other compounds, is not a natural process. In this respect, non-interference in the processes of watercourses is considered as unfavourable habitat management.

Considering the above-described effects of nutrients of foreign origin discharged into the watercourses, non-management of the watercourse protection zones and leaving them to "develop naturally" is also considered as unfavourable management. By using the habitat management techniques described in these guidelines, it is possible to ensure good habitat conservation status or at least to improve it.

17.4 Contradictions of Conservation and Management

Contradictions of conservation and management of the habitat arise when the characteristic for ecosystem is not respected or if the conservation of a particular species (group of organisms) is rated higher than the requirements of other organisms. This also applies to the limitations set for the management of river habitats. For example, from the point of view of plant physiology, measures to limit the distribution of aquatic plants are most effective when plants are mown in the beginning of the vegetation season, when plants consume the most energy. This period overlaps with the bird breeding period and the spawning period of some fish species. Observations in recent years show that due to climate change, bird breeding occurs earlier. Consequently, mowing of aquatic plants could also be started earlier than it is now defined in the legislation. In addition, not all river habitats are suitable for the nesting of water birds and spawning of fish species for whose protection the aquatic plant mowing limitations were set. In several European countries there are no equal conditions, which are applied to all rivers, but each case is evaluated individually, taking into account the type of river, the inhabiting species, the presence of water-related species, as well as the condition of the habitat and the need for its particular management.

When managing river habitats, contradictions arise when the conditions for the good functioning of the river and the needs of terrestrial species must be harmonised. Most often problems are related to maintenance of an optimal river flow regime. In fast flowing rivers (1st variant of the habitat), it happens, for example, by focusing on the habitat requirements for woodpeckers; the riverbanks are left with too large amounts of dying and dead trees, which fall into the river, creating a greater obstruction than the favourable conservation status of the habitat allows (see Chapter 17.1.2). Consequently, hydromorphological alterations, to which fast-flowing rivers are sensitive to, develops in the watercourse.

Both variants of the habitat are also adversely impacted by the activity of beavers. Beaver impoundments are a valuable habitat – both as a structural element of the natural forest habitat, and as feeding areas for various bat and bird species (particularly *Piciformes*) (Lārmanis et al. 2000). However, maintenance of this habitat must not threaten the existence of the riffle habitat, and the area of this habitat may not be increased at the expense of the reduction of riffle habitat areas. Free flow is the only condition, under which watercourses can exist and their natural bottom structure and temperature regime can develop, especially in rivers with migrating fish and lamprey spawning grounds. Rivers as running water systems have no distinct succession, as, for example, lakes have, and they do not transform into another type of habitat. So in this case, the priority is conservation of the riffle habitat, because only this can ensure the conditions necessary for the existence of protected aquatic species.

By developing projects related to aquatic habitats, respecting of the functional characteristics of the water ecosystem and the requirements of aquatic organisms must be a priority even if the target species of the project is not an aquatic species. Such is the case, for example, in projects of re-meandering, the aim of which is to change the moisture regime of the river's adjacent territories and to create conditions suitable for their inhabiting species. The aim of re-meandering of the River Slampe was, upon restoring the flooding regime, to establish an important gathering site of migratory water birds and a breeding site for corn crakes (Ķuze et al. 2008). By facilitating the flooding of the areas adjacent to the re-meandered River Slampe reach, eight years after the completion of the project, it has been achieved that more than 5000 water birds are gathering in the area, the number of vocalising corn crake males has slightly increased (remaining close to the numbers detected prior to re-meandering). In the same period stable vegetation of higher aquatic plants characteristic of slow rivers in the naturalised River Slampe has not developed, the structure of the bioceonosis of macrozoobenthos organisms is simplified and does not match the one characteristic of potamal rivers (Priede et al. 2015). Also, the re-meandering of the River Dviete was carried out to restore the natural flow and corncrake habitats while during project development it was found that water habitats - rivers, lakes, ditches - leave neither positive nor negative effects on the corn crake population (Abaja, Eriņš 2015).

To ensure the flooding regime, a water holding stone cluster was created in the River Slampe, which does not meet the functionality conditions of a natural river, whereas, by re-meandering of the River Dviete, a large section of the lower reaches was designed without a gradient, ignoring the functions of natural rivers and the fact that the Valley of Dviete during the flooding period is mainly filled not with flooding waters of the River Dviete, but rather with the flooding waters from the River Daugava (Gruberts 2015). Thus, the requirements of the shore species were rated higher, and the functional requirements of the water ecosystem were met only partly.

Therefore, when developing restoration (re-meandering) projects for watercourses in the future, flow rate requirement values of the new river course must first be coordinated with the conditions for the creation of an appropriate natural riverbed profile suitable for aquatic organism habitats:

- bank slope inclination and riverbed profile provides for the existence of shallow shore areas,
- an appropriate cross section is designed in river meanders,
- pools and other structures characteristic for natural watercourses are maintained.

Moisture regime requirements of the shore habitats and their inhabiting species must also be met (Priede et al. 2015).

Chapter 18. 3270 *Rivers with Muddy Banks with Chenopodion Rubri p.p. and Bidention p.p. Vegetation*

18.1 Characteristics

18.1.1 Brief Description

Characteristics. The habitat type 3270 *Rivers with muddy banks with Chenopodion rubri p.p.* and *Bidention* p.p. vegetation (further, referred to as *muddy riverbank habitat*) includes muddy banks of rivers, side bars and low islets in the river and in its side arms which, due to greater level fluctuations, are without any vegetation during spring and at the beginning of summer. Later in the year annual pioneer nitrophilous vegetation (18.1, 18.2) if the weather conditions of the particular year are favourable. In years with a high water level, this habitat may not develop at all.

Plant communities are dominated by medium-high to high annual plants that have adapted to growing in nitrogen-rich soils. The characteristic species are, for example, *Chenopodium rubrum, Chenopodium acerifolium, Bidens cernua, B. tripartita, Xanthium albinum, X. strumarium, Polygonum nodosum*. Also present are plant species adapted to varying moisture conditions – *Rumex aquaticus, Ranunculus sceleratus, Alisma plantago-aquatica* and *Potamogeton natans*. The shore muddy deposits are used as a feeding area for common sandpiper *Actitis hypoleucos* and little ringed plover *Charadrius dubius* (Eņģele, Sniedze-Kretalova 2013).

Distribution. The distribution of the habitat is mostly related to the riverbanks of the large rivers

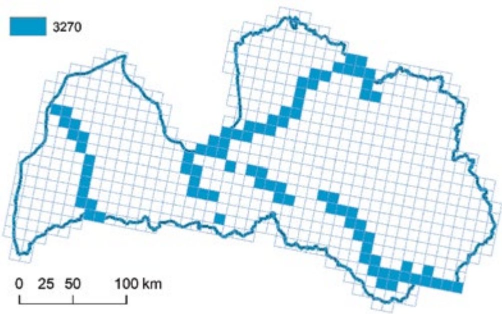

Fig. 18.3. Distribution of habitat type 3270 *Rivers with muddy banks with Chenopodion rubri p.p. and Bidention p.p. vegetation* in Latvia (source: Anon. 2013).

(Fig. 18.3) – the River Daugava, the River Gauja, the River Venta, possibly also the River Lielupe (Majore, 1962; Soms, 2010; Eņģele, Sniedze-Kretalova 2013).

As logging increases, facilitating soil washout from felling areas, the formation of sand bars with habitat characteristic vegetation has also been observed in medium-sized rivers. The total area of the habitat in Latvia is 122 ha, which corresponds to 0.002% of the territory of the country (Anon. 2013).

Perhaps, the total area of the habitat is greater. It varies depending on the hydrological conditions – in years with negligible spring flooding and a long summer low-water period, the total area can increase significantly. In some parts of the River Daugava, the formation of the habitat is related to the management of hydroelectric power station water reservoirs and the maintenance of the infrastructure (Fig. 18.4). The habitat also develops in small areas on washout cones of ravines in river valleys (Soms 2010).

Fig. 18.1. Small side bar in the River Gauja near Murjāņi. Photo: A. V. Urtāns.

Fig. 18.2. Annual vegetation on the washout of a small brook. Side arm of the River Gauja near Murjāņi. Photo: A. V. Urtāns.

The minimum requirements for a habitat to be recognised as such, are appropriate environmental conditions (at least 2 m wide muddy or sandy-muddy substrate areas, can also be without communities of characteristic species) (Eņģele, Sniedze-Kretalova 2013).

18.1.2 Indications of Favourable Conservation Status

This habitat is a natural and dynamic manifestation of the river hydrology and sediment transfer processes. Favourable conservation status of this habitat is characterised by both the dominance of annual plants and by their complete absence. The appearance of willow shoots indicates a possible transformation of a shoal into an islet or a shore terrestrial habitat with elements of an alluvial forest. Higher quality of the habitat is indicated by:

- a wider shore or sand bar area with open soil, suitable for the development of the habitat;
- an area inhabited by species communities characteristic for the habitat;
- an area without expansive and atypical species stands;
- higher number of characteristic species (Eņģele, Sniedze-Kretalova 2013).

18.1.3 Important processes and structures

Natural development of the habitat is determined by the transportation and accumulation of

Fig. 18.4. Lowering of the water level of the Riga hydroelectric power station's water reservoir in July and August of 2014 created temporary favourable conditions for the development of the habitat, but simultaneously adversely affected aquatic organisms. Photo: A. V. Urtāns.

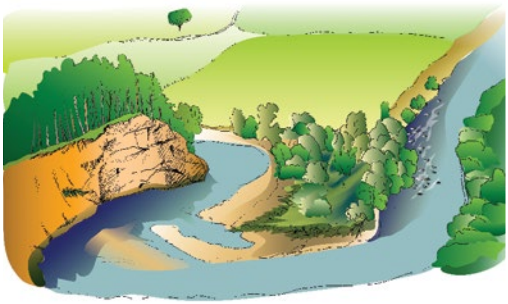

Fig. 18.5. Sand bars and pools in the River Amata at Zvārtes Cliff (before straightening of the river reach). Drawing by D. Segliņa.

sediments. Riverbeds are usually not straight. They usually form a series of erosion curves or meanders (Fig. 18.5). Simultaneously with riverbed erosion, side erosion also occurs (Fig. 18.6), when sediments deposit and conditions favourable to the existence of the habitat form in the curved part of the riverbed (Bambergs 1993).

For example, in the River Gauja, within the territory of Gauja National Park, the habitat usually forms on new shoals and new sandbanks on the lower parts of islets. From 1980–1984, 56 islets were observed in the River Gauja in Gauja National Park (Eberhards 1991). In comparison with 1927, the total number of islets has not changed significantly. However, from the 55 islets that were found in the River Gauja in the summer of 1927, only twenty have survived in the time period from 1977 to 1984. Approximately 35 islets have formed anew. The characteristics of the habitat have also changed significantly. In the time period between 1926 and 1930, sand shoals without vegetation, sometimes even 30–60 m wide, were characteristic for the River Gauja. In the 1970s and 1980s, shoals had become much narrower (Eberhards 1991).

It is determined by the level of spring flooding. When the flooding level is low, sand is not washed on top of the shoals, and with a low-water period repeating in several summers, the habitat overgrows with willows, and over time transforms into an alluvial forest.

Sometimes trees get stuck in the shoal. This causes the formation of an eddy. As the stream velocity decreases, sand accumulates in the initially low shoal, creating an autonomous islet, which overgrows with bushes and trees over time.

Fig. 18.7. Change of the River Gauja riverbed in the Sigulda-Nurmiži vicinity (source: Eberhards, 1991). *Upper edge of the valley*, *Riverbed of the River Gauja*

18.1.4 Natural Development of a Habitat

Formation of the habitat is affected by the volume of water in the river in different seasons, the geological structure of the riverbanks and the riverbed, as well as the bedrock. The rate and volume of bank erosion depends on bedrocks on the riverbanks, and how easily they can be eroded at a certain stream velocity. The uncertainty of the existence of this habitat is characterised by the movement of the bed of the River Gauja (Fig. 18.7) in the Sigulda-Nurmiži vicinity over a 150 year period (Eberhards 1991).

Depending on the volume of water, the natural succession of the habitat may evolve in different directions. Several successive years with prolonged low-water periods during the growing season contribute to the disappearance of annual vegetation and establishment of perennial plants. Most often such places are dominated by *Phalaris arundinacea*. In that case

Fig. 18.6. Islet with the formation of habitat characteristic vegetation in the outer curve of the River Gauja. Photo: A. V. Urtāns.

it can be considered that the EU protected habitat type 3270 *Rivers with muddy banks with Chenopodion rubri p.p.* and *Bidention p.p. vegetation* naturally transforms into another habitat of EU significance – 6430 *Hydrophilous tall herb fringe communities of plains and of the montane to alpine levels*.

In absence of regular disturbance, this habitat can overgrow with bushes and alluvial forest over time. Alluvial shore forests can also form on muddy shoals and low islets over the course of consecutive low-water years.

Unlike that which is previously described, in years with high water flow rate shoals can be fully flushed, disappear and start to form anew in other locations with a lower stream velocity. Such development of a shoal is also considered natural succession.

18.1.5 Pressures and Threats

The existence of the habitat is a dynamic manifestation of the processes naturally occurring in a river. It is determined by the volume of water in the river and stream velocity in different seasons, the geological structure of the riverbanks and the riverbed, as well as the composition of bedrocks. Decrease in area and even the disappearance of shoals and muddy shore areas may be caused and affected by riverbank strengthening works upstream from the habitat.

Such action contributes to increasing stream velocity in the river below the fastened river reach and possible erosion of the habitat-characteristic shores and muddy riverbanks, creating them anew in the lower courses of the river, where the stream velocity is lower.

18.2. Management Objectives in the Conservation of Muddy Riverbank Habitats

A conservation and preservation goal specific to this habitat is to provide successful breeding and feeding for common sandpiper *Acitis hypoleucos* and little ringed plover *Charadrius dubius*. These bird species nest on sandy or stony shoals.

18.3 Restoration and Management of Muddy Riverbank Habitats

In order for the habitat to exist, it is not possible and also not necessary to provide special management or conservation. The most important issue is to preserve the seasonal flooding rhythm and transportation of deposits.

Exceptional cases occur when rivers wash-out their shores endangering the human-created infrastructure. In such cases priorities of further management or conservation of the affected territory must be determined and actions must be taken according to these priorities.

18.4 Contradiction of Conservation and Management

The formation of shoals in rivers, where they have not previously been observed, may indicate changes in hydrological conditions, which can be caused by both natural processes (such as climate change-induced monthly runoff distribution changes, water flow changes caused by fallen trees of groups of trees) and human economic activities (increase of logging areas and intensely used agricultural areas).

If the amount of deposited inorganic materials exceeds 25% of the former pebbly riverbed, it is considered a significant change, which negatively affects the overall hydromorphological condition of the river (LVĢMC, 2014). In rivers, in which the formation of shoals and islets is a natural process observed for a long time period (such as in the River Gauja), the habitat's overgrowth with perennial vegetation and transformation into the habitat type 6430 *Hydrophilous tall herb fringe communities of plains and of the montane to alpine levels* is considered as a natural succession and should not be restricted.

If such tall herbaceous plant communities are not managed, it is possible that they will naturally transform into habitat type 91E0* *Riparian mixed forests of Quercus robur, Ulmus laevis and Ulmus minor, Fraxinus excelsior or Fraxinus angustifolia, along the great rivers (Ulmenion minoris)*. This model of development is possible, and its realisation depends on the management priorities for the specific area.

Glossary

Benthos – aquatic organisms that live on, in, or near the bottom of bodies of water, also including aquatic organisms living on plants.

Biogenic elements (biogenes) – nitrogen and phosphorus compounds in waters, including silica, in various ionic or molecular forms. Biogenic elements are nutrients for aquatic plants. Their excessive concentration may cause the increased development of aquatic plants, thus increased oxygen consumption, threatening the existence of fish and other aquatic organisms. Equal term – plant nutrients.

Biological oxygen demand (BOD) – the amount of dissolved oxygen consumed for biochemical oxidation to break down the organic or inorganic matter in a given water sample, expressed in milligrams per litre. Since the amount of oxygen in the water is limited, in cases when the oxygen is consumed increasingly, the BOD increases. Consequently, oxygen deficiency can have a negative effect on the aquatic ecosystem.

Catchment area – land area from which rivers and lakes collect their waters. It is separated from the adjacent catchment area by a watershed.

society.

EU priority habitat (*also EU priority protected habitat*) – types of habitats that are in danger of extinction, and that are located in the territory of the EU Member States, and for the conservation of which the Communities have a particular responsibility taking into account the proportion of the natural range of those habitats in all Member States. The priority natural habitat types are marked with an asterisk (*) in Annex I of Council Directive 92/43/EEC of 21.05.1992, on the conservation of natural habitats and of wild fauna and flora.

European Union (EU) protected habitat – a habitat that, in terms of the environmental conditions and the species community, conforms to any of the habitat types listed in Annex I of Council Directive 92/43/EEC of 21.05.1992, on the conservation of natural habitats and of wild fauna and flora.

Favourable conservation status – the natural range and area of habitat is stable or expanding; the specific structures and functions of the habitat that are required for the long-term existence of the habitat exist, and it is expected that they will exist in the nearest future; the conservation status of the habitat-specific species in the area of the Member State of the European Union is favourable.

Habitat – the concept used in this edition for the purpose of the Law on Species and Habitat Conservation. A habitat is a set of specific abiotic and biotic factors in an area where the species exists in every stage of its biological cycle.

Habitat creation – a set of biotechnical measures aimed at the creation of the environmental conditions, structure (species composition, age structure, etc.) necessary for the habitat, and the introduction of species in the place where the habitat has never existed. This also applies to sites, where the habitat has once existed, but the environment has been completely transformed and no features of the habitat have been preserved.

Habitat management – a set of biotechnical measures aimed at maintenance of the habitat in a favourable conservation status.

Habitat restoration – a set of biotechnical measures aimed at the restoration of the environmental conditions, structure (species composition, age structure, etc.) and species in the place where the habitat has once existed or still exists, but is in poor conservation status.

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

Humic substances - macromolecular, natural organic substances, which give the water a wide spectrum of colours (from yellow to black) to water. Depending on the degree of solubility in water, three fractions of humic substances are determined: *humin* – the fraction of humic substances that does not dissolve in water; *humic acids* - the fraction of humic substances that dissolves in water if the pH > 2; *fulvic acids* - the fraction of humic substances that dissolves in water in any environmental pH.

Littoral - the shallowest part of a lake, where sunlight reaches the bottom of the lake and macrophytes are able to develop (from Latin *litoralis* - sea shore).

Macrophytes – vascular plants, sporophytes, macroscopic algae and aquatic moss plants that have completely or partially adapted to life in water and are visible to the naked eye.

Macrozoobenthos – aquatic animals (mostly invertebrates) that inhabit the bed of water bodies and watercourses, and underwater objects on the bed; their size exceeds 1 mm; the sensitivity to environmental changes of macrozoobenthos organisms gives the opportunity to use them as indicators of environmental quality; populations of macrozoobenthos usually change due to the impact of three factors: overload of organic substances, transformation of substrates and toxic chemical pollution.

pH - a numeric value that specifies the concentration of hydrogen ions in a solution, expressed as the negative logarithm of the hydrogen ion concentration; in these guidelines it is used to describe the acidity and alkalinity of an aquatic environment (acid environment pH < 7.00; alkaline environment pH > 7.00); pH determines the solubility and biological availability (the amount of substances available for aquatic plants and organisms) of chemicals (such as biogenes, heavy metals and their compounds).

Phytoplankton – a complex of free-floating microscopic algae. The major groups in phytoplankton are cyanobacteria, green algae and diatoms. Phytoplankton accumulates dissolved inorganic and organic substances and through photosynthesis produces organic compounds, which are the basis for proper future functioning of the water ecosystem.

Plankton - microscopic organisms living in the water layer (from Greek *plankton* - drifting); plankton organisms are very diverse and can be divided into bacterioplankton (bacteria), phytoplankton (plants, mainly algae) and zooplankton (tiny invertebrate organisms, mainly crustaceans) – the most important are phytoplankton and zooplankton.

Recultivation – here the definition from the national regulatory enactments in Latvia are used: recultivation is the restoration of the initial value of the degraded site to prevent the threats to environmental quality, human health and life.

Saprobity – water pollution with easily degradable organic substances (from Greek *sapros* - rotting - and bios - alive), this indicator is used for pollution assessment.

Succession (= ecological succession) – a process of change in the species structure of an ecological community over time. It means that the habitats replace each other, for example, a mesotrophic lake transforms into a eutrophic lake and then into a transitional mire, and then into a raised bog.

Suspended substances - solid particles in water – of both mineral (for example, soil particles) and organic (algae) origin; high concentration of suspended substances reduces water transparency, and also indirectly affects the oxygen concentration and water temperature.

Transparency with Secchi disc (in lakes) – Secchi disc (a circular disc with a white surface, 30 cm in diameter) is used for measuring water transparency, i.e., the depth at which the disc is still visible; greater depth means that light is able to penetrate deeper and ensure photosynthesis; although the Secchi depth varies depending on the season and weather conditions, it is a simple, fast and effective method to identify possible lake pollution with nutrients or turbidity of the water.

Zooplankton - animal plankton, living in the water mass and feeding on algae; there are species that feed on organic substances or other zooplankton organisms; zooplankton consists of three major invertebrate groups: *Rotifera, Cladocera* and *Copepoda*.

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Annexes

Planning management of aquatic habitats, it is necessary to set a goal – what we want to achieve with planned measure? In order to facilitate the setting of the management objective and the choice of the appropriate management measure, the annexes of the guidelines provide a tool for the selection of general measures for the management of water habitats – Annex 1. for lakes and Annex 2. For rivers. Annex 3 illustrate river and lake management activities typical for aquatic habitat state in Latvia and are country specific.

Management relation to the Climate changes. It is expected that as a result of climate change, the annual average water temperature will rise, oxygen saturation will decrease, soil leaching processes under increased run-off conditions will increase during a vegetation-free season.

In such conditions:

- More intensive macrophyte development and overgrowth of waterbodies take place;
- Initially, there will be better conditions for algae, floating-leaved plants and freely floating lemnids, covering water surface and shading lower layers of the waterbody;
- Emergent macrophytes shall benefit and occupies shallow littoral zone;
- New conditions becomes more favourable for species tolerant to oxygent deficiency;
- Oxygen sensitive aquatic species gradually disappears.

With appropriate waterbody and their coastal zone management activities it is possible to lessen Climate change induced changes in river and lake habitats.

Annex 1. General Measures for the Management of Lake Habitats

With appropriate management of lake and its coastal zone it is possible to slow down ageing The owerall goal of lake habitat management is:

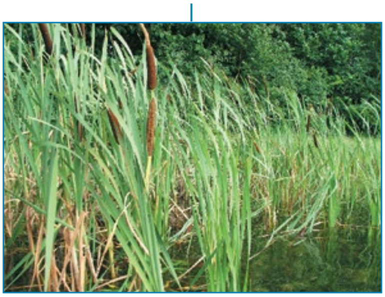
- Improve lake functionality ensuring that plant nutrients and materials of organic origin causing eutrophication are accumulated more slowly in the lake and that the oxygen dissolved in water is not reduced;
- Improve the functionality of the lake coastal zone to maintain a high nutrient accumulation capacity and prevent soil erosion from entering the lake.

1. Decrease of overgrowth with aquatic plants

Do emergent and floating-leaved plants cover more than 30% of the lake surface?

NO — Management measure is not necessary

YES — Mowing is necessary

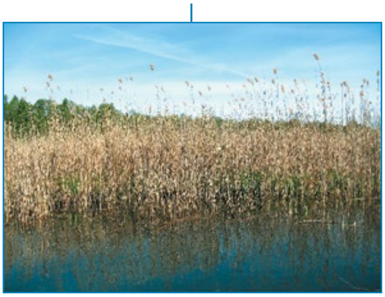


2. Reinforcing wave activity

Is the lake shore in the direction of prevailing winds (usually NW winds) densely overgrown with aquatic plants?

NO — Management measure is not necessary

YES — It is necessary to mow aquatic plants and create separate vegetation-free shore areas in order to allow waves to reach the shore.



3. Reduction of overgrowth with bushes. Creation of natural grassland and sand zone adjacent to the lake shore

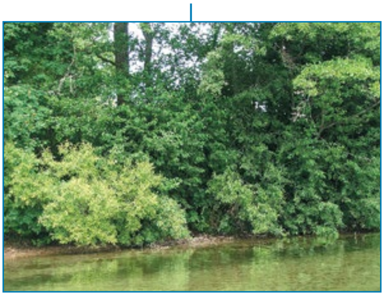
Is there a belt of grasslands along the lake shore?

YES

Management measure is not necessary

NO

It is necessary to cut shrubs in a 5 m wide belt to promote the development of sandy beaches and belt of semi-natural grasslands.



4. Creation of wind corridors

For lakes outside of valleys and forests – is the lake surrounded by a dense belt of trees?

NO

Management measure is not necessary

YES

Creation of wind corridors is necessary by felling shrubs and, if necessary, single trees, to promote wave activity and improve water quality in the lake

Annex 2. General Measures for the Management of Stream Habitats

One of the main reason for deterioration of water quality in Latvia are impeded water flow due to log jams and beaver dams, as well due to nutrient enrichment and overgrowth with macrophytes. With appropriate river and their coastal belt management it is possible to improve stream functionality, maintaining river natural selfpurification capability and aquatic species diversity.
The owerall goal of river habitat management is:

- provide that river flow is not impeded, safeguarding that river selfpurification and river type specific stream bottom structure is maintained with stones and pebbles in fast flowing streams, as well with detritus covered sand in slow flowing streams, both inhabited with appropriate organisms;
- nutrient leakage is reduced, thus decreasing massive development of macrophytes and algae.

1. Decrease of River overgrowth with aquatic plants

Do emergent and floating-leaved plants cover more than 30% of the river surface?

NO — Management measure is not necessary

YES — Mowing is necessary

2. Removal of excessive large wooden debris

Within 100 m river stretch flowing through the forest > 20 fallen trees (diameter > 10 cm). They are scattered and do not forms jams impeding stream flow
Within 100 m river stretch flowing through agricultural area > 12 fallen trees (diameter > 10 cm). They are scattered and do not forms jams impeding stream flow

NO — Management measure is not necessary

YES — Removal of excessive fallen trees is necessary at least in central part to avoid creation of log jams

3. Limitation of beaver activity

In fast flowing stream (stream velocity > 0,2 m/sec) in 2 km long stretch only one beaver dam is recorded or beaver dams are absent
In slow flowing stream (stream velocity < 0,2 m/sec) in 1 km long stretch only one beaver dam is recorded or beaver dams are absent

NO

It is necessary to limit dams and regulate number of beavers

YES

Management activity is not necessary

4. Development of optimal shading and coastal overgrowth structure

In fast flowing stream (stream velocity > 0,2 m/sec) the insolated and shaded shore sections form a mosaic with a ratio of 30:70.
In slow flowing stream (stream velocity < 0,2 m/sec) the insolated and shaded shore sections form a mosaic with a ratio of 50:50.
Closest to river bed stream bank has at least 1 meter wide grassland or natural sand belt;
More remote stream bank (1–3 m distance from the river bed) has young grey alder stand (< 20 year old), having no rot disease, or tree stand consist of longliving tree species

NO

In former agricultural areas it is necessary to reopen 1–3 m wide river bank zone or to cut rot disease infected grey alder or to replace it with more long lasting tree species.

YES

Management activity is not necessary

Annex 3. Illustrative Examples on Aquatic Habitat Management

Macrophyte overgrowth management

Temporary macrophyte storage on lake or river banks

River bank is prepared for the temporary storage of mown macrophytes.
Photo: A. V. Urtāns.

Mown macrophytes temporarily stored above the high water line so that aquatic organisms trapped in the macrophytes can return to the river. Photo: A. V. Urtāns.

Mown macrophytes temporarily stored above the high water line so that aquatic organisms trapped in the macrophytes can return to the river. R. Venta.
Photo: L. Urtāne.

Volume of mown macrophytes from an area of 0,2 hectare. R. Venta. Photo: L. Urtāne.

Stored macrophytes are transported to the composting area before autumn rains starts to raise water level. R. Venta. Photo: A. V. Urtāns.

After a month, stored macrophytes have started to decompose and have lost a remarkable amount of water and volume. R. Venta. Photo: A. V. Urtāns.

Macrophyte mowing techniques

Mowing by hand scythe is suitable for small areas with stony riverbed inaccessible for machinery.
Photo: L. Urtāne.

Mowing with folding scythe in deep areas inaccessible for machinery. Short folding scythe is more suitable for application and transportation. R. Oša, Arendole. Photo: A. V. Urtāns.

Mowing in a stream with steep banks inaccessible for machinery. R. Balda. Photo: L. Urtāne.

Mowing of macrophytes in shallow water using a grass trimmer. R. Venta. Photo: L. Urtāne.

Macrophyte cutter mounted on a boat suitable for mowing of larger areas. L. Durbe.
Photo: L. Urtāne.

Floatable TRUXOR equipped for mowing of macrophytes suitable for management of larger areas. Rāzna. Photo: Ē. Kļaviņa.

Removal of macrophytes from the waterbody

Working in small areas mown macrophytes can be compacted and using flow, directed to the deposition site. R. Venta. Photo: L. Urtāne.

Compacting of mown macrophytes to transfer them to a storage area a small distance away. R. Salaca. Photo: A. V. Urtāns.

Workers standing across the river and using flow peculiarities, direct compacted macrophytes downstream to temporary storage area. R. Venta. Photo: L. Urtāne.

Last in line worker lift mown macrophytes ashore. R. Venta. Photo: L. Urtāne.

Manual withdrawal of macrophytes. Before pulling them ashore, macrophytes are left to drain of water for several seconds for easier transfer. R. Venta. Photo: A. V. Urtāns.

If mown macrophytes do not fall in the water, it is much easier to transfer them. R. Venta. Photo: L. Urtāne.

Removal of macrophytes from lakes

Mown plants is necessary to transport and lift ashore to remove nutrients stored in macrophytes. Follow supporting wind direction helping transportation. L. Rāzna. Photo: L. Urtāne.

Floatable machinery TRUXOR equipped with reed rake is adjusted for macrophyte transportation ashore. L. Burtnieks. Photo: A. Soms.

Manual labour is needed for the compacting of macrophytes to move them ashore. L. Rāznas Photo: Ē. Kļaviņa.

Mown macrophytes brought ashore with floatable machinery. L. Rāzna. Photo: L.Urtāne.

In small areas mown macrophytes can be taken ashore manually. Photo: Ē. Kļaviņa.

Mown reeds are long and unbreakable and difficult to compact and transport. L. Rāzna. Photo: Ē. Kļaviņa.

Machinery used for macrophyte removal

Macrophyte root shearing has the most effective and long lasting effect.

Wheel tractors equipped with metallic chains for better stability. R. Venta. Photo: A. Lācis.

For stability, a double wheel system can be used. R. Salaca. Photo: A. V. Urtāns.

Harrows for shearing of the root system. R. Venta. Photo: A. Lācis.

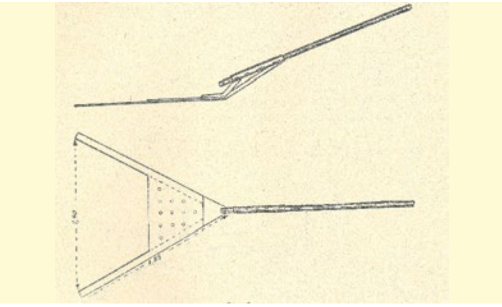
Harrows for shearing of the root system in action. R. Venta. Photo: A. Lācis.

Use of caterpillar tractor on shallow dolomite ground for macrophyte removal can be traumatic for aquatic invertebrates. R. Mūsa. Photo: A. V. Urtāns.

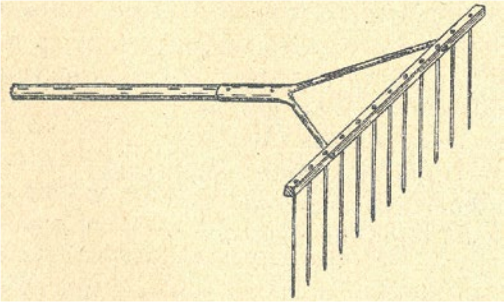
Use of caterpillar tractor on shallow dolomite ground for creation of a riffle. R. Mūsa. Photo: A. V. Urtāns.

Historical manual instruments for the cutting and removal of macrophytes

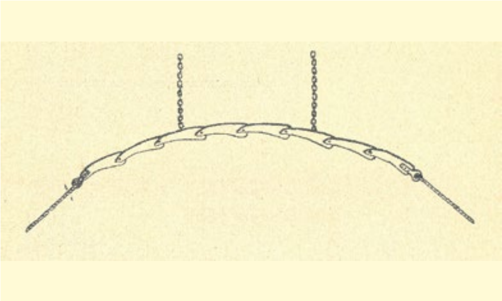
Elimination of macrophytes and shearing their roots has taken place for at least a century and is testified by drawings from the book "Melioration", 1932. By comparing drawings with equipment used nowadays, it can be concluded that the main principles of macrophyte elimination have not changed.



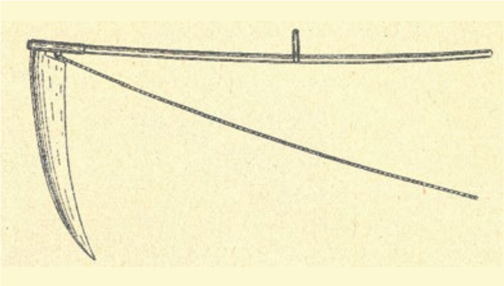
Macrophyte cutter. Consists of two 1,5 meters long knifes, joint under 60⁰ angle and attached to a long stalk. Operated by 3 workers – two of them roving the boat upstream, while third worker, standing on the backboard with short jerks pulled instrument towards himself.



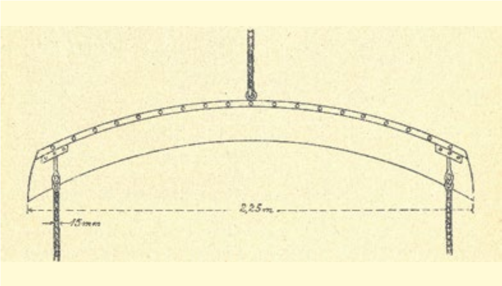
Author V. Ducmanis (Meliorācija, 1932) for the removal of mown macrophytes advise 40–50 cm wide metallic rake with 10 cm long rake fingers, located within 3 – 4 cm distance. This type of rake was attached to a long stalk and pulled along the river or lake bottom, releasing aquatic plants with all roots.



Series of scythes fastened together with a movable rivets. Each third element have a heavy chain to keep the scythe close to the bottom. Operated by two workers pulling the instrument with short jerks.



Scythe with long stalk operated by two workers – one worker is handling the arm and directs the scythe, while another worker pulls the rope and undertakes the cutting.



"Belov" knife was used for cutting submerged macrophytes, as well as emerged reeds and even bushes. Standard length 1,63 un 2,25 m. Instrument was operated by two workers.

Removal of excessive log jams and "catcher" control


In cases, when removal of excessive timber logs is done manually, they are sawn in dimensions that can be lifted manually. R. Svētupe. Photo: L. Urtāne.


Timber log removal, working "in chain" mode. R. Gauja. Photo: L. Urtāne.


Timber logs are sawn in dimensions that can be lifted manually. R. Svētupe. Photo: Ē. Kļaviņa.


Timber logs are lifted and stored above the high water line. In rivers with steep banks it is a time and effort consuming activity. R. Svētupe. Photo: Ē. Kļaviņa.


Removal of a log jam hindering water flow. R. Palsa. Photo: L. Urtāne.


Use of lifting mechanisms to withdraw timber from the river. R. Palsa. Photo: L. Urtāne.

Use of a four wheel ATW for large dimension log withdrawal from the river. R. Palsa. Photo: L. Urtāne.

A hand pulley is used for the removal of large dimension wood from rivers with steep banks inaccessible for machinery. Photo: A. V. Urtāns.

Large dimension log removal with wheel tractor. R. Kauliņa. Photo: L. Urtāne.

Large dimension log removal with power lift. R. Vitrupe. Photo: A.V.Urtāns.

Due to safety and technical reasons logs can be sawn more easy on the shore. R.Kauliņa. Photo: L. Urtāne.

Excess timber logs are sawn in dimensions on the shore. R. Kauliņa. Photo: L. Urtāne.

In difficult to access places, sand covered logs and wooden debris can be burnt on site. R. Riežupe. Photo: Ē. Kļaviņa.

After log burning, the huge sediment bar, covering the area formerly suitable for salmonids, re-opens. If not taken out mechanically, it shall be scoured away during the autumn rain period. R. Riežupe. Photo: A. V. Urtāns.

Bank squeezing and stream narrowing

Narrowing of the channel to increase stream velocity, to scour sediments and reopen the gravel bottom. Photo: A. V. Urtāns.

Stone riprap on both banks ensures bank stability, increased stream velocity, scouring of sediments, reopening of the natural gravel channel bed. Photo: A. V. Urtāns.

Rows of stone promote narrowing of the stream, and sediment scouring. Photo: L. Urtāne.

Area behind the stone line starts to overgrow with grasses and becomes stabilised. Method is applicable for small streams, which due to bank erosion have become wide and shallow. Photo: L. Urtāne.

Management of rivers entering the sea for fishermen and fish migration

River mouth blocked by sand sediments, interrupting fish migration. R. Kurliņupe. Photo: G. Rubenis.

Excavated sand sediments are disposed nearby. R. Kurliņupe. Photo: G. Rubenis.

Excavated sand sediments are disposed nearby. R. Kurliņupe. Photo: G. Rubenis.

The renewed area is very unstable and will only last until the next storm, after which the activity must be repeated. R. Kurliņupe. Photo: G. Rubenis.

The River Vēverupīte before the removal of dense reed stands hindering water flow into the sea.
Photo: A. V. Urtāns.

The River Vēverupīte after the removal of dense reed stands hindering water flow into the sea.
Photo: A. V. Urtāns.

River habitats before and after management activities

Management of macrophyte overgrowth

Objective: maintain optimal river overgrowth and water flow conditions.

River before macrophyte mowing. R. Vircava
Photo: L. Urtāne.

The same stretch of the River Vircava after the clean-up.
Photo: L. Urtāne.

Log jam removal and re-creation of riffle areas

Objective: removal of excessive log jams to improve water flow and establish suitable riverbed conditions for *Margaritifera margaritifera and Unio crassus.*

River before log jam removal. R. Vircava
Photo: L. Urtāne.

River after log jam removal. Rifle area recovers. R. Vircava
Photo: L. Urtāne.

Excessive log jam removal, bank stabilization and riffle area development

Objective: removal of "debris catchers" in the central part of the stream and bank stabilization with stones to lessen adverse effect of water fluctuation induced by operation of small hydroelectric power station.

Eroded and widened river before riffle area reneval. R. Kauliņa. Photo: L. Urtāne.

River stretch with installed riffle and bank stabilisation with stone riprap. R. Kauliņa. Photo: L. Urtāne.

River habitats before and after management activities

Management of macrophyte overgrowth and restoration of lamprey and salmonid spawning areas

Objective: decrease lasting impact of sediment accumulation, maintain optimal macrophyte overgrowth state for the river reach, renew lamprey and salmonid spawning areas, renew former landscape for the waterfall – Ventas rumba.

Historically river reach below the one of the widest natural waterfall in Europe (270 m) was free of macrophytes. It was maintained through regular ice movement during spring periods as well as of timber floating. Waterfall Ventas Rumba around 1900. Ilustration from "Malerische Ansichten aus Livland, Estland un Kurland" (1901).

The River Venta before cutting and root shearing of macrophytes. Former open central part of the river is overgrown with vegetation characteristic for terrestrial plant communities. R.Venta. 2011. Photo: L. Urtāne.

After cutting and root shearing of macrophytes. R. Venta. September 2011. Photo: L. Urtāne.

To maintain achieved result, in 2014. and 2015. area was mown using trimmer. Photo: L. Urtāne.

Due to nutrient saturated river bottom and low water level, macrophyte stand has re-occupied its previous area. The same river reach before repeated macrophyte cutting and their root shearing August, 2016.

River stretch after mowing and root shearing of macrophytes. Macrophyte stand has become more loose but still prone for regrowth. September 2016. Photo: L. Urtāne.

River management as a tradition and celebration

Members of the NGO "Kroma kolna bruoliste", dressed in national costumes, installs riffle area in the River Balda and celebrates river clean-up. Photo: L. Urtāne.