

LOKNA

*Krške lokve i barjanska okna*  
*Krški kalupi i barjanska okna*  
*Karst ponds and marsh springs*





Misučajnica Pond  
(Photo: Patrik Krstinić)



# Introduction

The cross-border project entitled 'Preservation and promotion of water biotopes - ponds and marsh springs for the future', which has the acronym LOKNA, has been implemented since 2015. The leading partner is the Priroda Public Institution, and the project partners are the Town of Krk, the Ljubljana Marsh Nature Park, and the Slovenian Geodetic Institute. The aim of the project is the preservation and revitalisation of small water biotopes, primarily drying and permanent karst ponds on the island of Krk (Croatia) and the marsh springs in the area known as Ljubljana Marsh (Slovenia). As far as the Croatian part is concerned, the project has so far included scientific research on the wildlife in three ponds in the western part of the island of Krk, focusing on flora, dragonflies, bats, birds, amphibians and reptiles. It has also included a workshop for children, and cleaning and revitalising in the traditional way a pond in the Poljica area which in the past was used as a source of water by the local inhabitants. It is also planned to find, list and explore the main characteristics of a further 60 ponds of interest on the island of Krk, which should be as diverse as

possible. These would be only some of the most representative of a total of approximately three hundred ponds that have been preserved on the island of Krk, which is sometimes called the 'Golden Island' and is rich in natural heritage. The objective of these endeavours is to create a comprehensive online database in order to preserve at least some of the knowledge about ponds for the future. The project also includes establishing a 'Ponds Educational Trail' and publishing a tourist-educational excursion map.



*Water quality parameters measurement  
(Photo: Patrik Krstinić)*

The joint objectives and tasks of the Slovenian and Croatian project partners include:

- the geolocation of 70 water biotopes (60 ponds on the island of Krk and 10 water biotopes in Ljubljana Marsh)
- carrying out scientific research on water biotopes
- organising educational workshops and field trips for elementary school pupils
- organising an exhibition of photographs of water biotopes
- printing promotional and educational materials
- designing and laying out two educational trails that connect water biotopes
- creating an interactive website with access to water biotope maps
- organising conferences and media promotion of the project and important natural heritage
- raising public awareness about the significance of biological diversity
- emphasising the importance of natural heritage.

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The karst ponds on the Kvarner islands are locally important freshwater and/or brackish habitats. It is estimated that there are several hundred more significant ponds on the Kvarner islands. If we try to assess their overall role in preserving biological diversity, for example for the entire Kvarner area, then their cumulative importance is at least at a regional level. This is because ponds in a certain way enable wildlife to communicate (in conservational biology, ponds can be characterised as 'stepping stone' habitats). In addition, they connect isolated and separated populations and provide feeding places during migrations, and so on.

All karst ponds, including smaller ones, are distinguished, among other things, by their great biological productivity, extraordinary biological and landscape diversity, complex biogeochemical cycles, interconnected substance cycles, and the ability to clean up various pollutants. There are several types of pond, including those that dry up, those that hold water only a few weeks



*Goldfinch (Carduelis carduelis) at watering place*  
(Photo: Andrej Radalj)

or months in the year, and permanent ones that can be small or large in size. In addition, ponds can be of natural or anthropogenic origin, filled with fresh or brackish water, and can be used as a source of drinking water for people or animals.

The relative richness of the aquatic vegetation, whose growth depends on the depth of the water and its distance from the bank, supports a variety of animal life. The most prominent are amphibians. There is a par-

ticularly numerous species of frog (*Pelophylax* sp.) that is very loud in the breeding season. The world of water insects is also varied. The aquatic beetles that swim in the water column between the stems and leaves of aquatic plants are particularly noticeable. The areas surrounding the ponds are enlivened by both daytime and nocturnal flying species, such as numerous dragonflies, birds and bats.

## *The history of the ponds on the island of Krk*

Ponds are by definition small marshes. They come in different types and can be of natural or anthropogenic origin. Ponds are characterised by the permanent or temporary stagnation of rainwater, and sometimes by a flow of spring water. Their emergence on the island of Krk has to do with the development of the relief, but even more so with human activity throughout history.

As far as karst ponds on the island of Krk are concerned, their origin in most cases has









Pond in Salinj area  
(Photo: Patrik Krstinić)



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to do with human intervention in the landscape. The rudimentary method of building anthropogenic ponds can be traced back to the Bronze Age. This was a time when humans learned how to process milk into cheese, which resulted in an increased number of livestock that required watering. Another probable cause was intense deforestation (cutting down trees) for the purpose of creating pasture. It can be assumed that the loss of the former lush forests of the island resulted in a reduction in the number of water sources (natural watering places for livestock), which is why the construction and maintenance of artificial bodies of water was of great importance. Ponds were constructed in karst sinkholes (dolines) or depressions in the ground by covering the bottom with a layer of impermeable clay and making it thoroughly compact. If a pond was also used by livestock, this made its maintenance more convenient, as the animals would constantly press and repair the impermeable clay layer with their hooves. Ponds that were used exclusively as a source of water for people were



*Small pond above Stara Baška  
(Photo: Marko Randić)*

surrounded by dry stone walls with a narrow entrance (known locally as *stuba*) that enabled easy access for humans but prevented livestock from entering the pond.

Many battles in the past were fought over water rights. In antiquity, a special role in the distribution of water resources was played by the Romans. It is known that regulations regarding the right of access to water date back to this period, so the allocation of ponds (but also source areas) to specific pastures

is probably due to them. Even today, we can find ponds divided by 3, 4 or more dry stone walls, whose aim is to direct livestock from individual pastures to the water. In this way, water resources in ponds were communally managed, and water was a common asset that was owned jointly and which required a rational approach. Examples of such ponds where 3 or 4 dry stone walls lead to the same pond can be found next to the Veli Kaslir and Kaslirić hillforts above Punat. The area of Petilokva also features a well supposedly from Roman times. Its depth is unknown, but it has been discovered that the stone steps continue under the water in the form of oak ones. These are usually covered with water, which prevents the wood from rotting.

In late antiquity and the Byzantine period, water from the roofs of buildings was collected in cisterns and used as a water supply. Wells were built of carved stone on water veins, which is why they were locally called 'living water'. Some of these, for example Zdenac na Kandiji (the Candia Well), have



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a distinctive snail shape. The name indicates that it was probably built or reconstructed during or after the War of Candia (the Cretan War).

## Natural features of karst ponds

The main types of shallow bodies of water and small marshes on the island of Krk include shallow lakes and water reservoirs, salty and brackish ponds and coastal marshes, anthropogenic and natural ponds of different shapes, sizes and depths, temporary ponds (which occasionally dry up), concrete ponds, ponds with springs, ponds next to water sources, wells and other small bodies of water and marshes.

Ever since man started seriously interfering with natural processes, adapting the landscape for his needs and changing small marshes, numerous ponds have emerged but also disappeared from the island of Krk. In recent times, small marshes and ponds have been dried up for sanitary reasons (for example to fight malaria), but also for other



*Pond next to Jezero  
(Photo: Marko Randić)*

reasons connected with urbanisation and 'the progress of civilisation'.

The disappearance of ponds and small marshes has resulted in the removal of whole worlds consisting of numerous plant and animal species that depended on marsh and water habitats. The only remaining testimonies of these - if any - are scant scientific records in dusty old books and magazines. For the most part, such records were never even collected. Unfortunately, some of the small

marshes that have somehow been preserved are now being used as dumps for waste, including toxic waste, which permanently endangers or even destroys their wildlife and reduces or completely disables the biological function of the ponds.

One of the objectives of the LOKNA project is to list, describe and save these small bodies of water from oblivion. Many ponds in the coastal area and on the islands emerged as a result of human endeavour and were in the past used for water supply purposes. Because of this, such small bodies of water require permanent care and maintenance. Due to a lack of maintenance in recent times, many ponds have become overgrown with vegetation and more and more mud has accumulated on their bottoms, which gradually causes their complete disappearance.

## Lifecycle of a karst pond - sediment accumulation

When observing the lifecycle of a karst pond, the processes by which muddy sedi-



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*Lipica - small pond with a water source*  
(Photo: Marko Randić)

ment emerges and accumulates on the bottom are particularly interesting. The depositing of mud on the bottom of a pond often leads to it silting up and disappearing, i.e. the transformation of water into land. At the end of their lifecycle, such ponds with excessive accumulation of muddy sediment usually first become completely overgrown with marsh vegetation and then turn into grassland, which over time, if there is no grazing or mowing, develops into forest. This pro-

cess usually takes decades or even centuries to complete. The scientific term for it is succession.

Over the course of several decades or more, Živa Pond (*the Living Pond*) close to Poljica would probably be just another example of succession if it wasn't for human intervention. As part of the LOKNA project, this pond has been thoroughly cleaned of mud deposits. This is particularly important for a pond that in the past played a crucial role in supplying water to people in periods of drought. Because of this, cleaning mud from the bottom of ponds was in the past a regular activity for local people and was important in maintaining the pond in a functional state and slowing down succession. The cleaning was performed periodically, usually every few years. Local people claim that Živa Pond had previously been thoroughly cleaned of mud some sixty years ago, after which it was only occasionally taken out every now and then. Eventually, this practice ceased completely due to changes in the way of life.



*Toad spawn (Bufo bufo)*  
(Photo: Patrik Krstinić)

If we take into consideration that during the recent cleaning as much as 20 cubic metres of mud was taken out of the pond, we can get an idea of how quickly a small karst pond like this one can fill up with mud and disappear.

Today, many ponds on the island of Krk are walled in with concrete. In this way, the ponds can be more easily maintained and the build-up of silt can be kept under con-



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trol. However, this has some negative side effects too. Concrete prevents unhindered access for aquatic and marsh plants, as well as the numerous animals that bury into the natural substrata of the mud. Without this contact and the mutual adjustments that have evolved over thousands of years, biological diversity is hard to maintain in the new, manmade habitats.

### **Ponds - oval, circular and annular structures in the landscape**

Ponds are often aesthetically beautiful elements in the landscape. Their regular circular structure easily attracts attention. The regularity of their form is even more accentuated by the regular concentric circles of vegetation inside them. Since the water level oscillates during the year, annular sections are formed on the banks of the pond, which periodically dry up or are flooded with water for shorter or longer periods of time. A variety of aquatic and marsh plant species have adapted to these varying ecological condi-

tions. In addition, ponds can have belts of marsh and aquatic plants depending on the depth of the permanent water. Usually, only aquatic plants can grow in the central parts of a pond. In fact, this part of the pond is often devoid of vegetation, which results in a kind of circle being formed in the pond, around which there are concentric rings of marsh vegetation.

A nice example of an annular, although not entirely regular, distribution of aquatic



*Kolitovica Pond  
(Photo: Patrik Krstinić)*

and marsh vegetation can be found in Menkova Pond close to Poljica. Since this is a permanent pond, its central part is mostly devoid of plants on the water's surface. Closer to the banks, there is a ring of floating aquatic vegetation (pondweed and duckweed) and abundant submerged aquatic vegetation. This is then followed by a pronounced ring of marsh vegetation with densely arranged stems of spike rush (*Eleocharis palustris*). Closer to the banks, there are two more pronounced rings: the first is practically devoid of vegetation (with the exception of a few very resistant plants that have adjusted to the constant shifting between dry and moist conditions (most notably a species of the Apiaceae family), and the second, which has a wider perimeter, abounds in bentgrass (*Agrostis* sp.) of an intense green colour.

Circular and annular pond structures are even more pronounced and unusual in ponds that are surrounded by dry stone walls, and are also more dramatic when several dry stone walls lead to one pond. A nice example





*Cattail (Typha sp.)*  
(Photo: Patrik Krstinić)

is Diviška Pond above Baška, which is located on a rocky plateau close to the cliffs on the south-eastern coast of the island of Krk, on the edge of the protected bird reserve. This pond is at the intersection of five pastures. The dry stone walls that lead to the pond provide separate access to the water for sheep.

### The plant life of ponds and small marshes

The specific flora and vegetation are important biological elements of standing waters such as ponds and small marshes. Without water and wet ground, these specially adapted plants could not survive. It is also important that the water in small marshes is not polluted with harmful and toxic human waste. Such preserved habitats abound in macrophytes (aquatic plants) and helophytes (marsh plants). Aquatic plants that can be found in bodies of water on the island of Krk (ponds, small and shallow lakes) include filamentous cyanobacteria, *Charophyta*



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Aquatic marsh plants  
(Photo: Patrik Krstinić)

algae, mosses, ferns and seed plants.

The most comprehensive and diverse group of macrophytes are seed plants. The most widespread species in this region are pondweed (*Potamogeton*), coontail (*Ceratophyllum*), and water lilies (*Nuphar luteum*). There are also many other aquatic plants present.

Apart from macrophytes, the banks of Krk ponds are home to numerous marsh plants that are not completely submerged in water but are nevertheless dependent on moist soil close to bodies of water. Marsh plants include different grasses, sedges, *Apiaceae*, water mints and numerous other species. Marsh plants are distinguished by a variety of shapes and survival strategies, from very successful grasses (*Poaceae*) with light, flexible hollow stems that gently bend in the wind, and which have numerous stamens in inflorescences that release pollen into the air current, to sedges (*Carex*) with sharp, serrated leaves (that can even cut us!). There are also *Apiaceae* plants with complex inflores-

cences with compound umbels that seem to form a single flower, fragrant deadnettle (*Lamiaceae*) full of glands with essential oils (a nice example is water mint!), rushes (*Juncus*) with leaves that can be spiny at the top, and other plants whose roots are buried in the mud and moist soil on the banks of ponds and lakes.

## Pond fauna

Thanks to the variety of aquatic and marsh plant species, ponds are also home to a variety of animal species, such as dragonfly larvae, water bugs and beetles, mosquito-fish, tadpoles and numerous other aquatic animals. Around the ponds, there are richly structured habitats of various insects, amphibians, reptiles, birds and bats.

## Insects in ponds

Due to their large number and the important role they play in circulating substances, insects are one of the most significant elements in pond ecosystems. After leaving the





*Duckweed and frogs*  
(Photo: Patrik Krstinić)



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egg, insect larvae have to go a long way before they transform into adults. Freshwater insects come in a great variety of shapes in both larvae and fully developed adults. Some species live in water only in certain parts of their lifecycle, while others spend their entire lives in the water. For example, the larvae of dragonflies and caddisflies live in water, while adult specimens spend most of their time flying. Because of this, they have developed different organs: the larvae of these insects have well-developed gills and no wings, while adult specimens have wings and breathe through a special respiratory system called a trachea. On the other hand, beetles that live in ponds spend all their lifecycle in the water. Adult water beetles have developed interesting breathing systems. For example, members of the *Dytiscus* genus, which are found in most ponds on the island of Krk, breathe by going to the surface and upending. They collect a bubble of air under their elytra and breathe it during immersion. Land and water forms of individual species that are found in Krk ponds also differ



*Dragonfly (Odonata)*  
(Photo: Patrik Krstinić)

in the way they feed: the caddisfly larvae of the *Limnephilus* genus feed on rotting plant remnants, while adult winged specimens have developed organs for licking plant sap. Caddisfly larvae spend their lives in structures that they build by binding small pieces of wood or stone together using their spinning gland secretions.

The overgrowing of ponds and their succession into terrestrial habitats leads to the

loss of environments necessary for the development of water insects, which then impoverishes the overall biodiversity of the island of Krk. Members of the dragonfly fauna (*Odonata*), which are a typical 'amphibian' insect group - their larvae live in the water as predators, while adults fly in the air, skilfully manoeuvring and hovering above the water's surface, hunting for smaller flying insects - are also important as indicators of the threat posed to a water, especially smaller bodies of water. Another group of insects which inhabit ponds, but which we would maybe not expect to be so-called amphibious water organisms, are butterflies. At a pond in the Poljica area in the western part of the island of Krk, we found the very attractive Brown China Mark (*Elophila nymphaea*). This nocturnal moth is interesting for the fact that its caterpillars live in standing waters, breathe with gill-like organs, and feed on aquatic plants. The Brown China Mark is one of the 11 aquatic moths known in Europe, most of which are endangered and in need of protection.





*Smooth newt (Lissotriton vulgaris)*  
(Photo: Marko Matešić)



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## Amphibians and reptiles in and around ponds

Amphibians are also good indicators of environmental pollution. Since their skin is very permeable (they breathe and absorb water through it), they are very sensitive to pollutants. In addition, depending on their developmental stage, they can use both terrestrial and aquatic habitats, and are therefore affected by pollutants in both habitat types. In this way, they can alert us to dangerous environmental conditions that can result in serious health issues for humans. Two types of amphibian are found in Krk ponds: newts and frogs. The major morphological difference between these two species is that newts have tails during their entire life while frogs lose their tail at the end of their transformation from the tadpole stage. The smooth newt (*Lissotriton vulgaris*) is the only newt species that inhabits the island of Krk. Although they hibernate in winter on land, smooth newts on the island of Krk frequently overwinter in ponds. The biggest thre-



*Tadpoles and cyanobacteria*  
(Photo: Marko Randić)

at to the Krk population of smooth newts is the mosquitofish, an invasive fish species that has been introduced into ponds to control mosquito populations. Mosquitofish are predators that feed on smooth newt eggs and larvae, but also on other tiny organisms that live in ponds, and therefore compete for food with adult newts. During the inventory of Krk ponds, it was observed that smooth newts only inhabit ponds in which there are no mosquitofish.

Because of their diversified wildlife and habitat structure, ponds are also attractive to reptiles. During research on herpetofauna as part of the LOKNA project, the following amphibians were found in and around ponds in the western part of the island of Krk: wall lizards (*Podarcis siculus*), grass snakes (*Natrix natrix*), black whip snakes (*Hierophis carbonarius*), and pond sliders (*Trachemys scripta*). The black whip snake is particularly interesting as it is strictly protected and listed for protection in EU directives on the conservation of wildlife and natural habitats.

## Birds at the ponds

Ornithological research conducted on the island of Krk has mostly been aimed at bird reserves and areas that are particularly rich in birds, such as the aquatic and marsh habitats of Jezera close to the Njivice and Ponikve reservoirs. The LOKNA project was the first to include ornithological research on small ponds as special habitats on this island, which is rich in interesting bird speci-





*Jay (Garrulus glandarius)*  
(Photo: Andrej Radalj)



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Long-tailed tit (*Aegithalos caudatus*)  
(Photo: Andrej Radalji)

es. Ornithological research on selected ponds as part of this project has revealed 50 bird species. Some of them are very interesting, such as the wonderfully coloured kingfisher (*Alcedo atthis*), which comes here mostly in the colder part of the year, the water rail (*Rallus aquaticus*), which can be found, usually in pairs, at nearly every larger pond on the island of Krk, the rare little egret (*Egretta garzetta*), the grey heron (*Ardea cinerea*), and other species. Some songbird species regu-

larly visit the ponds. While working on the project, in the colder part of the year, we noticed that almost every pond has its 'own' robin (*Erithacus rubecula*), but also that small songbirds regularly come to the ponds for water, where predatory sparrowhawks (*Accipiter nisus*) may be waiting for them.

### Bats at the ponds

Bats (*Chiroptera*) take advantage of the diversity and variety of insects that fly over the ponds at dusk and night. Some of the bats even specialise in hunting above or around the surface of bodies of water.

Research conducted as part of the LOKNA project revealed a bat species that was previously unknown on the island of Krk: the serotine bat (*Eptesicus serotinus*). Other species that were discovered at ponds include the greater horseshoe bat *Rhinolophus ferrumequinum*, Kuhl's pipistrelle (*Pipistrellus kuhlii*) and the lesser noctule (*Nyctalus leisleri*). These four species have been confirmed by catching them in hunting nets, and

at least six more bat species were determined by echolocation (recording of their sound), which indicated their presence around the researched ponds.

### Vulnerability and protection of ponds

Until recently, ponds were of great importance to the inhabitants of the Kvarner islands, and continue to be so in areas whe-



Dokulovo - a pond between Punat and Stara Baška  
(Photo: Marko Randić)



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*Črkote - dry stone walls at the pond  
(Photo: Marko Randić)*

re raising livestock still takes place. Before a water supply system was introduced and people adopted new, easier ways of earning a living, ponds literally meant life in the waterless karst landscapes. These recent changes resulted in the reduction and sometimes even complete disappearance of certain traditional activities and knowledge associated with ponds. However, in some areas, especially in the southern part of the island of Krk, where sheep are still bred in the tradi-

onal way, ponds even today have their original function of providing water for livestock. In other parts of the island, which have turned more towards tourism or are located close to towns, ponds have often been filled in or polluted, or have disappeared during urbanisation and construction work. On the other hand, ponds that can be used for watering gardens or as water reservoirs for other purposes have sometimes maintained their original function.

Even those ponds that have not been filled in, but which are located in areas where there is no need to water livestock any more, have often been neglected and fallen into ruin. People stopped cleaning them of accumulated mud and removing vegetation, with the result that these ponds were gradually reclaimed by the land as they became overgrown.

There are several examples of such cases on the island of Krk. In addition, in some ponds the clay bottom subsided and was never repaired. Consequently, they were emp-



*A pond surrounded by a dry stone wall  
(Photo: Patrik Krstinić)*

tied of water.

The flora and fauna of ponds have often been affected by human intervention. At the beginning of the 20th century, ponds were reservoirs of malarial mosquitos and sources of infection. Certain parts of the island were ravaged by malaria, and experts on combating the disease started introducing mosquitofish as an effective biological method to fight mosquitos. A leading figure in this ac-



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tivity on the island of Krk in the early 20th century was Dr Oto Trausmiller. In more recent times, guided by the knowledge of pioneers in the biological fight against mosquitos (Dr Majnarić and Dr Trausmiller), the method of introducing mosquitofish into small bodies of water that were sources of mosquitos was systematically applied by the sanitary expert Josip Kenk. Besides confirming the efficiency of the biological method in the fight against mosquitos while significantly reducing the use of chemicals in combating mosquito larvae, his work is also significant because he was the first to systematically record all the locations and data on ponds and other small bodies of water on the Kvarner islands into which he had introduced mosquitofish (such as pond type, exact location, photos, sketches, whether it was a permanent or temporary body of water, etc.). For some ponds, he also collected the first significant data on their wildlife.

By raising awareness of the need to preserve biodiversity, we have become aware that



*Solution pan - kamenitza  
(Photo: Sunčica Strišković)*

the conservation and maintenance of ponds is highly important. However, we have also learned that the introduction of alien species, such as the aggressive and invasive mosquitofish (or, more recently, the red eared and yellow-bellied slider) can have a negative effect on the richness and diversity of the indigenous wildlife on the island. The Physical Plan of Primorje-Gorski Kotar County provides for the protection of all larger and more important ponds on the is-

land of Krk (a total of 317) as especially valuable parts of the natural landscape. We feel confident that the results of the LOKNA project will contribute to preserving and protecting karst ponds on the island. It is our obligation to save this natural and cultural treasure for future generations.

To conclude, here is a small example of how the project taught us in which direction we should continue our endeavours. While cleaning Živa Pond of accumulated mud, we learned that one should respect traditional knowledge in this procedure.

It is necessary to pay attention not to break through the impermeable layer of clay in the process of cleaning. Unfortunately, nowadays traditional knowledge about ponds has fallen into oblivion because fewer and fewer people have this knowledge. The LOKNA cross-border project may be a chance to save some of this knowledge from being lost and to preserve part of our material cultural traditions in their natural surroundings.

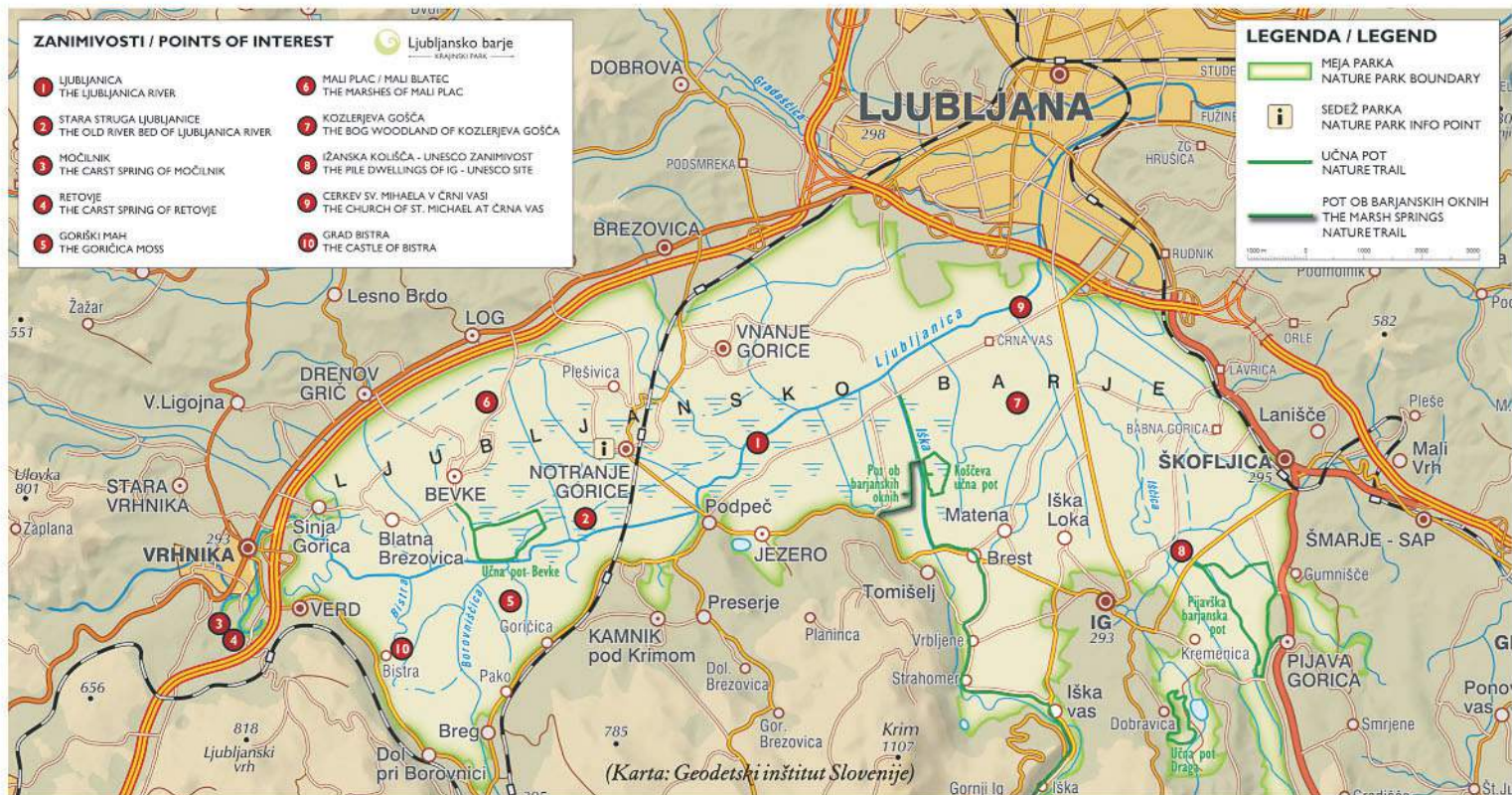




*Ljubljana Marsh autumn*  
(Photo: Davorin Tome)



# The marsh springs





## Ljubljana Marsh Nature Park

The Ljubljana Marsh (Slovenian: Ljubljansko barje) is located in Central Slovenia, in the southernmost part of the Ljubljana Basin, and represents the largest wetland in the country. Most of the water in the Ljubljana Marsh is stored in the ground, but during heavy autumn and spring rainfall floodwater covers the meadows, fields and sometimes even settlements. Humans have undertaken persistent efforts to change the marsh landscape to make their lives on the floodplain easier. More radical interventions began during the reign of Maria Theresa, who in 1769 issued the Decree on Draining and Settlement of the Ljubljana Marsh. Following the construction of the Gruber Channel in Ljubljana, the Ljubljana Marsh was heavily drained, thereby enabling the building of the Ižanska Road in 1830 and the settlement of the central part of the marshy plain. Due to the deep, soft and wet soil, it was necessary to build on wooden piles. Farming on the marshy plain was also far from



*Snake's head fritillary (Fritillaria meleagris)*  
(Photo: Davorin Tome)

easy. In order to increase the run-off of the floodwater, farmers dug drainage ditches along every meadow, field and field path.

The inhabitants of the Ljubljana Marsh noticed that the upper layer of the marsh soil, i.e. peat, burned well. It was first excavated and dried for heating homes, and in the mid-19th century it started to be excavated in large quantities. Farming on the marsh was thus soon replaced by peat extraction;

the dried peat was sold in Ljubljana and its surroundings as heating fuel. By the end of the 19th century, most of the peat in the marshland had been excavated. This led to the lowering of the surface and water returned to the Ljubljana Marsh, making a mockery of hundreds of years of attempts at land drainage. Some inhabitants emigrated abroad, others found work in Ljubljana, while others took up farming again. Farmers used a large portion of the marsh plain as meadows and grew crops for their own use in fields. They planted alders between the plots, which dried out the soil and provided protection in severe winds. This resulted in the creation of a colourful marsh mosaic of meadows, fields and forests, intertwined with alder hedges and a dense water network. Mowing the wet meadows prevented them from becoming overgrown with woods and allowed them to become populated with an extremely varied meadow flora and fauna. The onset of intensive farming and urbanisation has increasingly impoverished this diverse marsh mosaic and put at risk the drinking water and soil



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quality. Motivated by the desire to preserve the nature and landscape of the Ljubljana Marsh the area was designated the Ljubljana Marsh Nature Park in 2008.

The majority of conservation measures in the park focus on the wet meadows, as they exhibit the highest degree of biodiversity. Here, one can find a wide range of plant species, which in many places, mainly due to land drainage, have already died out: the snake's head fritillary (*Fritillaria meleagris*), the common cotton-grass (*Eriophorum* sp.), meadow orchids, etc. The diverse colours in the meadows are complemented by the sounds of buzzing insects and the singing of birds. Although the marsh plain covers barely one per cent of Slovenian territory, **half of all Slovenian bird species** nest in the Ljubljana Marsh, and even more stay here during the winter or rest during migration. The most typical marsh bird species can be easily spotted or heard in the meadows, hedgerows and low growing shrubs. The corn crake (*Crex crex*), the Eurasian curlew (*Numenius*



Corn crake (*Crex crex*)  
(Photo: Peter Buchner)

*arquata*), the common quail (*Coturnix coturnix*), the Eurasian scops owl (*Otus scops*), the whinchat (*Saxicola rubetra*), the common grasshopper warbler (*Locustella naevia*) and the hen harrier (*Circus cyaneus*) appear on the list of the most endangered species at both the European and global level. However, they can still be seen in the Ljubljana Marsh. The marsh plain also boasts **twice as many butterfly species than the entire British Isles**, in total around 90 species. The last

numerically strong population of the tufted skipper (*Carcharodus flocciferus*), but also the false ringlet (*Coenonympha oedippus*), can be found here.

The wide network of drainage canals and ditches is also a highly important habitat in the Ljubljana Marsh. It is home to animal species which spend at least part of their lives in the water or by the water: amphibians, water birds and dragonflies. **Approximately 50 species of dragonfly**, which is more than half of all the species in Slovenia, have been recorded in the Ljubljana Marsh. Many endangered species, such as the ornate damselfly (*Coenagrion ornatum*), the common clubtail (*Gomphus vulgatissimus*) and the scarce chaser (*Libellula fulva*), can be observed around the ditches and canals. The croak of the European tree frog (*Hyla arborea*) echoes here during the summer nights. The mix of different running and standing waters is of utmost importance to the numerous amphibians: the yellow-bellied toad (*Bombina variegata*), the Italian crested newt (*Tri-*



# The marsh springs

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*turus carnifex*), and the European green toad (*Bufo viridis*). **The marsh plain is home to 70 per cent of all amphibian species living in Slovenia.**

The continuing presence of water in the marsh soil and in the River Ljubljanica protects a very rich cultural heritage. Archaeologists have discovered a **40-thousand-year-old wooden arrow point**, well preserved medieval swords, a Roman boat over 15 metres in length, and other finds in the River Ljubljanica basin. To date, the remains of 43 pile dwellings have been found in the Ljubljana Marsh. **Two groups of pile dwellings near Ig** have been entered in the **UNESCO World Cultural Heritage List**. The most significant pile dweller finds in the Ljubljana Marsh are the remains of a pile dweller's cart, **the world's oldest wooden wheel with axle**, which is around 5,150 years old. The Ljubljana Marsh, however, is not only a treasure trove of biodiversity and cultural heritage. The vast marsh plain acts as a flood retention basin, while the deep and complex

marsh soil in combination with the marsh plants serves as a natural water treatment plant. The humidity of the soil cools the air; therefore the Ljubljana Marsh is always one to two degrees cooler than its periphery. Last but not least, the Ljubljana Marsh is also a source of food and drinking water for humans.

## Water - the main element of the Ljubljana Marsh

When mentioning the Ljubljana Marsh, one most often thinks of the River Ljubljanica, floods and fog. These are the different forms of water that have always defined this area. The River Ljubljanica was the main transport artery between Nauportus (Vrhnika) and Emona (Ljubljana) in Roman times. Flooding caused difficulties as far back as the reign of the Empress Maria Theresa, who wanted the marshy plain to become a granary for her numerous army. To live well in and around the Ljubljana Marsh calls for a good knowledge of the laws of nature in this area defined by water.

The water in the Ljubljana Marsh occurs in three forms: surface water, groundwater and water in the air.

If one climbs a hill on the outskirts of the Ljubljana Marsh in autumn or spring, there is often a thick layer of fog below. In spring, the thick fog is replaced by mists which float immediately above the ground like skilful dancers. The surface waters of the Ljubljana Marsh can be observed throughout the year. The main marsh watercourse, the **River Ljubljanica**, threads its way lazily all the way from Vrhnika to Ljubljana. It is fed by the rich hinterland of the Notranjska region (Cerkniško jezero/ Lake Cerknica and Planinsko polje/Planina Field) and **by its numerous tributaries in the Ljubljana Marsh** (Mala and Velika Ljubljanica, Bistra, Borovniščica, Iška, Ižica, Gradaščica, Mali Graben, etc.) There is also an **exceptionally dense network of artificial drainage canals and ditches**, whose total length is about five thousand kilometres. The central part of the marsh plain, the solitary Kostanjevica Hill,



*Scarlet dragonfly (Crocothemis erythraea)*  
(Photo: Dejan Veranič)



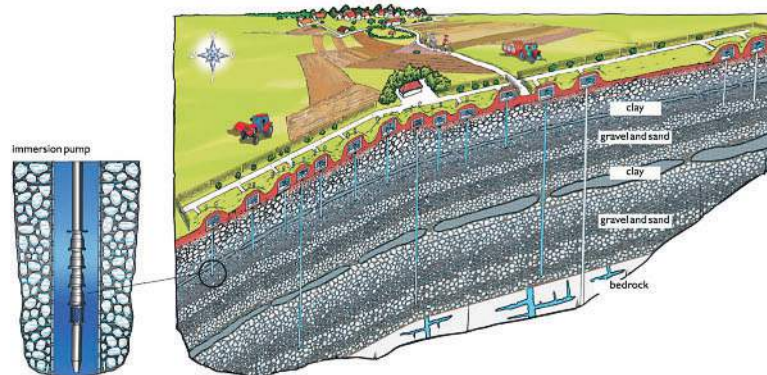


## *Ponds and marsh springs for the future - Lokna*

boasts a small marsh and the remainder of a transitional marsh, the Mali Plac Nature Reserve. A flooded forest, home of many amphibians, is situated in the north-eastern part of the Ljubljana Marsh near Vič. Small standing waters can also be found on the periphery of the Ljubljana Marsh. Numerous species of fish, water birds and turtles live in the numerous ponds, former clay pits, near Vrhnika and Ig. With a depth of 51 metres, a karst lake situated near Podpeč is Slovenia's deepest lake.

In contrast to the surface waters, which account for only one per cent of the Ljubljana Marsh Nature Park area, groundwater is located below the entire surface of the marsh plain. The groundwater comes to the surface where the different layers are in contact with each other. This occurs in the shape of numerous natural springs (marsh springs). It is also found in the many boreholes built for the purpose of drinking water abstraction. A number of karst springs are located on the karst periphery of the Ljubljana Marsh, all

*Illustration of the Brest pumping station with a detail of the immersion pump (Illustration: Marijan Pečar)*



the way from Vrhnika to Ig. The best known are the springs of the River Ljubljanica between Vrhnika and Bistra. Far less known are the springs on the periphery of alluvial fans, which are the gravel deposits of rivers. Hydrogeologists discovered the highest number of **alluvial fan springs** on the periphery of the alluvial fan of the River Iška. The gravel deposits of the Iška reach a depth of several ten metres, where there are **large supplies of drinking water**, which is pumped out in the Brest pumping station.

The surface and groundwater of the Ljubljana Marsh join forces during excessive and long-lasting autumn and spring rainfall. The watercourses overflow their beds and flood the marshy plain.

During the **annual floods**, water covers about 15 per cent of the area, and more than half of the area of the Ljubljana Marsh in times of **extraordinary flooding**. At such times, the marsh plain has the appearance of a pile dwellers' lake of times gone by.



**Map with 3 types of marsh springs**  
(Map: Mihael Brenčič, Oddelek za geologijo NTF UL)



## The marsh springs - a unique water phenomenon

Marsh springs are a lay term for all the springs and smaller water areas in the territory of the Ljubljana Marsh and its periphery. An examination of written records, the narratives of locals, and the list of the marsh springs in the Ljubljana Marsh compiled as part of the LOKNA project reveals that this is a very varied water phenomenon. Its diversity is reflected both in its denomination and the typology of the phenomenon. While collecting data on the marsh springs from local people, different terms were mentioned: springs, windows, pools, bubbling springs (Slovenian: *retje*). The locals named certain springs after the owners of the plots on which they are located (the Urh window was named after a family name Urh) and others after the type of vegetation around the springs (Jevšnik was named after jelše, the Slovenian word for alder). Hydrogeologists classify the marsh springs according to the area in which they occur, i.e.:



*One of the springs at Iška Lokna  
(Photo: Barbara Zupanc)*

- real marsh springs in high marshes
- alluvial fan springs and sources on edges of alluvial fans
- karst springs on the karst edges of the Ljubljana Marsh.

**Real marsh springs** are open water surfaces located in high marshes. As real high marshes today no longer exist in the area, real marsh springs can also no longer be found. They vanished together with the high water that was drained after the first major

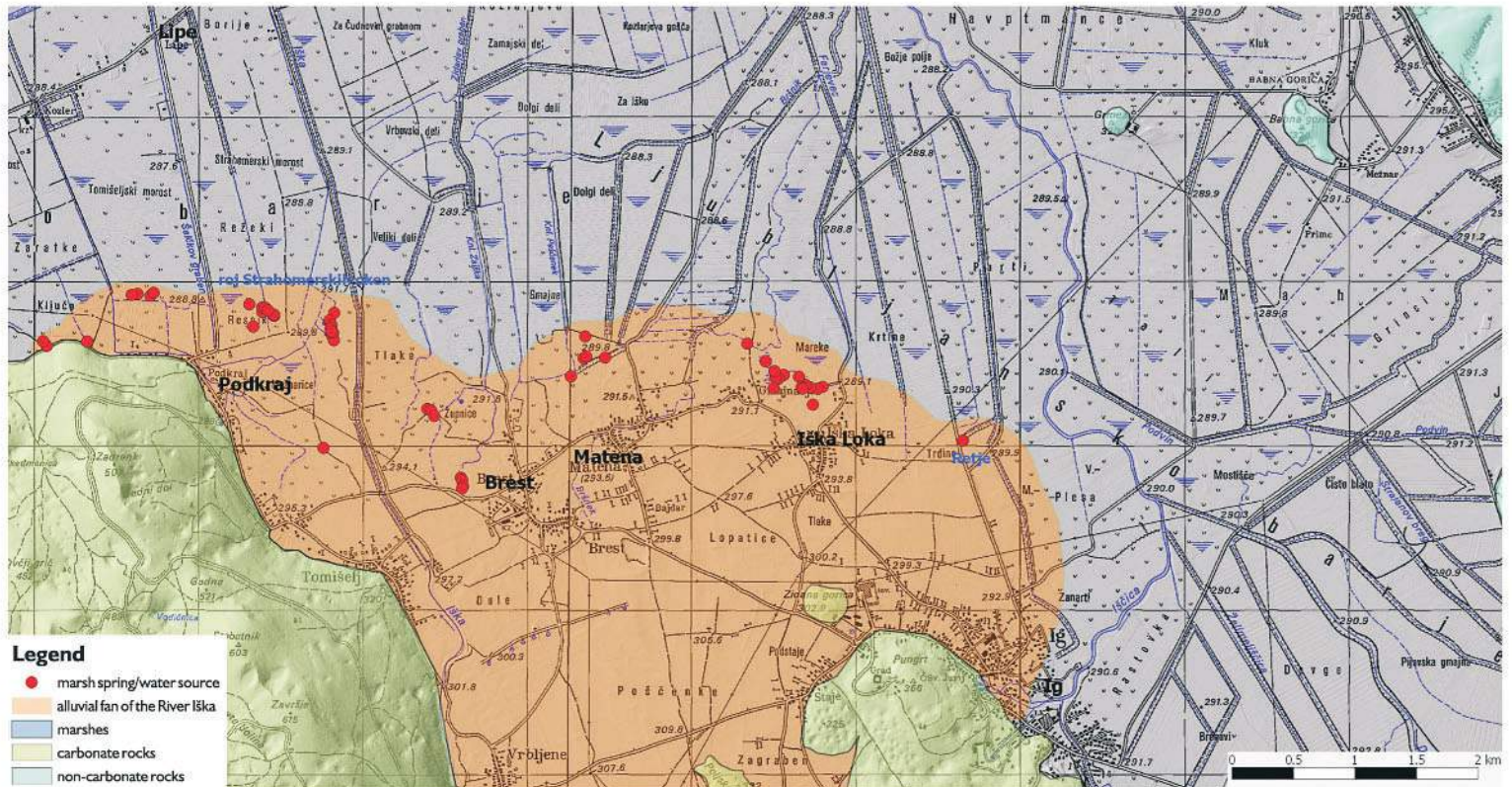
draining activities. Their locations can be discerned on the Josephian military topographic maps of the first survey for Central Austria, which was conducted in the Marsh from 1784 to 1785. The following was recorded in an explanation whose origin coincides with the maps for the area of Notranje Gorice: "The open waters called lake windows are almost inaccessible."

**Alluvial fan sources and springs** are situated at the edge of alluvial fans, the gravel deposits of rivers. The greatest diversity and number of the water phenomena in question can be observed at the boundary of the alluvial fan of the River Iška. While compiling a list, hydrogeologists discovered as many as 53 of them. The majority come in groups, such as Strahomer spring group. They are classified, depending on the inflow of water, into shallow and deep alluvial fan windows and springs.

*Marsh spring at the alluvial fan of the River Iška  
(Base map: GURS 2016, authors: Mihaela Brenčič,  
Teja Keršmanc, UL Naravoslovnotehniška fakulteta,  
Oddelek za geologijo)*



# The marsh springs



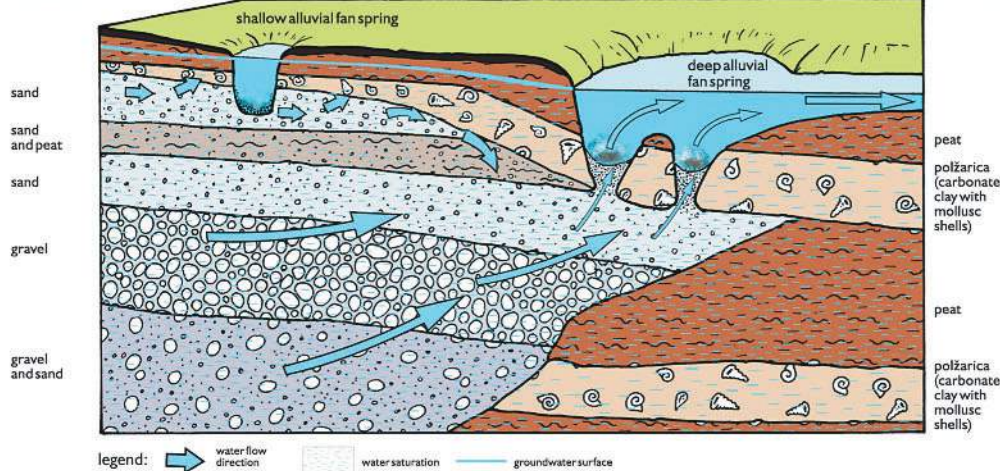


# The marsh springs

ALLUVIAL  
SEDIMENTS

MARSH  
SEDIMENTS

*Two types of alluvial fan spring/source  
(Illustration: Marijan Pečar)*



*Karst spring near Goričica  
(Photo: Barbara Zupanc)*

Shallow alluvial fan springs depend on contact between the low permeable marsh deposits (clay, clayey silt and fine sand) and the more permeable gravel river deposits (gravel and sand), where the water from the upper section of the aquifer comes up to the surface. These springs are characterised by fluctuations in water level and temperatu-

re. The largest group of shallow alluvial fan springs is located near Iška Loka, where hydrogeologists identified two big groups: Mareke and the Lošca springs. Some springs have dried up completely, while others resemble big puddles more than springs.

Shallow alluvial fan springs are distinguish-

ished from sources by not having a natural run-off and are hence also usually larger than alluvial fan springs. At the boundary of the alluvial fan of the River Borovniščica, there lies the powerful bubbling spring Anžutovo retje, which with its area of 20 m x 16 m ranks among the largest marsh springs listed.





*Marsh spring in Podkraj  
(Photo: Maša Bratina)*



Deep alluvial fan springs are recharged with water from the lower section of the aquifer, where the water comes to the surface through channels. As the water coming to the surface is under pressure, it washes away different layers of marsh soil on its way from the lower section of the aquifer to the surface: so-called polžarica (carbonate clay with mollusc shells) and peat. Polžarica is a layer of light grey clay of variable thickness found under the peat layer. It is a lake deposit which gets its name from the numerous mollusc shells found in it. Together with the water, fine particles of clay and particles of brown peat and white snail shell come to the surface. In contrast with shallow alluvial fan springs, the temperature in the deep springs remains constant throughout the year, 11 degrees Celsius. The two biggest groups of deep alluvial fan springs are situated between Brest and Podkraj: the Jevšnik spring group and the Strahomer spring group.

*Water level measuring rod at Strahomer springs  
(Photo: Maša Bratina)*





# The marsh springs

**Karst springs** are situated at the karst edges of the Ljubljana Marsh, which runs from Vrhnika to Ig in the foothills of the Krim mountain range. The best known karst springs are the springs of the River Ljubljana between Vrhnika and Bistra: Mala and Velika Ljubljana, Ljubija and Bistra. Far less known are the numerous smaller karst springs between Goričica and Pako, which are covered in marsh sediment. They can only be observed during periods of heavy rainfall when water trickles from the ground in small streams.

## The importance of the marsh springs in the past and today

The uniqueness of the phenomenon of the springs in the Ljubljana Marsh is supported by a number of references in literature dating back to the 17th century. The earliest mention of the marsh springs is found in the "Glory of the Duchy of Carniola" by polymath Janez Vajkard Valvazor (1689): "the area between Ljubljana, Ig and Vrhnika has

*many such incredibly deep pools or holes filled with water. They are usually called springs. Nobody can measure their depth, which shows that these small pools or holes are permeable beneath and reach down to the opening of a hidden channel deep in the ground or better said extend upwards from it. A lot of beautiful fish live in many of them."*

Prior to major draining works, the Ljubljana Marsh was completely different from today. It was covered in ombrotrophic bog, which was very difficult terrain, as there were no well-trodden paths. Only fishermen and hunters dared to venture out into such a landscape, and even they had to be extremely careful not to fall into the marsh window, which was vividly described by Ivan Šubic in a detailed nature study on the Ljubljana Marsh in 1886:

*"Hunting required a lot of caution and skill. Sometimes a foot sank and men were forced to drag each other out of the sludge and mud. The ground shook with every step. Marsh windows or bubbling springs (Seefenster) posed the big-*

*gest threat. These springs were sometimes open but sometimes fraudulently covered in a thin crust of moss and sedge. Woe betide any lonely man who lost his way there! He vanished without trace in the window. Even after draining had already advanced, workers in the field often came across covered springs. They pushed a pole through the thick crust, yet they could only rarely reach the bottom. Well-known lake windows were located near Lavrica, Loča, Plešivica, Kostanjevica, Bevke and elsewhere. The face of the Ljubljana Marsh swiftly underwent change with the progress of draining."*

Following major draining work in the Ljubljana Marsh, the ombrotrophic bog was replaced by meadows and in time also by fields and settlements. The elderly locals of Podkraj said that as shepherds they were afraid that grazing livestock would fall into a marsh spring. Only the persistent and strong who were equipped with ropes managed to pull animals out of the springs. Farmers regarded the marsh springs as a piece of useless land. Hence, they often fi-



# The marsh springs

lled them up or redirected the water flow to nearby canals. On the other hand, the locals also mention that the water from the marsh springs was used as drinking water and for washing dishes and clothes until their houses were connected to the water supply network. The locals of Iška Loka said that the marsh springs were a place for play and fun, as when they were children they used to skate there in winter, while during the warmer months of the year they went there to catch fish and crayfish.

Today, people still occasionally fall into the marsh springs. Farmers like to fence off the larger springs to prevent their cattle from falling into danger. It is also often the case that marsh springs and sources are filled in. In the case of shallow marsh springs and sources, the phenomena dry up in time. As for deep sources and springs, the water flow is only redirected and a new spring or source soon emerges in the vicinity of the filled-in location. A closer look at filled-in marsh springs reveals that all such areas witness the

spread of the invasive Canadian goldenrod (*Solidago canadensis*) and the gigantic tall goldenrod (*Solidago gigantea*), which create thick stands that quickly spread to nearby fields and meadows. Less noticeable at first glance, yet all the more dangerous, are the pesticides used in intensive farming.

They seep down into the ground where the sources of drinking water are located. The locals mentioned that since the intensive cultivation of corn in the Ljubljana Marsh, they no longer dare drink the water from the marsh springs. The most poisonous pesticides have already been banned for several years. However, the time it takes them to break down in the soil is extremely long.

Many locals are aware of the fact that the marsh springs are a lot more than just useless holes. Mr Jože Krašovec from Podkraj, a long-standing voluntary fire fighter, emphasises that the marsh springs are crucial in the summer period during peat fires, as they represent the closest source of water for extinguishing them. Microbiologist Dr. Ja-

nez Hacin highlights the importance of the marsh springs in the irrigation of the meadows and fields during drought periods, which can be achieved through regulating the system of dams in the canals into which the water from the marsh springs flows. The marsh springs also provide a significant indication of groundwater levels. Groundwater level measurements of the marsh springs have been performed since 1967.

Many locals of the Ljubljana Marsh are proud of the fact that such a unique water phenomenon is in their immediate vicinity and they would like to present it to the general public. The inhabitants of Tomišelj and Podkraj have thus established a cultural society called The Sources of Tomišelj (Kulturno Društvo Izviri Tomišelj), which in 2010 prepared some of the marsh springs for visitors.

*The four seasons:*

*1. autumn*

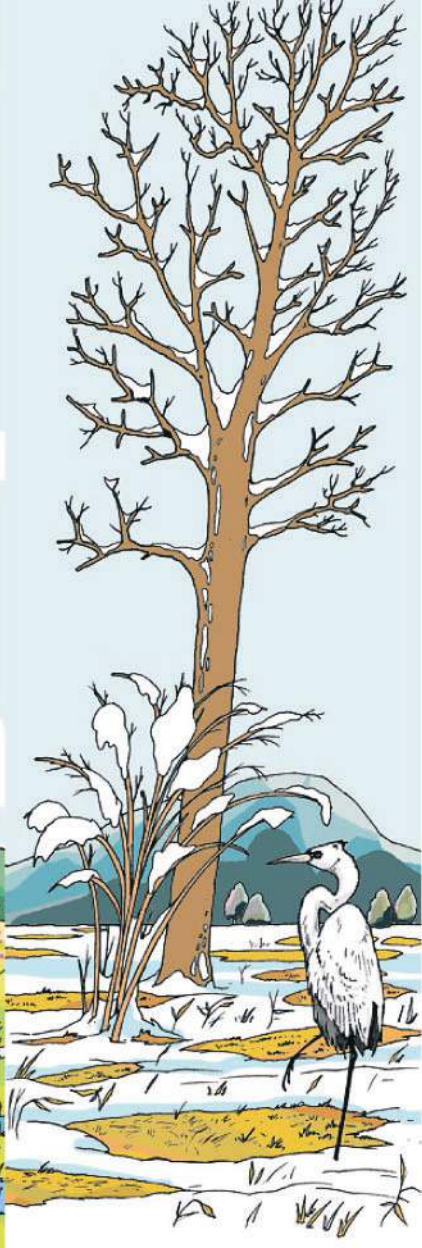
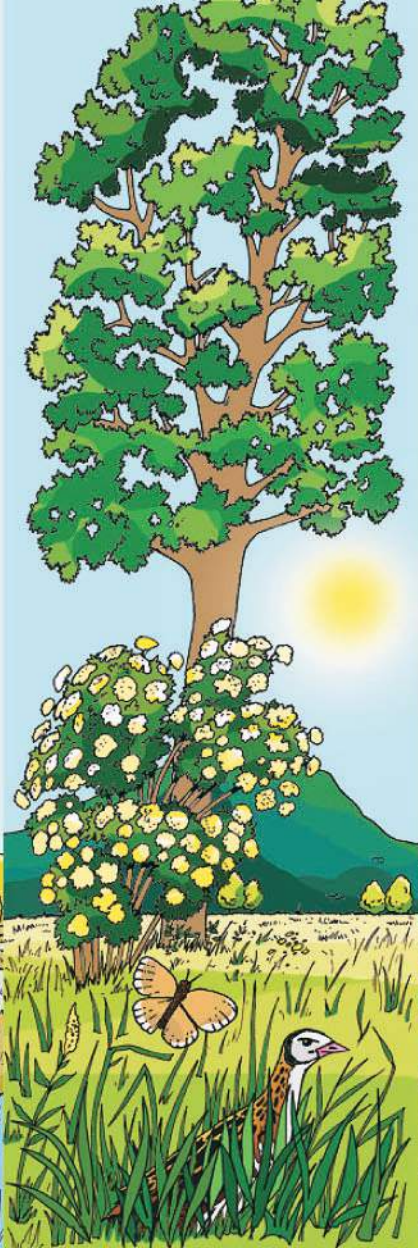
*2. summer*

*3. spring*

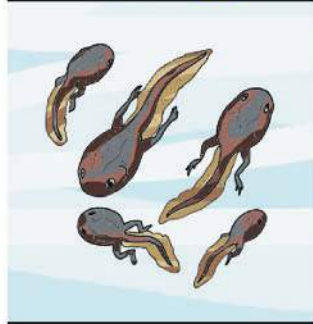
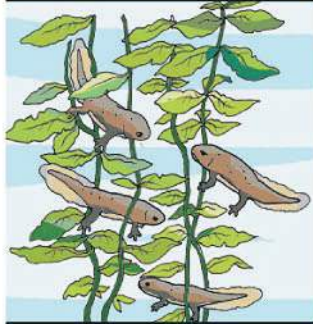
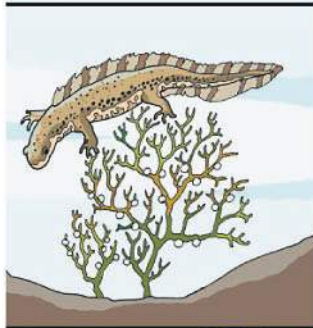
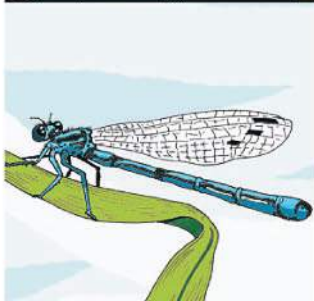
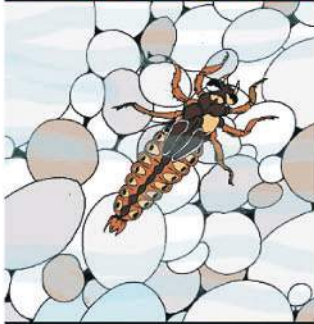
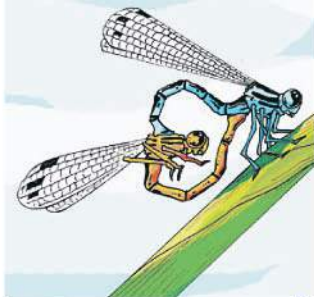
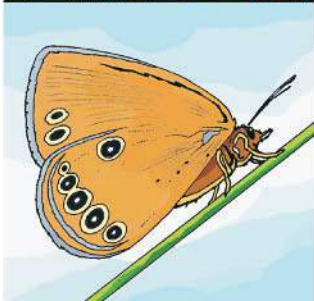
*4. winter*

*Illustration: Marijan Pečar*











## *Preservation and promotion of water biotopes - Lokna*

### **Marsh spring educational trail**

One of the activities of the LOKNA project is to set up a marsh spring educational trail in the Ljubljana Marsh. The Ljubljana Marsh Nature Park has been co-operating in the setting up of the trail with locals, the representatives of the Institute of the Republic of Slovenia for Nature Conservation, and hydrogeologist Dr. Mihael Brenčič.

When selecting the route, the Park's main principle has been to intervene in untrodden parts of the Ljubljana Marsh as little as possible and to put already existing trails to the fullest use. Thus, the starting point of the trail is in the vicinity of the main road at Podkraj, at the karst edge of the Ljubljana Marsh. In the vicinity of the introductory information table, there is the Šentjanž

stream, which comes to the surface at a karst spring below the little church of St. John the Baptist. From the asphalt path, the trail continues from the settlement to a field path leading to the Strahomer springs.

A wooden platform with a fence has been installed by the springs for safe viewing. The platform has information boards featuring colourful illustrations helping visitors discover the phenomenon of the marsh springs throughout the territory of the Ljubljana Marsh, the Iška alluvial fan and the group of Strahomer springs.

The key to understanding the marsh springs is a knowledge of the different soil structures of the alluvial fan and the marsh, as shown by two pillars by the information boards. There are wooden bricks at the fence of the platform that can be used to show the marsh soil types of the past and today, and the development stages of the animals linked to the water and the Ljubljana Marsh across the four seasons. These interpretative tools make natural science interesting for

the youngest visitors.

The path continues from the Strahomer springs to the Jevšnik canal, which is the confluence of the waters from the group of Jevšnik springs. An information board nearby explains the importance of the marsh springs for humans in the past and today.

The total distance of the trail is about 2 kilometres, and it is best to walk along it. It will take you approximately 1 hour in one direction together with stops along the way. If you wish, you can continue walking along the educational trail by the River Iška and along the Corncrake educational trail in the immediate vicinity.

In this case, you should add about an hour or two. You can also get there by public transport. Ljubljana Passenger Transport city bus No. 19b will take you to Lipe, from where you can walk 1.5 km by the River Iška along the Okljuk educational trail and then turn right onto the trail passing through the marsh springs.

*Animal development phases:*

1. *False ringlet*

2. *Dragonfly*

3. *Newt*

4. *Yellow-bellied toad*

*Illustration: Marijan Pečar*



# The marsh springs

## Marsh spring workshops

Neatly arranged educational trails alone will not help preserve the marsh springs if the locals do not recognise the importance of these phenomena and see them as important natural assets. The workshops which the Ljubljana Marsh Nature Park organised in primary schools at Ig and in Borovnica were the first step towards raising awareness of the marsh springs. Pupils in the introductory part discovered the geological history of the Ljubljana Marsh and were acquainted with the basic layers of soil that today comprise the Marsh: gravel, sand, clay and peat. They also got to know the different types of aquifer: fissure, karstic, artesian, subartesian and alluvial. Group of pupils made their model of an aquifer in the practical part, which they all tested together at the end. They learnt how the alluvial marsh springs work on a model of an artesian aquifer.

The pupils participated very well in the workshops, as is shown by their impressions



*We also made a model of a karst pond  
(Photo: Anton Zvanut)*

below:

*"I liked the marsh springs project, as I learnt many new things about the Ljubljana Marsh. The most fun part was when we split into groups and had workshops. In this way, we were able to see with our own eyes what is happening to the marsh."*

Katja Potočnik, Ig Primary School

*"It was a great experience. I learned a lot. I*

*listened closely, because the topic interested me. I would repeat the experience if I could. Now I know what an aquifer is."*

Karmen Centa, Dr Ivan Korošec Borovnica Primary School

*"On Monday 16 November, we had workshops on the subject of the marsh springs. We learnt what the marsh springs are and how they are formed. We also got to know some other characteristics of the Ljubljana Marsh and went 2 million years back into the past. We got to know how the Ljubljana Marsh came into being. I personally enjoyed the final part most when we used different materials to make our own models."*

Zala Kramar, Ig Primary School

*"The lecture was instructive. We heard many new things about the landscape in which we live. I liked the second part best when we were making models."*

Tadej Tinta, Dr Ivan Korošec Borovnica Primary School



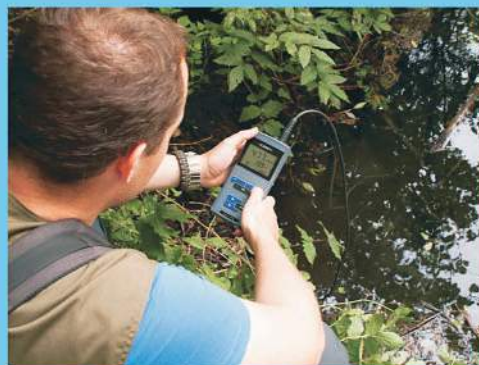
## *Ponds and marsh springs for the future - Lokna*

### Looking at the marsh springs - looking at the future

The Ljubljana Marsh is an extremely complex landscape hiding its essence below the surface. The deep soil, consisting of different layers, and the groundwater create unique conditions.

The annual floods and soft marsh soil have not deterred humans from building houses, roads and railways or from farming on the marsh plain. However, such interventions have to be thought out well if they are to be successful. Houses in the Ljubljana Marsh have to be built on stilts, preloading dikes have to be built for roads, and rocks and stones have to be banked up behind railways. Farmers in the Marsh know very well that not every crop can grow in the marsh soil.

They are also aware that they need to carefully monitor the floods and prudently assess in which areas it makes sense to plant. In addition to what is grown in the marshy pla-



*Observations must be continuously recorded  
(Photo: Dejan Veranič)*

in, it is also important how crops are planted and which products are used for spraying. The source of drinking water stored in the alluvial fan soil is extremely important for humans in and around the Ljubljana Marsh. Yet this source is not unlimited. Both the locals and experts point out that the level of the groundwater is dropping. At the same time, the locals say that ever since the intensive farming of corn began in the Marsh, they no longer dare drink the water from the

marsh springs. The level of the groundwater and its quality in the marsh soil can be observed in the marsh springs.

The modification and loss of the marsh springs is a process that cannot be stopped. However, it can be studied and consequently better understood. The continuous monitoring of the phenomenon of the marsh springs and additional research to identify more precisely the causes and means of their creation are needed so as to arrive at a comprehensive picture of them. A better understanding of the phenomenon will also lead to a more positive attitude.

Information activities related to the marsh springs are hence of the utmost importance. The workshops on the subject that have already been conducted in certain schools in the area and with the local adult population have raised considerable interest. The main target group in the ongoing information activities should also include the owners of plots with marsh springs. The greatest gu-





ardians of the marsh springs could be the owners of plots who understand the phenomenon well and thus also appreciate it. The continuous monitoring of the marsh springs as a phenomenon in its entirety, scientific research and well informed locals also pave the way for sustainable tourism.

People are becoming more aware that drinking water is a priceless treasure that has to be protected. The better we understand where sources of drinking water are and how our activities have an impact on the quality of these sources, the more successful we will be in our efforts to protect them. A look through the marsh springs provides an insight into groundwater. A look at the marsh springs from the earliest times to the present uncovers the impact of human activity on the supply and quality of the groundwater. It is worth making an effort to preserve the marsh springs, as in this way we will also preserve a look at our own future.

*River Iščica (Photo: Branko Čeak)*



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