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Titel | Title

Mapping of potential habitats of Austropotamobius torrentium (Schrank, 1803) as a basis for a possible reintroduction in the catchment area of the Erlauf in the Ötscher-Tormäuer Nature Park

verfasst von | submitted by

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1 ABSTRACT

In this master thesis the distribution and abundance of stone crayfish (*Austropotamobius torrentium* (Schrank, 1803)) in a selected area of the Ötscher-Tormäuer Nature Park was analysed. The study area consists of the Erlauf river and its tributaries (Ötscherbach, Greimelbach, Lassing and Angerbach).

For this purpose, chemico-physical and ecological parameters of the water bodies were recorded in order to draw conclusions on the habitat suitability for the stone crayfish. The calculation of the associated chemical index, the hydromorphological database and the subsequent evaluation with Q-GIS showed that the potential quality and suitability as a crayfish habitat is given in many stretches of the investigated watercourses, especially in the Lassing, Ötscherbach, Angerbach and Erlauf. Only a short stretch of the Lassing above a reservoir is considered unsuitable. The water quality in all watercourses is considered to be very good, as the chemical index is above 90 valency points everywhere.

Despite this, only 6 records of stone crayfish were made in a short stretch of the Lassing in two years. No other crayfish species, such as the signal crayfish (*Pacifastacus leniusculus*), were found.
Possible reasons for the low number of stone crayfish are the timber drift in the 17th century and the construction of the Wienerbruck power station with its dams. Both have led to fragmentation and habitat alteration.

In conclusion, a residual population of stone crayfish can be found in the Ötscher-Tormäuer Nature Park, but it will not be able to sustain itself in the long term.

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2 INTRODUCTION

Originally, the noble crayfish *Astacus astacus* (Linnaeus, 1758) and the stone crayfish *Austropotamobius torrentium* were native to most running waters in Lower Austria. The stone crayfish is the most abundant species and has its occurrence in small, often isolated streams, while the noble crayfish nowadays is highly endangered (Hager, Eder and Hödl 1998).

Humans have directly or indirectly impacted the distribution and abundance of crayfish. Today, there are a number of other species in Lower Austria, such as the Galician swamp crayfish *Astacus leptodactylus* (Eschscholz, 1823), the Kamber crayfish *Orconectes limosus* (Rafinesque, 1817) and also the signal crayfish *Pacifastacus leniusculus* (Dana, 1852), the latter two introduced from America (Eder & Hödl, 1998). The so-called crayfish plague, a fungal infection caused by *Aphanomyces astaci* (Schikora 1906), which is often fatal, especially for native species, was also introduced to Austria (Oidtmann & Hoffmann, 1998). The signal crayfish, on the other hand, has developed a partial resistance to this disease (Hager, 2018).

Relatively little is known about the occurrence and distribution of crayfish in the area of the Ötscher-Tormäuer Nature Park. In 2019, an individual stone crayfish has been reported from a section of the Lassingbach. However, there are no data on the occurrence of other crayfish species. Furthermore, it is not known whether neozootic species such as the signal crayfish are already present.

Therefore, the aim of this study was to investigate the current status of crayfish within the Ötscher-Tormäuer Nature Park with special reference to the distribution and habitat requirements of the stone crayfish in order to derive possible conservation management steps.

3 DISTRIBUTION AND STATUS OF CRAYFISH

3.1 Worldwide distribution of crayfish

Crayfish, as the largest mobile invertebrates in inland waters, are present in all parts of the world except Africa, Antarctica and the Indian subcontinent where native taxa are lacking. Crayfish are divided into three families of decapods: Astacidae, Cambaridae and Parastacidae (Pöckl & Souty-Grosset, 2009).

There are over 640 species worldwide, with the greatest species diversity in North America and Australia (Crandall & Buhay, 2008). Northern hemisphere crayfish belong to the superfamily Astacoidea with the families Astacidae and Cambaridae. Both the native noble crayfish and the stone crayfish belong to the Astacidae (Pöckl & Füreder, 2009).

There are five species of crayfish native to Europe - the noble crayfish (*Astacus astacus* (L., 1758)), the European or Galician swamp crayfish (*Astacus leptodactylus* (Eschholz, 1823), the Russian crayfish (*Astacus pachypus* (Rathke, 1837)), the white-clawed crayfish (*Austropotamobius pallipes* (Lereboullet, 1858)) and the stone crayfish (*Austropotamobius torrentium* (Schrank, 1803)) (Pöckl & Souty-Grosset, 2009). All these species belong to family Astacidae. The natural European distribution of the two Astacidae genera, *Astacus* and *Austropotamobius*, is not known, as crayfish were introduced to Sweden as early as the 16th century, and their distribution in other parts of Europe, such as the British Isles, northern Germany and eastern Switzerland, can also be traced back to human influence (Pöckl, 1998a).

In addition to the native species, there are introduced crayfish in Europe. The spinycheek crayfish (*Orconectes limosus* (Rafinesque, 1817)) was introduced to Germany in 1890 and is now one of the most widespread species in Europe. It was mainly brought for the fishing industry. In the 20th century, the signal crayfish (*Pacifastacus leniusculus* (Dana, 1852)) was introduced to Sweden and the red swamp crayfish (*Procambarus clarkii* (Girard 1852)) to Spain, both mainly for economic reasons. Some other originally non-native species were brought to Europe through aquaristics and the edible crayfish trade, such as the marbled crayfish (*Procambus virginalis* (Lyko, 2017)), the Australian redclaw crayfich (*Cherax quadricarinatus* (von Martens, 1868)), and the Australian yabby (*Cherax destructor* (Clark, 1936)) (Pöckl & Souty-Grosset, 2009).

Only in Ireland, Norway and Estonia there are currently no North American crayfish in Western Europe (Pöckl & Souty-Grosset, 2009).

In addition to the American and Australian crayfish, the Galician swamp crayfish (*Astacus leptodactylus* ((Eschscholz, 1823)), which originates from the Ponto-Caspian basin, has also been released in many European water bodies (Pöckl & Souty-Grosset, 2009).

3.1.1 Distribution of crayfish in Austria

Four species are considered native to Austria, as they had already formed reproducing populations before 1900. These are the noble crayfish *(Astacus astacus)*, the stone crayfish (*Austropotamobius torrentium*), the white-clawed crayfish (*Austropotamobius pallipes)* and the European or Galician swamp crayfish (*Astacus leptodactylus*). In addition, there are three introduced species - the spinycheek crayfish (*Orconectes limosus*), the signal crayfish (*Pacifastacus leniusculus*) and the red American swamp crayfish (*Procambarus clarkii)* (Füreder, Weinländer & Perlinger, 2009).

A. astacus occurs throughout Austria but is restricted to larger streams with many hiding places and clay banks. *A. torrentium* is the most common species and colonises smaller streams at higher altitudes. Occurrences of *A. pallipes* are restricted to only two valleys in Carinthia and Tyrol. Typical *Astacus leptodactylus* habitats comprise lakes, gravelpit waters and backwater areas of rivers (Pöckl, 1998a).

3.1.2 Crayfish in Lower Austria

There are only two native species in Lower Austria, *Astacus astacus* and *Austropotamobius. torrentium.* The stone crayfish is the most widespread species. It is likely that one of the two species occurs in varying densities in almost all water bodies (Hager, Eder & Hödl, 1998). The species inventory in Lower Austria also comprises the Galician swamp crayfish, as well as the alien species signal crayfish and camber crayfish (Füreder, Weinländer & Perlinger, 2009).

It is not known whether the occurrence of *A. leptodactylus* is due to natural immigration or introduction (Hager, Eder & Hödl, 1998).

3.2 Causes of threats to native crayfish

Throughout Europe, populations of native crayfish are declining, and many species are critically endangered. The main reasons for the decline are habitat destruction and climate change effects such as droughts, land use and toxic substances, poor fishery management and the introduction of non-native species and diseases (Füreder, 2016).

Other literature sources (Hager, Eder & Hödl, 1998; Gamperl, 1990) identify similar causes for the decline of native crayfish populations.

These include habitat alteration due to construction measures and river straightening, resulting in a loss of structural diversity and changes in flow velocity, as well as water pollution from agricultural run-off and industrial toxic substances.

One of the main causes of the disappearance of many crayfish populations was the introduction of allochthonous species and, in this way, the crayfish plague (Hager, Eder, & Hödl, 1998).

3.3 Crayfish plague

Crayfish plague is a disease caused by the water fungus, *Aphanomyces astaci* (Schikora 1906), which is a major threat to European crayfish. The fungus was introduced from North America at the end of the 19th century, probably with infected American crayfish. The pathogen subsequently spread throughout Europe. The infection is still the biggest threat to native crayfish.

Crayfish plague is a highly contagious disease associated with a high mortality rate in some crayfish species, including *A. torrentium*. The causative aquatic fungus, *Aphanomyces astaci*, belongs to the oomycete family and is a filamentous fungus (Oidtmann & Hoffmann, 1998).

All European crayfish are highly susceptible to crayfish plague. North American species are considered to be largely unaffected. A possible reason for this is the common evolutionary development and thus an adaptation. The fungus infects the crayfish but cannot penetrate deep into skin layers. In case of infection, the pigment melanin is deposited around the entry site, which prevents further penetration (Cerenius & Söderhäll, 1984). With the next moult, the fungus is repelled and thus reenters the water. This defence mechanism has not evolved in European species (Svoboda et al., 2017).

3.4 The stone crayfish *Austropotamobius torrentium*

The following study will focus on the stone crayfish. Its distribution, ecology and biology will be discussed in more detail.

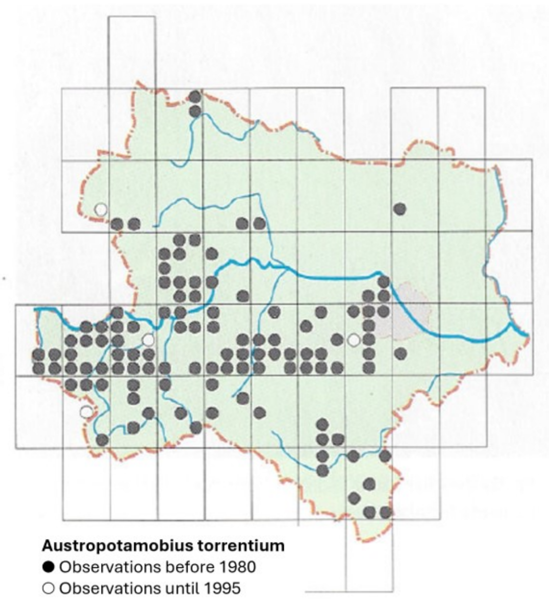

Figure 1 Distribution of *Austropotamobius torrentium* in Lower Austria (Peknyi & Pöckl, 1999)

The stone crayfish can be found in 20 countries and regions in Europe. Its distribution is restricted to central and south-eastern Europe. In the Alpine arc, the stone crayfish is widespread, and reaches the highest genetic diversity in the Balkan Peninsula (Pöckl & Souty-Grosset, 2009). According to that, this crayfish species is the most widespread in Lower Austria (figure 1) and is found in smaller rivers, with the main distribution being in the Mostviertel, the southern Waldviertel and the Alpine foothills (Hager et al., 1998; Pekny & Pöckl, 2000).

The typical habitat of the stone crayfish in Austria are the headwaters and upper reaches of water bodies with stony sediments. Forest streams are particularly favoured. However, the species can also be found in cooler, stagnant waters. Small streams with low water flow are also colonised. Stone caves and scours are important for permanent colonisation in order to be able to survive the increased volumes of water during periods of snowmelt The crayfish can therefore be found mainly under stones in the flow-calmed parts of the stream (Pöckl, 1998a).

The stone crayfish requires cold, clean, calcareous water. The optimum temperature in summer is between 14-18°C and should not rise above 23°C (Pöckl, 1998a). Sites with *A. torrentium* are therefore mostly located in narrow, shallow headwaters with lower stream orders, as well as steeper slopes and low current velocities. Where *A. torrentium* is present, there is also a higher proportion of woody debris and abundant refugial structures, but a lower proportion of stone boulders larger than 40 centimetres (Weinländer & Füreder, 2012).

In addition to these habitat requirements, the stone crayfish is also very sensitive to organic pollution (Pöckl, 1998a). It can therefore be used as a bioindicator for good water quality (Streissl, Chovanec & Käfel, 1998).

A. torrentium can be distinguished from other crayfish by a number of characteristics.

It is the smallest of the native crayfish, reaching a maximum body length of 12 centimetres, but usually remaining below 8 centimetres (Pöckl & Eder, 1998). The rostrum has a broad base with untoothed longitudinal sides that meet anteriorly to form an equilateral triangle. The acumen is not separated and is very blunt compared to other species. There is no median keel. The body is smooth with no spines or humps, and there are also no spines behind the cervical furrow. The colour is brown to olive but can also vary to light brown.

The claws are robust and strongly grained on the upper side. The dorsal side is the same colouration as the rest of the body, while the ventral surface of the claws is usually dirty white and brightly coloured. Males have stronger claws (Pöckl, 2009).

The greatest risk of confusion is with *A. pallipes* (Pöckl & Eder, 1998).

3.5 Conservation status

The Red List of Threatened Species lists four crayfish species in Austria (table 1) at different levels of threat. *A. leptodactylus* and *A. pallipes* are classified as critically endangered, *A. astacus* as endangered and *A. torrentium* as vulnerable (Petutschnig, 2009).

Table 1 IUCN Red List Categories and Criteria for Austrian crayfish species (Petutschnig, 2009)

	Categorie		
Astacus astacus (Linnaeus, 1758)	EN	Endangered	20 % probability of extinction in 20 years or 5 generations (maximum 100 years).
Astacus leptodactylus (Eschscholtz, 1823)	CR	Critically Endangered	50 % probability of extinction in 10 years or 3 generations (maximum 100 years).
Austropotamobius pallipes (Lereboullet, 1858)	CR	Critically Endangered	50 % probability of extinction in 10 years or 3 generations (maximum 100 years).
Austropotamobius torrentium (Schrank, 1803)	VU	Vulnerable	10% probability of extinction in 100 years.

Internationally, crayfish are protected by the Bern Convention and the Habitats Directive.

The stone crayfish and the white-clawed crayfish are listed in Annexes II and V, while the noble crayfish is only represented in Annex V.

Annex II lists animal and plant species of Community interest whose conservation requires the designation of special areas of conservation. Annex V describes species of Community interest whose removal from the wild and exploitation could be subject to management measures (Council Directive 92/43/EEC, 1992).

4 STUDY AREA

The study area for this thesis is located in the southern Mostviertel in Lower Austria in the Ötscher-Tormäuer Nature Park. The Nature Park covers an area over 170 km² in five municipalities (Annaberg, Mitterbach, Gaming, Puchenstuben and St. Anton) and is thus the largest in Lower Austria.

The Nature Park has its namesake in the 1893 metre high Ötscher peak. The Ötscher massif rises 600-800 metres above the foothills of the Alps. Its location on the mountain periphery means that it receives high rainfall of up to 1.800 mm per year.

The area is located in the northern limestone Alps on the border between the pre-alpine highlands and the high alpine mountain ranges. The landscape is characterised by the close juxtaposition of limestone and dolomite rocks with soft marl and sandstone. Limestone and dolomite form massive mountain ranges and rugged rock faces, while marl and sandstone shape forested, undulating mountains and basins (Heinrich & Wessely, 2015).

The close interaction of limestones and dolomites in the study area is shown in figure 2 (detail of geological map published by the Geological Survey of Austria).

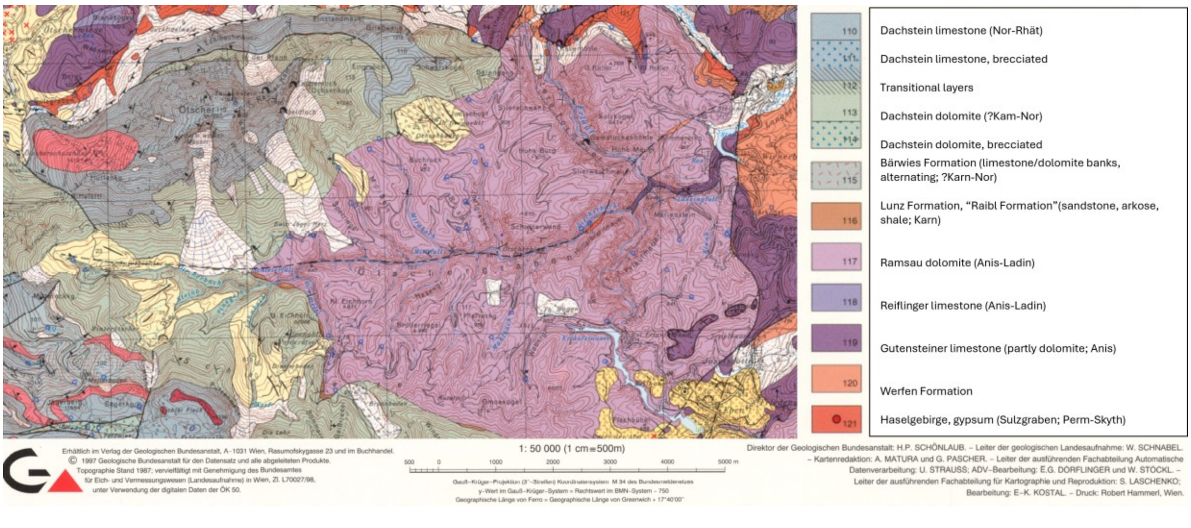

Figure 2 Geological map (Sheet Mariazell 72) of the study area showing the rock types with Ramsau dolomite in purple around the Ötscher (Record description in the federal reporting network 6810, Geologische Bundesanstalt Wien, 1997)

The summit of the Ötscher consists of Dachstein limestone, which changes to Dachstein dolomite towards the south. Southeast of the summit, in the area of the Hintere

Tormäuer and Ötschergräben, Ramsau dolomite is found. There are also several moraines (yellow areas) from the Würm glaciation.

To the south of the Ötscher, a system of more than 20 kilometres of gorges has been formed, the so-called Ötschergräben and Tormäuer.

More than two thirds of the total area of the Nature Park area is forested. Forests therefore represent the largest habitat complexes in terms of area, in some municipalities over 80%.

4.1 Protected areas and important habitats

The Nature Park is of national and international importance and part of the European protected areas "Ötscher-Dürrenstein" (FFH area and bird sanctuary), comprising the Ötscher-Dürrenstein Landscape Protection Area as well as numerous natural monuments (caves, trees, etc.) (figure 3 & figure 4). In addition to the beech forests, their replacement communities, the dry slope beech forests, ravine and slope mixed forests, the moor forests and the subalpine beech forests are of particular importance, as they occur in highly representative populations. Other highly representative habitats are the alpine and subalpine habitat types that are naturally characteristic of the Alpine region. Above the tree line, a variety of habitats have developed, such as natural limestone cliffs and rock outcrops, limestone screes and limestone pioneer grasslands. Due to the calcareous water, thick sinter deposits (calcareous tufa springs) with occurrences of rare spring snail species and fens in the wet surroundings of the streams develop at the outlets of the springs. Along the near-natural mountain streams additional representative habitat types, such as the lavender willow and buckthorn riparian scrub exist. The numerous karst formations include a high number of caves, e.g. the Ötscher caves, the longest cave system in Lower Austria.

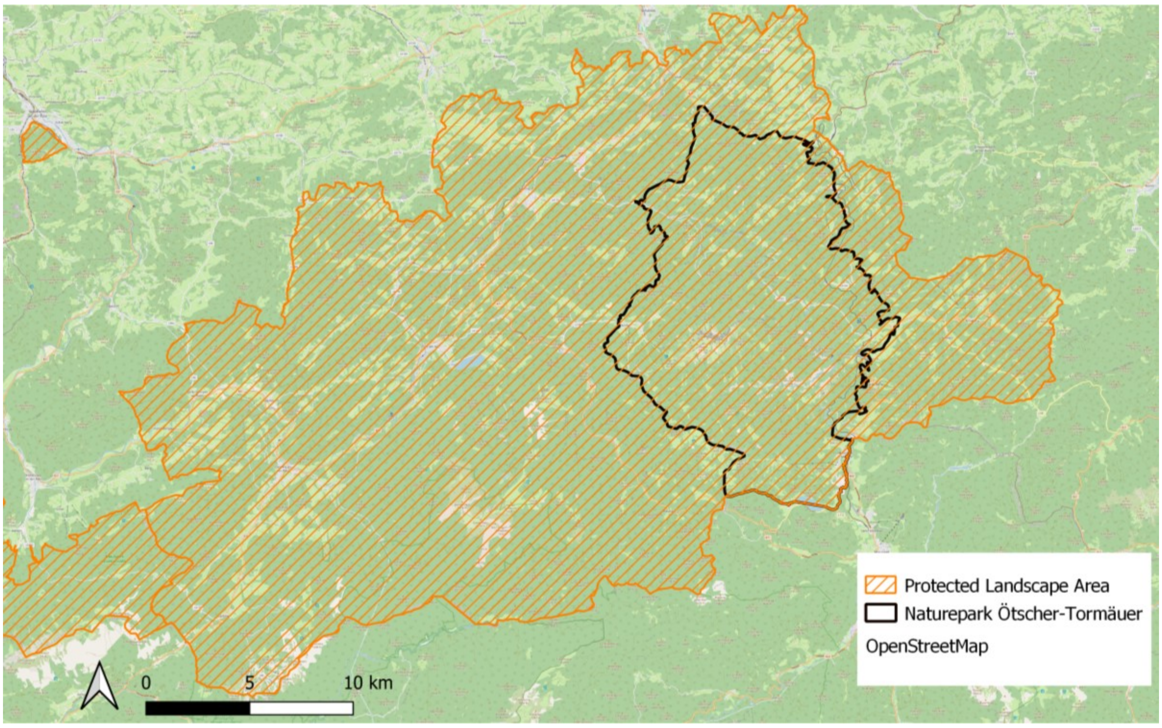

Figure 3 The Ötscher-Tormäuer Nature Park (black) embedded in the Ötscher-Dürrenstein nature reserve (orange). Data source: Department RU5 - Nature Conservation / Office of the Lower Austrian State Government - http://www.noe.gv.at/. Data source background map: basemap.at. Map created in January 2025

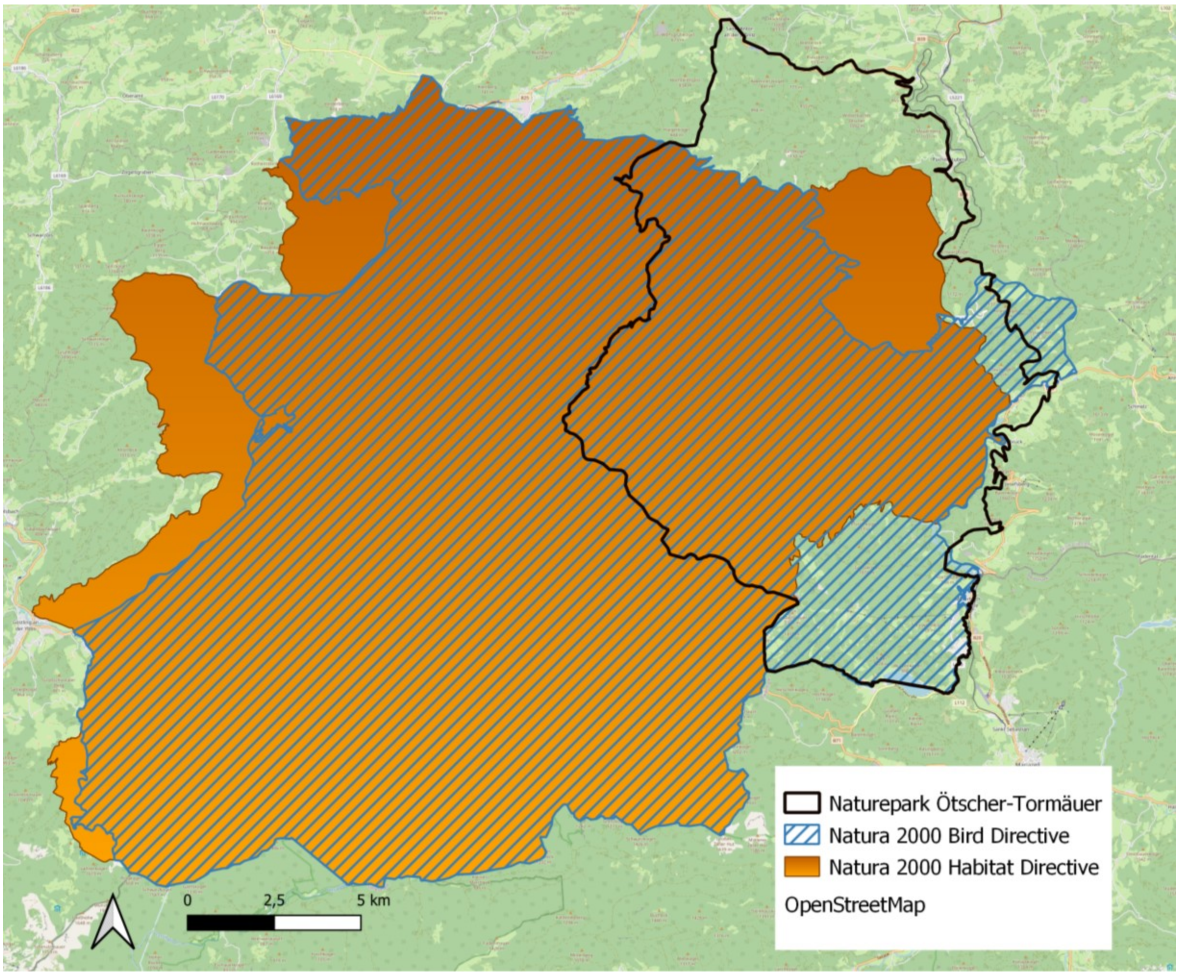

Figure 4 The Ötscher-Tormäuer Nature Park (black) in the Ötscher-Dürrenstein Natura 2000 protected area. Data source: Department RU5 - Nature Conservation / Office of the Lower Austrian State Government - http://www.noe.gv.at/. Data source background map: basemap.at. Map created in January 2025

4.2 The study area in detail

The present study focuses on the rivers and watercourses in the southern part of the park. The investigations were carried out at altitudes between 620 and 790 metres above sea level, i.e., in the montane elevation zone. The water bodies studied were limited to a section of the Erlauf and selected tributaries. These include the Ötscherbach with all its permanently flowing tributaries, the Lassingbach and the Angerbach.

There are also three reservoirs in the study area that were sampled. These are the Erlauf, the Wienerbruck and the Stierwaschboden reservoir. Both the Erlauf and the Stierwaschboden reservoir are formed by the Erlauf river. The Wienerbruck reservoir is an impoundment of the Lassing.

4.3 The watercourses in the study area

4.3.1 Erlauf

The Erlauf, a tributary of the Danube, is about 70 kilometres long, rises at Mariazell in Styria and has its mouth into the Danube at Pöchlarn in Lower Austria.

Downstream of Lake Erlauf at the Styrian-Lower Austrian border the river transverses the Ötscher-Tormäuer Nature Park where a number of tributaries discharge - Ötscherbach, Angerbach, Trefflingbach and Kleine Erlauf.

Together with the Hintere and Vordere Tormäuer, the Erlauf created a canyon system some 20 kilometres in length with a number of tourist facilities e.g. recreation areas and hiking trails.

Two power plants are located along the Grosse Erlauf in the study area: a dam was built at Mitterbach to create the Erlauf reservoir where hypolimnetic water release feeds the Wienerbruck power plant. Immediately downstream, the Ötscherbach discharges into the Erlauf, followed by another dam, which supplies the Erlaufboden power plant.

4.3.2 Angerbach

The Angerbach is a right tributary of the Erlauf and rises north of Reith in the municipality of Annaberg. After about 5 kilometres it flows into the Erlauf at Erlaufboden.

The source of the Angerbach is 975 metres above sea level. The river covers an elevation range of 440 metres, with the first section being particularly steep.

4.3.3 Lassing

The Lassing is an approximately 15-kilometre-long tributary of the Erlauf River. It originates south of Annaberg and converges with the Erlauf in the Ötschergräben region. The Wienerbruck power station, along with its associated dam, was constructed at the beginning of the 20th century. Downstream of the dam, the Lassing River forms the Lassing waterfall, which drops 90 metres in elevation. In the initial stretch, the Lassing flows through populated areas and agricultural land before reaching the Wienerbruck reservoir.

Beyond this point, the riverbed remains unobstructed, leading to the formation of a natural gorge landscape until its confluence with the Erlauf.

Figure 5 illustrates the location of the Erlauf, Angerbach, and Lassing rivers within the study area, defined by a 100-metre-wide buffer. Surrounding land use information is derived from the CORINE Land Cover 2018 dataset provided by the European Environment Agency.

It is evident that only the Lassing River passes through populated areas. The varying shades of green correspond to different forest types, which constitute the predominant land use in the region. Within the depicted section, the Erlauf River flows through the gorge of the Hintere Tormäuer, which accounts for the sparsely vegetated areas. Additionally, it is apparent that all three river systems intersect agricultural areas, with the Angerbach River having the largest proportion of agricultural land.

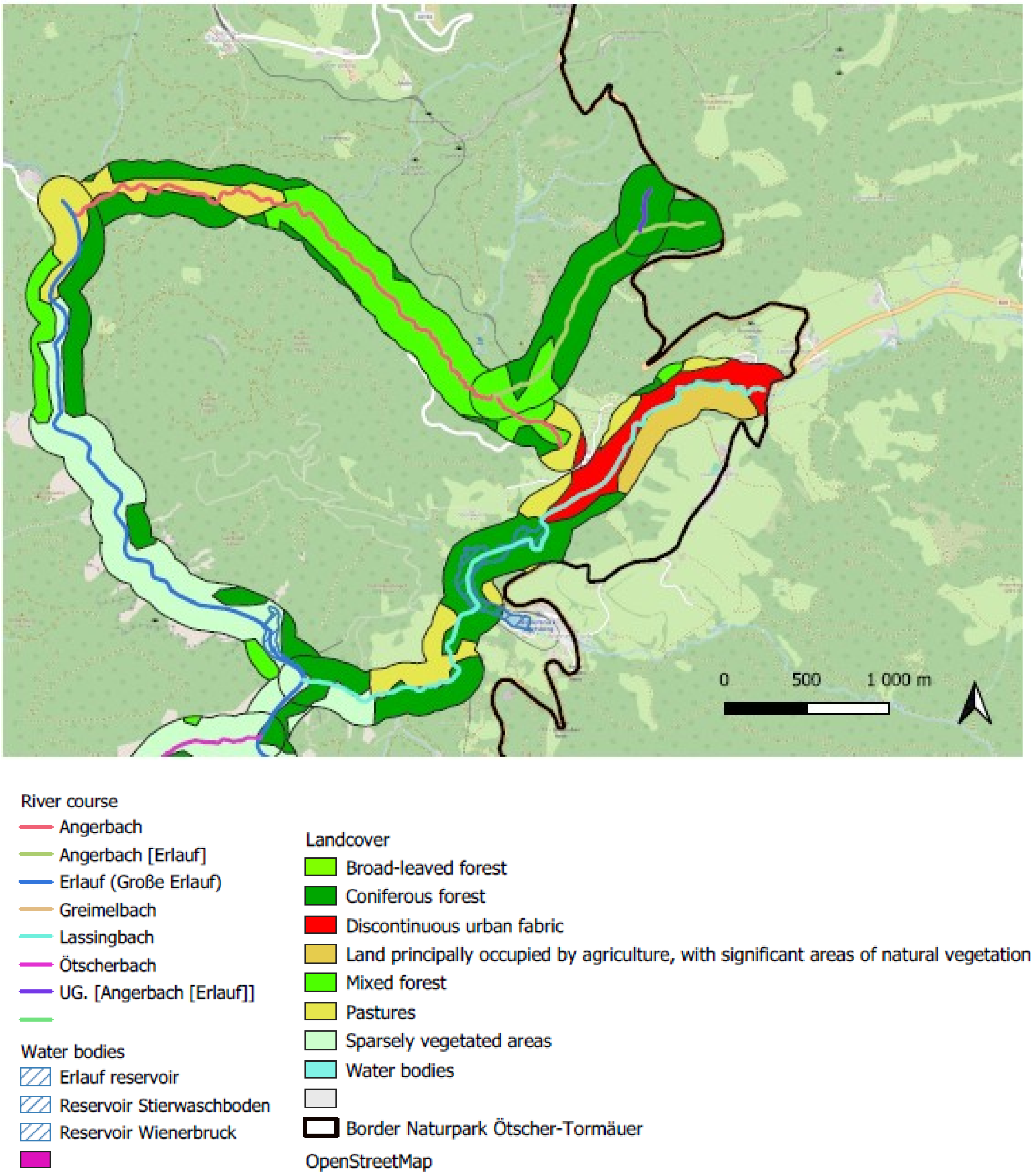

Figure 5 Stream sections of Angerbach and Lassing within the study area. For a 100-metre buffer the surrounding land use is shown. Data source: (European Environment Agency) (2019). Corine Land Cover 2018 (raster 100m) version 20 accounting layer, June. 2019 https://data.opendatascience.eu/geonetwork/srv/api/records/5a5f43ca-1447-4ed0-b0a6-4bd2e17e4f4d

4.3.4 Ötscherbach & Greimelbach

The Ötscherbach River remains completely unobstructed throughout its entire course, spanning 9 kilometres from its source to its confluence with the Erlauf, and has preserved its natural flow. The vegetation along both banks is characteristic of gorge forest ecosystems, with species such as *Acer* sp., *Tilia* sp., and *Salix* sp. One of its tributaries, the Greimelbach, is influenced by surrounding red deer feeding areas, some agricultural land use, such as alpine pastures (e.g., the Vorderötscher refuge), and, to a lesser extent, tourism, as a heavily trafficked hiking trail runs alongside the stream. The landscape patterns in the region include a variety of forest types and the sparsely vegetated ravines typical of the Ötschergräben which also can be seen in figure 6.

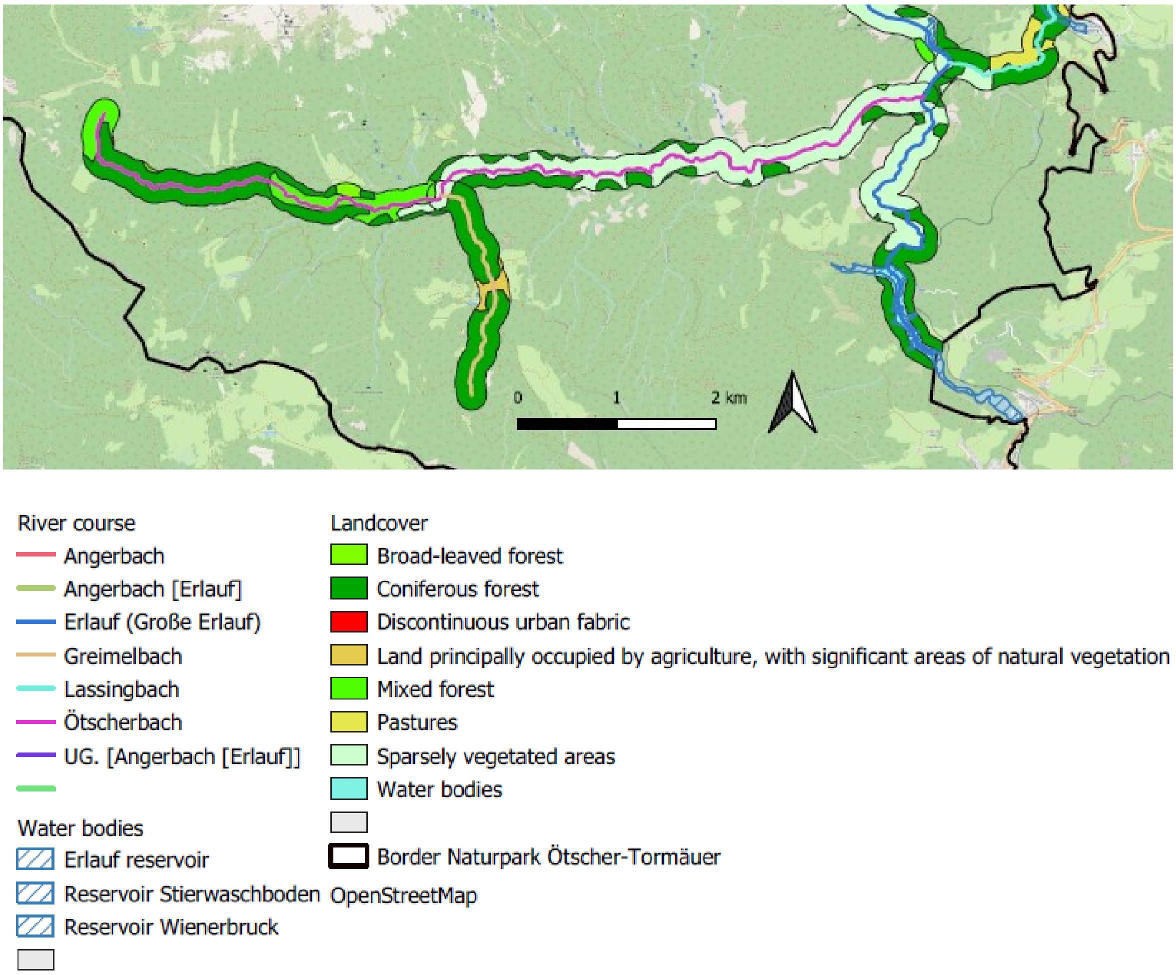

Figure 6 Stream sections of Erlauf, Greimelbach, Ötscherbach and Lassing) within the study area. For a 100-metre buffer the surrounding land use is shown.
Data source: (European Environment Agency) (2019). Corine Land Cover 2018 (raster 100m) version 20 accounting layer, June. 2019
https://data.opendatascience.eu/geonetwork/srv/api/records/5a5f43ca-1447-4ed0-b0a6-4bd2e17e4f4d

4.4 Hydromorphological description

The incorporation of the European Water Framework Directive into the Austrian Water Act resulted in the need to develop new assessment procedures for the ecological status of running waters (Hartmann & Moog, 2012).

Regional classifications include either landscape elements, like ecoregions, biogeoprahic provinces or a combination of both (Hawkins & Norris, 2000).

The typification of watercourses in Austria combines considerations of purely abiotic factors with biocenotic elements. In addition to these watercourse bioregions, catchment area and altitude are also considered in the hydromorphological typology ('Leitbilder') by Wimmer et al. (Wimmer, Parthl, & Wintersberger, 2012a). These typologies can be used to assign the study stream to water body types.

The purpose of water body typology is to classify the different natural water bodies in a descriptive system on the basis of a given set of ecological parameters. This also allows statements to be made about the character of a water body, references to other water bodies and its ecological status (Wimmer, Parthl, & Wintersberger, 2012a).

The classification of hydromorphological types is based on several concepts. The starting point are the ecoregions according to Illies (Illies, 1978). These are regions published in the "Limnofauna Europapaea" which are based on zoogeographical principles. From the 25 ecoregions in Europe, only 6 are of significance for Austria. The study area Ötscher-Tormäuer Nature Park is assigned to ecoregion 4, the Alps, more specifically to subregion Northern Alps (Moog et al., 2001).

For a typology of watercourses within restricted areas, e.g. the watercourses in Austria, the level of ecoregions needs some fine-tuning. Therefore, Fink et al. (2000) provided a more detailed classification based on a combination of geo-ecological parameters such as geology, climate, elevation, catchment area and vertical vegetation gradients. This results in 40 natural river basin types, 17 running water type regions and 9 special types. According to this classification, the study area is located in the Limestone Pre-Alps (Fink, Mogg, & Wimmer, 2000).

A further linkage of abiotic factors with biocenotically similar stream types resulted in the 15 stream bioregions that form the basis for the definition of the hydromorphological types proposed by Wimmer et al. (2012b) using morphological, water body-specific characteristics such as alignment, gradient, substrate distribution and other morphological structures such as deadwood, bank characteristics and differences in depth and width of the watercourse. In the context of the streams investigated in the present study, all watercourses belong to the bioregion Limestone-Prealps (bioregion 5). Catchment elevation is divided into 5 groups, with all study streams falling in the 500-to-799-metre range above sea level, thus belonging to group 3. Finally, according to the inventory of Wimmer & Moog (1994), the catchment area of Lassingbach, Ötscherbach and Angerbach are of class 3, the section of the Erlauf within the study area of class 4. The combination of bioregion, catchment elevation and stream order define type 5-3-3 for Lassingbach, Ötscherbach and Angerbach, and 5-3-4 for the Erlauf.

4.4.1 Hydromorhological descriptions for the study streams according to Wimmer et al. (2012b)

<u>Type 5-3-3: Ötscherbach, Lassingbach and Angerbach (figure 7)</u>

The runoff is characterised by nival and winter-nival regimes. The valley form is described as notch and trough valley, the slope is medium to steep. The watercourse is mostly 5-15 metres wide, predominantly elongated, branched, sometimes sinuous, and fast flowing. The stream bed is shaped by distinct gravel bars, high bedload, steep and shallow banks, undercut slopes, woody debris, and a generally high variability in width and depth. Floodplain vegetation is present. The riverbed is characterised by a heterogeneous substrate distribution with dominating stone and gravel fractions. A special feature of this type of watercourse is the partial development of canyon areas. This description fits the rivers in the study area, as the hydromorphological surveys have also shown.

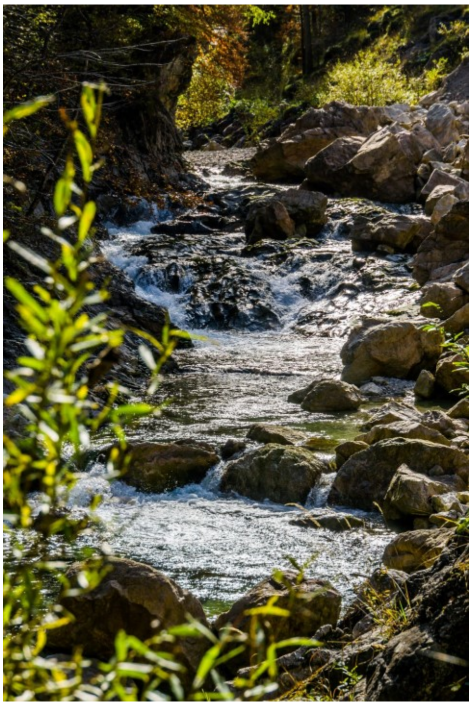

Figure 7 The type 5-3-3 of the hydromorphological model, as shown by a section of the Ötscherbach. Photographer: Fred Lindmoser

Type 5-3-4: Erlauf (figure 8)

In contrast to type 5-3-3, these are larger rivers with a moderately nival flow regime and a higher stream order (up to 6). The gradient is medium to steep, and the alignment is stretched to sinuous. Streams of this type are 15-50 metres wide and fast flowing to turbulent. The morphological structures are the same as described for the previous type. However, the riverbed is dominated by rocks and coarse gravel; Ravines may be present. This description fully applies to the section of the Erlauf in the study area.

Figure 8 The described type 5-3-4 of the hydromorphological model, as shown by a section of the Erlauf. Photographer: Fred Lindmoser

5 MATERIAL AND METHODS

The aim of this study was, on the one hand, to map the existing stone crayfish populations in the Ötscher-Tormäuer Nature Park and, on the other hand, to create a map of potential stone crayfish habitats. In a first step, chemico-physical parameters were collected in order to calculate the chemical index and thus to verify the water quality.

At the same time, hydromorphological surveys and an area-covering crayfish mapping were carried out. For this purpose, the ecological habitat parameters of each water body were recorded, and the existing crayfish populations were mapped and further investigated by means of crayfish traps and night-time inspections.

5.1 Chemico-physical parameters

The physico-chemical assessment procedure of water bodies includes parameters such as pH, water temperature, conductivity, several oxygen parameters and nutrients, for example nitrate and nitrite. One method of summarising these individual parameters and presenting them in a dimensionless index is the so-called Chemical Index (CI) (Hess & Wärtling, 2000).

The Chemical Index (CI) developed by Bach (1980) combines the oxygen balance and nutrient load with parameters relating to the physical properties of the water. It is a weighted water quality index. Its application is limited to running waters (Bach, 1980).

For each sample, eight parameters are measured (table 2). Next, for each parameter, valency points between 0 and 100 are obtained from a set of nomograms given in Annex 10.1. which are subsequently weighted (table 2). The CI for each sampling point is calculated using a multiplicative approach (Hess & Wärtling, 2000) given by the following equation:

$$CI = \prod_{i=1}^{n} q_i^{wi} = q_1^{w1} \times q_2^{w2} \times \ldots \times q_n^{wn}$$

n… number of parameters used

q_i… Subindex for parameter *i*

w_i…weighting for parameter *i*

Table 2 Paramaters of the Chemical Index (CI) by Bach (1980) and their weighting factors

Parameter		Unit	Weighting
1	oxygen saturation	%	0,20
2	BOD_5	mg/l	0,20
3	Temperature	°C	0,08
4	Ammonium NH_4	mg/l	0,15
5	Nitrate NO_3	mg/l	0,10
6	Phosphate PO_4	mg/l	0,10
7	pH-Value		0,10
8	Conductivity	µS/cm	0,07
	n=8		Σ=1

The calculations yield index scores between 0 and 100 and can then be categorized according to water quality classes.

5.1.1 Chemical Index

In the chemical analysis of water quality, physico-chemical parameters (pH, temperature, conductivity), oxygen levels and various plant nutrients (ammonium, nitrate, phosphate) are determined (Hess & Wärtling, 2000). These parameters can be used to calculate the chemical index shown above.

Taking samples

Water quality tests were conducted at selected points, where pH, water temperature, and conductivity were directly measured and recorded on-site. For additional analyses, water samples were collected and transported in cool bags for further testing. All water samples were taken on 7 May 2019.

At each sampling location, a 2-liter plastic container was repeatedly rinsed with the water before being filled by drawing it against the flow direction. Stones and other debris were removed using a kitchen sieve, and the water was then transferred into 1-liter dark glass bottles, which were sealed airtight. The bottles were carefully labelled and packed into an insulating bag for transport.

Details on the specific parameters tested and the equipment used are provided below.

Oxygen

The biocoenosis in a stream is strongly dependent on oxygen which governs its overall fitness as well as species composition. In the context of the CI, oxygen is measured both in terms of dissolved oxygen saturation (%) and Biological Oxygen Demand (BOD_5). Oxygen saturation describes the ratio of dissolved oxygen concentration to the maximum of oxygen dissolvable, which is temperature and pressure dependant, and was measured using the electrode of a WTW oximeter.

When measuring the biochemical oxygen demand, the physiological conditions of a water sample are optimised to such an extent that the oxidisable substances are the only limiting factor for oxygen consumption. The oxygen consumption is therefore directly proportional to the amount of organic impurities contained.

BOD_5 values provide an indication of the oxygen depletion in the water, which is caused by biochemical degradation processes (Hess & Wärtling, 2000).

To determine the BOD5 Oxitrop single measuring systems from WTW were used

In a first step, the water was saturated with oxygen and then the vessel was closed with the rubber seal belonging to the Oxitrop.

The water samples were stored at a constant temperature of 20°C and the values were read again after five days.

Water temperature

The temperature of a body of water primarily determines the reaction rate of chemical processes and the solubility or volatility of various elements. The relevant oxygen content for the biocoenosis in a stream is also heavily dependent on the water temperature (Hess & Wärtling, 2000). This parameter was measured with the WTW oximeter which also has a temperature sensor.

Conductivity

Conductivity is a measure of the total concentration of ions dissolved in water. It can therefore be used as a parameter for the biogenic and anthropogenic input of dissolved substances into water (Hess & Wärtling, 2000).

The measurement was carried out with a WTW conductometer directly at the sample sites.

pH

The pH-value is a measure of the acidity of a solution in a scale ranging from 0 to 14 (Gorde & Jadhav, 2013). The pH is defined as the hydrogen ion concentration given as negative decadic logarithm: pH = -log c(H^+). The higher the concentration of H^+ ions, the stronger its acidity (Hess & Wärtling, 2000). Water with a pH-value below 7.0 is considered acidic while it is alkaline with a value greater than 7.0.

The pH value was measured directly at the test sites in the water using a WTW pH meter. To do this, the probe was immersed in the flowing water until readings were stable.

Ammonium (NH_4^+), Nitrate (NO_3^-), Phosphate (PO_4^{3-})

One of the most important indicators of pollution in flowing waters is ammonium. It is formed during the microbiological decomposition of nitrogenous, organic substances under low-oxygen conditions. Ammonium can enter water bodies directly, especially in the case of agricultural overfertilization (Bach, 1980).

Ammonium and nitrate are the primary nitrogen sources for plants, which is why an increased concentration of nitrogen compounds contributes to the eutrophication of water bodies (Hess & Wärtling, 2000).

Equally critical for water quality is contamination with phosphates, which can enter the water through detergents or fertilisers. Phosphorus is a minimum nutrient and controls algal growth, making it a key contributor to the eutrophication of water bodies (Hess & Wärtling, 2000).

Ammonium NH_4^+

The ammonium value is determined using the MERCK Ammonium test kit (figure 9) which includes a colour chart comparator. The ammonium ions form a yellow-brown compound, which is then determined by visual comparison with the colour fields of a scale.

The determination is carried out as follows:

- 20 ml of the water sample are added to each of the two glasses. Glass B remains the blank sample.
- Add 5 drops of reagent 1 NH_4-1 to glass A. Then mix the sample.
- Add 5 drops of reagent 2, NH_4-2 with potassium tetraiodomercurate.

- Reagent 3, NH_4-3 sodium hydroxide, is also added with 5 drops and mixed.
- Leave the sample to stand for 3 minutes.
- Compare the samples with the colour chart until the test tubes match in colour when viewed from above. Then read the corresponding value on the chart.

Figure 9 The determination kit for the ammonium content from Merck KGaA (left); the test tube and the three reagents are shown at right

Nitrate NO_3^-

Nitrate was analysed with Fluka Analytical's Aquanal®-plus (figure 10).

The method is used to determine NO_3- ions. A suitable reducing mixture is used to reduce nitrate to nitrite. Nitrite is oxidized by an aromatic compound, which then combines with a second reagent to form an azo dye in a further reaction. The colour can then be determined using a scale.

The exact procedure is as follows:

- A reaction flask and glass B are each filled with 5 ml of the water sample.
- 1 level measuring spoon of reagent 1, sulfanilic acid, is added to the reaction flask and then shaken for 30 seconds.
- Add 1 level measuring spoon of reagent 2 - Boric acid and Cadmium to the reaction bottle. Then shake again for 30 seconds. Leave the solution for 5 minutes.
- Pour the contents of the reaction bottle into glass A and place on the color scale.
- Read off the corresponding value.

Figure 10 The Fluka Analyticy Aquanal-plus nitrate determination kit (left). The sample glasses, the reagents (black containers) and the colour scale for comparison is shown at right

Phosphate PO_4^{3-}

MERCK's phosphate test kit (figure 11) was used to determine the phosphate concentration.

As with the previous methods, this method also involves comparison with a colour scale.

In a sulfuric acid solution, orthophosphate ions combine with molybdate ions to form molybdate phosphoric acid, which is reduced with ascorbic acid to form phosphorus molybdenum blue.

The analysis is carried out as follows:

- Tube A and tube B are each filled with 20 ml of the water sample. Tube B remains as a blank sample.
- In tube A, 5 drops of reagent 1, sulphuric acid, are mixed.
- Then a level measuring spoon of reagent 2 is added.
- The measuring glass is shaken until the reagent is completely dissolved.
- Allow the glass to stand for 3 minutes.
- Compare the samples with the colour chart until the test tubes match the colours as closely as possible when viewed from above.
- Read the corresponding value.

Figure 11 Phosphate test kit from Merck (left). The comparator with the sample glasses and the colour scale is shown at right

5.1.2 Sampling sites

The selection of sampling sites for the CI measurements were based on the following aspects:

- All water bodies in the study area should be represented.
- The CI sampling sites should represent ‘worst case’ scenarios in the mapping area, including locations with the highest possible anthropogenic impact due to tourism, hunting or agricultural activities.

Sampling site 1 - Lassing waterfall (figure 12)

The first sampling site is located immediately upstream of the Lassing Waterfall, near a popular hiking trail that includes a bridge crossing the Lassing River. The sampling point is situated just below the bridge pictured on figure 12. The flow velocity at this location is low, and the water depth reaches a maximum of 30 cm. Due to scouring, several small side channels have been partially disconnected from the main flow of the stream.

At midstream, small gravel islands have formed, with stands of *Salix* L. spp. present. The water surface is only partially shaded by larger trees. Both the on-site investigations and the water sampling were conducted at midstream

Figure 12 Sampling site above Lassingfall between a smaller two-metres-high waterfall and the bridge over the Lassing. The hiking trail runs along the river and over the bridge; Own photograph

Sampling site 2 – Ötscherbach around Ötscherhias (figure 13)

The Ötscherhias, seen on figure 13, is a tourist facility in the centre of the Ötschergräben gorge and accessible by a popular hiking trail. The Ötscherbach is a hard-substrate channel with high current speed at midstream and between 5 and 10 metres wide. Due to scouring, small side channels, cascades and gravel banks provide a high degree of structural diversity and heterogenous depth profiles. Close to the hiking trail the banks are flat, but very steep on the opposite bank, with rock face up to 50 metres high. There is no shading tree canopy. The stream is accompanied in this section only by single riparian trees (*Salix* L: spp., *Pinus mugo* Turra, *Amelanchier ovalis* Medikus).

Figure 13 Sampling site Ötscherbach - Picture left: Ötscherhias restaurant with the hiking trail along the Ötscherbach; Picture right: actual measuring point 10 metres downstream from the bridge to the Ötscherhias; Own photographs

Sampling site 3 – Greimelbach (figure 14)

The Greimelbach rises on the northern face of the Gemeindealpe at an altitude of over 1000 metres above sea level and, after 2,5 kilometres, discharges into the Ötscherbach at an altitude of about 750 metres above sea level. The Greimelbach has a rapid flow and is characterized by several small waterfalls; maximum width is 5 metres. The accompanying vegetation on both sides is a canyon forest with *Acer pseudoplatanus* L., *Ulmus glabra* Hudson, *Pinus mugo* Turra and *Fagus sylvatica* L.

In the immediate vicinity of the spring and also in the further course of the stream there are feeding grounds for red deer. This is also the reason for the selection of this sampling point in order to evaluate a possible impact on water quality.

Figure 14 Sampling site Greimelbach; Own photograph

Sampling site 4 – Angerbach (figure 15)

The Angerbach, seen on figure 15, rises at the north of Reith at 970 metres above sea level, situated in the municipality of Annaberg, and, after a length of 5 kilometres, discharges into the Erlauf near Erlaufboden. The elevation range of its catchment is 440 metres. At the downstream sampling point the Angerbach is bordered by pastures. In order to investigate the impact of cattle grazing, the sampling site was selected precisely here.

Figure 15 Sampling site Angerbach in Erlaufboden with agricultural area on the right bank of the river; Own photograph

Sampling site 5 – Erlauf reservoir (figure 16)

The Erlauf reservoir is the larger of the two reservoirs and has a capacity of 1.4 km³.

The reservoir was created in 1908-1911 with the construction of a 37-metre-high dam.

The reservoir is almost 2.800 metres long, but on average only 50 metres wide, with a maximum depth of 26 metres (Simmler, 2013).

The banks of the reservoir are partly mixed forests used for forestry and partly steep rock faces with little vegetation. There is a hiking trail around the reservoir.

Due to the fluctuating water levels, there are widely varying water levels, especially at the inlet of the Erlauf. This leads to the strong growth of aquatic plants and various types of grass and sandbanks.

Due to the use of the water for electricity production and the associated water level fluctuations, the water is permanently in motion and resembles a lenitic section of a stream. This is also the reason why the chemical index has also been taken for this site.

When taking samples, care was taken to mix the zones - surface, middle layer and deeper zone. Measurements were also taken at several points around the reservoir and combined into a mixed sample.

Figure 16 Sampling site Erlaufstausee. Top: directly downstream of the inlet of the Erlauf with water plants in the foreground; bottom: centre of the reservoir with steep rock faces and forests with dominant spruce. Photographer: Fred Lindmoser

Sample site 6 – Wienerbruck reservoir (figure 17)

The Wienerbruck reservoir, which also operates the Wienerbruck power station in the Ötschergräben, has a surface area of approximately 10 hectares, making it significantly smaller than the Erlauf reservoir in Mitterbach. Due to its relatively shallow depth, typically only a few metres, the reservoir experiences increased growth of algae and aquatic plants, particularly during the summer months. The lakebed consists of mud and sand.

The riparian vegetation is sparsely developed in some areas, resulting in insufficient shading of the water surface. In the western, less accessible part of the reservoir, there is a region with reeds and rushes, providing a sanctuary for various waterfowl.

The Mariazell Railway tracks run along the eastern shore of the lake, and at the northern end, a bridge crosses the water surface. On the opposite bank, there are a road and hiking trails. The water level in the reservoir fluctuates in response to the operations of the power station, although these fluctuations are less pronounced than those observed in the Erlauf reservoir.

As previously noted at sample site 5, a mixed sample was taken from multiple locations and varying depths within the reservoir.

Figure 17 Wienerbruck reservoir with the tracks of the Mariazell Railway on two sides and a hiking trail on the northwestern shore. Photographer: Fred Lindmoser

The figure 18 illustrates the distribution of the survey points in the different water bodies.

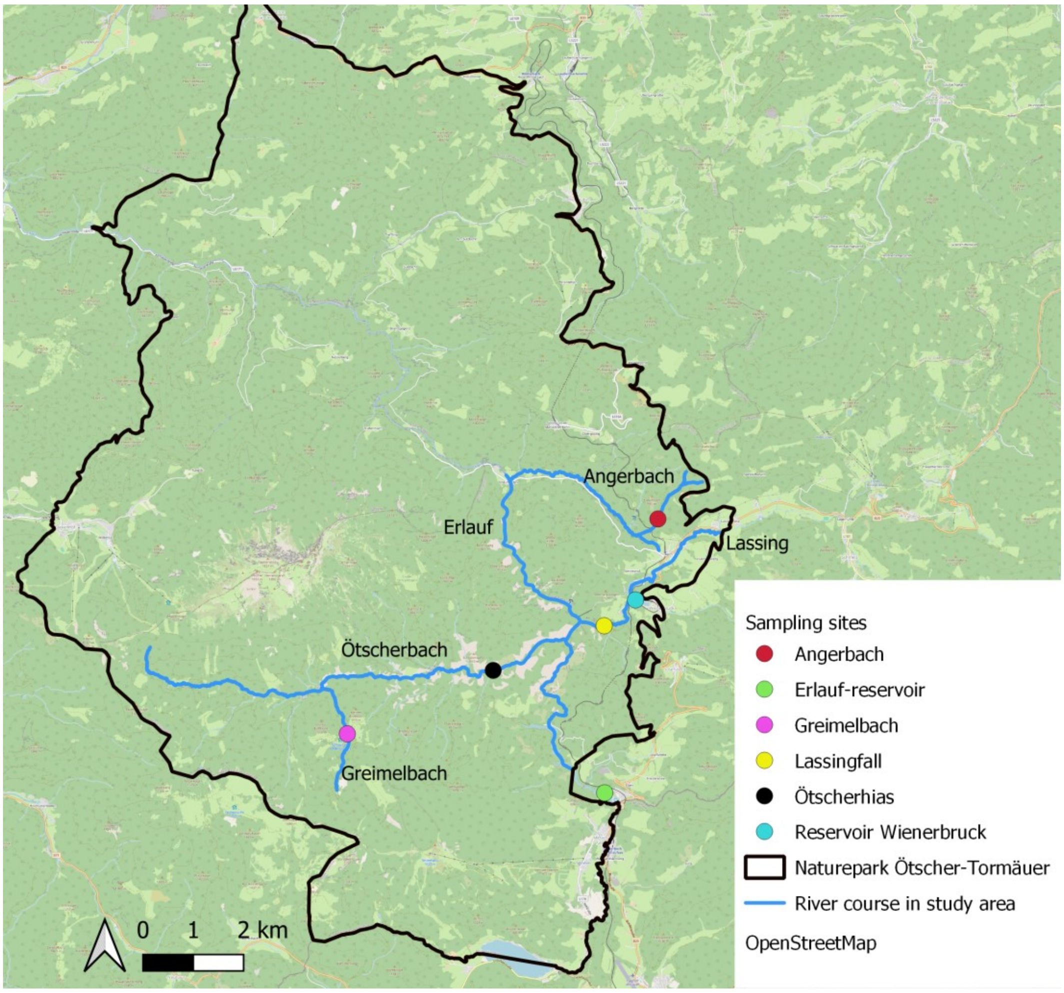

Figure 18 Overview of the study area with the sites for the chemico-physical analyses

5.2 Hydromorphological and ecological parameters

In addition to the chemico-physical analyses of the water bodies, ecological parameters were also recorded.

A hydromporhological survey was designed for this purpose (see Annex 10.2: Hydromorphological Survey Sheet). The assessments is based on the typology of watercourses in Austria published by the Federal Ministry of Agriculture, Forestry, Environment and Water Management in 2012 (Wimmer, Parthl, & Wintersberger, 2012a) with relevant parameters selected as basis for the mapping of crayfish . The survey sheet was expanded to sharpen the description of the riparian vegetation, based on the ecomorphological determination of water bodies according to Werth (Werth, 1987).

In the hydromoprhological survey, some additional parameters were collected, including the classification into choriotopes, the flow behaviour and course of the river, morphological structures such as waterfalls, sandbanks, dead wood and the bank profile on both sides. In addition, the vegetation structure on both banks was assessed according to predefined criteria, including the degree of shading by the canopy.

The runoff in conjunction with flow is an essential design element for the shaping of a riverbed and, thus, sediment sorting and shaping of the existing substrate. Substrate diversity decreases from structurally rich rhithral waters downstream to more homogeneous potamal waters. However, erosion, rearrangement and sedimentation processes also have an influence, and so different substrates can frequently alternate on a small scale. The higher the morphological dynamics and activity of a watercourse, the greater the substrate diversity (Wimmer, Parthl & Wintersberger, 2012a).

According to Steffan (Steffan, 1965), choriotopes are partial habitats of the riverbed. The structure-forming substrates are defined according to grain diameter (Moog, 2014). The term refers to sediments such as sand, gravel and rock as well as organic materials and living plant parts (Moog, 2014).

In this study, the term choriotopes is used to refer to substrates categorised by grain size. The categorisation of the 7 fractions is shown in the following table 3 based on Wimmer et al. (2012b).

Table 3 Categorisation and description of choriotopes (Wimmer et al., 2012b)

Substrate designation	**Description**	**Grain size**
Megalithic	Coarse stones, blocks and bedrock	>40 cm
Macrolithic (blocks)	Boulders and coarse stones up to max. 40 cm in diameter predominant, variable proportions of stones, gravel, sand	20-40 cm
Mesolithic (stones)	Fist-sized to hand-sized stones with variable gravel-sand content	6,3-20 cm
Microlithic (coarse gravel)	Coarse gravel with proportions of medium and fine gravel	2-6,3 cm
Akal (gravel)	Fine and medium gravel	0,2-2 cm
Psammal (sand)	Sand	0,063-2 mm
Pelal	Silt and mud	<0,063 mm

In addition to the choriotopes, other parameters were used for ecological characterisation. The following table 4 provides a detailed description.

Table 4 Additional parameters for the assessment of ecological status - see also hydromorphological data sheet in the Annex 10.2

Habitat parameter	Description	Classification
Stream order number	Position of site within a river network	Stream order 1 to 12
Elevation sampling point	Site position above sea level in metres	Elevation
Choriotopes	Percentage of individual choriotopes • Megalithic • Macrolithic • Mesolithic • Microlithic • Akal • Psammal • Pelal	Low proportion (up to 5%) Medium proportion (10% to 20%) High percentage (25% or more)
Flow characteristics	Selection of the appropriate description of velocity • quickly flowing • slowly • flow calmed and flow pattern • homogeneous • heterogeneous • turbulent • turning water	Present / absent
Line routing	Selection of the line of the river section • coiled • stretched • commuting • meandering • furring	Present / absent

Table 4 continued

Habitat parameter	Description	Classification
Morphological structures	Selection of existing morphological structures, multiple answers possible • waterfalls, cascades • gravel and sand banks • transport of bed load • dead wood and rootstocks • width and depth variance	Present / absent
Water width	Specification in metres	<1m, 1-5m, 5-25 m and 25-100m
Shore profile	Selection of the existing bank profile separated into left and right • steep • flat • undercut bank • erosions • man-made	Present / absent
Vegetation structure	Selection of the predominant vegetation on the left and right bank side • typical ravine forest (*Tilio-Acerion*) • typical local beech forest • riparian forest with *Quercus* sp., *Ulmus* sp., *Fraxinus* sp. • riparian shrubs dominated by *Salix* sp. • knee timber vegetation with *Pinus mugo* • tall herbaceous meadows • herbaceous riparian vegetation • unvegetated • spruce monoculture	Present / absent
Cover/shading	Percentage of shading along the left and right banks	>1%, 1-5%, 5%-25%, 26%-50%, 51%-75%, 76%-100%

5.3 Survey of stone crayfish populations

The mapping of stone crayfish in the area was carried out in two cycles in 2020 and 2021, each from May to October. In the first year, nocturnal inspections were carried out on a total of 33 nights in Angerbach, Lassing and Ötscherbach (a total of approx. 25 kilometres) and on a section of the Große Erlauf between the Wienerbruck power plant and Erlaufboden (approx. 5 kilometres). In addition, for 3 nights crayfish taps were set up in each of the six water sections.

In the second year of the study, crayfish traps were set up for 20 days and the Lassing was intensively studied with a total of 12 nocturnal surveys.

Thus, the entire investigation took place with 45 nightly inspections and 20 days with set crayfish traps.

A crayfish trap is a usually cylindrical container with wire or plastic meshes and funnel-shaped entrances on at least two sides. Bait is placed in the centre. If an individual can reach the bait, it can no longer leave the trap.

Four different models were used as crayfish traps, depending on the water depth and current velocity.

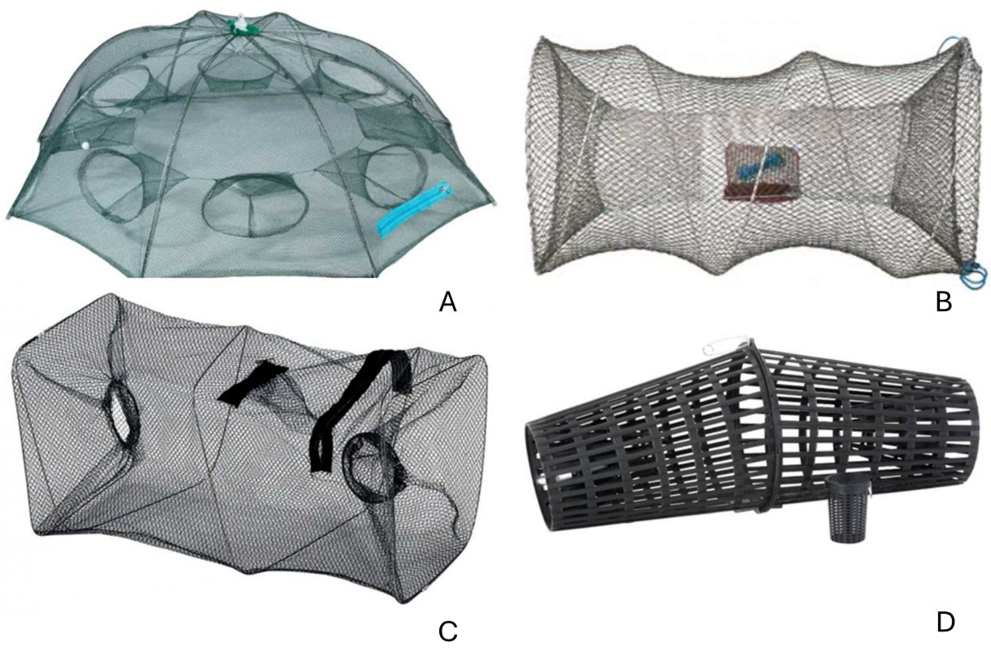

Figure 19 Crayfish trap models used in the present study A Balzer Crayfish Trap; B bait fish trap from Behr; C Perca Original decoy fish traps; D foldable fish trap from Sänger

The model A in the illustration shows the Balzer Crayfish-Trap with a mesh size of 5 mm made of 100% polyester with a central fan bait and 7 entrances to the centre.

This method of trapping was used mainly in the resaervoirs Erlaufstausee and Wienerbrucker Stausee, and also in a 3-metre-deep and 10-square-metre basin above the Lassingfall. This ensured that all seven entrances to the trap could be used.

In addition, a bait fish trap from the Behr company with a mesh size of 5 mm was also used. This trap has a diameter of 30 cm and a total length of 60 cm. Two of these models could be used at the same time. Due to its length, this method could only be used in places with sufficiently deep water – such as in the natural, deeper pools along the Lassing, as well as in the reservoirs.

Perca Original decoy fish traps, model C in figure 19, with a diameter of 22 cm and a length of 45 cm were used primarily at remote study sites because of their practical foldability. This method was used along the Lassing between the dam and the waterfall and downstream of the waterfall to the Wienerbruck power plant.

The last model to be used was the foldable fish trap from Sänger with the dimensions 10x35 - 15 x 50. Included is a bait basket that can be closed with a clamp. This model was used to examine the entire Lassing.

The survey of stone crayfish populations in 2020 was conducted along the entire river courses using two different methods.

The courses of the Erlauf, Ötscherbach, Lassingbach and Angerbach were mapped during nightly inspections of the riverbed using artificial light. A Ledlenser H7R.2 headlamp with 200 lumens and an LED hand lamp were used. When crayfish were detected, the species, sex, size, weight and any injuries, as well as any special features such as egg-bearing females, were recorded (see Annex 10.3: Biological data sheet). The animals were then released immediately.

The measurements were taken with a standard measuring tape, and the weight was determined using a digital kitchen scale from the company Soehnle. To do this, the individual was placed in a plastic container, and both were then placed on the scales. The tare weight of the container was then subtracted from the total weight.

In addition, 6 crayfish traps were set at approximately 200 m intervals in all sections of the watercourse for 3 consecutive nights. The traps were placed in the water in the afternoon and, in the case of strong currents, weighted with stones or tied to the bank and left in the water overnight before being retrieved the next day. Catches were identified and released immediately.

In the first year only strong-smelling dog food (Frolic) was used as bait.

In a second survey cycle in 2021, the Lassing was intensively sampled as all crayfish were found in one section of this stream in the first year.

From May to November, crayfish traps were set for 20 days and removed the next day. In addition, the Lassing was surveyed with nightly inspections on a total of 12 days.

In 2021 the traps were baited with three different types of bait (strong smelling dog food, cat food and fish remain).

As in the previous year, the biological data sheet was used for each individual.

5.4 Habitat suitability analysis with QGIS

In order to assess the potential distribution and suitability of the stream sections in the Ötscher-Tormäuer Nature Park for the stone crayfish, a habitat suitability model was created using QGIS 3.28.2 Firenze.

The stone crayfish is subject to the European Commission's Habitats Directive and can be found in Annexes II and V. Therefore, a favourable conservation status of the natural habitat must also be ensured.

To determine suitable habitats, important parameters for the habitat of the stone crayfish must first be selected by means of a literature search. For this classification, the following parameters of habitat quality and impairment were used, backed up by supplements provided by Berger and Füreder (2018).

Table 5 Parameters selected for the habitat quality of streams for stone crayfish and categorisation into three quality classes

Habitat quality	1 – good	2 – moderate	3 – low
Waterbed	very heterogeneous streambed with different grain size classes and sufficient hiding places; no muddy material	Average degree of heterogeneity of the streambed and hiding places	artificial, monotonous streambed with insufficient structural diversity
Banks	High structural diversity of the riparian zones	Medium structural diversity of the riparian zones	Monotonous structure of the riparian zones
Dead Wood	Abundant dead wood	Medium deadwood abundance	No or very little deadwood
Riparian vegetation	Natural composition with shrubs, conifers and deciduous trees Woody fringe at least 10 metres wide	narrow vegetation strip (1-10 metres) for shading and minimal buffering	no or no continuous vegetation strip
Flow characteristics	Natural varied flow pattern with regular pool and low to medium flow velocity.	Only limited heterogeneity of flow characteristics	Monotonous flow characteristics due to lacking watercourse structures
Continuity	Area without migration barriers	Small number of barriers or passable barriers	Impassable barriers
Habitat size	Large	Medium	Small
Landuse	Surrounded by natural vegetation, no negative influence from adjacent land use	Low or medium probability of inputs from adjacent land use	High probability of inputs from land use (agriculture, settlements, industry), intensive fisheries
Runoff regime	Natural runoff regime	Low to medium manipulations (velocity, volume)	Strongly manipulated

As can be seen in the table 5, the nine parameters were divided into three quality classes and a rating scheme was defined. In a next step, all watercourse sections were evaluated in this matrix, so that each section received a value (1-3) per parameter, where 1 indicates good, 2 moderate and 3 low habitat suitability.

For each parameter a shapefile was created, and the respective value was added. These vector files were then converted into raster files. This enabled a raster overlay and thus the intersection of the different parameters. For better visualisation, the resulting file was vectorised again.

6 RESULTS

6.1 Chemico-physical parameters

The chemical index for each sampling site was calculated using the data given in table 6. The data for the Erlauf were obtained from the survey of water quality in Austria in accordance with the Water Quality Monitoring Ordinance ((GZÜV) BGBl. II Nr. 479/2006 i.d.g.F.; BMLRT, Abteilung I / 2 Nationale und internationale Wasserwirtschaft). As described in the Methods chapter, the chemical index was calculated using a multiplicative method.

Generally, all eight chemico-physical parameters show narrow ranges only. In terms of oxygen saturation, the two reservoirs and the Erlauf are worth mentioning with oversaturations above 100%. Especially in the reservoirs, there is a strong growth of aquatic plants and algae in the summer months, which can explain the oversaturation. Differences can also be seen in the temperature, where the reservoirs have the highest water temperatures with 20.6°C for the Erlauf reservoir and 20.8°C for the reservoir in Wienerbruck. The coldest water body with 7.8°C was the Greimelbach. The data or nutrients (ammonium, nitrate and phosphate) were generally low in all water bodies with nitrate and phosphate below detection limit at three sites each, indicating drinking water quality.

The pH values are in the range of 7.87 to 8.48 and are therefore slightly alkalinic. The lowest value is again found in the Greimelbach and the highest in the Erlauf.

The conductivity reflects the calcareous geology of the catchments and also shows small ranges with a minimum of 314 µS/cm in the Greimelbach and a maximum of 435 µS/cm in the Erlauf.

Table 6 Chemico-physical parameters at the seven sampling sites

	Oxygen saturation (%)	BOD_5 (mg/l)	Temperature (°C)	Ammonium (mg/l)	Nitrate (mg/l)	Phosphate (mg/l)	pH-Value	Conductivity (µS/cm)
Greimelbach	96,6	0,8	7,8	0-0,05	5	0	7,87	314
Erlauf reser-voir	128,1	1,1	20,6	0-0,05	0	0,015	8,18	332
Ötscherbach (Ötscherhias)	97,4	1,2	13,4	0,05	0	0,046	8,00	324
Lassing	98,4	0,9	15,2	0,05	0-5	0	8,26	454
Wienerbruck reservoir	112,2	1,1	20,8	0,08-0,12	0	0,046	7,98	375
Angerbach	84,1	1,0	14,7	0	5	0	8,03	357
Erlauf	101,5	1,2	9,5	0,003	0,85	0,002	8,48	435

After calculating the chemical index, valency scores between 91 (Erlauf reservoir, reservoir in Wienerbruck and Erlauf) and 96 (Ötscherbach in the area of the Ötscherhias touristic facility) were obtained, illustrated in figure 20.

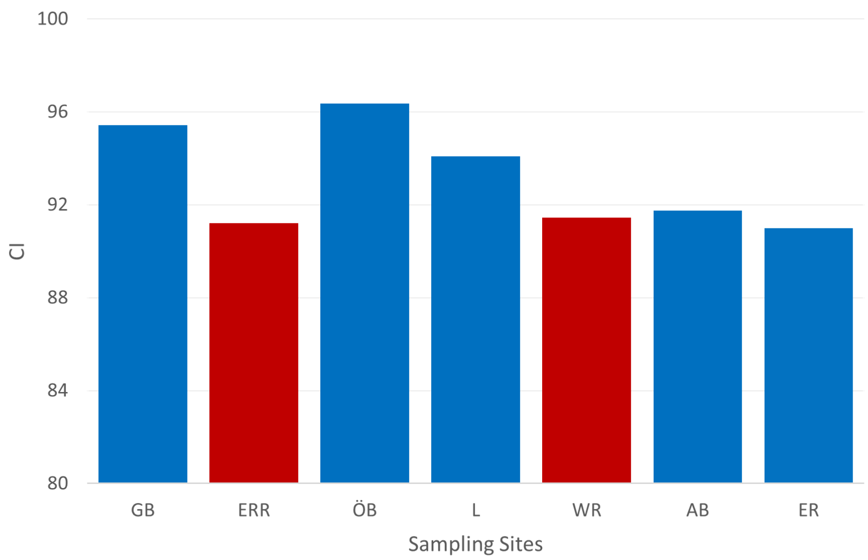

Figure 20 The chemical index for the seven sampling sites (Gb= Greimelbach, ÖB= Ötscherbach, L= Lassingbach, AB= Amgerbach, ER= Erlauf). Red columns indicate the two reservoirs (ERR= Erlauf reservoir, WR= Wienerbruck reservoir), because the CI should be strictly applied only in running waters

In a final step, those valency scores are transformed into the four main- and three subclasses of water quality given in table 7.

Table 7 Water quality classes based on CI index scores (Blondzik et al., 1998)

Index score	Water Quality class
100-83	I
82-74	I-II
73-56	II
55-45	II-III
44-27	III
26-18	III-IV
17-0	IV

Consequently, all water bodies in the study area are in quality class I.

6.2 Hydromorphology and ecology of the investigated water bodies

As already described in Chapter 3.2, the hydromorphological data sheet for the survey of ecological parameters was used for actual sites where stone crayfish were found. This was only the case in one section of the Lassing between the waterfall and the power station during the two survey years, which is why an evaluation of the hydromorphological parameters was only possible for this area.

The parameters were recorded at all six sampling sites. As the stone crayfish occurrences are only 150 metres apart, the ecological factors hardly vary. Only the exact composition of the choriotopes is slightly different. The following results were obtained for all other factors:

1. Stream order number: 3
2. Elevation: 650 – 620 metres above sea level
3. flow characteristics: homogeneous & current calmed
4. Morphological structures: pools, gravel and sand banks, deadwood
5. line: stretched
6. Watercourse width: 1-5 metres
7. Shore profile: steep bank - ravine character
8. Vegetation: typical ravine forest (*Tilio-Acerion*)

Figure 21 A typical crayfish habitat in the Lassing; own photograph

In figure 21, a typical crayfish site in the Lassing illustrates the prevailing habitat. The line of the Lassing is elongated in this area with a maximum width of 4 metres but still has a low current velocity with a variety of different morphological structures such as pools, deadwood and gravel banks. The typical ravine forest with maple and lime trees provides up to 50% shading on the stream bed. Due to the character of the ravine, the bank rises steeply on both sides.

The following diagram shows the distribution of choriotopes at the stone crayfish sites in the Lassing (figure 22). The distribution of the choriotopes at the individual sites shows a mixing of the different substrates with an increased proportion of macrolithal, which means a grainsize from 20 – 40 cm.

At the first site, the microlithal with a grain size of 2-6.3 cm is missing. In contrast to the other sites, a high proportion of mesolithal can be seen here. The macrolithal is predominant.

It is striking that the mesolithal with a grain size of 6.3-20 cm is missing at site 2. In comparison to the other sites, a higher proportion of Psammal is found. At this site, too, the predominant grain size of 20-40 cm is found in the macrolithal.

Sampling sites 3 and 5 are the only ones where all choriotopes are present, although the macrolithal is predominant here as well.

At site number four, the megalithal with a grain size larger than 40 cm is more strongly represented than at any other site. This is the first basin below the waterfall. It contains mainly large to medium-sized stones and very small sediment with a grain size of 0.2-2 cm. The microlithal, with a grain size of 2-6.3 cm, is absent at this site.

The fifth site has the smallest percentage of megalithal with grain sizes larger than 40 cm compared to the others. In contrast, a relatively high percentage of mesolithal with grain sizes of 6.3-20 cm can be found here.

At the last site, number 6, the distribution of the individual choriotopes is the most even, with psammal with a grain size of 0.0063-2 mm being completely absent.

In summary, it can be said that the macrolithal (20-40cm) is predominant at all six sites. In addition, the megalithal, akal and pelal are found in varying proportions at all sites, whereas the mesolithal, microlithal and psammal choriotopes are not found everywhere.

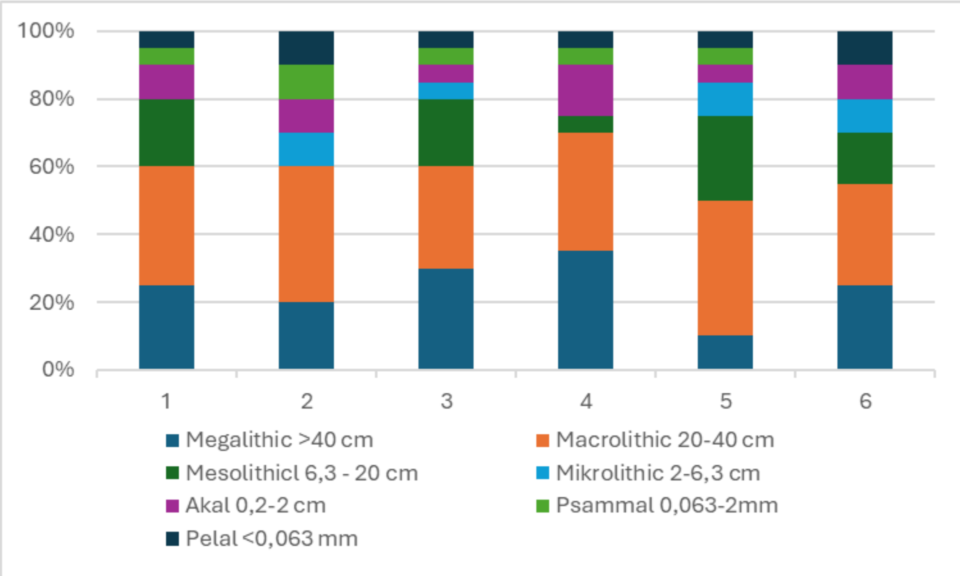

Figure 22 Distribution of choriotopes at the six sites with stone crayfish occurence in the Lassing

In addition, the arithmetic means were calculated from all six data sets in order to provide a synopsis of the overall choriotope situation of the Lassing (figure 23). It can be clearly seen that the largest proportions (24% and 35%) are megalithic and macrolithic. This means that substrates with grain sizes of 20 cm and larger are predominant.

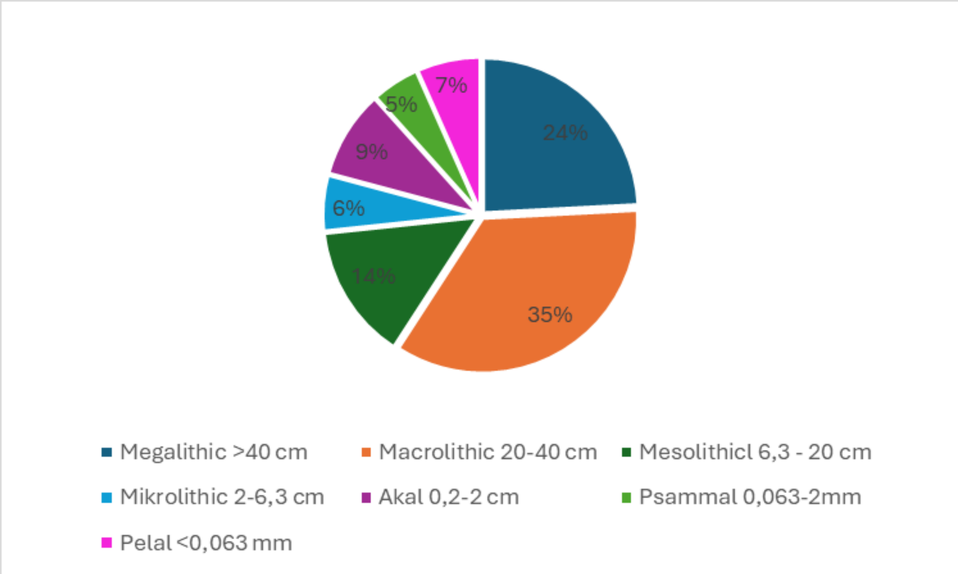

Figure 23 Distribution of choriotopes (arithmetic means) at stone crayfish sites in the Lassing

In conclusion, an optimal habitat for the stone crayfish in the Ötscher-Tormäuer Nature Park is defined by the following key elements: steep ravine forests with sufficient shading and an extended stream section 1–5 m wide with a stream order of 3 at altitudes of 650–620 m above sea level. The stream bed contains pools, gravel and sand banks, as well as deadwood, and is mostly covered with coarse sediments with a grain size of > 20 cm. The flow is homogeneous and lentic. Based on the chemical index value of over 90, the water quality is good with high oxygen levels and low nutrient loads.

6.3 Occurrence and distribution of *Austropotamobius torrentium*

Despite extensive nocturnal surveys of the entire river systems in the study area in the first study year, the even more intensive monitoring of the Lassing in the second year and the use of crayfish traps with a variety of baits, only a total of 6 records of *A. torrentium* could be accomplished.

The records consist of 2 males and 1 female in both 2020 and 2021, with the three individuals located in the same section of the Lassing and the sampling points only 156 metres apart from each other, situated between the Wienerbruck power plant and the waterfall of the Lassing. During the first year, two individuals were caught during night-time inspections and one individual was caught in a trap. In the second year, all three individuals were caught directly during nocturnal surveys. Figure 24 shows the records in an overview map of the entire Nature Park (upper right insert) and in more detail in the main map where all individual records in a section of the Lassing only 156 metres long are indicated.

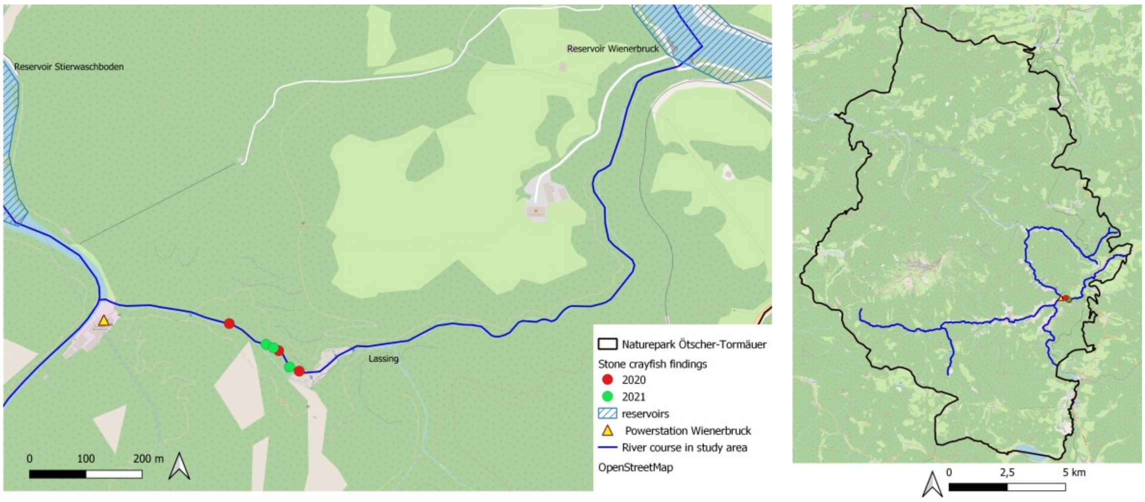

Figure 24 Stone crayfish sites in the 2020 (red dots) and 2021 (green dots) mapping surveys. The right insert shows the location of the crayfish records within the borders of the Ötscher-Tormäuer Naturparke

A biological data sheet was completed for all six records. As can be seen in the table 8, the size varies from 7 cm to 10 cm total lenght, with the male individuals being the largest. The weight also differs from 14 grams for the smallest crayfish (7 cm) to 20 grams for the largest male with 10 cm total lenght. Due to the annual moultings, markings with permanent markers or similar methods are not possible.

Table 8 Data for the 6 stone crayfish records in the Lassing

Nr.	Coordinates of site	Sex	Size (cm)	Weight (g)	Damage/ special characteristics
1	47,85200 N 15,29209 E	male	10	19	
2	47,85200 N 15,29308 E	female	7,5	15	1 claw missing, bluish colouring
3	47,85240 N 15,29130 E	male	7	14	
4	47,85239 N 15,29129 E	male	10	19	
5	47,85239 N 15,29129 E	male	9,5	20	
6	47,85239 N 15,29317 E	female	8	16	1 claw missing, bluish colouring

Nevertheless, due to sex, biometry and claw damage, there is some evidence that record pairings # 2 and 6 (specimen A), 1 and 4 (specimen B), as well as 3 and 5 (specimen C) are the same individuals. This is also supported by figure 25 und figure 26 comparing the specimen from the two years. Based on this, no length and weight increments could be observed in B, whereas in the second male C an annual total length increment of 36% and a weight increment of 43% was found. The corresponding data for the female (specimen A) were 7% and 7%, respectively. No eggs or reproductive behaviour could be observed during the study period.

In figure 25 and 26, a sample of the recorded specimens is depicted.

Figure 25 *Austropotamobius torrentium*, ventral view of the female (specimen A) in comparison 2020 left and 2021 right; first pleopods are vestigial and the female has no gonopod pairs, the right claw is missing, bluish colouration; own photographs

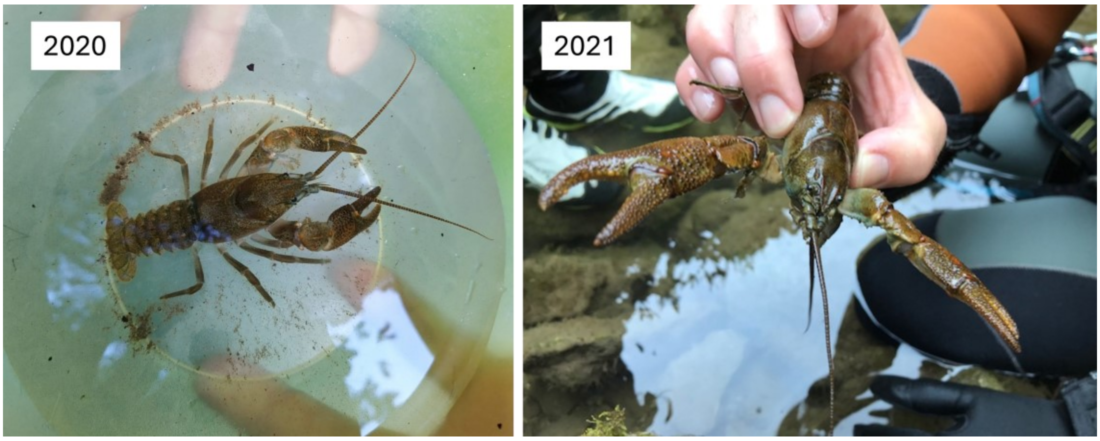

Figure 26 *Austropotamobius torrentium*: dorsal view of a male (specimen B) in comparison 2020 left and 2021 right; claws robust and strong, upper side strongly grained¸ own photographs

6.4 Habitat suitability of the study area for *A. torrentium*

Based on the hydromorphological and ecological data base at the crayfish record sites and on landuse information presented in chapter 3.3, a habitat analysis was carried out for the entire study area using Q-GIS Version 3.28.2 Firenze. For this, a set of 9 selected habitat parameters for uniform river sections was defined and each parameter ranked into quality scores (1= good, 2= intermediate, 3= bad; table 9).

Table 9 Classification of river sections, based on nine habitat parameters. Quality classes are indicated by colours: green- good, yellow- intermediate, red- bad

	Angerbach spring area	Angerbach	Erlauf	Greimelbach	Lassing Dam wall - Waterfall	Lassing Waterfall - Power plan	Lassing upstream water resorvoir	Ötscherbach spring - hut	Ötscherbach hut - estuary
Waterbed	2	2	1	1	1	1	3	1	1
Shore	1	1	1	1	1	1	2	2	1
Dead Wood	1	1	2	1	1	1	3	2	1
Riparian vegetation	1	2	2	1	1	1	2	2	1
Flow characteristic	1	1	1	1	2	1	2	1	1
Continuity	2	1	2	2	2	2	2	2	2
Habitat size	1	1	1	2	2	1	2	1	1
Landuse	1	2	1	1	1	1	3	1	1
Runoff regime	1	1	1	1	1	1	2	1	1

As shown in table 9, the majority of habitat parameters were rated as good (1).

However, it is also clear to see that 'Continuity' was only rated 'Good' in one river section, the main stretch of the Angerbach which is connected to the large Erlauf.

For a synopsis of habitat suitability, the 9 key habitat parameters were analysed in combination (figure 27). Sections that can be categorised as suitable habitats for stone crayfish are shown in green, orange indicates intermediate suitability and red indicates habitats with only low ecological potential.

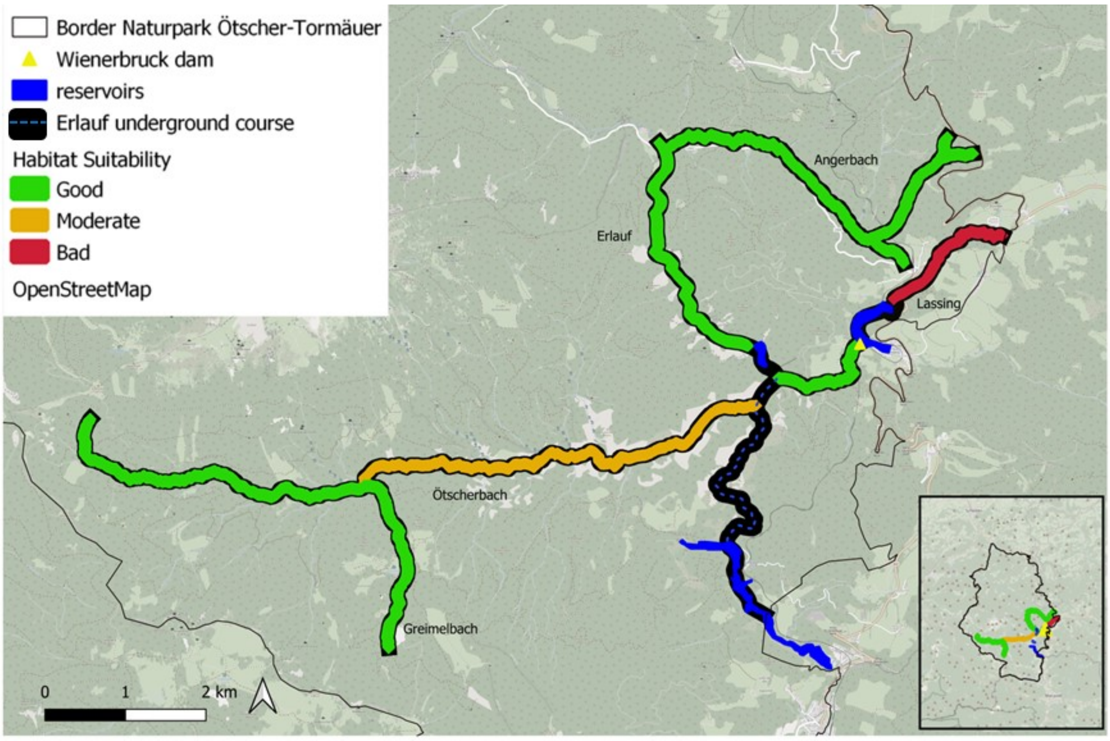

Figure 27 Habitat quality categorised as good (green) for Greimelbach, Angerbach, Erlauf and sections of Ötscherbach and Lassing, moderate (orange) for a section of Ötscherbach and poor (red) for the section of Lassing upstream of the dam (yellow triangle); the right insert shows the location of the waters within the Nature Park

As also indicated in table 9, figure 27 clearly shows that the Lassing upstream of the dam (yellow triangle in figure 27) has only a rather low ecological potential as habitat for stone crayfish. Greimelbach and the Ötscherbach in the headwater region as well as the Angerbach with the section of the Erlauf included in the study area and also the Lassing between the waterfall and Wienerbruck power station emerged as the most suitable habitats in the study area. All six individuals were also found in this section of the Lassing.

The habitat quality in a large part of the Ötscherbach is rated intermediate. This is due to habitat parameters shore structure, dead wood, riparian vegetation and continuity, which were rated as class 2 only. Due to the gorge landscape pattern of the Ötschergräben, the bank vegetation and canopy is mostly lacking and therefore no shading of the river as well as very little dead wood is provided. In addition, there is a large number of smaller and larger waterfalls, which represent barriers for crayfish. The bank zones are also largely uniform and offer no diversity.

7 DISCUSSION

7.1 Chemico-physical Parameters

The geographical location of the study area at low-order streams close to the source and the lack of settlements and industrial facilities as well as large-scale agriculture already led to the assumption that the water quality should be correspondingly high. This was also confirmed by the chemical and physical analyses based on the Chemical Index (CI). With valeny point scores above 90, all waters in the study area are assessed as quality class I.

This result is also consistent with the description of the hydromorphological models according to (Wimmer, Parthl & Wintersberger, 2012b). Both types 5-3-3 and 5-3-4 occurring in the area are described as oligo-mesotrophic, which indicates low to medium nutrient loads.

The Erlauf, as the largest river in the area, is of particular importance as the water quality is continuously monitored by the Water Quality Monitoring Ordinance of the Federal Ministry of Agriculture, Forestry, Regions and Water Management. As stone crayfish are sensitive to low levels of dissolved oxygen and to chemical pollution (Pöckl, 1998; Pöckl & Streissl, 2005; Holdich & Lowery, 1988) from a water quality perspective, the *status quo* is considered to be favourable for *A. torrentium* habitats, even at the sites moderately impacted by tourism and agriculture.

7.2 Crayfish plague

Crayfish plague is a highly contagious infectious disease caused by the fungus *Aphanomyces astaci* (Schikora, 1906). *Aphanomyces astaci* is a primitive ascomycete that reproduces via spores that enter the water (Füreder, 2009).

In Europe, crayfish native to Europe are highly sensitive to the pathogen, in Austria in particular noble crayfish and stone crayfish (Oidtmann & Hoffmann, 1998).

The zoospore is mobile in the water and usually attaches itself to wounds or sensitive spots on the crayfish (Füreder, 2009). Preferred spots are the underside of the crayfish's tail, joints and eyes, because the cuticle is thin here (Oidtmann & Hoffmann, 1998). This is where germination begins, involving lipolytic enzymes. This allows the lipid layer of the cuticle to be penetrated. The immune response of native crayfish is delayed and further hyphal growth cannot be stopped, causing the individual to become completely colonised by the fungus with lethal effects (Füreder, 2009).

Symptoms begin to appear just one day after infection, with behavioural abnormalities such as scratching. As the infection progresses, paralysis sets in. The flight reflex diminishes and eventually disappears completely. There is also frequent loss of individual limbs (Oidtmann & Hoffmann, 1998).

The following factors may contribute to the presence of the crayfish plague in the area under investigation:

The presence of American crayfish as carriers

American crayfish often carry the pathogen for life (Oidtmann & Hoffmann, 1998). American species have developed strategies against the fungus in the course of evolution. They immediately encapsulate the fungal hyphae after penetration, thus preventing further growth (Füreder, 2009). The fungus is not killed in the process, but the pigment melanin is deposited around the fungus, which prevents further growth (Oidtmann & Hoffmann, 1998).

No American crayfish were found in the entire study area, which is why this type of pathogen spread can be ruled out. Due to the backwaters and the Wienerbruck power plant, an upstream migration via the Erlauf seems unlikely.

Presence of the pathogen

The pathogen must be introduced into the water, as described above, which often occurs through American crayfish species. However, it can also happen through direct transmission of the spores through fishing equipment or transport water from stocked fish (Oidtmann & Hoffmann, 1998). In the present area under investigation, this cannot be ruled out in the past, although transmission via the neoprene suits of canyoning aficionados seems possible. Currently, all providers and guides of canyoning tours are aware of the issue and all equipment is dried and disinfected before the tour.

The Wienerbruck reservoir is also stocked with fish. Here, too, the possibility of transmission of the fungal spores in the past cannot be excluded. For this reason, during ongoing stocking, care is taken to quarantine the fish outside the reservoir. The spores survive in water for up to 2 weeks, but only a few days in a dry environment (Oidtmann & Hoffmann, 1998).

In order to prevent the pathogen from spreading in the future, these transport routes must be eliminated.

Locally infected crayfish

Locally infected species could also be a source of infection. This could occur through the introduction of spores and their spread downstream, but also through migration in the water (Oidtmann & Hoffmann, 1998).

There is a very low density of stone crayfish in the study area, which is why this route of spread can also be ruled out. In addition, no collected specimen showed signs of infection. The missing claw in the female individual may also be due to another injury. Crayfish have the ability to autotomy, which means they can consciously cut off limbs to escape from predators (McVean, 1982). The separation occurs at a predetermined breaking point in the joint membrane. The lost limb is replaced in several steps and regains its original function (Pöckl, 1998a).

7.3 Predators

In headwater streams crayfish have two main natural enemies: fish and terrestrial predators, especially birds and mammals (Englund & Krupa, 2000). Among the birds, herons and egrets deserve special mention. As for mammals, otters and mink are a threat (Holler & Woschitz, 2008).

Because of their size and thin shells, juvenile crayfish are part of the diet of almost all fish species. The number of predators decreases with increasing size (Michel et al., 2011).

Fish can play a role, especially in the reservoirs, as they are artificially introduced here. However, only very few fish were observed in the section of the Lassing where the stone crayfish were found, so this cannot explain the population decline.

In the case of the otter, it can be said that it is widespread throughout Lower Austria and that the population density in the Mostviertel region is increasing. This is shown by studies of droppings and associated density estimates. In the study area, an increase of one to two density classes has been recorded, shown in figure 28.

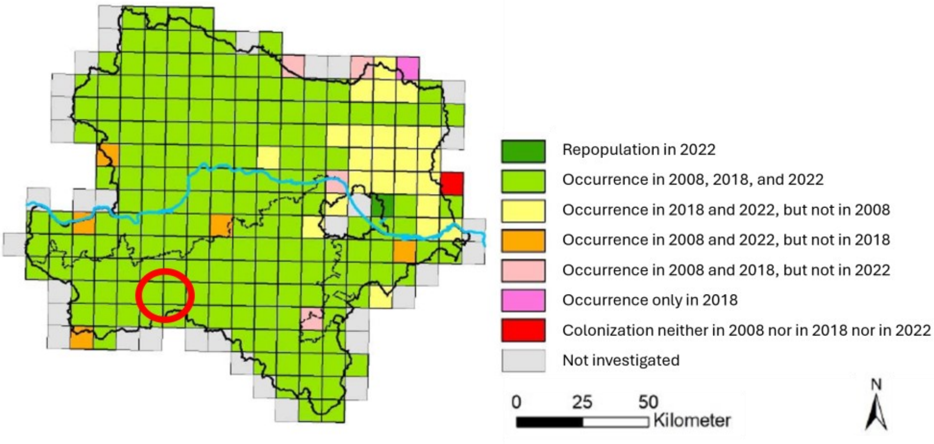

Figure 28 Comparison of the occurrence of the otter 2008, 2018 and 2022 in Lower Austria. The study area is marked in red. Source: ZT Kofler Umweltmanagement, Lampa S., Ludwig T. (2023) Fischotterverbreitung und Populationsgrößen in Niederösterreich 2022/23. Endbericht. https://www.noe.gv.at/noe/Naturschutz/Fischotter_Kartierung_2022-23_.pdf

In addition to direct predation, the spread of the crayfish plague by the otter can also pose a threat, as this species is able to move quickly between bodies of water (Holler & Woschitz, 2008).

Healthy, natural crayfish populations can rarely be wiped out by predation on its own. This alone cannot explain the decline in the study area. However, detailed studies examining the specific influence of mammals and birds on the dynamics of crayfish populations are currently limited. Further research in this area would be necessary to gain a more comprehensive understanding of the predation effects of mammals on crayfish.

7.4 Feeding behaviour of the stone crayfish

Crayfish are very frugal and versatile in their choice of food. The spectrum ranges from detritus, living aquatic plants and algae, small animals such as worms, leeches, insects and their larvae, snails and mussels to dead fish.

In gut analyses, the main dietary component of adult animals consists of plants from riparian woodlands and leaves (Pöckl, 1998b). In natural crayfish populations, detritus – i.e., plant and animal fragments undergoing decomposition – can account for up to 20% of the total food weight (Momot, Gowing & Jones, 1978).

The watercourses in the study area, especially the Lassing, are lined with vegetation typical of ravine forests, which means the presence of deciduous trees. Maples, willows and ash trees, in particular, are abundant, which not only provides shade for the watercourse but also results in leaf litter, thus representing a well-stocked food source.

There is a lack of specific documentation of macroinvertebrate research in the area of the Ötscher-Tormäuer Nature Park.

However, own observations highlight the presence of aquatic invertebrate groups typical for low-order streams. *Gammarus sp*. are relatively common and found in all water bodies in the study area. In addition, larvae of Plecoptera, Ephemeroptera and Trichoptera are abundant. Although detailed taxa inventories are lacking, macrozoobenthos densities seem to be sufficiently high in order to support large crayfish populations in the water bodies of the study area.

7.5 Possible reasons for the decline of *A. torrentium* populations in the study area

One explanation for the low number of crayfish recorded can be found in the history of the region associated with wood trift. Timber was transported across the Erlauf as early as the 14th century. With industrialisation in the 17th century, the demand for wood increased steadily, and there was a shortage of wood, especially in Vienna. As a result, lumberjacks began to clear entire valleys, mostly by clear-cutting. The wood was then transported to the rivers, usually by sledge, and then onwards across the water courses towards the Danube (Tippelt, 2001). There were different methods for floating. Drifting was used on smaller rivers such as the Erlauf and its tributaries. Small dams were built in order to transport the timber into the Große Erlauf and to the Danube. Some of these so-called ‘Klausen’ were built in the Ötschergräben and also along the Lassing (Wiesenhofer, 2015).

During this process, the stream bed was severely affected, which led to a change in the biocoenoses. Unfortunately, there are no scientific data on the presence of stone crayfish in the region from this time. Only oral history accounts on children playing with the crayfish in the streams and on the use of crayfish as food exist, which suggest that a higher population density of crayfish must have prevailed in those times.

Another major intervention in the natural water systems was the construction of the Wienerbruck power station. The Wienerbruck power station was built in 1910 and opened in 1911 and was used to provide electricity for the Mariazell railway. It is the oldest power station in Lower Austria, fed by the waters of the Lassing and Erlauf rivers. The dams in Wienerbruck and Erlaufklause were built for this purpose, creating two reservoirs - Wienerbruck and Erlaufstausee (Elmayer-Vestenbrugg, 1961).

From both reservoirs, the water is directed to the power station via underground pressure tunnels. This is also associated with extensive drainage of the original streambeds of the Erlauf and Lassing (Felsinger & Schober, 2002). This led to heavy fragmentation of the streams, thereby heavily limiting migration of aquatic organisms.

Downstream, the movement of crayfish, especially juvenile animals, is much easier. They lack the ability to move through areas with riffles and waterfalls. In mountain streams, such as in the study area, there are a large number of these disturbances, which, while not a complete barrier, can greatly reduce the movement of crayfish (Bubb, 2004).

Artificial barriers also have the potential to influence the movement and spread of crayfish, although more precise information on this is still lacking. In any case, connectivity within the catchment area and between populations is advantageous and may be necessary to enable dispersal and colonization (Bubb, 2004).

Artificial barriers can also be used to prevent the migration of non-native crayfish. In this way, crayfish barriers can also be used as a management measure (Vaeßen et al., 2013).

The ability to move in the water also has an impact on gene flow and genetic exchange between populations.

Population simulations of genetic dispersal patterns and recovery potential show that significant genetic differentiation can be observed upstream of barriers. Nevertheless, the simulations show that the restrictions on gene flow cannot be attributed solely to anthropogenic influences. However, the combination of dispersal constraints and biological traits indicates that local populations are vulnerable to environmental disturbances and have limited potential for recolonization. Although no reliable correlation between anthropogenic structures and current gene flow can be established, it can be summarized that barriers, such as impoundments and dams, affect species' dispersal and the recovery of affected populations (Whiterod et al., 2016).

All of these factors can gradually lead to the extinction of local populations and are possible reasons for the current situation.

7.6 The Minimum Viable Population (MVP) for crayfish

Due to the small number of stone crayfish found in this thesis, the question arises as to the minimum size of a population that is necessary for survival.

Theoretical and practical work has shown that populations that have been reduced in number or range are at risk of extinction. This phenomenon underlies the concept of the minimum viable population (MVP). The MVP defines a number of individuals that are necessary for the survival of a population over a certain period of time (Brook, Traill & Bradshaw, 2006).

According to Shaffer, 1981 there are four key Factors Affecting MVP:

1. Genetic Diversity – A small population may suffer from inbreeding and genetic drift, reducing adaptability.
2. Environmental Variability – Natural disasters, climate changes, and resource availability can threaten small populations.
3. Demographic Stochasticity – Random variations in birth and death rates can impact small populations.
4. Catastrophes – Rare but severe events (like disease outbreaks or habitat destruction) can wipe out small groups.

In the literature, general numbers like 50 individuals can be found to keep the inbreeding rate below 1% (Lehmkuhl, 1984). With a population size below 50, the population will suffer from inbreeding depression in the short term (Nunney & Campbell, 1993).

Studies have also shown that a population size with a geometric mean of 500 is required for birds and mammals with average levels of variation; for highly variable populations, the value can increase to 5000. A population with a geometric mean size of 500 requires a habitat that can support a population that is at least an order of size larger (Nunney & Campbell, 1993).

Determining the minimum viable population (MVP) for crayfish species is complex due to various ecological and environmental factors. While specific MVP values for crayfish are not well-documented, several studies provide insights into their population dynamics and conservation needs.

However, the notion of a universal minimum population size that applies to all species and under all conditions is also being questioned.

According to Flather et al. 2011, neither theoretical models nor empirical data support this universal threshold. The risk of extinction depends on a variety of factors, which requires a more differentiated consideration that takes into account the specific needs and conditions. Individual assessments are needed for population viability that take into account the ecological and biological characteristics of each species (Flather et al., 2011).

7.7 Potential distribution of *A. torrentium*

The habitat analysis using Q-GIS on the basis of nine selected quality parameters for stone crayfish habitats shows potential habitats predominantely in the Greimelbach, Ötscherbach and Lassing areas and in the estuaries of the Angerbach and Erlauf. The actual population can also be found in the described area of the Lassing between the waterfall and the power station.

These habitat characteristics used for the analysis are also consistent with the results of other studies. The study "Association between stream habitat characteristics and native and alien crayfish occurrence" by Weinländer and Füreder was used as the data basis for the habitat suitability of *A. torrentium*. In this study, factors responsible for the presence or absence of crayfish were evaluated. A total of 17 different habitat features were found – altitude, slope, stream order, width, depth, velocity, water temperature, the presence or absence of macrophytes, briophytes, woody depris, shelters and stones in different sizes. (Weinländer & Füreder, 2012).

In this case *A. torrentium* were mostly found in headwaters with lower stream orders, steeper slopes as well as smaller widths and depths. The stone crayfish was also found more abundantly at sites with a higher proportion of woody depris, refuges and a lower proportion of megalithal. Occurrence is statistically significantly related to slope, hiding places, altitude, presence of bryophytes, and woody debris (Weinländer & Füreder, 2012).

Auer et. al. also identified water depth, morphological suitability and shading as suitable parameters. The morphology was divided into 3 classes based on the criteria of depth variability, presence of hiding places, sediment distribution on the bed, siltation phenomena and bank shape. These characteristics can also be found in the table used for the analysis (Auer et al., 2015). The watercourses in the present study area were divided into sections that were as homogeneous as possible, and the hydromorphological survey form was filled out at a typical point by means of on-site surveys in order to determine the habitat condition.

The habitat analysis showed that five river sections could be classified as good. This is consistent with a study by Pöckl & Streissl (2005), which summarises the typical habitat characteristics for the stone crayfish as follows:

- a naturally high substrate heterogeneity
- a high number of suitable hiding places
- a highly variable flow pattern
- natural riparian vegetation
- little fluctuation in water temperature, with a maximum of 20°C
- low organic pollution.

All these factors also describe the possible habitats in the Ötscher-Tormäuer Nature Park. The habitat requirements of the stone crayfish are thus theoretically met.

One main problem in the study area is the fragmentation of the habitat by the Wienerbruck power plant and associated reservoirs and dams, resulting in the worst rating of the Continuity factor.

Figure 29 shows an overview of the different barriers in the area. A distinction is made between artificial barriers, such as the dams on the Erlauf and Lassing, and natural barriers, such as waterfalls. The largest natural barrier is the Lassingfall, with a drop of about 90 metres.

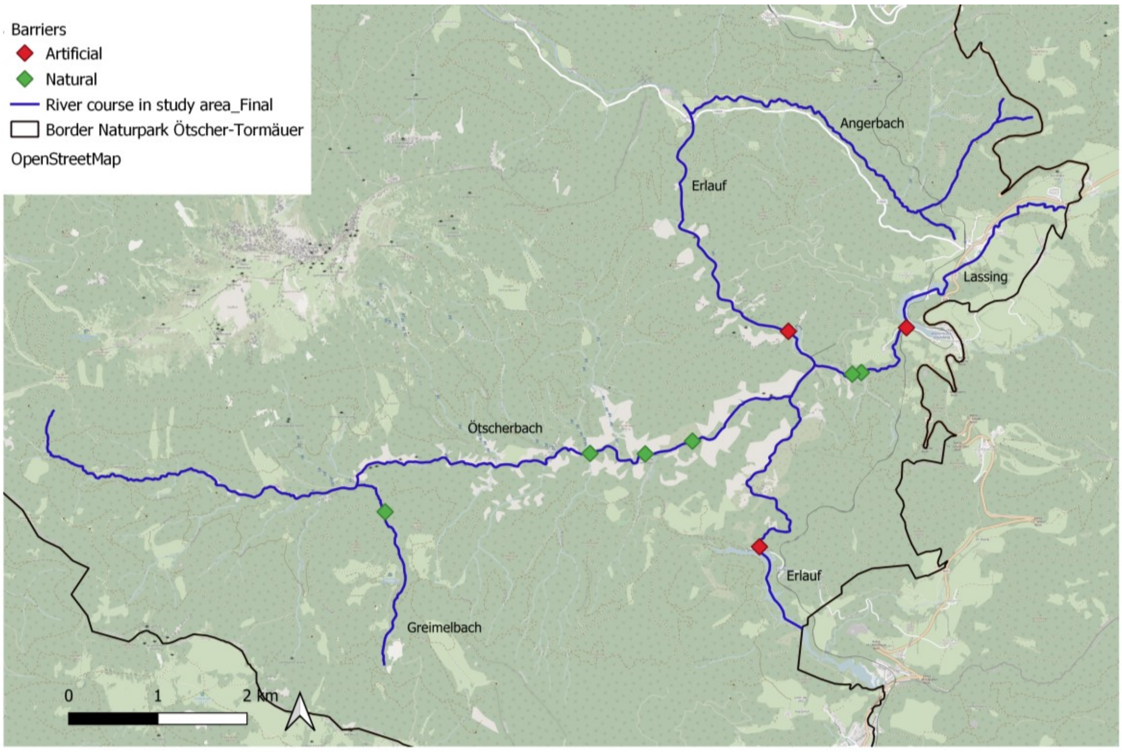

Figure 29 Barriers for stone crayfish in the watercourses of the study area, divided into artificial (red diamonds) and natural (green diamonds)

There are several reasons for this - in many unobstructed, near-natural sections, smaller and larger waterfalls act as barriers, such as in the Greimelbach and Ötscherbach. In the area of the power station, it is the dam proper causing complete fragmentation of the adjoining sections. In the entire study area, only the Ötscherbach, Greimelbach and the lower part of the Lassing as well as the Angerbach and Erlauf are considered as fully connected. The Wienerbruck power station with its three reservoirs completely interrupts the connection between these two groups of habitats. This also means that no genetic exchange can take place between populations from the Erlauf upstream.

Furthermore, table 9 shows that the Lassing upstream of the reservoir received the worst rating. In this area, the river traverses a settlement and agricultural area. The bed of the stream is heavily obstructed here and some of the surrounding vegetation is completely absent. Furthermore, the section has no connection to other watercourses in the study area, as the Lassing is dammed in the Wienerbruck area, and the course of the river is therefore interrupted by the dam. Even without this artificial intervention, the high Lassingfall would be a natural and insurmountable barrier for crayfish.

In conclusion, habitat suitability is favourable with respect to ecological parameters such as structural diversity in the watercourses (deadwood, choriotopes), land use and bank vegetation. The majority of streams are near-natural water courses with typical accompanying vegetation (ravine forest, willow groves) in a sparsely populated area with low levels of agricultural impact. The ecological key deficiency is lacking continuity and the size of the habitats, which are significantly disrupted by both natural and artificial barriers.

7.8 Future perspective

The present study has shown that the abundance of crayfish in general and stone crayfish in particular is scarce, consisting only of a relic population in the selected area of the Ötscher-Tormäuer Nature Park.

Although the habitat analysis revealed that many potential habitats exist, their number is impaired by the power plant and the dams, so that natural migration upstream is not possible.

This also means that the problematic signal crayfish cannot enter the area. The area could therefore also be used as a refuge and breeding ground for the endangered stone crayfish.

The last remaining population in the Lassing will be monitored by the Nature Park Management in the coming years. However, their complete extinction cannot be prevented without reintroduction.

For reintroduction, other crayfish populations from areas outside the study area in other parts of the Park and in neighbouring areas, particularly in Lake Erlauf and the Erlauf River at the lake's outlet, could be used. Further mapping is therefore recommended in order to improve the current knowledge of crayfish distribution in the region.

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9 LIST OF ILLUSTRATIONS, FIGURES AND TABLES

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10 ANNEX

10.1 German abstract

In dieser Masterarbeit wurde die Verbreitung und Häufigkeit von Steinkrebsen (*Austropotamobius torrentium* (Schrank 1803)) in einem ausgewählten Gebiet des Naturparks Ötscher-Tormäuer untersucht. Das Untersuchungsgebiet umfasst den Fluss Erlauf und seine Nebenflüsse (Ötscherbach, Greimelbach, Lassing und Angerbach).

Zu diesem Zweck wurden chemisch-physikalische und ökologische Parameter der Gewässer erfasst, um Rückschlüsse auf die Habitateignung für den Steinkrebs zu ziehen. Die Berechnung des zugehörigen chemischen Index, die hydromorphologische Datenblätter und die anschließende Auswertung mit Q-GIS zeigten, dass die potenzielle Qualität und Eignung als Krebslebensraum in vielen Abschnitten der untersuchten Gewässer gegeben ist, insbesondere in Lassing, Ötscherbach, Angerbach und Erlauf. Nur ein kurzer Abschnitt der Lassing oberhalb eines Stausees wird als ungeeignet eingestuft. Die Wasserqualität in allen Gewässern wird als sehr gut bewertet, da der chemische Index überall über 90 Valenzpunkten liegt.

Trotzdem wurden in einem kurzen Abschnitt der Lassing in zwei Jahren nur 6 Nachweise von Steinkrebsen erbracht. Andere Krebsarten, wie der Signalkrebs (*Pacifastacus leniusculus*), wurden nicht gefunden.
Mögliche Gründe für die geringe Anzahl von Steinkrebsen sind die Holzflößerei im 17. Jahrhundert und der Bau des Kraftwerks Wienerbruck mit seinen Staudämmen. Beides hat zu einer Fragmentierung und Veränderung des Lebensraums geführt.

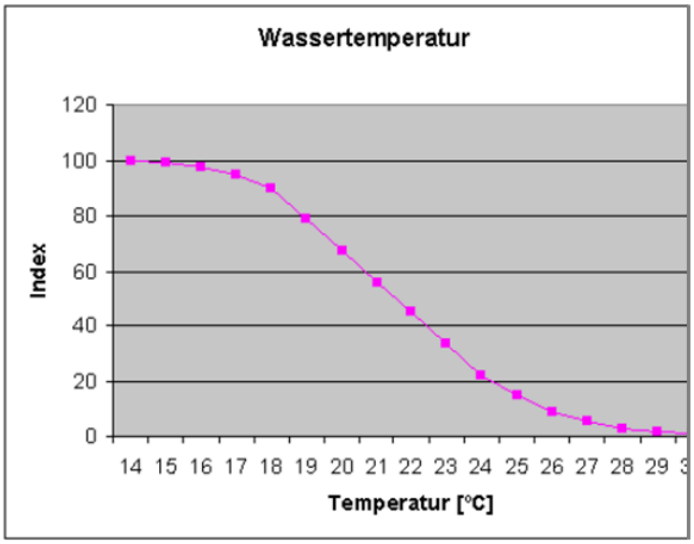
Zusammenfassend lässt sich sagen, dass im Naturpark Ötscher-Tormäuer noch eine Restpopulation von Steinkrebsen vorhanden ist, die sich jedoch langfristig nicht selbst erhalten kann.

10.2 Chemical Index Nomograms after (Institut Dr. Flad, 2023)

Tabellen u. Diagramme für die Bestimmung der Subindices zur Ermittlung des CI:

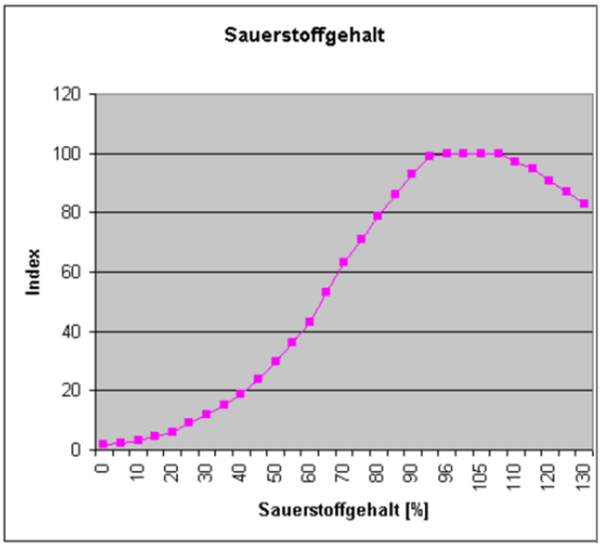
Wassertemperatur

Temperatur	Index
14	100
15	99
16	97,5
17	95
18	90
19	79
20	67,5
21	56
22	45
23	33,5
24	22
25	15
26	9
27	5,5
28	3
29	1,5
30	1
unter 14:	100
über 30:	1



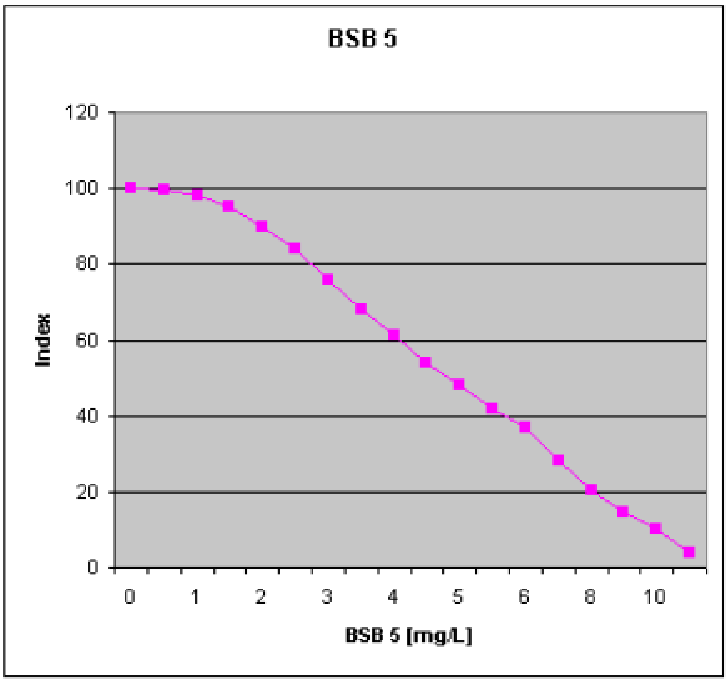
Sauerstoffgehalt

Sauerstoffgehalt	Index
0	2
5	2,5
10	3
15	4,5
20	6
25	9
30	12
35	15
40	19
45	24
50	30
55	36
60	43
65	53
70	63
75	71
80	79
85	86
90	93
95	99
96	100
100	100
105	100
106	100
110	97
115	95
120	90,5
125	87
130	83



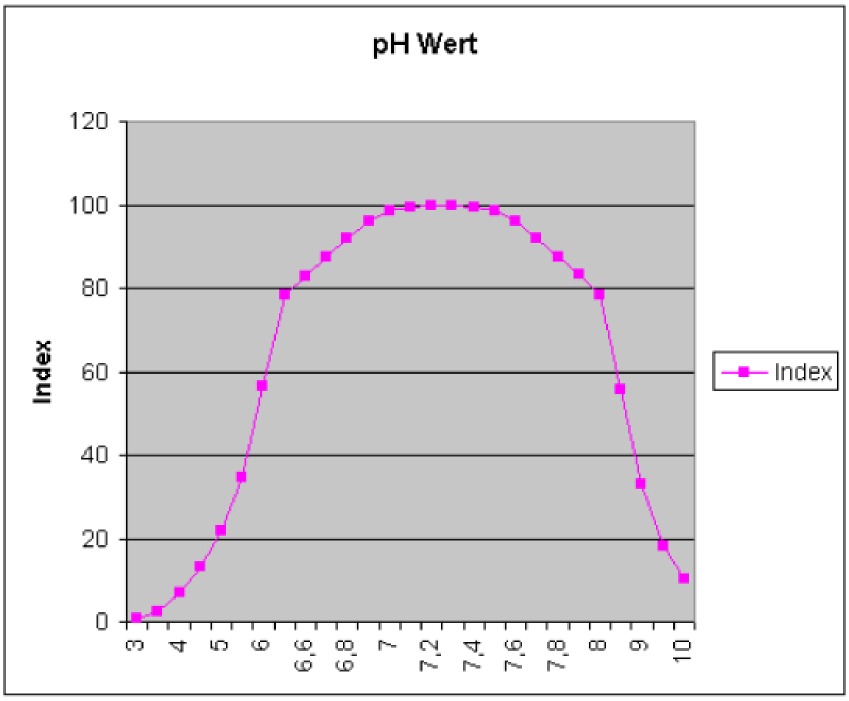
BSB 5

BSB 5	Index
0	100
0,5	99,5
1	98
1,5	95
2	90
2,5	84
3	76
3,5	68
4	61
4,5	54
5	48
5,5	42
6	37
7	28
8	20,5
9	14,5
10	10
15	4
über 15:	3



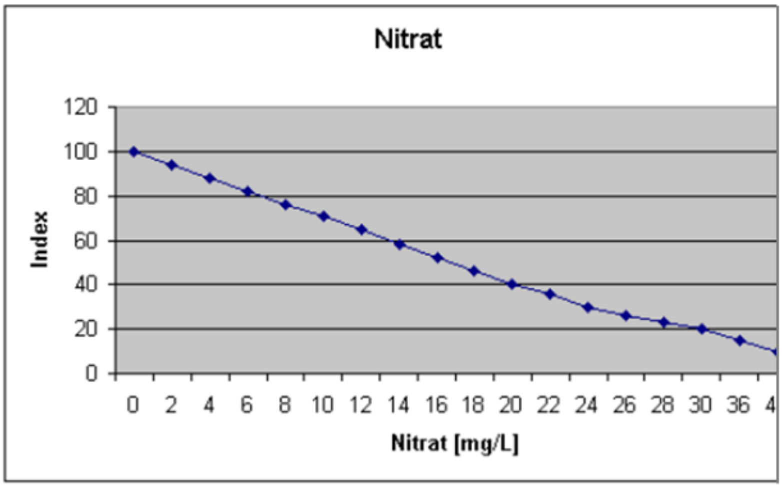
pH Wert

pH	Index
3	1
3,5	2,5
4	7
4,5	13
5	22
5,5	34,5
6	56,5
6,5	78,5
6,6	83
6,7	87,5
6,8	92
6,9	96
7	98,5
7,1	99,5
7,2	100
7,3	100
7,4	99,5
7,5	98,5
7,6	96
7,7	92
7,8	87,5
7,9	83,5
8	78,5
8,5	55,5
9	33
9,5	18
10	10,5



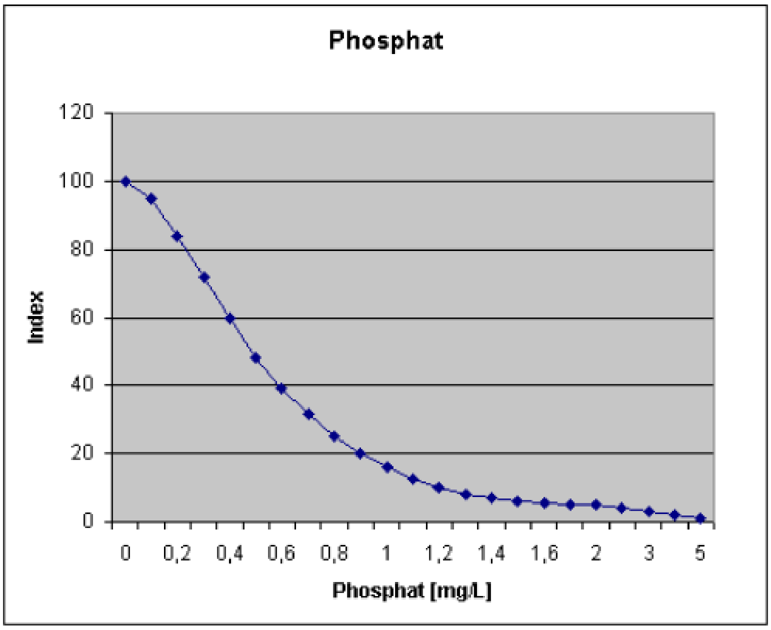
Nitrat

Nitrat	Index
0	100
2	94
4	88
6	82
8	76
10	70,5
12	64,5
14	58,5
16	52,5
18	46,5
20	40,5
22	35,5
24	30
26	26
28	23
30	20
36	15
40	10
über 40:	10



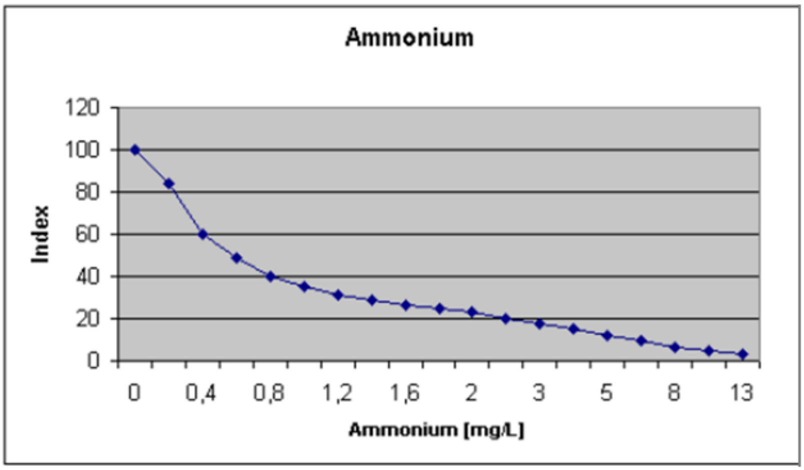
Phosphat

Phosphat	Index
0	100
0,1	95
0,2	84
0,3	72
0,4	60
0,5	48
0,6	39
0,7	31,5
0,8	25
0,9	20
1	16
1,1	12,5
1,2	10
1,3	8
1,4	7
1,5	6
1,6	5,5
1,8	5
2	5
2,5	4
3	3
4	2
5	1



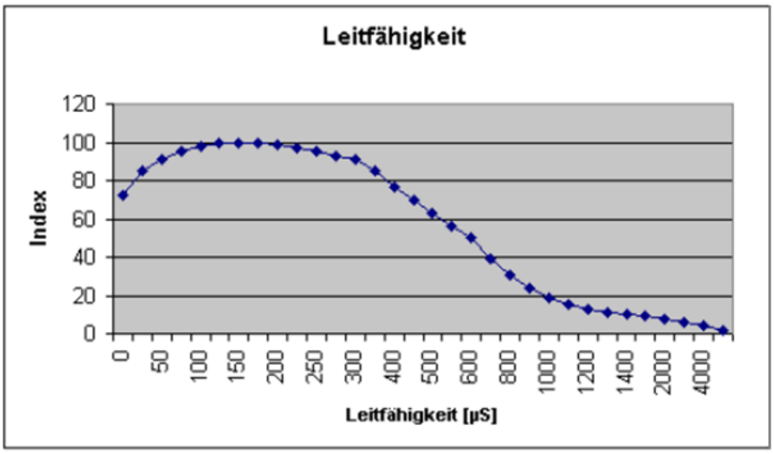
Ammonium

Ammonium	Index
0	100
0,2	84
0,4	60
0,6	49
0,8	40
1	35
1,2	31
1,4	28,5
1,6	26,5
1,8	24,5
2	23
2,5	20
3	18
4	15,5
5	12
6	10
8	6,5
10	4,5
13	3,5
über 13:	3



Leitfähigkeit

Leitfähigkeit	Index
0	72
25	85
50	91
75	95
100	97,5
125	99,5
150	100
175	99,5
200	98,5
225	97
250	95,5
275	93
300	91
350	85
400	77
450	70
500	63
550	56
600	50
700	39
800	31
900	24
1000	19
1100	15
1200	13
1300	11
1400	10
1500	9
2000	8
3000	6
4000	4
5000	2



10.3 Hydromorphological data sheet used in the present study

Name/ Sampling Site ______________________ Nr.

river code

coordinates ______________________

sea level ______________________

gradient ______________________

temperature ______________________

Choriotope	
Megalithal >40 cm	
Makrolithal 20-40 cm	
Mesolithal 6,3 - 20 cm	
Mikrolithal 2-6,3 cm	
Akal 0,2-2 cm	
Psammal 0,1-2mm	
Pelal (Schlick, Schluff, Schlamm)	

Flow behavior	
homogenous	
heterogenous	
rapidly flowing	
turbulent	
eddy water	
slow flowing	
calm	

Line	
winding	
stretched	
swinging	
meandering	
forking	

Morph. Structures	
waterfalls, cascades	
gravel and sand banks	
bedload transport	
deadwood, rootstocks	
width variance	
depth variancce	

width of water	
< 1 m	
1-5 m	
5-25 m	
25-100 m	

shore profile	L	R
steep bank		
shallow bank		
bank erosion		
berakwater		
embanked		

Structure of vegetation	L	R
Gorge forest typical of the location (Tilion-Acerion)		
Beech forest		
Alluvial forest with Quercus sp., Ulmus sp., Fraxinus sp.		
Riparian woody vegetation dominated by Salixarten		
Bush vegetation mit Pinus mugo		
Tall herb communities		
Herbaceous riparian vegetation		
without vegetation		
Spruce monoculture		

cover/shade	L	R
5 - 76-100%		
4 - 75-51%		
3 - 50-26%		
2 - 25-5%		
1 - >5%		
´+ - >1%		

Notes:

10.4 Biological survey sheets for the crayfish records of the present study

Biological Sheet

Sampling Site/ Name: Lassing between waterfall and power station

2020

Nr.1

coordinates	47,852004 N 15,292089 E
Species	Austropotamobius torrentium
Quantity	1
Sex	male
Size (cm)	8 cm
Weight (g)	19
Notes	

Nr.2

coordinates	47,852004 N 15,293084 E
Species	Austropotamobius torrentium
Quantity	1
Sex	female
Size (cm)	7,5
Weight (g)	20
Notes	one claw missing, slightly blue coloration

Nr.3

coordinates	47,852399 N 15,291295 E
Species	Austropotamobius torrentium
Quantity	1
Sex	male
Size (cm)	7
Weight (g)	14
Notes	

Sampling Site/ Name: Lassing between waterfall and power station

2021

Nr.4

coordinates	47,852399 N 15,291295 E
Species	Austropotamobius torrentium
Quantity	1
Sex	male
Size (cm)	8,5 cm
Weight (g)	19
Notes	

Nr. 5

coordinates	47,852399 N 15,291295 E
Species	Austropotamobius torrentium
Quantity	1
Sex	female
Size (cm)	8
Weight (g)	20
Notes	one claw missing, slightly blue coloration

Nr. 6

coordinates	47,852399 N 15,293170 E
Species	Austropotamobius torrentium
Quantity	1
Sex	male
Size (cm)	8,5
Weight (g)	15
Notes	