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Titel der Arbeit

Fish species assemblage, abundance and biodiversity in an old, modified Danube side arm. A description of the habitat relations of *Umbra krameri* Walbaum*, 1792.*

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1. Abstract

Effective conservation of endangered fish species requires an understanding of species–habitat relationships as well as spatial and temporal distribution patterns. Thus, modelling the habitat relationships of fish species may be a valuable tool for conservation planning. The aim of this study was to describe the key environmental factors of the European mudminnow habitat in the national park Donau-Auen in Austria. The occurrence and abundance of the European mudminnow *U. krameri* and its relation to other fish species in a modified side arm of the Danube downstream of Vienna was examined over a stretch of 10 km in autumn 2013. Generally, *U. krameri* was the most abundant species and occurred in habitats with low species richness and biodiversity. Moreover, ordination statistics were used to identify abiotic environmental key variables of the mudminnow habitats and to identify factors that structure the fish assemblage. The structure of the species composition of the fish assemblage in the system was highly attributed to the amount of woody debris. Out of 30 variables a set of six factors revealed a significant model, which described the relation of the species to the environmental conditions. *U. krameri* preferred disconnected ditches and ponds with dense reed belts, indicating its primordial association to swampy and marshy habitats.

Keywords

European mudminnow, Umbridae, endangered fish species, habitat analysis, fish assemblage

Zusammenfassung

Die Entwicklung und Anwendung von Schutzmaßnahmen zum Erhalt von gefährdeten Fischarten setzt ein grundlegendes Verständnis der Art-Lebensraum Beziehungen und den zeitlichen Verteilungsmustern voraus. Daher ist die Modellierung der Habitatbeziehungen von Fischarten ein wertvolles Instrument für die Naturschutzplanung. Das Ziel der vorliegenden Arbeit ist es, die wichtigsten Umweltfaktoren des Lebensraums des europäischen Hundsfischs, *U. krameri*, im Nationalpark Donau-Auen zu beschreiben. Im Herbst 2013 wurde über eine Strecke von 10 km in einem modifizierten Seitenarm der Donau östlich von Wien, das Vorkommen, die Abundanz und die Vergesellschaftung des Europäischen Hundsfischs mit anderen Fischarten untersucht. *U. krameri* war die häufigste Art und trat in Lebensräumen mit geringem Artenreichtum und niedriger Biodiversität auf. Ökologische Schlüsselvariablen von Hundsfischhabitaten sowie relevante

Umweltfaktoren zur Strukturierung der Fischartengemeinschaft wurden mittels eines Ordinationsverfahrens ermittelt. Die Fischgemeinschaft wurde maßgeblich durch die Menge an Totholzstrukturen bestimmt. Von 30 Eingangsvariablen ergab ein Set aus 6 Faktoren ein signifikantes Model, welches das Verhältnis der Arten zu den Umweltvariablen zueinander wiedergab. *U. krameri* bevorzugte abgeschnittene Gräben und Tümpel mit dichtem Röhricht, was eine ursprüngliche Bindung dieser Art an sumpfige, moorige Habitate vermuten lässt.

Schlüsselworte

Europäischer Hundsfisch, Umbridae, gefährdete Fischarten, Habitatanalyse, Fischvergesellschaftung

2. Introduction

Freshwater ecosystems are the ecologically most important and impaired ecosystems (Dudgeon et al., 2006). According to the estimations of Ricciardi & Rassmussen (1999) the extinction rate is distinctly higher for aquatic then for terrestrial species. Consequently, many freshwater species are vulnerable to extinction (Richter et al., 1997; Jelks et al., 2008). Protection efforts for preservation and restoration of aquatic habitats are attempts to counteract the ongoing decline of aquatic species. Therefore, knowledge about- and analysis of species-environment relations and distribution mechanisms are essential for planning effective protection measures (Sindt et al., 2012). During the past two centuries, most large rivers in Europe have been greatly impacted by the construction of hydro power plants, regulation work for navigation purposes, land reclamation projects and large-scale flood control measures (Dynesius & Nilsson, 1994). In Austria the Danube regulation started in 1875. A single, straightened channel, stabilized by riverside embankments and rip-raps was created. The regulation efforts lead to major changes in run-off characteristics, and changed transport of bed sediments and suspended load (Schiemer et al., 1999). The former side-arms of the original braided system were cut off, leading to disruptions of the lateral connectivity of water bodies in relation to the minor and major river beds. The concentration of the erosive forces resulted in a deepening of the riverbed and a decline of the groundwater level in the floodplain area. These factors combined with sedimentation and conversion of floodplains to dry land led to permanent changes and a loss of aquatic habitat. In fact, the active floodplain surface area downstream of Vienna measured 352 km² prior to regulation. Since that time 23 % of the floodplain area has been drained and about 60 % has been disconnected from the river by river engineering works (Schiemer & Waidbacher, 1992). At present, disconnected backwaters (palaeopotamon), which are not flooded

on a regular basis, are prone to loss by successional processes within the coming decades due to aggradation, and they represent more than 50 % of the whole floodplain (Schiemer et al., 1999).
At the floodplain scale, water bodies created by fluvial processes through lateral as well as vertical erosion, and the subsequent channel migration and abandonment, include sidearms, backwaters, cut-off braided channels, oxbow lakes, floodplain ponds and marshes (Amoros et al., 1987b; Galat et al., 1997). The erosional and sedimentational effects of floods form a mosaic of many different aquatic habitats on the floodplains (Amoros & Bornette, 2002), each of them having a characteristic assemblage of fish species. Therefore, fish habitat including the habitat for everyday functions (feeding and resting) and the habitat for critical stages (breeding and refuge) is directly affected by regularization works (Vlad et al. 2013).

Various studies of stream fish ecology have been implemented to relate fish assemblage structure to their environment (reviewed in Matthews, 1998). Fish typically select thermal habitats in which the growth rate is near maximum (Jobling, 1981) and which at the same time maximizes the metabolic resources necessary for growth, activity and reproduction (Kelsch, 1996). Fish assemblages are also structured by biotic factors, such as competition (Grossman, 1982; Ross et al., 1985; Schlosser, 1987) and predation (Power, 1984; MacRae & Jackson, 2001), and by physical factors, such as habitat diversity (Gorman & Karr, 1978), and physicochemical gradients (Matthews et al., 1992; Taylor et al., 1993; Lappalainen & Soininen, 2006). At the same time, the flow regime, such as channel morphology, (Schlosser, 1985; Marchetti & Moyle, 2001; Lamouroux & Cattanéo, 2006), the substratum type (Humpl & Pivnicka, 2006) and riparian vegetation also play a critical role (Maridet et al., 1998; Growns et al., 2003).
Ecological fish guilds are groups of species with similar preferences for certain biological factors like feeding behaviour or habitat preferences. Ecological guilds are often used as indicators for the ecological integrity and functioning of river systems (Schiemer et al., 1991; Schiemer & Waidbacher, 1992; Kummer et al., 1999). Changes in the composition and distribution of guilds in space and time can give different information on the processes and habitat availabilities, which in turn structures fish communities. Generally, with decreasing hydrological connectivity of floodplain water bodies, the richness and diversity of species and ecological guilds decrease (Aarts & Nienhuis, 1999). Through anthropogenic disturbances the guild of species which are highly adapted to specifically riverine conditions (rheophilous species) has declined more than generalists in most European rivers (Aarts et al., 2004). The decline of rheophilous species is caused by degradation and fragmentation of their lotic (reproductive) habitats in the main and secondary channels. By contrast, stagnophilous species inhabit different types of side arms and oxbows in late successional

stages. The stagnophilous guild has suffered through the eutrophication by industry and agriculture, the habitat loss through land reclamation (Schiemer & Waidbacher, 1992) and by the drainage of swamps and the loss of muddy backwaters with abundant submerged vegetation and high amplitudes of oxygen saturation and temperature (Lelek 1987).

The most endangered stagnophilous species in Austria is the European mudminnow *Umbra krameri*, Walbaum 1792 (Spindler & Wanzenböck, 1995). In 1975 *U. krameri* was listed as extinct in Austria and was than later rediscovered by Wanzenböck (1992) in a palaeopotamon type water body in the "National Park Donau Auen" in Lower Austria near to the Slovakian border.

U. krameri is an endemic Pannonian species and belongs to the *Esociformes* and is the only indigenous species of the genus *Umbridae* in Europe. It is native in Austria, Bulgaria, Croatia, Hungary, Moldova, Romania, Serbia, Slovakia, Slovenia and Ukraine (Kottelat & Freyhof, 2007). Povž (1995) summarized the former distribution and the characteristic habitats of the European mudminnow in the Carpathian Basin and Kuehne et al. (2014) described its more recent distribution. Pekárik et al. 2014 analysed its key habitat requirements in the Danube inland delta in Slovakia. *U. krameri* individuals preferred habitats with, narrow channel width, low velocity, dense aquatic vegetation, mixed vegetation cover and absence of bank regulation.

In the most areas of its distribution similar factors are responsible for the declines of its meta populations. Through land-reclamation measures, stream regulation and hydro power production the natural habitats of the European mudminnow are destructed (Lake Balaton – Hungary (Biro & Paulovits, 1995); Szigetköz floodplain – Hungary (Guti, 1995); Mura, Drava – Croatia (Leiner, 1995); Danube floodplain – Austria (Spindler & Wanzenböck, 1995)). For that reason it is considered a highly endangered species (Maitland, 2000; Wilhelm, 2003). It is listed on the IUCN Red List of threatened species as vulnerable A2c. Freyhof (2011) states that its population decreased by > 30 % over the last 11 years with a continuing downward trend. Moreover, it is listed in the Annex II of the EC Habitats Directive, and in the Appendix II of the Convention on the conservation of European Wildlife and Natural Habitats (Bern Convention).

It inhabits in richly-structured small canals and slowly flowing and stagnant waters (Bohlen, 1991), oxbows (Povž, 1995) or densely vegetated palaeopotamon waters (Geyer, 1940). It has a relatively short lifespan of about 2 to 4 years, an average length of 5 – 9 cm (Povž, 1995) and a maximum length of 17 cm (Pavletic, 1954). It prefers water temperatures ranging from 5 to 24 °C and pH values ranging between 6 and 6.5 (Povž, 1995). The mudminnow nourishment consists of larger crustacean plankton and invertebrate larvae. The spawning season reaches from March to April at temperatures between 12.5° and 16.5° C (Bastl, 1988). The spawning takes place on patches of detritus free vegetation (Bohlen, 1995; Kovac, 1995). As a special adaptive feature *U. krameri* is able to use its swimbladder for accessory aerial respiration. Thus, it is highly resistant to low oxygen conditions (Heckel & Kner, 1903; Geyer, 1940).

The aims of this study were a) to determine the actual distribution of the European mudminnow along the longitudinal course of the Fadenbach system in Lower Austria, and b) to describe the co-occurrence with other fish species and c) analyse its abundance along the longitudinal course and its size structure. Furthermore, d) to analyse the habitat requirements of *U. krameri* by means of a multivariate model describing the relation of the species to several river-morphological, physical, and chemical factors.

3. Study area

The study area is located east of Vienna in the "Marchfeld" (Lower Austria) on the north river bank of the Danube between river kilometres 1892.50 and 1905.50 in the area of the National Park Donauauen. It represents a water body called Fadenbach between the villages "Mannsdorf a. d. Donau" and "Eckartsau/Witzelsdorf" (sea level: 147 m).

Before river regulation in 1870 the Fadenbach was a permanently connected side arm of the Danube floodplain and as such integrated into the discharge events of the Danube. A longitudinal continuous river continuum with a water depth with more than one meter in the riverbed was approximately given at a mean water level of the Danube. The current velocities were generally low and at low discharge some areas might have falling dry.

Since the regulation of the Danube channel and the construction of the "Marchfeldschutzdamm" more than 100 years ago, the superficial connection (surface water) with the Danube main channel has been strongly reduced. The only permanent connection is given through the groundwater aquifer. The longitudinal course of the Fadenbach system is characterised by several meanders (Schulz, 2013). Today, from the upper reach, which mainly flows through urban and agricultural territories, except of a few ponds, only a dry and scrubby depression is left. The second part of the Fadenbach between "Orth" and "Eckartsau" was separated by the "Marchfeldschutzdamm" three times. Despite of the missing connectivity, this section comprised the most ecological intact areas and represented a refuge for a variety of endangered species (macrophytes, plants and animals) (Reckendorfer & Keckeis, 2001). In this part, the European mudminnow (*Umbra krameri*) was rediscovered by Wanzenböck in 1992. The protection of the European mudminnow as a highly threatened species was the main goal of the EU LIFE-project "Gewässervernetzung &

Lebensraummanagement Donauauen". A reconnection of the water bodies by artificial channels aiming to improve the ecological quality was initiated in 1998 – 2004. The implemented actions aimed at a higher longitudinal connectivity of the system and the creation of refuges during low water periods. The stretch is located in a alluvial forest and consists of a series of pools. The water body is inherently supplied by groundwater. Only in case of high discharge events of the Danube, water enters through a culvert and former upstream connections into the Fadenbach system. No data of the average annual duration are known. Tockner & Schiemer (1997) mention an average duration of less than 4 days for semi-disconnected water bodies inside of the levee. Thus, a lower duration can be expected for the Fadenbach. The groundwater levels follow the level of the main stream and induce seasonal surface water level fluctuations in a range of 1.3 m (Spindler, 2006).

The third part is characterized by a high silting tendency and is completely disconnected in times without flooding events. The mouth is located below "Witzelsdorf". Here, the water body is connected to a meander of the "Rosskopfarm", which itself is also strongly isolated from the Danube main channel by the levee (Schulz, 2013).

4. Sample Sites

Between 21. - 25. September 2013 overall 24 sites between "Mannsdorf an der Donau" and "Eckartsau" were sampled (*Fig. 1*). The distribution of sites covered the longitudinal course of the middle section of the system and simultaneously enabled a comparison of the results with previous studies (Spindler & Wanzenböck, 1995).

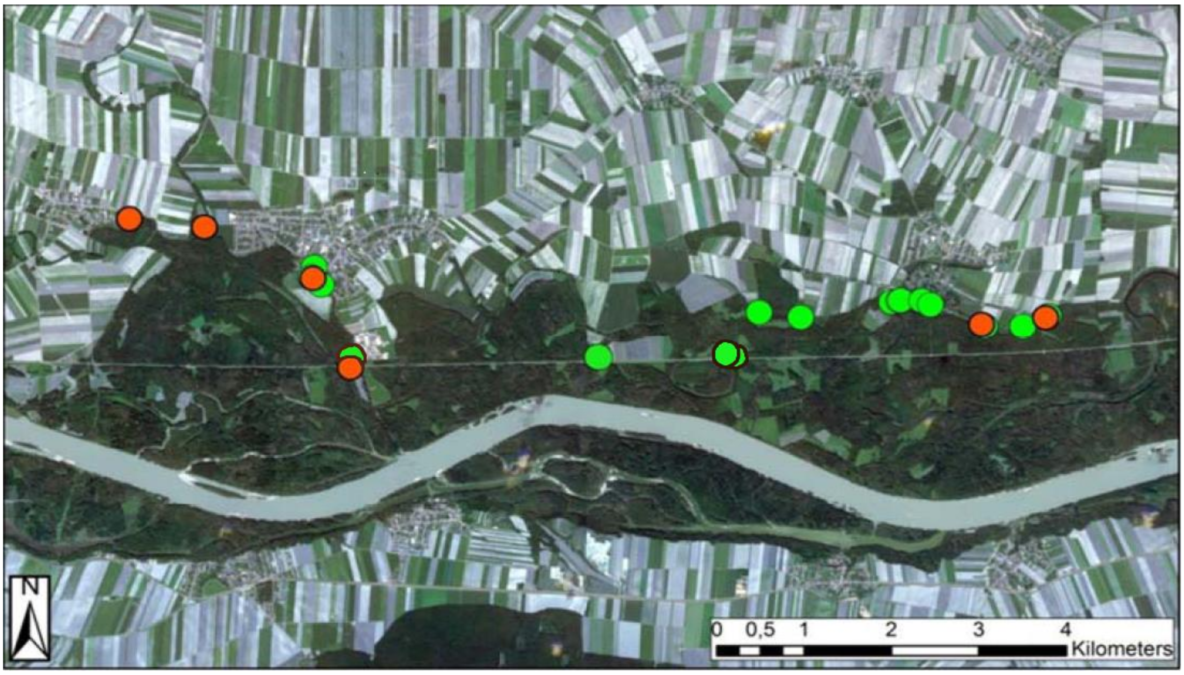

Figure 1: Distribution and location of the sampling sites at the Fadenbach system in the area between "Mannsdorf an der Donau" and "Witzelsdorf". Green symbols indicate occurrence of U. krameri and red symbols indicate its absence.

Site 1 "Mannsdorf ": Site 1 sits at the east entrance of the commune "Mannsdorf" in direct vicinity to the "Wiener Strasse" and belongs to the second segment of the Fadenbach. The hill slope situation is steep and only a few patches of grasses and single shrubs constitute to the riparian vegetation in a range of 1 m from the wetted shoreline. Here, the water body of the Fadenbach for the first time shows a perennial character along its longitudinal course, but at the date of examination it was only connected to the lower end. Aquatic vegetation is represented by patches of submerges only, while the sediment consists of sapropel and a great amount of woody debris is structuring the bed (*Fig. 2*).

Figure 2: Site 1 "Mannsdorf"

Site 2 “Labfeld”: Site 2 belongs to the second segment of the Fadenbach” system and is located between the communes of “Mannsdorf” and “Orth” at the “Labfeld” nearby to the “Wiener Strasse”. It is characterised by dense alluvial forest and is therefore highly shaded. The shore is highly modified by beaver activity, like clipped off/ fallen trees and entrances to beaver lodges. Aquatic vegetation is represented by a dense mat of *Lemna trisulca*. The water has a brownish grey colour with intensive foul smell. The water body is perennial and was connected at both transect ends at the point of examination. Over the whole site the substrate consists of sapropel (*Fig. 3*).

Figure 3: *Site 2 “Labfeld“*

Site 3 “Castle Orth”: This site is located westward of the castle in “Orth” at the “Jägergrund”. The study site lays directly behind a little sluice for flood control. The very steep angle of the hillside is more than 45 °. At the time of examination the site was isolated from the upper part of the Fadenbach. The water regime was rated to be perennial. The height from wetted shoreline to bankfull is the highest of all examined sites with around 4.5 m. The aquatic vegetation is strongly dominated by *Lemna trisulca* and only a low amount of coarse woody debris is present. The left shore line is artificial with a woody sheet pile wall. The right shoreline is vegetated with dense grass patches. In the channel woody debris represents potential cover for fish. The shading is high because of the high hillside, which also includes some big trees and buildings (*Fig. 4*).

Figure 4: Site 4 "Castle Orth"

Site 4 “Castle Orth / pond 1”: Site 4 is located south-west of the castle in “Orth” at the area of the national park centrum. It represents restructured parts of the Fadenbach. The channel has been widened and dredged to create a suitable habitat and a refuge at times of low water levels and as an overwintering habitat for the European mudminnow (Spindler, 2006). The riparian vegetation is composed of patches of grasses and single shrubs. There is a low amount of submerged and no other aquatic plants in the pond.

Site 5 “Connection of ponds in Orth”: This site is located between the two ponds on the area of the national park centrum. It is perennial and was at the date of examination only connected superficially to the eastern pond. A few submerged and floating leaf plants exist in the very shallow water. The shading can be high due shading from shrubs and trees accompanying the channel. A high amount of coarse woody debris structures the water body. The substrate is homogeneous with silt and coarse organic matter.

Site 6 “Castle Orth / pond 2”: Site 6 is located in the south-west direction of the castle in the area of the national park centrum. The left shore is vegetated with dense macrophytes reaching into the pond. The right shore is steeper than the left and is interrupted by entrances to beaver lodges. The vegetation is dominated by submerged plants like *Ceratophyllum hirsutum* and *Myriophyllum verticillatum*. The water body is perennial and is occasionally connected to the Fadenbach system.

Site 7 “Baxter bight”: Site 7 is located in western direction of the “Baxter” company in “Orth”. It is about 150 m apart from a culvert through the “Marchfeldschutzdamm”. The riparian vegetation is dominated by trees of the hard wood flood plain forest, which induces high shading. Moreover, there is a great amount of coarse woody debris in the water body. Aquatic vegetation is represented by a small amount of *Lemna trisulca*. The water has a brownish grey colour with a distinct foulish smell. The water body is perennial and connected at both ends of transect (*Fig*. 5).

Figure 5: Site 7 "Baxter bight"

Site 8 “Levee / culvert”: This site is located in western direction of the “Baxter” company near the levee and is connected by a culvert to the old meander on the other side of the levee. The culvert enables a water supply during flood events (Spindler 1995). With the connection from the old loop to the “Wachtelgraben” and further to the “Große Binn” and is as such the only temporary superficial connection to the main river. As such this forms the only potential corridor for fish immigration to take place into the Fadenbach and for the dispersal from the Fadenbach to the main channel of the Danube. The water depth increases successively in direction to the levee. The sediment is more diverse than at the other examined sites. Besides the omnipresent silt material at this site, sand and gravel are also present. The water body is perennial and connected to both sides. A massive stem of a tree was lying along the site with some intermediate sized coarse woody debris in the water body at the time of examination. No aquatic vegetation had been observed (*Fig. 6*).

Figure 6: Site 8 " Levee/culvert"

Site 9 ”Levee / southern”: Site 9 is the only site which is located at the southern side of the Marchfeld levee. It belongs to the third segment of the Fadenbach and is located west southwest of the “Baxter” Company in “Orth”. It is connected to the Danube by the “Wachtelgraben” and the “Große Binn” (see description of site 8). At the date of examination it was connected to the culvert (northern) end only. A high amount of coarse woody debris from the riparian forest is structuring the water body. The channel is very wide and it is periodically flooded by the regime of the Danube main channel. The substrate is entirely dominated by fine-grained material (silt/clay). There is no riparian vegetation in a range of 1 m of the wetted shore line and no aquatic vegetation had been observed at the point of examination (*Fig. 7*).

Figure 7: Site 9 "Levee/southern"

Site 10 “Levee/pond 1”: Site 10 is located between the villages of “Orth” and “Eckartsau” at the “Unterer Stockmais”. This site was part of the LIFE-Project “Gewässervernetzung und

Lebensraummanagement Donauauen” (LIFE98NAT/A/0056422) (Spindler, 2006). Within the project a deepening of the bed for approximately 2 m had been conducted. The water is brown coloured and vegetated with submerged (*Chara sp*., *Ceratophyllum hirsutum*) and emerged (*Hydrocharis morsus-ranae*) macrophytes and small patches of floating leave plants. The substrate is silt with patches of sand, while reeds dominated the riparian vegetation. The site is perennial and was not connected to any other site at the point of examination (*Fig. 8*).

Figure 8: Site 10 "Levee/pond 1"

Site 11 “Levee / pond 2”: Site 11 is located at the “Grenzböden” between the villages of “Orth” and “Eckartsau”. This site was also part of the LIFE Habitat management project. Here a deepening of approximately 2m and a widening of the shorelines has been conducted (Spindler, 2006). The water is very clear in contrast to most of the other sites, which were examined in this study. The aquatic vegetation is dominated by submerged macrophytes (*Chara sp*., *Myriophyllum verticillatum*, *Ceratophyllum demersum*). The substrate is composed of sand with few patches of fine-grained material. The water body is perennial, and was connected to the Fadenbach system at the lower end (*Fig. 9*).

Figure 9: Site 11 "Levee/pond 2"

Site 12 “Levee / pond 3”: This site is located at the “Grenzböden” between the villages of “Orth” and “Eckartsau”. It is the relict of the third meander of the Fadenbach and it lies in the immediate vicinity to the levee. Spindler (1995) reported dense submerged vegetation, but also indicates to an incipient silting up of the pond. Nowadays, the water is shallow with sparse amounts of emerged vegetation. In direction to the levee, the water depth declines successively and passes over into a reed belt. The water body shows a tendency of silting, probably due to high amounts of allochthonous input from the accompanying alluvial forest (*Fig. 10*).

Figure 10: Site 12 "Levee/pond 3"

Site 13 “Upstream Porau”: Site 13 is located south of “Eckartsau” at the beginning of “Porau”. The water body was connected at the upper end only. The aquatic vegetation is dominated by submerged *Ceratophyllum hirsutum*. The substrate is composed of silt and organic matter. The water has a strong putrid smell and has a brownish-grey colour. The hillside is much steeper on the right than on the left shore and only the left shoreline is vegetated by patches of grass (*Fig 11*).

Figure 11: Site 13 "Upstream Porau"

Site 14 “Downstream Porau”: Site 14 is located south of “Eckartsau” towards the end of “Porau”. It is characterized by a straight course with a wide and shallow wetted littoral shore. Along the shore several entrances of beaver lodges can be found. Along the channel a dense alluvial forest induces a high degree of shading. The water has a strong smell from anoxic decomposition of the allochthonous organic material coming from the alluvial forest. A dense mat of *Lemna trisulca* is the only aquatic vegetation, which prohibits light penetration into the water column. The hillside slope is very steep with angles of > 45° and without riparian vegetation. Only a few trees are overgrowing. Because of beaver activities many trees could be found in the waterbed. The substrate is composed of silt, sapropel and woody debris (*Fig. 12*).

Figure 12: Site 14 "Downstream Porau"

Site 15 “Upstream swimming bath / underneath defecator”: This site is located south west of the football ground in “Eckartsau”, in direct vicinity of the sewage plant of the village. A small side arm enters at the right shore. At its inlet eroded bare patches of coarse material (granular and pebble gravel) at the banks are visible. The substrate varies from silt to gravel. The right shore showed overgrowing trees and coarse woody debris, while no riparian vegetation occurred on the left shore. The aquatic vegetation is dominated by *Ceratophyllum hirsutum* and *Myriophyllum verticillatum*, beneath *Stratiotes aloides* as emerged and *Lemna trisulca* as floating leaf plants (*Fig. 13*).

Figure 13: Site 15 "Upstream swimming pool, downstream of the sewage treatment plant"

Site 16 “swimming pool Eckartsau”: Site 16 is located in the south west of the park in “Eckartsau”. It was used as a swimming pool in the past. The Fadenbach is dammed by a barrage and the bed is made of concrete slaps. As such it is possible to classify the substrate as technolithal (artificial substrate). Due to sedimentation a layer of silt with a thickness of few decimetres exists there. The pool was isolated surficial to the Fadenbach at both ends. Because of the artificial shoreline there is no riparian vegetation, except some individual trees that grow over. There is scattered aquatic vegetation with *Sagittaria sp.* and submerged *Ceratophyllum hirsutum*. In comparison with the other sites an intermediate amount of coarse woody debris was found (*Fig. 14*).

Figure 14: Site 16 "Swimming pool Eckartsau"

Site 17 “Downstream swimming pool Eckartsau”: Site 17 is located prior to the “western footbridge” and next to the old swimming pool. The channel flow seems to be temporary and at a lower discharge only a few small pools remain. It was disconnected to the prior water body at the time of sampling. A little pond remains and narrows into a few decimetre broad channel. The riparian vegetation is dominated by sedges (*Carex spp.*) and *Rubus sp.* In the pond coarse woody debris is present, and a few aquatic plants (*Lemna trisulca*) were observed (*Fig. 15*).

Figure 15: Site 17 "Downstream swimming bath Eckartsau"

Site 18 “Flowing reach castle Eckartsau”: This sampling site is located nearby the castle in “Eckartsau” underneath the “western footbridge”. The width is low and the hillside slope is very steep. It is the only site with a recognizable flow-velocity. The riparian vegetation is dominated by *Typha sp.*, *Carex spp.* and *Rubus sp*. at both shores. The streambed is overgrown by dense aquatic vegetation with many macro algae of the genus *Zygnema* and frequent stocks of *Stratiotes aloides*.

Due to single large trees shading can occur only temporary. The substrate consists of gley, silt and sand (*Fig. 16*).

Figure 16: Site 18 "Flowing reach castle Eckartsau"

Site 19 “Upstream stone bridge park Eckartsau”: Site 19 is located at the stone bridge at the “Schlossgasse” in south-eastern direction from the park of the castle in “Eckartsau”. Here, the relative small channel of the Fadenbach widens and the water body is deeper compared to other reaches in the park (compare site 18 and site 19 in Tab. 1). The Site is perennial and shadowing can occur temporary due to single groups of trees. The shorelines are vegetated with dense *Carex spp.* and *Typha sp.* stocks. The aquatic vegetation consists of floating leave plants (*Nuphar lutea*, *Hydrocharis morsus-ranae* and *Stratiotes aloides*) and submerged macrophytes (*Ceratophyllum hirsutum*) (*Fig. 17*).

Figure 17: Site 19 “Upstream stone bridge park Eckartsau”

Site 20 “Upstream beaver dam Eckartsau”: This site is the upper part of a separating beaver dam. In consequence of the impoundment by the beaver dam the water depth is relatively high. Only a few patches of *Lemna trisulca* constitute the aquatic vegetation. At the right shore a few grasses and shrubs overgrow the water body, but most of the shore consists of bare soil. At the left side grasses and shrubs cover the shore. The shading is mostly induced by the forest located near to the left shore. The water depth declines successively upstream from the dam (*Fig.18*).

Figure 18: Site 20 "Upstream beaver dam Eckartsau"

Site 21 "Downstream beaver dam Eckartsau": Site 21 is located east from the park from the castle in "Eckartsau" directly below a beaver dam, its course is straight and due to high in-stream vegetation the shoreline is not identifiable as one consistent line. At the left bank a small band of alluvial forest can be found. At the right shore a meadow is connected to the watershed. The forest located near to the left shore mostly induces shading. A dense population of grasses covered the left shoreline, while the right side was covered by grasses and shrubs with lower densities. The aquatic vegetation is dominated by emerged sedges (*Carex spp.*), reeds (*Phragmites australis*) and floating leaf plants (*Lemna trisulca*). No submerged vegetation has been observed (*Fig. 19*).

Figure 19: Site 21 "Downstream beaver dam Eckartsau"

Site 22 "Wildlife feeding site": Site 22 is located southwards from "Eckartsau". The bed of the Fadenbach is widened and deep. Shrubs and grasses dominate the riparian vegetation. The whole water body is vegetated with dense stocks of submerged plants (*Ceratophyllum demersum*, *Myriophyllum verticillatum*) and algae (*Zygnema sp.*). The right shore is eroded and consists of silt and gravel (*Fig. 20*).

Figure 20: Site 22 "Wildlife feeding site"

Site 23 "Upstream bridge Eckartsau": This site is located upstream of a bridge on the forest road between "Eckartsau" and "Witzelsdorf". It is accompanied by a band of alluvial forest and does not show a high degree of siltation. The watercourse is straight without depressions in the shoreline. The water had a brownish-grey colour with an intense smell. The site is probably perennial and was settled by small patches of *Lemna trisulca*. Some coarse woody debris and high amounts of fallen leaves were observed at the date of examination. The substrate is composed of sapropel mixed with sand and gravel along the shores (*Fig. 21*).

Figure 21: Site 23 "Upstream bridge Eckartsau"

Site 24 "Downstream bridge Eckartsau": This site is a small patch at the lowest eastern part of the Fadenbach between "Eckartsau" and "Witzelsdorf", which is accompanied by a band of alluvial forest. Thus, high shading through the adjacent trees and the high embankment is given and a high degree of siltation caused by coarse woody debris and fallen leaves is obvious. The site is located below a bridge at which the longitudinal connectivity is occasionally interrupted. Only residual water was found at the date of examination. No aquatic vegetation has been observed and the remaining water area was about 8 m². The whole substrate is classified as sapropel (*Fig. 22*).

Figure 22: Site 24 "Downstream bridge Eckartsau"

5. Material & methods

5.1 Fish sampling method

All sites were sampled by electro-fishing along the banks with a continuous current generator EL 62II Honda GX160. The voltage output was adjusted to reduce incidental mortality and maximize efficiency in each sample reach. The immobilised fish were collected by two operators with dip nets. Caught fish were kept in containers (ca. 1.0 m x 0.5 m x 0.5 m) with water from the sampling site and adequately supplied with oxygen. Every individual was identified to the species level, measured (± 0.5 cm) and weighted (± 1 g). After this procedure all fish were released back into the sampling site. Fishing time (± 30 sec) and area of the sampled reach (± 1 m^2) has been recorded as measures for the sampling effort. The abundance of single species was expressed as catch per unit effort (CPUE), and related to the number of fish that was caught per minute sampling time as well the number of fish per square meter.

Nomenclature for the fish species was used after Kottelat & Freyhof (2007) and ecological guilds were defined according to Schiemer & Waidbacher (1992).

5.2 Abiotic factors and water body morphology

In this study the habitat classification has been conducted following Flosi & Reynolds (1994). The Fadenbach – Oxbow was divided into channel geomorphic units. Channel geomorphic units are homogeneous areas of a channel that differ in depth, velocity, and substrate characteristics from adjoining areas creating different habitat types in a stream channel (Moore et al., 1995). Because the system that was examined in this study was mostly lotic at the time of sampling, velocity wasn't a relevant factor. Only at two sites (18 and 19) a water-velocity was observed, but the values were below the sensitivity (± 0.02 m sec^{-1}) of the inductive flow-meter. Water depth of every site has been quantified by wading along a zigzag pattern and measuring depth every 0.5 m to the nearest 1.0 cm by a measuring rod. Substrate composition was estimated by wading along six zigzag transects at each site according to the paddle count technique from Bevenger & King (1995). Substrate was classified in six different size classes according to Rosgen (1994) by visual estimation.

To categorise "cover" and "refuge" I used the rational technique according to Stevenson & Bain (1999). For enumerating woody debris, the quantity and the diameter of all of the wooden parts that were greater than one centimetre and that intercepted the zigzag transect were counted and classified into four diameter classes (1-5, 6-10, 11- 50, > 51 cm). For further analyses, the average of the number of each size category of the three compartments per site was used. In order to estimate the mean width, the aquatic and the riparian vegetation each sampling site was split into three lateral and four longitudinal transects.

Width was measured in all of the three lateral transects per site from wetted shoreline to wetted shoreline. Additionally, bankfull width and the distance between bankfull to water surface were measured to the nearest 1.0 cm by a measuring rod. For every site mean depth and width was computed and used for further analyses.

Vegetation cover for each of the three longitudinal sub-transects was categorised by the dominant vegetation type (emergent, floating, or submerged). Very common and dominant taxa were determined and noted. If species determination was not possible in the field, one or two exemplars were taken and defined in the laboratory.

At both shores, the riparian vegetation in an area of 1 m distance from the wetted shoreline was categorised as trees, shrubs, reeds and was then recorded as percentage coverage per meter according to Stevenson & Bain (1999).

5.3 Hydro-chemistry

Water samples were taken using PE–tubes that have been washed in the water of the examined site. Water samples were cooled in the field by cooling bags and transported to the laboratory where they were preserved in a refrigerator at 4 °C up to a maximum of three days. Afterwards the probes were analysed in the laboratory.

The ion concentrations of Na, K, Ca, and Mg were detected by ion chromatography according to OENORM EN ISO 14911:1999. Cl, SO_4, and NO_3 were analysed by ion chromatography according to OENORM EN ISO 10304-1:2012. The ion chromatographic analyses have been implemented on a Metrohm 761 Compact IC. The filtration has been done inline by a Metrohm 788 IC Filtration Sample Processor. The degasification of the probes and eluents has been executed inline by a Metrohm 837 IC Combi Degasser.

NH_4 and PO_4 were analysed photometric after OENORM ISO 7150-1:1987 and OENORM EN ISO 6878:2004, respectively. In that system the cations have been unstitched by a tartaric acid (4 mM)/dipicolinacid (0.75 mM)) eluent in a Metrosep C2 150/4.0 mm tube. The anions have been unstitched by a $NaHCO_3$ (1mM)/Na_2CO_3 (4mM) eluent in a Metrosep A Supp 5 150/4.0 mm tube. The chromatograms have been evaluated by the software IC Net 2.3.

5.4 Statistical analyses

For definition of groups of sites with similar habitat conditions hierarchical cluster analysis (Ward method, squared Euclidean distance) was used. The environmental data had different units, so the data was standardized by a z-transformation. The fish abundance data (expressed as CPUE) has been sorted into the clusters of sites. To check similarities in fish abundances between the groups of sites by an ANOVA with additional Bonferroni post-hoc test was applied.

Weight–length relationships were analysed applying simple linear regressions. The length-weight data has been transformed ($\log_{10}$ transformation) to get a linear form of the relationship. I used the following equation:

eq. 1: $\log W = \log a + b \log TL$

In the equation W is the wet weight in gram, TL is the total length in cm, *a* is the intercept and *b* is the slope of the regression.

For the description of the species-environment relations I used ordination methods. To test for differences in the occurrence/abundance of species concerning geo-morphological and hydro-chemical factors the program CANOCO 4.5 was used.
In order to check if a linear or non-linear method is more suitable for the description of the community data in relation to the environmental variables I used a Detrended Correspondence Analysis (DCA). The length of the first gradient and its relation to the following gradients gives information about the homogeneity and which method describes the data best (Lepš & Šmilauer, 2003). As the species data set was relatively homogeneous and some of the variables were categorical, I used redundancy analysis, a method based on a linear model. The null-hypothesis was that there are no differences between species abundances in relation to the environmental factors. As such it is possible to note that all species behave equal along the environmental gradients. A forward selection with a partial Monte Carlos permutation test was used to detect whether an increase of explained variability though additional variables is larger than expected by a random contribution (Lepš & Šmilauer, 2003). An additional Monte Carlo permutation test has been applied (499 permutations) to test if the model significantly differed from a random effect. The first axis and all canonical axes were tested separately.
Similarity of fish species composition between the 21 macro habitats with fish occurrence was evaluated using non-metric multi-dimensional scaling (NMDS) and cluster analysis. Combination

of clustering and ordination can be an effective way of checking the adequacy and mutual consistency of both representations (Clarke & Gorley, 2006).

All NMDS calculations and subsequent analyses were performed using PRIMER v6.0 (Primer-E Ltd, Plymouth, MA, USA). The abundance values were transformed using a fourth root transformation. All environmental variables were normalized, transformed using a log (X + 1) transformation, and similarity matrices were generated using Euclidean distance. Subsequently, a subset of environmental variables that best correlated to the fish community structure was used to split samples into groups using the LINKTREE procedure. To determine statistical significance a permutation test (Simprof test, 999 permutations) was used. Only splits where the p - value was less than 0.05 were performed.

To compare communities among sites Shannon-Wiener Diversity Index and Evenness was used as diversity index. For quantification of differences in the fish assemblages at different sites Bray-Curtis Similarity Index (Bray & Curtis, 1957) was used. The Similarity coefficient describes the ratio between species turnover between two sites and the species number over two sites. The following equation was used for the Bray-Curtis Similarity:

eq.2: $$C_N = \frac{2jN}{(N_a + N_b)}$$

In the equation N_a is the total number of individuals at site A, N_b is the total number of individuals at site B and 2jN is the sum of the minor of two abundances for species that had been found on both sites. For identical samples the value is 1 and for samples without shared species it is 0 (Magurran, 2004).

6. Results

6.1 Abiotic factors

6.1.1 Morphology, connectivity, structure, cover & vegetation

All sites, except site 17 (downstream swimming pool “Eckartsau”) and site 24 (last sampling point downstream bridge “Eckartsau”) are presumably perennial with a persistent water body througout the whole year. At the time of our study the Fadenbach system was represented by single fragments of pools, rather than a continuous water body. Site 10 (“levee /Pond 1“) and site 16 (“swimming pool Eckartsau“) were not connected to the adjacent water bodies. Twelve of the examined sites only had a one-sided (up- or downstream) connection and ten sites were connected at both sites to the water body (*Tab.* 1). Independent of the location along the longitudinal course the average width varied between 1.5 m and 22.5 m. The average water-depth between sites ranged from 0.12 m to 1.05 m. The bottom material of sixteen sites mainly consisted of mud with a layer of organic material (sapropel). At seven sites patches with sand and alluvial gravel and small stones existed. The substrate of site 22 ("wildlife feeding site") mostly consisted of sand, alluvial gravel and small-sized stones. At this sampling point flood induced erosions were present, which implies a corresponding dynamic of the waterbody. The weighted density of woody debris varied between 0 and 7 whereby at twenty-two sites wooden structures were found in the water body. Eleven sites were vegetated by emerged vegetation. Five of these sites showed very high coverages with 30 to 60 % of the water body. Submerged vegetation was found at 13 sites, from which 7 sites were covered by 30 to 60 %. 16 sites had stands of swimming leaf vegetation, mainly *Lemna trisulca*. The surfaces of six sites were covered from 30 to 90 %. Only a scarce vegetation of the riparian zone (width 1m) was recorded for most sites. The riparian areas consisted mostly of bare soil. Some sites showed low densities of shrubs and trees (Sites 18 and 19) and a high density of trees (Sites 11 and 22).

6.1.2 Hydro-chemistry

The average water temperature was 11.8 °C (± 2.3) and the average pH value was 8.1 (± 0.1), respectively. The oxygen saturation differed considerable between the sampled sites ranging between 3.7 and 66.7 %. Those values correspond to concentrations of 0.4 and 8.0 mg l^{-1} oxygen in the water. Conductivity values ranged between 417 and 1022 µS cm^{-1}. The conductivity values were highest at the first two sampling points in "Mannsdorf", followed by the lowest values (sites in the national park centre "Orth a.d. Donau" (3, 4, 5, and 6)). Then the values rose successively along the longitudinal course. Similar patterns for the free ions sodium, calcium, magnesium, chloride and sulphate were observed. The values for orthophosphate fluctuated between 10 and 425 µg l^{-1}. Five sites showed distinct increased values, these were the two sites in "Mannsdorf" (sites 1 and 2), pond 1 (site 10) at the levee, the old swimming pool in "Eckartsau" (site 16) and the last sampling site (site 24). The ammonia concentrations ranged between 5.4 and 832.0 µg l^{-1}. Even for that factor the first two sites (sites 1 and 2) showed the highest values in the Fadenbach system. Even, high concentrations were detected for the Sites 6 ("Castle Orth/Pond 2"), 11 ("levee/Pond 2") and 22 ("wildlife feeding"). The nitrate values fluctuated between 2.3 to 30.5 µg l^{-1}. Whereby, the highest concentrations were observed at sites 1 and 2, again. Site 22 and the sites around the castle in "Eckartsau" (17, 18) showed elevated concentrations (Tab. 2).

Table 1: Abiotic factors of the examined sites at the sampling time 25.-26.10.2013: Mean: average value; SD: Standard deviation; Width = width from wetted shore line to wetted shore line; depth = depth; substrate = substrate heterogeneity; woody debris: amount of wood in the water body; Veg_{em} = emerged Vegetation; Veg_{sub} = submerged vegetation; Veg_{float} = floating leaf vegetation; Rip_{weed} = riparian reeds; Rip_{shrub} = riparian shrubs; Rip_{tree} = riparian trees.

				Mean		SD	Mean		SD	Mean	Mean	Mean	Mean	Mean	Mean	Mean	Mean
Site #	bankfull height (m)	permanence	connectivity	width (m)			depth (m)			substrate	woody debris	Veg_{em} (%)	Veg_{sub} (%)	Veg_{float} (%)	Rip_{weed}	Rip_{shrub}	Rip_{tree}
1	3.10	1	2	5.03	±	1.69	0.51	±	0.38	0.00	1.42	0.00	0.00	32.00	0.01	0.00	0.00
2	2.75	1	1	4.77	±	0.47	0.48	±	0.19	0.00	1.58	0.00	0.00	90.00	0.02	0.00	0.00
3	4.50	1	2	4.57	±	0.40	0.21	±	0.07	0.00	3.17	0.00	10.00	90.00	0.03	0.00	0.10
4	2.45	1	1	14.13	±	4.59	1.05	±	0.54	0.33	1.33	0.00	0.00	2.00	0.01	0.00	0.00
5	2.15	1	2	4.23	±	0.98	0.27	±	0.12	0.00	4.08	1.00	13.00	0.00	0.04	0.01	0.13
6	2.65	1	2	22.47	±	7.95	0.74	±	0.34	0.00	0.50	0.00	60.00	0.00	0.01	0.00	0.60
7	2.60	1	1	9.97	±	0.25	0.47	±	0.19	0.00	4.50	0.00	0.00	5.00	0.05	0.00	0.00
8	2.70	1	1	8.85	±	1.70	0.36	±	0.23	0.42	3.17	0.00	0.00	0.00	0.03	0.00	0.00
9	2.05	1	2	3.73	±	1.16	0.37	±	0.15	0.00	3.58	0.00	0.00	0.00	0.04	0.00	0.00
10	3.45	1	3	7.33	±	2.85	0.26	±	0.10	0.00	0.33	30.00	7.00	15.00	0.00	0.30	0.07
11	3.05	1	2	8.37	±	2.32	0.31	±	0.17	0.17	0.00	3.00	80.00	3.00	0.00	0.03	0.80
12	0.81	1	2	8.73	±	1.16	0.17	±	0.05	0.00	3.42	2.00	8.00	0.00	0.03	0.02	0.08
13	1.45	1	2	8.63	±	0.61	0.31	±	0.14	0.00	2.58	0.00	37.00	12.00	0.03	0.00	0.37
14	1.30	1	1	12.47	±	0.15	0.48	±	0.22	0.00	2.25	0.00	10.00	80.00	0.02	0.00	0.10
15	2.70	1	2	9.98	±	2.73	0.48	±	0.21	0.17	2.17	32.00	47.00	3.00	0.02	0.32	0.47
16	1.46	1	3	13.08	±	2.75	0.55	±	0.15	0.17	2.25	7.00	10.00	15.00	0.02	0.07	0.10
17	3.25	2	2	1.51	±	1.46	0.23	±	0.20	0.33	1.08	2.00	0.00	5.00	0.01	0.02	0.00
18	1.40	1	1	2.19	±	0.29	0.14	±	0.04	0.00	0.42	66.67	33.33	0.00	0.00	0.67	0.33
19	1.40	1	1	13.47	±	3.10	0.45	±	0.22	0.00	1.33	63.33	33.00	5.00	0.01	0.63	0.33
20	1.05	1	2	3.81	±	0.30	0.38	±	0.18	0.00	0.25	0.00	0.00	47.50	0.00	0.00	0.00
21	1.00	1	2	3.42	±	0.14	0.27	±	0.10	0.00	0.64	30.00	0.00	58.33	0.01	0.30	0.00
22	2.31	1	1	11.17	±	0.70	0.98	±	0.40	1.08	0.00	8.00	80.00	0.00	0.00	0.08	0.80
23	2.90	1	1	5.47	±	0.06	0.41	±	0.15	0.33	0.50	0.00	0.00	25.74	0.01	0.00	0.00
24	2.90	2	1	2.90	±	1.13	0.12	±	0.21	0.00	7.04	0.00	0.00	0.00	0.07	0.00	0.00

Table 2: Chemical variables of the sampling sites at 25.-26.10.2013

site #	O_2 (mg l^{-1})	O_2 (%)	conductivity (µS cm^{-1})	T (°C)	pH	sodium (mg/l)	potassium (mg/l)	calcium (mg/l)	magnesium (mg/l)	chloride (mg/l)	sulfate (mg/l)	P-PO_4 (µg/l)	N-NH_4 (µg/l)	N-NO_3 (µg/l)
1	0.5	5.7	951.3	14.3	8.2	29.6	24.6	122.8	39.1	66.5	96.1	94.0	831.7	10.8
2	0.4	4.3	1021.7	13.4	8.0	15.7	13.3	139.4	48.1	64.7	78.1	168.4	816.9	11.3
3	1.3	13.7	416.7	13.9	8.1	9.3	8.2	59.1	12.9	15.7	20.7	39.0	19.5	4.1
4	0.8	6.3	481.3	9.4	8.0	10.8	6.6	67.5	18.1	20.9	23.3	27.6	17.7	2.3
5	0.5	4.0	598.3	13.8	8.1	12.8	8.2	69.3	29.2	35.8	51.3	42.8	25.0	2.9
6	0.9	8.7	554.7	10.2	8.2	13.4	7.1	62.5	28.7	35.9	63.0	20.8	128.9	3.6
7	0.9	8.3	475.7	15.7	8.1	10.1	6.5	69.1	15.5	17.7	14.8	24.3	19.5	6.1
8	0.4	3.7	439.0	14.4	8.1	9.9	6.4	63.6	14.2	15.8	12.9	17.2	12.4	6.8
9	2.2	21.3	440.7	14.8	8.3	9.8	6.6	63.5	13.9	15.7	11.7	38.4	16.4	0.0
10	8.0	66.7	707.7	7.1	8.4	13.2	15.8	96.5	33.5	33.8	39.2	424.9	27.2	4.5
11	7.7	65.9	636.0	6.8	8.2	14.2	5.1	96.8	26.5	22.8	26.7	14.0	326.8	5.9
12	1.3	11.6	715.0	9.3	8.3	15.8	10.2	104.4	29.8	29.1	5.8	33.2	9.7	2.9
13	0.8	7.0	795.7	12.8	8.0	15.9	6.0	117.7	37.3	37.5	43.5	19.6	32.5	2.9
14	1.0	8.7	763.0	12.0	8.1	16.6	9.5	114.7	37.4	39.8	35.2	68.7	23.0	8.4
15	0.6	6.0	516.0	12.3	8.2	12.3	8.9	61.1	24.3	25.5	11.1	10.1	20.5	4.3
16	2.5	23.0	511.3	12.1	8.2	14.2	10.2	59.8	26.8	28.1	20.4	246.0	21.5	2.9
17	1.8	14.3	882.3	12.4	7.9	20.2	3.2	103.3	35.1	36.2	48.0	65.7	62.0	15.3
18	5.8	50.7	1005.3	12.0	8.1	26.7	3.1	136.5	51.2	57.8	153.9	21.0	16.9	30.5
19	1.4	12.7	956.3	11.5	7.9	26.7	3.4	137.4	51.7	58.2	151.2	29.9	5.4	3.8
20	0.5	13.0	735.7	11.2	8.0	23.0	6.2	80.6	37.4	52.4	76.5	27.8	8.4	3.6
21	0.6	5.3	770.3	11.2	7.8	22.7	4.5	85.9	35.4	52.0	54.8	20.4	9.9	3.2
22	1.1	11.5	765.7	8.5	8.1	17.2	3.5	106.1	33.6	27.2	60.4	50.8	264.1	10.4
23	1.7	15.3	797.7	11.3	8.0	16.0	6.2	114.4	35.4	27.8	52.4	87.8	13.9	6.1
24	1.0	13.0	800.0	11.5	8.3	15.9	6.1	116.1	36.0	28.3	45.3	304.6	22.5	9.5

6.1.3 Grouping of sites by morphological & hydro-chemical factors

The hierarchical clustering (Ward's method, squared Euclidean distance) of sites according to selected environmental variables (bankfull, riparian shrubs, conductivity, pH, sodium, potassium and orthophosphate) revealed three main clusters. The first cluster contained two sites (1, 2), the second cluster included 19 sites (3 -17, 20, 22-24) and the third cluster four sites (18, 19, 21) (*Fig*.23). The fractionation into the three groups can described by a decline of bankfull height from cluster 1 to 3, a small amount of shrubs in cluster 2, high conductivity values in the first and third cluster, and a decline of the orthophosphate and ammonia concentrations of the sites from the first to the third group.

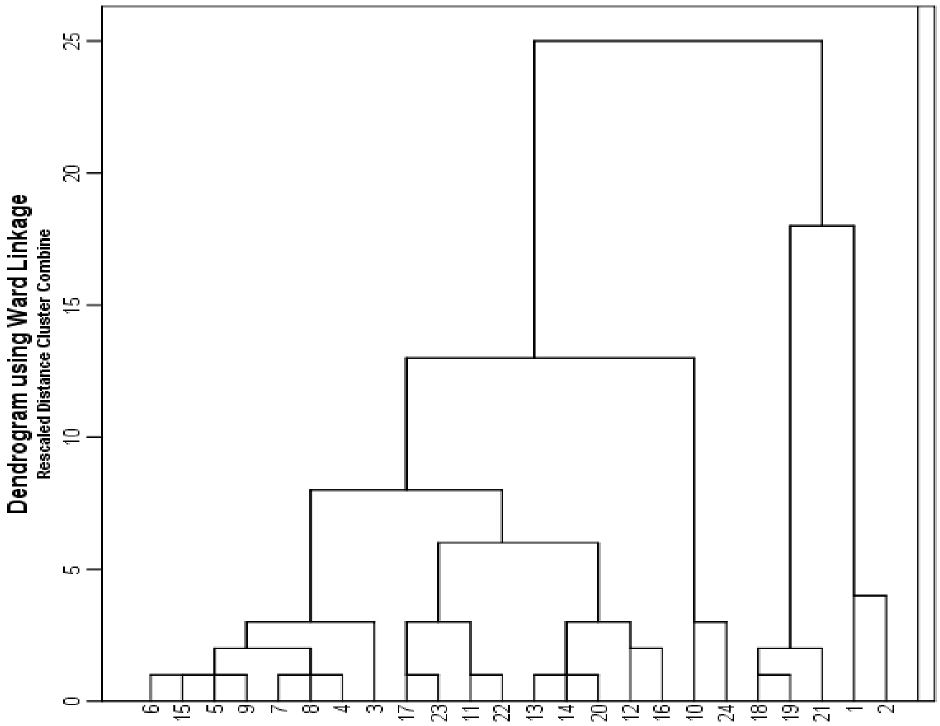

Figure 23: Dendrogram of the cluster analysis. Separation of the sampling sites by selected morphological and hydro-chemical factors.

6.2 Fish assemblage

6.2.1 Species occurrence, endangered species & ecological guilds

During this study, altogether 17 different species have been observed. From these, 9 were classified as eurytopic (53 %), 7 (41%) as stagnophilous and *1 (6 %)* as *rheophilous (Tab. 3*). According to Schiemer & Waidbacher (1992) two of these species are listed as potentially endangered, two as endangered, two as strongly endangered and two as endangered by extinction. About 47 % of the registered species are listed in the red list of Austria (IUCN 2014) as at least potentially endangered. The highest number of individuals was given by the European mudminnow followed its only relative of the family Esocidae in Europe, the pike.

The highest biomass represented the pike with an amount of 4696 g (~ 40 %), the crucian carp 1837 g (~ 15 %) and the tench 1643 g (~ 14 % of the total catch). 24 % of all species (*Abramis brama*, *Alburnus alburnus*, *Blicca bjoerkna*, and *Proterorhinus semilunaris)* occurred at one single site (*Fig. 24*). Two species (*Squalius cephalus*, *Leuciscus idus*) were registered at two sites, one (*Scardinius erythrophthalmus*) at 3 sites and two species *(Rhodeus amarus*, *Rutilus rutilus*) at 4 sites. Further two species (*Leucaspius delineatus*, *Misgurnus fossilis*) have been observed at five sites and one (*Carassius gibelio*) at 7 sites. One species occurred at 8 (*Perca fluviatilis)* and 9 (*Tinca tinca*) sites, respectively. The two representatives of the *Esocidae* (*Esox lucius*, *Umbra krameri*) were observed at 15 and 16 sites, respectively. The crucian carp occurred at 90 % (19 of 21 sites) of all sites with fish occurrence.

Table 3: Total catch of the sampling series between 11.11. and 15.11.2013. The number of individuals of each species and the mean individual biomass as living wet weight in gram (g) and as percentage of total catch is listed. The frequency of occurrence is given as site number. Also indicated are the ecological guilds and the state of endangerment. Degree of endangerment: doe: danger of extinction, e: endangered, he: highly endangered, pot e: potential endangered, uc: uncertain. Ecological guilds: Eu: eurytopic, Rh: rheophilous, St: stagnophilous

Species	abbreviation	# individuals	% individuals	occurence (sites)	biomass (g)	% biomass	ecological guild	endangerment
Abramis brama	*Abram_brama*	3	0.37	5	74.6	0.62	Eu	
Alburnus alburnus	*Albur_albur*	27	3.34	9	52.1	0.44	Eu	
Blicca bjoerkna	*Blicc_bjoer*	6	0.74	9	71.2	0.60	Eu	
Carassius auratus gibelio	*Caras_aurat*	22	2.72	6, 9-12, 17, 19	1074.2	8.99	Eu	
Carassius carassius	*Caras_caras*	71	8.79	4, 6-8, 10-12, 14-17, 19, 22	1837.8	15.39	St	he
Esox lucius	*Esox_luciu*	100	12.38	3-6, 8-12, 15, 16, 19-22	4696.0	39.32	Eu	e
Leucaspius delineatus	*Leuca_deli*	94	11.63	9, 11, 13, 14, 17	2.2	0.02	ST	uc
Squalius cephalus	*Squal_cepha*	3	0.37	8, 9	21.6	0.18	Eu	
Leuciscus idus	*Leuci_idus*	5	0.62	8, 9	224.0	1.88	Rh	he
Misgurnus fossilis	*Misgu_fossi*	18	2.23	10 - 12, 17, 18	113.6	0.95	St	doe
Perca fluviatilis	*Perca_fluvi*	31	3.84	5, 6, 8, 9, 15, 16, 19, 22	431.8	3.62	Eu	
Protheorhinus semilunaris	*Prote_marmo*	4	0.50	22	3.5	0.03	Eu	
Rhodeus amarus	*Rhode_amaru*	22	2.72	8, 18, 19, 22	4.8	0.04	St	e
Rutilus rutilus	*Rutil_rutil*	71	8.79	5, 9, 8, 15	653.9	5.48	Eu	
Scardinius erythrophthalmus	*Scard_eryth*	45	5.57	8, 9, 15	543.3	4.55	St	pot e
Tinca tinca	*Tinca_tinca*	42	5.20	3, 4, 6, 8, 9, 15-17, 22	1643.3	13.76	St	pot e
Umbra krameri	*Umbr_kram*	244	30.20	3, 4, 6, 8, 10, 12-19, 21, 22, 24	495.3	4.15	St	doe
total		808	100.00		11943.2	100.0		
taxa total		17						

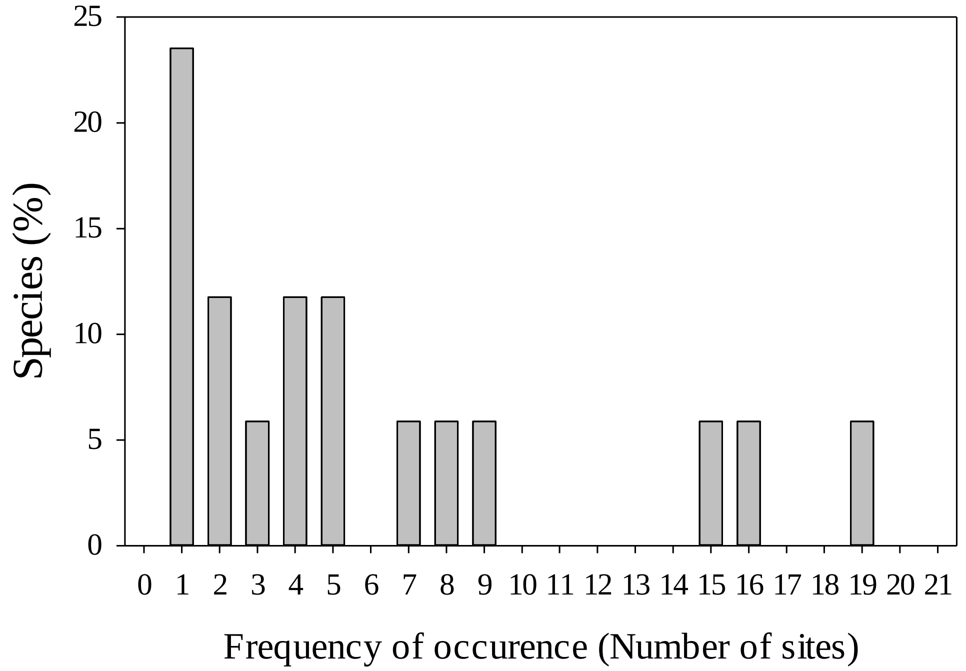

Figure 24: Frequency of species occurrence: 24% of all species occurred at only 1 site, and 5 % of all species occurred at 19 different sites.

6.2.2 Species Abundance

The abundance of single species is expressed as number of caught individuals (catch) per square meter (effort). *L. idus*, the only species belonging to the rheophilous guild showed the lowest, and those from the eurytopic and stagnophilous guild showed the highest abundances. *U. krameri*, *L. delineatus*, *C. carassius*, *E. lucius* and *R. rutilus* had the highest abundances in the total catch. In the eurytopic guild *A. alburnus*, *P. fluviatilis*, *A. brama* and *C. gibelio* exhibited intermediate abundances. In the stagnophilous guild these were *S. erythrophthalmus*, *T. tinca* and *M. fossilis* (*Fig. 25*). *B. bjoerkna* and *P. marmoratus* (both eurytopic) and *R. amarus* (stagnophilous) occurred in low abundances.

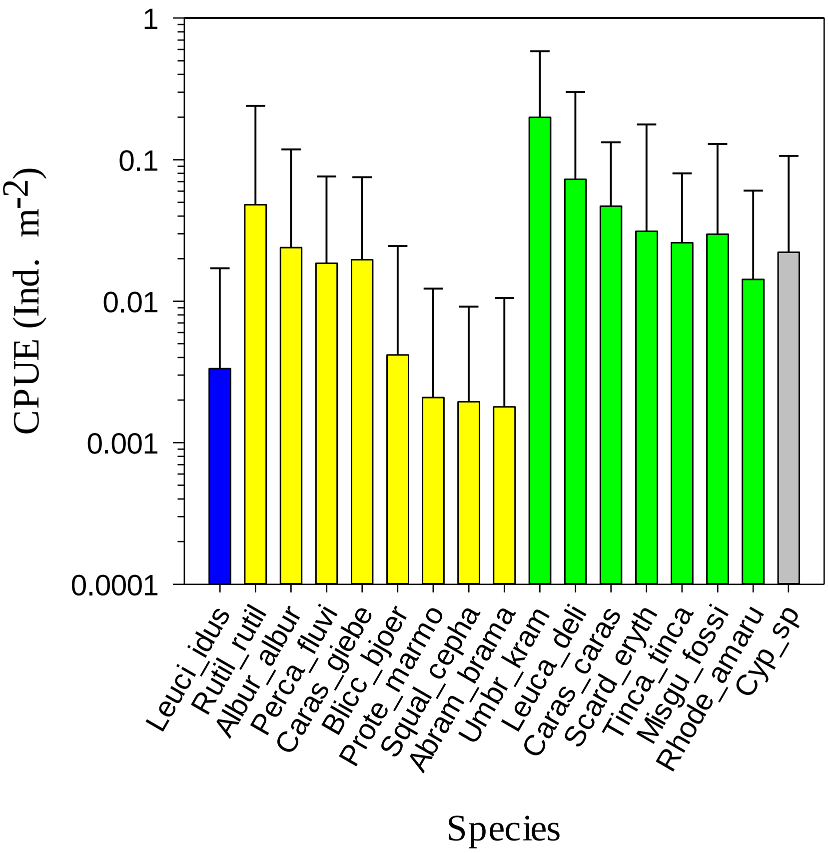

Figure 25: Average (± standard deviation) catch per unit effort of occurring species in the sampling area. Ecological guilds are shown in different colors. Blue =; yellow; eurytopic; green = stagnophilous; grey = indef.

Fig. 26 shows the fish abundance at the single sites along the longitudinal course of the water body, and compares overall abundance values with those for the mudminnow alone. Overall, there were three (1, 2 and 23) out of 24 sites with no fish occurrence. At the sites 3 and 4 *U. krameri* accounted for approximately 60 % and 75 %, of the fish abundance (0.64 and 0.44 ind. m^{-2}). At site 9 (levee /south) the highest observed abundances of 4.2 ind. m^{-2} were found. No individuals of *U. krameri* were observed at this site. In the middle part of the Fadenbach system in the area between "Orth" and "Eckartsau" the highest abundances of the mudminnow were observed, especially site 10 ("levee pond 1") (1.033 ind. m^{-2}) and site 15 ("upstream swimming pool/ downstream sewage plant") (1.64 ind. m^{-2}) revealed high densities of mudminnows. The species accounted for 74 and 75 % of the total catch at these sites, respectively. In the lower part of the Fadenbach (from site 20 "upstream beaver dam" to 24 "downstream bridge Eckartsau") low abundances between 0.08 and 0.14 ind. m^{-2} and infrequent occurrence of the mudminnow in comparison to the remaining water were found.

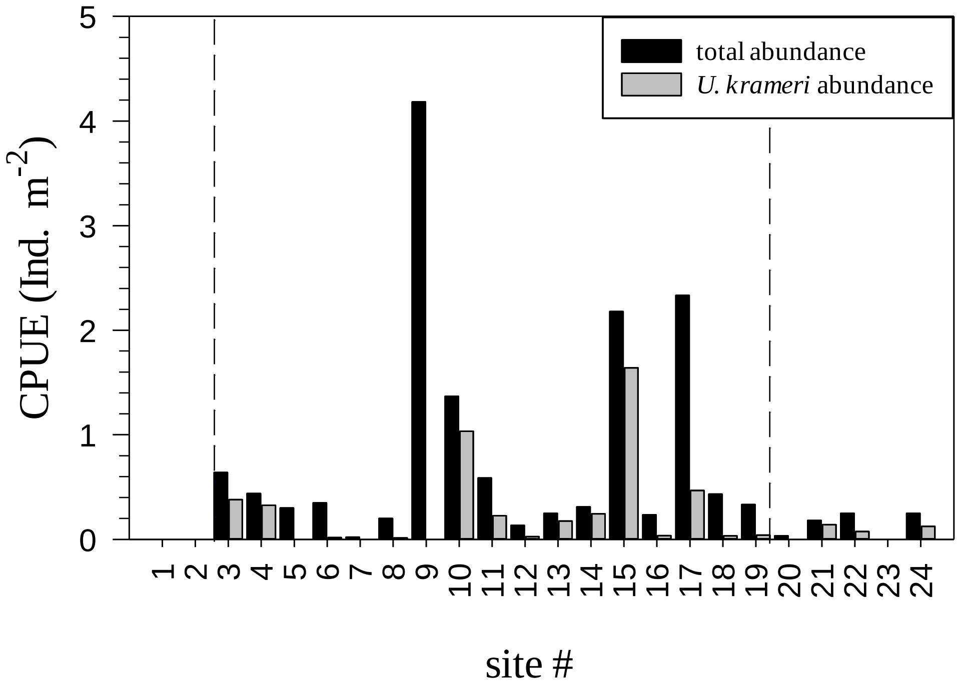

Figure 26: Longitudinal course of total fish abundance and U. krameri abundance per site in the Fadenbach system in September 2013.Upper, middle and lower part of the Fadenbach are separated by scattered lines.

6.2.3 Biomass

In *Fig. 27* box plots show the mean biomass of single species per sampled area. The species with the least mean biomasses were *R. amarus* (0.005 ± 0.005 g m^{-2}), *L. delineatus* (0.006 ± 0.001 g m^{-2}) and *P. semilunaris* (0.015 ± 0.013 g m^{-2}). In contrast, the highest mean biomass was given by *E. lucius* (0.628 ± 1.040 g m^{-2}), *Leuciscus idus* (1.002 ± 1.656 g m^{-2}) and *C. gibelio* (1.188 ± 1.956 g m^{-2}).

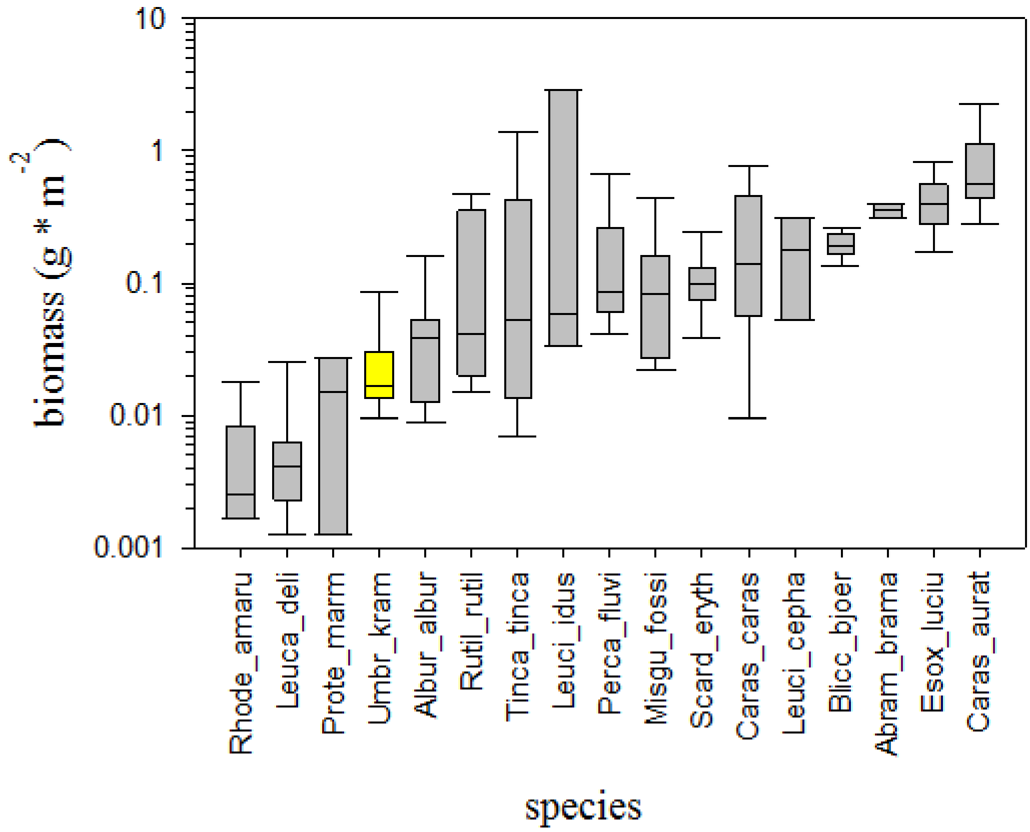

Figure 27: Box-Whisker-Plots for the mean biomass per species per area for the sampling series in the Fadenbach between 11.11. and 15.11.2013. Shown are the median, 25%, 75% and 95% percentiles.

The mean biomass of the entire catch compared to the sampling area ranged between 0 (Sites 1, 2 and 23) g m^{-2} and 1.95 ± 2.36 g m^{-2} (site 8). The sites 8, 19 and 20 showed the highest mean total teleost biomass values, whereas Site 18 showed the lowest fish biomass (*Fig. 28*).

The highest mean biomass of the mudminnow applied to the sampling area have been observed at the sites 18 (0.49 ± 0 g m^{-2}) and 24 (0.175 ± 0 g m^{-2}), whereby at these sites only one adult individual was registered. Several sites (4, 11, 12, 15, 19 and 21) showed similar values of the mean biomass of the mudminnow between 0.01 and 0.04 g m^{-2}. At all other sites *U. krameri* didn't occur or was present in low values only. Both the biomass of the entire catch and of *U. krameri* varied over the longitudinal course of the Fadenbach, no continuous gradient over the stretch could be identified.

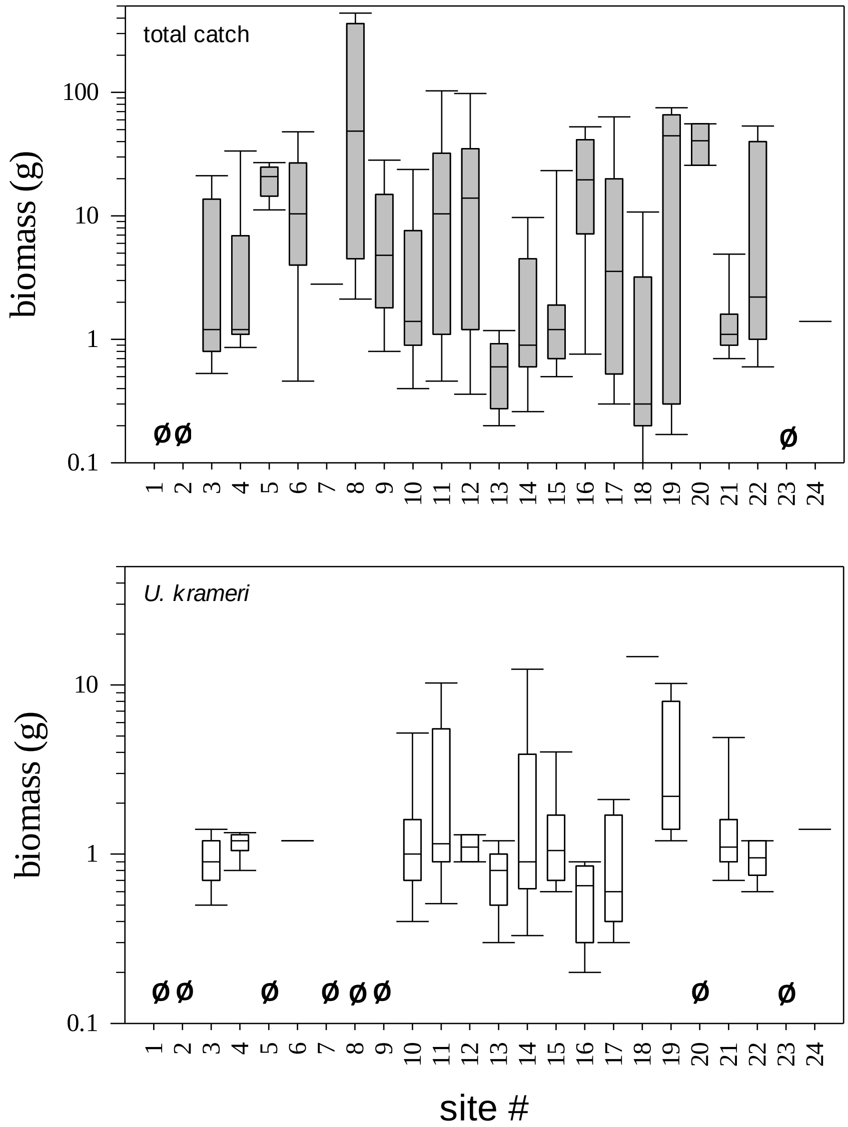

Figure 28: Box-Whisker-Plots: Biomass of the entire catch per sampling site (on top) and of the mudminnow (on bottom) per site. Shown are the median, 25 %, 75 % and 95 % percentiles.

The biomass of the ecological guilds was highest for the eurytopic species, and was for the stagnophilous species distinctly lower (*Fig. 29*). Biomass differed significantly between the eurytopic and the stagnophilous guild (t-test, t_{eury} = 6.95, t_{stagno} = 5.87, $d.f._{stagno}$ = 465, $d.f._{eury}$ = 200, P < 0.01). However, no differences in the biomass between the rheophilous guild and the eurytopic guild (t-test, t_{eury} = 6.95, t_{rheo} = 1.20, $d.f._{eury}$ = 200, $d.f._{rheo}$ = 4, P > 0.05) and between the rheophilous and stagnophilous guild could be found (t-test, t_{rheo} = 1.20, t_{stagno} = 5.87, $d.f._{rheo}$ = 4, $d.f._{stagno}$ = 465, P > 0.05).

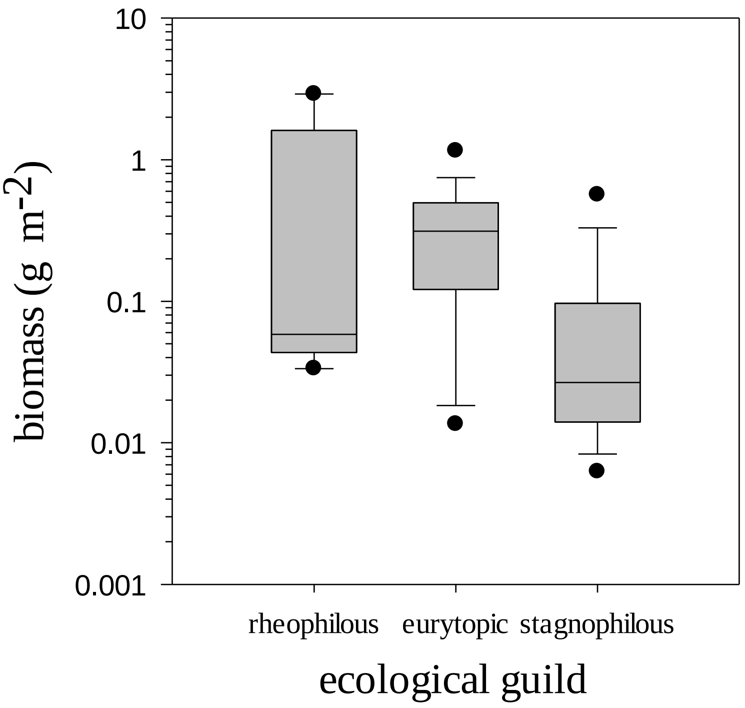

Figure 29: Box-Whisker-Plots of the biomass of the ecological guilds compared to the area for the sampling series in the Fadenbach between 11.11. and 15.11.2013. Shown are the median, 25 %, and 75 % and 95 % percentiles.

6.2.4 Length-weight relationships & size structure

Tab. 4 shows the mean length- and weight values, and the minimum- and maximum values of the 10 most abundant species. These values were used as basis for the length-weight regressions. The linear regression between length and weight was significant for all species and the *b* - value ranged between 2.07 for *R. rutilus* and 3.28 for *C. carassius* (*Tab.5*). The results of the linear regression (log fw = log a + b log TL) were: $r^2 = 0.92$; log a = - 5.089, b = 3.068.

The smallest and largest specimens were 2.1 and 10.8 cm, respectively. The 4-4.9 cm TL size group was numerically dominant and constituted 46 % of the total population (*Fig.30*). The length-frequency distribution of *U. krameri* showed a left skewed distribution and differed highly significant from a normal distribution (Shapiro-Wilk-test; W-Statistic: 0.712; P = 0.002).

Table 4: Shown are the mean length (cm) and the mean weight of every observed species in the Fadenbach at the sampling time between 11.11. and 15.11.2013. The standard deviation (SD), and the minimum- and maximum values are given.

	total length (cm)				weight (g)			
species	mean	SD	maximum	minimum	mean	SD	maximum	minimum
R. amarus	2.7	0.7	4.0	2.0	0.1	0.2	1.0	< 1
L. leucaspius	2.8	0.6	4.0	2.0				
U. krameri	5.0	1.6	11.0	3.0	1.9	2.7	17.0	< 1
P. semilunaris	5.0	1.4	6.0	3.0	1.0	1.0	2.0	< 1
A. alburnus	7.4	2.6	15.0	4.0	3.3	4.9	21.0	< 1
M. fossilis	8.5	4.6	22.0	2.0	7.1	12.4	46.0	2.0
S. erythrophthalmus	9.0	2.7	22.0	6.0	11.1	20.0	140.0	2.0
T. tinca	9.1	6.8	32.0	2.0	37.3	96.6	518.0	< 1
P. fluviatilis	9.2	2.8	16.0	6.0	13.1	14.3	55.0	2.0
C. carassius	9.2	3.9	17.0	2.0	52.1	24.1	102.0	< 1
L. cephalus	10.0	2.8	12.0	8.0	10.5	10.6	18.0	3.0
B. bjoerkna	10.7	0.8	12.0	10.0	11.8	2.9	16.0	8.0
R. rutilus	11.5	19.0	14.7	4.0	11.9	12.9	48.0	< 1
L. idus	12.0	10.0	27.0	6.0	74.7	124.1	218.0	2.0
C. gibelio	13.0	3.4	20.0	4.0	53.7	41.4	185.0	1.0
A. brama	14.3	0.6	15.0	14.0	25.0	3.0	28.0	22.0
E. lucius	17.9	5.5	42.0	9.0	47.5	82.6	550.0	4.0

Table 5: Values of the linear regression and statistics of the model of the length-weight relation of the 10 most common species for the sampling time between 11.11. and 15.11.2013. n = number of measurements; a = intercept with Y-axis; r² = coefficient of determination, p = significance level (< 0.05), CL = 95 % confidence interval.

species	*n*	log *a*	± CL	*b*	± CL	r²	*p*
Alburnus alburnus	16	-4,0284	-0,3669	2,3609	0,7332	0,78	< 0,001
Carassius auratus gibelio	20	-4,6780	-0,3049	2,9881	0,1454	0,99	< 0,001
Carassius carassius	73	-5,2444	-0,2488	3,2754	0,1258	0,99	< 0,001
Esox lucius	99	-5,4270	-0,2967	3,0806	0,1324	0,98	< 0,001
Misgurnus fossilis	16	-4,7712	-0,5918	2,8362	0,3032	0,98	< 0,001
Perca fluviatilis	32	-5,2642	-0,3965	3,1614	0,2031	0,99	< 0,001
Rutilus rutilus	55	-3,3141	-0,7254	2,0772	0,3712	0,85	< 0,001
Scardinius erythrophthalmus	49	-5,3023	-0,721	3,1618	0,3702	0,93	< 0,001
Tinca tinca	47	-4,5639	-0,2009	2,8661	0,1031	0,99	< 0,001
Umbra krameri	261	-4,4869	-0,2396	2,7349	0,1405	0,86	< 0,001

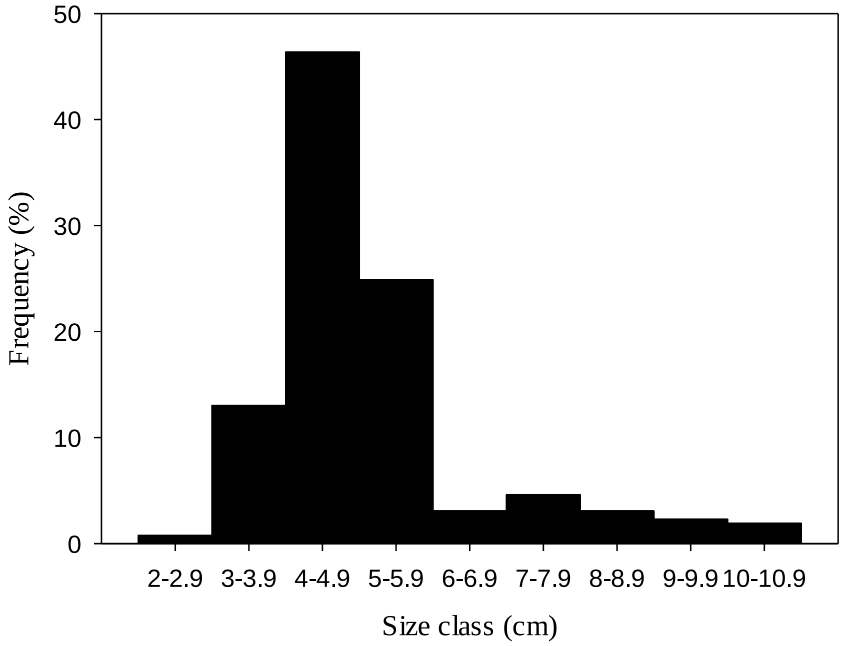

Figure 30: Length-frequency distribution of the European mudminnow (U. krameri) in the Fadenbach 2013.

6.3 α & β Diversity

The Shannon – Wiener Index (H') ranged between 0.00 and 2.18 and the evenness ranged between 0.4 and 1.0. Sites 14 and 15 (“downstream Porau” and “upstream swimming pool”) showed the highest α – diversity values. Lowest α - diversity was observed for the sites 9 and 19 (“levee south” and ”upstream stone bridge Eckartsau”). The highest evenness was registered for the sites 20 and 24 (“upstream beaver levee” and “downstream bridge Eckartsau”). For both, the α – diversity and the evenness no patterns along the examined section existed.

Regarding the ß- diversity, the highest similarity of species composition, stated as Bray – Curtis dissimilarity index, was estimated between site 4 and site 10 (0.61, 4 shared species) plus between site 3 and 4 (0.61, 3 shared species). In contrast the lowest similarity was found between site 9 and 14 (0.01, 1 shared species), site 15 and site 18 (0.01, 1 shared species), site 9 and site 18 (0.01, 1 shared species), and site 4 and site 9 (0.01, 2 shared species).

The species accumulation curve exhibited a tendency to saturation (*Fig. 31*). That indicates, that no intense alteration of the species quantity was to expect with a higher sample value. Overall, 17 species in 24 samples were observed in 2013.

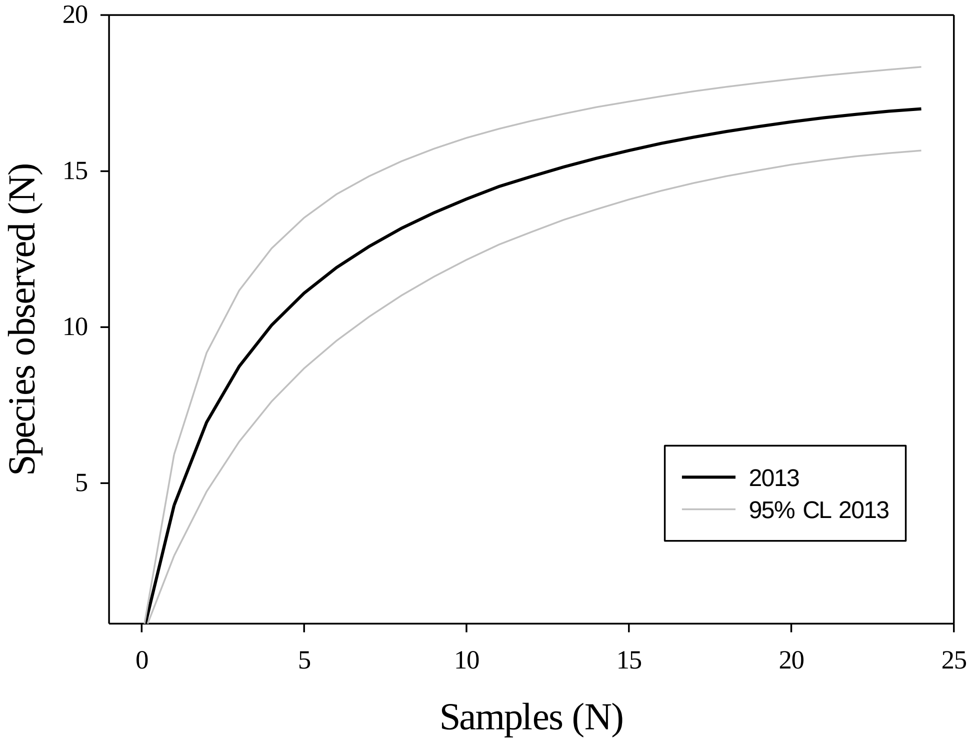

Figure 31: Species accumulation curve for autumn 2013.

6.4 Species - habitat relations

Both, total abundance (ANOVA, F = 0.331, $d.f._1$ = 1, $d.f._2$ = 22, P > 0.05), as well as the abundance of *U. krameri* (ANOVA, F = 0.451, $d.f._1$ = 1, $d.f._2$ = 22, P > 0.05) between the 3 groups of sites showed no significant differences. No fish occurrence was observed at sites related to the first cluster. The variability of the abundances was higher for sites in the second as for the third cluster (*Fig. 32*).

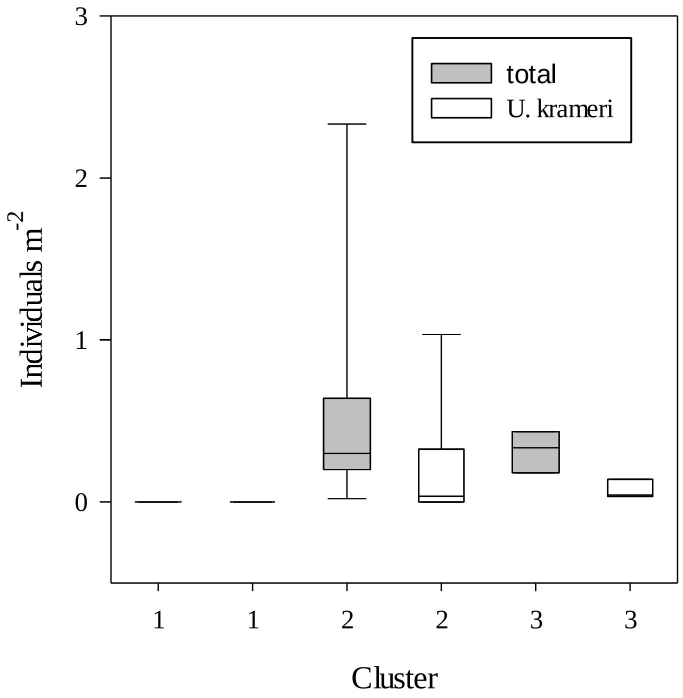

Figure 32: Box-Whisker-plots of the total fish abundance and abundance of Umbra krameri related to 3 groups (clusters) of sampling sites. Shown are the median, 25 %, 75 % and 95 % percentiles.

Clustering of the species data revealed 9 groups with a similarity of more than 50 % of the fish assemblage per site (*Fig. 33*). *Fig. 34* shows the ordination of the species data. Groups were formed at 20 % and 50 % similarity level. The stress value of NMDS (0.15) gives confidence that the 2-dimensional plot is an accurate representation of the sample relationships. The only significant split (A) in the assemblage data was between sites 3,4,6,8, 10-22 and 5, 7, 9, 24 at a 85 % level (ANOSIM R = 0.59). It was characterized by low (< 1.49) or high (> 1.52) amounts of woody debris

At a similarity level of 20 % two groups were separated and at a 50 % similarity level 7 groups were formed. Four groups existed which included more than one site. Samples 3 and 21 were quite similar in their species assemblage. Also, sites 4, 10, 11, 12 and 17 had a similarity of more than 50 % of their community within the group. Two additional groups existed (13, 14) (6, 8, 15, 16, and 19). Note, that sites with high mudminnow abundances (bubbles) were grouped together.

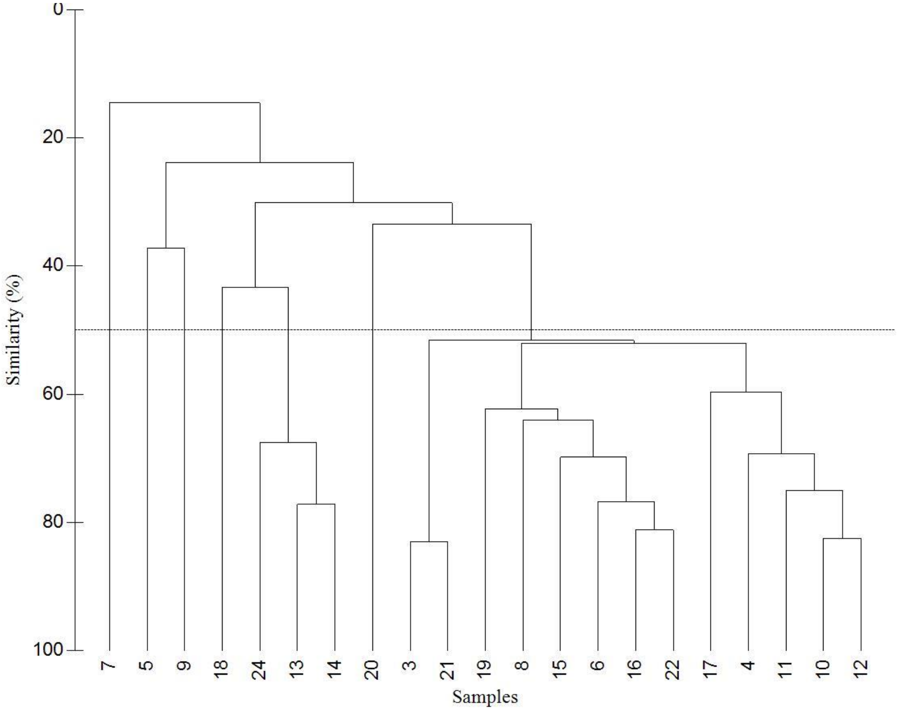

Figure 33: Dendrogram of the 21 sites with fish occurrence, using group-average clustering from Bray-Curtis similarities on fourth root transformed abundances. The groups of sites separated at a 50 % similarity threshold (line) are indicated.

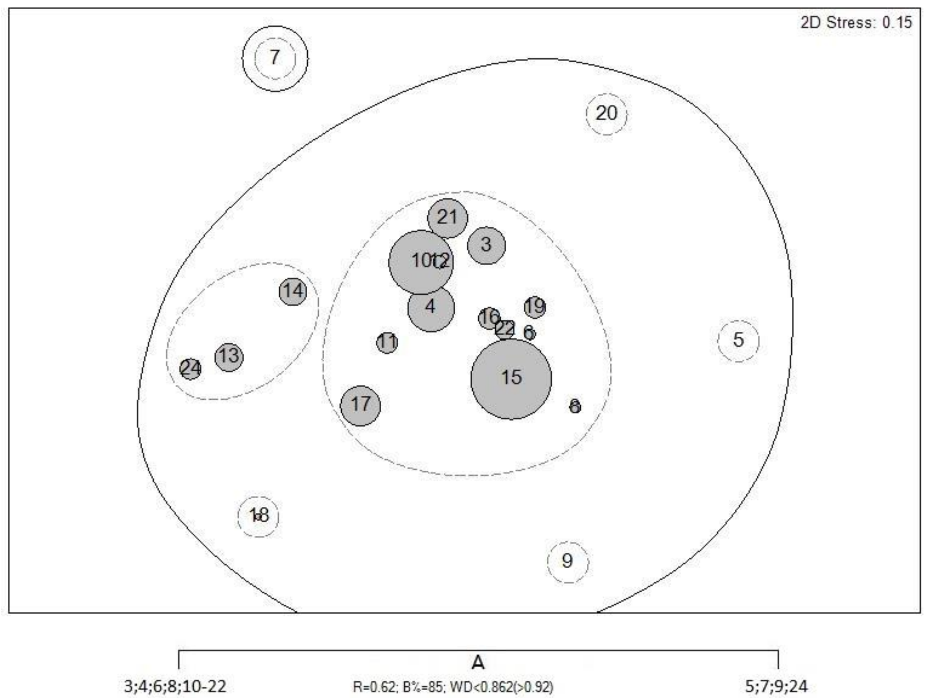

Figure 34: 2-dimensional MDS configuration (on the top) with superimposed clusters from Fig. 33, at similarity Levels of 20 % (continuous line) and 50 % (dashed line) and tree diagram of assemblage-environment split at 85% level obtained from SIMPROF test.

The Detrended Correspondence Analysis revealed a length of the first gradient of 2.626 SD and it explained 30.0 % of the species data (*Tab. 6*). This value indicated a relative homogenous structure of the data set and a low species turnover along the first gradient. The second gradient had a length of 2.695 SD and explained 15.1 % of the species data. The length of the first gradient was < 3 and the differences between the gradients were low. Therefore, a linear method (RDA) was used for further statistical analysis of the species-habitat relations.

Table 6: Results from a Detrended Correspondence Analysis of the species - and environment data for the Fadenbach 2013.

Axes	1	2	3	4	Total iner
Eigenvalues	0.573	0.287	0.107	0.054	1.910
Lengths of gradient	2.626	2.695	2.916	2.215	
Species-environment correlations	0	0	0	0	
Cumulative percentage variance					
of species data	30	45.1	50.6	53.5	
of species-environment relation	31.4	46.2	0	0	
Sum of all eigenvalues					1.910
Sum of all canonical eigenvalues					1.910

The forward selection showed that the highest marginal effects were reached with the variables riparian reeds (R.-Weeds) ($\lambda 1 = 0.08$), conductivity (Cong.) ($\lambda 1 = 0.07$), magnesium (Mg) ($\lambda 1 = 0.07$), sodium (Na) ($\lambda 1 = 0.07$) and potassium (K) ($\lambda 1 = 0.07$) (*Tab. 7*). The independent estimation of the effect of one variable to the data distribution is shown as conditional effect. The highest independent explanatory power were given by the variables riparian reeds (R.-Weeds) ($\lambda A = 0.08$), K ($\lambda A = 0.08$), pH ($\lambda A = 0.1$), nitrate ($\lambda A = 0.08$), width (D) ($\lambda A = 0.1$) and sulphate ($\lambda A = 0.06$), but only the variable width was significant ($p < 0.05$) (*Tab. 7*). The 6 variables with highest independent explanatory power were included into the model.

The sum of all canonical eigenvalues showed that 49.5 % of the total variation in species data could be explained by these selected variables on the first two axes. The first and second canonical axes described 30.7 and 8.1 % of the species data, respectively. The cumulative percentage variance of species-environment relation of the first axis and second axis was 61.9 and 16.5 %, respectively (*Tab. 8*). The explanatory effect of the first ($P < 0.05$) and of all axes together ($P < 0.05$) was significant (*Tab. 9*).

Table 7: Marginal and conditional effects for the species-environment data set obtained from the summary of forward selection.

Marginal Effects		Conditional Effects			
Variable	λ1	Variable	λA	*p*	F
R.-Weeds	0.08	R.-Weeds	0.08	0.148	1.68
Cond.	0.07	K	0.08	0.108	1.73
Mg	0.07	pH	0.1	0.054	2.26
Na	0.07	$N\text{-}NO_3$	0.08	0.09	2.07
K	0.07	Width	0.1	0.048	2.51
WD	0.06	Sulfate	0.06	0.166	1.57
Width	0.06				
Chloride	0.06				
Sulfate	0.06				
Ca	0.06				
$N\text{-}NO_3$	0.06				
pH	0.06				
Veg_Emer	0.05				
Bankfull	0.04				
Connect.	0.04				
P-PO4	0.03				
$N\text{-}NH_4$	0.03				
Veg-Float	0.03				
R.-Shrubs	0.03				
Depth	0.02				
Veg_Sub	0.02				
Substrate	0.01				

Table 8: Summary of the RDA results for species and environmental data. All four eigenvalues are canonical and correspond to axes that are constrained by the environmental variables.

Axes	1	2	3	4	Total variance
Eigenvalues	0.307	0.082	0.048	0.032	1.000
Species-environment correlations	0.762	0.69	0.768	0.742	
Cumulative percentage variance					
of species data	30.7	38.8	43.7	46.8	
of species-environment relation	61.9	78.4	88.1	94.6	
Sum of all eigenvalues					1.000
Sum of all canonical eigenvalues					0.495

Table 9: Summary of Monte Carlo test results (499 permutations under reduced model) for the first and for all canonical axes from RDA analysis.

	Test of significance of first canonical axis	Test of significance of all canonical axes
Eigenvalue/Trace	0.307	0.495
F-ratio	6.188	2.290
P-value	0.028	0.018

Fig. 35 shows the results of the redundancy analysis for the species response in relation to the environmental variables with the highest descriptive power. The distance between the species points in the biplot scaling approximates the Euclidean distance between the species distribution.

The species *A. alburnus*, *L. delineatus*, *P. fluviatilis* and *S. erythrophthalmus* were highly similar in their distribution. Their species maxima were negatively associated with the amount of riparian reeds and the width of the water body. They were negatively correlated with the sulfate and potassium concentration and showed a positive correlation with the pH value. No clear patterns based of the ecological guilds could be observed for this group. It consisted of 3 eurytopic and 2 stagnophilous species. Rheophilous species were absent.

A second group of species had their maxima on the left side of the first axis, and were composed of three stagnophilous species (*M. fossilis, R. amarus, C. carassius, T. tinca*), two eurytopic species (*C. gibelio, Sqaulius cephalus*) and one species of the rheophilous guild (*Leuciscus idus*).

Yet, this second association was more scattered along the first axis and showed a positive relation to nitrate, sulfate and a negative correlation with the pH value and to the potassium concentration. Note, that *Rhodeus amarus* showed the highest affinity to high nitrate concentrations. Both associations included eurytopic species, however most stagnophilous species were on the left side of the plot, whereas most eurytopic species were located on the right site of the plot.

The maxima of the two species *E. lucius* and *U. krameri* are positioned in a greater distance to the other species in the ordination space, and reveal therefore specific relations with the environmental variables. The pike was positively correlated with pH value and the potassium concentration and negatively correlated with the nutrients ($N\text{-}NO_{3,}$ $[SO_4]^{2-}$). The mudminnow was positively associated with riparian reeds and negatively with the pH value. Moreover, it was positively related to the potassium and negatively related to the sulfate concentration. *E. lucius* and *C. carassius* showed the most similar position in the ordination compared to *U. krameri*.

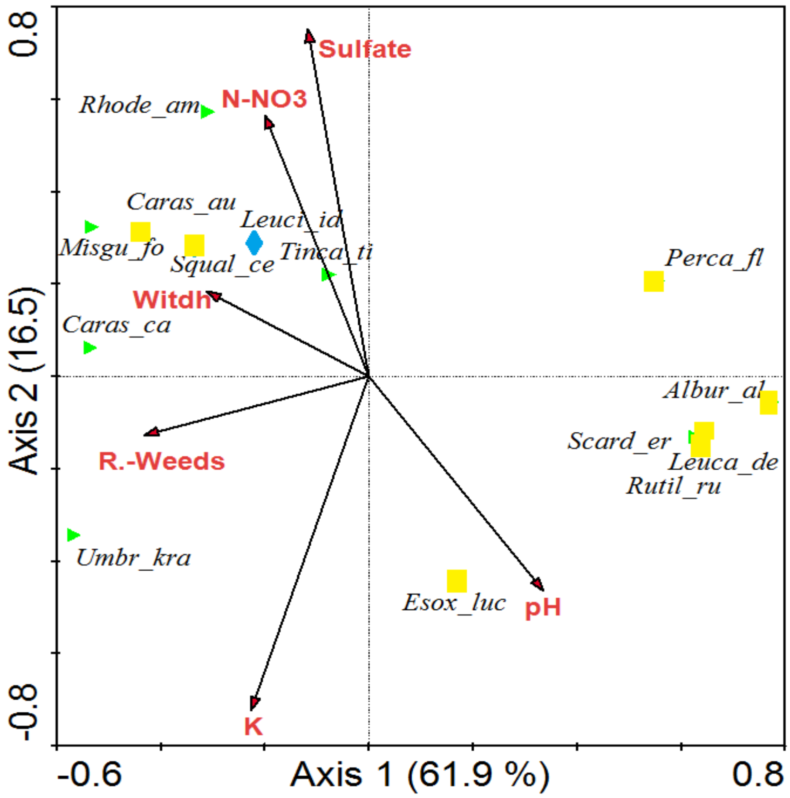

Figure 35: Biplot of the species - environmental variables (RDA analysis). Environmental variables are shown as arrows. R.-Weeds (riparian reeds), K (potassium), Width (width of the stream bed). Species are shown as symbols and labelled by their generic name. Albur_al (Alburnus alburnus), (Blicc_bj) Blicca bjoerkna, Caras_au (Carassius gibelio), Caras_ca (Carassius carassius), Esox_lu (Esox lucius), Leuc_id (Leuciscus idus), Misgu_fo (Misgurnus fossilis), Perca_fl (Perca fluviatilis), Rhod_am (Rhodeus amarus), Scard_er (Scardinius erytrhophthalmus), Squal_ce (Squalius cephalus), Tinca_ti (Tinca tinca), Umbr_kr (Umbra krameri). Symbols refer to ecological guilds: Diamonds (rheophilous), right triangles (stagnophilous), quadrats (eurytopic). Note that species symbols have to be interpreting as arrows and a linear response of the species is assumed. Only the most abundant species have been included into the model.

Fig. 36 illustrates the sites where fish occurred related to the different environmental factors. Five sites (9, 10, 18, 19 and 24) showed individual positions in the ordination plot, site 9 and site 24 are the sites with the highest connectivity to the main channel and were grouped together and could be distinguished from all remaining sites. They were negatively related to the stream width and the amount of riparian reeds. Site 18 and site 19 were characterized by high nutrient levels and low pH values. Site 10 had high stocks of riparian reeds and high potassium concentration.

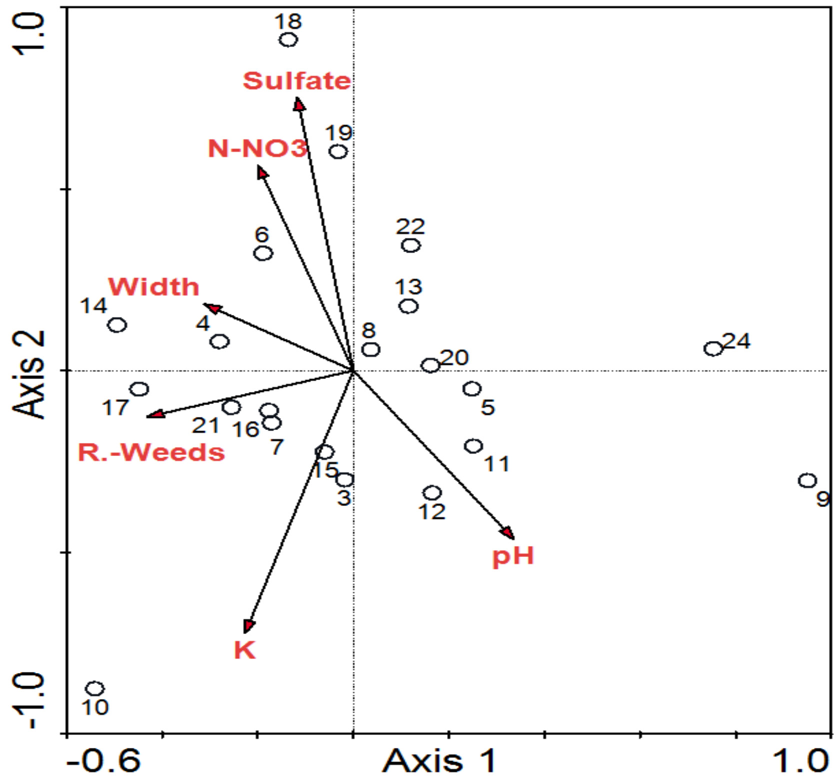

Figure 36: Biplot shows the relation between environmental variables and sampling sites. Abbreviations of the environmental variables like in Fig. 35.

No clear patterns of the Shannon - Wiener Index of the sites related to the environmental factors were observed. For example for sulphate, the diversity was highest in the intermediate range and declined to both directions, except site 9 in the fourth quadrant which showed intermediate diversity. Even the extreme habitats (9, 10, 17, 18 and 19) had similar diversity values in comparison to sites located near the centre of the diagram, with the exception of Site 8, which is located nearest to the centre and had the highest diversity (*Fig. 37*).

The abundances of *U. krameri* in the Fadenbach system were obvious highest at the sites 10 and 15, which were defined by low sulphate and nitrate levels, high Potassium concentrations and intermediate (Site 15) to high pH (Site 10) values. *Fig. 37* shows a gradient along the first ordination axis. With a decline of the nutrients sulphate and nitrate and with an increase of the pH value and the potassium concentration the mudminnow abundances increased successively.

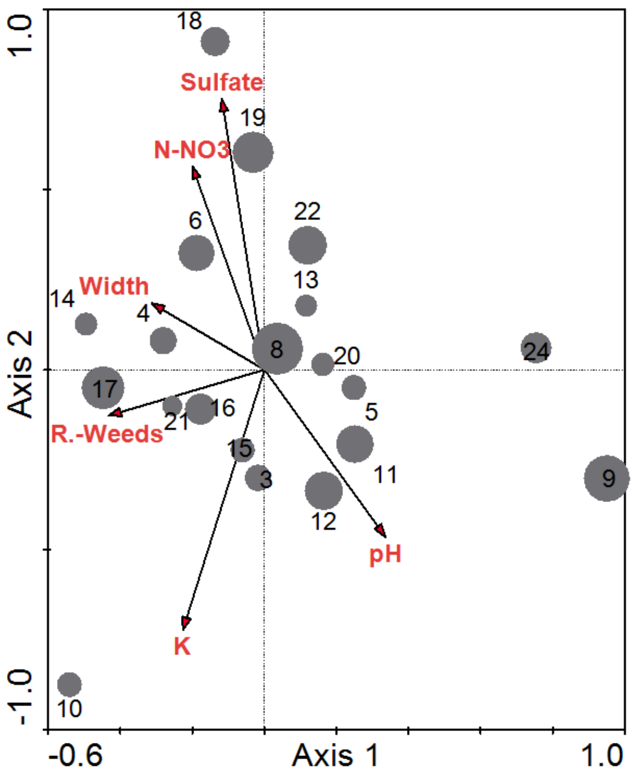

Figure 37: Biplot shows the relation between environmental variables and the sampling sites compared to the biodiversity (bubbles). The size of the bubbles reflects the Shannon Wiener- diversity index of the single site. Abbreviations like in Fig. 35.

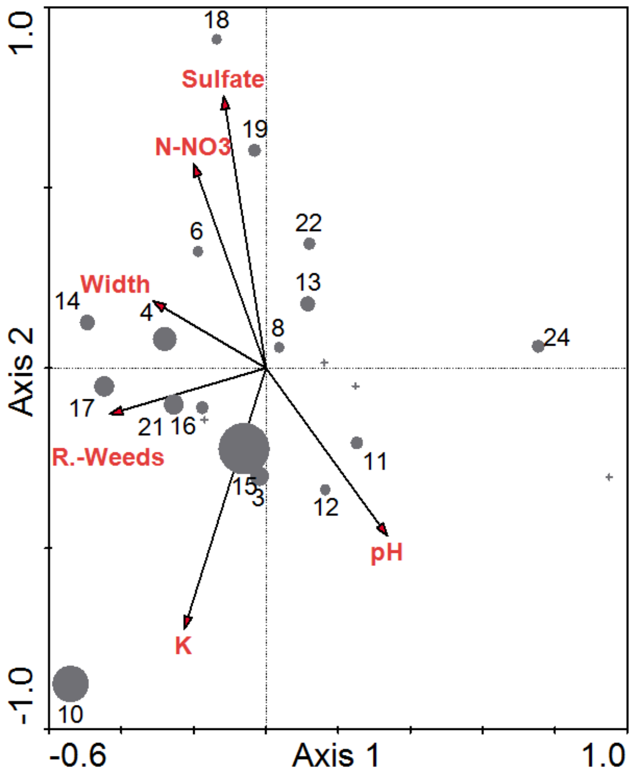

Figure 38: Biplot shows the abundance of U. krameri at single sites in relation to the environmental variables. Abbreviations like in Fig. 35.

7. Discussion

7.1 Environmental observations

The Fadenbach system had a variety of different habitats, including temporary ponds, persistent water bodies with temporary or permanent connection to the adjoining waters, and flowing canals with low flow-velocities. Morphological differences can be probably attributed to different degrees of connectivity with the main channel and with groundwater aquifers. These connections are a function of the position in the floodplain. The substrate of the whole system mainly consisted of fine grained material (silt, detritus, sapropel), what is characteristic for disconnected water bodies. Some sites with an increased connection to the main channel contained also patches of sand, fine to medium-sized gravel and coarse gravel. Reckendorfer & Hein (2006) documented a thickness of about 176 ± 25 cm of fine grained material for the isolated parts of the Fadenbach. The sediment consisted of on average approx. 4.5 % of organic matter.

At over 79 % of all sites the oxygen saturation had values lower than 1.9 mg l^{-1}; which is the mean lowest observed effect concentration (LOEC) for freshwater fish in Western Europe (Elshout et al. 2013).

A high conductivity level of most sites indicated a minor turnover of the water, only slight dilution through the groundwater aquifer, and high allochthonous nutrient intakes from the alluvial forest and agricultural runoff. Similar and even higher conductivity values were reported for mudminnow habitats in Serbia (Sekulic et al. 2013). Two sites (1, 2) had very high ammonia levels. This compound is derived from plants and animals, and produced as a result of the decomposition activity of organisms and sewage by micro-organisms. Moreover, it can be introduced in waters by the release of fertilizers and industrial emissions (Currie et al. 2010). The ammonia levels for mudminnow habitats stated in other studies (Spindler & Wanzenböck 1995, Spindler 2006, Sekulic et al. 2013, Müller 2011) are distinctly lower with the highest value of 0.22 mg l^{-1} for a channel in Serbia.

The orthophosphate values indicated a high to very high productivity of the whole system (especially sites 10, 24, 16 and 2); however, no gradient along the distance to the main channel was observed. In general, dissolved nutrient content of riverscape patches increases with connectivity to the river (Knowlton & Jones, 1997; Schiemer, Baumgartner & Tockner, 1999). In contrast to this pattern the highest observed nutrient levels occurred at the extremely disconnected sites 1 and 2. In disconnected water bodies, nutrient content also depends on surrounding land use and successional stage (Bornette et al., 1998). To identify the sources of the elevated nutrient loadings further investigations are required.

The cluster analysis generated no clear gradient of the environmental characteristics of the sites along the Fadenbach system. Nevertheless, it excluded two of three sites without fish occurrence by environmental factors. Thus, it can be assumed, that the main determining factors for fish occurrence and their distribution had been examined.

7.2 Species occurrence, endangered species & ecological guilds

The observed species assemblage is characteristic for mostly disconnected water types. With increasing isolation time, the ability of sensitive species to harsh environmental conditions declines and the risk of becoming exposed to lethally anoxia or high temperatures rises. Hence, the Fadenbach contained mainly species of eurytopic and stagnophilous guilds. Whereby, approx. half of all species are listed with an endangered status. For the occurrence of *U. krameri*, *M. fossilis*, *L. leucaspius* and *C. carassius* in this area, the Fadenbach system performs an essential habitat (key habitat).

The only observed species of the rheophilous guild occurred only at two sites in the area of the dam in Orth. The first, Site 8 is connected by a culvert to the Danube which enables species from the main channel to immigrate at times of flood events. And the second, Site 9 is located south from the dam and is directly connected to Danube main channel at high water levels of the main channel. The stagnophilous species *U. krameri*, *M fossilis*, *C. carassius* and *R. amarus* were absent at this main channel influenced habitat. *R. amarus* and *M. fossilis* occurred only at sites (10-12, 17, 18) with very fine grained substratum. Small water bodies like floodplain water bodies face higher risk of low oxygen saturations as main channel habitats (Reckhow, 1978). Under such environmental conditions life histories have evolved to handle anoxia and hypoxia in disconnected water bodies of advanced successional stages like the Fadenbach. For instance, the facultative air-breathing of the weather loach (*M. fossilis*) (Jobling, 1995) or the production of alternative anaerobic end-products in crucian carp (*C. carassius*) and bitterling (*R. amarus*) are leading to an exceptional capacity of long-term anoxic survival (Nilsson & Östlund-Nilsson, 2008).

7.3 Biomass, abundance patterns, length-weight relations & size structure

Only sites 8 and 9 showed high fish abundances and a characteristic assemblage of species (like *A. alburnus*) associated with main channel river habitats. Altogether a bimodal distribution over the longitudinal course of the Fadenbach system was given. Both, the mean biomass of the entire catch and the mean biomass of the mudminnow varied over the longitudinal course of the Fadenbach. No continuous gradient along the body of water could be observed. Thus, the position of the sites in the water course is not a relevant factor for the total biomass and the mudminnow biomass, respectively. In contrast, Perkaric et al (2013) reported of a decline of the biomass from source of channels down to its outlet.

The mean biomass of the ecological guilds was highest for the eurytopic and distinctly lower for the stagnophilous guild. Significant dissimilarities existed between the eurytopic and the stagnophilous guild.

Miŝik (1964) reported of the standing stock of mudminnows in the canal system of the great Danube Island in Slovakia. He detected 11000 - 12000 individuals ha^{-1} corresponding to 25.5 - 27.5 kg ha^{-1}. In the Fadenbach system a significant lower density of 2982 ± 4400 individuals ha^{-1} corresponding to 0.66 ± 1.20 kg ha^{-1} was present. Noticeable is the deviation of the individual/biomass relation between the studies. The individual/biomass ratio for the Slovakian Danube was 535 (Miŝik 1964) and for the Fadenbach 2485. This result implies a disturbed population structure (high amounts of juvenile individuals, very low amount of adults) or a poor nutritional support for the mudminnow in the Fadenbach system.

The *b* - value of the length-weight relations for *U. krameri (2.73)* in the Fadenbach system was lower than those given by Libosvárský and Kux (1958) (2.94 -3.21). The value of the Fadenbach population indicates a negative allometric growth, what is common for eel – like shaped species (Froese 2006). In fact, that is not true for all mudminnow species (Kuehne et al. 2014). Wilhelm (2003) reported a *b* – value of 3.06 for *U. krameri* in the River Ér in Romania (no information about season of sampling are given). His interpretation was that the weight increases faster than the length. Miŝik (1966) considered that the *b* – value refers to the feeding conditions of the population. Under that assumption it is conceivable, that for *U. krameri* the nutritional conditions are lower for the Fadenbach population compared to Ér population. Otherwise the deviations are traceable to differences of the sampiling season. Generally, seasonal differences in length–weight relationships can be related to feeding activities or reproduction (Wootton 1990).

In the literature the range of length-weight comparisons of *U. krameri* is very wide spread. Geyer (1940) mentioned a weight of 2.5g for individuals of 6 cm. Whereas Wilhelm (1984), Libosvárský and Kux (1958) and Nisik (1966) gave values of 3.3g, 4.5g and 5g for the same length, respectively. Libosvárský and Kux (1958) and Nisik (1966) used standard length (SL). Whereas no information was given which length parameter have been used in the other studies. With my model, using TL, a

6 cm long European mudminnow would have a weight of 5.57 g which exceeds all values reported in aforementioned studies.
The size class of 4 - 4.9 cm was most abundant and included 46 % of the total population. This corresponds to an age of 0^+ (Geyer (1940), Libosvárský and Kux (1958), Miŝik (1966), Wilhelm 1984). Compared to former studies (Spindler & Wanzenböck 1995), a high percentage of small individuals and only a small portion of large adult individuals were observed in the Fadenbach in 2013. In 1993 the size classes between 5 and 8 cm were numerically dominant, in 1994 the classes between 4 and 8 cm, and in 1995 between 6 and 10 cm dominated (Keckeis & Sehr, 2013). The smallest individual in 2013 was 2.1 cm, no individual smaller than 4.0 cm was observed in the Fadenbach system in former studies (Spindler & Wanzenböck 1995). Length-data were compared to a growth study of *U. krameri* in the river Ér conducted by Wilhelm (2003). Under the assumption of a similar growth rate, the Fadenbach population was entirely composed of 0^+ to 3^+ individuals in 2013.

7.4 Bio-Diversity & Species - habitat relations

Compared to the Danube main channel in the same section as the Fadenbach with a Shannon H' of ~ 2.5 (Sehr et al., 2013), the Fadenbach was characterized by low to intermediate diversity. Reductions in faunal diversity are typically associated with the inception of regulation of floodplain rivers (Welcomme, 1994). According to the intermediate disturbance hypotheses (Connell, 1978), reduced diversity may result from an increasing predictability of riverine habitats with increasing flow regulation.
The number of species that co-occurred with *U. krameri* was 4 (1 to 9 species) indicating its high adaptive potential to extreme habitats. Moreover, sites with the highest mudminnow abundances had lower diversity values in comparison to sites with low occurrence of *U. krameri*.

NMDS showed that the sites with high mudminnow abundances were highly similar in their fish assemblage what underlines the low diversity in the mudminnow habitats as described above. No gradient of the fish assemblage along the longitudinal course could be observed. The longitudinal reach was not determining the fish assemblage; the assemblage was attributable to the individual situation of the environment per site. Two clusters of sites were separated at an 85 % level by the amount of woody debris. Sites of the first group were characterized by minor abundances or single individuals and/or "high" connectivity to the main channel. The amount of woody debris was a major factor in structuring fish community in the Fadenbach system. Sites with minor to intermediate amounts of woody debris were inhabited by mudminnow dominated fish assemblages. Woody debris is important cover in stream habitats as it provides refuge from high velocities and predation (Beechie & Sibleys, 1997). In the Fadenbach system as mostly stagnant system the refuge function of the woody debris seemed to be less important. High amounts of woody debris favor the anaerobic fouling processes, act negatively on the oxygen balance, and promote the succession. More important for the grouping of sites might was, that high amounts of woody debris indicate high stands of riparian trees, which inhibit growth of aquatic vegetation, riparian reeds and shrubs by shading, what makes these sites to minor attractive habitats for *U. krameri*.

Regarding the habitat requirements two species associations with different responses to the environmental variables (riparian reeds, potassium, width, nitrate, sulfate, and pH value) could be distinguished in the Fadenbach system. The positions of the species of the first group in the model were mainly attributed to the environmental conditions of Site 9. Most of the species of that group belong to the eurytopic guild. In the model they were negatively related to the width of the water body and the amount of the riparian reeds. That artifact is attributable to the enormous fish density at Site 9. The water body may have been used by individuals of the main river for reproduction or drifting larvae and juveniles entered during the last inundation of the flood plain. Here, the connection to the main river was the primary determining factor, and other environmental factors were secondary. The presence of the only rheophilous species, *L. idus*, was attributable to immigration by individuals into the Fadenbach system during a flood event. Its position in the biplot (*Fig. 34*) referred to their presence at Site 8, which is connected to site 9 by a culvert. Since the culvert was not passable by bigger fish with a head width of more than circa 3 cm they were not able to emigrate. Consequently, their positions in the diagram didn’t reflect their ecological preferences.

The stagnophilous species *C. carassius*, *M. fossilis*, *R. sericeus* and *U. krameri* were grouped together in relation to the width and the riparian reeds. Pekárik et al. (2008) reported about a similar species assemblage, additionally including *P. semilunaris*, to be typical for water bodies of the palaeopotamon type in the Danube basin.

Esox lucius, as the top predator in the system had its optima in areas with similar high pH values as the first group, but showed no distinct response to the other variables. That might underline the eurytopic traits of that species. *U. krameri* had an individual position in order to the environmental variables and shared the highest similarity with its next native relative, the pike, and with the stagnophilous crucian carp. However, the angles between the species points implied only a slight similarity between these species. The mudminnow was negatively correlated to the species of the first group, what indicated a clear differentiation of habitat types between *U. krameri* and these species. This pattern can be explained by a low competitive power of the mudminnow and the limited opportunity of the species of the first group to persist within the harsh conditions of the mudminnow habitats. That contributes to observations of Holopainen, Tonn & Paszkowki (1999) who stated, that an adaption to anoxic condition of typical floodplain species is often accompanied by low competitive power and predation avoidance, resulting in minor population densities and high mortalities in multispecies assemblages. The negative correlation of *U. krameri* to the nutrient levels underlines its vulnerability to high nutrient loadings from agriculture, runoff and subsequent eutrophication as stated earlier by different authors (Bíró and Paulovits 1995; Wanzenböck & Spindler 1995; Sekulić et al. 1998). As well, this negative response to the free nutrients (nitrate, sulfate) might indicate a relation of this species to sites with high aquatic macrophytes stands. High stands of macrophytes lead to a conversion of nitrate to ammonium (e.g. Kofoed et al., 2012). This would contribute to observations of Pekárik et al. (2014), who described the key habitats of *U. krameri* in the Slovakian inland delta of the Danube. They stated that ideal mudminnow habitats are covered by ~ 40 % macrophytes.

No relation existed between the presence of the mudminnow and the pH value. Since the lowest observed pH value in mudminnow habitats was 7.8, our data is in consensus with the current knowledge of the mudminnows lower pH pessimum of 7.0 observed in other field studies (summarized in Kuehne & Olden, 2014). In contrast to its relative, the acid tolerant *U. pygmea*, which can persist at low pH values of > 3 (Dederen et al. 1986), the European mudminnow seems to have a minor adaptability to acidic waters. Only Povž (1995) reported an occurrence of *U. krameri* in waters with pH values lower than 6.5.

The presented model suggests a preference of *U. krameri* for habitats with a highly structured shore line by reed belts as described earlier by Geyer (1940), Kux & Libosvarksy (1957), and Spindler & Wanzenböck (1995). In consequence of high seasonal water level fluctuations, caused by fluctuating ground water influx, these characteristic swamp structures may provide a refuge avoiding predation for the mudminnow at times of high water levels. Riparian vegetation provides shading and thus a thermal refuge while seasonal droughts in the summer (Swales, 1982; Naiman et al., 1988). In the river Warta (Poland) it has been shown, that the fish abundance and diversity are highly affected by removing and regrowing riparian vegetation (Penczak, 1995). Also Wanzenböck & Spindler (1995) emphasized the importance of an extensive land-water interface due to well-developed swamp vegetation as a key habitat factor for the mudminnow.

The redundancy analyzes didn't include the oxygen saturation, because the concentration was measured only one time at each site and at different times of the day. As a result of high vegetation stands at some sites, high diurnal fluctuations of the oxygen content in the water are probable. Different authors (e.g. Guti, 1940; Sekulic et al. 2013) discussed the ability of *U. krameri* to breathe air through a modified swimbladder and about the resulting ability to persist at low oxygen conditions. Sekulic et al. (2013) concluded that low oxygen saturation is no limiting factor for *U. krameri* in the environment.

No patterns of the α – diversity can be observed along the environmental gradients. That implies that the combination of variables is not sufficient to describe diversity patterns and that other factors are determining. Nevertheless, sites with high *U. krameri* abundances are associated with a low Shannon diversity, what underlines the affinity of the European mudminnow to harsh environments and its low interspecific competitive abilities in connected waters (*Fig. 36, Fig. 37).*

8. Conclusion

Collectively, my results reveal the ability of the European mudminnow (*U. krameri*) to survive in poor-quality water. It prefers swampy areas with dense riparian reed vegetation, occurs with low fish diversity and is associated with only a few, but endangered, stagnophilous and eurytopic species. A preservation of its habitats would simultaneously preserve its associated fish fauna like the threatened species weather loach (*M. fossilis*) and crucian carp (*C. carassius*). Thus, in a conservation sense, the European mudminnow is a suitable umbrella species for the protection of stagnophilous fish assemblages and swampy habitats. The presented results should be used for further research that deals with the understanding of the ecological adaptability of the European mudminnow and the physicochemical conditions of its habitat.

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Register of illustrations

List of tables

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Publikationen

REITER, R., FEY, D., **SEHR, M.**, SCHNEEBERGER, H. (2011): "Water-Jet-Plattform" - eine Möglichkeit des stromlosen Sauerstoffeintrags im Zulaufwasser von Forellenteichen. Aquakultur und Fischereiinformationen AUF AUF. Heft 3: 14-17.

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EDV Kenntnisse

MS Office, STATGRAPHICS Centurion XVI, SPSS, Sigmaplot, ASTERICS, ArcGIS, Canoco 4.0, PRIMER v.6.0, EstimateS, Surfer 7.0, R