1.1. The global water cycle

Additional Danube tales -

Sagas and Legends

The dogs of Kuenring

In the 12th century, the knights of Kuenring built Castle Aggstein on the precipitous Aggstein rock opposite the present-day village Aggsbach Markt. The Kuenringers were at first a powerful, honourable family, but in the course of the centuries they turned into robber barons. The brothers Hadmar and Heinrich von Kuenring in particular were vagabonds and murderers. If their worthy forefathers had called themselves “the dogs of Kuenring” because they were faithful to the emperor and the empire, for the people who feared the robber barons, this description now acquired a completely different, evil meaning. “Only the sky falling can defeat the dogs and their castle,” the two brothers sneered and boasted.

Heinrich spent most of his time plundering in the Waldviertel region of Austria; his brother Hadmar, in turn, to come into money blocked the Danube with a chain that was stretched from bank to bank and forced thereby every ship sailing downstream to stop. If the ship was caught in the chain, Hadmar and his followers descended from the floodplain forest, fell upon the “pepper sacks”, as he sarcastically called the good merchants, relieved them of their gold and their goods and threw them in the dungeon of his castle. They were only freed on payment of a high ransom.

But the plundering brothers pushed their luck too far. The duke, who was enraged by the ruthless actions of the two knights, decided to take the castle and to have the two brothers hanged from a willow tree.

It was not at all easy to subdue the two brothers, however. They were slyer than a fox and their castles of Aggstein and Dürnstein were enthroned like impregnable eyries on steep cliffs.

Good advice was dear and the duke finally even asked his court jester if he knew how to capture the Kuenringers. “My Lord,” answered the rogue, “one catches mice with bacon, foxes with meat, Hadmar and Heinrich, the two robbers, with treasure. One only has to know how to trick them properly and the wildest ones fall into the trap too – didn’t the ancient Greeks in the old days trick the brave Trojans with a wooden horse?”

The advice pleased the duke and he armed a ship laden with the most precious objects: gold and silver, valuable silks, delicious wine and victuals filled the ship to the brim.

They launched the ship far away on the upper Danube and allowed it to glide downstream. Below the many goods, hidden in the belly of the ship, however, crouched several dozen of the duke’s bravest warriors. They lay in wait, weapons in hand, for the moment the ship would hit the Kuenringers’ chain at Aggstein.

The ship sailed peacefully down the Danube until finally Castle Aggstein came into view.

Down from the trumpet house on the mighty tower the imperious horn of Aggstein sounded, ordering all ship’s captains to land forthwith. Anyone who did not obey the horn would in any case be caught a few ship’s lengths later by the invisible chain.

But the helmsman steered his ship obediently to the bank, where Hadmar was waiting with his gang and where he was the first to leap aboard. How his eyes sparkled with joy when he saw the rich booty that offered itself to him and promised even more valuable treasure below deck. Chest by chest, ball by ball, barrel by barrel he had it carried away.

But as his followers sought to force their way into the belly of the ship, suddenly the duke’s warriors broke out, cut down the scoundrels, overpowered their commander too and clapped him in irons.

The duke’s people, for their part, had now got their hands on a precious haul. With the captured Kuenringers they sailed merrily down the Wachau valley to Vienna. But first they removed the chain across the Danube.

Robbed of its lord and leader, the Aggstein fortress capitulated and was destroyed. Hadmar, who the good duke did not sentence to death, but who was banished from the land, died shortly afterwards, far from his home in a poor village upstream.

“Fiery Dragon Wolf protects Obedska bara”

It is very often that bountiful natural areas are the setting of legends, myths and fairy tales. Such is the case of the Obedska bara wetland near the Sava in Serbia, where stories of knights and princesses who sought refuge in its woodlands still exist in local folklore.

The fortress of Kupinik (today Kupinovo village), at the very edge of the wetland, had the privilege of being the residence of Vuk Grgurevic, one of the most legendary Serbian heroes.
Vuk Grgurevic acquired a remarkable reputation for his courage and the nickname "Zmaj Ognjeni", which could be translated into English as "Fiery Dragon". His name, "Vuk", means "wolf" in Serbian, so his whole name "Zmaj Ognjeni Vuk" actually means "fiery dragon wolf".

Historians suppose that he was born in the Serbian Smederevo, a fortress and a town on the Danube river and one of the Ottoman-free areas at the time, while others were suffering under the harsh Ottoman rule. He was an extramarital son of prince Grgur Brankovic. When Vuk was still baby, his father was arrested and blinded by the Ottomans. Surrounded then by cousins who were fighting over trifles while the country was in ruins, he grew up isolated and without love or attention, but his faith and skills steadily developed.

As a young boy, he spent most of the time near the Danube River, watching soldiers practicing horse riding and military know-how. It was said that a birth mark predicted his great soldier career.
He gained his first military experience by crossing the Danube to fight the Hungarians and to bring food and goods to the starving Serbian people. The story about a brave young man started to spread.
After the fall of the town of Smederevo in 1459, while the other members of the Brankovic family spent a quiet time in the Ottoman empire, Vuk, restless and righteous, decided to move to Hungary.

And the Hungarian king recognizing his abilities and respecting his noble ancestry gave him Kupinik fortress, which became the centre of the Serbian state. The fortress lies in the south of Srem, an area between the Sava river and the Fruška gora mountains. His arrival to Srem was a big relief to the Serbs living in that part of the land, as Ottoman soldiers often crossed the river to rob and torture.

Once in Srem, and willing to fight, Vuk Grgurovic was delighted with his role of a border-land protector.
The rarely populated Srem was a huge wetland area at the time, where rivers, ponds, reed beds and wet meadows interweaved with virgin oak forests and fields. Obedska bara oxbow lake, in its center, hosted the largest heron, egret and ibis colonies in this part of Europe, comprised of tens of thousands of birds as well as rich wildlife. That mystical setting was the home of Fiery Dragon Wolf, who flew, like the fire-breathing creature from the fairy tale, from one to its other side, to protect and save his people. The vast wilderness was offering a perfect hiding.

He fought with the Hungarians against the Czechs, the Poles, the Austrians and the Turks. In 1471 he gained the title of despot of Serbia, and also received large possessions. Vuk married Barbara Frankopan, a Croatian - Dalmatian noblewoman, but unfortunately they didn’t have any descendants.
In 1481, he fought against the Turks in central Serbia, where he rescued about 50,000 people. He settled them in Banat, mostly around Temisvar, a town in today’s Romania.

Despot Grgurevic knew that the Christian faith was very important for the Serb minority in Hungary, so he founded monasteries all over Srem. Some of them, such as Grgetek Monastery on the Fruška Gora mountains, remained until nowadays the way he built them.

His aim was to care for a better life for his people, in Hungary and in the Ottoman empire. Hence, maintaining the balance between the two forces and making the right decisions in this complicated situation, were difficult tasks. But, he managed somehow. Always ready to help, he took part in many battles, over and again, and had become well respected among Serbian people as well among Hungarian and Ottoman rulers.

It was at that time that the Serbian people started to tell stories about their fearless hero, Fairy Dragon Wolf. Popular lore thus wished to show great respect for Vuk Grgurevic and preserve memories of his deeds for the future generations.

Fairy Dragon Wolf died on April 16, 1485, one year after peace was made between Hungary and the Ottoman Empire. Everybody believed that, since he was marked to be a soldier at his birth, he couldn’t stand living a peaceful life, without battles and adventures.

The Ages of Knighthood vanished, but the memory of Fairy Dragon Wolf is still so alive and picturesque that, although circumstances had changed a lot, when problems are around Obedska bara, it is believed that his spirit will appear. To save the people and to protect the wetland.

1.2. Stages in the water cycle

Woods to protect water sources: Vienna as an example for sustainable forestry management

Woods that are in the vicinity of water sources are particularly important. In order to ensure the best possible water quality and balanced quantities of source water, they need to be managed with particular care.

The City of Vienna, for example, draws most of its water from the Alps. The woods in the area of the sources that are used to supply Vienna are the property of the city. The declared aim of forestry management is to achieve optimum soil quality. The woodland soil should be absorbent, and able to retain and filter water. In order to achieve this, the natural processes must be consciously recognised and promoted.

The individual leaves of a forest reduce the force of the rain and thus protect the soil against erosion. The rainwater drips onto the woodland floor from the leaf canopy. Wood and soil, with plants, mosses, humus and earth, are a filter and a water reservoir. The woodland soil filters dust and possible pollution out of the rainwater. The water is retained in the cavities in the soil, seeps deeper only slowly, and comes back to the surface again, sometimes in the form of springs. Cavities in the soil are created among other things by life forms such as fungi and worms. Slowly rotting foliage offers them the best subsistence.

In the woods protecting the water sources near Vienna, there are few clearings, and timber is felled only in a few areas. The felled trees are towed out of the woods using rope cranes, or sometimes even horses, which protects the woodland floor better than if heavy machinery was used.

The tree species in the woods are determined by soil and climate. An aim of the City of Vienna managing the woods is also to achieve a natural rejuvenation of the woodland stock. The seeds of older trees fall to the earth and germinate. If the stocks of game are too high, this type of growth is impossible as the game gnaws the young trees, which prevents them from developing. The stocks of game are therefore kept at a level that permits natural rejuvenation.
In these woods the use of artificial fertilisers, herbicides or insecticides is not allowed.

The Black Sea

In the early stone age the Black Sea was an inland sea. Its surface was 150m below that of the Mediterranean Sea. In the 8th millennium BC the water level in the Mediterranean Sea rose, the Bosperus and the Dardanelles Straits were flooded and the current connection between the Black and the Mediterranean Seas was created. The sea level rose rapidly. The sea flooded the coasts and pushed into the interior. This natural event may be the basis of many peoples' stories of the Great Flood.

The basin of the Black Sea descends to the south, and in the south the deepest point is 2,212m deep. The Black Sea stretches over an area of 432,000 square kilometres. Its catchment area is six times as large. Rivers such as the Danube, Kuban, Dnjepr, Don and Dnjestr deliver 350 cubic kilometres of river water annually. The surplus water in the Black Sea flows out into the Mediterranean via the Bosporus, which is in places only 40m deep.

The Black Sea is characterised by the existence of two completely different layers of water which have nearly no water exchange. The water of the bottom layer has a very high salinity and is containing hydrogen sulfide. The water from the surface to 150-200m below is less saline and less dense, and is rich of animal and plant life.

The Danube opens into the Black Sea and brings an average of 6,500 cubic meters of water per second – and the pollution that has found its way into the river from the whole Danube basin.

A mass of nutrients causes the growth of algae in the sea. The algae die and their decomposition uses up the available oxygen in the water. The transparency of the water decreases. The sea loses its balance.

The Black Sea is highly sensitive to pollutants. There is almost no water exchange with one of the Seven Seas, and it was in the 1960s that eutrophication started to get a severe problem. In the 1960s to the 1970s the Black Sea was at the edge of an environmental disaster. It was nearly to shift, the sensitive ecosystem was disturbed. Measures and precautions to reduce for example nitrogen depositions showed effects very slowly. It was only in the last few years that a decrease of the ecological effects of eutrophication can be noticed.

In addition to nutrient pollution, other pressures on the Black Sea ecosystems include organic pesticides, heavy metals, incidental and operational spills from oil vessels and ports, over-fishing and invasions of exotic species.

2.1. The sections of a river

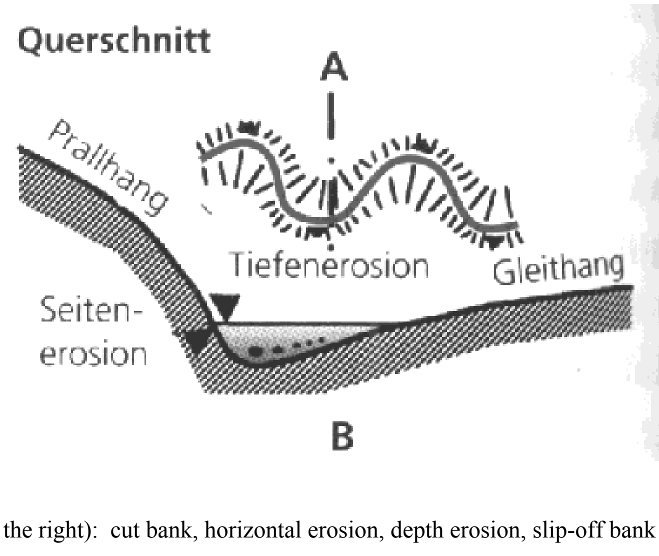
The sections of a river

Upper course

If groundwater reaches the surface, one speaks of a source. If the water in mountain areas collects together quickly into a little brook or stream it is called a spring source. If the water accumulates on the surface over a wider area out it is called a marsh source. In flat areas where the source water cannot flow away immediately a pond source develops.

If many source streams meet, a mountain stream grows. The water in a mountain stream flows steeply down a valley, its steep gradient means it has the energy to transport larger stones. When the snows melt, a mass of stones and gravel is carried down into the valley. Through the abrasion of the stones on the rock foundation the mountain stream slowly cuts its bed into the mountain. This process, known as depth erosion or vertical erosion is found primarily in the upper course.
Seen from above, the valley of such a mountain stream is more or less straight.

Cross section upper course:



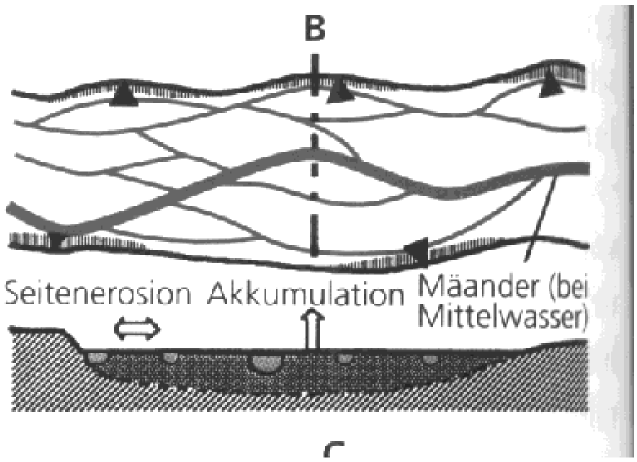
for diagram (from the left to the right): cut bank, horizontal erosion, depth erosion, slip-off bank

Middle course

If the stream reaches the valley bottom, or converges with other mountain streams, then eventually the valley it is flowing in becomes shallow. As a result of the water delivered from the tributaries, the stream has become a river and it is already over three metres wide. The large rocks have been reduced on the way, the riverbed now consists mainly of gravel. If a tributary from the mountains now joins it, it also brings a mass of gravel with it.

When it floods, the river carries a lot of gravel, which, when the water level falls, it can no longer move. This is deposited as islands or on the bank. As a result, it divides the riverbed into numerous arms, between which there are shingle islands. Whenever there is a major flood, these islands lying in the current are carried with it and deposited again somewhere else. At the same time, the river brings gravel from higher up again. This river section is therefore called the bed load exchange reach.

Middle course – split course in plan and cross section:



for diagram: horizontal erosion accumulation meanders (at mid water)

When the river tears away a bank or an island, we speak of *horizontal erosion*. If the river cuts out a new bed one speaks of *depth erosion or vertical erosion*. If an oxbow lake is filled up, then *accretion* takes place. Are all three processes balanced out, without one process dominating, there is a balance in the bed load exchange reach, which is continually changing. The gravel banks of a bed load exchange reach are usually without vegetation, because the annually recurring floods allow no vegetation to take place.

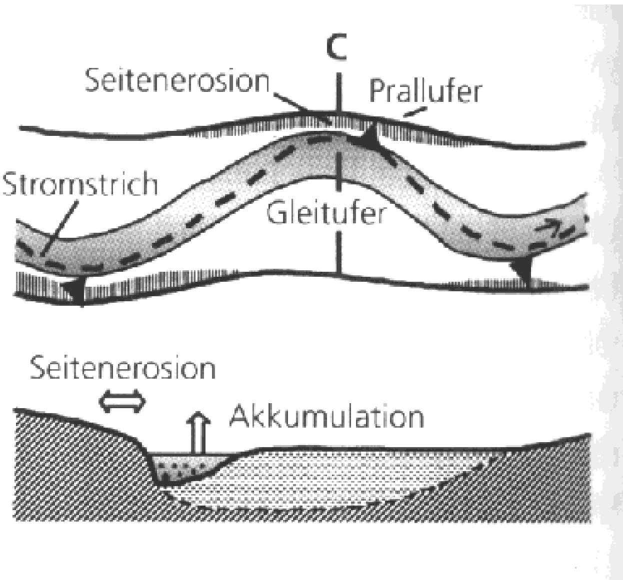
When the river flows out of the mountains onto a plain, it slows down and deposits river gravel in a huge pile. This "pile" is called the debris cone. The "Small gravel island (on the Hungarian side called Szigetköz)" and the "Large gravel island (on the Hungarian side called Csallóköz)" at the beginning of the Slovakian-Hungarian stretch of the Danube are examples of such a debris cone. The fact that the Danube is a large river and has been transporting gravel from almost every major river valley of the north-eastern Alps since the ice age can be seen from the size of the "Szigetköz". The debris cone is 50 km long and just on the Hungarian side covers 6,000 ha.

Lower course

Rivers that flow through depressions or plains are called lowland rivers. The water flows sluggishly, the gradient of the riverbed is only a few centimetres per kilometre. The force of the flowing water is no longer enough to transport larger pieces of gravel, only sand and very fine gravel are carried by the river. It is noticeable that the river water is much more murky than in the upper and middle course. When it rains in flat areas instead of stones topsoil is washed into the rivers. The soil particles are so small that even a small current is sufficient to keep them in suspension. They are therefore known as suspended matter. These particles cause muddy water, but are no pollutants.

A lowland river whose riverbed is made of sand develops a winding (meandering) course. The outer side of a river bend, called the cutbank, is lightly undermined; the river carries the bank material to the next inner bank, to the slip-off bank, where it is deposited. The steep outer banks and the shallow inner banks form as a result of horizontal erosion and accretion. There is hardly any depth erosion down below because of the low gradient.

Meandering course in plan and cross section:



for diagram: horizontal erosion — cut bank
current — slip-off bank
horizontal erosion — accumulation

When it floods, the lowland river inundates a wide floodplain in which it deposits its muddy sediment. Thus, in the oxbow lakes cut off from the river a layer of loam builds up over the course of time that causes the oxbow lake to form new land.

If the gradient in the river becomes even shallower and the floodplain consists very much of clayey material, then the rivers loops become larger and more regular, it flows in meanders. In a river floodplain forest in its natural state, apart from the river bed there is a great variety of wetlands:
side arms that the river flows through, connected old arms of the river, ox-bow lakes

– old arms separated from the river – oxbow lakes that have formed land,
marshy tributary mouths, blocked up tributaries (river lakes), riverine marshes and riverine sand dunes.

The mouth

Inland, all smaller rivers and streams flow into a larger river that sooner or later reaches the sea. If this river carries a lot of solids with it, then it deposits them in a river delta. This also happens when rivers flow into lakes.

Here, at the end of its course, the Danube has practically no gradient anymore, so that it can spread out in all directions and deposit the solids it has brought with it. This is why the delta usually has several arms through which the river water flows into the sea. Because the current is very slow, the river also deposits sediments on the banks of its arms. At high water levels the natural embankments are overflowed and the land between the river arms is flooded. In the Danube delta, at medium water levels 60% of the delta is flooded, at high water this is 90%.

Examples of river deltas are the Danube delta, the Ebro delta, the Nile delta and the Volga delta.

When rivers flow into the sea with a strong tidal influence, then a "funnel mouth" is formed, called an estuary. The additional erosive effect of the incoming high tide and the outflowing ebb tide, the river mouth in the vicinity of the sea expands ever more widely.

Examples of "funnel mouths" are the estuaries of the Elbe, the Loire, the Weser and the Thames.

<u>Average gradient of the Danube</u>

	Altitude difference (m)	Length of stretch (km)	Gradient (‰)	Stretch
Upper course	34	30	1.13	Donaueschingen/Germany – Sigmaringen/Germany
Middle course	529	950	0.56	Sigmaringen/Germany – mouth of the Raab/Hungary
Lower course	113	1800	0.06	Mouth of the Raab/Hungary – mouth of the Danube into the Black Sea/Romania,Ukraine

Additional Danube Tales:

“Tasty Danube“ – fish recipes from the Danube basin

Hungary: fish croquettes

This recipe can be found in Hungarian cookery books from as early as the 17th century.

Ingredients
400g fish fillet without the skin (e.g. perch, pike or carp), 1 bread roll, 5 tbsps milk, 2 tbsps freshly chopped parsley, 2 well-beaten eggs, 50g flour, 50g fine breadcrumbs, oil for frying, salt and freshly ground pepper, fried parsley stalks, slices of lemon and ground paprika to garnish.

Preparation
Roughly chop the fish in a mixer. Soak the rolls in milk for 10 minutes, then dry them out and mix with the fish. Add parsley, 1 egg, salt and pepper. Form the mixture by hand into approx. 6-cm-long and 2-cm-thick croquettes. Coat the croquettes first in flour and then in beaten egg and finally in breadcrumbs. Heat the oil in a deep pan and fry the croquettes on a medium heat until they are golden brown. Sprinkle with paprika and serve.

Bulgaria: fish plaka

Ingredients
1kg freshwater fish, 500g onions, 1½ dl oil, 100g carrots, 100g celery, 450g tomatoes, 2 tbsps flour, salt, pepper, 1 bay leaf, 2–3 cloves of garlic, 1 lemon, 20g breadcrumbs, 1 tsp paprika, 1 tsp sugar, ½ bunch parsley, ½ l warm water.

Preparation
Clean the fish, wash and dry it, sprinkle with lemon juice and salt it. Cut the onions into thin slices. Heat 1 dl oil and fry the onions gently. Then add grated carrot and grated celery and briefly fry gently. Skin 300g tomatoes, cut into small pieces and add to the half-cooked onion mixture. Cook gently until everything is soft. Dust the lightly cooked vegetables with flour, allow to brown, add paprika, and then add first a little cold water then warm water. Add salt, pepper, bay leaf, diced garlic and parsley and cook on a medium flame for 10 minutes. Line an ovenproof dish with oil, put in the vegetables, then lay the fish in it and cover with the remainder of the chopped tomatoes. Drizzle each tomato slice with oil and coat with breadcrumbs and sugar. Bake in the oven at 200°C until golden brown. Serve cold.

Austria: trout au bleu

Cooking au bleu
Neither scale the fish nor hold it too hard, so that the mucus on the skin, which holds the colour, is not damaged. Carefully wash the fish under water and gut it, holding it by the tips or its head. Then cook in hot broth, which will not be used for preparing the fish sauce afterwards.

Fish-broth ingredients
In 1l of water: 20g salt, approx. 1/16 l vinegar, 6 peppercorns, half a small bay leaf, 60g sliced onions, 100g thinly sliced root vegetables, parsley.

Preparation
Cook all the ingredients until the water has taken the taste of the spices (approx. 10 minutes). Then put the fish into the broth. It must be well covered with broth, no longer boiling but just allow to poach. The fish is done as soon as the eyes appear like white balls. Serve with boiled potatoes in butter.

Slovakia: poached carp with caraway seed

Ingredients
4 carp fillets, 1 tbsp coarsely ground caraway seeds, 3 tbsps butter, 2 tbsps freshly chopped parsley, 1 onion cut into rings, the juice of 1 lemon, 175 ml dry white wine, salt and freshly ground pepper, dill and mint to garnish.

Preparation
Wash fish fillets and dry with kitchen roll. Season with salt and pepper and rub caraway into the fish fillet. Melt half of the butter in a large pan. Add half of the onion, lemon juice and wine. Bring to the boil, reduce heat and lightly simmer for 10 to 12 minutes. Add the fish and poach for 10 minutes. Carefully remove the fish fillets and keep warm on plates. Allow the stock to reduce. Add the remaining butter, salt and pepper. Pour the sauce over the fish and sprinkle with the chives. Garnish with herbs and serve with polenta and French beans.

Croatia: grilled fish

Ingredients
Freshwater fish, scaled and gutted, 5 tbsps olive oil, 1 tbsp. salt, freshly ground black pepper, 1 bunch of finely chopped parsley, twigs of fresh herbs to taste (e.g. thyme, sage), 1 lemon.

Preparation
Wash the prepared fish and dry with kitchen roll. Mix the parsley with the olive oil and coat the fish on both sides. Salt and pepper inside and out according to taste. Stuff the fish with the twigs of fresh herbs and two thin slices of lemon and roast for 10 minutes each side on the grill. Serve with potatoes and Swiss chard.

Germany: fried barbel

Ingredients
1 kg barbel, butter or olive oil, salt, pepper, flour.

Preparation
Cut the barbel into slices three fingers wide; divide the larger pieces again, wash, dry, season with salt and pepper and coat with flour. Then fry quickly in butter or oil until crispy, garnish with lemon wedges. Serve with potato salad.

Ukraine and Republic of Moldova: njemen carp in kvass and lemons

Ingredients
1.75–2.25 kg carp, cleaned with head and spine removed, salt and freshly ground black pepper, 45 g butter, 8 spring onions finely chopped, 2 tbsps brown sugar, ½ bay leaf, 5 crushed juniper berries, grated peel and juice of one small lemon, 425 ml Kvass (low-alcohol, rye-bread beer) or flat beer, 3 tbsps crushed ginger biscuits, 50 g flat-leaf parsley finely chopped.

Preparation
Wash the fish well and pat dry. Cut into 4 cm strips and sprinkle with salt. Leave to cool for one hour. Melt the butter in a heavy enamel or steel casserole dish at medium heat and lightly fry the onions for 2 minutes while stirring. Add sugar, herbs, lemon juice and peel and season with pepper. Stir for a few minutes, pour in the Kvass and simmer for 20 minutes. Pour through a sieve, throw the remaining ingredients away, then pour the stock back into the pot. Stir in the crushed ginger biscuits and cook until they have dissolved and a mush has developed. Add the fish, spoon the sauce over it, cover the pot and cook at a medium to low heat for approx. 12 minutes. Using a fish slice, lay the strips of fish on a serving dish. Reduce the sauce somewhat over a high flame and serve. Garnish the fish with the parsley.

2.2. Geology of the Danube basin

The formative power of water

Turbulent water movement makes water particles also to move at right angle to the direction of flow, creating both rebound– and sliding banks and with that to the fluctuation between erosion and deposit. Flowing water exerts thrust onto the riverbed, which moves larger stones over each other and smaller ones are transported in a rolling and bouncing way. Boulders are subject to rubbing, pushing and grinding movements, as well as chemical solution while being transported. Thus the boulders quickly loose their edges and corners and become more and more round and elliptical.

Less resistant stones, like lime- and sandstones, are reduced to half of their size after 50 to 100 km in average; whereas with more resistant ones, like fine-grained granites or quartzites, it takes about 100 to 300 km, provided they do not break up earlier. A selection is related to the reduction in size, which depends on the following parameters:

- rock density (not to be mistaken for specific gravity)
- pore volume (free space between the aggregates)
- aggregate binding (how strong are the aggregates connected to each other)
- fissility of the individual components
- brittleness of the individual components
- presence of gaps and cracks
- solubility of the individual components.

The largest sediments are found along river stretches with the strongest current. Smaller aggregates are simply pulled along and are not able to settle down. Along the shallow banks of the Danube one finds first of all young deposited coarse sediments, like gravel and coarse sand (in the lower course of the river the sediments become finer). Inland the grain size decreases very quickly, until fine sand, silt and clay prevail, which only get there during flooding.

What does the Danube transport?

Every large river carries a huge amount of material, such as:

-dissolved material (Ca_2, Fe_3, Mg_2, etc)
-suspended material (clay, silt fine sand) and
-boulders

The percentage varies a lot, pending season, run-off, slope and type of area, which the Danube and its tributaries are flowing through. In winter the content of the finer material is higher than in summer, as the Danube carries less water and thus has a reduced dragging force, enabling it to carry only little coarse material.

Fine material is mainly transported by floating. The dissolved material mainly gets into the rivers through the springs. This is why the relation between material transported mechanically and dissolved is opposed over the course of the year and the content of the spring water is highest at low run-off. The total transported material is little influenced by the normal run-off, but rather by the floods, which can increase the volume significantly.

Scales for simple identification of hardness

The lists show how one can distinguish quickly between minerals according to their hardness using simple and easily available materials. For example, a mineral is always scratched by a harder object or mineral, but not the reverse. By trying to scratch a mineral with different materials whose precise hardness is known, one can achieve an accurate classification of it. As every mineral can be measured by its degree of hardness, this is very useful for classification purposes. Traditionally, in mineralogy, the Friedrich Mohs scale of hardness (drawn up in 1822) is used, which has ten levels. In technology there are naturally more precise and detailed scales.

Only the most important minerals for determining rocks are mentioned in the lists. There are many with a hardness below 3 or between 4 and 6, hence the gaps in the lists. But these minerals are not important to our objectives, as they occur relatively seldom in rocks. And the reason why some minerals are mentioned several times is that they can display a certain spectrum according to their chemical composition.

The list below shows the hardness of some materials according to the Mohs hardness scale. In the third column, important rock-forming minerals are mentioned that often occur in gravel. A list showing the Mohs hardness scale itself is also shown.

Hardness of some materials according to the Mohs hardness scale

Test material	**Mohs hardness scale**	**Minerals that it can scratch**
Candle wax	1	
Matchstick	1.5	
Fingernail	2.5	
Copper wire, copper coin	3	Calcite, chlorite, mica
Brass plate or wire	3.5–4	Dolomite, serpentine
Iron plate	4–5	
Iron nail	5–5.5	
Widow glass	5.5	
Knife	5.5–6	Amphibolite (hornblende), pyroxene

Steel file,* steel nail	6.5	Amphibolite, pyroxene, feldspar, epidote
Quartz, porcelain	7	Epidote, olivine
Widia stone drill	9	Quartz, chalcedony, granite
Emery paper**	9–9.5	+/− anything apart from diamond
Glasscutters	10	

* The hardness level corresponds to a normal file; there are also files of special alloys and hardened steel which can achieve a hardness of almost 8.
** With emery paper care should be taken that it is coated with corundum (hardness 9) or silicon-carbide (h. 9.5); there are also softer papers, e.g. glass paper, for which quartz (hardness 7) is used.

Hardness scale according to Friedrich Mohs

Mineral	Hardness	Minerals that it can scratch
Talcum	1	
Rock salt	2	
Calcite	3	Calcite, chlorite, mica
Fluorite	4	Dolomite, serpentine
Apatite	5	
Feldspar	6	Amphibolite (hornblende), pyroxene
Quartz	7	Feldspat, epidote, olivine
Topaz	8	Quartz, chalcedony, granite
Corundum	9	
Diamond	10	

Geological overview

On its way to the Black Sea the Danube goes through many geological formations. It touches or crosses zones of varying ages – from areas that are over a million years old to basin sediments that developed much more recently, and which it is shaping now with its deposits. The Danube also encounters diverse rocks, some that it clears away easily, and others that put up great resistance. Geological processes did not occur only in the distant past. They are taking place everywhere and all the time.

The Danube has its source in the Black Forest in Germany, the remains of the early Palaeolithic Variszian Mountains. At the source the river bed is formed of crystalline rock, mainly granite, gneiss and slate. Then the Danube reaches a completely different kind of area, the Molasse zone. This has been collecting the detritus of weathering and erosion of the surrounding mountains since the Tertiary period, above all that from the Alps. As a result there are relatively young sediments to find (limestone, sandstone, gravels, sands, clays and so on), which were either left behind by the "Ur-Sea" (Paratethys) or by rivers (Rhone, Danube and their tributaries).

At Regensburg (Bavaria) the Danube meets part of the former Variszian Mountains, the Bohemian Massif, whose southern edge it follows. The tributaries from this bring crystalline rocks with them (granite, gneiss, amphibolite, granulite, serpentine and so on) The tributaries bring a lot of material from the Alps, above all Mesozoic limestone, dolomite and sandstone, but also crystalline rocks from the central Alpine region.

From Krems in Austria the Danube crosses the Molasse zone again; then at Vienna it breaks through the foothills of the Eastern Alps, where it encounters Mesozoic and early Tertiary limestone, sandstone and other sedimentary rocks. After the Vienna Gate the Vienna basin opens out, a late Tertiary breakthrough basin between the Alps and the Outer Western Carpathians (Small Carpathians). The Hungarian Gate, on the border between Slovakia and Hungary, is near the interface of these two mountain ranges. Here, Palaeolithic crystalline rocks (granite, slate, quartzite), Mesozoic limestone, dolomite, late Tertiary limestone and calcareous sandstone get into the river.

East of here begins the Little Hungarian Plain, another breakthrough basin of the late Tertiary period, which together with the Great Hungarian Plain forms the Pannonian basin. At 500–600 km across it is the largest basin of this type in Europe. In both parts, late Tertiary and Quaternary, unconsolidated (loose) sediments predominate. The morphological boundary between the basin sections runs north of Budapest. South of the Danube it consists of the Bakony Hills, mainly of Mesozoic limestones and dolomites – here again, part of the Carpathians is crossed – and on the Danube and to the north of it, of late Tertiary volcanic rocks. The latter are part of an extensive former volcanic belt, which accompanies the Carpathian arc to the south (Transdanubian Median Mountains). The northern tributaries additionally bring Mesozoic and Palaeolithic sediment and crystalline rock from the Slovakian Erz Mountains.

For a long time of its long journey through Hungary the Danube does not leave the soil of the flat, wide lowland plain. Thus hardly any new material gets into the river and the sediment it is carrying with it is ground increasingly fine. Only at the breakthrough stretch in the Southern Carpathians east of Belgrade (on the Serbia–Romania border) does coarser material (late Palaeozoic and Mesozoic sedimentary rock and crystalline stone) again get into the river; this is soon deposited again after passing the Iron Gate.

Now the Danube enters the Moesian Platform of Walachia, flat and wide like the Pannonian Plain. Here late Quaternary sediments cover very old Precambrian, Palaeozoic and Mesozoic rocks deep below. The tributaries from the south bring Mesozoic and early Tertiary sedimentary rocks from the Balkan Mountains in Bulgaria. The section of the former Variszian Mountains buried below the Moesian Platform come to the surface in Dobrudscha (Romania) and here for the last time provide new rock material (crystalline rocks, volcanic rocks, sedimentary rocks).

In the last section, the Danube again flows through a geologically young area (late Tertiary and Quaternary). The coarser part of the sediment has long been deposited upriver. Finally, only almost dissolved and suspended material flows into the Black Sea, creating an enormous delta that grows a bit larger every year as a result of the great amount of sediment. The table below gives an overview of the geological periods from 545 million years ago until today.

Overview of geological periods

Period			**When it occurred**
Precambrian			up to 545m years ago
Palaeozoic	Early Palaeozoic		545–354m years ago
	Late Palaeozoic		354–248m years ago
Mesozoic			248–65m years ago
Cenozoic	Tertiary	Early Tertiary (Palaeocene)	65–24m years ago
		Late Tertiary (Neocene)	24–1.8m years ago
	Quaternary (“ice ages)	Pleistocene	1.8m–10,000 years ago
		Holocene	10,000 years ago to today

Features of frequent river gravel in the Danube basin

For a rough distinction of stones the description of the five characteristics of form, surface, granularity, structure and hardness is sufficient. In addition, one can test the solubility in acid.

The stones belong to four major groups:

- Intrusive igneous rock – (plutonic rock) rock that develops from magma deep within the earth, these include granite, aplite (or haplite) and pegmatite
- Extrusive igneous rock (volcanic rock) – rock that develops from magma on the earth’s surface; includes, for example, basalt
- Metamorphic rock – rock that is formed from other rocks under high pressures and temperatures; these include for example, gneiss, amphibolite, quartzite, marble and serpentine
- Sedimentary rock – 1) rocks that develop through the erosion and weathering of other rocks and are often transported by water, ice and wind; 2) rocks that have been formed by the remains of animals or plants; 3) rocks that have been formed by material dissolved in the water; these include radiolarite, flinty slate, limestone, dolomite, conglomerate, breccia, sandstone and siltstone.

Differentiation according to the external form (of the most frequent occurrence):

- ✓ round to ellipsoid: quartz, radiolarite, limestone, dolomite, conglomerate, breccia, plutonic rock, volcanic rock, marble, serpentine, quartzite
- ✓ flat: quartz, flinty slate, limestone, sandstone, siltstone, marble, serpentine, banded rocks (e.g. gneiss, amphibolite, quartzite)
- ✓ knobbly: quartz, radiolarite, dolomite, conglomerate, breccia, breccia, gneiss
- ✓ stick-shaped: banded rocks

Differentiation according to surface:

- ✓ very smooth: quartz, radiolarite, flinty slate, siltstone, limestone, serpentine
- ✓ rather smooth: quartz, radiolarite, flinty slate, fine-grain sandstone, siltstone, limestone, dolomite, conglomerate, breccia, volcanic rock, serpentine, quartzite
- ✓ rather rough: radiolarite, coarse-grain sandstone, conglomerate, breccia, plutonic rock, volcanic rock, banded rock (gneiss, amphibolite, quartzite), marble
- ✓ very rough: breccia, plutonic rock

Differentiation according to granularity:

- ✓ dense (grain diameter < 0.1 mm): quartz, radiolarite, flinty slate, limestone, dolomite, siltstone, volcanic rock, serpentine
- ✓ fine grain (grain diameter 0.1 - 1 mm): sandstone, volcanic and plutonic rock, gneiss, amphibolite, quartzite
- ✓ medium grain (grain diameter 1 - 3 mm): sandstone, volcanic and plutonic rock, gneiss, amphibolite, marble
- ✓ coarse grain (grain diameter 3 – 10mm): conglomerate, breccia, volcanic rock, plutonic rock, gneiss, marble
- ✓ large grain (grain diameter > 10 mm): conglomerate, breccia, plutonic rock, pegmatite
- ✓ variable grain (greatly differing grain sizes): conglomerate, breccia, volcanic rock (porphyry), plutonic rock, amphibolite and serpentine (e.g. through the inclusion of granite)

Differentiation according to structure (may be present, but does not have to!):

- ✓ stratified (sedimentary rock): flinty slate, limestone, conglomerate
- ✓ banded (metamorphic rock): gneiss, amphibolite, serpentine, marble, quartzite flow structure (volcanic rock)

Differentiation according to colour:

- ✓ colourless to white: quartz, granite, aplite, pegmatite, quartzite, marble, granulite
- ✓ yellow to yellow-brown: quartz, limestone, dolomite, sandstone, siltstone, conglomerate, breccia, volcanic and plutonic rock, gneiss and other banded rocks, quartzite
- ✓ red to reddish brown: quartz, radiolarite, limestone, sandstone, siltstone, conglomerate, breccia, volcanic and plutonic rock, gneiss and other banded rocks, quartzite
- ✓ light to dark green: radiolarite, volcanic and plutonic rock (seldom), gneiss and other banded rocks, serpentine
- ✓ dark green: amphibolite
- ✓ light to dark grey: quartz, radiolarite, flinty slate, limestone, dolomite, conglomerate, breccia, sandstone, siltstone, volcanic and plutonic rock, gneiss and other banded rocks, quartzite, marble
- ✓ black: flinty slate, volcanic and plutonic rock

Differentiation according to hardness:

- ✓ rather soft - the stone or most of its constituents can be scratched with copper or brass: limestone, dolomite, conglomerate*, breccia*, calcerous sandstone, gneiss, slate, marble, serpentine
- ✓ moderately hard - the stone or most of its constituents can be scratched with a knife: sandstone*, conglomerate*, breccia*, volcanic rock, gneiss, amphibolite
- ✓ very hard - the stone or most of its constituents cannot be scratched with a knife, but can themselves scratch glass: quartz, radiolarite, flinty slate, (quartz), sandstone, volcanic rock, granite and related rocks, quartzite
  (* dependent on constituents, e.g. chalky, flinty, crystalline)

Differentiation according to reaction to dilute hydrochloric acid:

- ✓ effervesces easily and clearly: limestone, calcerous marble
- ✓ does not effervesce, or only weakly and with difficulty; reaction often only after high acid concentration or heating: dolomite, dolomite marble
- ✓ only effervesces if calcerous constituents or bonding agents are present: sandstone, conglomerate, breccia

Classification of sediment according to grain size

The table below gives an overview of how geologists and technicians divide sediments into different classes according to the average size of components. Further subdivision varies, and can therefore be different in some countries or individual specialist areas.

Classification of sediments according to grain size (overview)

Material	**Grain size**
Clay	< 0.002 mm
Silt	0.002–0.063 mm
Sand	0.063–2 mm
Gravel	2–63 mm
Stones	63–200 mm
Boulders	> 200 mm

Current speed and grain size

The two tables below show the current speed of the Danube and the current speeds that allow different materials to be transported.

Current speed of the Danube

Measuring point	**Current speed**
Passau	2 m/sec
Vienna	2.5 m/sec
Mid-Danube	0.6–1 m/sec
Lower Danube	0.6–1 m/ sec
Mouth	0.2 m/sec

Current speeds that allow the transportation of particular grain sizes

Material	**Assumed diameter**	**Minimum current speed**
Fine sand	0.01 cm	approx. 0.02 m/sec
Coarse sand	0.1 cm	approx. 0.3 m/sec
Fine gravel	1 cm	approx. 1 m/sec
Gravel	10 cm	approx. 3 m/sec
Boulders	100 cm	approx. 8 m/sec

Erosion and accumulation

The connection between the Danube river gradient and landscape-forming processes is shown in the table below. With a steep gradient and a fast current – that is, mostly in the upper course of a river – erosion of the river bed predominates, primarily vertically (depth erosion). There the water energy is working against the gradient, which is why one speaks of regressive erosion. Gradually, the differences in level are balanced out to a uniform gradient from the source to the mouth. Because the Danube passes through mountains several times, its gradient curve has three prominent kinks, at Regensburg, in Germany, and at the breakthrough points of the Hungarian Gate, Hungary, and the Iron Gate, Serbia/Romania.

Where there is a low gradient – mostly in the middle course and lower course of a river – the erosion mainly affects the banks (horizontal erosion). In the process banks are undermined and the overhanging banks break away. Rock can be carried away in the form of stones, gravel and sand, in the form of suspended material (fine sand, silt and clay) and in the form of dissolved material.

Accumulation (deposition) predominates in the lowland on the inner side of river curves and in retreating floodwater. Deposition occasionally narrows the river and as a result it can be forced to change its bed or to shift. The result is a further valley bottom in which the river wanders back and forth between the sides.

The connection between Danube river gradient and landscape-forming processes

River section	Average gradient	Dominant formation mechanism
Upper course (to the Hungarian Gate)	1%	Vertical erosion and transport
Mid-course (to the Iron Gate)	0.1%	Transport and horizontal erosion
Lower course (to the mouth)	0.03%	Accumulation and transport

Down as far as the Hungarian Gate the Danube is considered to be a mountain river. In such a river, which divides itself from a main course into many smaller courses that all share the same river bed and then reunite in it, one speaks of **furcation**. **Meanders** are a feature of lowland rivers, in which the whole river bed winds and loops.

The development of the Danube

Some 25 million years ago there was a precursor of the Danube ("PreDanube"), which had its source in Switzerland near Geneva and ran eastwards along the Western Alps. But it reached its destination as early as Munich – the sea of Paratethys, an arm of the sea reaching as far as the Indopacific. Then, large parts of the present-day course of the Danube were covered by sea. Many of what are today independent rivers, such as the Rhone and the Rhine, were part of this first west–east river system in the "Molasse zone" (from Latin "molere = to grind), the collection basin for the products of weathering from the Alps and the Carpathians.

Approximately 17 to 18 million years ago, tectonic movements in the Eastern Alps tied the Molasse basin in and formed a prominent watershed west of Vienna. A precursor to the Rhone was able to dominate the area to the west. There was thus a reversal in the direction of the river. The flow-off to the east, in contrast, was limited and short. This "Ur-Rhone" had its greatest catchment area some 12 million years ago, which included the precursors of the Main and the Rhine. We can first speak of an "Ur-Danube" some nine million years ago. Because the Western Alps were raised higher than the Eastern Alps, the foothills of the Alps were tilted to the east. The outflow of many rivers into the Rhone was interrupted, the direction of flow reversed again. The watershed also sank, so that it no longer represented a barrier to rivers coming from the west. The Paratethys retreated to the depression of the Vienna basin and as its connection to the adjoining seas was gradually cut off, became a freshwater lake ("Pannonian Lake").
In the further course of things the mouth of the Danube shifted further eastwards with the retreating or drying out Paratethys. If this was still north of Vienna seven million years ago, it was two million years ago that the Danube first reached the Black Sea. In the west, too, the Danube was able to gain terrain. Here it even managed to penetrate parts of the present-day Rhone–Rhine catchment area. It achieved its greatest catchment area approximately four million years ago.

About two million years ago, as a result of the cold and warm periods in the Quaternary Period (ice ages), there was a rapid alternation of deposition and erosion. In this period, the present-day landscape gradually emerged.

2.3. Life under water

Environmental conditions

The physical parameters, such as current speed and oxygen content of the water continually change on the way downstream and are dependent on the surroundings of the flowing water. A further parameter is the cloudiness or transparency of the water.

The current speed is determined by the gradient. The water temperature is dependent on the altitude and the distance from the source region, and the oxygen content is dependent on the one hand on the temperature and, on the other, on the turbulence of the water, and thereby again on the gradient. Suspended material that clouds the water appears above all in the lower course or in streams in lowlands with fine-grained soils. Likewise, these parameters change according to the situation in the river. These are differentiated into the fast-flowing centre of the river bed and the calm inlets, and there are other conditions again in the old oxbow lakes that are only covered when the river floods.

The flow-off quantity is dependent on the type of precipitation, its frequency and distribution. If there is long, continuous rain or if the melting snow in the mountains coincides with heavy rainfall, then there is high water. The river overflows its banks and spreads large quantities of water over its floodplain. The carrying power of the flowing water increases and gravel banks, sand islands and parts of the bank are torn away and deposited again in other places. In times of the year with little precipitation, there is little flow-off in the catchment area; the river is at low water.

Water movement and the adaptation of organisms

The constant current in a river places mechanical demands on its vegetable and animal inhabitants but also means a constant flow of nutrients and food. Repeated flooding are disturbances for the communities of life in the rivers and floodplains. Animal and plant species have adapted to this and developed many coping strategies to deal with these disturbances.

a) Adaptations against being washed away

- flat body construction
- suckers
- living under large stones
- living in a gravel bed
- compensation wandering

b) Adaptations against drying out

- long dry spells in floodplain ponds: single-celled protozoa, small crustaceans, rotifers, fresh-water sponge
- long dry spells in seldom flooded areas of floodplain forest: tadpole shrimp, Branchiopoda
- low oxygen requirements for surviving in dry spells in old side-arms, surviving low-water periods in damp mud: crucian carp, weather fish, mudminnow
- short development periods: mosquito, fire-bellied toad
- Rigid dryness by closing the damp body surface: mussel, river snail

c) Utilisation of the current for food intake

- fixed form of living, e.g. digging into the substrata, building nets, using sludge as a nutrient base in reduced current

d) Utilisation of the current as a dispersal mechanism

- species whose larvae and young are washed away with the current or floodwater are, for example, larvae of mussels, almost all species of fish
- plant species with seeds that can float, e.g. summer snowflake
- underwater plants whose torn off shoots can put down roots again after drifting away, e.g. pond water crowfoot

e) Utilisation of the floodplain forest for reproduction and obtaining food

- adult fish use the floodplain forest for food intake, eggs and larvae live in the gravel cavities in the river bed, e.g. zope, asp, golden orfe/ide, Danube salmon, sneep, Berg’s bream, gudgeon
- spawning places and young fish in quiet side-arms. Adult fish seek food in the current, eg. schraetser, barbel, sichling, vimba, frauennerfling (*Rutilus pigus*)
- spawning places and young fish stages are in the flooded floodplain forest, adult fish are in the protected inlets and oxbow lakes (weed spawners), e.g. pike, carp, rudd, white bream, Aral bream, European perch, tench
- fish species and amphibians with exclusive habitats in rarely flooded ponds of the floodplain and very cut off oxbow lakes, e.g. mudminnow, weatherfish, crucian carp
- life cycle in ponds that only rarely fill with water during flooding, long stages in dry spells, e.g. tadpole shrimp, Branchiopoda
- settlers in open areas created by the river dynamics:

  plants: purple willow, white willow, black poplar, German false tamarisk, rosemary willow, salt cedar (tamarix) animals: on gravel and sandbanks: little ringed plover, common sandpiper, common tern, little tern

on steep banks: sand martin, kingfisher, bee-eater

- pioneer plants on dried out muddy areas: mudwort and small sedges

Zoning of rivers according to leading species

The upper course

In mountain streams because of the high proportion of water flowing in from springs there are only limited temperature fluctuations over the year (temperature difference < 10°C). The steep gradient and the heavy run-off during melting snow means that there is a stony or rocky substrata to the bed of the stream. The low temperatures and the turbulence of the water mean that the oxygen content is very high. The current is turbulent.

Fish regions

Because of the favourable living conditions for brown trouts, the upper course is described as a trout region. Other oxygen-loving fish species in this zone are the bullhead, Eurasian minnow (in lowlands) and European brook lamprey.

Feeding types

In wooded catchment areas, the bed of the stream is in the shade. The entry of nutrients comes from outside in that leaves, needles, flowers and branches fall to the bed of the stream from bank-side trees. The most important animal group are the detritivores. Freshwater shrimps and caddis-fly larvae chew up the plant material that are already being broken up by bacteria and moulds and thereby create finer particles, that form the basis for the further food chain. The particles, known as detritus form part of the food for the group of grazers.

These include the larvae of stoneflies, mayflies and caddis flies, which have developed wide-ranging adaptations to live in the current. A second source of food is the growth of rock algae and plant algae on stones and dead wood. Some species of caddis fly build nets between stones, with which, as filter-feeders, they catch detritus floating in the current. Grazers and detritivores, again form the main source of food for flatworms, stonefly and mayfly larvae that live on other animals. The end of the food chain are brown trout and bullheads.

The middle course

From a width of three to five metres one speaks of a river. The banks are so far apart that the bank-side woodland no longer overshadows the riverbed. The water is clear, so that sunlight can penetrate to the bed of the river. The gradient and the current speed can still be considerable in the transition between upper course and mid-course, for example in a furcation stretch at the foot of a mountain. The river bed consists of gravel and shingle (20cm – 0.2 cm), in lowland rivers also of sand. As a result of the cool water temperatures and the turbulence when the river overflows the many gravel banks the water is well supplied with oxygen.
Example: the upper Tisza between the tributaries of Viseu/Viso and Norsava/Borsa.

If the gradient reduces, a more winding course with marked erosion and sedimentation banks and larger gravel banks and sandbanks develops. The gradient is between 2% and 0.2%. There are considerable differences in the substrata between the bank and the centre of the river, which again bring rich colonisation opportunities for organisms. Still-water areas alternate with zones with faster currents.
Example: the Danube from the Swabian Alb to Gönyü.

Fish regions

Furcating stretches are the preferred habitat of the grayling. Middle-courses with these living conditions are therefore called grayling regions. The annual water temperature fluctuates between 10^{o} and 17^{o}C. Sneep, gudgeon, chub, European chub, brown trout, and burbot, as current-loving fish species, are typical inhabitants of the grayling region.

The lower part of the middle-course is called the barbel region. The water temperature fluctuates between 12^{o} und 18^{o}C. The current-loving fish species barbel and sneep appear as lead species. Other species are the carp fish white bream, the European chub, asp, golden orfe/ide, frauennervling and the sterlet as well as the schraetser, zingel, Danube streber and European perch.

Feeding types

Most invertebrates in the mid-course live in the cavities of the gravel banks or sandbanks. This form of living offers protection against mechanical injury during high water, protects the eggs and the juvenile stages against being washed away, and nevertheless sufficient water enriched with particles flows through the cavities. At night, in the protected inlets, the cavity dwellers, mostly water insects migrate to the bottom of the river and feed as grazers on the lawns of algae. Carnivorous species then find rich spoils. Among the animal genera there are still many species from the upper course, such as mayflies, stoneflies, and caddis-fly larvae as well as snails such as the river snail.

In areas protected from the current, such as inlets and oxbow lakes, rich stocks of water plants develop: pond-water crowfoot, water starwort, pond weed. They form an ideal substrate for the rich growth of algae, rock algae, protozoa, clinging filter-

feeders such as rotifers and moss animals and are used as nutrients by an increasing number of grazers. Snails, larvae of frogs and frog-like amphibians (Anura), mayfly larvae.
A large number of carnivores use the broad spectrum of prey. These include leeches, carnivorous mayfly larvae, water beetles and fish.

The lower course

When the river reaches the lowland, the gradient is so shallow that the river mainly carries sand and finer solids. It now runs through its lower course as far as the mouth.

Examples

Danube: below the mouth of the Vah: gradient less than or equal to 0.17‰

Rhine: below the mouth of the Ahr: gradient less than or equal to 0.17 ‰

Weser: below the gap through the Wiehen Mountains: gradient less than or equal to 0.2 ‰

Tisza: below the mouth of the Szamos: gradient less than or equal to 0.09 ‰

The current speed is low, the riverbed deep. The riverbed consists of a sandy substrata; fine sandy to clayey sediments are deposited in the floodplain forests. The oxygen content can fluctuate greatly. As a result of the inflow of many tributaries, the river is carrying a large amount of suspended material and organic particles from the catchment area. For this reason the water is less transparent but usually richer in nutrients than in the upper- and mid-course.

The lower courses of big rivers have a wide inundation area. The floodplain forest is characterised by numerous side waters (see chapter on types of river courses and forms of river mouth), which display a rich world of flora and fauna. The period of inundation during floods is longer than in the upper- and mid-course.

Examples

The area where the Drava joins the Danube (Kopački rit) is flooded for an average of 100 days a year.

During periods of flooding, the waters of the floodplain forest are connected with the main stream, so that an exchange of life forms can take place. This is a matter of life and death for the reproduction of many species of fish.

Examples

The preferred spawning ground of many species of carp, but also of the pike, is inundated meadows during floods. These additional feeding grounds for juvenile fish previously made much higher fish stocks possible than nowadays.

Fish region

The characteristic species of the lowland rivers, the Aral bream region, are fish of the carp group. The water temperatures reach over 20°C in summer. The lead species is the Aral bream, which with its protrusible mouth searches the muddy bottom for worms, insect larvae, snail shells and small crustaceans. Further fish species are the Prussian carp, white bream, tench, carp, common dace, Amur bitterling, pike, zander, European perch and the catfish. Various species of sturgeon are present as migratory fish

Feeding types

Increasing cloudiness in the lower course makes life difficult for rooted underwater plants. As they disappear, there is hardly any suitable substrata for the growth of algae and protozoa any more. Plants with floating leaves and freely floating water plants have better chances.

The washed out nutrients that accumulate in the lower course as well as the lower current speeds make it possible for vegetable plankton to develop – floating rock-algae and plant-algae. These again offer the source of food for animal plankton, mainly small crustaceans and water fleas. Plankton-eating fish of the open water, such as sichling or zope, are a new feeding type in the lower course.

Food particles floating in the water are the basis of life for the group of filter-feeders. These include mussels, sponges, moss animals and net-building caddis flies. In favourable places the bottoms of whole river arms are covered in mussels. The embankments of the lower course that represent secure habitats against flooding, are particularly heavily colonised by filter-feeders.

Example

Measured according to weight, five times as many mussels as insects live in the Bulgarian stretch of the Danube

Some of the inorganic particles that fall to the river floor in quiet oxbow lakes and side-arms are partly broken down by bacteria. These, like the organic sludge, are the nutrient base for sludge-eaters: ring worms such as the sludge worm (Tubex) and larvae of various midge-fly species. In the oxbow lakes where there is nutrient-rich water, the bottom is colonised by fewer species in extreme density. After the sinking of the suspended material, the water of the oxbow lake offers sufficient light for submerged water plants, so that here many grazers such as snails and amphibious larvae find food.

As carnivores beetles, dragonfly larvae, bugs and fish find rich nutrients. The existence of colonies of heron and cormorant is an indication of rich stocks of fish.

The mouth

There is only one river mouth of the delta type in the Danube catchment area – the Danube delta. At 8,000 squ. km it is three times the area of Luxembourg.
The delta begins 70 km before the actual mouth, with the splitting of the Danube into several arms. Above Tulcea it separates into the Kilia arm, which forms the border between Romania and the Ukraine, and the Tulcea arm. The latter soon splits into the southern arms of Sulina and Sfantu Gheorghe. Between the main arms there is a mosaic of reed marshes, lakes, canals and sand dunes. The Sf. Gheorghe arm is the oldest, as the well-developed meanders show. As the youngest of the three river arms, the Kilia arm, forms its own delta on Ukrainian territory. The rich cargo of solid material is evident through the numerous islands on its course through the delta.

Annually, approx. 30 cu. m of solids are deposited in the delta. However, the Danube's cargo of solids has been reduced a quarter by the damming of the river for the reservoir at the Iron Gate. In 1990 the outflow was distributed 57% through the Kilia arm and 20% and 23% each through the Sulina and the Sf. Gheorghe arms respectively. The Danube reaches its highest water level from April to June. In this period, 90% of the delta is flooded, during medium water levels, this is 60%. The lowest water levels occur from September to October.

In the 1970s to the 1980s there was a plan to turn most of the delta into a productive landscape of arable farming, poplar plantations, reed plantations and fish ponds. Since then, a fifth of the delta area has been dammed off. However, since 1990 some of these have been reconstructed as inundations areas (for example Balina, Cernova)..

Fish region

The zone in which seawater and freshwater mix is known as the Danube ruffe-flounder region. In the case of the Danube, because of the large outflow on one hand and the low tidal inflow of seawater on the other hand, it is limited. Characteristic is a high content of nutrient and cloudy material. In its main arms the Danube is an entry gate for migratory fish such as the Danube herring, and types of sturgeon – the beluga sturgeon, starry sturgeon, fringe-barbel sturgeon, and Russian sturgeon. They grow to adulthood in the adjacent coastal area of the Black Sea and form the end of a food chain that has its basis in the large quantities of dying vegetable plankton that form out of the Danube. The region takes its name from the Danube ruffe, which lives in both fresh and brackish water, and the flounder, a marine bottom-feeder that lives in the brackish sea area in front of the delta and in some small lagoons, and which needs the water to have a salt content of at least 1% for the development of its eggs. In the upper layers, the Black Sea has a salt content of 1.7%. Further typical inhabitants of the brackish-water zone are the flathead mullet and some types of gudgeon.

Feeding types

The invertebrate fauna in the flowing branches in the Danube delta are subject to similar conditions as they are in the lower course. The fauna of the delta lakes is extremely species-rich and covers all the functional feeding types. Because of the clear water and the shallow depth, the energy contribution of sunlight can be converted into vegetable biomass more effectively than in the river. Enormous amounts of animal plankton form the basic food for the rich fish stocks of the delta. Large colonies of fish-eating pelicans, cormorants, pigmy cormorants, types of heron, white-tailed eagle, gulls and terns live from them, as well as mammals such as the otter, European mink and the mink.

Leading species for individual Danube sections

Upper Danube (source rivers and first 30 km)

Animals:	brown trout, bullhead	→ mountain streams

Upper Danube (middle course)

Plants:	German false tamarisk, grey willow,	→ furcation stretches
	blue iris, marsh gentian	→ low moorland meadows
	purple osier willow, white willow, black poplar	→ floodplain forests in the middle course
Animals:	Danube salmon, golden orfe/ide, Eurasian minnow, Loach	→ current- loving fish of The golden orfe/ barbel region
	little ringed plover	→ gravel banks of the middle course
	common curlew	→ lowland moor, flooded meadows
	bluethroat	→ floodplain forest, bushes

Mid-Danube (lower course)

Plants:	white willow, black poplar, wild vine, summer snowflake	→ soft-wood floodplain forests
	small-leaved ash, common oak	→ hardwood floodplain forests
	water chestnut, fringed water lily, water shamrock	→ oxbow lakes, fish-ponds
Animals:	gudgeon	→ sandy, shallow water
	European mudminnow, crucial carp, fire-bellied toad, Danube crested newt, European pond turtle	→ floodplain forest, ponds, oxbow lakes
	dice snake	→ riverbanks, oxbow lakes, fishponds
	little tern	→ sandy riverbanks
	whiskered tern	→ river lakes, fishponds, lakes
	ferruginous duck	→ flooded marshes, fishponds
	night heron, squacco heron, spoonbill	→ colonies in floodplain forests, marshes
	black kite	→ floodplain forests
	white-tailed eagle	→ large floodplain forest complexes

Lower Danube (lower course)

Plants:	salt cedar (tamarix)	→ sandy river embankments
	Greek liana	→ hardwood floodplain forests
	floating fern	→ oxbow lakes, fishponds
	reeds	→ oxbow lakes, floating reed islands (plaurs)
Animals:	sturgeon: e.g. beluga, Russian sturgeon,	→ mainstream, sandy-shingle bottom fringe-barbel sturgeon with a strong flow

Danube herring	→ river arms with a sandy bottom and a strong flow
Dalmatian pelican, white pelican	→ river lakes, lakes
pigmy cormorant, glossy ibis	→ colonies in marshes

2.4. Habitats of the floodplain forest

Leading species of the river arms with gravel islands

1. **Stonefly larva**

Insect. Length up to 1 cm, slim body. Six legs and two long tail feathers. Most species are dark brown. Sit preferably under stones or on moss beds. Food: grazing on algae and organic particles, some species also feed on other animals. Needs oxygen-rich and clean water. Adult stonefly fly up-river to lay their eggs.

2. **Freshwater shrimp**

Crustacean. Length up to 2 cm. Belted back shell. Movement through contracting and expanding its back shell. 4 antennae, 7 pairs of legs. Eggs develop in the thorax. On water plants and on the bottom in current shadows. Food: fallen leaves, rotting vegetation (detritivores); important source of food for fish.

3. **Caddis-fly lava**

Insect. Length up to 2.5 cm. Most types build a case out of silk thread that is formed from the gland on the lower lips. They cover these with pieces of branches, grains of sand, small snail shells. Food: grazing on algae and organic particles. Some types feed on other animals.

4. **Grayling**

Current-loving fish of smaller cold rivers with a gravel bed. Length up to max. 50 cm. Territorial. Food: water and aerial insects and other invertebrates. Lays eggs in spawning pits that are covered with shingle. Larvae live briefly in the cavity system of the shingle bed. Juveniles live alone. Adults are territorial. Need oxygen-rich water and a well-irrigated shingle bed.

5. Schrätser

Current-loving fish that prefers the depths of larger rivers. Occurrence: Danube catchment area. Length 15 to 20 cm. Lives alone above sand and shingle riverbeds. Food: small fish, crustaceans, worms, insect larvae. Lays eggs on gravel banks under flowing water.

6. Sneep

Current-loving river-bottom fish over shingle riverbeds. Length up to 40 cm. Food: uses its horn-like jaws to scrape algae and animalcules off the stones they live on. During the spawning season migrates in shoals into tributaries, spawns on shingle banks. Previously a very common fish and caught as pig food (in German, *Nasenstechen* – or mass catching of sneep).

7. Common tern

Breeds on rivers on sparsely vegetated gravel and sand banks. Length 35 cm. Needs broad, shallow riverbeds with clear water with plentiful fish. Hunting flight a few metres above the water; preys on small fish and water insects in diving flight.
2-3 eggs; hatching time 21-22 days. Juveniles are fully fledged after four weeks. Clutch and fledglings are endangered by flooding. Migratory bird.

8. Little ringed plover

Small wader. Length 15 cm. Breeds on shingle islands on wild rivers. Has found a substitute habitat in gravel pits. Food: small animals in the bank zone. 4 eggs, that are well camouflaged between stones on bare shingle. Hatching time 22 - 27 days. Fledglings leave the nest immediately. Migratory bird.

9. Bluethroat

Songbird of wet willow thickets near water. Also in alders and reeds. Length 14 cm. Males have striking cornflower-blue breasts. Nest hidden near the ground. Food: insects, worms, berries. Song of the males from a singing vantage point, melodious, incorporating imitations of other species. The Sami of Scandinavia call it the “bird of a thousand tongues”. Migratory bird.

10. German tamarisk

Gravel-bank bush of the furcation zones in the upper mid-course. Foothills of the Alps and Carpathians. Height, 1m – 2.5 m. Scale-like, small, grey-blue leaves. Flowers, whitish-pink. Blossoms May to September.

11. Pond-water crowfoot

Submerged. Floating, up to 6 m long, round stalks. Feathery leaves. Stalks that have been torn away can put down root elsewhere. In streams and rivers with shingle beds. Flowers, white with a yellow centre, rising above the water. Blossoms June to August.

Floodplain forest with oxbow lakes

Prevalent from the mid-courses of all rivers. In the valleys, rivers could previously spread very widely during flooding; the floodplain forests therefore covered large areas alongside the river. In the lower mid-courses they were often penetrated by several arms of the river that continually carried their banks away. Cut off side arms and oxbow lakes enrich the spectrum of water habitats. Floodplain forests that had been preserved were historically often hunting grounds of rich royal families. A modified form of this habitat are the flooded pastures and meadows along the Sava (Lonjsko Polje, Croatia).

Leading species in floodplain forest with oxbow lakes 1

1. **Mayfly larva**

Insect that spends most of its life in water. Length 0.5 – 2 cm. Adult mayflies live for a few days at most. The larvae always have three tail feathers; gills are often visible on the abdomen. Larva live crawling along the ground, swimming between water plants, dug into the sand or cavities in mid-course rivers with gravel beds. Food: vegetable particles, grazing on algae of stones and water plants (grazer). Development period 1-2 years.

2. **Painter’s mussel**

Mollusc with two-part shell. Length 7-9 cm. Half embedded in sand or muddy bottom, often together in large numbers. Has one foot with which it can move through the sand, but no head. Food: strains river water with plankton and organic particles through the mouth and expels used water (filter feeder). Larvae hang on the gills of fish and after two to three months fall to the bottom again. One mussel filters several hundred litres of water per year.

3. Aral bream

A fish of standing and slow-moving water. Length up to max. 75cm. Seeks its food in the muddy bottom with its protrusible mouth: worms, insect larvae, snails, mussels, small crustaceans. Spawns in shoals between water plants. Edible fish with many bones.

4. Danube crested newt

Tailed amphibian (newt). Length up to 15 cm. From April to late summer in vegetation-rich small waters. Upper side blackish. Belly orange with black spots. Male has a comb on its back and tail during the mating season. Food: water lice, worms, tadpoles. Eggs are stuck individually on water plants. Larvae have gills.

Floodplain forests are important retreats for almost all types of amphibian.

5. Tree frog

Frog-like amphibian (*Anura*). Inhabits river valleys and their floodplain forests as well as wetlands with dense shrubbery. Length up to 5 cm. Climbs around in bushes and reeds in search of food: insects and spiders of all kinds. Males sit on the small ponds from April to June and croak during dusk and the night time in order to attract females.
Eggs in small clumps. Buried in damp earth they hibernate through the winter.

6. European pond turtle

Reptile in the waters of floodplain forests. Length up to 20cm. Shell dark, head and limbs dark with yellow spots. Very shy, flight distance 20 – 30 m. Likes to sun itself on tree-trunks lying in the water during the day, Main times of activity: morning and evening. Food: small fish, frogs, worms and crustaceans. Lays eggs in early summer on sunny banks.

7. Cormorant

Large black bird on rivers with plentiful fish. Length approx 90 cm. Breeds in colonies in the trees in floodplain forests. Very often perches on branches holding its wings out to dry. Food requirement: approx 750 g fish per day. Was persecuted by humans as a fish eater. 4-5 eggs. Catches its prey by diving and swimming under water. Flight: low over the surface of the water.

8. Beaver

Rodent. Length up to 90 cm. Weight up to 18 kg. Has a wide, flat tail and short legs. Good swimmer. Previously hunted for its coat. Food: water and bank-side plants; in winter it eats the young bark of willows and poplars. Has to fell the tree in order to reach the branches. Needs one night to fell a 30-cm-thick willow. Digs its lodge into the river embankments in sandy areas.

9. Watermilfoil

Underwater plant in still and slow-flowing waters. Stalks with slit leaves several metres long. Has small pink flowers with ears that rise out of the water.
Underwater plants are important as providers as oxygen and as a basis for lawns of algae, as a hiding place and egg-laying place for water animals.

10. White willow

20 –25 m high tree with irregular crown. The leaves are 5-10 cm long and matt white on the underside. From a great distance they look silvery. Grows on frequently flooded river banks. Soft wood. In the past, the young branches were used for basket weaving. Can stand in water for a long time without damage.
The fine seeds, which can fly, germinate very quickly on freshly flooded bank sand.
Freyer's purple emperor feeds on the leaves of the white willow.

Leading species in floodplain forest with oxbow lakes 2

11. Mosquito

Insect with rapid development time. Length 7-9 mm. Nocturnal. Females sting mammals and birds and use their blood for the development of their eggs. One species lays its eggs on wet banks; the larvae develop the next time it floods. The larva stage lasts one week. Larvae hang from the water surface with their tails and strain plankton and organic particles. A second species lays its eggs in puddles and wagon tracks.

12. Dragonfly larva (club-tailed dragonfly)

Insect. The larva, which lives in water, grows up to 3 cm long and the flying dragonfly reaches 5 cm. Examples on the Danube: club-tailed dragonfly (Gomphus) in flowing water with a sandy bottom. The larvae (nymphs) live in water for three to four years and prey on water insects, worms and also amphibian larvae and young fish. Creeps up on the prey slowly, then grabs it suddenly with its labial mask. For its last moult it climbs up a marsh plant at night, which it then leaves as a finished dragonfly. Adult dragonflies hunt flying insects. Mating in the air. Egg-laying by letting the eggs fall over water.

13. Freyer’s purple emperor

Butterfly. Some shimmer in various tones of blue. Wingspan up to 6.5 cm. Caterpillar in the tops of species of willow whose leaves they eat. With two horns on its head, the caterpillar resembles a green slug. The caterpillar winters in the tree and develops into a butterfly in June. Only on the lower course of the Danube.

14. European perch

Predatory fish in still and slow-flowing waters. Length 15 to 45 cm. Two dorsal fin. Forms hunting groups to catch fish. Juveniles eat invertebrates, adults eat fish. Between April and May, females lay strings of eggs near the bank among stones and water plants, which are then fertilised by the males. Small edible fish with few bones.

15. Kingfisher

Striking, shimmering blue bird with an orange breast. Length approx. 16 cm. Food: small fish, which it lies in wait for on an overhanging branch. Once it sees one, it dives into the water to catch it. Needs clear waters with plentiful fish and steep banks of loess or sand. Here they dig burrows the depth of an arm with a breeding cavity at the end.
6-7 eggs. Hatching time 18 to 21 days. The young leave the burrow after 3-4 weeks and continue to be fed by their parents. Typical of river courses in their natural state where the river continually creates new breaks in the banks.

16. Black stork

Large stalking bird of secluded woodland areas. Loner. Length 97 cm. Builds its nest on old trees, also uses the eyries of birds of prey. Food: fish, water insects, frogs, which it catches stalking through shallow water. 2-5 eggs. Hatching time 30 days. Young are fully fledged after two months but continue to be fed. Bird of passage. Europe’s greatest density of black storks is in the floodplain forest of the Hungarian Danube at Gemenc.

17. Grey heron

Large stalking bird, which like all types of heron breeds in colonies. Length 90 cm. Often there are mixed colonies with cormorants, night heron and squacco heron. Such colonies are an indication of a plentiful supply of fish. Hunts for fish on its own. Away from water it hunts mice, grasshoppers and snakes. Requires approximately 500g of animal feed per day. 3-5 eggs. Hatching time 26-27 days. Young leave the nest after 6-7 weeks.

18. White-tailed eagle

Europe's largest bird of prey. Length 60-80 cm. Wingspan up to 240 cm. Adult bird brown with a yellow bill and white, wedge-shaped tail. Food: water birds, fish up to 8 kg, land animals such as hares or foxes. A white-tailed eagle remains true to its territory and partner all its life. To breed, it needs large trees that allow a free flight to the eyrie. White-tailed eagle eyries are the largest birds' nests of all: old eyries can grow to 2 m wide and 5 m high. Normally 2 eggs. Hatching period 38-42 days. Young remain in the nest for three months. In winter, the white-tailed eagles follow water birds on large, ice-free rivers.

Floating-leaf ponds

Large, oxbow lakes and shallow lakes of the Danube delta. Changing water levels in the area of influence of river floods. Mostly shallow and in the process of turning into dry land. Many plants in floating-leaf ponds prefer waters with summer warmth, therefore the floating-leaf ponds are particularly densely covered in the lower Danube. Productive fish waters, therefore also bird life.

Leading species of floating-leaf ponds

1. Midge-fly larva

Insect. Length up to 2 cm. Related to the mosquito, but does not suck blood. The blood-red larva builds a cocoon in the mud. It sits there and with wave-like movements swirls organic particles and fresh water into the tube. Lives in the lower courses of the river and in heavily polluted waters. Many species. Very important fish food.

2. Water flea

Crustacean. Very small. Length 0.4-0.6 cm. Glides in the water with feelers on each side of its head. Breathes through gills. Food: bacteria, suspended algae, suspended organic particles. Reproduces rapidly in spring after the massive blooming of plant and rock algae provides rich nutrient. Survives the winter as a fertilised egg. Important fish food.

3. River snail

Mollusc with a pointed shell in vegetation-rich floodplain forest waters.

Length 5-6 cm. Breathes through its skin. Has a rasping tongue with which it can scrape off the growth of algae and web of vegetation (grazer). Lays eggs in spawn strings on water plants. Can live to an age of three or four years.

4. Carp

Fish of still or slow-moving water. Length 30 to 80 cm. The wild form is long. Protrusible mouth. Four barbels on the side of its upper jaw. Nocturnal. Food: searches the muddy bottom for invertebrates and plant particles. Spawns preferably in flooded meadows. Needs a temperature of 18^{o} C for egg development. In earlier times, the carp of the Danube delta migrated upriver to spawn into the inundation areas north of the delta. After the construction of embankments there was a sharp fall in the carp catch. Life span up to 50 years. Has been bred in carp ponds since Roman times.

5. Catfish

Predator. Lives in muddy-bottomed lakes and in the lower courses of rivers. Length up to 300 cm. Nocturnal. Territorial. Two long barbels on the upper lip and four on the lower lip. Orients itself by touch and smell. Is able to sense sound waves through an air bladder that is linked to its ear by small bones. Food: devours animals of all kinds up to the size of a duck. Lays eggs in shallow water in a spawning burrow, which is watched over by the male. Lives to the age of 70. Good food fish.

6. Pike

Predatory fish in vegetation-rich still and flowing waters. Length up to 120 cm. Territorial. Lies in wait for its prey well-camouflaged between water plants. Food: fish, as well as amphibians, water birds and small mammals. Spawns in flooded meadows or in vegetation-rich shallow water. Very good food fish with many bones

7. Pond frog

Amphibian of the frog family living in vegetation-rich waters. Length, up to 15 cm. Lateral sounding bladders. Spends the whole summer on the water. Food: insects, snails, worms, occasionally also smaller vertebrates such as fish and fledglings. Clumps of spawn with several thousand eggs. Winters in the bank-side mud.

8. Dice snake (tessellated water snake)

Snake. Well adapted to life in water. Length 75-90 cm. Lives in slow flowing rivers and vegetation-rich lakes in the lowlands. Suns itself directly by the water.

Lies in wait for a long time under water, broken by briefly coming up for air. Food: fish, more rarely amphibians. Small fish are swallowed immediately. Larger fish are dragged ashore and swallowed there. The 5-25 eggs are laid in rotting vegetation or damp, warm places on the bank. Hibernates in winter.

9. Whiskered tern

Thin bird in marshes with clear water and many floating-leaf plants. Length 25 cm. Black cap and light cheeks, red bill. Dark breast but light underwings. Food: mainly insects caught from the water, also worms, small fish, young frogs. Nest building and brooding only begins when the floating leaves are fully developed, form the second half of July. Small colonies, often on water-lily leaves. 2-3 eggs, hatching time 19 days. Young learn to fly in three weeks. Migratory bird.

10. Red-breasted goose

Goose. Winterer on the western Black Sea coast. Length 55 cm. Striking colouring. Feathers contrasting black and white, only breast, cheeks and bill chestnut brown. Food: leaves, berries, lichens. Breeds on river-banks in a small area of eastern Siberia, often in the protection of nests of birds of prey. Approx. 75-90% of world stocks winter in the Danube delta.

11. European white Pelican

Very large water bird. Length 150 cm. Wingspan 270-330 cm. Inhabits extensive marches with scattered shallow waters and warm, shallow lakes. Large throat sac for transporting caught fish. Food: specialising in fish. Can catch fish up to a weight of 2 kg. Pelicans hunt in a group. They form a chain of drivers, which beating their wings drive the fish into shallow water. There they are eaten together. Breeds in colonies in old reed beds with direct access to water. 2-3 eggs. Hatching time 30 days. Young are naked. Only after 8-14 days does a thin covering start to grow. The young are fed with half-digested fish from the throat sac. At 12-15 weeks the juveniles start to fly and fish for themselves. Migratory bird. Two types breed in the Danube delta and Bulgaria's Lake Srebarna.

12. Fringed water lily

Floating-leaf plant, warmth-loving. In old river arms and shallow lakes. Lily-type leaves, creeping root stems, flowers are the only part that rise above the water. Yellow. 5-8 flowers out of one bud. Bloom for one day only. Water depth 50-150 cm.

13. Water chestnut

Floating-leaf plant, warmth-loving. In nutrient-rich old river arms and shallow lakes. Endures floods and dry spells. Grows anew each year from seeds or shoots. The fruit have been eaten since the Stone Age. Sensitive to water pollution.

Reed beds

Advanced stage of turning into land oxbow lakes and lakes of the Danube delta. As an assertive plant, the reed drives out most other plant species in shallow water. Protected breeding ground for many species of water bird. Specialised insect fauna. Retreat for less competitive fish species. The floating reed islands of the delta are the result of the adaptation to the changing water levels.

Leading species of the reed beds

1. **Great silver water beetle**

Insect. Very large water beetle. Length of beetle 3.5-5 cm. Length of larva 7 cm. Lives in water both as larva and as adult. Goes on land to pupate. The beetles gather air from the surface of the water with their feelers. Feeding of the larva: mainly water snails. Feeding of the adult beetle: algae and water plants, carcasses. Larva development 1-2 months. Poor swimmer.

2. **Weather fish**

Bottom-living fish of floodplain forest ponds and ditches. Length 15-30 cm. Nocturnal. Burrows through the sludge on the bottom for small invertebrates with its barbels (organs of touch) on its upper and lower jaws. Can breath air when oxygen is in short supply, as it can absorb oxygen through blood vessels in its intestines. Burrows into the mud when the water dries up.

3. **Crucian carp**

Fish of shallow, still or very slow-flowing waters. Also colonises the smallest bodies of water. Length 20-35 cm. High-backed body with high dorsal fin. Lives in shoals between water plants where it also lays its eggs. Food: invertebrates, also water plants. Can manage with little oxygen. Survives dry spells buried in the mud and ice formation in wet mud.

4. Great reed warbler

Songbird of the reed beds. Length 19 cm. Loud, rasping song. Brilliant orange inside throat easily visible when singing. Food: mainly flying insects. In early May builds an elaborate nest between three or four stalks of reed. 4-6 eggs. Hatching time 14-15 days. Young leave the nest after 12 days. Start flying after 16 days. Migratory bird.

5. Coot

Water bird the size of a small duck. Related to the crane. Length 38 cm. Webbed feet. Prefers shallow water with water plants and muddy bottom. Food: water plants, bank-side plants, additionally insects, snails, mussels. Breeds in waters with reeds. Floating nest made of reed stems. 7-10 eggs. Hatching time 21-24 days. Young can swim from the second day.

6. Spoonbill

Large, stalking bird with typical, long wide bill, spoon-shaped at the tip. White plumage with crest. Length 86 cm. Breeds in colonies in large reed beds, sometimes together with heron. Spoonbills need shallow water with a muddy bottom to feed. There, with a mowing movement, they sieve the upper layer of mud for midge larvae, snails, mussels, crustaceans, tadpoles and small fish. Large nest in the old reeds, sometimes on low trees. 3-5 eggs. Hatching time 24-25 days. Young leave the nest after 4 weeks. Migratory bird.

7. Purple heron

Large stalking bird with grey-chestnut brown plumage. Somewhat smaller than the grey heron. Length 79 cm. Nests in extensive areas of reed and willow thickets.
Seeks its food in hidden water-holes in the reed beds. Food mainly fish, also frogs, snakes, lizards and mice. Nests in colonies in the old reeds, often high above the water. 3-5 eggs. Hatching time 24-28 days. Young are cared for or 3 weeks and leave the nest at 7-8 weeks.

8. Little bittern

Small stalking bird that lives hidden in the reeds. Length 35 cm. Can climb through the reeds very well with its long claws. Also fond of small reed beds. In danger, it freezes with its head vertically upwards and thus resembles a bundle of reed stems (post position). Food: small fish, young frogs, tadpoles, newts and water insects. Nest of reeds above the water. 3-6 eggs. Hatching time 10-19 days. Bird of passage.

9. Reeds

Bank-side plant. It spreads through subterranean runners. In the process it grows so thickly that it drives out other bank-side plants. Height up to 3m. The reed stems are hollow inside while the stem walls become woody. The stems are stiffened at regular intervals by horizontal “knots”. As a result the reeds can withstand rain, wind and the weight of birds’ nests. The roots grow up to 80 cm deep into the earth. On the lower Danube the web of roots of the reeds forms floating islands called the “plaurs”. They can rise and fall with changing water levels. From late summer, reserve material is stored in the lower part of the roots. In the spring, new shoots are formed with the help of this material. In a warm climate the reed stem grows up to 4.5 cm per day. On one square meter between 20 and 60 reed shoots grow out of the root web.

10. Bulrush (reed mace)

Bank-side reed plant. The strap-like leaves all come from the stock. Height up to 200 cm. The seeds are between the leaves in bulbous brown spikes. The bulrush is the only marsh plant whose seeds can germinate under water. It is therefore in a position to colonise newly created areas of water.

Habitats of the floodplain forest

Into the present century, natural floodplain forests that are only little influenced by people stretch along the rivers of the Danube basin. Forms of utilisation for the residents were, for example, cutting into the floodplain forest for firewood, meadows and pastures on cleared areas, hunting, fishing and the cutting of willow for basketry.

Various habitats of the floodplain forest appearing along the Danube:

- mountain stream valleys of the mountains (Alps, Tatra, Carpathians, Dinarian Alps, mountain areas in Serbia)
- gravel banks with little vegetation in the middle-course

  (mostly in large mountain valleys at the outflow from the mountains)
- floodplain forests with river arms, oxbow lakes, forest ponds (along all large rivers in the basins)
- rocky breakthrough stretches (Danube: Swabian Alb, Frankish Alb, Bohemian woodland, Central Hungarian Mountains, Southern Carpathians, Balkan Mountains)
- frequently flooded river mouths (Kopački rit, mouth of the Morava, mouth of the Isar)

- river-mouth lakes (stretch of the Danube in Walachia, Romania, Ukrainian bank of the Danube
- large oxbow lakes (Lake Srebarna, Bulgaria; Obedesska Bara, Serbia)
- sand islands and sandbanks (Danube: Bulgarian-Romanian border)
- river-mouth delta (Danube delta)

The Danube delta

The delta which has developed at the mouth of the Danube into the Black Sea is unique in Europe, unique in its extent and the richness of its species. The Danube delta extends over approximately 8,000 square kilometres, more than three times the size of Luxembourg. Of this, 1,200 sq. km is in the Ukraine and 6,800 sq. km in Romania.

The delta starts 70 km before the actual mouth with the separation of the Danube into several arms. Above Tulcea it splits into the Chilia arm, which forms the boundary between Romania and the Ukraine, and the Tulcea arm. The latter soon splits into the southern arms of Sulina and Sfantu Gheorghe. Between the main arms there is a mosaic of reed marshes, floodplain forests, inner lakes, natural and man-made channels, sand dunes and costal biotopes. Only 9% of the area of the delta is never flooded. The Sfantu Gheorghe arm is the oldest arm, which the well-developed meanders show. The Chilia arm is the youngest of the three river arms and forms its own delta on Ukrainian territory.

The delta developed 10,000 years ago. The “pile” of sand that then began to fill a bay of the Black Sea has been growing since the end of the last ice age. The river arms of the Danube grew out into the sea. The deposited sand was carried along the coast by sea currents so that the rest of the bay was transformed into a sea lagoon. The lagoon was slowly filled with fine Danube sediment, the seawater became fresh and the present-day lakes and marshes developed.

There are 12 different habitats (Unesco classification) in the delta:
River arms, lakes between 0.80 m and 2.50 m with open areas of water and floating-leaf vegetation, lakes with floating reed islands (“plaurs”), flooded reed and willow shrubbery, floodplain forests with willows and poplars, sand and mud beaches, wet grassland, steppe grassland, settlements, sand dunes (“grinduri”), steep banks and non-flooded woodland. The area of the delta is adjoined by numerous river lakes and former lagoons that are now used as fish ponds. The predominant habitat are the reed beds, which are the biggest on earth. They are, however, repeatedly interspersed with open areas of water.

Flora and Fauna in the delta

Reed marshes (phragmites) make up more than half of the area of the delta area. They are accompanied by stands of bulrushes (*Typha* and *Scirpus*).

The shallow lakes are mostly overgrown with floating-leaf vegetation; white water lilies (Nymphea alba), yellow water lilies (Nuphar lutea), cancer scissors (*Stratoides alloides*), water chestnut (*Trapa natans*) and fringed water lily (*Nymphoides peltata*). In higher places there are tree groups of the genera willow (*Salix*), poplar (*Populus*), elder (*Alnus*) and oak (*Quercus*). Steppe grasses are characterised by Federgras (*Stipa sp*.). Dry woods of the dunes are very rich in species. Among these are the luxurious growth of tendril plants: silk vine (*Periploca gracea*), old man's beard (*Clematis vitalba*), wild grapevine (*Vitis sylvestris*) and hops (*Humulus lupulus*).

Over 300 bird species have been observed. 176 of these are breeding birds. An overview published by the Danube delta's biosphere reserve illustrates the importance of the delta for the bird world.

Some breeding and winter migrants of the Romanian Danube delta:

* in % of the world (W), of the polar arctic (P) and European (E) population

Important bird species		%*
Pygmy cormorant	Phalacrocorax pygmeus	61 (W)
White pelican	Pelecanus onocrotalus	52 (P)
Dalmatian pelican	Pelecanus crispus	5 (W)
Night heron	Nycticorax nycticorax	17 (E)
Squacco heron	Ardeola ralloides	26 (P)
Little egret	Egretta garzetta	11(E)
Purple heron	Ardea purpurea	11 (E)
Red-breasted goose	Branta ruficollis	90 (W)
Glossy ibis	Plegadis falcinellus	30 (E)
Spoonbill	Platalea leucorodia	<1 (E)
White-tailed eagle	Haliaeetus albicilla	<1 (W)
Marsh harrier	Circus aeruginosus	4 (E)

There are 28 species of mammal in the Danube delta, including the otter (*Lutra lutra*), the mink (*Mustela erminea*), the European mink (*Mustela lutreola*) and the wild cat (Felis sylvestris).

Also the fish fauna in the transition zone between fresh and salt water reaches the highest number of species within the Danube basin (98 species in the Ukrainian delta, 84 species in the Romanian part of the delta). Species that are important to fisheries are: the mostly severely threatened types of sturgeons, the Danube herrings (*Alosa tanaica, Alosa immaculata*), carp, zander, pike, catfish and tench. Many carp in the shallow lakes have been displaced by the Prussian carp (*Carassius gibelio*), a fish that originally comes from east Asia.

Additional Danube tales - Examples of "new species" – neozoa

Muskrat (*Ondatra zibethicus*)

Originally from North America, the muskrat was introduced in the early 20th century near Prague (as a fur animal) and from there rapidly spread to large areas of the rest of Europe. It was favoured by its high rate of reproduction. The muskrat is active all year round. It is an excellent swimmer and diver and likes to build its burrows in bank-side bushes, with an exit under water, well protected from sight. Occasionally, muskrats build large, dome-shaped nests of reeds and rushes above ground.

The muskrat belongs to the family of hamster-like animals (burrowers). It feeds mainly on vegetation; in winter it also eats shells and snails. As a result, high numbers of muskrats can be a threat to domestic freshwater mussels.

Red-eared terrapin / red-eared slider (*Trachemys scripta elegans*)

This type of terrapin, loved as a domestic pet, originates from North America. Through the releasing of "unloved" pets, wild populations of these terrapins developed on the rivers of the Danube basin. The already threatened European pond turtle (*Emys orbicularis*) is being pushed out and is thus even more threatened by the red-eared terrapin.
The animals grow up to 30 cm long and can reach an age of 30.

Zebra mussel (*Dreissena polymorpha*)

Widespread in the Danube basin since the mid 20th century, the zebra mussel is small (2.5–4 cm long) and has three sides. It lives on stones, wood and other material, attaching itself firmly to the ground with sticky threads. The eggs are laid in water in summer; afterwards there is a free-living lava stage, a ground-living stage and finally the firmly attached mussel.

The zebra mussel can live for ten years. Its original habitat is probably the tributaries of the Black Sea; they were spread by dredgers building the Suez canal and by ships, and were distributed throughout Europe. Large numbers collecting together, for example on ships' hulls, can lead to economic damage (through increased fuel consumption caused by higher water resistance and through arduous repair work on blocked filtration units).

Mantis or killer shrimp (*Dikerogammarus villosus)*

This shrimp has only been found in the Danube basin since the end of the 20th century. Owing to its size (of up to 3 cm long) and its powerful mandibles, this species eats indigenous and non-indigenous species of shrimp. Within one decade it has become the dominant type of shrimp in the Danube, partly through being carried by ships and partly through active migration. Shrimps play an important role in the food chain as fish food.

Giebel (*Carassius gibelo*)

This species, which belongs to the carp family, has long been known in the Black Sea area and is continually spreading westwards, driving out the indigenous crucian carp (Crassius crassius). The Danube is one of its migration routes. In the 1980s there was a massive population growth in the lower Danube and migration of this fish species as far as the upper course of the river. Today, up to 60% of the total Danube delta fish catch consists of this species. A special reproductive strategy has facilitated this victory march: male giebel are comparatively rare. The eggs laid in mixed spawning swarms, with other species of carp, are not fertilised by alien sperm, but are encouraged in their development. These eggs produce exclusively female giebel.

Examples of “new plants” - neophytes

Canada golden rod (*Solidago canadensis*)

The Canada golden rod was introduced as a garden plant from North America owing to its beautiful yellow blooms. It quickly found its way from our gardens into the habitat of the floodplain forest. Owing to its numerous light seeds, which can fly a long way with the aid of a wreath of hair, it was able to spread quickly. Once it has gained a foothold, its creeping runners help it to conquer large areas of the floodplain forest areas and so also to drive out the indigenous flora.

Box elder (*Acer negundo*)

This species, too, was originally introduced from North America as a garden plant, but owing to its rapid growth was also used in forestry. The box elder ran wild in the floodplain forests relatively quickly. Its typical helicopter-like flying seeds help its dispersal. Its characteristic features are its leaves, which consist of three to five serrated or lobed leaflets, and the bark of its twigs, which remains green for several years.

Himalayan balsam (*Impatiens glandulifera*)

This pinkish-white flowering plant was imported as a garden plant from eastern India and the Himalayas. As a nutrient- and water-loving plant it has spread vigorously in our floodplain forests in recent decades and driven out other indigenous large shrubs. The plant is helped by the mechanism whereby its seeds are sprayed several metres when the ripe fruit is touched (hence the name of its English relative, touch-me-not, and in German *Springkraut*).

3.1. Biodiversity in riverine landscapes

Biodiversity – a comprehensive term for diversity

As a result of the threat to many animal and plant species, in recent years diversity of species and habitats has increasingly become a focus of attention.

Biological diversity is the diversity of life on earth: it includes all life forms and the ecosystems of which they are a part. Biodiversity forms the foundation for sustainable development and is the basis for the environmental health of all ecosystems and the source of economic and ecological security for present and future generations.
Diversity is a feature of landscapes and species, but also of the inanimate natural world and of human culture. The term biological diversity covers all these aspects. Biodiversity is a short form of this term.

Biodiversity includes the variety on the earth at several levels, as described below.

✓ We call the variability within individual species genetic diversity. In the set of genes and characteristics, no individual of one species is like any other in the natural world. This genetic diversity can be seen in the innumerable variety of breeds of domestic animals that humans have bred from the wild root stock. The pink domestic pig, the mangalista pig (the Hungarian „curly coat" or in German „wool pig") and the wild boar belong to one individual species, but clearly differ from each other.

✓ Species diversity relates to the total number of different species occurring in one area. The level of observation can range from the school pond to a river valley, the Danube basin or the whole world.

✓ Habitat diversity is the third level of biological diversity. Various habitats are distinguished by characteristic species and environmental conditions. Close relations mean that habitats are more than the sum of their parts. In a pond, for example, one can distinguish the areas of open water with water lilies, water beetles and fish from bank-side vegetation with reeds, butterflies and dragonflies.

In short: Biodiversity includes the diversity of species, genetic diversity within species and the ecological diversity of habitats. We humans are part of this complex diversity.

Biodiversity is currently a constant topic, because the diversity of our environment, indeed that of the whole world, is disappearing dramatically. Many species of plants and animals are threatened or have already become extinct. The habitats of our environment are becoming more monotonous. Old breeds are disappearing and we are using ever fewer breeds of domestic animals.

The term biological diversity achieved wide recognition in the course of the 1992 World Summit for Sustainable Development in Rio de Janeiro. The governments of many countries signed the Convention on the Protection of Biological Diversity. Its aims are the maintenance of biodiversity, the sustainable use of its components, and the fair distribution of the benefits from the use of its genetic resources.

Species diversity: in figures

Our knowledge of species diversity is still very limited. Some regions, such as Europe, have been well researched, but we know much too little about many tropical habitats. We also know very little about the diversity of invisible organisms such as fungi, micro-organisms and insects.

Even today, there is still no total view of the large variety of species in the Danube basin. The following table gives a list of the known data and estimates.

Species diversity in the Danube

Species	Number in the Danube
Animal and plant species in Europe's floodplain forests	approx. 12,000
Plant species worldwide / in Europe / in the Danube Floodplain National Park (Austria)	approx. 300,000 / 12,000 / 623
Bird species worldwide / in Europe / in the Danube delta	approx. 10,000 / 520 / 320
Amphibians worldwide / in Europe / in the Danube basin	approx. 3,500 / 71 / 31
Fish species worldwide / in freshwater / in the Danube	approx. 27,000 / 8,000 / 100
Mammals worldwide / in Europe / in the lower course of the Danube	approx. 5,500 / 250 / 43
Described species on earth	approx. 1,750,000
Estimated number of species on earth	5,000,000–30,000,000

In the Danube floodplain forest east of Vienna a total of 5,000 species of animal and 623 species of plant have been recorded.

In the Danube delta in Romania and the Ukraine, until now 5,200 species of plant and animal have been recorded, including 950 higher plants, 717 plankton algae, 91 fish species and 315 bird species. Species such as the pigmy cormorant and the white pelican have the largest worldwide stocks in the Danube delta.

The importance of biodiversity

From human perspective we can basically talk of selfish and unselfish arguments for the importance of biodiversity.

It is unselfish when all life forms from the smallest algae to the chimpanzee can claim the right to life. Many ethical thoughts and religious tendencies are based on this understanding of values.

From a selfish point of view, we profit directly from biodiversity in numerous ways. Flora and fauna are of economic importance and value. Species diversity ensures our food, drink, medicine and raw materials.

Habitats fulfil important ecological regulatory functions. They have a positive influence on water and air quality, climate, soil evolution and protection from catastrophes and pest attacks.

Biodiversity conceals many still unresearched secrets. For example, about medically effective plant material or genetic material for the growing of our domesticated plants.

Diverse habitats are also of aesthetic value and offer attractive recreational opportunities.

We profit directly from some of the goods and services biodiversity provides, others are of indirect benefit.

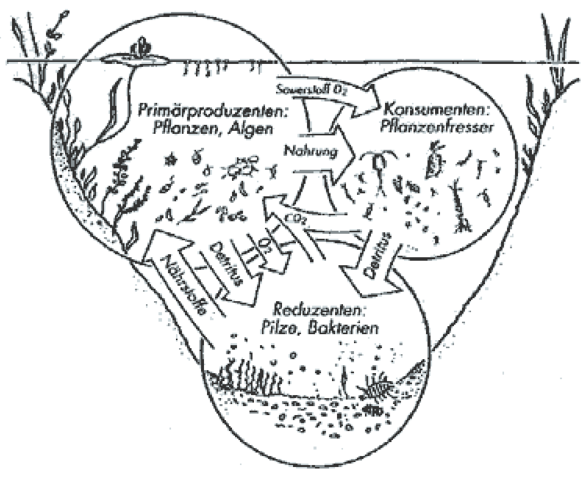
The loss of species and of genetic diversity is final! With regard to this, the protection of biodiversity can also be seen as a precautionary measure. Even if organisms ostensibly yield no value for us humans, unique and future life should not be carelessly destroyed. *"Keeping every cog and every wheel is the first precaution of intelligent tinkering"* Worldwatch Report (92).

3.2. The values of intact water worlds

Self-purification in flowing waters

The quality of our water bodies is threatened by waste water from households and industry as well as by fertiliser and pesticide residues from agriculture. In many regions pollution in the Danube has been greatly reduced by water-treatment plants. Residues from agriculture and from the air, so-called diffuse residues, however, can hardly be prevented by water-treatment plants. The pollution of the Danube with nitrate is currently 60% the result of such diffuse residues. At best this problem can be dealt with by reducing the residues (for example through organic farming).
Pollution within certain thresholds, however, is effectively dealt with by river landscapes that are close to their natural state. Behind this function is the assimilation of the residues in the nutrient cycle of the water bodies.

The nutrient cycle in a model of standing water



In water bodies plants function as producers. In photosynthesis they transform inorganic nutrients into biomass using the sun's energy. In the process, oxygen is released. Animals feed on this vegetation. They are the so-called consumers. In turn, a range of predatory animal species feed on the other animal species. When plants and animals die, their organic biomass is broken down by fungi and bacteria, the so-called destroyers, into inorganic substances again. Parts of this escape into the atmosphere or are deposited in sediments. Part of the nutrients is absorbed by the plants again. The cycle is complete.

Self-purification, the example of the discharge of waste water

Through discharging of untreated waste water, large amounts of organic biomass get into a water body. The ratio of the destroyers in the water and of their consumers rises sharply because of the supply of nutrients. With heavy consumption of oxygen the organic pollution is converted into inorganic nutrients. The vegetation reacts with increased growth. The biomass and the oxygen production rise. Now there is also sufficient vegetable nutrient available to the consumers.
The simplified processes described do not necessarily follow one another, but often also run simultaneously. As a whole, the pollution increases the turnover of nutrients in the water body.

3.3. Protected areas in the Danube basin

Examples of protected areas

Danube-Morava-Thaya floodplain forest
Between Vienna and Bratislava lays the widest continuous belt of floodplain forests in Central Europe. The Danube floodplain forest east of Vienna lines the banks of one of the last free-flowing areas in the upper course of the Danube. In 1996 the area was declared a national park. The diverse landscape, with floodplain forests, oxbow lakes, gravel banks and meadows is home to a wealth of species. 5,000 species of animals, including 60 species of fish and 700 plant species have been identified in the area.
The Morava is the border river between Slovakia and Austria and joins the Danube at the eastern end of the national park. Is the Danube at Vienna still showing distinct characteristics of a mountain river, with the Morava a slow-flowing lowland river flows into the Danube.
Together with stretches of the Thaya, Danube and Morava floodplain forests have been identified as a cross-border Ramsar site. The area covers a total of 30,000 ha. The symbolic animal of the important cross-border cooperation is the white stork (*Ciconia ciconia*). It nests in old oaks on the Austrian side, but likes to find its food in the extensive cultivated meadows on the Slovakian side.
In addition, the area is home to the imperial eagle (*Aquila heliaca*), the kingfisher (*Alcedo atthis*), the beaver (*Castor fiber*) and the European pond turtle (*Emys orbicularis*). Botanical specialities are the solitary clematis (*Clematis integrifolia*), water chestnut (*Trapa natans*) and the summer snowflake (*Leucojum aestivum*).

Mura-Drava wetland area

This area of the Mura and the Drava forms a 380-km-long natural floodplain forest corridor of exceptional importance – from Austria, through Slovenia, Croatia , Hungary and Serbia down to the point where the Drava joins the Danube.

More than 100 bird species, including the white-tailed eagle (*Haliaeetus albicilla*), sand martins (*Riparia riparia*), bee-eaters (*Merops apiaster*) and the last little terns (*Sterna albifrons*) in Central Europe breed in this area. Further rare species are the beaver (*Castor fiber*) and the otter (*Lutra lutra*). More than 50 fish species profit from the diverse and uninterrupted (and not intersected by dams) river habitat. One of the main characteristics of this area is the still high fluvial dynamics. Sediments are shifted, islands formed and banks undermined.

One of the threats to the area is the extraction of large amounts of sand and gravel directly from the river.

Parts of this area are already protected as a national park, Ramsar site or by national protection categories. A large international biosphere reserve, which takes into account the special features of the Drava and Mura, is in the planning phase.

Upper, middle and lower Tisza

The Tisza, with a length of 966 km, is the longest tributary of the Danube. Its catchment area includes Hungary, Slovakia, Serbia, Ukraine and Romania. In all sections of the Tisza there are still natural stretches of river and diverse riverine habitats. 60 species of fish, including sturgeon and Danube streber (*Zingel streber*), occur primarily in the upper course. The birds species that stand out include the corncrake (*Crex crex*), the sand martin (*Riparia riparia*), the white-tailed eagle (*Haliaeetus albicilla*) and above all the native species of heron. The otter (*Lutra lutra*) is native to the area. The beaver (*Castor fiber*) has been reintroduced within a Life project. The diversity of habitats ranges from floodplain forests, watercourses and oxbow lakes to extensive wetlands.

One of the danger factors has several times proved to be the mining activity in the catchment area, which is responsible for serious harm on water bodies as a result of toxic waste. Apart from this, large areas of the riverine landscape have been drained and converted into agricultural areas. A range of protected areas such as the Ramsar Site Felső-Tisza in Hungary and the Ramsar Site Stari Begej - Carska Bara in Serbia have been identified along the Tisza.

The Danube delta

At over 650.000 ha, the Danube delta is the biggest wetland area in the Danube basin. The Danube flows in three main arms and innumerable channels through a landscape with enormous reed beds, lakes and shallow bays, as well as extensive marshes, islands and sand dunes. As Europe's largest remaining natural wetland, the Danube delta is one of the continents most valuable habitats for wetland wildlife and biodiversity.

315 species of birds inhabit the delta. For the white pelican (*Pelecanus olocrotanus*), the Dalmatian pelican (*Pelecanus crispus*) and the pigmy cormorant (*Phalacrocorax pygmeus*) the breeding grounds are of global significance. For the red-breasted goose (*Branta ruficollis*) and many other birds of passage, the area is an important wintering and resting place.

In total, 1,600 species of plant and 3,600 species of animal have so far been identified in the Danube delta. The delta also provides a suitable habitat for the wild cat (*Felis sylvestris*) and the European mink (*Mustela lutreola*).

Economically, fishing plays a major role. The catch is approximately 3,000 t per year, but is falling. Notable species are the pointic shad (*Alosa pontica*) and the sturgeon species. But reeds, too, are used to a great extent. In recent years, above all eco-tourism has acquired

increased significance.
The navigation sector is growing as well to a major source of income for the area, so shipping is also one of the possible threats to this natural area. Shipping routes have to be continually safeguarded by hydro-engineering measures. Fish numbers and fisheries might be threatened by the pressures resulting from navigation.
The ecosystems have been affected by many changes. In the past, above all intensive farming and draining of the wetlands had negative effects. In the meantime, however, some areas with joined efforts have been restored.
Most of the Danube delta is now protected as a cross-border Biosphere Reserve. Apart from this, parts have been designated as a Ramsar Site and a UNESCO World Natural Heritage Site.

Additional Danube tales - Plants for weaving

These are some plants of the wetlands and riverine habitats that are used as weaving material:

- √ Narrow-leaf bulrush or cat tail (*Typha angustifolia*): well suited for weaving, mats and wall coverings

- √ Broad-leaf bulrush or cat tail (*Typha latifolia*): more useable for plaiting, slippers, bags, cushions, beehives and bread baskets

- √ Rushes (*Juncus*-species, above all the common rush *Juncus effusus*): used for mats, baskets, creels

- √ Sedges (*Carex*-species): used for chair seats

- √ Common bulrush / club rush (*Schoenoplectus lacustris*): used for cushions and chair seats

- √ Purple moor grass (*Molina caerulea*): worked into baskets in straw-weaving techniques, brushes for indoors

- √ Willows:
    - o Common osier (*Salix viminalis*): the epitome of the “basket willow”; branches grow up to 3 m long and are particularly tough; the osier is used throughout Europe for wickerwork, baskets and much more
    - o White willow (*Salix alba*): used for various wickerwork and baskets
    - o Purple osier willow (*Salix purpurea*): used for small, soft wickerwork and as a binding.

Instructions for wickerwork constructions

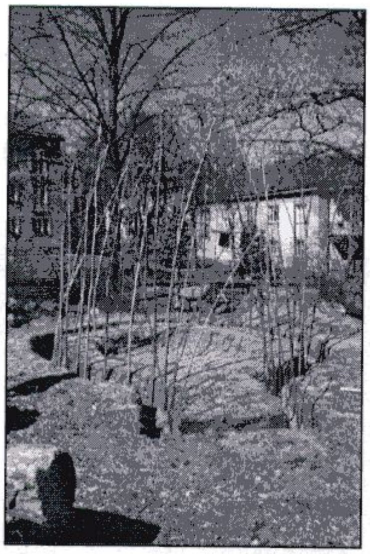
The wicker house described here represents a “natural construction” with living material.

The willow is a tree with a very high capacity for regeneration. If one sticks a cut off branch in the earth and ensures it is well watered, it takes root and shoots again relatively quickly, adapting to its new habitat. As a riverside plant and floodplain forest plant, the willow is regularly subjected to floodwater. But if one of the smooth, flexible branches is torn off, it can relatively easily take root again in another place and form a new plant. Under the earth willows form a deep web of roots that holds fast in the soil and protects it from being undermined.

The willow's ability to regenerate itself is used in building various living constructions. But the mother tree, too, shoots again strongly after pruning, as a result of which, with regular pruning, the form of the pollard develops. Earlier, when wicker working was an important branch of the economy, such pollarded willows characterised wide areas of riverine landscapes and wetland areas.

The construction described here is just one example of the manifold possible uses of willow, for instance in making tunnels, tents, fences or even self-invented works of art.

Building a willow hut



When building a willow hut use canes between 2.5 and 3.5-m-long (according to how high the house is to be), which should be cut the day before use, so they are as fresh and flexible as possible. Using a lever, bore approximately 30-cm-deep holes in the ground in which to stick the branches. Digging out a trench in form of the house plan makes the orientation on the terrain easier and additionally makes it possible to bring good soil to the surface. Apart from this, after the ditch is refilled the canes are buried deeper in the earth, which increases the stability of the wickerwork construction.

Afterwards carefully bend the canes in towards the middle and tie them with a strong string.

4.1. Water in the household

Drinking water

In the countries of the Danube basin, groundwater from wells and springs is used as drinking water for the public water supply. In some countries, 95% of the public water supply comes from groundwater reserves. Often, the groundwater and spring water can be used directly as drinking water. If surface water is taken from rivers and lakes it first has to be purified to meet the quality requirements.

Drinking-water purification

As a first step to purify water, branches, stones and other coarse particles are caught in a protective grill. Then chemicals (aluminium salts) are added in order to flocculate any fine particles. The flocculated, suspended material sinks to the bottom in sedimentation basins and can be removed. Then the water passes through the filter beds with grit and active carbon filters. Increasingly, modern membrane filter plants are also used, where the water is forced through the finest tubes. By adding sodium hydroxide (NaOH), the pH value is corrected, because too low a pH value can damage the distribution pipes. The bacteria are killed off using ozone and UV light. Finally, the water is lightly chlorinated to keep it free of bacteria on the way to household water supplies.

Standards of drinking water

Drinking water must be pure and clear and must not have an aftertaste or any cloudiness. The optimum temperature is 8–12ºC. These standards are best fulfilled by drinking water from springs or wells.

Dripping taps and leaky pipes

Water loss through leaks in the public water supply varies in quantity considerably in different countries in the Danube basin, as shown in the table below.

Percentage water loss through leaks in public water supply in seven countries in the Danube basin, selected countries, 2004

Country	**Water loss as percentage of total water supply**
Bulgaria	50
Czech Republic	32
Germany	3
Hungary	35

Romania	31
Slovak Republic	27
Slovenia	40

Waste water spoils or harms rivers

Between 85% and 95% of waste water in the upper course of the Danube is nowadays purified in modern water treatment plants.

Household waste water harms the environment primarily through organic materials that cause over-fertilisation (eutrophication). As a result of the high number of nutrients that are supplied as nitrates and phosphates in the waste water, there is an enormous growth of algae. The algae cloud the water so that after a while there is only enough light for photosynthesis to occur just at the levels near the surface. The algae at deeper levels die off. Large quantities of oxygen are used up by micro-organisms in the ensuing decomposition processes. This leads to a shortage of oxygen in the water bodies.

How a water-treatment plant works

A modern water-treatment plant works in several stages.

Mechanical purification

First, coarse materials like stones and gravel are caught in the grit trap, then the floating impurities are removed by rakes. In the settlement tanks there is a reduced current flow so the suspended material settles on the bottom as sludge. Fats and oils are drawn off from the surface of the water. Mechanical purification can remove up to 30% of the pollutants.

Biological purification

This stage of purification is an accelerated imitation of processes that take place in the natural world. Micro-organisms (bacteria, amoebae, rotifers, fungi and so on) mainly break down organic pollutants. The necessary oxygen is pumped into aeration tanks through pressurised air pipes, where ammonium is converted to nitrate (nitrification). In a further phase, the nitrate is converted by anaerobic micro-organisms into nitrogen gas, which then escapes into the atmosphere (denitrification). The micro-organisms together with the pollutants they have absorbed settle to the bottom as “activated sludge”. In addition, **chemical purification** takes place: in this process, phosphates are fixed and discharged by the addition of iron salts.

When the water leaves the water-treatment plant, despite several stages of treatment it is still not 100% purified. There remains a residual, even if limited, pollution after going through the water-treatment plant, which pollutes water bodies. Even if all the inhabitants of a city are connected to water treatment plants – which is already an essential step – we remain dependent on the self-purification powers of our rivers and lakes.

A by-product of the waste-water purification is slurry. This consists mainly of dead micro-organisms that have sunk to the bottom. After further biological decomposition and dehydration, the slurry is either incinerated or dumped. In future more attention will have to be paid to the disposal of slurry.

The table below shows the percentage of the population who are connected to the public water supply, public sewers and water-treatment plants in some of the Danube countries.

Percentage of population connected to the public water supply, public sewer system and water-treatment plants in some countries of the Danube, 2004

Country	**Public water supply**	**Public sewer connection**	**Water-treatment-plant connection**
Bulgaria	99	68	43
Germany	98	93	93
Croatia	68	40	24
Austria	86	87	87
Romania	63	48	27
Serbia	69	33	14
Slovak Republic	83	55	50
Slovenia	85	53	30
Czech Republic	87	75	70
Hungary	92	51	30

In households that are not connected to the public sewers, the waste water flows into cesspits, which have to be pumped out regularly and maintained.

4.2.Agriculture

The situation in agriculture in the Danube basin

Intensive agriculture requires high consumption of water and adds to soil erosion; furthermore nutrients and agricultural chemicals from fields and factory farms get into the water.
In the Danube basin, the amount of water withdrawn for irrigation of agricultural areas varies widely. In Croatia, Austria, Serbia, Montenegro, Slovenia, Switzerland and the Czech Republic, water consumption by agriculture makes up less than 10% of the total water withdrawal. In Bulgaria, Germany, the Republic of Moldova, the Ukraine and Hungary, water consumption by agriculture amounts to 20-40%, in Romania and Bosnia & Herzegovina to 50- 60% of the total.

On average, agricultural areas represent about 47% of the land coverage in the Danube region. In Austria, Slovenia and Bosnia-Herzegovina, this figure lies between 20-40%, in Germany, the Czech Republic, Slovak Republic, Croatia, Serbia, Montenegro, Romania and the Republic of Moldova between 40-60%, and in Hungary, Bulgaria and the Ukraine between 60-90%.

Use of fertilisers

The use of nitrogen fertilisers in agriculture is a significant factor accounting for the negative effects on water bodies by nutrients. As a result of the high nutrient input, water bodies, in particularly slow-flowing ones, become over-fertilised – eutrophication happens. Algal growth explodes. When organisms die, much oxygen is consumed during the decomposition processes, which eventually leads to a total lack of oxygen in the water body.

The amount of nutrient fertiliser used per inhabitant per year averages 16.6 kg in the Danube countries. In Germany, the Czech Republic, Croatia and Hungary, it is between 20 and 30 kg. Austria, Slovakia, Slovenia, Serbia, Montenegro, Romania, Bulgaria and the Republic of Moldova use between 10 and 20 kg. In Bosnia and Herzegovina, less than 10 kg of nitrogen fertiliser is used per person per year.

Use of pesticides

Plant protection products (pesticides) from agriculture that get into surface waters and the ground water harm water organisms and are also toxic for humans. Some pesticides are now banned (e.g. DDT). As pollutants can potentially be stored in the soil for years, it is possible that waters are still polluted by these substances today despite the ban. Some pesticides accumulate in aquatic animals, for example fishes. Often, residues of pesticides are found even in agricultural products that we consume. Water bodies in the Danube area were found to contain elevated levels of DDT, Atrazine and Lindan.

Intensive animal husbandry

Animal sewage from farms with intensive stock-rearing also increases nutrient input into the water. In particular, cattle and pig fattening farms release enormous amounts of sewage into the water. Again, the result is the eutrophication of water bodies. The amount of sewage produced by one cow is 32.5 times that produced by a human. In the Danube basin, there are especially the big pig fattening farms that pollute the waters with their sewage.

Drainage and damming up

Many wetlands have been and still are being made useable for agricultural use through drainage and damming up of wetlands and floodplains of rivers, which causes a drastic loss of habitats. Floodplain forests and wet meadows close to rivers are the most endangered habitats along the Danube. Extensive dams for flood protection, drainage systems and irrigation channels for agriculture have been erected in the large plains of the middle and lower courses of the Danube (Hungary, Serbia and Romania) since the 16. Century.

Share of biological agriculture on agriculturally useable areas in countries along the Danube:
Germany 4.1%
Austria 13%
Slovak Rebublic 2%
Slovenia 3.2%
Czech Republic 5.5%
Hungary 1.8%.

Principles of sustainable farming

Sustainable agriculture requires a very good knowledge of the area under cultivation by the farmer. The farmer makes the best of the available resources to produce economically successful, high-quality agricultural products without detrimental impacts on the environment. The use of fertilisers and chemical plant protection products should be minimised and irrigation should be optimised. Animal husbandry is appropriate to the species and the maintenance and conservation of the cultural landscape is assured.

A chance for a sustainable development in agriculture

Following political changes in Central and Eastern European countries, agricultural production declined. The use of fertilisers and pesticides was notably reduced. Against the background of the economic upturn, we have now a unique chance to implement sustainable practices in agriculture.

Irrigation

Agriculture is obviously depending on rain, but frequently fields are being irrigated to increase productivity or to make agricultural exploitation feasible. Water will be used from groundwater or on surface from storage dams. Irrigation systems used by agriculture are mostly inefficient and up to 60% of the water either seeps away into the ground, evaporates or is lost by leaks in the irrigation system. A high water usage is also linked to a leaching out of nutrients from the soil and especially in dry areas uncontrolled irrigation causes the accumulation of free salts (soil salination). Excessive use of the groundwater can cause a decline of the water table. An irrigation system for an area of 1 000 hectare consumes as much water as a city 100 000 people.

Drip Irrigation

An alternative to conventional irrigation, like drainage channels or sprinkler systems is drip irrigation. Pipes are being installed above or below ground and small quantities of water are being provided from small openings near the roots of the plants. Advantages of drip irrigation are reduced usage and more efficient use of the water with reduced evaporation. Adding of fertilizer and pest control of plants through the drip irrigation system can be controlled accurately, leading to reduced usage; but the initial cost of such a system is higher than for conventional systems.

4.3. Hydro power

Other forms of renewable energy generation

Biomass
Regenerating raw material is described as biomass.
The use of plant and animal products for energy generation has great potential. Thus, for example, wood, straw and reeds, but also liquid manure can be used for heat and electricity generation. Water is heated by the combustion of gas obtained from vegetable material or manure and steam is created to drive turbines.
Because the carbon dioxide released through the combustion was previously withdrawn from the atmosphere when the plants were growing, the use of biomass is carbon-dioxide neutral and does not contribute to environmental pollution. Apart from this, regenerating raw materials can be produced as bio-diesel to fuel vehicles. Biomass is available as stored solar energy the whole year round and can be easily stored.

Geothermal energy
In the interior of the earth, temperatures reach up to 6,000 degrees C. The heat penetrates from the earth's core, which mostly consists of nickel-iron alloy, to the earth's surface. In the process the earth's strata but also subterranean water reservoirs are heated up. In order to make geothermal energy sources usable, they have to be brought to the surface through bore holes. Either one brings subterranean heated water or steam to the surface and pumps it back down as cooled water after use, or one pipes water from the surface down to the hot rock strata and pumps it back up to the surface to use as hot water.
In geothermal electricity generation, this hot steam is piped through turbines, thereby producing electricity. Geothermal energy can also be used to heat buildings directly. Geothermal energy is permanently available. In thermal baths, where warm water comes to the earth's surface, you can feel the heat of the earth yourself.

Hydroelectric power plants in the Danube basin

One of the first hydroelectric power plants on the Danube came into service close to Passau in Bavaria in 1927.
On the upper course of the Danube – in the first 1,000 km from the source to Gabčikovo in Slovakia – where the higher gradient creates good preconditions for building flow power plants, there are 59 dam stages. In this area the dams hold up the Danube on average every 16 km. There are chains of power stations on the Danube in Germany and Austria. This means that the dam reservoir area of the next power station starts immediately after the dam of the previous one. The stringing together of power plants turns the river into a chain of dam areas and there are left few stretches where the Danube can flow freely. In the upper course, these stretches are Vohburg-

Weltenburg and Straubing-Vilshofen in Germany and the Wachau and Vienna-Bratislava in Austria and Slovakia. Downstream from Bratislava is the Gabčikovo power plant in Slovakia and the two power plants at the Iron Gate, a breakthrough valley of the Danube in the border region between Romania and Serbia.
The two dams at the Iron Gate form a backwater lake stretching back up the Danube to Novi Sad in Serbia. The backwater stretches along the Danube up to 310 km upstream and also into the Sava and the Tisza and into smaller tributaries. The "Iron Gate 1" hydroelectric power plant is the most important and biggest hydroelectric power plant on the Danube. The artificial reservoir of the second power plant "Iron Gate 2" is 80 kilometres long. In the backwater area of the dams so much sediment has been deposited that 10 per cent of the reservoir has been filled up.
In all, the Danube is dammed for 30% of its length. There are a further 700 major dams on the main tributaries of the Danube. Some tributaries are dammed for 90% of their length. There are also chains of hydroelectric power plants on the main tributaries of the upper Danube. The Lech, for example, has 32 dams covering 90% of its course. There are also hydroelectric power plants on Danube tributaries with high gradients in the middle and lower course of the Danube catchment area. Examples are the Mur, the Sava and the Drava, which rise in the Alps, and the Olt, the Arges and the Bistrita, whose sources are in the Carpathians. The Olt is dammed by a chain of 24 power plants in the last 307 kilometres of its total length of 615 kilometres.

Pumped-storage hydroelectricity

With pumped-storage hydroelectricity, the water is saved in a reservoir. Little water flows through the power station. Then, when there is a period of increased energy need and additional electricity has to be put into the network, the held back water is released in a torrent into the power station turbines. When the water supply has been used up or the peak electricity requirement is over, then the water flow to the turbines is almost completely shut down. Water is held back and stored in the reservoir again.

The frequent alternation between high and low outflow from the power plant often changes the water depths and current speeds. Animals are washed away when the water is released, and the banks dry out during the storage phase.
On the Austrian Drau/Drava, the 50% reduction in fish stocks and the approximately 80% reduction in ground-living small animals has been in connection the described kind of power plants and the damming of the tributaries.

Hydro power generation in some countries of the Danube

Use of hydro power for energy generation differ greatly in the countries of the Danube basin.

Selected countries, electricity generation in per cent, 2004

	Hydro-power	Conventional thermal power	Atomic power
Bulgaria	6.8	10.9	82.3
Croatia	33	67	0
Austria	67	32.5	0
Romania	28.5	61	10.5
Serbia	33	67	0
Slovakia	18.6	18.6	62.8
Slovenia	28.1	36.9	34.9
Czech Republic	5.5	53.3	41.3
Hungary	0.5	57.5	40.7

Sturgeons, threatened fish species in the Danube basin[1]

1) General information on sturgeon in the Danube basin

Phylogenically, sturgeon are living fossils. They belong to the group of *bony fishes* that have inhabited the earth for approximately 200m years. Sturgeon occur throughout the whole of the *northern hemisphere*, that is, in central and northern Europe as well as in Asia (China, Siberia) and in north America. Of three families, one (Chondrosteidae) is long extinct. The Polydontidae include two species, whereas the majority of sturgeon alive today are counted among the Acipenseridae (currently 30 species).

Sturgeon have a unique and unmistakeable form with a long snout and small, bony plates on the skin. The position of the mouth on the lower side of the head indicates that the sturgeon predominantly feeds on small animals that live in the sediment. Sometimes, however, other fish are also eaten. The smallest sturgeon, the sterlet, grows to a maximum of 16 kg and 1.2m. The largest, the hausen, or beluga, can grow up to 8 m long and weigh over three tonnes. The other sturgeon species in the Danube can weigh between 100 and 1,000 kg and reach a few metres in length.

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[1] By guest author Jürg Bloesch

The different sturgeon species are often hard to distinguish. For this reason, genetic methods are increasingly being used, with which one cannot just determine species, but also caviar, meat and whole populations. This has great practical significance, as it could be used to control the black market and poaching. All sturgeon are migratory fish. Here we distinguish two groups: the anadromous sturgeon, which live in the sea and migrate to their spawning grounds in the rivers, and the potamodromous sturgeon, which live in fresh water and migrate within it, whether it is to spawn or for feeding.

Although the 30 existing sturgeon species exhibit individual features, there are common **biological characteristics of the sturgeon**:

1) Practically all species can interbreed, as a result of which fertile and sterile hybridsdevelop; this may be an advantage for sturgeon-farms, but can have ecologically catastrophic consequences when a fertile hybrid and/or species intentionally or unintentionally gets into waters for which it is an alien species.
2) All sturgeon reproduce in fresh water or in water with a low salt content. Most live in the sea, and thus swim up the major rivers to their spawning grounds.
3) Sturgeon have a very long life cycle and live to be well over 30 years old; the fish are only sexually mature after 3 to 16 years, depending on species and gender.This is important for fishing, as over-fishing cannot be compensated for in the short term.
4) The results of spawning vary greatly from year to year and are essentially dependent on the availability of spawning areas and the prevailing current during the spawning season.
5) Sturgeon prefer to return to the same spawning area. The spawning migrations are therefore predictable, which heavily increases the pressure on fish stocks from fishing.
6) The spawning fish display a complex age structure.

Six species of Acipenseridae occur naturally in the Danube basin:
Acipenser gueldenstaedti (Danube or Russian sturgeon)
Acipenser nudiventris (fringe barbel sturgeon or ship sturgeon)
Acipenser ruthenus (sterlet)
Acipenser stellatus (stellate or starry sturgeon)
Acipenser sturio (common, Atlantic or Baltic sturgeon)
Huso huso (beluga or great sturgeon)

Two species are now considered extinct: *A.sturio* and *A.nudiventris* (in the upper Danube; in the lower Danube their status is unclear). However, in 2003 an example of *A.nudiventris* was found in Serbia and in July 2005 in the Mura (in Hungary), which indicates that there are still small residual stocks.

2) Comparison of the situation of the sturgeon in the Danube (and tributaries) before the construction of the dams (at the Iron Gate), before over-fishing of stocks and today

With the construction of the "Iron Gate I" power station (completed 1972), the lower Danube was cut off from the mid and central Danube. The river continuum was interrupted by such dams, which massively changed the flow-off regime (damming, current), sediment transport (e.g. lack of gravel transport and the deposition of fine materials lead to loss of spawning places and spawning substrata of the sturgeon) and the groundwater conditions. Later (1985) came the "Iron Gate II", 80 km below the first power station.

It is apparent that today the beluga is only rarely encountered above the "Iron Gate" and above Budapest and in all major tributaries (Sava, Drava, Tisza) it has disappeared.

A.gueldenstaedti (Russian sturgeon) und *A.stellatus* (Starry sturgeon) show a similar distribution picture to the beluga, whereas the purely freshwater sturgeon *A.ruthenus* (sterlet) was distributed further upstream and still is. The occurrence of *A.nudiventris* (ship sturgeon) is disputed, as it has only been caught sporadically in the last 30 to 40 years.

3) Present-day threat scenarios and solutions

People have been attracted by the size and special appearance the sturgeon since time immemorial. Sturgeon are used for caviar (their eggs) and meat as well as handicraft works (skin and bones) and raw materials for the chemical industry.

Without doubt the caviar industry puts great pressure on sturgeon fishing, because it brings in the greatest profits. Beluga caviar in particular is much sought after. The CITES quota for caviar are unfortunately hardly kept, and poaching and the black market are booming. (Since April 1998 the Washington species-protection agreement CITES, "Convention on International Trade in Endangered Species of wild fauna and flora", has covered all sturgeon species and regulated the trade in endangered species through the stipulation of annual quota per country for meat and caviar, see www.cites.org).

In the course of history there have been various population crashes because of over-fishing of sturgeon stocks, for example in the 16th, 18th and 19th centuries.
Also the great river regulation projects carried out on the Danube and its tributaries in the 19th and 20th centuries had particularly negative effects. The priority then was navigation, flood protection and gaining land for cities and agriculture.

Since 1950, the massively rising pollution of the Danube played an increasingly negative role, as well as the over-fishing of disappearing stocks.

As is usual with ecological connections, it is true that there is no simple link between cause and effect. Nevertheless, the following general summary of the essential dangers and the main threats to the Danube sturgeon can be given:

- in the upper Danube (from the source to Bratislava): *destruction of habitats*, for example the spawning grounds, by river regulation and hindrances
- in the mid-course of the Danube (from Bratislava to the Iron Gate gorge): *prevention of migration* by the Iron Gate power station dam

- in the lower Danube (below the Iron Gate, including the delta down to the mouth into the Black Sea): *over-fishing, over-exploitation, pollution, altered run-off regime* (currents) through power stations and water diversion for irrigation.

Over-fishing

In the course of the 20th century, and in particular since 1989, the sturgeon catch, particularly in Romania and the Ukraine, has fallen drastically. The catching of full-grown sturgeon that are economically valuable and ecologically important is particularly problematic. The general conditions in fishing to protect the sturgeon are insufficient and not internationally harmonised.

Obstacles to migration

Although we do not yet know and understand the migratory behaviour of the sturgeon down to the last detail, it is clear that the two power stations, Iron Gate I and II, completely interrupt the migration of the sturgeon from the lower to the middle Danube. This was particularly clear in the time after the construction, when for some years the fish that wanted to migrate collected there and then could be easily caught. Today, with decimated stocks, one only occasionally finds the sturgeon above the dams. True, individual exemplars that get through the shipping locks into the reservoir and the middle Danube can be found, but this is not sufficient to guarantee the propagation of the population.

Today the life cycle of all anadromous migratory sturgeon is only going on in the lower Danube. Above the Iron Gate there are only residual stocks of earlier sturgeon populations or populations of the freshwater variety, the sterlet (*Acipenser ruthenus)*, which however is partly supported by stocking programmes from sturgeon farms.

The river regulation as a result of the construction of power stations, shipping and flood protection include the straightening of the course (cutting off of meanders), works across the river (dams, locks, weirs) and works alongside the river (hard embankments, boulders, concrete walls), and partly also changes to the riverbed (dredging). This has consequences for the river eco-system: changed hydrological regime (flow-off, current), dredging and matting of the river bed (blocking of the cavities through fine materials) and morphological monotony (the interlocking of the land and water is lost). These changes have effects on the flora and fauna, and many ecological functions are massively affected or lost.

In the Danube and its tributaries many sturgeon habitats have been negatively affected or lost. But sturgeon need spawning grounds that are suitable and reachable for migration and reproduction (shingle beds well-supplied with oxygen), a suitable flow regime (currents that trigger spawning migrations) and the right temperature and water quality.

Pollution

The complex "chemical cocktails" of substances that get into the water as a result of the industries today represent a largely unresolved problem.

Not only fish, and thus especiallythe sturgeon in the Danube, but also other water life forms are negatively affected by hormonal endocrine substances, heavy metals and organic substances that are not easily biodegradable. This affects in particular the animals sturgeons eat (above all invertebrates such as insect larvae, worms and snails that live in the sediment of the waters). The food chain is thereby disrupted. Endocrines can affect the fertility of the sturgeon and reduce or completely disrupt the reproduction of other living organisms. The accumulation of heavy metals in the food chain can even endanger human health at the top of the food chain (fish consumption).

Additional Danube tales - Ship mills

In the upper course of the Danube the current is so strong that the mills had to be near the banks. In the middle and lower course, the river flows more slowly. In these sections the mills were set up further towards the middle of the river, where there was more current. They were tied up by iron chains to the bank or to pillars. Or the millers anchored the mills to the riverbed with heavy baskets full of stones.

There were times when there were so many ship mills on the rivers that the authorities had to regulate who was allowed to mill where. In big cities such as Vienna, Bratislava and Budapest, ship mills were part of the townscape up until the 1930s and were an everyday sight.

With fluctuating water levels, the mill simply floated up and down, but during high water the large amount of driftwood and drifting ice floes could be dangerous. There were good anchorages and bad ones, to which the current drove larger amounts of flotsam. Correspondingly there were often argues about the best or worse mill sites. If one could not catch the ice, uprooted trees or other large objects, the mill wheel or the ship were destroyed.

How do you repair a broken wheel? The river never stops flowing, and so the wheel cannot be stopped. It is much too heavy to lift it into a neutral position. The solution: a large board is placed vertically in the current in front of the wheel. As a result, behind it, by the mill wheel, the current is quieter, because the water flows through underneath and one can stop the enormous wheel and repair it while it is stopped.

Farmers liked to bring their corn to the miller when the weather and the water conditions were favourable. Since several farmers would usually then meet at the mill at the same time, there were often long queues, hence the proverb that is still current today: “He who comes first, mills first”.

4.4. Navigation

Important artificial water routes in the Danube basin

Rhine–Main–Danube Canal

Over a distance of 171 km, the Rhine–Main–Danube Canal connects the River Main at Bamberg with the Danube at Kelheim in Germany. Thus the connection was made between the Danube and the catchment area of the Rhine, and it was possible for ships to travel from the North Sea to the Black Sea. The canal is 55 m wide and 4 m deep and has 16 locks.

As early as Charlemagne the attempt was made to create a water route between the Rhine and the Danube. In the following centuries the idea was repeatedly taken up, but not fully realised until the 20th century. Construction work began on the present-day Rhine–Main–Danube Canal in 1960 and was completed in 1992.

Danube–Tisza–Danube canal system

The Danube –Tisza canal system is in the Serbian province of Voyvodina. It consists of two practically independent component systems in the regions of Backa and Banat. In the Backa region the canals are fed by the water of the Danube; in Banat the water from the Tisza and smaller tributaries flows into the canals. The Danube–Tisza–Danube canal system includes 330 km of navigable canals on which 1,000-ton ships can travel.

The region's economy is dominated by agriculture and industry. On the main canals there are many industrial plants and large settlements.

From the earliest times the people in this region went to considerable effort to protect all their belongingsfrom floods. The first coordinated measures started in the 18th and 19th centuries. Three canals were dug to drain marshes and to permit navigation: the Bega Canal, the Teresia Canal and the Danube–Tisza Canal. After the Second World War these canals were linked. Today the canal system serves mainly as a water route for shipping and as flood protection for the region. Construction work on the canal system began in 1947 and was completed in 1977.

Danube–Black Sea Canal

This 64.4-km-long canal is on the lower course of the Danube in Romania and leads from the Danube at Cernavoda to the Black Sea at Agigea. At Poarta Alba, a 32.7-km-long side canal branches off. The Poarta Alba–Midia Navodari Canal flows into the Black Sea at Navodari. The catchment area of the two canals is 939.8 sq. km. The main task of the Danube–Black Sea Canal is to reduce the distance to the Black Sea for shipping. Construction of the canal began in 1975 and was completed in 1987. There are locks on the canal at Cernavoda, Agigea, Ovidiu and Navodari. Sections of the Carasu valley were incorporated in the construction of the canal. The canal's main functions are for navigation and flood protection. In addition, the area is densely populated and there are industrial plants, a nuclear power plant and hydroelectric power stations along this canal.

Projects to develop the Danube for navigation

As part of "Transport Corridor Number VII" of the Trans-European Networks for Transport (TEN-T) program, large stretches of the Danube are to be developed for navigation by deepening the river for larger ships. These stretches include the river sections of Straubing–Vilshofen in Germany, Vienna–Bratislava in Austria and Slovakia, Palkovicovo–Mohacs in Hungary and the shallow stretches between Bulgaria and Romania. On the Straubing–Vilshofen stretch for example the only possibility to increase the depth of the water would be by damming up the river. On the downstream stretches regulations and dredging would be necessary.

An other kind of project within the TEN-T program deals with the construction of a navigation canal in the Ukrainian part of the Danube delta, the Bystroye Canal. This canal is flowing through one of the most environmentally valuable areas of the Danube delta. The dredging work has already started.

All these stretches and aeras are of great ecological value and there are many protected areas, such as national parks, UNESCO World Heritage sites, biosphere reserves and Ramsar sites situated along these stretches of the river.

This means that the differing interests will have to be weighed and a balance of interests has to be found.

4.5. Industry

Examples of chemical accidents in the Danube basin

On 30 January 2000, the dam of a tailings pond at a gold mining plant at Baia Mare in western Romania burst. Some 100,000 cu.m of highly poisonous cyanide lye thus got into the Tisza through the Sasar stream and the rivers Lapus and Szamos. Some two weeks later the water, polluted with 100 tonnes of cyanide sludge, reached the Danube, and after a further two weeks and 2,000 km it reached Tulcea on the Danube delta and the Black Sea.

The cyanide leaching process makes it possible to win pure gold from gold-mining tailings. However, enormous quantities of water and poisonous chemicals are used in the process.

As a result of this accident, the drinking water supply for 2.5 million people was endangered and 1,200 tonnes of fish died in Hungary. In the rivers Szamos and Tisza the aquatic life was seriously damaged and the thresholds for cyanide were exceeded as far down as the mouth of the Danube on the Black Sea.

A few weeks later, on 10 March 2000, the dam at the Baia Borsa Novat tailings disposal site in the northern Romanian Carpathians burst. More than 100,000 tonnes of heavy metal ore sludge escaped and some of it reached the upper Tisza.

As a result of international cooperation it was possible to clean up the site. The Baia Mare and Baia Borsa accidents have shown that risk analyses and prevention of such events are of the highest importance.

Additional Danube Tales -

The Bulgarian gardeners in Vienna

The numbers of Bulgarians in Austria were insignificant, but the concentration in one trade, gardening, turned them into a group that was noticeable for the city and that was prominent as food suppliers for the Viennese.

At the end of the 19th century, they came up the Danube from Bulgaria to Vienna as seasonal workers. Some of them bought arable land, planted vegetables and again employed Bulgarian seasonal workers. These travelled the route between work and their homes with ships on the Danube via Vienna or Bratislava. Also in other parts of Austria, such as in Seewinkel in Burgenland (then still part of the Hungarian part of the empire), in Wiener Neustadt, Graz, Linz and Salzburg, many Bulgarian vegetable growers settled.

The Bulgarians brought highly developed techniques in market gardening with them, new tools and above all a sophisticated irrigation system. Thus they were able to bring in considerable harvests on soil that in Austria was described as “uneconomic”. As well as new working techniques, they also brought new products onto the market, such as bell peppers, spring onions, leeks and aubergines. At first the Austrian customers rejected these new vegetables, so some, such as Petar pop Nikolov, a famous Bulgarian travelling gardener, had to fall back on sales tricks and persuasion techniques. Thus he prepared aubergine recipes directly in the market or provided recipes with them. The competition invigorated business, even if there were occasionally conflicts between the Bulgarian and the traditional market gardeners. Many Bulgarian families remained in the country and after 1945 became Austrian citizens.

The “Egyptian System”

The unbeatable success of the Bulgarian gardeners was based on their sophisticated irrigation system. They brought it with them from their comparatively dry homeland where water has to be treated with care. This water-saving form of irrigation is still practised in many Mediterranean countries today. Instead of watering on a large scale, the Bulgarians banked on a well-thought-out channel system with shallow gradient.

One or several main channels are constructed from which the water then flows into the horizontal channels that cross them. These side channels were spaced six metres apart; the space in between was filled by the long crop areas, which were divided by small walls of earth into 1.2-m-wide beds. These walls of earth were just high enough so the water could not flow away, but could spread and slowly seep into the earth. Not every side channel was flooded at the same time; they flooded one after another, and then they were blocked off with earth from the main channel.

Once the water was diverted into a side channel, they had to work fast, because 600–800 litres of water per minute was flowing through the channel. They removed some of the earth surrounding the beds so water from the side channel could flood each bed. The channel was blocked again with the earth removed from the bed walls, then the next was opened, the water was allowed to flow in, the channel was blocked, and so on. The “earth moving” was usually done by hand; the gardeners needed only one flick of the wrist to do it.

When new beds were laid out, the work was done with great care and precision on the right gradient for the irrigation system and the main channels were carefully checked for their stability and durability. The Bulgarian gardeners always preferred irrigating with the “living water” of the rivers or streams rather than well water, because it was warmer and the crops did not suffer a “cold shock”, which inhibited their growth every time they were watered. Another advantage of using river water for irrigation was that more nutrients are dissolved in river water, which the vegetables can absorb through their roots.

4.6. Flood protection

Flood protection measures in the Danube basin

More than seven per cent of the catchment area in the Danube basin is regarded as inundation area. A very small part of this still exists in its natural form. Six per cent of the population in the Danube catchment area live in areas at risk of floods. The spread of floods is restricted by water regulation. Embankments and flood walls are built to withstand floods that statistically occur every 100 years. However, higher floods can happen at any time. In the Danube basin, 60,000 sq. km would be affected by regular or occasional floods in the absence of flood-protection measures. However, technological flood protection changes the landscape and the flowing waters.

In the last two centuries in the Danube basin, wetlands near rivers have been heavily affected.

Large-scale river regulation for flood protection, but also for navigation, started in Austria in the 19th century. In Hungary, Serbia, Bulgaria and Romania the first dikes were built as early as the 16th century, and extended in the 19th and 20th centuries. Floodplain forests and inundation areas were thereby cut off from the rivers and the connection was lost. Of the extensive inundation areas that still accompanied our rivers in the 19th century, only 19 per cent remain today. In Hungary, 3.7m hectares and in Romania 435,000 hectares are behind dams or dikes. In the upper course of the Danube, flood protection measures are frequently associated with dams. The Danube itself is regulated over 80 per cent of its course. The Tisza has been shortened by 32 per cent by cutting off the meanders and is now regulated for 70 per cent of its length. In the Danube delta, 100,000 hectares of inundation areas have been dammed off. However, some 15 per cent of these areas have been reconnected to the waters of the Danube delta through restoration measures.

Effects of flood protection measures on water bodies

Flood-protection measures such as damming of rivers and building dykes mainly effect the connection between the river and the floodplains of the adjacent land. 80% of the wetlands of the Danube have been destroyed in such a way. Large dams and the disconnection of river-meanders disrupt the exchange between surface- and groundwater. This exchange is important for the creation of bank filtrate and thus for the supply of drinking water. The damming of large flooded areas also had disastrous consequences for the fishery on the Danube. For fishes like carps or pike the temporary flooded plains serve as breading grounds. Along the middle section of the Danube fishery has lost its importance after the building of the flood protection structures.

Ecological flood protection on the Sava

In the middle Sava an exemplary project demonstrates the possibility of flood protection through the retention of natural inundation areas. For the first time, flood-plain forests have been conserved in order to provide flood protection. This approach, which includes the whole river catchment area, is the main reason for the security against floods and the retention of the high ecological value of the Sava. With 109,000 hectares, it is the largest floodplain forest area in the Danube basin. Downriver from Zagreb, large quantities of water flow off into the floodplain forest and in this way the burden of floods can be reduced. The area on the central Sava demonstrates impressively how floodplain forests can ameliorate the flood waves. The core area of this floodplain forest system is the Lonjsko Polje national park. The retention of natural inundation areas is the first step to a sustainable development in the middle Sava and, apart from flood protection, represents the basis for preserving traditional forms of farming in inundation areas (such as grazing and wood utilisation).

Additional Danube Tales -

Navigation “uphill” - towing

Towing used to be a time consuming, expensive and hazardous affair. Nonetheless, until steamships became more common, particularly in the upper stretches, towing was the only way of transporting ships against the current. Already the Romans towed their large rowing ships upstream.

The admiration and amazement must have been indescribable when the first steamship in Austria, the “Maria Anna”, after a 55-hour-journey, arrived at Linz, puffing. The fact that the ship had travelled from Vienna to Linz all on its own, without being pulled by horses, was celebrated on both sides of the river with music, cheers, gun salutes, and with incredulous faces of the spectators.

At the beginning, the steamships had only very weak motors, and when the water current was fast they could not pass dangerous sections with vortices or rocks. One such section was the Strudengau in Austria. For a long time, until the 1870s, tow horses were needed there to pull the steamships upstream.

The first horse in the row of tow horses had to be a very calm, reliable and experienced one. Behind it came pairs guided by riders. The last horse carried the so-called “after-rider”. This horse had the most difficult task: to counterbalance the one-sided pressure on the thick hemp rope leading to the ship and which made a bend towards the ship behind its harness. These animals doing that job had to be exchanged several times per day.

Behind the horse-team went the “tower”, often a young boy, whose job it was to release the rope when it got caught somewhere in a tree or a large rock. For large towing operations, a “Zille”, a river boat, had to swim between the ships and the river bank to hold the rope and to prevent it hanging into the water. When crossing the river, not only the horses and towers did have to reach the other side, but the heavy, thick rope, which was up to 200 m long, as well. Once on the other side, the horses were re-yoked and the journey continued, until a rock face, dangerous currents and whirls, or other obstacles forced the towers to change to the other side of the river again.

It was the lack of wood that made it necessary, instead of using ships only once and then taking them apart, as it happened often, to tow them back, empty or laden. Wine and crops were two of the goods that were often transported upstream on the Danube. Often several ships were joined into “trains”.

The towpath, nowadays used by joggers and strollers, was the path used by the horses and towers of a tow-train. Sometimes such paths were on both sides of the Danube, sometimes on one side only. The riverbank which was higher up usually was better suited, as the ship rope could not hang into the water as easily. To ensure that the path remained passable, the adjoining communities were obliged to keep their respective sections free from trees, shrubs and other obstacles. This was already heavy duty, but after floods or ice-jams floods, this meant extremely great effort and hard work.

Tow-paths did not exist everywhere. Moreover, the river bed kept changing, so that it happened that even ship pilots lost their ways. In some sections, such as the sections near the Žitný ostrov river island in Slovakia and the Szigetköz river island in Hungary, it was simply impossible to construct broad and passable paths. When the conditions on the route between Komárom in Hungary and Bratislava in Slowakia made it necessary to reload the cargo and to transport it over land to the next navigable section, this enterprise could take up to two weeks. Sand banks, shelves, and dense shrubbery and mud made even short trips a troublesome adventure. Or take the section between Dunaföldvár in Hungary and Zemun in Serbia - instead of by animals, the ships had to be towed human-powered. The mail boat’s journey on this stretch could then sometimes last up to 22 days.

5.1.The countries in the Danube basin

Language diversity in the Danube basin

Languages in the lower course

Romanian is spoken in Romania. The language descended from Latin, the language of the Roman Empire and was previously written in Cyrillic script. Today the Latin alphabet is used. As a Romance language, Romanian is related to Italian and French.

In the Republic of Moldova the majority of people speaks Romanian and, since independence, writes in the Latin alphabet. 13.8% of the population speaks Ukrainian as their mother tongue and 13% Russian. Apart from this, Bulgarian is spoken and Yiddish and Hebrew by Jewish Moldavians. The Gagauzian minority speaks a Turkic dialect.

In the Ukraine people speak Ukrainian, and primarily in the east of the country also Russian. Ukrainian is written in a variant of Cyrillic. Ukrainian is an east-Slavic language that is related to Russian.

In Bulgaria people speak Bulgarian and use the Cyrillic script. As present-day Bulgaria was part of the Ottoman empire for a long time, Turkish is also a widely spoken language.

In the past, Jews fleeing persecution in Spain came to the lower course of the Danube. In major Jewish communities such as in Ruse, the birthplace of nobel prize winner Elias Canetti, and in Galati, a Spanish dialect is spoken. Hebrew is spoken at religious ceremonies.

Languages in the middle course

In the middle course of the Danube, Hungarian, Slovakian, Romanian, Serbian, German, Croatian, Romany and Albanian are spoken.

Serbian is a Slavic language and is written in the Cyrillic script, but also the Latin alphabet is in common use. Apart from in Serbia, Serbs live along the Danube in southern Hungary and in Croatian Slavonia. Until the civil war a few years ago, Serbs also lived in the Croatian Krajina. They were settled there by the ruling Habsburgs, in the 16th century to protect the border against the Ottomans.
In Serbia, 15% of the population speak Hungarian and over 2% Slovakian.

Albanian is an Indo-European language. It is spoken in Albania and by many people in Serbia.

In Croatia, the official language is Croatian, in Istria also Italian and Slovanian. Croatian is a south-Slavic language that is related to the Serbian and Bosnian language. The Latin alphabet is used. Some 5% of the population are Serbs. As well as this, Bosnians, Italians, Hungarians, Albanians and Slovene, among others, also live in Croatia.

In Bosnia-Herzegovina, Bosnian, a South-Slavic language is spoken and the Latin alphabet is used. Bosnians, Serbs and Croats live in the country. Correspondingly, the official languages are Bosnian, Serbian and Croatian.

A South-Slavic language is also spoken in Slovenia – Slovenian. The Latin alphabet is used. Slovenian is spoken in Austria, Italy and Hungary. 1 to 2 % of Serbs, Croats and Bosnians live in Slovenia.

Hungarian is related to Finnish and Estonian. It is the only non-Indo-European language in Central Europe. As the historical Hungary extended far beyond the borders of present-day Hungary, Hungarian is still spoken in many other countries. Large Hungarian minorities live in Slovakia, Croatia, in the Serbian Vojvodina, in the Serbian-Romanian Banat and in the Romanian Carpathian arc with Transylvania.
Alongside Hungarian, Romany, the language of the Roma, Romanian and Slovakian are spoken in Hungary. The Danube Swabians were settled by the Habsburgs in present-day Serbian Backa, Vojvodina and Banat and in the southern Hungarian area around Pécs. They emigrated in boats downstream along the Danube. One type of boat often used for this was the “Ulm Box” (“Ulmer Schachtel”).

Slovakian is one of the West-Slavic languages, like Czech and Polish, with which it is related. It is the national language in Slovakia and above and beyond this is spoken in Hungary, Romania, Serbia and the Czech Republic.
In Slovakia, again, there are 9.75% Hungarians and 1.7% Roma as well as Czechs, Ruthenians and Ukrainians with their own mother tongue.

A very particular example of many cultures living together in the smallest space is present-day Serbian Vojvodina. With Serbs, Hungarians, Danube Swabians, Croats, Slovaks, Walachians from Romania, Ruthenians from the Ukraine and Bosnians, the region represented a multinational world.

The language of the Roma, Romany, belongs to the Indo-Iranian language family. It is related to Persian and Kurdish. The Roma have lived in Hungary since the 13th century and make up 5% of the population. Many also live in Slovakia and in Romanian Transylvania.

Languages in the upper course

In the Czech Republic about 90,4% speak Czech, 1.9% of the population are Slovakian. There live also Roma, German, Hungarian, Ruthenians and Polish people. Up until the end of the Second World War, three million people had German as their mother tongue. Czech is spoken from over 12 million people as mother tongue.

In southern Germany besides the Bavarian dialect, Franconian and Alemannic-Swabian dialects are spoken. In addition, the languages of the immigrants of the recent decades are spoken.

In the area of present-day Austria, alongside German, Croatian, Hungarian, Slovenian and Romany have also been spoken for centuries.

Up until the Second World War, millions of people in the towns of the Danube area spoke Yiddish in everyday life. Yiddish contains words from Hebrew, from Slavic languages and from German. It is written in a Hebraic alphabet. Many Yiddish or Hebrew words live on today for example in the Viennese dialect.

The Danube connects us

Alongside different languages and cultures there are many features in common in the Danube basin. For ages the lives of many people have been influenced by the Danube and its tributaries. From early times, trade routes connecting northern Europe with the Mediterranean Sea went through the Danube basin. Amber, ores, salt and furs were transported to the south and exchanged there against jewellery and metal weapons. Some of these routes were named „amber roads“ after amber, an important commodity of the time. Several amber roads crossed the upper and central Danube. The most important of these roads crossed the Danube between Vienna and Bratislava and passed through Sopron, Szombathely, Maribor, Ljubljana and Zagreb down to the Mediterranean Sea. Like these many of our present-day towns and cities grew up along earlier trade routes.

Another route leads to the south along the Danube and the Inn. Gold and copper from Transsylvania were then exported down the Mureş and Tisza and then upriver along the Danube and the Inn and through routes over the Alps to the Mediterranean Sea. This early international trade led to the development of the first inter-regional shipping traffic.

The Danube basin – a cultural area

Many sites in the Danube countries go back to Celtic settlements. The Celts were a group of peoples with shared cultural and linguistic characteristics. An early centre of a Celtic culture was in Hallstatt in the Austrian Alps. The place gave its name to a historical period of several hundred years.

Starting from the upper and central Danube basin, the Celts expanded along the rivers. Along the Danube, the Tisza and Mureş to the Carpathian area. And in the south along the Velika Morava towards Macedonia.
Danube towns such as Regensburg, Passau, Linz, Vienna, Bratislava, Belgrade and the Bulgarian Vidin go back to Celtic settlements. The name of Vienna is supposed to derive from the Celtic word Vedunia – which means woodland stream. The Celts called Budapest “Ak-ink”, „ample water“, in allusion to the many thermal springs.

The river names Lech, Isar and Danube are also of Celtic origin. “Dan” means something like „big river“. In the Roman era this became “Danuvius” or “Danubius”.
At the highpoint of their extent, large areas of the Danube basin were embedded in a

Celtic civilisation.

The Greeks on the Danube

From the 7th century BC, large Greek cities such as Athens, Corinth and Milet in Asia Minor extended their trading to the north and founded daughter cities on the coast of the Black Sea and the lower course of the Danube.
South of the Danube estuary, Histria was founded on a bay of the Black Sea. The name of the city is derived from Istros, the Greek name for the Danube. Today the excavations of the ancient city lie on Lake Sinoie, which developed from a sea lagoon.
Tomis, the present-day Constanța, and Kallatis, today Mangalia, grew on what is now the Romanian Black Sea coast. Inland, the Greeks founded Axiopolis on the Danube, the present-day Cernavodă.
The earlier city layouts are often still visible. The modern main square of Constanța lies exactly over the Greek agora, the market and gathering place of ancient Tomis.

The Iron Gate with its rapids and shallows was a natural and difficult barrier for the Greek rowing boats to pass. Thus the Greek area of influence was limited to the lower Danube and the Black Sea.
From the daughter cities in the Danube basin, salt fish was transported to the motherland in round-bellied amphorae. Also cereals, wood, hemp, linen, raw metal and animals were transported southwards. In the other direction came oil, wine, weapons, jewellery and ceramics from the Mediterranean. Greek wine in amphorae was a particularly sought-after commodity. Greek was the language of trade and was spoken throughout the Black Sea area.

The Romans on the Danube

In the 3rd century BC, the Romans extended their empire to the Danube. The Danube became a border-line. Military camps grew up along the river with civilian settlements in their immediate surroundings.

Most present-day cities on the Danube were already fortified settlements in Roman times. Regensburg in Germany, for example,was the Roman Castra Regina or Passau, the Roman Batavis. Tulln, in Austria, was called Comagenis and was a port for the Roman Danube fleet. The Hungarian Györ, Roman Arabona, lies on the mouth of three rivers into the Danube and goes back to a Roman fortress. The Bulgarian Silistra, too, already existed in Roman times as Durostorum.

Budapest, Roman Aquincum, was for many hundred years the most important and populous Roman city on the whole of the Danube. Here was the residence of the governor of lower Pannonia. Another important city was the present-day Serbian Sremska Mitrovica, Roman Sirmium. Situated on the Sava, it was the residential city of many emperors and one of the main cities of the Roman empire.

Latin was spoken everywhere in the Roman-dominated Danube basin from the source to the mouth. There was a unified legal and administrative system and a common currency. The public authorities had markets and gathering places, called „forum“, built, as well as theatres, aqueducts and roads. Aqueducts and sewage systems facilitated a special bath culture. Water was transported many kilometres through aqueducts from the sources into the cities and there into big public baths, the thermal baths.

Where the Roman empire extended beyond the Danube, bridges were built, the most important at Drobeta-Turnu Severin. In AD 103, a 1070m-long Danube bridge was completed after two years of construction under the direction of a Greek architect from Damascus called Apollodorus. Nineteen wooden arches on 20 stone pillars spanned the river. The pillars towered 45 m above the surface of the water.
In ancient times there were bridges were today there are none. Thus to the west of the old estuary at Oescus, there was a Roman bridge with a length of 1150 m.

Landscape names such as Pannonia or Dakia come from the ancient world and are still used. The Romanian language derived from Latin.

In general, Roman roots are referred to with pride. An example of this is the coat of arms of the Romanian town of Drobeta-Turnu Severin, with the Roman Danube bridge. The names of some towns recall their Roman names even today. The German Augsburg, Roman Augusta Vindelicorum, the Romanian Cluj-Napoca, Roman Napoca, or the Black Sea city of Constanța, Roman Constantiana.

Additional Danube Tales - Games, our grandparents played

Germany: *Auf der Donau bin i g'fahre* [I sailed on the Danube]

It goes like this: All the children join hands in a circle and walk round singing the song "I sailed on the Danube", using the name of one of the children after "and the ship's called…". The child whose name is called out turns around after the line "…shall turn around!", and stands with their back to the centre of the circle. This child continues to walk and sing with the others. The game lasts until all the children are facing outwards, and then in the same way facing inwards again. The text and the tune are not difficult and the German song can probably be learned by children who don't speak German as their mother tongue.

Text:
Auf der Donau bin i g'fahre, und a Schiffle hab i g'sehn,
und des Schiffle heißt…und die/der…soll sich drehen.

[I sailed on the Danube and saw a ship
and the ship's called…, and…shall turn around.]

Austria: Where are you off to?

It goes like this: All the children stand still in a circle, except for one who walks around the outside of the circle. He or she touches one of the children in the circle, who quickly runs away in the other direction, also along the outside edge of the circle. When they meet again, the children briefly exchange the following words:

First child: “Hallo, Frau/Herr Meier. Where are you off to?”
Second child: “To Constanța/the Black Sea/Bulgaria [or wherever is appropriate]!”
First child: “I want to go there too!”

At this sentence, the two children begin to run round the circle again, each in their own direction. Whoever gets to the gap in the circle (which was made by the child leaving it) first stands in it; the other child starts from the beginning again to find a Frau or Herr Meier. Meier is a widespread common name in Austria.

Hungary: Donkey, who’s riding?

One child is the donkey and kneels on all fours. Either they shut their eyes (no cheating!) or their eyes are blindfolded. The other children silently agree who is going to play the next rider. This child sits on the back of the “donkey” and shouts: “Donkey, who’s riding?” (in other places it is: “Donkey, who are you carrying?”). If the blindfolded child guesses right, then the donkey is freed and the rider becomes the new donkey. If they guess wrongly, another child joins the first on the donkey’s back and starts asking “Donkey, who’s riding?” Thus there are ever more children on the back of the donkey until the whole “tower” collapses. This game ends in a big, funny jumble.

Hungary: Catching flies

Some six children stand in a row. Opposite them stands one child with a ball. This child throws the ball to one of the children in the row, who catches it and throws it back. When they catch the ball, the children have symbolically caught a fly, which they hold between closed hands and must not let out. If the ball is thrown to them again, they can naturally open their hands to catch it and to through it back, but should then press them tightly together again. In this way, each time they catch the ball, the children pretend to catch invisible flies between the palms of their hands. The first one to have caught ten has won and is the new ball-thrower. But watch out! If the ball-thrower is kidding and only pretends to throw the ball, and a child opens their hands without catching it, then all the flies fly away and they have to start catching flies and counting from the beginning again. A funny game for teasing and kidding.

The word „Danube“ in the most common Danube languages

German:	Donau
Hungarian:	Duna
Croatian:	Dunav
Macedonian:	Dunav
Serbian:	Dunav
Bulgarian:	Dunav
Russian:	Dunaj
Ukrainian:	Dunaj
Slovakian:	Dunaj
Romanian:	Dunârea
Albanian:	Danub
Turkish:	Tuna

5.2. The Catchment area of the Danube

Climate and hydrology

There are great climatic variations in the catchment area of the Danube owing to the relief and the wide west-east extent of the area. The areas in the north west are heavily influenced by the maritime climate, with high precipitation. The eastern areas are in the area of the continental climate with lower precipitation and typically colder winters. The catchment area of the Drava and Sava are subject to the Mediterranean climate.

This climate pattern is diversified by the variability of the relief, in particular the different exposure to the prevailing westerly winds and the differences in altitude. These lead to different landscape regions with differing climates and vegetation.
Owing to regional differences, the precipitation ranges from below 500 mm to over 2,000 mm per year. This has great effects on the surface flow-off and the discharge of the rivers. The regime of the Danube is decisively influenced by the regional precipitation patterns. Particularly large quantities of water flow into the Danube from the Alps and the Carpathians.

Mountains in the Danube basin

The mountains go through the basin in a wavy line. The Alps, coming from the west, end at Vienna and are continued north of Bratislava by the Carpathians. These form a long question mark at the end of which are the Balkan Mountains. To the west these are joined by the Dinarian Mountains. In the angle of the Eastern Carpathians and Southern Carpathians are the highlands of Transylvania. In the west these are bordered by the Apuseni Mountains of the Hungarian plain.

The Danube rises in the up to 1,000-m-high Black Forest and is accompanied in the south by the Alps and in the north by medium-high mountains from 500 to 1000 m. These prevent any “flowing away” towards the North Sea. In the area of Vienna the Danube fights its way between the Alps and the Inner Western (or Little) Carpathians and shortly past Bratislava forms an inland delta. It fans out for some 80 km into three arms.

At the “Danube Knee” north of Budapest the river comes up against a mountain, turns abruptly to the south and crosses the Hungarian plain. In the gorges of the Iron Gate the Danube forces its way through the Carpathians and the Balkan Mountains. Afterwards it flows through the lowland between the Balkan Mountains and the Southern Carpathians until at the ridge of the 450-m-high Dobrudscha it is diverted northwards. On the way to the north it branches several times. Through the inflow of the Siret and the Prut, the Danube turns to the east again and flows out into the Black Sea. In the delta the Danube forms three arms of the river.

The Alps in the west are between 3,000 and 4,000 m, and still 2,000-m-high before Vienna. The mountains are continued north of Bratislava in the form of the Western Carpathians. They start with the approximately 700-m-high Inner Western (or Little) Carpathians, turn north east and reach the Polish-Slovakian border in the High Tatra, at 2,655 m the highest peak of the whole Carpathian arc. These are joined in eastern Slovakia by the Outer Eastern Carpathians. Their highest summit is in the Ukraine and is just over 2,000-m-high. The adjoining Inner Eastern Carpathians are all within Romania. They are up to 2,300-m-high. The Southern Carpathians again reach an altitude of up to 2,543 m. South of the Danube and the Iron Gate, the mountain range is continued as the Balkan Mountains. West of the Balkan Mountains, parallel to the Adriatic coast, are the Dinarian Mountains. These form the southern border of the great Hungarian plain.

The most important tributaries

In its upper course, the Lech is the last “wild” river in the Alps, with many gravel and shingle banks. Birds like the little ringed plover build their nests here, directly on the gravely banks.

The Inn, at its confluence with the Danube in Passau, is bigger than the Danube itself. The water of the Inn is green and for kilometres does not mix with the grey-brown water of the Danube.

The Morava gets its water from the Czech Republic, Slovakia and Austria. It is the border river between Slovakia and Austria. In the shadow of the iron curtain the river and wetlands meadows and woods remained protected from disturbance. On the Morava there is Europe’s largest colony of storks breeding in trees. The storks build their nests on ancient oaks in the water meadows.

The Drava is the tributary to the Danube with the fourth highest quantity of water. The Kopački rit, where the Drava joins the Danube, is a unique riverine landscape. At the time of melting snow in the Alps this area is under water for weeks on end. The Kopački rit at the mouth of the Drava is one of the most important spawning grounds in the Danube basin for more than 44 fish species.

The Sava is the tributary of the Danube with the most water. Its water and that of its tributaries has flowed through Ljubljana, Zagreb, Banja Luka and Sarajevo. It discharges into the Danube in Belgrade. 160 pairs of white-tailed eagles breed in the floodplain forests of the Sava and the Drava.

At 966 km, the Tisza is the longest tributary of the Danube. Originally 1,430-km-long, it has been shortened by regulation. No other tributary of the Danube has such a large catchment area. It is almost twice as large as Austria.

The Velika Morava flows into the Danube between Belgrade and the Iron Gate. For thousands of years it has been a connecting route to the Mediterranean area. The Celts spread out southwards along the Velika Morava.

The River Timok rises in the Balkan Mountains. Where it flows into the Danube three countries border each other - Serbia, Romania and Bulgaria.

The River Iskar is the largest tributary in Bulgaria. It rises in the Rila Mountains, flows through the suburbs of Sofia and crosses the Balkan Mountains.

The River Olt divides the Tara Romanesca/Campia Romana into the western Oltenia with the capital Craiova and the eastern Muntenia with the Romanian capital Bukaresti.

The River Siret rises in the Ukrainian Outer Eastern Carpathians. Between Belgrade and the Danube delta it is the tributary with the greatest quantity of water. Its inflow causes the Danube to change course and flow eastwards, where it flows into the Black Sea.

The River Prut rises in the Ukrainian Outer Eastern Carpathians. It is the border river between Romania and the Republic of Moldova. The Republic of Moldova has access to the Danube for almost one kilometre next to the mouth of the Prut.

The Danube branches into three river arms where it flows into the Black Sea. The Danube delta is the largest area of reed beds in the world. It is interspersed with over 600 lakes or areas of open water. The white pelican lives here.

Additional Danube tales -

Language jumble

Vocabulary:

Language	**Child**	Pronunciation	**Water**	Pronunciation	**River**	Pronunciation
Albanian	fëmijë	femij	ujë	uj	lumë	lum
Bulgarian	дете	deté	вода	wodل	река	rekل
Croatian	dijete	diںte	voda	wda	rijeka	rijéka
German	Kind	ˈkmt	Wasser	ˈvasɐ	Fluss	fluss
Hungarian	gyerek	djérek	vيz	wies	foly´	fjoh
Macedonian	дете	déte	вода	wda	река	réka
Rumanian	copil	kopil	apă	apں	râu	riu
Serbian	dete	déte	voda	wda	reka	réka
Slovak	decko	détzko	voda	wda	rieka	riéka
Slovenian	otrok	otrk	vôda	wda	reka	réka
Turkish	çocuk	tschtschuk	su	ssu	ırmak	rmak
Ukrainian	дитина	ditيna	вода	wodل	ричка	ritschka

6.1. THE CONSERVATION OF DIVERSE AND HIGH- QUALITY RIVERINE LANDSCAPES

Restoration projects in the Danube basin

The consequences of river regulations, the damming off of floodplain forests and reservoir dams, including the lowering groundwater level, the decreasing water quality and the increasing danger of floods have led to a rethinking process in the last years.

Pilot projects have been implemented since the 1990s. Their objective is to restore the river in a way that is closer to nature, to renaturate it. Species-rich riverine habitats are to be maintained and actively promoted. The valuable functions of riverine landscapes are to be improved again.

A 1999 study identified areas of 300,000 ha on the Danube and the five major tributaries that are well suited for restoration, although only large stretches of river were proposed. For Austria for example, a restoration requirement of 84,000 ha has been ascertained as requiring better flood protection, the securing of groundwater levels and the improvement of self-purification power of the water bodies.

In recent years many projects have been taken up, from the rebuilding of small streams in the cultural landscape to the restoration of large inundation areas of the Danube. Four projects are briefly presented here.

Integrated Danube programme in Baden-Württemberg in Germany

The impacts of the catastrophic floods in the upper course of the Danube in 1992 were decisive for the beginning of this comprehensive project. Along the 285-km-long stretch between Donaueschingen and Ulm, a total of 223 individual restoration measures are planned and a large number of them have already been implemented. Specifically, the passage of the Danube and its tributaries is to be improved though bypass channels, passable ramps and fish stairways as well as sufficient supplies of residual water. In addition, oxbow lakes will be joined up again and dynamic stretches will be developed. Flood protection will be improved through technical solutions, river widening and expansion of the natural inundation areas. Up until September 2004, €16m had been invested (excluding land purchases).

The heraldic animal of the project, the little ringed plover (*Charadrius dubius*) has profited from the measures taken, and the beaver (*Castor fiber*) is a native animal again.

Danube salmon habitat – restoration of three Danube tributaries in Austria

Between 1999 and 2003, the habitat of the endangered Danube salmon (*Hucho hucho*), but also for other plants and animals, was improved. A total of 13 weirs that previously obstructed the migration of the fish were made passable. The Danube salmon now has a 78 km migration route and spawning area. A further emphasis of the project was the ensuring of dynamic river stretches on the Pielach. By purchasing bank-side plots, it was possible the river bank to be eroded and deposited elsewhere without the landowner being financially affected.

As well, a regulated section of the Melk was rebuild and structured to be closer to its natural state. The total cost of the project was €3.5m, 50% of which was contributed by the European Union in the framework of LIFE.
As well as migrating species of fish, sand martins (*Riparia riparia*) kingfishers (*Alcedo atthis*) and naturally also people have benefited from the restoration of the region.

The Danube floodplain forest east of Vienna in Austria

Since 1996 a range of restoration projects have been carried out in the Danube Floodplain National Park. In this section the regulated Danube is still adjoined by wide belts of floodplain forest. For decades, however, these have lacked the connection with the Danube, they were drying out and turning into dry land.
In the framework of the restoration, numerous oxbow lakes have been more closely connected with the mainstream. This has happened e.g. through the reduction of the bank reinforcements. Thus, the current not only flows through the floodplain forest during floods but also at lower water levels. The drying out of the floodplain forest waters is thus prevented. The river dynamic ensures the shifting, the formation of new breaches of the banks, gravel banks and slip-off banks. Many fish species now find appropriate spawning grounds again. Other fauna and flora also profit from the newly gained diversity of habitats. Further measures were the networking of waters, the promotion of extensive cultivation of meadows, the dismantling of bank reinforcements and forest roads.

Wetland restoration in the Persina Nature Park and in the Kalimok-Brushlen protected area in Bulgaria

In 2000, Romania, Bulgaria, the Republic of Moldova and the Ukraine agreed about the protection and improvement of the “green corridor” of valuable wetlands in the lower course of the Danube.
In the past, the floodplain forests and wetlands were cut off from the Danube by dams and drained to turn them into agricultural areas. Valuable inundation areas and nutrient sinks were lost in the process.
In 2002 in the frame of the ”Danube-Black Sea Stragegic Partnership”, two restoration projects were started in two selected protected areas (Persina and Kalimok/Brusheln). The aim is the hydrologic reconnection of these wetlands. Danube water is to flow into the wetlands again through openings in the dams, weirs and canals.
The important spawning areas will thereby be accessible to fish again. The habitat for water birds such as the white-tailed eagle (*Haliaeetus albicilla*), the Dalmatian pelican (*Pelecanus crispus*) and the corncrake (*Crex crex*) will be improved.
Together with the local population and other stakeholders, the project is to be completed. The costs of approximately €4.2m are being covered by the World Bank, the EU, Bulgaria and other partners.

The islands of Balina and Cernova – two restoration projects in the Rumanian delta

Balina and Cernova are two islands in the Chillia branch of the Danube delta, both once arable areas.

The dykes surrounding Balina were opened at four spots already in 1994. In 1996 restoration works were started on Cernova. And already one year after the opening of the dykes and the restoration of the links to the Danube, that the restoration works showed effects. On both islands characteristic aquatic plants resettled. Fish use them again as spawning grounds. Even salination of the formerly drained soils inclined and took a way to the better by the natural floods.

Nowadays , in the delta at least 10,000 ha of the area are restored.

6.2. TOGETHER FOR THE RIVERS

Situation of the Black Sea

The unique ecosystem of the North-Western Shelf of the Black Sea is burdened by excessive loads of nutrients and hazardous substances from the coastal countries and the rivers that enter it – the most important of which is the Danube, followed by the Dnjestr and the Dnjepr. As a consequence of the relatively low water level the parts in the North-West are especially influenced by eutrophication and nutrients. The powerful inflow of phosphates and nitrates brought by rivers result in a proliferous growth of phytoplankton. This leads to a shortage of oxygen which reduces biodiversity near the bottom of the Sea.

Pollution inputs and other factors have radically changed Black Sea ecosystems beginning around 1960, and seriously threatening biodiversity and our use of the sea for fishing and recreation.
In addition to nutrient pollution, other pressures on the Black Sea ecosystems are organic pesticides, heavy metals, incidental and operational spills from oil vessels and ports, over-fishing and invasions of exotic species.

Since 1996 a certain recreation of the Black Sea can be noticed, but the changes are still unstable and the Black Sea not in the conditions of the environment observed in the 1960s. Algae blooms are still heavy and species diversity still not is as it was.

Also fish stocks declined, in the 1990s being three times less than in the 1960s. Near the Romanian coast even only a tenth of the former fish stock can be achieved. In 1980 only five species instead of 25 as it was in 1960 were of commercial interest.

In the Black Sea 165 fish species can be found, and also four species of marine mammals, three species of dolphins and the very endangered Mediterranean Monk Seal.