Assessment of temporal and spatial development of benthic Danube fish species stocks in the area of the hydropower plant Freudenau by comparing longline fishing results

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Abstract

Freudenau is the latest constructed Hydropower plant (HPP) on the Austrian Danube located in Vienna. Within the framework of the HPP construction, a fish ecological preservation of evidence took place in 1993/1994 in the surrounding Danube main channel affected by the HPP between river kilometres 1945.5 – 1917. Thereby, as well as for the followed-up fish ecological investigations in 1999/2000 and in 2014 inter alia standardized longlines baited with *Eisenia fetida* were fished focusing on benthic fish species. By comparing the catches of these longlines fishing investigations via CPUE (catch per unit effort), we attempt to assess temporal and spatial changes in the benthic fish biocoenosis related to the construction and operation of the HPP. Therefore, the investigation area was subdivided into sections according to the direct influence of the HPP on this Danube stretch into Head of Impoundment, Transition Zone, Central Impoundment and Tailwater. By using the, CPUE, count of caught fish species, species classification referring to habitat requirements by Jungwirth (2003) and Zauner & Eberstaller (1999 & 2003) and changes of the benthic fish biocoenosis in individual sections across the three investigation periods impacts on the altered fish habitats by the HPP could be analysed. Clear changes in benthic fish species abundance and occurrence could be observed and could be linked to the changed habitat after impounding the river. Thus, a trend in the benthic fish biocoenosis from a rheophilic assemblage to a more indifferent one could be observed. Further, CPUE-values of most native fish species clearly declined with in the investigation periods while invasive Gobiidae species, which immigrated in the 90s became the most abundant benthic fish species in the investigation area. While strongest altered sections like the Central Impoundment and the Transition Zone seem to be suitable habitats for this invasive species, most native species show only low CPUE-values.

Zusammenfassung

Das Wasserkraftwerk Wien/Freudenau ist das jüngste an der Österreichischen Donau. Im Rahmen des Kraftwerksbaus 1993/1994 wurde eine fischökologische Beweissicherung im direkten Einflussbereich des Kraftwerks durchgeführt (Stromkilometer 1945.5 – 1917). Bei dieser Untersuchung sowie den darauf folgenden, 1999/2000 und 2014, wurden standardisierte, mit Eisenia fetida beköderte, Langleinenausgelegt um die benthische Fischfauna der Donau zu beproben. Durch den Vergleich der Ergebnisse der verschiedenen Untersuchungen per CPUE (catch per unit effort) wurde versucht räumliche und zeitliche Veränderungen in der Zusammensetzung und in den Abundanzen der benthischen Fischfauna zu analysieren. Das Untersuchungsgebiet in wurde in vier verschiedene Abschnitte gegliedert: Stauwurzel, Übergangsbereich, zentraler Stau und Unterwasser. Aufgrund der Lage der Abschnitte ist anzunehmen, dass diese unterschiedlich stark vom Kraftwerkt beeinflusst werden. Anhand von verschiedenen Parametern wie CPUE, Fisch Fangzahlen, Habitatpräferenzen der einzelnen Arten wurden räumliche und zeitliche Veränderungen über die drei Untersuchungszeiträume analysiert. Es konnten deutliche Veränderungen in der Abundanz sowie in der räumlichen Verteilung im Untersuchungsgebiet festgestellt werden. Es ist ein klarer Trend von einem ehemaligen rheophilen Fischbestand zu einem mehr indifferenten festgestellt werden. Zusätzlich wurden sinkende CPUE-Werte für die große Mehrheit der heimischen Fischarten nachgewiesen, während im gleichen Zeitraum invasive Grundelarten einwanderten und die heutige Fischvergesellschaftung dominieren. Vor allem injenen Abschnitten des Untersuchungsgebiets die starke Veränderungen in der Habitatstrukturdurch Schaffung von monotonen Blockwurf Ufersicherungen aufweisen, bilden diese Grundeln extrem hohe Bestandsdichten aus und dominieren die benthische Fischbiozönose, während heimische Arten geringe CPUE-Werte aufweisen.

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1 Introduction

With a total length of 2857 km (BMUB, 2003) the Danube is one on the biggest rivers in Europe. From its origin at the confluence of the rivers Brigach and Breg in the Black Forest (Germany), it flows across the European continent to the Danube Delta in the Black Sea. With a total size of approximately 817.000 km^2 (BMUB, 2003), its catchment area covers and drains large parts of Central and South-Eastern Europe. Between Germany and the Black Sea, the Danube flows through Austria, Slovakia, Hungary, Croatia, Serbia, Bulgaria, Romania, Moldova and the Ukraine. Its course connects several ecoregions and enabled southward migration of freshwater fauna and flora during ice ages and subsequent recolonization in warmer periods. This is one of the causes of its high fish species diversity and number of endemic species (Jungwirth, et al., 2014; Reyjol, 2007). The Danube is therefore of zoo-geographical relevance (Illies, 1978; Banarecu, 1964; Balon, 1986) and can even be called a hotspot of biodiversity.

In regard of geomorphological elevations, the Danube can be subdivided into three sections. Between the source in the Black Forest, along the northern foothills of the Alps, through the Vienna Basin and down to the Devin Gate it is referred as "Upper Danube". The following "middle reach" stretches through the Pannonian Plain and extends to the gorge of the Iron Gates at the border between Serbia and Romania in the southern Carpathian Mountains. The third section is called "Lower Danube" and runs from the Iron Gates towards the Danube Delta in the Black Sea (Jungwirth, et al., 2014). Especially the Upper Danube (Austria, Germany) features a steep slope (approximately 0.43% in Austria) with a high potential for hydropower usage (Jungwirth, et al., 2014).

The Austrian Danube has been used for hydropower production for more than half a century. With the gradual construction of ten run-of-the-river hydropower plants (HPPs) a chain of HPPs along the Austrian Danube was created between 1956 and 1998, leading to large impounded stretches. Only two so-called "free flowing sections" remain: the Wachau valley (rkm 2038 to rkm 2002) and the stretch between the HPP Freudenau (rkm 1921) in Vienna and the Austrian-Slovakian boarder (Jungwirth, et al., 2014). Besides the hydropower usage of the river, construction of dams and regulation measures for flood protection and navigation have changed the geomorphological properties of the Austrian Danube significantly over the last 125 years. Nowadays, 246 of the Austrian Danube's 350 km are declared heavily modified water bodies (HMWB) as defined in Annex II of the EU Water Framework Directive (ICPDR, 2005).

The most recently constructed HPP along the Austrian Danube is the HPP Freudenau in Vienna (see maps 9.1). This HPP, which backs up water on a length of approximately 28 km across a drop height of 8.3 m, was built in 6 years (Verbund, 2016). Between 1992 and 1998 the construction works were carried out. Within the framework of the so-called “preservation of evidence” a fish ecological investigation took place in 1993/94. At that time, the river was still free flowing in this stretch. A follow-up study was conducted in 1999/2000, i.e. one to two years after filling of the impoundment (Waidbacher, 2002).

Since the Danube stretch under investigation is altered by the construction and operation of the HPP, the project “"Donau-Stauraum Freudenau: Ökosystem-Response 15 Jahre nach Einstau” is meant, inter alia, to carry out another fish ecological preservation of evidence fifteen years after filling of the impoundment. Within the framework of this project, this study assesses the status quo of the benthic fish fauna and temporal changes in the benthic fish biocenosis over the three above mentioned investigation periods as well as changes in spatial distribution patterns of the benthic species in the area of the HPP Freudenau (river kilometer (rkm) 1917 to 1945.5).

After filling of the reservoir, water depths and flow velocities changed in the river stretch affected by the HPP, thereby also changing fish habitats. Therefore, this study’s investigation area was subdivided into four sections: Head of Impoundment, Transition Zone, Central Impoundment and Tailwater (Matschnig, 1995). Since large parts of the river’s main channel in this stretch feature water depths above 2.5 m measured from the surface, today’s most common fish sampling method, electro-fishing, was found to be inadequate. Depth limitation of the electric field used in electro-fishing and many benthic species’ adaptions to their habitats (e.g. reduced or missing swim bladders and reduced galvanotaxis (Bammer, 2010; Hellig, et al., 2015)) called for a different methodological approach. Moreover, the main channel’s water’s low visibility depth during most of the year makes the spotting and landing of stunned or attracted fish, which is necessary in electro-fishing, rather difficult.

In his publications from 1991 and 1996, Zauner says that the autecology of most benthic fish species of the Austrian Danube is only inadequate investigated. As reasons he states the species’ partially hidden way of life as well as their mostly low economic importance. Besides, characteristics of the Austrian Danube´s main channel like large width, deep sections and a usually high water turbidity might further complicate extensive research. It is these river characteristics, along with partially occurring high flow velocity, which also made investigation of benthic species in their natural habitats difficult in this study. Instead of the standard electro-fishing approach we used standardized longlines (after Zauner, 1991) to sample the fish fauna. While longline fishing is frequently seen as supplementary fishing method only, it is nevertheless an appropriate tool for sampling of benthic fish species (Bundesamt für Wasserwirtschaft, 2007). This was proven in various investigations of the Austrian Danube (Bammer, 2010; Matschnig, 1995; Waidbacher, 2002; Zauner, 1996), especially in stretches with higher water depths. Standardized longlines were already used during the fish ecological investigations in 1993/94 (Matschnig, 1995) and 1999/2000 (Waidbacher, 2002), so that comparability of the three investigations via "catch per unit effort" (CPUE) could be assumed. By comparing the CPUE values identification of temporal and spatial trends in fish abundances is made possible. This allowed us to answer the following questions:

Which benthic fish species occur in the investigation area in 2014? Did benthic fish species' abundances change between the three investigation periods (1993/94, 1999/2000, 2014)? Can these changes be related to the construction and operation of the HPP Freudenau? How do changes of conditions in the river stretch altered by the HPP Freudenau affect benthic fish species' distribution?

By answering these questions, this study makes a contribution to understanding how run-of-the-river hydropower plants change rivers and how they affect the benthic fish species that inhabit them.

2 Study area

2.1 Investigation Area

The study area comprises the Danube´s main channel between Kritzendorf at rkm 1945.5 and the southern tip of the Viennese Danube-Island at rkm 1917. It covers the whole Viennese Danube’s main channel as well as a small part of the Danube in the Federal state of Lower Austria between Kritzendorf and Kahlenbergdorf (rkm 1937). In regard of fish regions, this stretch is classified as Barbel zone (Epipotamal groß) (BMLFUM, 2013), as is the entire Austrian part of the Danube. According to the Austrian Leitbildkatalog published by the Bundesamt für Wasserwirtschaft (Bundesamt für Wasserwirtschaft, 2014) this stretch has an adapted guiding principle (2010 historical enquiries by Haidvogl, Spindler & ezb (Bundesamt für Wasserwirtschaft, 2014)).

For the investigation at hand, the main channel was divided into sections (Table 1, page 10) according to the direct influence of the run-of-the-river hydropower plant Freudenau (see Map of Investigation area, page 54). The zoning was introduced by Schiemer (1994) and previous fish ecological investigations in this area (Matschnig, 1995; Waidbacher, 2002), is based on the assumptions that average flow velocity and average water depth are altered by the HPS. The average flow velocity (MQ Vienna ~2000 m³/s (BMLFUW 2014)) decreases from the Head of Impoundment towards the Central Impoundment, whereas the average water depth increases. In 2014 the Tailwater of the HPP Freudenau was sampled additionally to the Head of Impoundment-, Transition zone- and Central Impoundment section sampled by Matsching & Waidbacher (Matschnig, 1995; Waidbacher, 2002).

Due to these hydro-morphological variations, the sections differ in regard of the river´s bank and in-bed structures and fish habitats.

Table 1: Sections

Section name	RKM
Head of Impoundment	1945,5 to 1935
Transition Zone	1935 to 1928
Central Impoundment	1928 to 1921
Tailwater	1921 to 1917

Additionally and independently of the zoning, artificial “Side Habitats” were constructed. These artifical created bank structures were built on the left bank of the Danube Island during the construction of the HPP Freudenau. They are connected to the river´s main channel (see Table 2) and form an important enrichment of the impounded area´s monotonous, riprap-dominated habitat structures. These “Side Habitats” feature shallow water zones (up to 2,5m water depth) with low flow velocity compared to the main channel and a sandy/silty substrate. Furthermore, woody debris and macrophytes occurring in these habitats increase the general diversity of fish habitats in these side water bodies. In order to prevent disturbances big rocks have been placed to separate these areas from the main channel and function as a barrier for motorboats.

Table 2: Side Habitats

Habitat label	Section	Connection to Danube at rkm
A	Central impoundment	Originally connected via pipes at 1922.75 rkm with the Danube, pipe consistency due to sedimentation questionable.
B	Central impoundment	1924.89 1924.55 1924.25 1924.00
C	Central impoundment	1926.90 1926.74 1926.37 1926.14 1926.01 1925.90
D	Central impoundment	1927.50 1927.35
E	Transition zone	1928.60 1928.80
F	Transition zone	1929.50
G	Transition zone	1930.77
I	Head of impoundment	1935.95 1935.68 1935.25 1935.08
	Transition zone	1934.80

Since the sampled stretch of the Danube is part of an international Passenger- and Cargo-waterway longline fishing need to comply with traffic regulations in order to avoid interference with traffic on the waterway. Due to the location of the navigable channel, landing stages and the close surroundings of the power plant, it is not possible to sample along the left bank between rkm 1945.5 and 1938 and in the inaccessible area close to the power plant (1921 km). Additionally, landing sites, the navigable channel and harbor entrances did not allow sampling between rkm 1937.6 and rkm 1917 along the right bank (except between rkm 1923.8 and 1923.6 and around rkm 1925.75). Additionally, sampling was not possible in the surroundings of a cable ferry at rkm 1941.75.

2.1.1.1 Head of Impoundment

The Head of Impoundment section is the longest of the four sections (length: 10.5 km) and features the biggest diversity of stream fish habitats. Most of this section is located in the federal state of Lower Austria, with only the area between rkm 1937.25 and 1935.0 on Viennese grounds.

On the right bank, the main channel of this section is connected to the riparian waterbody system of the Strombad Kritzendorf and Klosterneuburg via the so-called "Klosterneuburger Durchstich", branching of at rkm 1945.35 and joining the main channel again at rkm 1937.8.

In the area of the Strombad Kritzendorf (rkm 1944 – 1942), the right bank is dominated by broad, shallow, run-over gravelbars and groyne fields. The groynes were construction at a right angle from the riverbank, varying in condition and length (up to 130m). From rkm 1942.9 to 1935 the riverbank is dominated by riprap structures and features only small patches of gravel bars and another groyne field between rkm 1940.1 and 1938.

In contrast, the left riverbank is completely dominated by steep homogenous riprap structures. Exceptions are the inlet of the Schmieda/Gießgang, which connects the Korneuburger riparian system to the Danube (rkm 1943.6), the port entrance of the dockyard (rkm 1943.0) and marina Korneuburg (rkm 1942.5), the inlet of the Donaugraben (rkm 1940.1), the intake structure of the new Danube and the northern tip of the artificially built Viennese Danube Island. The tip of the Island is, as a part of the Viennese flood protection system, massively protected by riprap structures to prevent erosion even during extreme flood events. Further downstream, the island offers a heterogeneous mix of fish habitats on the left bank of the Danube´s main channel. These are shallow gravel bars, sandy/silty bays and the artificially constructed Habitat I (rkm 1936.4 – 1934.8).

2.1.1.2 Transition Zone

The Transition Zone section is completely located within the urban area of Vienna. Compared to the Head of Impoundment, the average flow velocity of the river is decreasing more strongly between the upper and the lower end of the section. The right riverbank of this section is entirely made of riprap and features several landing sites. At rkm 1933.5 the Danube Channel branches off via hydropower station and lock Nussdorf. The left riverbank features a mix of riprap, gravel bars and a few concrete structures around the Reichsbrücke and a small harbor upstream of the bridge. Furthermore, the three artificially constructed Side Habitats G, F and E are connected to the main channel. Additionally, the two permanently fixed ships (around 190 m of length) of the Bertha-von-Suttner school create an exceptional structure at rkm 1931.5.

2.1.1.3 Central Impoundment

Figure 1: Hydropower plant Freudenau, view from Tailwater (Photo: Bernolle)

The Central Impoundment stretches from rkm 1928 to the HPS Freudenau at rkm 1921. This section features the highest average water depth and the lowest average flow velocity within the investigation area. The right riverbank is dominated by riprap, landings sites and the here located marina Vienna (rkm 1926.3). Only small side arms at rkm 1924. 8 (Habitat Ostbahnbrücke) and rkm 1922.99 (Niederbrückenhabitat) as well as a small marina at rkm 1923.4 (Harbor Pagode) enrich the monotonous riprap habitat structure.

In contrast, the left bank clearly shows a higher diversity of habitats. The Side Habitats, B, C and D are located in this stretch. Furthermore, it features two small bays upstream of the

Ostbahnbrücke. Nevertheless, riprap bank structures are dominating the left bank as well. Exceptions are a stretch between rkm 1923.3 and 1923 with a mix of gravel and bigger stones and a gyronefield (rkm 1922.3 and 1922.1) with short groynes separated by small bays with a flat gravel bank.

The direct surroundings upstream of the HPP and lock Freudenau (rkm 1921.7 to 1921) were closed to any fishing activity due to security regulations. At rkm 1921.5, the upper end of the fish pass of the HPP Freudenau creates a possibility for fish to bypass the dam.

2.1.1.4 *Tailwater*

The Tailwater comprises the stretch between the dam of the HPP Freudenau (rkm 1921) and the southern tip of the Viennese Danube Island (rkm 1917). This stretch is also the upper end of one out of two remaining "free-flowing sections" (Jungwirth, et al., 2014) of the Austrian Danube, the Donau - Auen National Park which preserves the last remaining major wetland environment in Central Europe (Nationalpark Donauauen, 2016).

Like upstream of the HPP and lock Freudenau sampling was not possible due to security regulation in the direct surroundings downstream of the weir, turbine outlet and lock.

On the left bank, riprap is the dominating bank structure in the direct surroundings of the HPP. At rkm 1920.5 the fish pass is connected to the Tailwater. From rkm 1920.28 to 1918.3, a groynfield is located. The upper groynes of this field feature a gap next to the bank, which enables fish movement along the riverbank towards the attraction flow of the fish pass. State of maintenance and length (up to 65 m) of the groynes vary.

A special feature is the artificial dotation of gravel by ships at rkm 1920.3, which is done to compensate the interruption of the sediment continuum by the upstream HPP and to limit the ongoing riverbed degradation in the Tailwater of Freudenau (Habersack et al. 2012). A small share of this introduced gravel sediment is temporarily stored a few hundred meters downstream, creating a flat gravel bank between the above-mentioned groynes. At the upper tip of the Rohrbrückeninsel (rkm 1918.2) even more gravel is deposited creating a vast flat gravel bar which is overrun by high flow velocity extending to rkm 1917.3. The southern tip of the Danube Island consists of sheet pile (rkm 1917) and is used as landing site.

The right bank of the Tailwater consist almost entirely of a steep riprap bank. Also a lot of navigation occurs here due to the navigable channel and the harbours Freudenau (rkm 1920.25) and Albern (rkm 1918.4) which are located along the right bank. Additionally the lock Freudenau is located on the right side of the river. Furthermore, the Donaukanal a sidearm, that braches of at rkm 1933.7 (see Transition Zone) joins the Danube´s main channel again at rkm 1919.45.

3 Concepts & Methods

3.1 Sampling design

3.1.1 Longline setup

In order to ensure comparability longlines were set up according to previous longline fishing investigations in the sampling area by Matschnig (1993/94) and Waidbacher et al. (1999/2000) after Zauner (1991). Some of the original material used in these investigations was still available and could be used either directly or as template for the construction of new longlines. The longlines' main rope is a polyamide line of approximately 52 m length (3,5 mm Ø). At both ends, a knotted loop served connect the longline to the anchor via carabiner during the setting of the longlines (See longline setting procedure, page 11 & 12). Between the loops, the rope was marked at 1 m intervals along 50 m of its length. At each mark a 20 cm long side leader made of 0.40 mm braided fishing line and ending in a snap swivel was sewed on. The hook leaders, provided with loops, could then be easily clipped to the snap swivel of the side leader. The snap swivels also prevent the leaders from supercoiling at high flow velocities. Hook leaders were self-tied in order to guarantee durability during the fishing in spite of considerable strain on the material. The 30 cm long hook leaders, consisting of T-Force Super Soft, 0,255 monofil, 8,35kg fishing line (Trabucco) represent the weakest part of the setup, being the predetermined breaking point.

Due to the fact that the fish need to hook themselves and should remain caught on the hooks for hours, barbed, sharp and robust hooks were found to be most suitable. The used hooks (sizes 6, 8, 10, 12) were produced by Balzer (GAMTEC speci Karpfenhaken) and Gamakatsu (G-CODE). Hook sizes, the designation of which vary between manufacturers, were chosen to match the hooks used in the previous investigations.

3.1.2 *Longline fishing*

The following setting procedure was used to bring out a longline (see illustration page 12)

1) Anchoring of the motorboat at the favoured fishing location with a minimum distance to the bank of 2 m in order to prevent pedestrians from easily touching the longline and to avoid bites of Gobiidae during the setting procedure (see discussion: Invasive Gobiidae, page 42).
2) Attachment of anchor buoy 2 (offshore anchor buoy) at one end of the longline and bringing out the line while continuously clipping baited hook leaders zo the side leaders on the longline. During this process the anchor buoy 2 drifts downstream, thereby spreading the line longitudinally and preventing entanglement (step 1 in Figure 2)
3) When the other end of the longline is reached, an anchor is attached to it via carabiner and the end of the longline is sunk and marked with anchor buoy 1 (bankside buoy). The anchor and the buoy are connected with a strong rope, which is required later for lifting of the anchor and bringing in of the longline (step 2 in Figure 1)
4) Transferring buoy 2 in direction of the river's middle and anchoring the longline's second end, which is marked by an anchor buoy (offshore buoy, attached via rope)(step 3 & 4 in Figure 1)

Stepwise haul-in procedure used to bring in the longline:

1) Lifting the anchor at anchor buoy 2 (offshore buoy), removing the anchor and reattaching the buoy to the end of the longline. Due to the current, the buoy moves towards the bank, thereby lifting the line and preventing entanglement on the river bed.
2) Lifting of buoy 1 (bankside buoy) and hauling-in of the longline hook by hook.
3) Noting of each hook's status (hook lost, bait missing or caught fish) and hook number (1-50) in the protocol while hauling-in.

Due to the complexity of the procedure and the simultaneous handling of the motorboat, longline, buoys, anchor etc. at least two person were required on board.

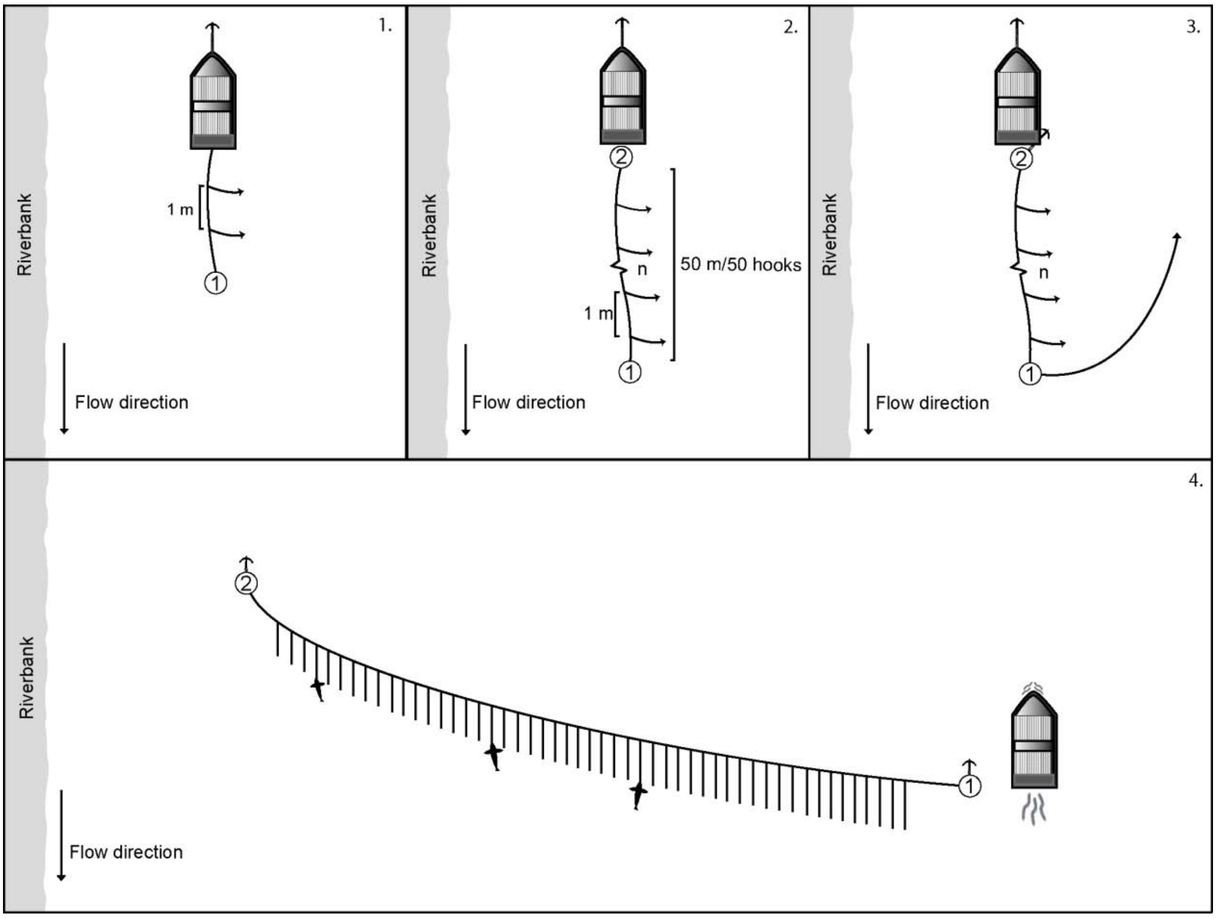

Figure 2: Longline fishing procedure

Figure 3: Set longline marked by inshore anchor buoy (2) and offshore anchor buoy (1) (Photo: Bernolle)

3.1.3 *Bait*

As fishing bait redworm (*Eisenia fetida*) were used. All hooks were adequately baited for the fishing with the bait covering a large part of the hook. The condition of all hooks and hook leaders was checked regularly after usage. Blunt or bent up hooks or damaged hook leaders were replaced to avoid a bias due to fishing material wear.

3.1.4 *Temporal and spatial selection of fishing locations*

The sampling was conducted between March 18 and October 13, 2014 in order to include seasonal patterns from spring to autumn. A total number of 99 longlines were placed.

With 50 hooks on each longline, this amounts to 4950 baited hooks. The 99 longlines where fishing on 34 dates, setting the longline between 14:30 and 19:00 pm on day 1 and hauling them in the following morning between 9:00 and 12:00 am. Occasionally, these times had to be slightly changed due to weather conditions etc. in order to avoid the risk of capsizing. Detailed sampling locations and rkm can be found in 12. 1Maps.

Table 3: Fished longlines per section (including all longline fished in 2014)

Section name	Count of fished longlines [n]	Stretch length [rkm]
Head of Reservoir	33	10.5
Transition Zone	26	7
Central Impoundment	26	7
Tailwater	14	4
Total	99	28.5

3.1.5 Processing of Samples

For each hauled-in longline several parameters were noted on a pre-set data-form (see 9.2 Protocol, page 64 & 65).

- Editor
- Sampling date
- Stretch number
- Time of setting and hauling-in
- River kilometer (rkm)
- Section
- Position of longline (left bank/right bank)
- Discharge at water gauge Klosterneuburg - (data offered by viadonau)
- Water temperature at measurement point Vienna - Nußdorf (data offered by viadonau)
- Water depth on the location of the buoys (bankside and offshore buoy)
- Distance between next bank and buoys (taken by laser distance meter)
- Prevalent bank and habitat structures (dependent on water level)
- Site plan including landmarks for orientation and the position of the longline
- Hook number 1 to 50
- Hook status (empty hook/hook lost/caught fish species)
- Attributes of caught fish species: size[mm] and weight [g]
- Fish taken for further Gastro-interdestinal analysis
- Special features, e.g. signs of predations on caught fish, parasites, anomalies..

The caught fish were immediately landed by dip net, unhooked with a forceps, measured and weighted. All caught fish except *Neogobius melanostomus* (used for a master thesis about gastrointestinal analyses (Ebm, 2016), were released as quickly as possible to reduce stress for the fish. Badly injured and obviously strongly exhausted fish with minimal probability of survival were percussively stunned and killed.

3.1.5.1 Water temperature measuring point Vienna - Nußdorf in 2014

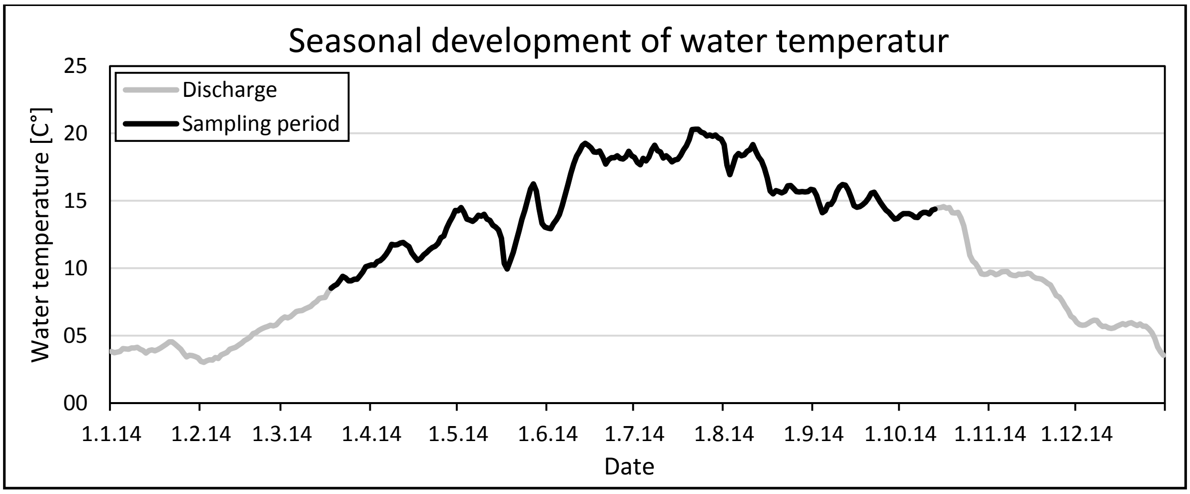

Figure 4: Danube water temperature at measurement point Vienna – Nußdorf (data by viadonau)

In 2014, the annual mean water temperature measured at Vienna Nußdorf was 11.5 °C (data provided by via donau GmbH). The mean temperature during the sampling period was higher with 15.0 °C. Daily average temperatures ranged between 8.5 C° at 18th of March and 20.3 °C between 21th and 23th of July.

3.1.5.2 Discharge at water gauge Korneuburg in 2014

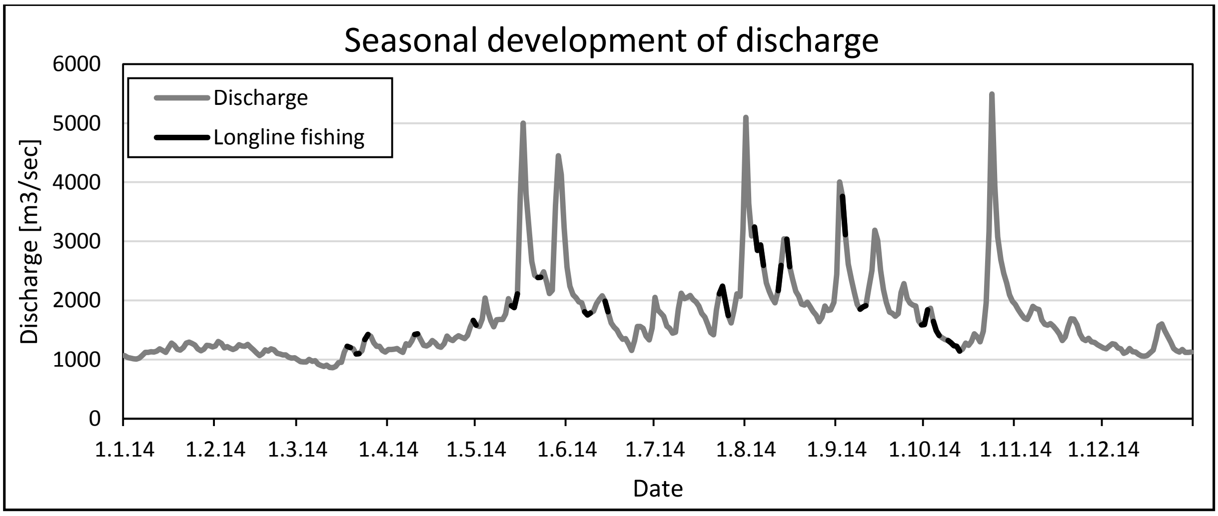

Figure 5: Danube discharge [m^3/sec] at water gauge Korneuburg (data by viadonau)

In 2014, the annual mean discharge at the water gauge Korneuburg was 1676.45 m^3/sec. Furthermore, for the Danube typical discharge patterns can be observed with rising discharge in spring caused by snowmelt in the Alps and several discharge peaks during summer due to glacier melt and strong precipitation events. In 2014, sampling took place in various discharge conditions between 1095 m^3/sec and 3759 m^3/sec during the summer half year with a mean value of 1887.66 m^3/sec for the sampling period.

3.2 Data Analysis

3.2.1 Descriptive Analysis

The collected data of this longline fishing investigation (see processing of samples 3.1.5, page 14) was incorporated in the data analysis. Due to the sampling method the focus is on analysis of the results for benthic fish species. Therefore, the fish species were classified according to their feeding guilds (Jungwirth et al 2003 see 9.3 Basic characteristics of caught fish species, page 71), and only the benthic species were taken into consideration.

Subsequently, the current data was compared to data taken at previous investigations of Matschnig (1995) and Waidbacher et al. (2002). Thus, the impact of the construction and operation of the HPP Freudenau on the benthic fish community could be analysed. To ensure spatial comparability Matschnig's (1995) and Waidbacher's (2002) raw data was sectored according to the subdivision of the sampling area in the investigation at hand. Additionally, longlines fished by Waidbacher et al. (2002) inside the Side Habitats as well as longlines with numerous hook losses in the current investigation were excluded from the analysis in order to maintain comparability. Matschnig's investigations from 1993/94 were part of a limnologic preservation of evidence of the fish biocenosis, which was conducted within the framework of the construction of the HPP. Since the Danube was then still free flowing in this stretch, Matschnig's data can be regarded as reference from a free flowing Danube section. This way, changes in the benthic fish biocenosis in the obviously most strongly altered Central Impoundment section might become more clearly visible. We can therefore presume that, in 1993/94, the section, nowadays labeled as Central Impoundment, showed a similar benthic fish biocenosis as the Head of Impoundment and the Transition Zone. Since the Tailwater section was only sampled in the current study, it was taken into account only for the analysis of the 2014 data.

For the descriptive analysis the catch per unit effort (CPUE) was used as an indirect measure of the abundance of fish species (Paloheimo & Dickie (1964) in Harley et al. 2001, Maunder et al. 2006). By using for every fishing, standardized gear (similar bait, hook sizes, and line strength) combined with considered similarity of fishing conditions, like discharge and water temperature, an equal fishing effort can be assuered. By doing so, changes in the CPUE can be assumed to show trends in changes of species abundance (Zauner, 1991). Dividing the catch C [number of caught individuals of one species] by the Effort E [count of fished longline] results in the CPUE.

$$CPUE = \frac{C}{E}$$

The CPUE was calculated for the total catch of a species as well as for each section individually. For the latter, the caught species was divided by the fished longlines in each section. The comparison of data from the previous investigations with the results of the current sampling was conducted by comparison of CPUE values for selected longlines. Increasing or decreasing CPUE-values can be interpreted as signs of changes in fish species abundance and species composition over space (sections) and time (sampling periods 1993/93, 1999/2000, 2014).

3.2.1.1 Habitat preferences of the fish biocenosis

The operation of the HPP Freudenau and the corresponding impoundment have altered the hydro-morphology, longitudinal connectivity and the riverbank in investigation area. By using the count of caught fish species and species classification referring to habitat requirements (see 9.3, page 66) by Jungwirth (2003) and Zauner & Eberstaller (1999 & 2003) and changes of the fish biocenosis in individual sections across the three investigation periods impacts by the altered flow velocity could be analyzed. Furthermore, these results can hint at changes in prevalent habitat conditions since changes conditions can conflict consequently with species requirements (see 9.3, page 66) which can be observed in changed CPUEs values as well.

4 Results

4.1 Longline fishing results 2014

For the evaluation of the results 90 of a total of 97 longlines baited with *Eisenia fetida* were selected. Damaged lines or large hook losses occurred in six longlines, while for three lines a different bait was used so that these were excluded from the analysis.

Table 4: Species list with corresponding total- and sectoral abundance[1]

	Abundance per section				Total Abundance
Species:	Head of Impoundment	Transition Zone	Central Impoundment	Tailwater	
Abramis brama		1			1
Ballerus sapa				1	1
Barbus barbus	3			3	6
Blicca bjoerkna	1	1	2	3	7
Cottus gobio				6	6
Gymnocephalus cernua			1		1
Gymnocephalus schraetser	36	8	13	20	77
Leuciscus cephalus	1		2		3
Leuciscus idus	1			1	2
Lota lota	1				1
Neogobius melanostomus	75	133	178	42	428
Perca fluviatilis	3		2		5
Ponticola kessleri	15	20	16	1	52
Romanogobio albipinnatus	1			1	2
Rutilus pigus	2			2	4
Rutilus rutilus	1		1	1	3
Sander lucioperca	1	1			2
Silurus glanis		1	3		4
Vimba vimba			1		1
Zingel streber	1			8	9
Zingel zingel	14	6	3	18	41
Total	156	171	222	107	565

[1] including 90 longlines selected for further evaluation

In 2014, in total 565 fishes out of 21 species were caught on longlines (see Table 4). With 428 caught individuals the longline fishing catch was clearly dominated by the invasive species *Neogobius melanostomus* followed by *Gymnocephalus schraetser* (n =77), invasive *Ponticola kessleri* (n =52), and *Zingel zingel* (n =41). In contrast, all other species were caught considerable less frequently or even only single catches. By looking on the abundance per section, it becomes obvious that the pattern of caught fish species per section is manly correlating with catches of *Neogobius melanostomus*. The Central Impoundment (n =222) features the highest values followed by Transition Zone (n = 171) and Head of Impoundment (n = 156).

Since every longline carries 50 hooks a total amount of 4500 fished hooks is considered in the analysis. Of the 4500 fished hooks 3340 hooks remained empty, i.e. without catch (with or without bait still on the hook), and 504 hooks were lost. The majority of hook losses can be explained by the longline haul in procedure. Frequently, rupture of the hook-leaders occurred due to entanglement or hooking of structures in the river or on the river bottom. Other possibilities of hook losses are hooking of flotsam or big fish individuals (e.g. *Barbus barbus, Silurus glanis*), that might have been able to sever the hook leaders. Therefore, it is not possible to determine the reasons for and the hook losses.

Fish length of the catch 2014 ranges from 60 to 540 mm (see Figure 4). The majority of caught fish measured between 80 and 190 mm. Rarely, fish with a length above 280 mm could be caught.

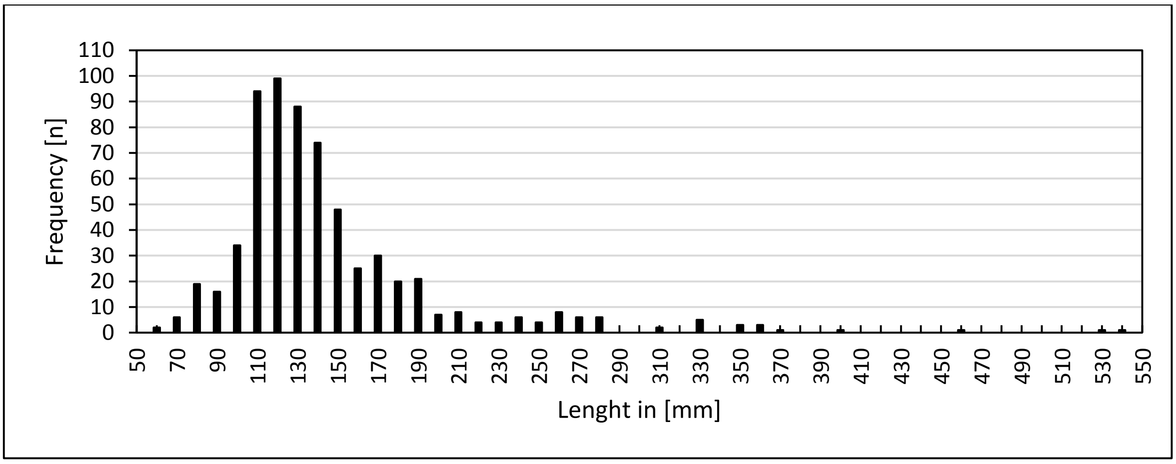

Figure 4: Length frequency diagram of all fish species caught during the investigation in 2014

4.2 Descriptive comparison between 2014, 1993/94 and 1999/2000 sampling data

4.2.1 Basic fishing parameters

Table 5: Basic parameters of selected longlines fished in each sections during the three investigation periods

Parameter	Section	1993/94[1]	1999/2000[2]	2014
Total count of longlines	Head of Impoundment	64	19	28
	Transition Zone	17	20	23
	Central Impoundment	-	12	25
	Tailwater	-	-	14
	Sum	**81**	**51**	**90**
Total count of caught fish	Head of Impoundment	272	89	156
	Transition Zone	96	78	171
	Central Impoundment	-	36	222
	Tailwater	-	-	107
	Sum	**368**	**203**	**656**
Total caught fish/longlines	Head of Impoundment	4,25	4,68	5,57
	Transition Zone	5,65	3,90	7,43
	Central Impoundment	-	3,00	8,88
	Tailwater	-	-	7,64
	Sum	**4,54**	**3,98**	**7,28**
Total count of caught fish species	Head of Impoundment	21	17	15
	Transition Zone	14	14	8
	Central Impoundment	-	12	11
	Tailwater	-	-	13
	Sum	**21**	**20**	**21**

1 Matschnig 1995
2 Waidbacher & Straif 2002 ; longlines fished inside the Side Habitats not included

As shown in Table 5 more longlines were fished in 2014 than in for previous investigations. Further, in 2014, the count of caught fish is considerably higher (CCF_{2014} = 656) than in the other investigation periods, which is also reflected in a clearly higher “Caught fish per longline” ratio (CF/LL_{2014} = 7.28). The count of caught fish species remained nearly the same between the three investigation periods. 21 documented species were caught on the longlines in 1993/94 (Matschnig, 1995) and 2014 and 20 species in 1999/2000 (Waidbacher, 2002). Nevertheless, considerable differences of caught fish and between sections and sampling periods become obvious which cannot explained by a differing sampling effort for single sections and investigation periods (see Table 5, page 20). Rather, varying conditions in sections and over by construction and operation of the HPP time can be made responsible for these patterns. Additionally it becomes obvious that already in the reference data of the 1993/94 sampling sectoral differences of basic parameters could be observed, mirroring the habitat suitability for fish species of the stretches at that time.

Table 6 shows the caught fish species from 1993/94 (Matschnig, 1995), 1999/2000 (Waidbacher et al., 2002) and 2014 with their species-specific total CPUE of each sampling period across all sections (for species numbers of caught species see 9.6 Count of fish species over all investigation periods).

Table 6: Caught species CPUE values for sampled periods across all sections (s.n.c. = species not caught)

	Sampling period		
Fish species	**1993/94[1]**	**1999/2000[2]**	**2014**
Abramis brama	0,01	0,02	0,01
Alburnus alburnus	0,01	0,06	s.n.c.
Ballerus sapa	0,15	0,02	0,01
Barbus barbus	1,12	0,35	0,07
Blicca bjoerkna	0,12	0,06	0,08
Chondrostoma nasus	0,02	s.n.c.	s.n.c.
Cottus gobio	0,21	0,41	0,07
Gobio gobio	0,01	s.n.c.	s.n.c.
Gymnocephalus baloni	0,07	0,29	s.n.c.
Gymnocephalus cernua	s.n.c.	0,04	0,01
Gymnocephalus schraetser	0,59	0,55	0,86
Leuciscus aspius	0,05	s.n.c.	s.n.c.
Leuciscus cephalus	0,05	0,20	0,03
Leuciscus idus	s.n.c.	0,02	0,02
Leuciscus leuciscus	s.n.c.	0,04	s.n.c.
Lota lota	s.n.c.	s.n.c.	0,01
Neogobius melanostomus	s.n.c.	s.n.c.	4,76
Pelecus cultratus	s.n.c.	0,02	s.n.c.
Perca fluviatilis	0,14	0,75	0,06
Ponticola kessleri	s.n.c.	0,33	0,58
Romanogobio albipinnatus	0,44	s.n.c.	0,02
Romanogobio uranoscopus	0,05	s.n.c.	s.n.c.
Rutilus pigus	s.n.c.	s.n.c.	0,04
Rutilus rutilus	s.n.c.	s.n.c.	0,03
Salmo trutta fario	0,04	s.n.c.	s.n.c.
Sander lucioperca	0,06	s.n.c.	0,02
Sander volgensis	0,02	0,02	s.n.c.
Silurus glanis	s.n.c.	0,02	0,04
Vimba vimba	0,37	0,06	0,01
Zingel streber	0,35	0,06	0,10
Zingel zingel	0,64	0,67	0,46

[1] Matschnig 1995

[2] Waidbacher & Straif 2002 ; longlines fished inside the Side Habitats not included

The fishing results differ in regard of occurring species and CPUE between the sampling periods. The CPUE values represent a wide range from “not occurring” to the maximum CPUE value $CPUE_{Neom2014} = 4,76$ for *Neogobius melanostomus* in the sampling period 2014. Low CPUE values occur in all sampling periods and can only be seen as proof of the species’ presence. Predictions regarding stock are unreliable in these cases.

Since longline fishing does not seem to be an optimal sampling method for all fish species, the focus of the further comparison between data from 2014 and the previous results is on a selection of species. Therefore, the most abundant benthivorous fish species after (Jungwirth, et al., 2003) within the three investigation periods were selected for a detailed descriptive sectoral comparison. The selected species are *Barbus barbus*, *Cottus gobio*, *Gymnocephalus schraetser*, *Neogobius melanostomus*, Ponticola kessleri, Romanogobio albipinatus, *Vimba vimba*, *Zingel streber*, *Zingel zingel*.

4.2.2 Descriptive comparison of temporal and spatial occurrence patterns of selected fish species

4.2.2.1 *Barbus barbus* (Linnaeus, 1758)

Figure 6: Juvenile Barbus barbus (Photo: Bernolle)

In 1993/94, *Barbus barbus* was the most frequently caught fish species, resulting in the highest CPUE value ($CPUE_{93/94(Bar)}$ = 1.12) (see Table 6, page 21). By having a closer look on the CPUE values for each section and investigation period, it becomes obvious that *Barbus barbus* has almost equal values for Head of Impoundment ($CPUE_{93/94HI(Bar)}$ = 1,16) and Transition Zone ($CPUE_{93TZ(Bar)}$ =1) in 1993/94. In 1999/2000 the CPUE values noticeably decrease by more than half in Head of Impoundment and Transition Zone. The Central Impoundment shows the highest CPUE value in this investigation period. In 2014, *Barbus barbus* was only caught in low numbers in the Head of Impoundment and the Tailwater, with none caught in the sections in between. By comparing the CPUE values of the sampled sections of 1993/94 and 2014 a clear decrease of *Barbus barbus* becomes obvious. For the Head of Impoundment the CPUE value drops from $CPUE_{93/94HI(Bar)}$ = 1,16 to $CPUE_{2014HI(Bar)}$ = 0,11 and in the Transition Zone from CPUE $_{93TZ(Bar)}$ = 1 to “not proven by longline”.

Table 7: Comparison of CPUE values for *Barbus barbus* between sampling periods and sections (N/A = no data available)

		Sampling period			
		1993/94	1999/2000	2014	
Section	Head of Impoundment	1.16	0.37	0.11	CPUE
	Transition Zone	1	0.30	0.00	
	Central Impoundment	N/A	0.42	0.00	
	Tailwater	N/A	N/A	0.21	

4.2.2.2 *Cottus gobio* (Linnaeus, 1758)

Figure 7: Cottus gobio (Photo: Meulebroek)

Cottus gobio was caught in in 1993/94, 1999/2000 and 2014. In 1993/94, a difference in CPUE values between Head of Impoundment and Transition Zone is evident, while the CPUE values for all sampled section are very similar in 1999/2000 with the highest value in the Central Impoundment. In 2014, *Cottus gobio* could only be caught downstream of the HPP Freundenau (Tailwater section) and was missing completely in the other sections.

Table 8: Comparison of CPUE values for Cottus gobio between sampling periods and sections (N/A = no data available)

		Sampling period			
		1993/94	1999/2000	2014	
Section	Head of Impoundment	0.06	0.37	0.00	**CPUE**
	Transition Zone	0.76	0.40	0.00	
	Central Impoundment	N/A	0.50	0.00	
	Tailwater	N/A	N/A	0.43	

4.2.2.3 *Gymnocephalus schraetser* (Linnaeus, 1758)

Figure 8: Gymnocephalus schraetser (Photo: Bernolle)

Gymnocephalus schraetser was sampled during each investigation and in each section. In 1993/94 CPUE values nearly identical. In 1999/2000, the highest CPUE value is reached in the Head of Impoundment section. The Transition Zone and the Central Impoundment values are alike again. In 2014 the CPUE values were highest in the Head of Impoundment ($CPUE_{14HI(GymS)}$ = 1.29) and the Tailwater ($CPUE_{14Tw(GymS)}$ = 1.43). Transition Zone and Central Impoundment CPUE values are notably smaller: $CPUE_{14TZ(GymS)}$ = 0.35 and $CPUE_{14CI(GymS)}$ = 0.52.

Table 9: Comparison of CPUE values for Gymnocephalus schraetser between sampling periods and sections (N/A = no data available)

		Sampling period			
		1993/94	1999/2000	2014	
Section	Head of Impoundment	0.58	1.00	1.29	**CPUE**
	Transition Zone	0.65	0.30	0.35	
	Central Impoundment	N/A	0.25	0.52	
	Tailwater	N/A	N/A	1.43	

4.2.2.4 *Neogobius melanostomus* (Pallas, 1814)

Figure 9: Neogobius melanostomus (Photo: Ebm)

Neogobius melanostomus was not caught on longlines during the investigations in 1993/94 and 1999/2000. However, in 2014, it is the species with the highest CPUE value by far ($CPUE_{14(Neom)}$ = 4.76). Additionally, there are differences between the sections: While CPUE values are high for all of the four sections, the values for the Head of Impoundment ($CPUE_{14HI(Neom)}$ = 2.68) and the Tailwater ($CPUE_{14Tw(Neom)}$ = 3.00) are relatively low. The remaining two sections feature extremely high CPUE values: $CPUE_{14TZ(Neom)}$ = 5.78 for the Transition Zone and $CPUE_{14CI(Neom)}$ = 7.12 for the Central Impoundment.

Table 10: Comparison of CPUE values for Neogobius melanostomus between sampling periods and sections (N/A = no data available)

		Sampling period			
		1993/94	1999/2000	2014	
Section	Head of Impoundment	0	0	2.68	**CPUE**
	Transition Zone	0	0	5.78	
	Central Impoundment	N/A	0	7.12	
	Tailwater	N/A	N/A	3.00	

4.2.2.5 *Ponticola kessleri* (Günther, 1861)

Figure 10: Ponticola kessleri (Photo: Bernolle)

Ponticola kessleri could not be caught on longlines within the investigation area in 1999/94. By 1999/2000, however, it was already present in all sampled sections. The Head of Impoundment ($CPUE_{99HI(Pon)}$ = 0,63) featured the highest, the Transition Zone and the Central Impoundment far lower values. In 2014, the fishing results show roughly similar CPUE values for the Head of Impoundment, Transition Zone and Central Impoundment.

Table 11: Comparison of CPUE values for *Ponticola kessleri* between sampling periods and sections (N/A = no data available)

		Sampling period			
		1993/94	1999/2000	2014	
Section	Head of Impoundment	0	0.63	0.54	**CPUE**
	Transition Zone	0	0.20	0.87	
	Central Impoundment	N/A	0.08	0.64	
	Tailwater	N/A	N/A	0.07	

4.2.2.6 *Romanogobio albipinnatus* (Lukasch, 1933)

Figure 11: Romanogobio albipinnatus with bite marks by canine teeth of Sander lucioperca (Photo: Bernolle)

The CPUE values show that *Romanogobio albipinnatus* was occuring in the investigation area in 1993/94. In 1999/2000, however, the species could not be sampled by longlines in the area. In 2014, single catches resulting in extremely low CPUE values were made in the Head of Impoundment and the Tailwater. A comparison of the results from 1993/94 and 2014 for the sampled section shows a clear decrease in CPUE.

Table 12: Comparison of CPUE values for *Romanogobio albipinnatus* between sampling periods and sections (N/A = no data available)

		Sampling period			
		1993/94	1999/2000	2014	
Section	Head of Impoundment	0.38	0	0.04	**CPUE**
	Transition Zone	0.71	0	0	
	Central Impoundment	N/A	0	0	
	Tailwater	N/A	N/A	0.07	

4.2.2.7 *Vimba vimba* (Linnaeus, 1758)

Figure 12: Vimba vimba with typical head shape (Photo: Graf)

Vimba vimba was occuring in the Head of Impoundment and Transition Zone in 1993/94. The low and heterogeneous CPUE values for the following investigation period are difficult to interpret. However, by comparing the results from 1993/94 and 2014 a decrease in CPUE values becomes obvious.

Table 13: Comparison of CPUE values for *Vimba vimba* between sampling periods and sections (N/A = no data available)

		Sampling period			
		1993/94	1999/2000	2014	
Section	Head of Impoundment	0.30	0.11	0	**CPUE**
	Transition Zone	0.65	0	0	
	Central Impoundment	N/A	0.08	0.04	
	Tailwater	N/A	N/A	0	

4.2.2.8 *Zingel streber* (Siebold, 1864)

Figure 13: Comparision of *Zingel streber* (L) and *Zingel zingel* (R) (Photo: Bernolle)

The CPUE values of *Zingel streber* show that the fish species was caught in each sampling period. The highest CPUE values were obtained in the Head of Impoundment section in 1993/94 ($CPUE_{93HI(Zstr)} = 0.28$) and the Transition Zone ($CPUE_{93TZ(Zstr)} = 0.59$). In the investigation of 1999/2000, CPUE values were on a low level, and the species could not be caught on longlines in the Central Impoundment. In 2014, the species was only rarely occurring in the Head of Impoundment and more frequently in the Tailwater.

Table 14: Comparison of CPUE values for *Zingel streber* between sampling periods and sections (N/A = no data available)

		Sampling period			
		1993/94	1999/2000	2014	
Section	Head of Impoundment	0.28	0.11	0.04	**CPUE**
	Transition Zone	0.59	0.05	0	
	Central Impoundment	N/A	0	0	
	Tailwater	N/A	N/A	0.57	

4.2.2.9 *Zingel zingel* (Linnaeus, 1766)

Figure 14: Zingel zingel (Photo: Bernolle)

Zingel zingel was caught in all sections and in all sampling periods. The sections sampled in 1993/94 show increased CPUE values in 1999/2000. The section only sampled in 1999/2000 and 2014 (Central Impoundment) features a CPUE value similar to that of the Head of Impoundment ($CPUE_{99CI(Zzin)}$ = 0.42). In 2014, *Zingel zingel* obtained the highest CPUE values in the Head of Impoundment ($CPUE_{14HI(Zzin)}$ = 0.50) and the Tailwater ($CPUE_{14Tw(Zzin)}$ = 1.29). CPUE values of the stretches sampled in 1993/94 and 2014 seem to be rather stable. The 2014 data, however, shows a noticeably low value for the Central Impoundment and, as mentioned above, a high value for the Tailwater.

Table 15: Comparison of CPUE values for *Zingel zingel* between sampling periods and sections (N/A = no data available)

		Sampling period			
		1993/94	1999/2000	2014	
Section	Head of Impoundment	0.73	0.42	0.50	**CPUE**
	Transition Zone	0.29	1.05	0.26	
	Central Impoundment	N/A	0.42	0.12	
	Tailwater	N/A	N/A	1.29	

4.2.3 Fish biocenosis flow preferences

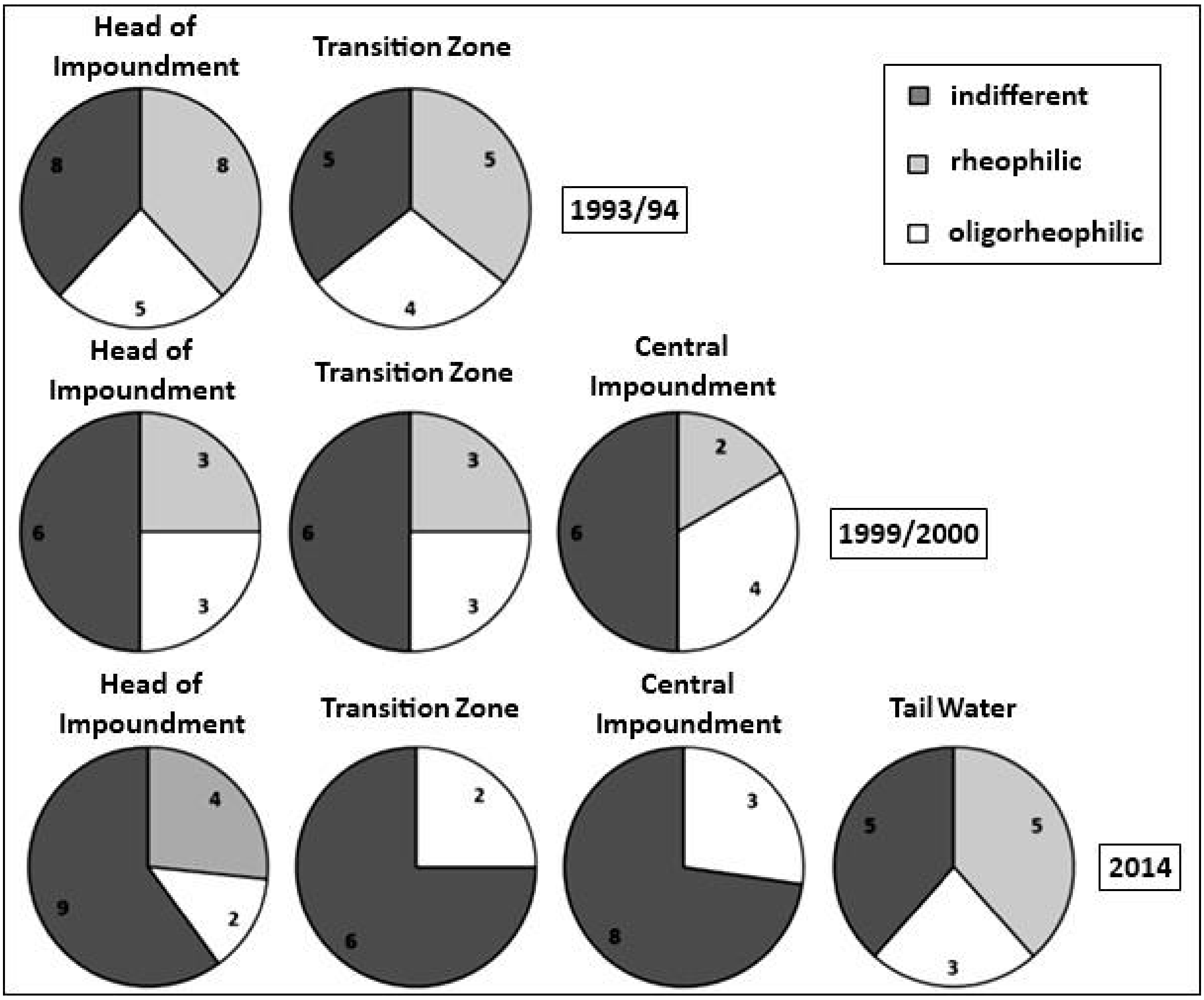

Figure 15: Fish biocenosis flow preferences over the three investigation periods. Values in pie charts represent quantities of fish species which can assigned to flow preference types (based on Jungwirth et al., 2003 and Zauner & Eberstaller, 1999; see 9.3)

Matschnig's data from 1993/94 suggest that the fish biocenosis consisted in similar proportions of rheophilic, oligorheophilic and indifferent species in both sampled setions. Since the Danube was still "free flowing" in the investigation area in these years, these proportions can be seen as reference conditions of a free flowing river stretch of the Danube in this area. In both sections of the Danube´s main channel, rheophilic and oligorheophilic fish species dominated.

In 1999/2000, all sections showed a larger proportion of indifferent fish species, while the proportion of rheophilic species had decreased. For oligorheophilic fish species only very small changes in the Transition Zone could be observed.

In 2014, the Head of Impoundment was dominated by indifferent fish species, followed by four rheophilic and only two oligorheophilic species. The Transition Zone and the Central Impoundment show similar proportions of rheophilic guilds. In both of them, indifferent species clearly dominate. Furthermore, only a small amount of oligorheophilic species occurred, while rheophilic species are completely missing within these sections. The Tailwater features indifferent and rheophilic species in similar quantity, with a smaller proportion of oligorheophilic species.

For comparison of the “rheophilie” results for each period and section, the difference between 1993/94 and 2014 is most noticeable. The 1999/2000 data can be seen as interim results. It becomes obvious that, in 1993/94, the proportion of the guilds in Head of Impoundment and Transition Zone are similar to those of the Tailwater in 2014. Additionally, rheophilic fish species did not occur in the Transition Zone and the Central Impoundment any more. In 2014, the Head of Impoundment features a high proportion of indifferent fish species, followed by rheophilic and oligorheophilic fish species.

5 Discussion

5.1 Influence of the HPP on benthic fish species

With the construction and operation of the HPP Freudenau the hydro-morphology of this Danube stretch changed considerably. This change in hydro-morphology as well as alterations in context of the construction of the HPP led to a change in native fish species habitats. Water depth increased in impounded areas while shallow littoral zones were reduced and sediment grain sizes now show an artificial gradient from coarse to fine between the Head of Impoundment and the Central Impoundment (Straif, 2011). In the Central Impoundment a large and deep pelagic area, which is atypical for the Austrian Danube, was created. Contrarily to the depth gradient flow velocity is reduced successively between the Head to Impoundment and the Central Impoundment (Schiemer et al. 1994; Jungwirth, et al., 2014). Since the fish biocoenosis of this Danube stretch was adapted to the hydro-morphological conditions of a free flowing river stretch before the construction of the HPP, a change within the fish fauna due to the construction of the HPP must be assumed.

In order to evaluate these changes CPUE values of different sampling periods are used. By comparing these, conclusions about the fish abundance are drawn (Paloheimo & Dickie (1964) in Harley et al. 2001). However, it must be kept in mind that changes in CPUE can only be seen as a soft indicator for fish abundance because the technique used to obtain them, i.e. longline fishing, is only a supplementary fish sampling method (Haunschmid, et al., 2010). The CPUE also can provide information about habitat suitability for different fish species in the river stretch now altered by the HPP.

Comparing CPUEs of the four sections (Head of Impoundment, Transition Zone, Central Impoundment, Tailwater of the river stretch can only lead to sound results if the structural differences between them and the different sampling sites are taken into consideration. Most of the sampling in the Central Impoundment and Transition Zone was done along the left bank, which shows structural deficits like dominating riprap bank structures, and connections to the artificial “Side Habitats”. These were initially built to compensate the loss of spawning and nursery habitat due to the replacement of formerly more dynamic bank structures by riprap (Straif, 2011). Furthermore, water levels are buffered in run of the river hydropower plant impoundments, which is leads to a clear contrast to the dynamic seasonally fluctuating water levels of a free flowing river stretch.

Due the higher diversity of habitats sampling in the Head of Impoundment and Tailwater took place on gravel bars and next to groyne fields. These mesohabitats are not present or very rare in the other two sections.

Additionally, the reduced flow velocity can lead to deposition of fine sediment, which can fill up to some extend the interstitial and might reduce therefore drift of macrobenthos especially in the Transition Zone and the Central Impoundment. The macrobenthos community, an important food source for benthivorous fish species, is consequently affected as well by these changes (Ebm, 2016). Most benthic fish feed primarily on macrobenthos inhabiting the sediment or entering the drift (Jungwirth, et al., 2003).

5.1.1 Native fish species

The counts of caught species in 1993/94 ($n_{93/94_}$species = 21) and 2014 ($n_{14\_species}$ = 21) seem similar, but they do not reflect the change in the fish biocoenosis due to alteration of habitats by construction of the HPP. Even though, the overall effort (i.e. number of fished longlines) was slightly increased (Count of $LL_{93/94}$ = 81; Count of LL_{2014} = 90) some species could not be recorded again. Several new species could be caught in 2014 their occurrence can probably be related to the changed habitat situation. However, several species were only caught occasionally or even only once in all of the three investigation periods, resulting in extremely low CPUE values, which are difficult to evaluate and can only be seen as proof of evidence.

For the majority of species a decline in total CPUE values can be determined. Exceptions are *Gymnocephalus schraetser*, *Silurus glanis* and the invasive Gobiidae species *Pontikola kessleri* and *Neogobius melanostomus*, which are discussed separately (see 5.1.2). Nevertheless, it can be assumed that the high catch rate of the invasive Gobiidae may have biased the catch rate of all native species. Of n_{t_hooks} = 4500, 497 hooks were occupied by invasive Gobiidae. Consequently, around 11.4% of the fished hooks were not available for native fish species.

5.1.1.1 *Barbus barbus*

Barbus barbus is one of the dominating cyprinid species in the barble zone of Austrian rivers. According to the guiding view of the Leitbildkatalog of the Austrian Fish Index (Haunschmid, et al., 2010) it should be an abundant species in the sampled Danube stretch. Furthermore, the species is of some importance for anglers and conservation as it indicates ecological quality and structural properties of riverine systems due to life-history patterns and habitat requirements (Britton & Pegg, 2011; Melcher & Schmutz, 2010). According to Schiemer et al. (1994) *Barbus barbus* belongs to a pool of species which can be caught frequently using longlines. While *Barbus barbus* was the species with the highest CPUE ($CPUE_{93/94(Barb)}$ = 1.12) in 1993/94, a decrease in CPUE in 1999/2000 and a further ongoing decrease in 2014 with $CPUE_{2014(Barb)}$ = 0.07 could be observed.

A look at the differences between sections shows that catches declined in the Head of Impoundment. In the Transition Zone and Central Impoundment, the species could not be documented via longlines in 2014. This change in *Barbus barbus* abundance after the construction of the HPP Freudenau is consistent with investigations (mainly electrofishing data) of the fish fauna in context with other Austrian Danube stretches influenced by HPPs (e.g. HPP Altenwörth, HPP Melk, HPP Ybbs-Persenburg and HPP Greifenstein (Jungwirth, et al., 2014; Schiemer & Waidbacher, 1998; Schiemer, et al., 1994). All of these fish investigations show a similar negative effect of flow reduction and habitat alteration by HPPs on *Barbus barbus* abundance. The effects is stronger the closer to the HPP the samples were taken.

The species is classified as rheophilic and as lithopilic spawner, demanding coarse spawning substrate with higher flow velocities for reproduction (see 9.3. page 66) (Melcher & Schmutz, 2010; Britton & Pegg, 2011). Therefore, it is not surprising that, especially in the Central Impoundments of HPPs, this species occurs in low abundances only. In contrast, the less effected Head of Impoundment of HPP Greifenstein, HPP Altenwörth and HPP Aschach show higher abundances. Nevertheless these values are surpassed by longline results in the “free flowing stretches” in the Wachau Valley and east of Vienna (Schiemer, et al., 1994). As a medium distance migrant the species is known to undertake spawning migrations in the Danube itself as well as into its tributaries. Since the longitudinal connectivity for a part of the sampled Danube stretch , is only given via the fish pass Freudenau (spawning migration can be assumed to be restricted. Surprisingly, depending on discharge and water level, the bypass channel of the HPP Freudenau's fish pass, featuring required spawning substrate and flow velocity, has been used as spawning ground by *Barbus barbus* in the last years (Meulenbroek et al. (in prep.), Nagl & Stadler (in prep)). Nevertheless, a large area of the Central Impoundment and Transition Zone seem to be an inappropriate habitat for this species. *Barbus barbus* requires a variety of habitats for certain life stages which are not or only partly given in these sections (Britton & Pegg, 2011; Melcher & Schmutz, 2010). The individuals caught on longlines in 2014 ($n_{14(Barb)}$ = 6) were all caught at sites with higher flow velocity.

5.1.1.2 Gymnocephalus schraetser

In his book about ecological studies of the Danube Percides Zauner (1996) names economic interests as driving force behind solutions of problems and issues in natural sciences. In many cases, species without economic value are scientifically investigated only to an unsatisfying extent. Besides *Zingel zingel* and *Zingel streber*, *Gymnocpehalus schraetser* also suffers from this phenomenon. During the inquiries for this thesis, it became clear there is still a lack of knowledge about these species. Nevertheless, Zauner (1991) created a solid base of knowledge about the previously mentioned Danube percids by his investigation of Austrian Danube.

In the framework of the investigation of the ecosystem response to the HPP Freudenau *Gymnocephalus schraetser* was sampled during each investigation period. Differences betweeen the sampling periods as well as between river sections can be observed. While the investigations in 1993/94 and 1999/2000 showed similar CPUE values ($CPUE_{93/94(GymS)}$ = 0.59; $CPUE_{99/00(GymS)}$ = 0,55) the sectoral results of the Head of Impoundment and Transition Zone show differences already one to two years, respectively, after filling of the Impoundment. In 2014, *Gymnocephalus schraetser* was highly abundant in the Head of Impoundment (CPUE =) and the Tailwater (CPUE =), while the Central Impoundment CPUE was within the range of the 1993/94 results.

It seems that, in general, *Gymnocephalus schraetser*, being an oligorheophilic fish species, can cope with the habitat change due to the construction and operation of the HPP best. Especially the Head of Impoundment and the Tailwater seem to be a suitable habitat for this species, while it is less frequent in the Transition Zone and Central Impoundment. By comparing the

2014 results with similar longline fishing investigations for other Austrian Danube stretches differences become obvious. Zauner (1991) compared investigations on the three Danube Percidae (*Gymnocephalus schraetser*, *Zingel streber*, *Zingel zingel*) in the Central Impoundment of the HPP Altenwörth, the Head of Impoundment of HPP Altenwörth and Aschach aswell as in the free flowing section of the Wachau Valley and east of Vienna. He describes the Central Impoundment of HPP Altenwörth as an ideal habitat for Gymnocpehalus schraetser, basing this hypothesis on a high CPUE value. Furthermore, he describes the Head of Impoundment section of HPP Altenwörth and Aschach as less attractive for this species, while the free flowing section shows even lower CPUE values. He draws the conclusion that a reduction of flow velocity seems to be the determining factor for increasing densities of this species in proximity to a downstream impoundment. This is completely contrary to conclusions that can be drawn from the results of the study at hand: The HPP Freudenau's Central Impoundment's CPUE value is similar to that obtained during the reference fishing in 1993/94 by Matschig. Furthermore, the HPP Freudenau's Head of Impoundment and Tailwater, which can be seen as the first part of the free flowing section east of Vienna, feature the highest CPUE values for *Gymnocephalus schraetser* as well as the highest mean flow velocities in our investigation area. Of course, by taking into account that various Danube stretches feature unique local conditions at each site, the differing results suggest that flow velocity is only one of many parameters defining a suitable habitat for *Gymnocephalus schraetser*. Therefore, further investigations on this species are required. Also, *Neogobius melanostomus*, which is nowadays highly abundant in the Danube and in the Central Impoundment of HPP Freudenau, was not present 1991 according to Zauner. It can be assumed that *Gymnocephalus schreatser* is affected by this invasive species by competition (BMLFUW, 2013).

5.1.1.3 Zingel streber

Zingel streber is described as a nocturnal rheophilous fish species, with a regressed swim bladder, adapted to high flow velocities (Kottelat & Freyhof, 2007; Zauner, 1996). Investigations by Zauner (1991) on flow velocity preferences lead to the conclusion that generally, near bed flow velocities between 0.4 – 0.7 m/sec are preferred. For the Austrian Danube the distribution can be seen as restricted to the free flowing river stretches and Head of Impoundment sections of the HPPs (Zauner, 2010; Zauner, 1996; Schiemer, et al., 1994) . In these areas, suitable habitats like shallow gravel bars overrun with high flow velocities still exist (Zauner, 2010). While *Zingel streber* showed a high CPUE in the sampling area in 1993/94, a considerable change became visible in the 1999/2000 data. All sampled sections showed a decrease in CPUE. In the Central Impoundment, the species was not detectable anymore using longlines, while Head of Impoundment and Transition Zone featured only low values. This effect is even enhanced in 2014 with an extreme low value in the Head of Impoundment and no caught specimens in the Transition Zone. These results correspond with the investigations by Zauner (1991). Impounded Danube sections can be seen as problematic for this species since it prefers a certain minimum flow velocity. Only in the HPP Freudenau's Head of Impoundment small populations can be found. It is to be assumed that the habitat requirements are fulfilled at least to some extend here. Nevertheless, hydro-morphological alteration due to the HPPs along the Austrian Danube put a strong pressure on this species. In which way the presently very numerous invasive Gobiidae influence this species is difficult to evaluate since the habitat preferences differ. However, a high CPUE value for the Tailwater section suggests that this might not be the crucial factor. Here, the Gobiidae species also occur but the free flowing sections east of Vienna (National Park Donauauen) seems to feature rather suitable habitats for the *Zingel streber*.

5.1.1.4 Zingel zingel

Zingel zingel, like *Zingel streber*, is described as nocturnal rheophilous fish species (Kottelat & Freyhof, 2007; Zauner, 1996) but according to the investigation by Zauner (1991) this species prefers lower near-riverbed flow velocities around 0.3 m/sec. Gravel is needed as spawning habitat. Being a typical benthivorous fish species, *Zingel zingel* feeds on aquatic invertebrates and small fish. The CPUE values of the three investigation periods paint a heterogeneous picture. *Zingel zingel* was caught in all sections in all sampling periods. Nevertheless, a trend becomes visible when comparing the sectoral CPUE values from 2014. From 0.5 in the Head of Impoundment the CPUE decreases via the Transition Zone (CPUE of 0.26) to the lowest value of 0.12 in the Central Impoundment. Therefore, it can be assumed that with increasing upstream distance from HPP Freudenau the habitat suitability for this species increases. The highest CPUE of 1.29 is reached in the Tailwater. Interestingly, the investigations by Zauner

(1991) show very different results. Zauner describes highest abundances of this species in the Head of Impoundments of HPP Altenwörth and HPP Aschach and interprets therefore that optimal habitat conditions for this species are given. Furthermore, high abundances for the Central Impoundment could be documented. Zauner relates these high CPUE values to similar abiotic conditions, particularly reduced flow velocity as in the earlier mentioned Head of Impoundment sections. This interpretation might also be valid, at least to some extent, for the corresponding sections of the HPP Freudenau. Additionally, Zauner documented considerably low CPUE values for the free flowing sections as well, especially for the section east of Vienna. He related this to the high flow velocity and a deficit of habitats with reduced flow velocity. Since the Tailwater of HPP Freudenau, featuring high flow velocities, shows the highest CPUE in 2014, it can be assumed that flow velocity is not the driving factor here. It is more likely that the high share of suitable habitats like the vast gravel bars of the Tailwater as well as the positive influence of the National Park with a more natural and dynamic river stretch are responsible for the more frequent occurrence of *Zingel zingel* in this section.

5.1.1.5 Cottus gobio

While Cottus gobio was caught in all sampled sections in previous investigations, in 2014 this species was only caught on longlines in the Tailwater section (CPUE of 0.43). In the sampled sections upstream of the HPP Freudenau this species could not be caught. *Cottus gobio* is known as crepuscular and hides during the day under and between structures like gravel, rocks, plant roots or wood (Zauner, 2010). Furthermore, a loose bed substrate is preferred as it allows the species to enter the upper layer of the interstitial to hide. Also, being a typical benthic fish species, *Cottus gobio* has no swimming bladder (Zauner, 2010). It can be assumed that due to the reduced flow velocity, fine sediment is deposited to some extent, which may result in a clogged interstitial in the Central Impoundment and Transition Zone. The occurrence of this species in the Tailwater can be related to “more natural” habitats like gravelbars, with sediment movement, which leading to a looser sediment. Furthermore, competition between Cottus gobio and the invasive Gobiidae must be assumed due to similar habitat and diet preferences.

5.1.1.6 Romanogobio albipinnatus

While Matschnig could record *Romanogobio albipinnatus* in the investigation area in 1993/94, the species was not caught again in 1999/2000. In 2014, in both the Head of Impoundment and Tailwater sections only one individual could be caught. Therefore, a decrease of abundance of this species in the investigation area can be assumed. About the reasons for this decline we can only speculate, since there is still a lack of knowledge in regard of this species' habitat requirements. It is known that *Romanogobio albipinnatus* feeds on small invertebrates and often appears in small groups (Kottelat & Freyhof, 2007). For spawning a sandy bottom is preferred, where several small portions of eggs are laid (Zauner, 2010). Furthermore, no special preferences for bank structures and substrates are known. The decrease in CPUE seems to be related with the HPP's construction since the species' abundance was already shown to be decreasing in 1999/2000, i.e. one to two years after filling of the impoundment. However, competition with Gobiidae species due to a niche overlap is also probable.

Romanogobio albipinnatus belongs the pool of species difficult to catch on longlines with the setup used in this study. It is probable that only mature fish can be caught because used hooks and bait sizes lead to size limitation of the catch. However, application of the same method resulted in considerably more caught individual in 1993/94.

5.1.1.7 Vimba vimba

Vimba vimba is classified as oligorheophilic and is known to occur in lower sections of large and medium sized rivers with low flow velocities (Kottelat & Freyhof, 2007; Jäger, 2007). The preferred spawning habitats seem to be shallow gravel sections in fast flowing river stretches. Furthermore, it is known that the lacustrine population of this species undertakes spawning migration into tributaries. Like most of the benthivorous fish species, *Vimba vimba* preys mainly on benthic invertebrates and insect larvae.

Comparison of the CPUE values between 1993/94 and 2014 shows a decline in abundance of this species. In 2014, only one individual was caught, while 30 individuals were caught with less fishing effort in 1993/94. According to Spindler et al. (Spindler, 1997) this species is quite abundant in impounded sections of the Danube. HPPs interfere with the longitudinal connectivity of the river and complicate spawning migrations even if fish passes are available. Probably, the strongly altered Central Impoundment and Transition Zone feature no or only small spawning habitats. Further reasons for the probable decline of the species uncertain. IUCN classifies the species as "Least Concern" in their Red List and names water pollution and damming as major threats (IUCN, 2016). For Austria, the species is listed as threatened by Federal Environment Agency of Austria (Spindler 1997).

5.1.2 Invasive Gobiidae

With 428 caught individuals, 75.8 % of the longline catch in 2014 belong to the family of Gobiidae. *Neogobius melanostums* is with n_Neom = 428 individuals clearly dominating the catch while *Pontikola kessleri* n_Ponk = 69 was less frequently caught.

Both species, classified as invasive fish species, are native to the Ponto-Caspian region (Black Sea, Caspian Sea, Sea of Azov). In 1994, first individuals of *Ponticola kessleri* were documented in the Austrian Danube (National Park Donauauen (Zweimüller, et al., 1995)), while *Neogobius melanostomus* was first recorded in 2000 in Vienna (Wiesner, et al., 2000). For both species, navigation is assumed to be the reason for dispersal, with juvenile individuals or eggs of these species being accidentally displaced within the ballast water of transport vessels (Zweimüller, et al., 1995; Weissenbacher, et al., 1998; Ahnelt, et al., 1998; Wolfram & Mikschi, 2002). Nowadays both species have established populations in the whole Austrian Danube (Wiesner 2003). One reason for this successful invasive dispersal seems to these Gobiidae species' high preference for riprap habitats, which is indicated in several investigations (BMLFUW, 2013; BfN, 2010). As large stretches of the Danube now feature riprap structures a large ecological niche is created, which is not or insufficiently occupied by native fish bioceonoses. By filling this habitat niche *Neogobius melanostums* has become the dominating benthic fish species along riprap habitats in the Danube.

This can also be seen as an explanation for their high abundance in the investigation area, where *Neogobius melanostomus* is clearly dominating the catch in 2014 (overall $CPUE_{14(Neom)}$ = 4,76) while it was not caught at all in the previous investigations. In contrast, *Ponticola kessleri* (overall CPUE value of $CPUE_{14(Ponk)}$ = 0,58) was less frequently caught in 2014 but already documented in 1999/2000 (Waidbacher et al., 2002). The real abundance of these two species can even be assumed to be higher than indicated by the CPUE values obtained in this study by fishing, since a methodological bias has very probably led to relatively lower values. Already after fishing the first couple of longlines it became clear that the high abundance of these 2 Gobiidae species on and along riprap structures are problematic. While the hooks of the longline were baited, one end of the line with a buoy on it was given out and taken by the flow velocity. Therefore, by being too close to the bank parts of the baited line where swimming on the surface along the riprap, while the already baited hooks where bouncing due to surface movement of the water in approximately 40 cm water depth. We noticed that already during the baiting gobies along the riprap where attracted by the moving bait. For several hooks the bait was already devoured while other hooks already caught fish before bringing the longline in position and deposit it on the river bottom. While fishing a standardized longline with similar fishing setup it can be seen as problematic if fish already prey on the bait in a greater extend during the longlines setting. While it is nearly impossible to exclude this problematic completely, it should be kept as small as possible. Each hook, occupied or without bait before the longline is set is reducing the possibility of catching further fish. In addition, this phenomenon unintentional could explain atypical catches of fish species biasing the results. (e.g. the of *Pelecus cultrats* on the longline in 1999/2000 (Matschnig, 1995)).Therefore, to avoid extreme high catches rates of gobys along the riprap which bias all other species catch rates, longlines where set with at least a 2 m distance to riprap bank.

Comparison of the sampling area's four different sections in regard of *Neogobius melanostomus* abundance leads to the following results: The Central Impoundment, which can be assumed most altered by the HPP Freudenau, features an outstanding high CPUE value ($CPUE_{14CI(Neom)}$ = 7.12), followed by the Transition Zone ($CPUE_{14TZ(Neom)}$ = 5.78). These sections can be seen as the ones with the most strongly altered habitats, since monotonous riprap structures are dominating here. In contrast, the Head of Impoundment and Tailwater feature similar and lower CPUE values ($CPUE_{14HoI(Neom)}$ = 2.68 and $CPUE_{14TW(Neom)}$ = 3.00). Nevertheless, comparing these stretches it should be taken into account that both in the Central Impoundment and in the Transition Zone the dominant bank riprap structure, which is known to be these Gobiidae's preferred habitat, was sampled. Since riprap is also an appropriate spawning habitat for these species (speleophil), it is even more problematic in this regard. The males of both species, which take care of the brood by protecting eggs, might additionally increase spawning success and therefore in the long run the CPUE values (BMLFUW, 2013).

In contrast, the remaining two sections, i.e. Head of Impoundment and Transition Zone, feature considerably more diverse habitats. Therefore, different meso-habitats like gravel bars and groyne-fields were sampled here. Especially on gravel bars with high flow velocities lower abundances of Gobiidae were recorded, which can be related to a lack of structures providing cover and protection from the strong current.

Since both species appear to have overlapping ecological niches interspecific competition can be assumed (BMLFUW, 2013). In the last years, a trend of decreasing *Ponticola kessleri* abundance in the Austrian Danube can be observed and seems to be due to a displacement effect, which is probably associated with the very frequent occurrence of *Neogobius melanostomus*. Furthermore, both species are classified as “high-risk species” for the native fish fauna according to the “Leitbildkatalog” of the Austrian Fish Index (BMLFUW, 2013). Besides, negative effects or even displacement effects, especially on native benthic fish species, are to be expected (Jurada, et al., 2005).

5.2 Longline Fishing as sampling method for benthic fish species

Every fish sampling method has its advantages and disadvantages depending on hydro-morphological conditions at the sampling site and of target fish species. Electrofishing, for instance, can only provide reliable results in shallow waters, where the electric field reaches the bottom of the waterbody. Only small parts of the Danube stretch studied here are shallow enough for electrofishing (≤ 2.5m water depth). The remaining area features water depths ≥ 2.5m and can therefore not be sampled by electrofishing. By supplementing results obtained with this method with data resulting from several additional fish sampling methods, blank spaces in the fish ecological picture can be closed.

Longline fishing, as such a supplementary fish sampling technique, is an established method, which targets especially benthic fish species that are generally not captured with other sampling methods (Haunschmid, et al., 2010). Longlines can be set regardless of water depth, they are not affected by high flow velocities and debris, also, does not generally impede their usage. The latter is obviously advantageous compared to net fishing. Zauner (1996) describes flow velocities of up to 2.5 m/sec as unproblematic for longline fishing. Additionally, water turbidity plays a minor role compared to electro- and net-fishing. While for electrofishing at least some visibility depth is required in order to recognize and land attracted or stunned fish with a dip net (Hellig, et al., 2015), too clear water reduces fishing success with nets because fish may notice the net. Due to these factors, longline fishing is of great use for gaining information about species composition in habitats where other sampling techniques may fail.

Nevertheless, certain conditions at the fishing site, like a very heterogeneous, structured river bottom (e.g. larger rocks, logs etc.), can be problematic for longline setting and haul in. The line can become entangled, which can result in hook losses and/or damaged or torn line. Under such harsh conditions, however, other sampling methods that focus benthic fish species, like electrified benthic frame trawl (Szalóky, et al., 2014), fish traps and nets, are problematic as well.

Due to the necessary selection of bait and exposition of the bait on the bottom of the river longline fishing is a selective fish sampling method. Additionally, hook and bait sizes determine the catch (Løkkeborg & Bjordal, 1995). Bigger sized bait appears to catch bigger fish. This is problematic for several fish species, like *Zingel streber*, *Cottus gobio* or *Romanogobius albipinatus*, the juvenile individuals of which have small mouths and are not able swallow the used baited hooks. Therefore, these species can only be caught within a certain size range. This becomes obvious when the length range of caught fish in this study is considered: lengths between 60 and 535 mm were observed, while the largest part of caught fish ranged from around 80 mm to 190 mm in length. On one hand, the high proportion of Gobiidae and Danube Percids among the catch could be a reason for range of fish length in the catch. On the other hand, there is a possibility that larger fish could tear off the hook or free themselves of it. This problem could be easily solved by using a larger range of hook sizes. However, in the study at hand changing of hook sizes would have led to little or no comparability with previous investigations in the study area, since Matschnig (1993/94) and Waidbacher et al. (1999/2000) only used hook sizes 6 to 12. Therefore, some fish species and size classes are underrepresented in the catch obtained in both this study and the previous investigations (Matschnig, 1995).

The lost hooks ($n_{losthooks}$ =504 out of the in total fished number of hooks n_{t_hooks} = 4500, i.e. 11,2%) is acceptable under the prevalent conditions in the investigation area. Nevertheless, on some longlines a like proportion of hooks were lost and in rare cases the entire lined ones. The majority of fished hooks remained empty (n_{empty_hooks} = 3340). The total catch in 2014 (n_xx = 656) and a $CPUE_{total\_2014}$ =7.28 are considerably higher than the corresponding values from 1993/94 ($CPUE_{total\_1994/94}$ = 4.54) and 1999/2000 ($CPUE_{total\_1999/2000}$ = 3.98) (Matschnig, 1995; Waidbacher, 2002). These extreme values in the 2014 data can be directely related to the invasive species *Neogobius melanostomus* and *Pontikola kessleri*.

For evaluation of the success in targeting benthic fish species the caught fish were classified after Jungwirth, et al. (2003). Only 61.9% of the caught species are classified as benthivorous ($n_{benthivorous\_2014}$ = 13, n_{total_2014} = 21). Taking the fish species abundances into account it becomes clear that the vast majority of 95.9% (n = 629) of the caught specimens are benthivorous.

Another factor influencing longline catches is the water temperature since fish are poikilothermic. Therefore, the metabolism, behaviour and ingestion of fish depend on the momentary water temperature during sampling. While the previous investigations took place between July and September in 1993/94 and June and early October in 1999/2000, sampling started in end of March in 2014, i.e four months earlier. The mean temperature in the sampling period (15.0 C°) was, however, clearly above the annual average temperature of 11.5°C and within the preferred temperature range for most species. Additionally, the discharge was taken into account. Discharge values between 1095 m^3/sec and 3759 m^3/sec occurred during the sampling period. The mean discharge in 2014 was 1887.66 m^3/sec, being similar to the annual mean-flow conditions of 1910 m^3/sec for the sampling area (Jungwirth, et al., 2014). Therefore, water temperature as well as discharge can be assumed comparable with the previous investigation.

Since the catching of fish on longlines necessarily involves hooking the fish, longline fishing affects the health of the sampled fish. Depending on the time of the catch, the fish spent hours hooked to the longlines before being hauled in with it. Besides the unfavorable effects of being trapped on the longline for several hours, which can be assumed to be stressful, the hook causes injuries. Depending on the exact location of the hook in the fish's mouth, its health was more or less severely affected. At fishing sites with high flow velocities fish health seemed to be more negatively affected and some fish were already dead when the line was hauled in. This might be due to exhaustion caused by the forced continual swimming against the current and the spot. Swimming capacity and endurance limits might have been exceeded leading to death by exhaustion. However, in many cases the hook could be removed successfully using a forceps and the fish could be released alive. Even though, fish health is affected, there exist due to the challenging framework of the sampling methodical only limited alternatives.

In addition, several cases of conspicuous bite marks on caught fish suggest that there might have been attacks by predators. In some of them, the tooth imprints could be related to pikeperch, which had attacked *Neogobius melanostomus* specimens caught on the longline. One pikeperch was even caught on a *Neogobius melanostomus*, which had taken the hook baited with *Eisenia fetida* before. Some *Neogobius melanostomus* seemed to have been fed on by grayfish. However, the invasive Gobiidae species can be seen as inserted within the food chain as several predatory fish species like *Silurus glanis* and *Sander lucioperca* prey on them.

6 Conclusion

Longline fishing is frequently described as a supplementary fish sampling method. Although there are several points of criticism regarding species selectivity due to fishing gear, setup and bait, comparability of fishing results, negative impact on fish and a time-consuming sampling process. It also provides considerable advantages compared to other fish sampling techniques focusing on benthic fish species. Longlines can be used under circumstances where other sampling methods face their limits and can therefore be used to obtain valuable information about benthic fish species occurrence and abundance in difficult cases.

By applying longline fishing a considerable change in benthic fish biocoenosis in the Danube stretch affected by the HPP Freudenau could be recorded. A noticeable change of the Danube´s main channel's hydro-morphology and flow velocity in the impounded area occurred. This led to a simultaneous change of fish habitats, which initiated a change in the fish biocoenosis and abundance of individual species. The sampled riverine benthic fish fauna of the main channel, adapted to the habitat conditions of a free flowing Danube stretch, responded negatively to the HPP construction and operation with only few exceptions. This was shown clearly by decreasing CPUE values for many species. Only for *Gymnocephalus schraetser*, known to cope well with impoundments, the overall CPUE increased. Keeping in mind that populations naturally fluctuate to some extent and that studies like the one at hand can therefore only record a momentary status, the majority of species, especially those with a high flow velocity preference, show a stepwise negative trend. Already in the 1999/2000, i.e. one to two years after filling of the impoundment, some negative effects could be concluded from the CPUE values. In 2014, these effects were considerably enhanced.

On the other hand, number and quantity of indifferent fish species seemed to increase with the changes. A clear shift towards a more indifferent fish community could be observed in the investigated stretch. Furthermore, different species occurrences in the four sections of the sampling area could be recorded. Corresponding CPUE values and fish habitat conditions show a clear sectoral effect of the HPP on certain benthic species. Especially this Danube stretch's typical indicator species, *Barbus barbus*, decreased in abundance, as did the FFH species *Cottus gobio*, *Romanogobio albipinnatus* and *Zingel streber* (listed in Annex II and /or Annex V of the Habitat directive of the European Union (92/43/EEC)(European Commission, 1992). Furthermore, these species, along with *Gymnocephalus schraetser*, show a clear pattern of occurrence according to their habitat preferences. In 2014, they could only be recorded in the Head of Impoundment- and/or the Tailwater section of the HPP Freudenau. In contrast, the Transition Zone and Central Impoundment provide suitable habitats for the two neozoan Gobiidae species *Neogobius melanostums* and *Pontikola kessleri*, which feature particularly high CPUE values here. Apparently, these sections, most strongly altered by the HPP and featuring large riprap structures, provide ideal habitats for these two invasive species, especially for the clearly dominating *Neogobius melanostomus*.

Apart from the Gobiidae, these two sections feature remarkable CPUE values for *Gymnocephalus schraetser* and *Zingel zingel*. However, they are clearly lower than in the Head of Impoundment and Tailwater section. It can be assumed that rheophilic species' occurrence will be more or less restricted to the Head and Impoundment sections of the impoundment in the future, where species like *Barbus barbus*, *Romanogoboi albipinnatus* and *Zingel streber* form small rest populations (Jungwirth, et al., 2014). Especially *Zingel streber* and *Romanogobio albipinnatus* populations can be seen as vulnerable as they feature very low abundances. Furthermore, these populations are "trapped" in the area between the weir of HHP Greifenstein and the Impoundment of HPP Freudenau and isolated from the free flowing stretch downstream of HPP Freudenau, which further endangers their long-term survival.

In contrast, oligorheophilic and indifferent species while become more common in the Transition Zone and Central Impoundment. The Tailwater section clearly benefits from the free flowing Danube stretch east of Vienna, where the majority of native benthic fish species show the highest abundances in the sampling area. Additionally, an effect of invasive Gobiidae, which have been recorded in high abundances in this Danube stretch since 2002 approximately, on native benthic fish is to be assumed. Therefore, not only the habitat alteration by the HPP Freundau can be made responsible for many species' low CPUE values in 2014. While the two invasive Gobiidae species recorded in this study will likely remain dominant in this impounded Danube sections in the future, several new Gobiidae species showing already invasive potential downstream of Austria and might be added in future. Therefore, improvement of habitat quality as well as the management of invasive and native benthic fish fauna in the Austrian Danube in the next decade might be an upcoming challenge.

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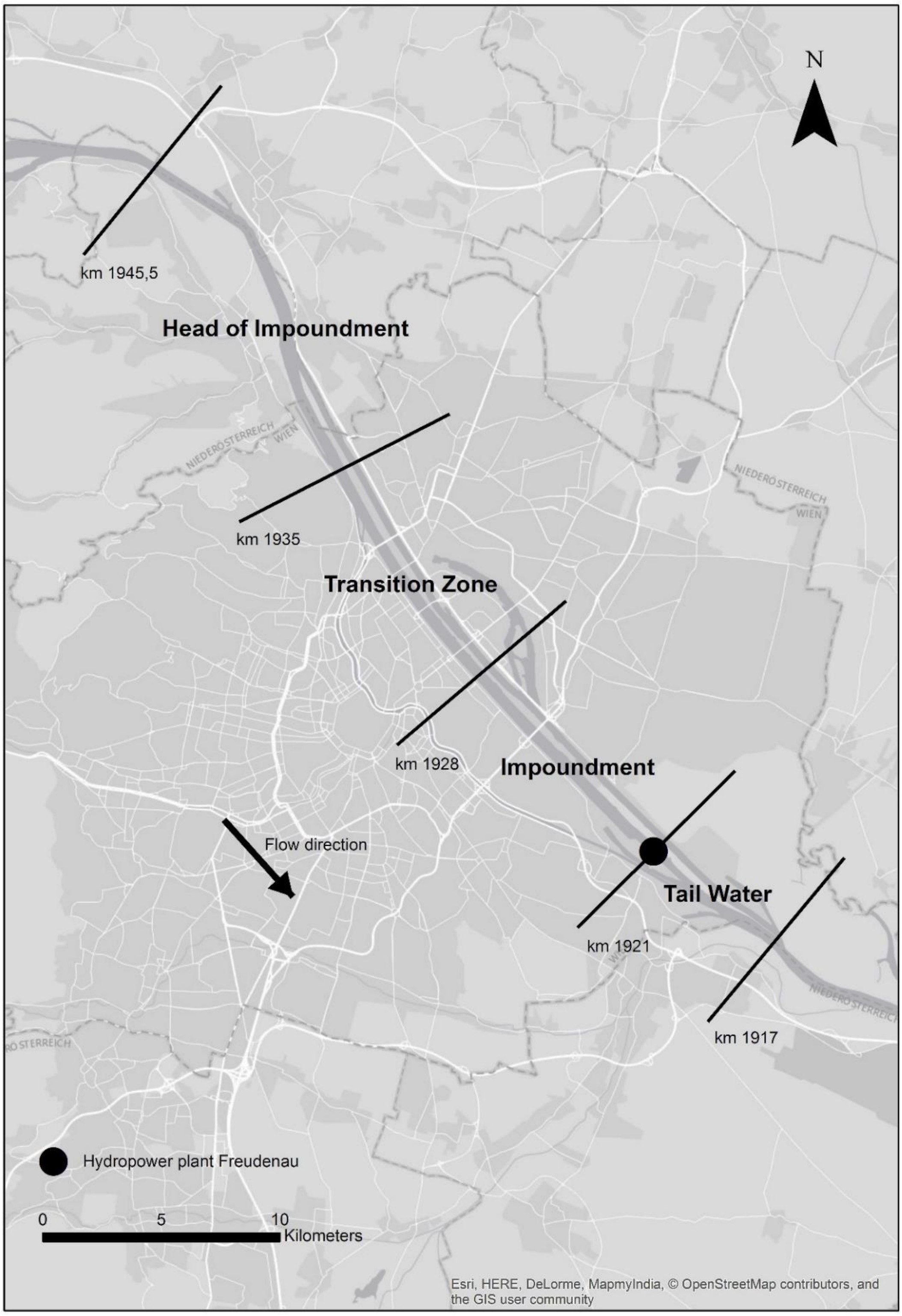
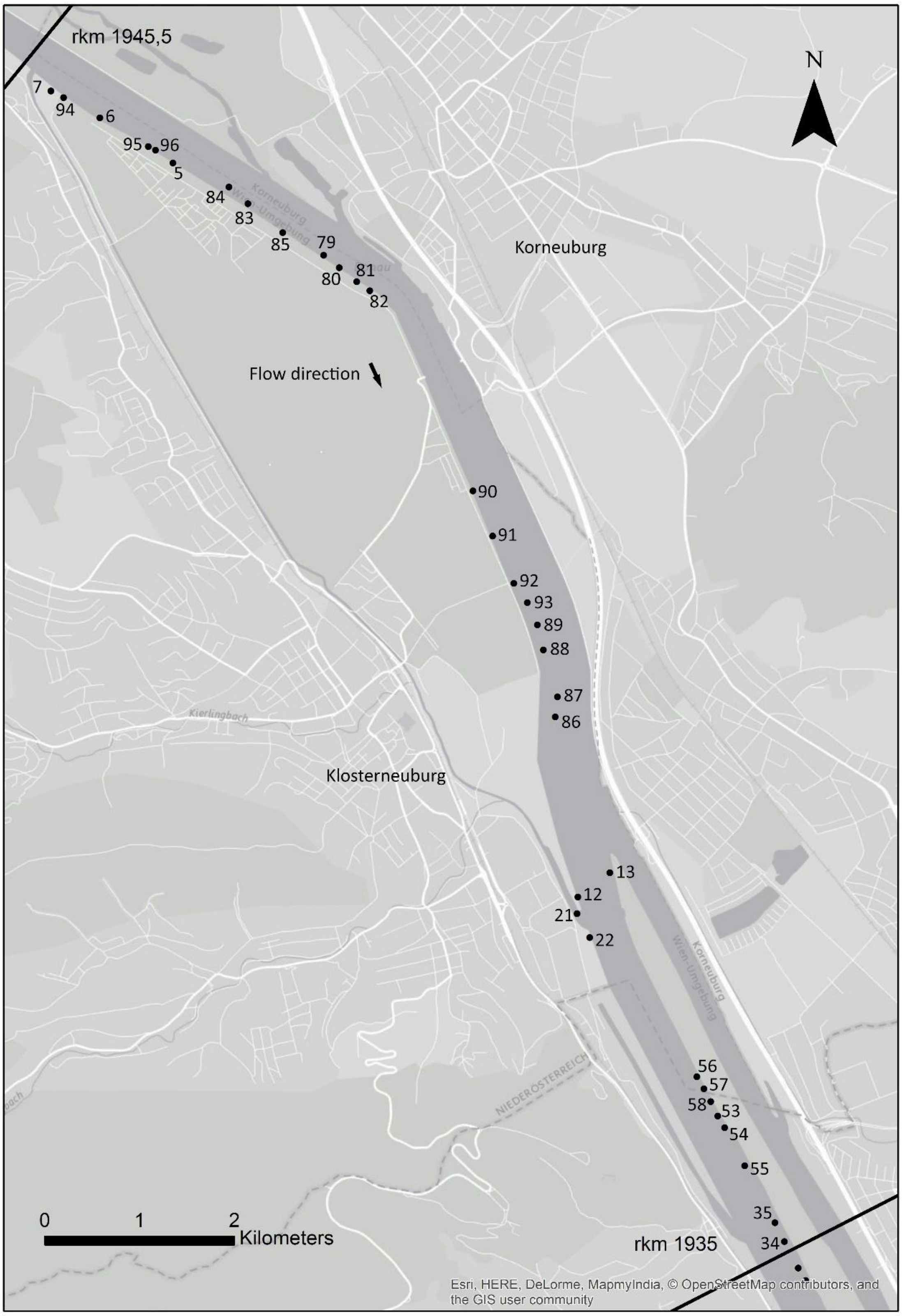
9 Appendix

9.1 Maps

9.1.1 Investigation area

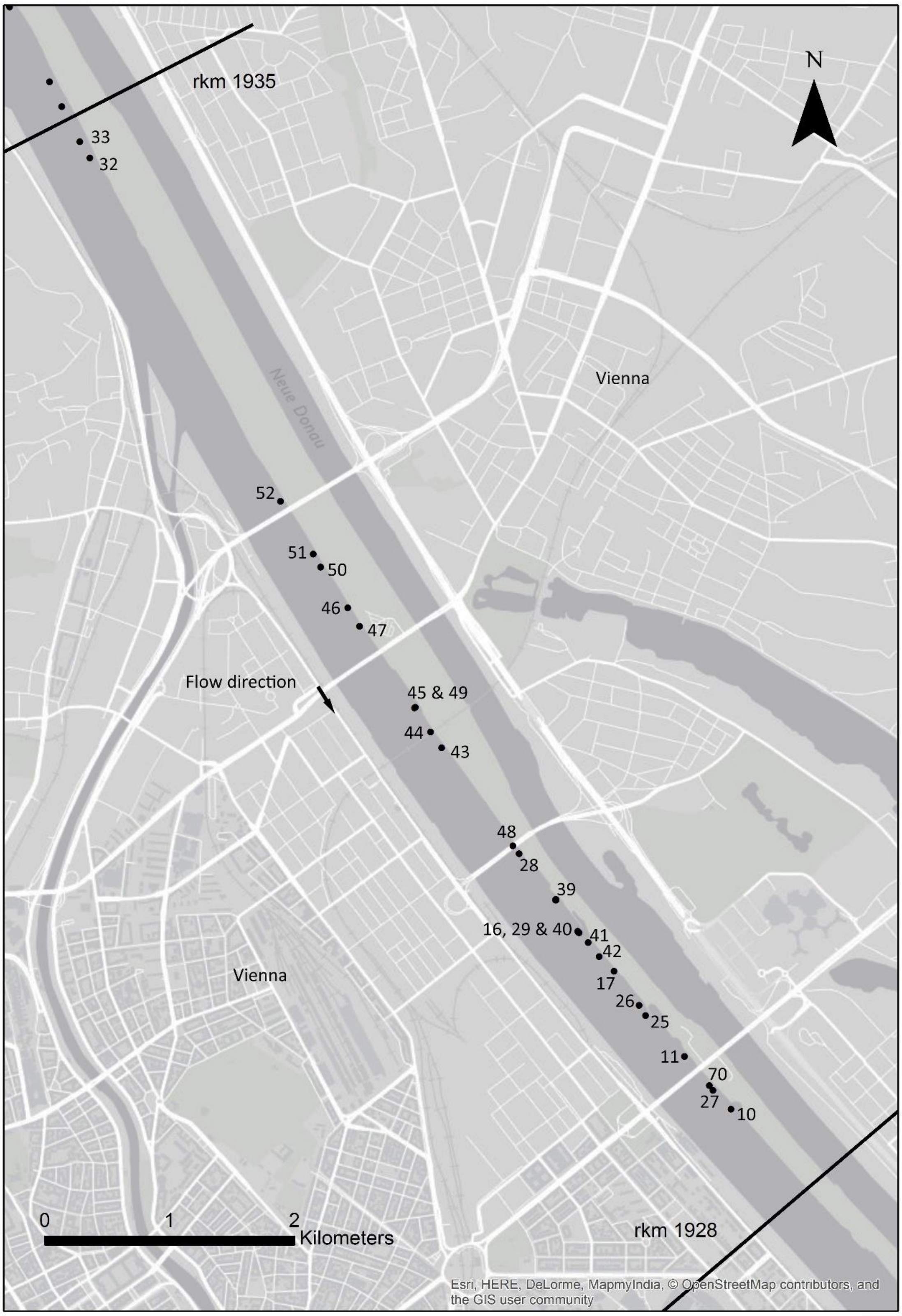


9.1.2 *Head of Impoundment*



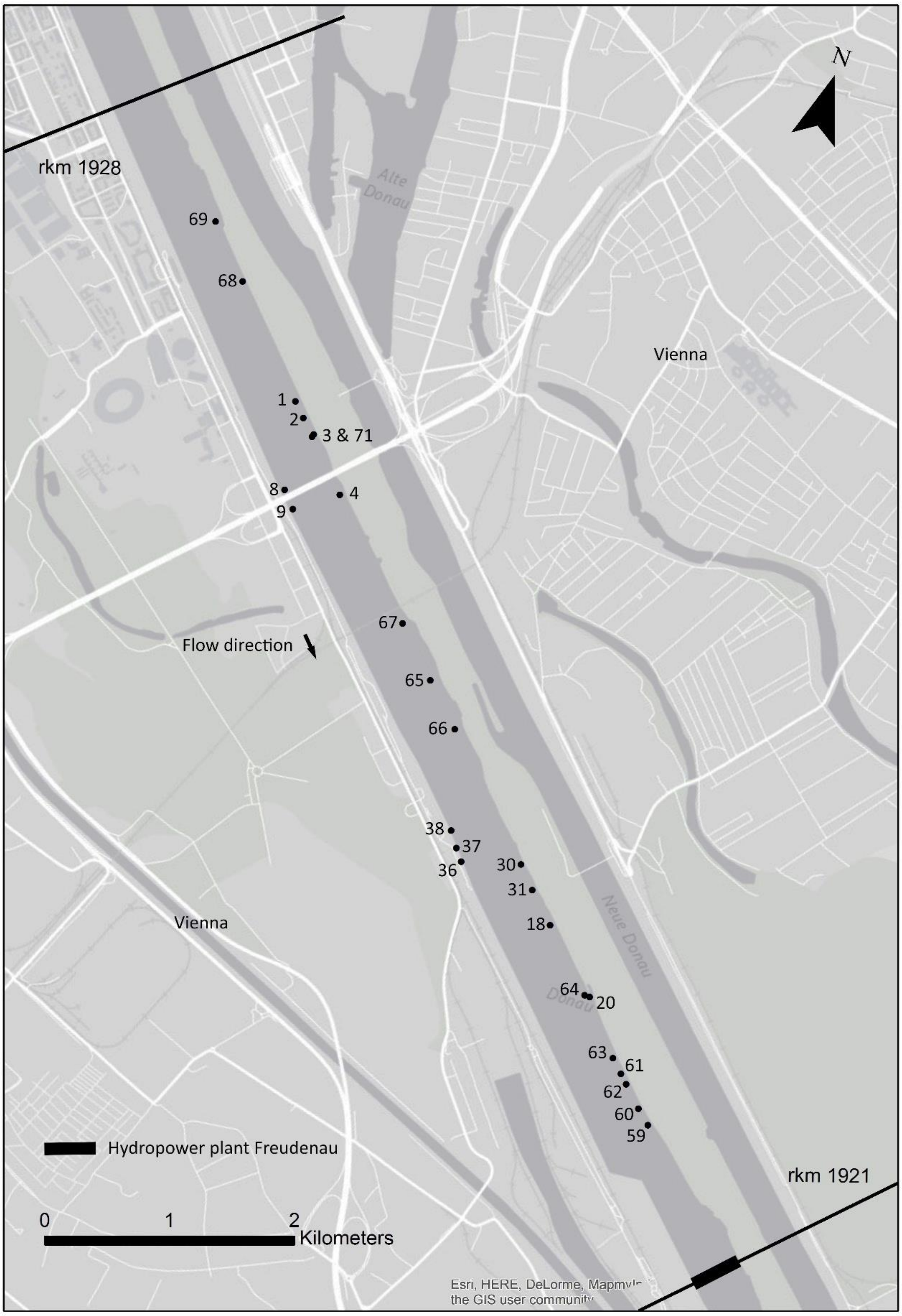
Longline ID	River kilometre	Comment
7	1945,20	17 hooks lost (not included in analysis)
94	1945,10	
6	1944,80	
95	1944,40	
96	1944,35	
5	1944,20	19 hooks lost (not included in analysis)
84	1943,80	
83	1943,60	
85	1943,30	
79	1942,98	
80	1942,80	
81	1942,60	19m of LL entangled in boat engine (not included in analysis)
82	1942,50	
90	1942,90	
91	1940,55	
92	1940,16	
93	1939,95	
89	1939,80	
88	1939,65	
87	1939,30	
86	1939,15	
13	1938,00	
12	1937,90	
21	1937,80	
22	1937,60	
56	1936,40	
57	1936,30	
58	1936,20	14m LL torn (not included in analysis)
53	1936,10	
54	1936,00	
55	1935,70	
35	1935,50	LL disorted for 50m (not included in analysis)
34	1935,10	
n = 33		

9.1.3 Transition Zone



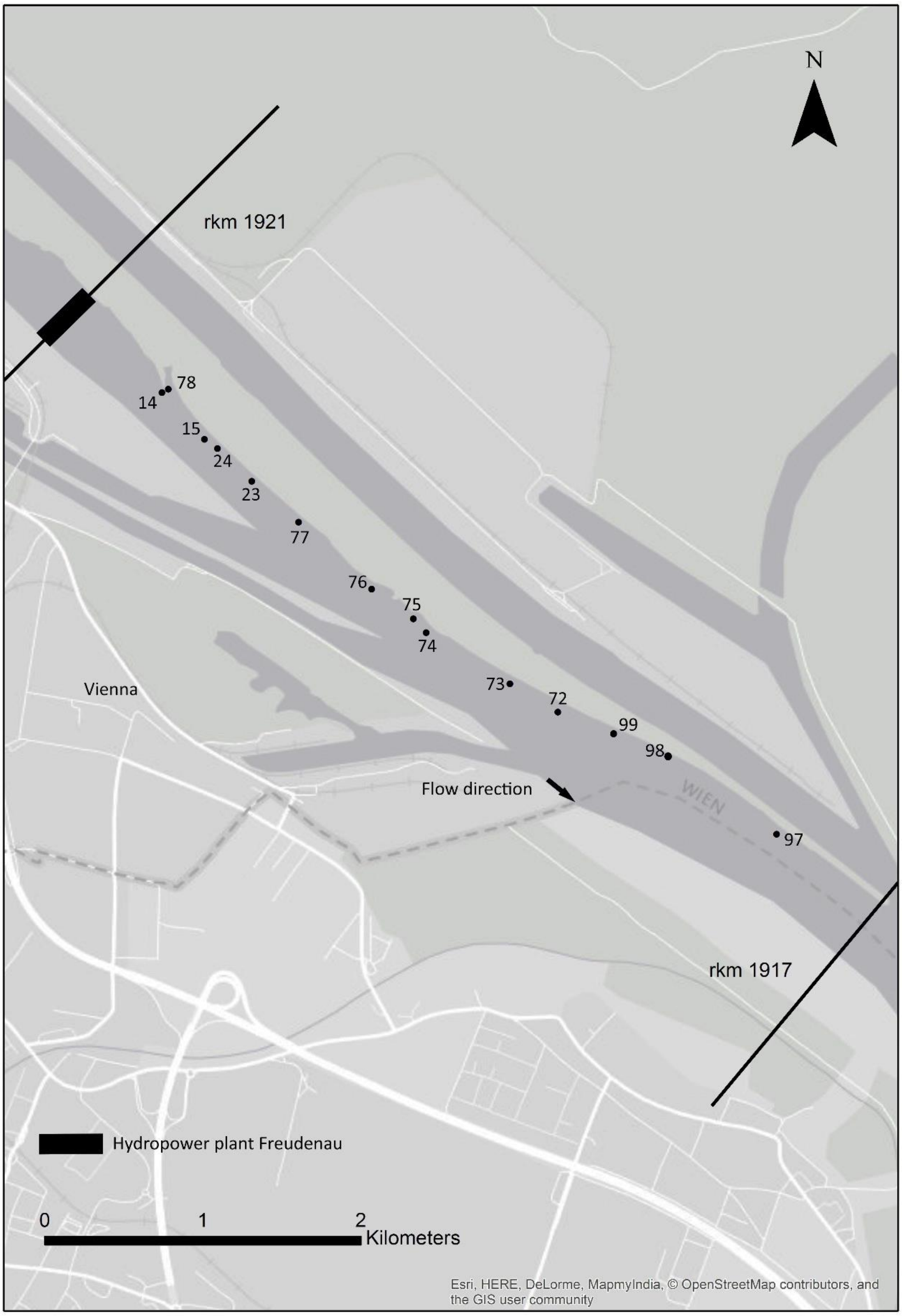
Longline ID	River kilometre	Comment
33	1934,90	
32	1934,80	LL entangled and torn in several parts (not included in analysis)
52	1932,70	
51	1932,35	
50	1932,30	
46	1932,00	
47	1931,90	
45	1931,35	
49	1931,35	Alburnus alburnus used as bait (not included in analysis)
44	1931,20	
43	1931,10	
48	1930,45	
28	1930,40	
39	1930,00	
16	1929,90	
29	1929,90	
40	1929,90	
41	1929,80	
42	1929,70	
17	1929,60	
26	1929,35	
25	1929,30	Baitfish shreds used as bait (not included in analysis)
11	1929,00	
70	1928,58	
27	1928,80	
10	1928,70	
n = 26		

9.1.4 Central Impoundment



Longline ID	River kilometre	Comment
69	1927,25	
68	1926,90	
1	1926,20	
2	1926,10	
3	1926,00	
71	1926,00	
8	1925,80	Hook losses during LL setting (in analyses)
9	1925,70	
4	1925,65	
67	1924,85	
65	1924,55	
66	1924,25	
38	1923,80	
37	1923,70	
36	1923,60	
30	1923,40	
31	1923,30	
18	1923,10	
19	1922,90	
64	1922,68	
20	1922,65	Baitfish shreds used as bait (excluded in analyses)
63	1922,30	
61	1922,15	
62	1922,20	
60	1922,00	
59	1921,90	
n = 26		

9.1.5 Tailwater



Longline ID	River kilometre	Comment
78	1920,50	
14	1920,50	
15	1920,27	
24	1920,20	
23	1920,00	
77	1919,70	
76	1919,30	
75	1919,10	10 m of LL entangled in boat engine (in analyses)
74	1919,00	
73	1918,60	
72	1918,35	
99	1918,00	
98	1917,80	
97	1917,30	
n = 14		

9.2 Protocol

Front side:

Protocol Project Freudenau 2014		
Editor:		
Date:		
Stretch number:		
Time	Set:	Haul in:
Rkm:		Section:
Position of LL	right bank	left bank
Weather conditions:		
Temperature:		
Water depth:	Buoy 1:	Buoy 2:
Distance to next bank:	Buoy 1:	Buoy 2:
Stretch lenght:		
Bank structure:		
Site plan:		

Rear side:

Nr.	Species	mm	g	Gastro.	Genetic.	Comment
1						
2						
3						
4						
5						
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9.3 Basic characteristics of caught fish species within the three investigation periods

Table 16: Basic characteristics of caught fish species within the three investigation periods based on Jungwirth et al., 2003 and Zauner & Eberstaller, 1999, translated from German and extended by Neogobius melanostomus

Fish species	Feeding guild	General flow velocity preference	Flow preferences at spawning ground	Structural preferences
Abramis brama	euryphag	indifferent	euryopar	without
Alburnus alburnus	euryphag	indifferent	euryopar	without
Ballerus sapa	benthivor	oligorheophil	rheopar	without
Barbus barbus	benthivor	rheophil	rheopar	minimal
Blicca bjoerkna	euryphag	indifferent	euryopar	minimal
Chondrostoma nasus	herbivor	rheophil	rheopar	minimal
Cottus gobio	benthivor	rheophil	rheopar	high
Gobio gobio	benthivor	rheophil	rheopar	minimal
Gymnocephalus baloni	benthivor	oligorheophil	limnopar	minimal
Gymnocephalus cernua	benthivor	indifferent	euryopar	minimal
Gymnocephalus schraetser	benthivor	oligorheophil	rheopar	minimal
Leuciscus aspius	piscivor	indifferent	euryopar	without
Leuciscus cephalus	euryphag	indifferent	euryopar	high
Leuciscus idus	euryphag	indifferent	euryopar	minimal
Leuciscus leuciscus	euryphag	indifferent	euryopar	minimal
Lota lota	benthivor	indifferent	euryopar	high
Neogobius melanostomus	benthivor	indifferent	euryopar	high
Pelecus cultratus	euryphag	indifferent	limnopar	without
Perca fluviatilis	piscivor	indifferent	euryopar	without
Ponticola kessleri	benthivor	indifferent	euryopar	high
Romanogobio albipinnatus	benthivor	rheophil	rheopar	minimal
Romanogobio uranoscopus	benthivor	rheophil	rheopar	minimal
Rutilus pigus	benthivor	rheophil	rheopar	minimal
Rutilus rutilus	euryphag	indifferent	euryopar	without
Salmo trutta fario	benthivor	rheophil	rheopar	high
Sander lucioperca	piscivor	indifferent	euryopar	minimal
Sander volgensis	piscivor	indifferent	euryopar	minimal
Silurus glanis	piscivor	indifferent	euryopar	high
Vimba vimba	benthivor	oligorheophil	rheopar	without
Zingel streber	benthivor	rheophil	rheopar	minimal
Zingel zingel	benthivor	oligorheophil	rheopar	minimal

9.4 1993/1994

Species	Section		Total abundance
	Head of Impoundment	Transition Zone	
Abramis brama	1	0	1
Alburnus alburnus	1	0	1
Ballerus sapa	6	6	12
Barbus barbus	74	17	91
Blicca bjoerkna	7	3	10
Chondrostoma nasus	2	0	2
Cottus gobio	4	13	17
Gobio gobio	1	0	1
Gymnocephalus baloni	6	0	6
Gymnocephalus cernua	0	0	0
Gymnocephalus schraetser	37	11	48
Leuciscus aspius	3	1	4
Leuciscus cephalus	3	1	4
Leuciscus idus	0	0	0
Leuciscus leuciscus	0	0	0
Lota lota	0	0	0
Neogobius melanostomus	0	0	0
Pelecus cultratus	0	0	0
Perca fluviatilis	8	3	11
Ponticola kessleri	0	0	0
Romanogobio albipinnatus	24	12	36
Romanogobio uranoscopus	4	0	4
Rutilus pigus	0	0	0
Rutilus rutilus	0	0	0
Salmo trutta fario	2	1	3
Sander lucioperca	3	2	5
Sander volgensis	2	0	2
Silurus glanis	0	0	0
Vimba vimba	19	11	30
Zingel streber	18	10	28
Zingel zingel	47	5	52
Total	272	96	368

9.5 1999/2000

Species	Section			Total abundance
	Head of Impoundment	Transition Zone	Central Impoundment	
Abramis brama	0	0	1	1
Alburnus alburnus	1	0	2	3
Ballerus sapa	1	0	0	1
Barbus barbus	7	6	5	18
Blicca bjoerkna	1	2	0	3
Chondrostoma nasus	0	0	0	0
Cottus gobio	7	8	6	21
Gobio gobio	0	0	0	0
Gymnocephalus baloni	6	5	4	15
Gymnocephalus cernua	0	2	0	2
Gymnocephalus schraetser	19	6	3	28
Leuciscus aspius	0	0	0	0
Leuciscus cephalus	6	1	3	10
Leuciscus idus	1	0	0	1
Leuciscus leuciscus	2	0	0	2
Lota lota	0	0	0	0
Neogobius melanostomus	0	0	0	0
Pelecus cultratus	0	0	1	1
Perca fluviatilis	13	21	4	38
Ponticola kessleri	12	4	1	17
Romanogobio albipinnatus	0	0	0	0
Romanogobio uranoscopus	0	0	0	0
Rutilus pigus	0	0	0	0
Rutilus rutilus	0	0	0	0
Salmo trutta fario	0	0	0	0
Sander lucioperca	0	0	0	0
Sander volgensis	1	0	0	1
Silurus glanis	0	1	0	1
Vimba vimba	2	0	1	3
Zingel streber	2	1	0	3
Zingel zingel	8	21	5	34
Total	89	78	36	203

9.6 Count of fish over all investigation periods

Species	Investigation period			Caught fish on longlines within the 3 periods
	1993-1994 [fished LL = 81]	1999-2000 [fished LL = 51]	2014-2014 [fished LL = 90]	
Abramis brama	1	1	1	3
Alburnus alburnus	1	3	0	4
Ballerus sapa	12	1	1	14
Barbus barbus	91	18	6	115
Blicca bjoerkna	10	3	7	20
Chondrostoma nasus	2	0	0	2
Cottus gobio	17	21	6	44
Gobio gobio	1	0	0	1
Gymnocephalus baloni	6	15	0	21
Gymnocephalus cernua	0	2	1	3
Gymnocephalus schraetser	48	28	77	153
Leuciscus aspius	4	0	0	4
Leuciscus cephalus	4	10	3	17
Leuciscus idus	0	1	2	3
Leuciscus leuciscus	0	2	0	2
Lota lota	0	0	1	1
Neogobius melanostomus	0	0	428	428
Pelecus cultratus	0	1	0	1
Perca fluviatilis	11	38	5	54
Ponticola kessleri	0	17	52	69
Romanogobio albipinnatus	36	0	2	38
Romanogobio uranoscopus	4	0	0	4
Rutilus pigus	0	0	4	4
Rutilus rutilus	0	0	3	3
Salmo trutta fario	3	0	0	3
Sander lucioperca	5	0	2	7
Sander volgensis	2	1	0	3
Silurus glanis	0	1	4	5
Vimba vimba	30	3	1	34
Zingel streber	28	3	9	40
Zingel zingel	52	34	41	127
Total	368	203	656	1227