



# *Fish Community Characterization of the Mura-Drava-Danube Region*

DTP3-308-2.3- lifeline MDD

D.T1.1.1 Fish population status report

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## **IMPRESSUM:**

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## HIGHLIGHTS AT A GLANCE

- 3 sections in the Mura, 6 in the Drava and 2 sites in Danube backwaters in Serbia sampled via electrofishing in Summer/Fall 2021.
- 10 sites in Mura and Drava sampled with eDNA
- In total, 54 fish species detected.
- 50 species recorded with electrofishing in the Mura (37), Drava (46) and Danube backwaters (27).
- 55 taxa (45 identified species and several groups of species not distinguishable on species level) recorded with eDNA sampling.
- At least 66 species are considered present in the TBR MDD based on integration of sampling results from the last 15 years.
- Detection of particularly rare or previously undetected species in the Mura (Danube salmon, balcanian barbel, bullhead, golden spined loach, minnow, monkey goby, etc.) and Drava (sterlet, Danube salmon, grayling, bullhead through eDNA sampling, catch of the racer goby).
- Vital populations of nase and barbel (typical riverine fish in Mura and Drava) assessed in most sections.
- Juvenile individuals of rheophilic species missing in sections affected by artificial flow fluctuations (below HPP Donja Dubrava).
- Longitudinal change of fish community well documented – significant decrease of rheophilic and increase of indifferent fish with increasing river length.
- Relatively low biomasses (~50-90 kg/ha) and abundances (1.000-3.000 Ind/ha) in all sections. Difficult sampling situation in some stretches have probably affected this result.
- High habitat variability calls for targeted and well-planned future investigations. Combination of eDNA and electrofishing recommended.
- High (seasonal/yearly) variability of fish cenosis suspected. Expressiveness of single samplings is limited.
- Ecological effects of hydropeaking in the Drava need to be investigated closer.
- Future investigation on migration behavior and migration distances of e.g. nase and barbel should be considered.
- Ecological importance of TBR MDD as biodiversity hotspot and unique river system confirmed.

## Contents

1	Introduction	3
1.1	State of knowledge and study aims	4
2	Methodology	6
2.1	Principle of electrofishing	7
2.1.1	Sampling equipment	8
2.2	Sampling strategy Mura and Drava	8
2.2.1	Fish handling and processing:	9
2.2.2	Calculation of stock characteristics	10
2.2.3	Environmental DNA (eDNA) sampling	11
2.3	Sampling in Danube-backwaters (Serbia)	14
2.4	Integration of previous sampling results	16
3	Results and Discussion	20
3.1	Mura and Drava	20
3.1.1	Hydrological situation	24
3.1.2	Section 1 – Mura – in Slovenia	26
3.1.3	Section 2 – Mura – Border-Mura Slovenia & Croatia	29
3.1.4	Section 3 – Mura – Border-Mura Croatia & Hungary	32
3.1.5	Section 4 – Confluence Mura-Drava	35
3.1.5.1	Drava above Mura-confluence (Section SD)	39
3.1.5.2	Residual flow stretch Drava (Section SR)	41
3.1.6	Section 5 – Drava – 25km downstream of Mura confluence	44
3.1.7	Section 6 – Drava – Border Drava Croatia & Hungary	47
3.1.8	Section 7 – Drava – downstream Donji Miholjac	50
3.2	Comparative Results	53
3.2.1	Selected Species	53
3.2.1.1	Nase – <i>Chondrostoma nasus</i>	53
3.2.1.2	Barbel – <i>Barbus barbus</i>	59
3.2.1.3	Chub – <i>Squalius cephalus</i>	64
3.2.1.4	Predatory fish species	65
3.2.1.5	Non-native fish species	67
3.2.2	Quantitative stock estimations	70
3.2.3	Comparisons on community level	75
3.2.3.1	Flow velocity preferences	75
3.2.3.2	Spawning habitat preferences	79
3.2.3.3	Habitat-structure preferences	80
3.3	Environmental DNA sampling	83
3.3.1	Species detection	83



3.3.2	Community composition and comparison with electrofishing	86
3.4	Danube	91
3.4.1	Pilot area Gornje Podunavlje	92
3.4.1.1	Physico-chemical parameters	92
3.4.1.2	Fish fauna of pilot area Gornje Podunavlje	92
3.4.2	Pilot area Karadorđevo	94
3.4.2.1	Physico-chemical parameters	94
3.4.2.2	Fish fauna of pilot area Karadorđevo	95
3.5	Previous fish population assessments	98
3.5.1	Analysis of species occurrence	99
3.5.1.1	Rare species	101
3.5.1.2	Non-native species	103
3.5.1.3	Nase and Barbel	104
3.5.2	Analysis of fish community structure	107
4	Conclusions & action recommendations	111
4.1	Current status of the fish fauna at a glance	111
4.2	Temporal dynamics of fish stocks	113
4.3	Sampling effectiveness	114
4.4	Effects of hydropower plants and -operation	116
4.5	Absence of predators – fisheries management	118
4.6	Presence of non-native species	119
4.7	Summary of threats for fish and conclusions	122
5	References	124
6	Appendix	127

# 1 Introduction

This report is the result of a study conducted within the DTP3-308-2.3 lifeline MDD, financed by the European Union's Interreg Danube Transnational Programme. The area analyzed and targeted by the present study (hereinafter called "target area") comprises river sections in the 5-country Biosphere Reserve Mura-Drava-Danube (TBR MDD, Figure 1), shared between Austria, Slovenia, Hungary, Croatia and Serbia. Spanning Austria, Slovenia, Hungary, Croatia and Serbia, the lower courses of the Drava and Mura Rivers and related sections of the Danube are among Europe's most ecologically important riverine areas. The three rivers form a "green belt" 700 kilometers long, connecting almost 1.000.000 hectares of highly valuable natural and cultural landscapes, including a chain of 13 individual protected areas and 3.000 km<sup>2</sup> of Natura2000 sites. This is the reason why, in 2009, the Prime Ministers of Croatia and Hungary signed a joint agreement to establish the Mura-Drava-Danube Transboundary Biosphere Reserve (TBR MDD) across both countries. Two years later, in 2011, Austria, Serbia and Slovenia joined this initiative. Together with Croatia and Hungary, the five respective ministers of environment agreed to establish the world's first five-country Biosphere reserve and Europe's largest river protected area. Step by step the TBR MDD was realized: Hungary and Croatia (in 2012), Serbia (in 2017), Slovenia (in 2018) and Austria (2019) achieved UNESCO designation. The pentilateral designation was submitted in 2020 and designation finally achieved in September 2021.

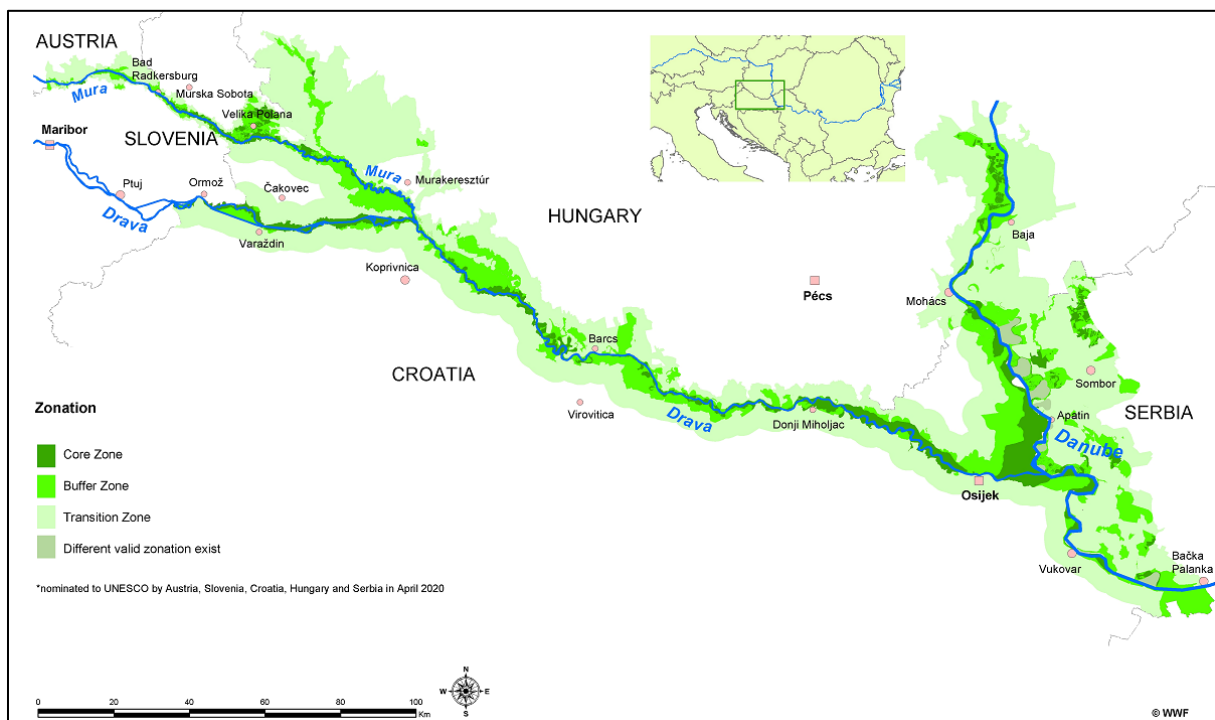


Figure 1. Map of the 5-country Biosphere Reserve Mura-Drava-Danube according to UNESCO designation in September 2021 (WWF Austria)

The project's work package "*Establishing the scientific knowledge base*" (WP T1) aims to investigate vertical, lateral and longitudinal connectivity within the Mura-Drava-Danube bio-corridor. All studies' results and the overlaid GIS data collected therefore build the basis for a synthesis report on biotic indicators and abiotic framework conditions that will contribute to the long-term conservation and restoration goals within the TBR MDD. The facts and results presented in this project therefore come from a first ever such scientific assessment, which was conducted between July 2020 and March 2022, setting the ground for future decision-making on 5-country level on river management and restoration. Whereas such activities and knowledge in each of the countries involved in the TBR MDD partly exist, this was the first time methods and sampling strategies were harmonized for the monitoring of biotic elements and the abiotic framework conditions for the Mura-Drava-Danube river corridor.

Information on the current status of the fish community in the TBR MDD is a major contribution to the above-mentioned knowledge base. For this purpose, the University of Natural Resources and Life Sciences, Vienna (BOKU), coordinated the "fish population status report" within the lifelineMDD project. The overall aim of this study was to analyze the status quo of the fish fauna in the sampled sections and to give an overview on potential issues/threats acting on the faunistic composition that need to be considered for future conservation and restoration strategies.

This report comprises results collected during a field sampling campaign in summer of 2021. Field sampling in different sections of the Mura and Drava in Slovenia, Croatia and Hungary was conducted by BOKU (electrofishing and eDNA sampling). INCVP (the Institute of Nature Conservation of Vojvodina Province, acting as project partner in lifelineMDD) contributed through coordination of an electrofishing campaign in Serbia, where Danube floodplain-waters were analyzed at two different locations. Selected results from former/earlier investigations and monitoring activities in the TBR MDD were integrated into this report when feasible.

## **1.1 State of knowledge and study aims**

Due to their longevity and sensitivity to different stressors in aquatic systems, the occurrence, abundance and structure of fish populations is a very good indicator for the ecological integrity and functioning of a river or a specific river stretch.

Although "fish-assessments" have been conducted throughout various occasions and various areas in the past, a comprehensive effort to characterize the fish community within these rivers within one coordinated sampling effort has not been performed yet. Nevertheless, the authors of this study have attempted to integrate existing knowledge on fish stocks as best as possible and analyzed selected publications and reports for this study. An overview on integrated studies is given in chapters 2.4 and 3.4. It is out of question that probably a higher number of publications and samplings could have been

integrated, especially when considering grey literature and publications available exclusively in Slovenian, Croatian, Hungarian or Serbian language. A detailed literature analysis was not undertaken within this project.

The sampling approach chosen for this study was an electrofishing survey using the “strip-fishing method” to characterize and quantify the fish stocks in selected stretches of the Mura and Drava. The method is based on a publication by Schmutz et al. (2001) and uses stratified random electrofishing in sampling strips within the investigated sections. This method is used as the standardized approach for fish sampling in Austria (assessing the fish-ecological status for the European Water Framework Directive) and can be recommended for medium sized to larger rivers. Limitations of this method apply when the river dimensions exceed the applicability of the electrofishing device. Electrofishing in the Mura and Drava had the purpose to gain knowledge on the fish community structure and enable a comparison of the fish communities between the sampled sections (longitudinal gradient from the Slovenian Mura to the Croatian Drava). Additionally, at all sampling sections, samples of environmental DNA (eDNA) were taken. The results were used to compare and supplement the electrofishing results and to gain a more comprehensive picture on species occurrence (especially potential occurrence of rarer species that are difficult to detect with electrofishing).

In the Serbian Danube backwaters, an electrofishing survey was coordinated by the project partner INCVP to characterize the fish community in water bodies not directly connected to the main channel (lateral connectivity). Focus of this investigation was the description of the lateral zonation of the fish community at two exemplary locations. The sampling in Serbia resulted in a separate report (provided as annex to this study) – selected results were incorporated into this report as well to get a more holistic picture.

Overall, the aims of this study can be summarized as following:

- Assessment of the number of currently occurring species in each sampling stretch and for the TBR MDD overall.
- Assessing the community composition (species dominance).
- Assessing the population sizes of most relevant riverine fish species.
- Identification of knowledge gaps that should be addressed in future surveys.
- Identification and description of longitudinal changes of the fish community.
- Identification of potential threats for the fish community and the potential to mitigate adverse effects.

## 2 Methodology

The aim of the study was to enable well-founded statements to be made on the condition of the fish stocks in the investigated stretches. By means of electrofishing, quantitative (standardized fish density & fish biomass) as well as semi-quantitative and qualitative parameters (relative fish frequencies, number of species, age structures, differences in community structure, etc.) were collected in the Mura and Drava as well as in two Danube backwater-systems. Results from these field surveys present the core of this report. Additional information was derived from eDNA analysis (only conducted in Mura and Drava) and the integration of pre-existing information on fish in the TBR MDD (selected previous fish surveys or monitoring results).

Fish population surveys in large rivers such as the Mura, Drava and Danube in the TBR MDD are methodologically difficult due to large spatial and temporal differences in abiotic characteristics (high habitat variability generally requires higher sampling intensity than rivers/sections with a homogenous habitat distribution) and due to a relatively large species inventory. Depending on their species-specific requirements, fish inhabit different habitat types within a rivesystem. In addition, many species shift between different habitats during their lifecycle (e.g. different habitats for spawning, juveniles and adults).

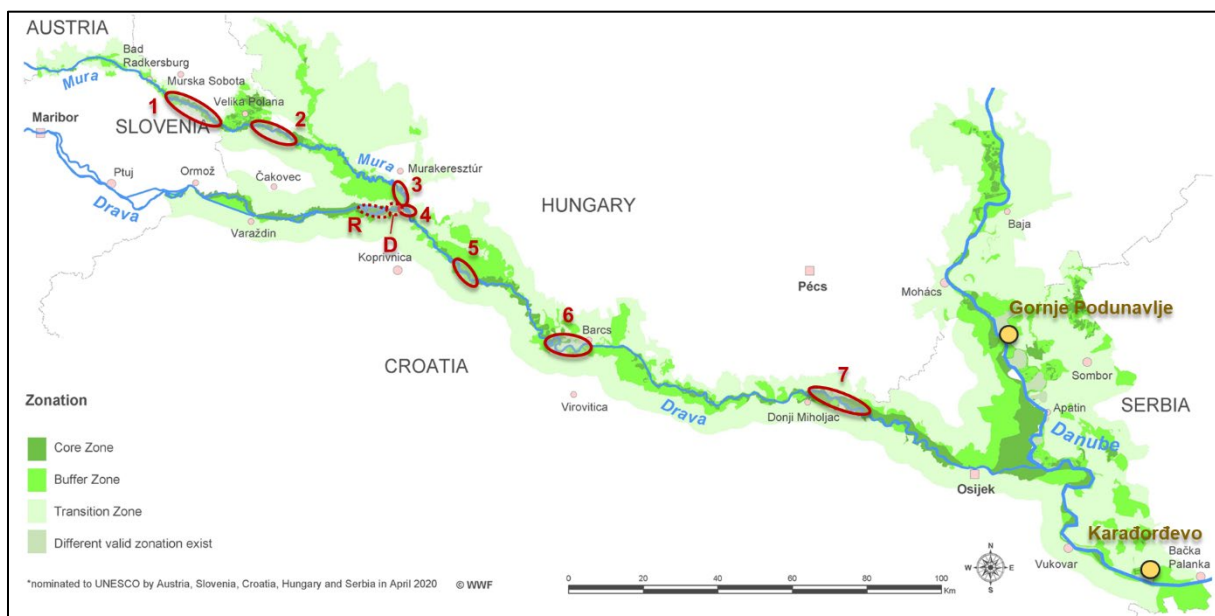


Figure 2: Distribution of sampled sections in Mura and Drava (red, samples conducted by BOKU) and yellow (sampling in Serbian Danube backwaters, conducted by INCVP). Sections 1 to 7 describe the longitudinal gradient in the Mura and Drava rivers. Sections "R" (residual flow stretch of HPP Donja Dubrava) and "D" (section below the HPP) where sampled additionally to gain insights in potential effects of hydropower operation.

To assess the fish community currently inhabiting the Mura and Drava, eight different sections along these rivers were selected, depicting the longitudinal change of the fish community within these rivers (Figure 1). The selection was based on preexisting



information on the overall habitat quality within the sections (mainly derived from the morphological quality). All sections were sampled in July 2021 with electrofishing boats applying a stratified-random-sampling approach (“strip-fishing method”, Schmutz et al., 2001). Additionally, in the sampled sections of Mura and Drava, eDNA samples were collected. Sampling in the Danube backwaters in Serbia consisted of two electrofishing sampling rounds (CPUE fishing at two different Danube discharge-levels) at two locations (“pilot area”). Three sites were selected in each pilot area with different connectivity/distance to the Danube main channel.

## 2.1 Principle of electrofishing

In running waters, electrofishing is established worldwide as a standard method for fish stock surveys. It is based on the principle that fish react (due to a response of their nervous system) to an electrical field established in the water with the electrofishing device. Fish within a certain range of the field will actively orient themselves towards the positive pole (anode) and swim towards it. This phenomenon is called “galvanotaxis”. When a fish reaches a certain proximity to the anode, it becomes immobilized by muscle paralysis (“galvanonarcosis”) and can be caught easily using a dip net. Details of these principles of electrofishing have been described for example by Cowx & Lamarque (1990).

Electrofishing in the Mura and Drava was conducted using a gasoline-powered generator (fishing unit) that produces electric energy (direct current) used to establish the electric field in the water via a submerged positive and negative pole. The generator, depending on size, power output and target area, can be either deployed on a boat, or used as stationary or backpack-mounted units. For the electrofishing within the current study, boat mounted generators were used. The anode of the boat units consists either of a hand held pole with a metal ring (“small” fishing boat) or a metal rake (horizontal steel cable with several vertical, immersed, wire elements; “large” fishing boat). The cathode (metal wire) hangs into the water in the back of the boat. To establish a closed electric field, both the anode and cathode need to be submerged. The current is turned on using a dead man’s switch that is activated with a foot-pedal and operated by a person at the front of the boat. For safety reasons, upon releasing/stepping down from the switch, the electric field is cut off.

The area around the boat in which fish are attracted to the electric field depends on a number of factors: the power of the generator, the conductivity in the water, and water temperature play an important role. Additionally, some species react stronger than others (e.g. species of the family of Percids) and there is a clear size-dependent reaction. Larger fish are more easily attracted to the field, however they are also stronger swimmers and can escape quicker from the vicinity of the boat. Overall, the area in which fish can effectively be caught is estimated to be 6 meters around the anode for the larger boat, and 2 meters around the anode for the smaller boat.

## 2.1.1 Sampling equipment

The fishing boats are adapted rubber boats for electrofishing (5m and 4m, respectively; Figure 3). The large boat is used to sample habitats within the main channel (water depths usually >50cm) and is operated by a team of at least 4 people (2 people with dip nets, one person to empty the nets and one navigator/driver). The smaller boat is used to sample habitats along the shoreline, smaller scaled structures or narrow sidearms. The crew of the small boat consists of three persons: a boat navigator, a fishing-pole (anode) operator and a dip net operator.

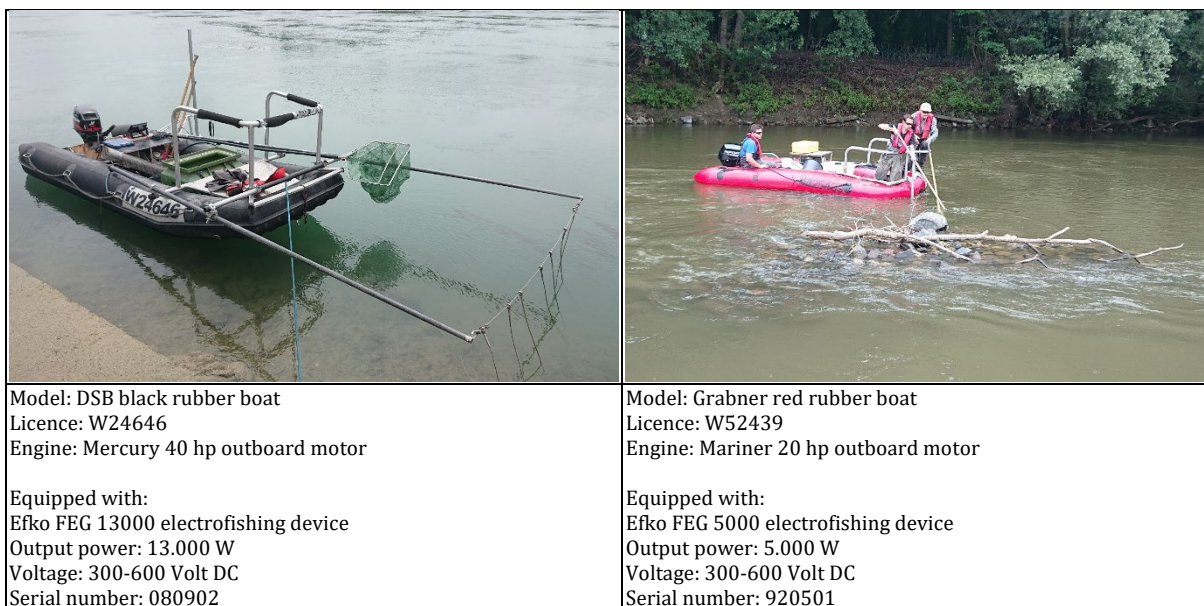


Figure 3: Used electrofishing boats during sampling in the Mura and Drava.

## 2.2 Sampling strategy Mura and Drava

The applied method of electrofishing is based on the standardized fish monitoring procedure that has been established in Austria for the purpose of Water Framework Directive monitoring and reporting. A guideline on electrofishing in Austrian streams and rivers has been published (BMLRT, 2019), that enables the calculation of a standard metric (Fish-Index-Austria; FIA) to assess the fish-ecological status of a water body. The basis for assessing the FIA is the comparison of current fish stock criteria with predefined reference conditions. All waterbodies in Austria are categorized into different fish regions according to their biogeographical setting, stream size, altitude, etc. Hence, a reference fish-cenosis is defined for each waterbody. Since this categorization is lacking for the Mura and Drava in Slovenia, Croatia and Hungary, the calculation of the fish-ecological status according to the Austrian standard method (in the sense of the Water Framework Directive) was not feasible.

However, the assessment of the current fish stocks within the Mura and Drava is based on the same principles described in the Austrian guideline. Whereas in small streams,

electrofishing with backpack generators and covering the full river width is applied (calculation of fish stock size after Seber & LeCren, 1967 or De Lury, 1947), in medium sized and large rivers, electrofishing by boat is conducted by sampling representative “strips” within the area of interest (sampling section). The latter method, which was also applied at the Mura and Drava, is called the “strip-fishing method” (Schmutz et al., 2001). It follows a stratified-random-sampling approach. The single fishing-strips (subsamples) are spatially defined areas within more or less uniform habitat types. The selection and location of the strips must be done in such a way that the habitat types present in the section are covered as representatively as possible. In theory, each existing habitat type within the defined section shall be sampled at least three times.

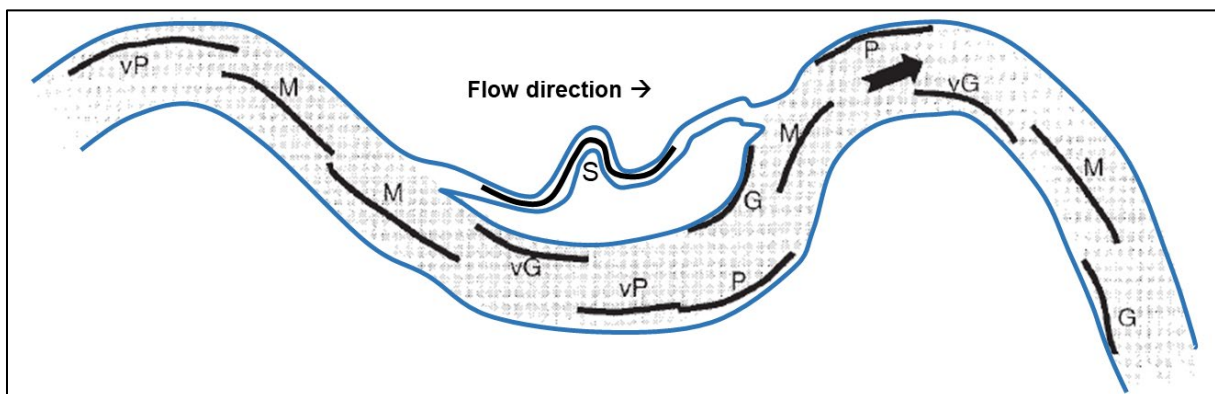


Figure 4: Conceptual example of fishing strips (dark lines) within a river section. Letters (M, P, G, etc.) represent categories of sampled habitat types (riffle, run, pool, etc.) and/or river units (shoreline, middle sections, side arms, etc.).

The length of the individual strips is primarily selected based on the habitat uniformity and usually ranging from 50-300 m. Starting- and endpoints of each strip are marked with GPS points. The strip width is determined based on the structure being fished and the anode's area of effect (usually 6m with the large boat, 2m with the smaller boat). The duration of fishing one strip usually takes between 2 and 10 minutes. Each individual strip can later be assigned to one of the habitat types occurring in the section and thus a standardized value of fish abundance (and fish biomass) for each habitat type can be calculated.

### 2.2.1 Fish handling and processing:

During an electrofishing run, the people operating the dip nets on the boat try to catch every fish that gets close to the anode and/or narcotized. Caught fish are immediately transferred to a large bucket filled with water. During each fishing run, the amount of fish that were observed/seen but not caught with the net, shall be monitored by all people on the boat. The relative amount of caught to uncaught fish (catch estimate, expressed as percentage for each individual) is later noted in the written protocol and used in further calculations. Two examples shall explain this principle:

- a) Seven specimen of nase were caught, and an additional three specimen were seen but not caught. → catch estimate amounts to 70% (for each caught nase); the three additional fish would be taken into account for the further analysis.
- b) A large amount of small sized fish of silver color is observed during sampling. Only 20% (=catch estimate) of the observed fish were caught. The caught fish in the bucket are later identified and each individual will be attributed with the catch estimate of 20%.

After fishing one strip (approx. 10 min.), a handwritten protocol is filled with information on the sampling strip and each individual fish caught. The protocol used during the sampling in Mura and Drava is provided in the appendix. Each fish is taken out of the bucket to determine the species, the total length, (optionally) total weight and any possible peculiarities that may be visible. The whole fish handling process usually takes no longer than 10 seconds per individual and is performed directly over the water-filled bucket to ensure the safety of the fish. Fish that have been protocolled will be released back into the river immediately. When performed correctly and carefully, the process of catching and handling does not harm the fish and mortality/injuries can be ruled out.



*Figure 5: left: Water tank used to keep caught fish during a fishing run; right: Measuring caught fish above the bucket and in proximity of the water for quick release after handling.*

## **2.2.2 Calculation of stock characteristics**

On species level, the age structure is a critical factor in assessing the health of a population. Therefore, plots displaying the length and abundance of individuals are produced (length-frequency graphs). On a community/section level, the species structure, total number of species, total fish abundance, amongst other factors, are important parameters. Furthermore, the fish community within a fished section can be characterized based on the catch numbers and catch biomass for each fishing strip within this section. Frequently used criteria in fish ecology are the number of individuals (fish density), and the biomass (fish weight) of fish present in the sampling unit. Both metrics can be indicated as absolute values (total catch per strip or per section), or standardized based on e.g. the strip-area



(individuals per hectare of water surface area), the fished length (individuals per 100 meters of fished strip length) or the minutes fished (individuals per 10 minutes). Within the assessment of this project, a standardization based on the fished area (individuals and biomass per hectare; Ind/ha; kg/ha) was conducted because it accounts for different boat sizes (effective width of the fishing gear). This enables the comparison of different sections or also potential future investigations.

According to the strip-fishing method, quantitative population estimates (Ind/ha, kg/ha) are yielded through weighting the number of caught individuals and biomass by the corresponding strip area and the “representativeness” of the habitat type (Schmutz et al., 2001). Thus, having information on the overall distribution of habitat types within a section is an important part of the calculation. This estimation can be derived from habitat mapping/visual estimation in the field and/or using aerial photography and orthophotos. Furthermore, each habitat type present in the sampling section should be sampled at least three times to account for the variability within the habitat types.

Within the scope of this project, a precise estimation on the habitat distribution could not be conducted. The reasons for this being that the investigated sections (respectively the Mura and Drava within the TBR MDD in general) display a high habitat diversity. Furthermore, the riverine habitats are in many parts not limited to the main channel, but a variety of sidearms, backwaters and oxbows exists, that are also used (to different extent) by the fish community. Due to the habitat heterogeneity and high total length of the sections (~10-20 km), an estimation of the habitat diversity during sampling could not be made. Additionally, the distribution of shoreline habitats within the main channel can only be assessed during low flow periods (better visibility of structures). Habitats in the river center are also underrepresented in the samples because water depth and water turbidity limited the ability to sample these areas adequately. A weighting process based on the representativeness of the habitat type was therefore skipped. Also, due to the high habitat variability, the number of sampling strips was considered too low to fulfil all requirements of standardized sampling approach (minimum of three strips per habitat type). These limitations need to be considered when interpreting the presented results on fish density (Ind/ha) and biomass (kg/ha). Both values should be regarded as approximations rather than universally valid.

### **2.2.3 Environmental DNA (eDNA) sampling**

Due to challenges and limitations of “traditional” fish sampling techniques like net- or electrofishing and enhanced by methodological progresses, environmental DNA (eDNA) sampling has become more widely applied in aquatic/riverine ecology in recent years. Electrofishing is often limited to littoral zones and/or relatively shallow habitats, which makes sampling in large rivers difficult. Net fishing on the other hand only allows sampling in slow flowing or stagnant areas making it spatially limited.



With the approach of sampling eDNA, water samples are used to identify genetic material of species/specimen that have been recently present at the sampling site. The collected genetic material consists of intracellular and extracellular DNA (skin cells, intestinal cells, scales, etc.). The theory and principles of eDNA are described by e.g. Taberlet et al., 2012. Recently, the method has been widely used in larger rivers to identify fish communities and/or to detect particularly rare species that are hard to record with traditional methods (Pont et al. 2018; Pont et al., 2022; Meulenbroek et al., 2022). Besides the relatively easy and cheap applicability, it has been pointed out that eDNA sampling is non-invasive and enables species detection without the need to capture individual specimens.

The eDNA sampling in the Mura and Drava was conducted to supplement the results from electrofishing. Since electrofishing was performed on only one day per section covering a relatively long distance (~10km), eDNA samples would potentially reveal additional species present in the sections. Furthermore, the relative species shares were to be compared between electrofishing and eDNA sampling.

Samples were taken at 10 different locations (Figure 6). Sections S1 and S5 were sampled at both up- and downstream ends. This was initially intended for all sites, but was not feasible because the relatively high time demand (~45 minutes for one sample) and the necessity to perform electrofishing.

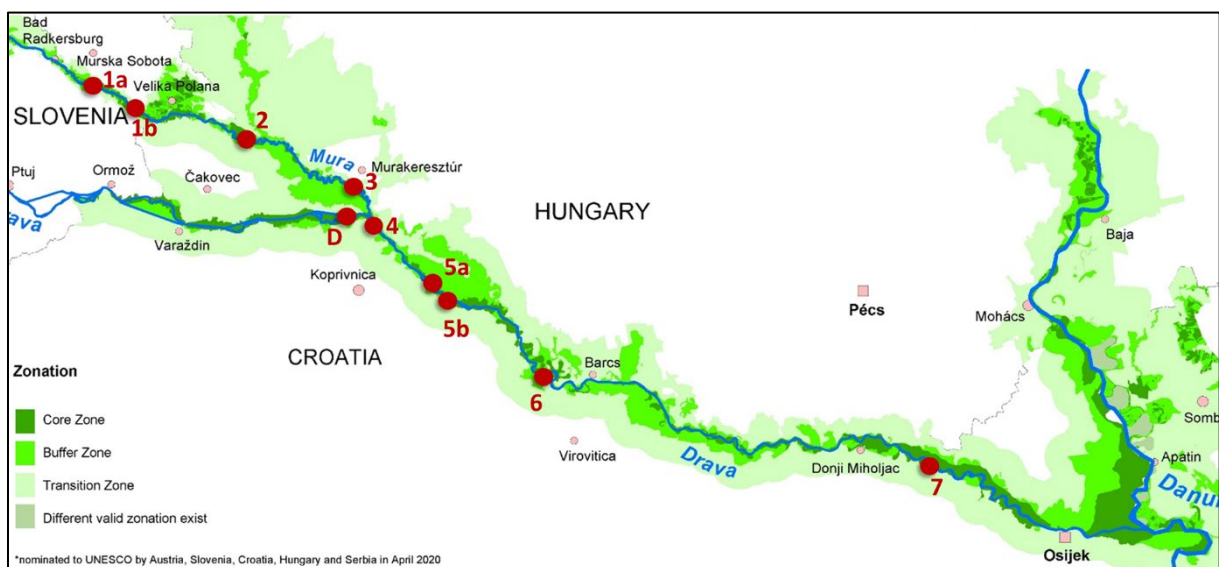


Figure 6: Location of eDNA sampling sites in Mura and Drava. Sections S1 and S5 were sampled at both up- and downstream section ends. Sample in section SD was taken below the confluence of the residual water (SR) below HPP Donja Dubrava.

The sampling equipment was mounted on the electrofishing boat. Water samples were collected using a peristaltic pump mounted to a regular cordless driver-drill. Sampling kits including sterile tubing and DNA filters (VigiDNA 0.45 µm crossflow filtration capsule) were acquired from SPYGEN. Depending on the clogging speed of the filter, the mean water volume filtered for one sample was 28 liters (20-42) and duration of filtering was 29 min. (18-45). To prevent DNA contamination from the fishing boat, the sampling tube is always oriented in upstream direction and inserted into the water in front of the

boat. Throughout the filtering cycle, the boat is navigated between the shorelines on one lateral transect to ensure homogenous sampling. At the end of filtration, the filter capsule is filled with conservation buffer (CL1, SPYGEN) to prevent eDNA degradation. The filters were kept throughout the field trip and later on sent to SPYGEN in France for further laboratory processing and analysis.



*Figure 7: eDNA sampling in the Drava. Water is filtered through the tubes using the pump mounted on the driver-drill. The filter (above the bucket) collects the genetic material.*

DNA extraction, amplification, high-throughput sequencing and bioinformatic analysis were performed by SPYGEN following the protocol described in Pont et al. (2018). Twelve PCR replicates were performed per sample. To monitor possible contaminants, negative extraction controls and negative PCR controls (ultrapure water) were amplified and sequenced in parallel to the samples.

For the current study, three possible genetic reference datasets were used. One from a sampling conducted throughout the Danube catchment in 2019/2020 by BOKU IHG (JDS4; Meulenbroek et al. 2022; Pont et al., 2022). One from the SPYGEN dataset and one from the EMBL GenBank.

The returned results from the laboratory include the number of positive replicates (out of 12 possible) and the number of sequences per species and sampling site. The number of DNA sequences can be used as an indicator for relative species share/abundance. Since some species/groups show no differentiation of haplotypes, it is impossible to distinguish them to species level.

## 2.3 Sampling in Danube-backwaters (Serbia)

Sampling in Serbia was coordinated by INCVP. A team from the University of Novi Sad, Faculty of Sciences, Department of Biology and Ecology conducted the electrofishing and wrote a separate report. The produced results and text have been copied to this document and partly aggregated or text-passages slightly adapted. The full report of the Serbian sampling effort is provided as attachment to this report (Bajić & Miljanović, 2021).

The scope of the study in Serbia was:

- Collection of data on the fish fauna in two pilot areas: determining the abundance, biomass and population structure for all caught species based on catches per unit of effort (CPUE).
- Comparison of the impact of different distances from the main channel of the Danube and between the pilot areas themselves.
- Comparison of sampled mesohabitat-types (based on species structure, relative and total abundance, biomass, age structure, presence / absence of individual species) for both pilot areas.

Two floodplain areas along the Danube in Serbia were selected, namely the “Gornje Podunavlje” (part of protected area Gornje Podunavlje) and “Bukinski rit” (part of protected area Karađorđevo).

The “Special Nature Reserve” Gornje Podunavlje received this status in 2001 and covers an area of 19.648 hectares, of which over 4.700 ha are water surfaces (two thirds old Danube sidearms and backwaters, whereas one third of the water surface is represented by the Danube main channel). It is located in the northwestern part of Bačka on the Danube's left bank between river km 1.367 to 1.433. On the north side, it is bordered by the state border with Hungary.

The Special Nature Reserve Karađorđevo was protected in 1997. The preserved area is an extended marsh complex, which is mostly located in the flood zone of the Danube (in its middle course through Serbia). It spreads in the southwestern part of Bačka, on the territory of the municipalities of Bac and Backa Palanka. The “Bukinski rit” is located in the alluvial floodplain along the left bank of the Danube, from river km 1.308 to 1.315.

Within each pilot area, three sampling sites (“localities”) were selected. The locations were chosen at different distance from the main course of the Danube, ie that the degree of connection with the Danube was at a different level. Within Gornje Podunavlje, the location closest to the Danube was Sakajtaš, in the middle distance was Mrtva Baračka, while the farthest was the Bajski kanal (Figure 6). Within the pilot area Karađorđevo, the nearest location was Dunavac, in the middle distance was Lovrenac-Račva and the farthest was Lovrenac (Figure 6).



All locations within Karadorđevo are located in the zone of active flooding, i.e. they are located between the flood dyke and the main course of the Danube, while within Gornje Podunavlje, this is the case only for the locality Sakajtaš.



Figure 8: Sampling localities within the areas of Gornje Podunavlje (left) and Karadorđevo (right).

Sampling in both pilot areas was performed on two occasions (rounds). In each case, in each pilot area and locality, samples were taken in five predefined mesohabitats (areas with relatively uniform habitat characteristics):

- 1: zones with a reed belt along the bank
- 2: zones with forest along the bank (most often white willow-Salix alba, poplar-Populus sp., Ash-Fraxinus sp., Acacia-Amorpha fruticosa etc.)
- 3: water surfaces densely overgrown with submerged or floating vegetation (thrush-Ceratophyllum sp., White water lily-Nymphaea alba, yellow water lily-Nuphar luteum, water nut-Trapa natans, etc.)
- 4: slow-flowing open waters without vegetation
- 5: shallow ponds with drainage channels.

Due to the size of the locality and due to the inhomogeneous distribution of fish at the localities Bajski kanal and Mrtva Baračka within the pilot area Gornje Podunavlje during the second turn, the number of samples increased to 6.

The anticipated nominal transect length of 20 meters in most cases was not sufficient for an adequate sample. Therefore, the transect length was in many cases extended to about 50m, and in some cases up to 100m. Standard keys were used to determine individual families, genera and species (Simonović, 2001; Kottelat & Freyhof, 2007).

Electrofishing was conducted using a battery-powered fishing device with direct-pulsed output current (voltage 400 V, power 5 kW). CPUE (Catch Per Unit Effort) sampling was applied. Each sampling unit was defined by the mesohabitat type.

Sampling dates are shown in Table 1.

Table 1: Sampling dates and number of samples within each pilot area.

Pilot area	Locality	Distance to Danube	Sampling round	Date	Number of transects	Fished length
Karadorđevo	Dunavac	nearest	1	21.07.2021	5	270
Karadorđevo	Lovrenac - Račva	medium	1	22.07.2021	5	250
Karadorđevo	Lovrenac	furthest	1	20.07.2021	5	210
Karadorđevo	Dunavac	nearest	2	18.08.2021	5	280
Karadorđevo	Lovrenac - Račva	medium	2	19.08.2021	5	190
Karadorđevo	Lovrenac	furthest	2	17.08.2021	5	270
Gornje Podunavlje	Sakajtaš	nearest	1	27.07.2021	5	235
Gornje Podunavlje	Mrtva Baračka	medium	1	28.07.2021	5	250
Gornje Podunavlje	Bajski kanal	furthest	1	26.07.2021	5	320
Gornje Podunavlje	Sakajtaš	nearest	2	31.08.2021	11	230
Gornje Podunavlje	Mrtva Baračka	medium	2	01.09.2021	5	660
Gornje Podunavlje	Bajski kanal	furthest	2	30.08.2021	11	690

Sampling locations were mapped using a Garmin GPSmap 60CSx. In addition, transect locations were recorded with the mobile application "Geo Tracker". The following physico-chemical parameters were measured: Conductivity and water temperature using a WTW conductivity meter (model: Cond 3110), dissolved oxygen and saturation using a WTW oximeter (model: Oxi 3205), pH-value was determined using a Testo pH meter (model 206), transparency was determined using a Secci disk and water depth was determined using a Speedtest depth gauge.

Fish weight was measured using a scale with a precision of 0.1 g (Ohaus Navigator 2100). Total length (TL) and standard length (SL) of caught fish were noted. All individuals, except for non-native species, were returned to the water after handling. Ecological and reproductive guilds were determined on the basis of reference literature (Kovač, 2015). Collected data were submitted to INCVP on CD.

## 2.4 Integration of previous sampling results

To put the results from the current survey in perspective and due to the fact that a single sampling can never reflect the dynamics and variability of fish populations and fish communities, it is crucial to also consider outcomes of previously conducted studies and surveys of the fish fauna in the MDD region. For this purpose, potential documents of relevance and selected publication were compiled by the authors. Project partners assisted with the provision of potential sources. Documents were screened and the data provided was used for this report. In most cases, the raw data used for the various studies was not available or could not be gathered within the frame of this work. Therefore, results and information provided in the documents itself were digitized (e.g. tables with catch data). Only data sources that contained information on the whole fish community



were included (publications that focused on single species or groups were not considered). A strong focus was laid on reports and publications in english language (or at least with english summaries or table descriptions). It is known that more information on the fish fauna of the TBR MDD would be available in German, Slovenian, Croatian, Hungarian and Serbian language from both white and grey literature. However, raw data is often difficult to obtain and can be complex to prepare. Some conducted surveys also lack detailed information on the applied methodology or precise sampling locations. The available and used sources are indicted in the table below.

Table 2: Overview on recent reports, publications, surveys containing information on the fish community within the TBR MDD region.

Author(s)	Study name	Data from year(s)	Study area	Information included	Data used for this survey
Jelić et al. (2012)	Fish fauna of the lower reaches of the River Drava and surrounding marshland habitats near Donji Miholjac (Croatian with english summary)	2006	Drava near Donji Miholjac	Total catch numbers and total biomass from electrofishing surveys	Relative fish abundance and biomass as proxy for community composition
Sály, P. (2019)	Fishes of the Drava river. In: The Drava River (pp. 281-297). Springer	2016	Drava near Barcs	Relative frequencies of small electrofishing survey near Barcs.	Relative fish abundance as proxy for community composition.
Sály, P. (2019)	Fishes of the Drava river. In: The Drava River (pp. 281-297). Springer	1992-2016	Croatian-Hungarian Drava	Compiled species records (presence/absence) from various recent and historic data sources.	Information on species presence/absence records.
Austrian Ministry for Agriculture, Regions and Tourism	National database from the national water monitoring program (GZÜV)	2010-2019	Austrian-Slovenian Mura	Electrofishing data from WFD-monitoring program. Total catch numbers and standardized abundance/biomass values from different samplings 2010, 2013 and 2019 in the border Mura.	Relative fish abundance and biomass from 6 samplings.
Joint Danube Survey 2	Technical report with results from the fish sampling and analyses from the Joint Danube Survey 2007	2007	Danube (3 sites in TBR MDD, Serbia)	fish survey of the Danube (from “source to mouth”), comprehensive overview and results in the report; detailed protocols/data from each sampling site with total catch numbers and standardized abundance/biomass available.	Relative fish abundance from 3 Serbian Danube sites.
Joint Danube Survey 3	Full report Joint Danube Survey 3; detailed paper on fish sampling available via ICPDR	2013	Danube (2 sites in TBR MDD Serbia)	fish survey of the Danube (from “source to mouth”), comprehensive overview and results in the report; detailed protocols/data from each sampling site with total catch numbers and standardized abundance/biomass available.	Relative fish abundance from 2 Serbian Danube sites.
Joint Danube Survey 4	Full report Joint Danube Survey 4; detailed paper on fish sampling not available at the time of release.	2019	Danube (4 sites in TBR MDD Serbia)	fish survey of the Danube (from “source to mouth”), comprehensive overview and results in the report – including eDNA sampling results; detailed protocols/data from each sampling site with total catch numbers and standardized abundance/biomass not published at time of release.	-

Sallai & Kontos (2008)	Data to the fish fauna of Croatian Drava sections	2007	Croatian-Hungarian Drava + backwaters	Total catch numbers from various electrofishing samples. Sites and methodology not described in detail	Qualitative information on community composition.
Sallai & Kontos (2008)	Data to the fish fauna of Croatian Drava sections	historic	Croatian-Hungarian Drava + backwaters	Loose collection of historic and recent records (including information from fishermen and anglers) on species occurrence	Qualitative information on historic records of species occurrence.
Sallai & Kontos (2005)	Fishfaunistical monitoring of the Hungarian part of the River Drava (1999-2004)	1999-2004	Hungarian Drava	Relative share of species frequency within sample. Seasonal differences described. Methodology and sampling sites largely unclear.	Qualitative information on community composition.
n.A.	Fishery management plan for Gornje Podunavlje Special Nature Reserve for the period 2012-2021	2012-2021	Serbian Danube + backwaters	qualitative and quantitative analysis of fish populations (species list, abundance, biomass, productivity, conservation status), sampling methodology, sampling locations, physical chemical and biological parameters of the aquatic habitats at sampling points	-
n.A.	Fishery management plan for Karadjordjevo Special Nature Reserve for the period 2013-2022	2013-2022	Serbian Danube + backwaters	qualitative and quantitative analysis of fish populations (species list, abundance, biomass, productivity, conservation status), sampling methodology, sampling locations, physical chemical and biological parameters of the aquatic habitats at sampling points	-
Institute for Nature Conservation of Serbia (2000)	Nature conservation study for the proposal of the designation of Gornje Podunavlje Special Nature Reserve	2000	Serbian Danube + backwaters	detailed qualitative analysis, species list, national and international conservation status, threats, conservation measures, sampling locations, sampling methodology	-
INCVP - Institute for Nature Conservation of Voivodina Province (2011)	Nature conservation study for the proposal of the designation of Karadjordjevo Special Nature Reserve	2011	Serbian Danube + backwaters	detailed qualitative analysis, species list, national and international conservation status, threats, conservation measures, sampling locations, sampling methodology	-
Podgornik et al. (2015)	fish faunistic assessment of the river Mura/hydroelectric plat Hrastje Mota; conducted by the Fisheries Research Institute of Slovenia (report in Slovenian)	2013-2014	Slovenian Mura	Extensive electrofishing survey of the whole Slovenian Mura. Total catch numbers and standardized abundance/biomass (strip-fishing) values available for different sampling sites and seasons.	Relative fish abundance from 4 stretches and 2 seasons each.

## 3 Results and Discussion

Within this chapter, results from the sampling campaign in the Mura, Drava and Danube are presented. In the Mura and Drava, electrofishing was conducted by BOKU Vienna in July 2021, focusing on the longitudinal change of the fish cenosis. Electrofishing in Serbia (coordinated by INCVP) focused on lateral differences in the fish community in Danube side waters by comparing two sections with different extent of connectivity to the Danube main channel.

### 3.1 Mura and Drava

In the Mura and Drava, electrofishing was conducted during 8 days in July 2021. Samples were taken in 9 different sections between the Slovenian Mura (close to Murska Sobota at river-kilometer 96) and the Croatian Drava below Donji Miholjac (river-kilometer 66,5) (Figure 7).

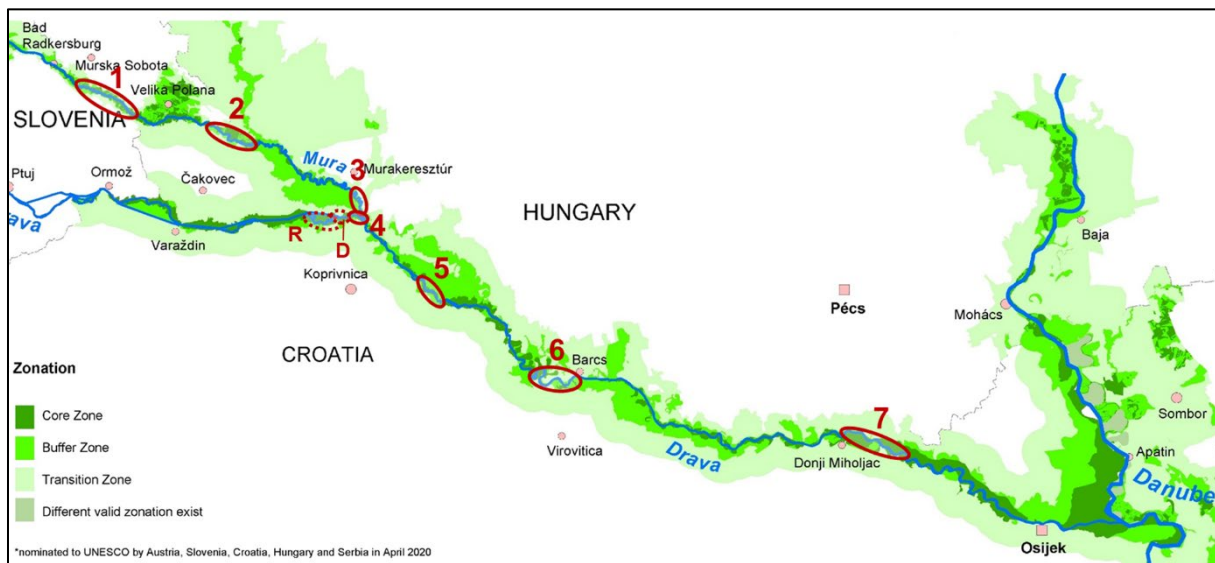


Figure 9: Sampling locations in Mura and Drava within the TBR MDD region. Sections 1 to 7 describe the longitudinal gradient, sections “R” (residual flow stretch of HPP Donja Dubrava) and “D” (section below the HPP) where sampled additionally to gain insights in potential effects of hydropower operation.

Picture © WWF

The sections are numbered from S1 to S7 according to their location within the longitudinal succession from the Mura to the Drava. Sections “SR” and “SD” represent the residual flow stretch (SR) of the HPP Donja Dubrava and the Drava section below the HPP until the confluence of the Mura (SD). These two sections are therefore located upstream of section 4. The number of fishing strips per section (indicating the sampling intensity) varied due to the time of sampling spent in the section. Not all sections were sampled for a full day (as indicated in Table 3). Section D for example was only sampled for about half a day on July 17, resulting in less sampling strips. However, the fish density in this section

was very low in all strips within the main channel. Only in a backwater bay, considerable amounts of fish and species were detected. Section 4 was also sampled in part on July 17 and on July 18 as part of sampling section 3 (lowest Mura stretch). The low number of strips in this section is still considered adequate because this section only covers the area in vicinity of the Mura confluence. The total fished length (summed lengths of each fishing strip) varied between about 5,5 and 9 km, with mean strip lengths between 200 and 280 m. The fished area ranged between 1,5 and 3,6 ha (mean strip areas of about 1.000 m<sup>2</sup>). It shall be noted that variation of fished strip length (and area) was high – from very small/short strips (e.g. at shoreline structures fished with the small boat) to longer, homogenous strips in the river middle.

The mean water depth indicated in Table 3 shows that depth was lower in the upper Mura sections and increased further downstream. However, the values refer to the water depth at the fishing strips and not the whole river. Deep areas/habitats in the sampled river sections (like deep pools) could not be sampled via electrofishing. In section D (mean depth >2m), the water was very clear (outflow of HPP) and the water depth in the sampling strips therefore higher.

The average values for flow velocity within the fishing strips shows that the current decreased significantly from 1 m/s in the uppermost section to 0,3 m/s in the lowest section.

Table 3: Overview on sampling effort, species number and total catch results per section.

Section	S1	S2	S3	S4	S5	S6	S7	SR	SD	Total
Date	15.07	16.07. 19.07.	18.07	17.07. 18.07.	21.07.	22.07.	23.07.	17.7. 20.7.	17.07.	
# fishing strips	35	43	25	10	33	28	28	24	7	233
Total fished length (km)	7,9	7,4	5,0	2,8	9,1	7,4	5,8	3,7	2,4	51,4
Total fished area (ha)	3,6	3,6	2,3	1,4	4,3	3,6	3,0	1,7	1,5	24,8
Mean length/strip (m)	228	171	200	278	275	264	206	152	346	221
Mean area/strip (m <sup>2</sup> )	1.025	829	922	1.383	1.300	1.274	1.059	693	2.078	1.063
mean water depth (m)	0,86	0,98	1,27	1,01	1,29	1,07	1,07	0,85	2,14	1,08
Mean flow velocity (m/s)	1,06	0,62	0,53	0,52	0,71	0,44	0,33	0,53	0,95	0,61
Mean fishing duration/strip (min.)	05:29	04:30	03:58	05:24	05:45	06:26	06:03	04:51	04:58	05:17
# species total	28	29	24	20	26	29	32	30	15	48
total fish catch	4.489	4.982	4.052	3.407	12.232	5.811	7.484	4.990	816	48.264

Overall, more than 48 thousand fish of 48 different species were caught via electrofishing. This number (referred to as “total catch”), is derived from the number of caught individuals and the estimation of the catch efficiency (relative share of caught individuals to visually assessed individuals during sampling; see chapter 2.2).



The full list of caught species is found in Table 4, whereby the latin species names are sorted alphabetically, and vernacular English names are added. Additionally, each species preference according to three important ecological parameters are given: flow preference, spawning preference and preferences for habitat-structural-features. This classification enables the identification of species with similar ecological requirements (guilds). The scheme is adopted from Zauner & Eberstaller (1999) and has been updated and complemented for several species. The classification aims at providing a simple and viable scheme to identify riverine fish species with similar habitat requirements and results from a combination of existing knowledge (literature) and sampling efforts conducted in Austrian rivers.

A species general flow or “current” preference is subdivided into for groups:

- Rheophilic: species that prefer areas with constant flow and medium to higher flow velocities.
- Oligorheophilic: species that prefer slow, but constantly flowing areas.
- Indifferent: Species without clear preference to flowing or stagnant areas.
- Limnophilic: Species that prefer stagnant areas (no flow velocity).

Species preferences to flow conditions at the spawning/reproduction sites are categorized into:

- Rheopar: Species that reproduce in flowing water areas.
- Euryopar: Species that reproduce in flowing and in stagnant areas.
- Limnopar: Species that reproduce in stagnant areas.

Preferences for habitat-structural-features (e.g. large rocks, river bottom structures, shoreline structures, dead-wood or vegetation) are also subdivided into three categories:

- Highly structure-bound: species that live directly in or are strongly dependent on structures throughout their lifecycle
- Medium structure-bound: species that live predominantly near structures within the river.
- Not structure-bound: species that are not associated with specific structural features.

Table 4: Caught fish species during electrofishing in Mura and Drava in July 2021. Preferences on flow conditions, spawning site preferences and structural preferences are based on Zauner & Eberstaller (1999).

latin name	common name	Flow preference	Spawning preference	Structural-preference
Abramis brama	Common bream	indifferent	euryopar	low
Alburnoides bipunctatus	Spirlin	rheophilic	rheopar	medium
Alburnus alburnus	Bleak	indifferent	euryopar	low
Ameiurus melas	Brown bullhead	indifferent		
Aspius aspius	Asp	indifferent	rheopar	low
Babka gymnotrachelus	Racer goby	indifferent	euryopar	high
Ballerus sapa	White-eyed bream	oligorheophilic	rheopar	low
Barbatula barbatula	Stone loach	rheophilic	rheopar	medium
Barbus barbus	Barbel	rheophilic	rheopar	medium
Blicca bjoerkna	White bream	indifferent	euryopar	medium
Carassius gibelio	Prussian carp	indifferent	limnopar	medium
Chondrostoma nasus	Nase	rheophilic	rheopar	medium
Cobitis elongatoides	Danubian spined loach	oligorheophilic	euryopar	high
Cottus gobio	Bullhead	rheophilic	rheopar	high
Cyprinus carpio	Carp	indifferent	limnopar	medium
Esox lucius	Northern pike	indifferent	limnopar	high
Eudontomyzon mariae	Ukrainian brook lamprey	oligorheophilic	rheopar	high
Gasterosteus gymnurus	Three-spined stickleback	limnophilic	limnopar	high
Gobio obtusirotris	Danube gudgeon	rheophilic	rheopar	medium
Gymnocephalus cernua	Ruffe	indifferent	euryopar	medium
Gymnocephalus schraetser	Striped ruffe	oligorheophilic	rheopar	medium
Hypophthalmichthys molitrix	Silver carp	indifferent	euryopar	low
Lepomis gibbosus	Pumpkinseed	limnophilic	limnopar	high
Leuciscus idus	Ide	indifferent	euryopar	medium
Leuciscus leuciscus	Dace	indifferent	rheopar	medium
Lota lota	Burbot	indifferent	euryopar	high
Neogobius fluviatilis	Monkey goby	indifferent	euryopar	high
Neogobius melanostomus	Round goby	indifferent	euryopar	high
Perca fluviatilis	Perch	indifferent	euryopar	low
Phoxinus phoxinus	Eurasian minnow	indifferent	euryopar	medium
Ponticola kessleri	Bighead goby	indifferent	euryopar	high
Proterorhinus semilunaris	Tube-nose goby	indifferent	euryopar	high
Pseudorasbora parva	Stone moroko	indifferent	euryopar	medium
Rhodeus amarus	Bitterling	limnophilic	limnopar	medium
Romanogobio carpathorossicus	Sand gudgeon	rheophilic	rheopar	medium
Romanogobio uranoscopus	Stone gudgeon	rheophilic	rheopar	medium
Romanogobio vladykovi	Danube whitefin gudgeon	rheophilic	rheopar	medium
Rutilus rutilus	Roach	indifferent	euryopar	low
Rutilus virgo	Cactus roach	rheophilic	rheopar	medium
Salmo trutta fario	Brown trout	rheophilic	rheopar	high
Sander lucioperca	Pikeperch	indifferent	euryopar	medium
Scardinius erythrophthalmus	Rudd	limnophilic	limnopar	medium
Silurus glanis	European catfish	indifferent	euryopar	high
Squalius cephalus	Chub	indifferent	euryopar	high
Tinca tinca	Tench	limnophilic	limnopar	high
Vimba vimba	Vimba bream	oligorheophilic	rheopar	low
Zingel streber	Danube streber	rheophilic	rheopar	medium
Zingel zingel	Zingel	oligorheophilic	rheopar	medium

### 3.1.1 Hydrological situation

The discharge of the Mura ranged from just above 100 to almost 200 m<sup>3</sup>/s during the sampling period. In the Drava, the discharge ranged between 400 and 700 m<sup>3</sup>/s. The discharge is recorded by several gauging stations operated by the Slovenia and Croatian hydrological services (Slovenian Environment Agency - arso.gov.si) respectively Croatian waters - voda.hr).

The discharge curve from the year 2021 for the stations Mursko Središće (Mura, rkm: 71,5) and Terezino Polje (Drava, rkm: 153) is presented in Figure 8. The recent (2010-2020) average mean discharge (MQ) for these stations is about 520 m<sup>3</sup>/s at station Terezino Polje and 160 m<sup>3</sup>/s at Mursko Središće.

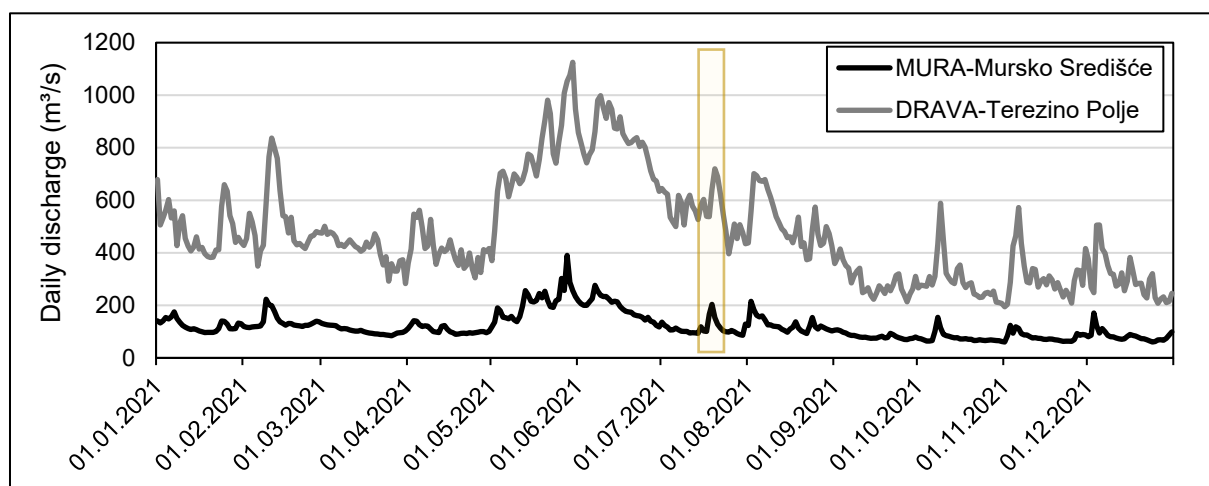


Figure 10: Daily average discharge (m<sup>3</sup>/s) in Mura and Drava in 2021. The yellow block indicates the sampling period between July 15 and 23. Data provided by Croatian water (voda.hr).

The discharge situation in July of 2021 is displayed in more detail in Figure 9. In the sampled stretches of the Mura (from the Slovenian Mura to the confluence with the Drava), the discharge is similar at all gauging stations. The discharge values at different gauging stations in the Drava below the Mura confluence differ slightly. Roughly 150 km lie between these stations and only small tributaries are located there. The differences in discharge are therefore mainly caused by precipitation in the area and the hydropower operation in the Croatian Drava powerplants (release and withhold of water at different temporal rates). During the second half of the sampling period, the discharge in the lower Drava (station Donji Miholjac) was about 20% higher than at station Botovo, caused by rainfall on July 16-18.

The average July discharge between 2010 and 2020 lies between 115 and 400 m<sup>3</sup>/s in the Mura (minimum daily discharge between 81 and 153, maximum between 154 and 1.100) and between 400 and 750 m<sup>3</sup>/s in the Drava (station Terezino Polje; minimum daily discharge between 280 and 500, maximum daily discharge between 560 and 1.250).

Overall, the discharge indicated imperfect conditions for electrofishing, which should be conducted during lower flow periods. Especially in the Drava, discharges below 400 m<sup>3</sup>/s would have enabled the sampling of more diverse in-stream habitats (in the middle of the river). In the Slovenian and Croatian Mura, discharge of about 100 m<sup>3</sup>/s would be suitable. Such situations are most commonly encountered in autumn.

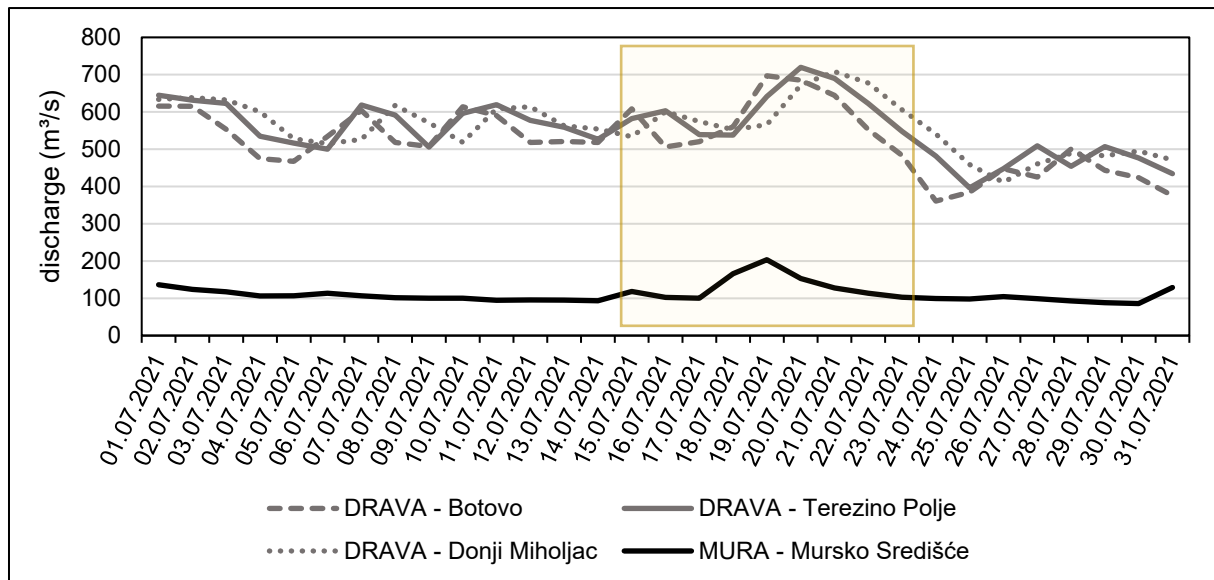


Figure 11: Daily average discharge (m<sup>3</sup>/s) in Mura and Drava in July 2021. The yellow block indicates the sampling period between July 15 and 23. Data provided by Croatian water (voda.hr).

We assume that the increased turbidity in the Drava during the second half of the sampling period is amplified by the agricultural land use in the surrounding area. During phases of increased runoff due to local precipitation, fine sediments are eroded from farm lands into the Drava river.

It is noteworthy that the sections S4 (partly), SR and SD are located upstream of the Mura-Drava confluence. The discharge in these sections is therefore different than in the presented charts. The discharge in these sections is significantly influenced by the operation of the hydropower plant in Donja Dubrava. During flow situations up to slightly above mean discharge, the power plant uses the storage capacity of the reservoir to adapt electricity production to the current market demand. This means that turbines are switched on during periods of higher energy demand (and price) and turned off when the energy is not needed. This leads to significant artificial flow fluctuations in the Drava below the power plant. The fluctuations are irregular but can occur up to three times per day with an amplitude of over 100% (increase of discharge when switching on the turbines and decrease when turning them off again). Unfortunately, no discharge data was available from the station in Donja Dubrava for the year 2021. More details on the ecological impacts of artificial flow fluctuations (“hydropeaking” or “hydrofibrillation”, Greimel et al., 2015) are found in chapter 4.4.

The following subchapters comprise the results for each of the sampled sections, containing a short overview on the locality and sampling effort as well as results on the total catch yielded in each section (abundances and biomasses per species). The measured water parameters (pH-value, oxygen content, water temperature, conductivity, discharge) were recorded during eDNA sampling (either in the morning or in the evening of the indicated dates). It shall be noted that the given values therefore might be variable throughout the day/s the sampling took place.

### 3.1.2 Section 1 - Mura - in Slovenia

The uppermost section of the Mura in Slovenia was sampled on July 15<sup>th</sup>. The sampled section is about 9,5 km long and extends between the towns of Beltinci (river kilometer 96) and Crenisovci (river kilometer 87) (Figure 10).

A total of 35 strips were sampled within this section, amounting to a total fished strip-length of 8 km. Based on the effective fishing width of each boat, a water surface area of about 3,6 ha was sampled. An overview on general sampling parameters can be found in Table 4. As mentioned earlier, the average strip in which the larger boat is sampling is deeper and many times in faster flowing areas than the sampled areas of the smaller boat (predominantly at shorelines).

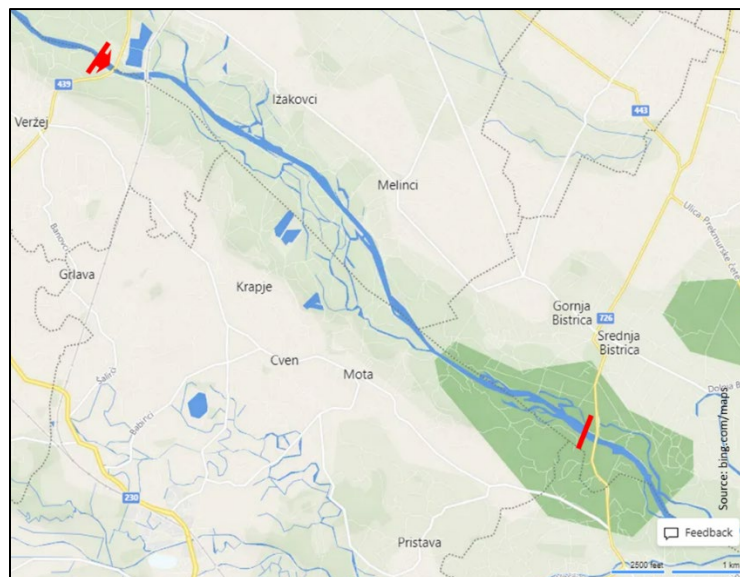


Figure 12: Location of section 1 in the Slovenian Mura- sampled via electrofishing on July 15<sup>th</sup>, 2021.

In section 1, a total of roughly 4.500 fish were recorded. The total fish biomass amounts to 294 kg. Most fish individuals were caught with the smaller boat (almost 75%). This is the case, because shoreline areas or gravel bars serve as habitats for juvenile fish individuals that occur in much higher densities than adult individuals. However, the by far greater fish biomass was yielded with the large boat (83%). This effectively means that most of the total catch consisted of small individuals and less larger fish, who in turn however account for most of the biomass. This fact underlines the importance to conduct an electrofishing effort with separate boats that enable the sampling of different habitats.



Table 5: Overview on locality and fishing effort in section S1.

Section 1		MURA		Slovenia	
Date:	15.07.2021				
Starting point:	Beltinci, Slovenia (rkm: 96)		46,589790; 16,177774		
End point:	Crenisovci, Slovenia (rkm: 87)		46,540507; 16,271445		
Section length: 9,55 km	Water Temperature: 22,1 °C		Discharge (m <sup>3</sup> /s): 123 (Mursko Sredisce)		
Conductivity: 300 µS/cm	pH: 7,99		Oxygen: 9,56 mg/L		
Fishing effort					
	small boat		large boat		total
Number of strips fished	18		17		35
total length fished (km)	3,01		4,98		8,00
total area fished (ha)	0,60		2,99		3,59
Average water depth (m)	0,5		1,2		0,9
Average maximum depth (m)	1,0		1,9		1,4
Average flow velocity (m/s)	0,7		1,3		1,1
Total catch					
total fish abundance (# individuals)	3.295		1.194		4.489
total biomass (kg)	49		245		294
total species number: 28					
flow preference:					
# rheophilic	9	# oligorheophilic	4	# indifferent	12
# limnophilic	3				
spawning preference:					
# rheopar	14	# euryopar	9	# limnopar	5
habitat structure preference:					
# highly structure-bound	8	# medium structure-bound	15	# not structure-bound	5

Altogether, 28 fish species were recorded within the one day of sampling in S1. The guild of indifferent species is dominant with 12, followed by rheophilic species (9), oligorheophilic (4) and limnophilic (3). Regarding the spawning preference, species that prefer fast flow at the spawning habitat (rheopar species) account for the largest share (14 species), followed by euryopar (9 species). 8 of the 28 caught species are considered to be highly bound to structural features in the river, 15 species are considered medium bound and 5 species not bound to structures.

The total and relative numbers of the total catch and total biomass are displayed in Figure 11. The most abundant species was the bleak with 1.772 individuals (almost 40% of the total catch). The spiralin followed with 1.119 individuals (25%). The following four species were caught in similar abundances and account for a total of 30% of the total catch: chub (463 ind.; 10%), barbel (366 ind., 8%), nase (303 ind., 7%) and dace (228 ind., 5%). All

other species where caught in abundances of less than 50 individuals (except for the Danube gudgeon with 63 ind.).

In terms of fish biomass (total catch biomass amounts to 294 kg), the three dominant species were the nase with a share of 42% (123 kg), followed by barbel (77 kg, 26%) and chub (48 kg; 17%), whereby the most frequent species (bleak) only accounted for 14 kg of fish biomass (5%).

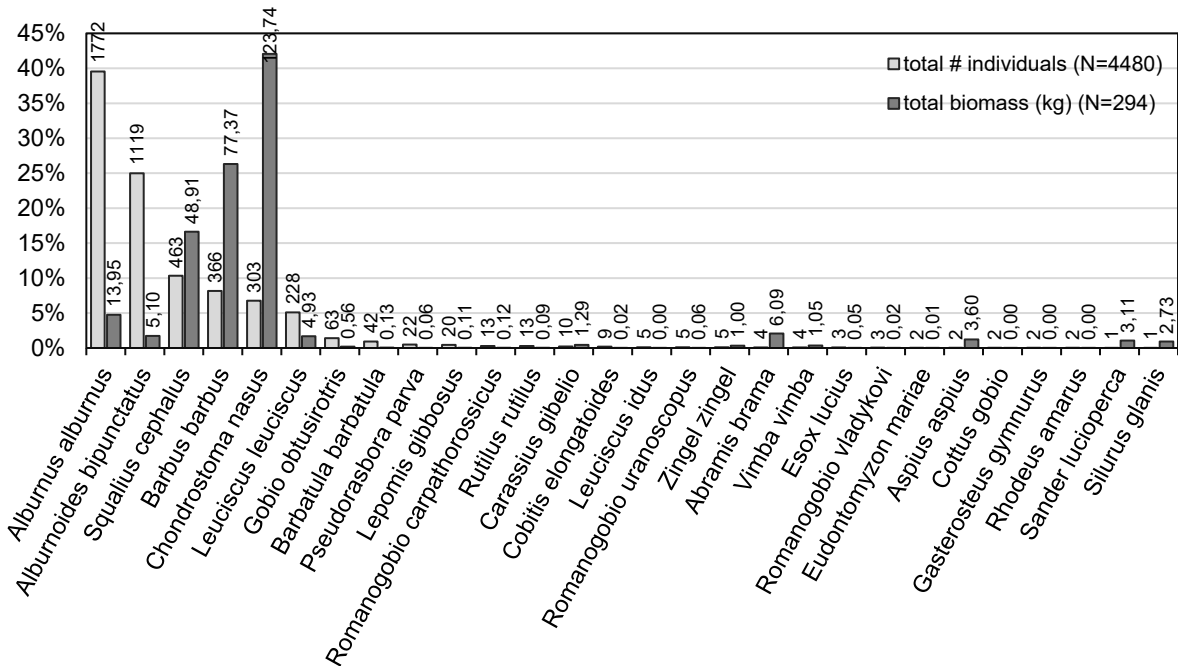


Figure 13: Relative and total numbers of caught fish individuals and fish biomass in kg in section 1 (Mura) per species. Data is arranged in descending order based on relative fish abundance. All caught and identified species are displayed.



Figure 14: Mura river in sampling section S1.

### 3.1.3 Section 2 – Mura – Border-Mura Slovenia & Croatia

Section 2 was sampled on July 16 and July 19. Due to problems with the motor of the larger electrofishing boat on the 16<sup>th</sup>, sampling of the lower parts of this section was repeated on July 19<sup>th</sup>. The water level (and turbidity) in section 2 was higher on the 19<sup>th</sup> compared to the 16<sup>th</sup>.

The section is a little over 17km long, although the middle part (with relatively homogenous habitat distribution) was sampled with less intensity than the uppermost and lower part of the section. Sampling started below the bridge in Mursko Sredisce (river kilometer 71,5) and commenced below the town of Podturen (river kilometer 54).

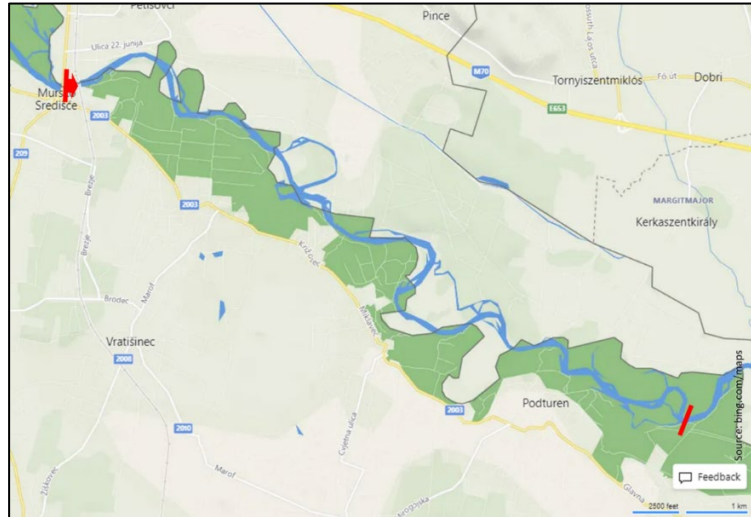


Figure 15: Location of section 2 in the Mura between Croatia and Hungary–sampled via electrofishing on July 16 and July 18, 2021.

Altogether, 43 fishing strips where sampled: 22 with the small, and 21 with the larger boat. This amounted to a total fished length of about 7,4 km and fished surface area of 3,56 ha. The average water depth within the sampled areas was similar to S1. However, the mean flow velocity in the sampled strips was significantly less than in S1 (0,6 m/s compared to 1,2 m/s). Although the flow velocity was not measured in a standardized way, but estimated as mean value for each fishing strip, this can be seen as an indicator for a reduced slope in S2 compared to S1 as a result of a higher degree of channelization in S1.

The sampling in S2 yielded a total catch number of just below 5.000 individuals and a total biomass of 186 kg. In total, 29 species where caught. 12 of the 29 species belong to the rheophilic or oligorheophilic guild, whereas 15 species are indifferent and 2 are considered limnophilic. 13 species are rheopar, meaning the prefer spawning habitats with active flow velocity. 11 species are euryopar (no clear flow preference at the spawning habitat) and 5 are limnopar (preferring stagnant areas).

Table 6: Overview on locality and fishing effort in section S2.

Section 2		MURA	Slovenia & Croatia				
Date:	16 & 19.07.2021						
Starting point:	Mursko Sredisce, Croatia (rkm: 71,5) 46,514946; 16,441020						
End point:	Podturen, Croatia (rkm: 54) 46,464819; 16,578226						
Section length: 17,5 km	Water Temperature: 19,7 °C (19.Jul.)	Discharge (m <sup>3</sup> /s): 99 (16.07.) & 198 (19.07.) (Mursko Sredisce)					
Conductivity: 282 µS/cm (19.Jul.)	pH: 8,07 (19.Jul.)	Oxygen: 8,73 mg/L (19.Jul.)					
Fishing effort							
	small boat	large boat	total				
Number of strips fished	22	21	43				
total length fished (km)	2,19	5,18	7,36				
total area fished (ha)	4,58	3,11	3,56				
Average water depth (m)	0,5	1,4	1,0				
Average maximum depth (m)	0,8	2,3	1,5				
Average flow velocity (m/s)	0,3	0,9	0,6				
Total catch							
total fish abundance (# individuals)	2.818	2.164	4.982				
total biomass (kg)	42	144	186				
total species number: 29							
flow preference:							
# rheophilic	8	# oligorheophilic	4	# indifferent	15	# limnophilic	2
spawning preference:							
# rheopar	13	# euryopar	11	# limnopar	5		
habitat structure preference:							
# highly structure-bound	7	# medium structure-bound	16	# not structure-bound	6		

Figure 14 shows the relative and total catch numbers and the biomass of the caught fish species. In terms of total catch, the bleak was the most frequent species (2.278 ind., 46%). The dace (714 ind.), the spiralin (575 ind.), the chub (434 ind.), barbel (337 ind.) and nase (139 ind.) follow with a share of 44% altogether. All other species were caught in abundances of less than 100 individuals.

The total fish biomass (186 kg) distributes mainly among chub (39 kg, 21% of total biomass) and carp (18% or 34 kg, albeit only 6 individuals were caught). The bleak (25 kg), the nase (26 kg) and the barbel (22 kg) had similar shares of about 13% of the total fish biomass.



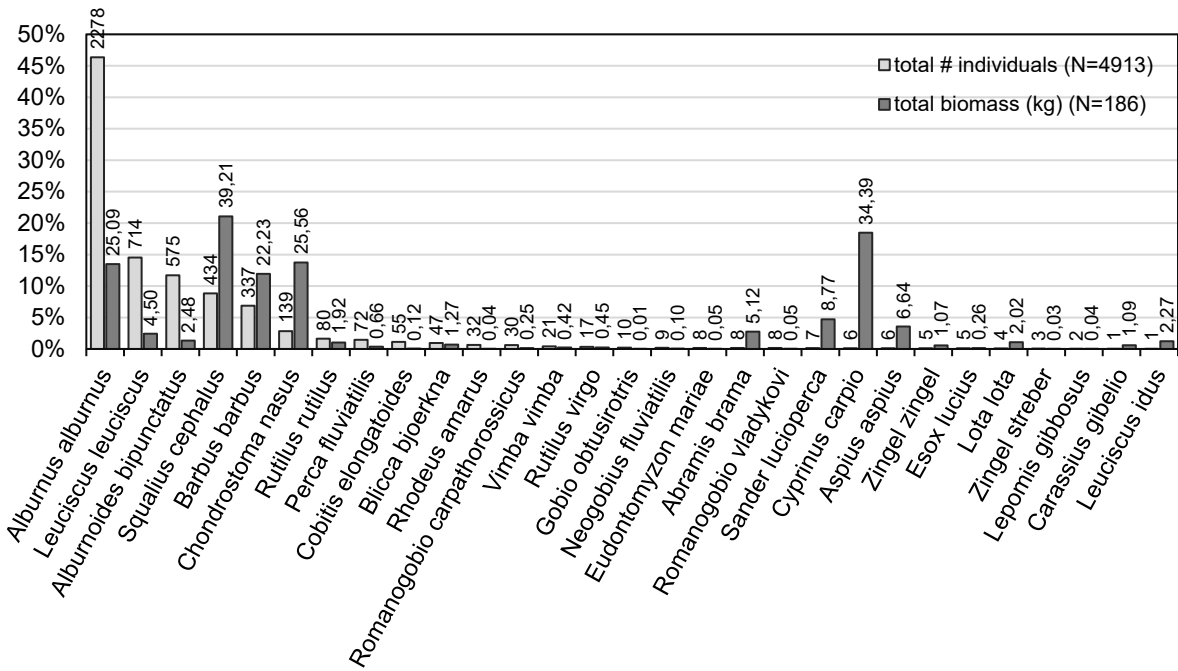


Figure 16: Relative and total numbers of caught fish individuals and fish biomass in kg in section 2 (Mura) per species. Data is arranged in descending order based on relative fish abundance. All caught and identified species are displayed.



Figure 17: Mura river in sampling section S2.



### 3.1.4 Section 3 – Mura – Border-Mura Croatia & Hungary

The lowest section in the Mura (S3) was sampled on July 18, 2021. The section extends over the lowest 13km of the Mura river. Sampling started at Kotoriba (rkm: 12,8) and ended close to the confluence into the Drava in Legrad (rkm: 0,5). The overall morphological situation in this section is that meanders are existing, but the outer banks and shorelines are mostly regulated. In some parts within this section, the rather wide channel profile still allows the formation of gravel bars and near-natural shorelines.

The discharge during sampling was about 130 m<sup>3</sup>/s. The total number of fishing strips in this section was 25, of which 13 were sampled with the small boat, and 12 with the larger boat. The total fished length amounted to 5 km and the total fished area was 2,31 ha.

The average and maximum water depths within the sampling strips was higher than in the sections upstream (S1 and S2), whereas the average flow velocity was slightly lower than in S2.

In total, just above 4.000 fish individuals were caught within this section. The total catch biomass was 133 kg. 23 fish species were recorded in section 3, which is less compared to the upstream sections

S1 and S2. This could be a consequence of the slightly lower sampling effort (strip number, total fished area). Of the 23 species, 12 rheophilic and oligorheophilic species were recorded, 11 indifferent and no limnophilic species. Species preferring spawning habitats with active flow velocity are most abundant with 13, followed by euryopar species (9) and just 1 limnopar species. Regarding structural features, the fish community is balanced between high to low structure bound species (7 high, 9 medium, 7 low).

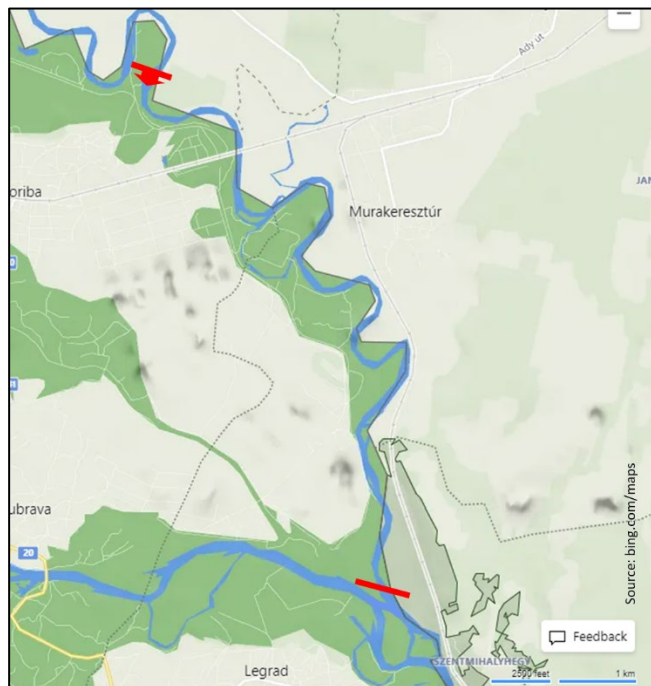


Figure 18: Location of section 3 in the Mura on the border between Croatia and Hungary – sampled via electrofishing on July 18, 2021.

Table 7: Overview on locality and fishing effort in section S3.

Section 3		MURA		Croatia & Hungary			
Date:	18.07.2021						
Starting point:	Kotoriba, Croatia (rkm: 12,8) 46,367276; 16,834874						
End point:	Legrad, Croatia (rkm: 0,5) 46,540507; 16,271445						
Section length: 12,3 km	Water Temperature: 21,3 °C		Discharge (m <sup>3</sup> /s): 131 (Gorican)				
Conductivity: 316 µS/cm	pH: 8,2		Oxygen: 8,73 mg/L				
Fishing effort							
	small boat	large boat	total				
Number of strips fished	13	12	25				
total length fished (km)	1,75	3,26	5,01				
total area fished (ha)	0,35	1,96	2,31				
Average water depth (m)	0,8	1,8	1,3				
Average maximum depth (m)	1,1	2,7	1,9				
Average flow velocity (m/s)	0,3	0,9	0,5				
Total catch							
total fish abundance (# individuals)	3.126	926	4.052				
total biomass (kg)	46	87	133				
total species number: 23							
flow preference:							
# rheophilic	7	# oligorheophilic	5	# indifferent	11	# limnophilic	0
spawning preference:							
# rheopar	13	# euryopar	9	# limnopar	1		
habitat structure preference:							
# highly structure-bound	7	# medium structure-bound	9	# not structure-bound	7		

Out of the total catch number of 4.025 individuals, the most frequent species was the bleak with over 2.000 individuals (50%), followed by the spirlin and the chub (572 and 535 ind., respectively 14% and 13%). The barbel, Danube roach, nase and dace follow with similar abundance of 189 to 147 individuals (~4% each).

The nase accounts for a third of the total catch biomass with 45 kg, followed by the chub (38 kg) with 29% and the bleak and barbel (16 and 15 kg, respectively 12 and 11%).

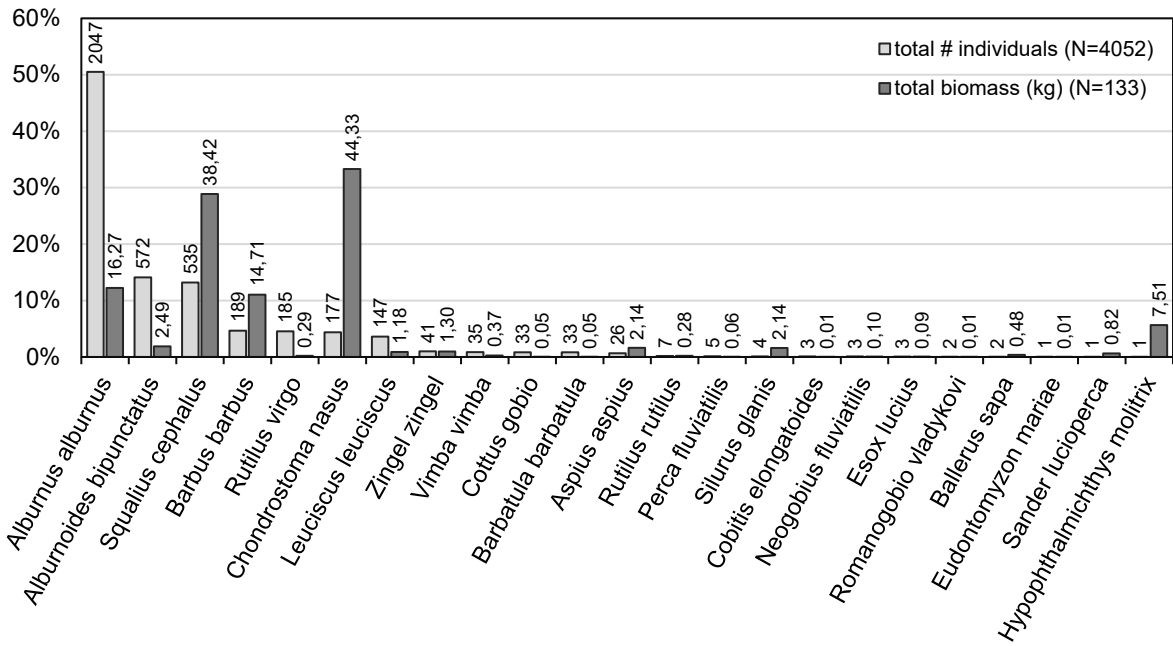


Figure 19: Relative and total numbers of caught fish individuals and fish biomass in kg in section 3 (Mura) per species. Data is arranged in descending order based on relative fish abundance. All caught and identified species are displayed.



Figure 20: Mura river in sampling section S3.

### 3.1.5 Section 4 – Confluence Mura-Drava

The area at the confluence of the Mura and Drava was sampled on July 17 and 18, 2021. The overall sampling effort was lower than for other sections, mainly due to the lesser areal extent that needed to be covered. Sampling of this area was conducted in part on the same day as sampling in the lowest part of the Mura. In many regards, the confluence of the Mura and Drava marks an area of interest for fish-ecological analyses. The morphological situation presents a system of side arms and islands that appear at different extents depending on the discharge situation. Major bank stabilization works have been carried out on the Hungarian border of the Drava (right hand side).

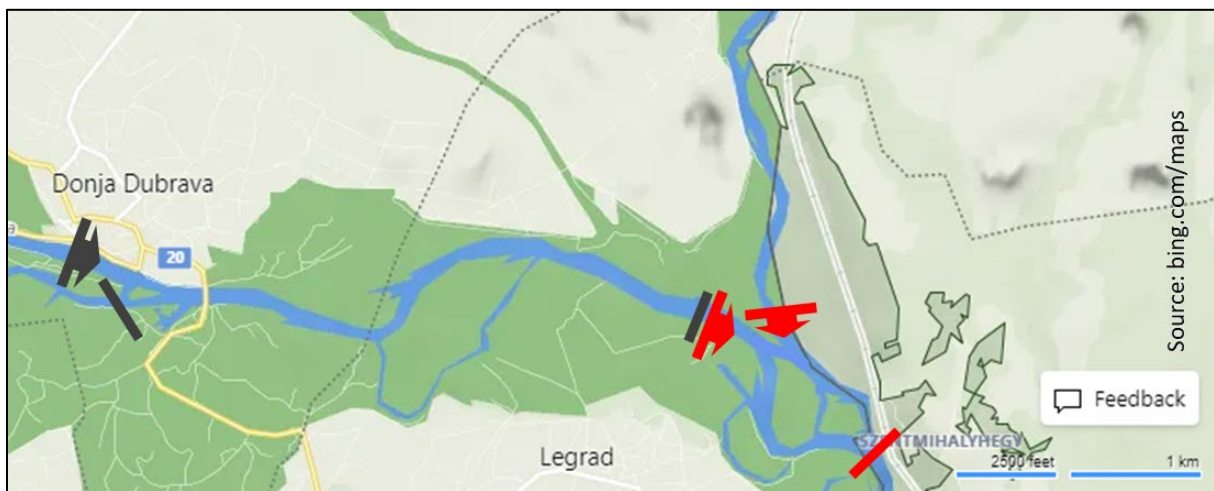


Figure 21: Location of section 4 – confluence of Mura and Drava – sampled via electrofishing on July 17 and 18, 2021. Starting points are indicated by the red arrows. The Drava section above section 4 extends from the outlet channel of the HPP Donja Dubrava to the beginning of section 4 (indicated by grey lines).

The sampling effort in S4 amounted to a total of 10 fishing strips, which is less compared to the sections sampled in the Mura. On the other hand, the total fished length (2,8 km) and fished area (1,38 ha) are high in relation to the extent of the section.



Table 8: Overview on locality and fishing effort in section 4.

Section 4		MURA/DRAVA		Croatia & Hungary	
Date:	17. & 18.07.2021				
Starting point:	Legrad, Croatia (Mura rkm: 0,5, Drava rkm: 235,5)		46,307697; 16,869787		
End point:	Legrad, Croatia (Drava rkm: ~234)		46,297719, 16,885613		
Section length: ~1,5 km	Water Temperature: 21,7 °C		Discharge (m <sup>3</sup> /s): 414 (17.07.) & 606 (18.07.) (Drava, Botovo)		
Conductivity: 250 µS/cm	pH: 7,68		Oxygen: 8,73 mg/L		
Fishing effort					
	small boat		large boat		total
Number of strips fished	4		6		10
total length fished (km)	0,71		2,07		2,78
total area fished (ha)	0,14		1,24		1,38
Average water depth (m)	0,4		1,4		1,0
Average maximum depth (m)	0,6		2,7		1,9
Average flow velocity (m/s)	0,4		0,6		0,5
Total catch					
total fish abundance (# individuals)	854		2.553		3.407
total biomass (kg)	3		128		131
total species number: 20					
flow preference:					
# rheophilic	5	# oligorheophilic	2	# indifferent	12
# limnophilic	1				
spawning preference:					
# rheopar	8	# euryopar	9	# limnopar	3
habitat structure preference:					
# highly structure-bound	5	# medium structure-bound	9	# not structure-bound	6

The total fish abundance (3.407 individuals) and catch biomass (131 kg) were comparatively high. Both fish abundance and biomass were caught mainly with the larger electrofishing boat. The total recorded species number was 20, of which 5 were rheophilic and 12 were indifferent. The overall community structure (Figure 20) shows that the fish abundance is dominated by the bleek (53%, 1.805 ind.). The next most frequent fish were the roach (14%, 468 ind.), the dace (13%, 450 ind.) and the vimba bream (6%, 205 ind.). Some species frequently caught in upstream parts of the Mura were caught in lesser densities in S4 – like the spiralin (2 individuals), the chub (22 ind.), the nase (61 ind.) and the barbel (123 ind.). The nase however had a high share of the total biomass (36 kg, 27%), topped only by the carp (37 kg or 28% albeit only 8 individuals were caught).



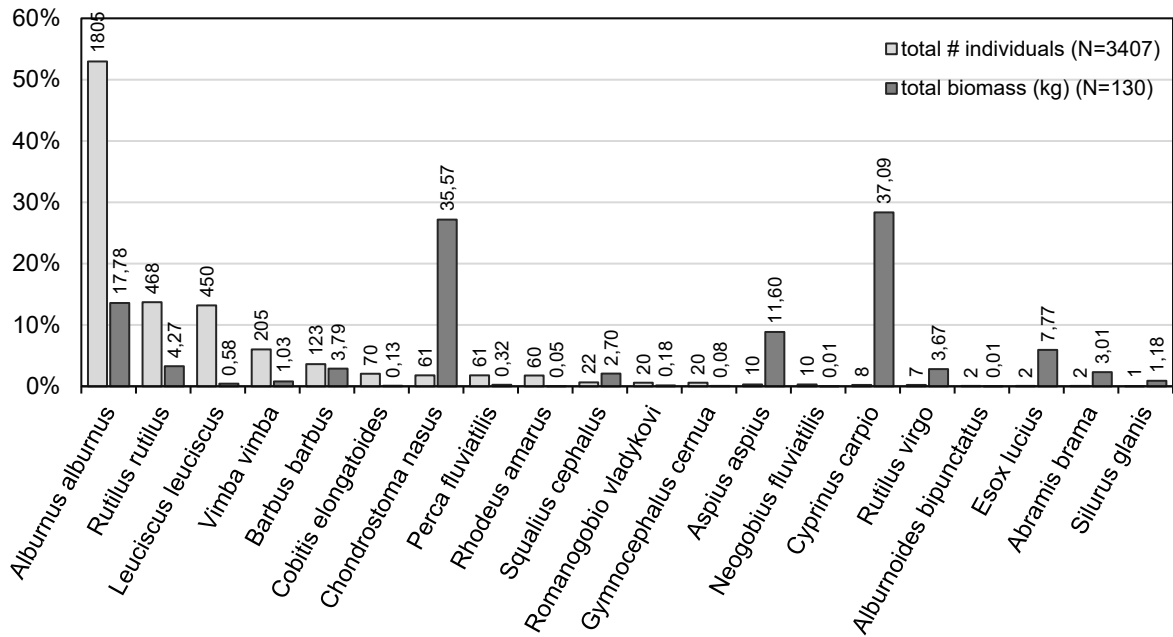


Figure 22: Relative and total numbers of caught fish individuals and fish biomass in kg in section 4 (Mura & Drava) per species. Data is arranged in descending order based on relative fish abundance. All caught and identified species are displayed.

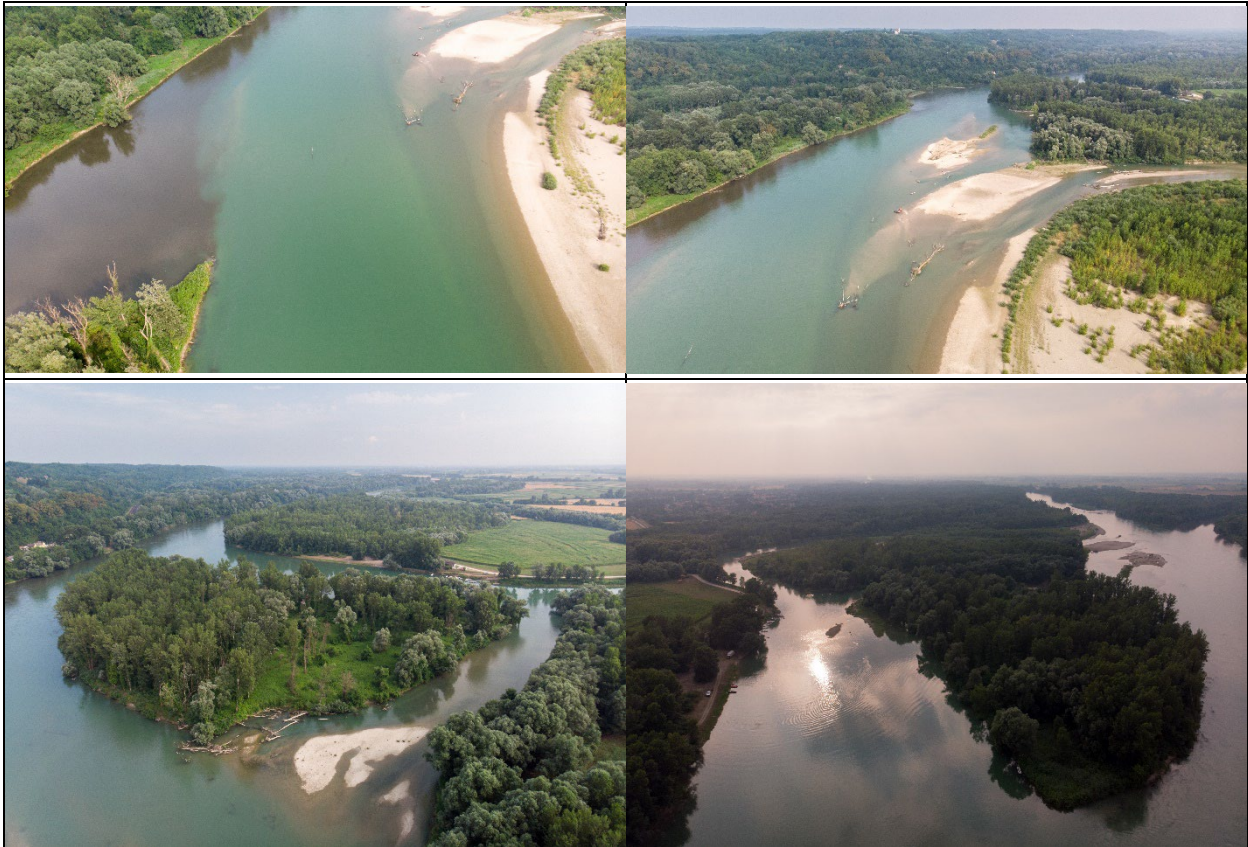


Figure 23: Confluence of Mura and Drava - sampling section S4.

Due to the hydropower operation at Donja Dubrava (~8km upstream), the natural flow is significantly altered in this section. Depending on the overall hydrological situation, the turbines are switched on and off up to several times per day, leading to major fluctuations in the Drava discharge. This form of operation (hydropeaking) potentially has severe ecological impacts, because the section below the hydropower plant is exposed to artificial flow fluctuations events. The periodicity and amplitude of the flow fluctuations (“peaks”) in the Drava follow the natural hydrological situation and the operational requirements of the power plant. That is to say, the peaks are not predictable or uniform. However, a hydropeaking pattern can be derived from gauging data in the Drava: In low flow periods, the measured discharge at the gauging station Donja Dubrava (Drava only) fluctuates between just over 100 m<sup>3</sup>/s to over 350 m<sup>3</sup>/s. During medium flow conditions, the discharge varies between 280 and 500 m<sup>3</sup>/s. Above 500 m<sup>3</sup>/s, the powerplant is operated with continuous and maximum turbine capacity (similar to a run-of-river powerplant).

The confluence of the Mura river, which has a natural hydrological regime, buffers the amplitude of the hydropeaks in the Drava to a certain extent. Still, the gauging station at Botovo a few kilometers downstream of the Mura confluence, displays significant flow fluctuations: 230-350 m<sup>3</sup>/s during low flow periods and 500-700 m<sup>3</sup>/s at medium flows.

More details on the operation at the powerplant Donja Dubrava and potential impacts on the fish community are discussed in chapter 4.4.

Although direct impacts of hydropeaking to the fish fauna of the Drava cannot be assessed through this study, it is obvious that the flow fluctuations change the riverine habitat availability and usability, especially in shallow shoreline habitats. These are habitats that are critical for juvenile rheophilic fish and although these habitats are generally available in large amounts in section S4, the usability of these habitats for fish is reckoned to be small due to the frequent exposure to water level changes.

### 3.1.5.1 Drava above Mura-confluence (Section SD)

The Drava stretch between the outlet channel of the hydropower plant Donja Dubrava and the confluence with the Mura was sampled on July 17 and only with the large electrofishing boat. Sampling of this section resulted in a smaller number of fishing strips. The sampled river section is about 6,5 km long. Seven fishing strips were sampled, resulting in a total fished surface area of 1,45 hectares. In total, 15 species were caught.

Table 9: Overview on locality and fishing effort in section SD.

Section "D"		DRAVA		Croatia	
Date:	17.07.2021				
Starting point:	Donja Dubrava, Croatia (rkm: 242)	46,313596,	16,791136		
End point:	Legrad, Croatia (rkm: 236)	46,307076,	16,870366		
Section length: 6,5 km	Water Temperature: 21,7 °C	Discharge (m <sup>3</sup> /s): 480 (Botovo)			
Conductivity: 250 µS/cm	pH: 7,68	Oxygen: 8,62 mg/L			
Fishing effort					
			Total (large boat only)		
Number of strips fished			7		
total length fished (km)			2,43		
total area fished (ha)			1,455		
Average water depth (m)			2,1		
Average maximum depth (m)			2,8		
Average flow velocity (m/s)			1,0		
Total catch					
total fish abundance (# individuals)			816		
total biomass (kg)			48		
total species number: 15					
flow preference:					
# rheophilic	4	# oligorheophilic	2	# indifferent	9
# limnophilic	0				
spawning preference:					
# rheopar	6	# euryopar	7	# limnopar	2
habitat structure preference:					
# highly structure-bound	3	# medium structure-bound	7	# not structure-bound	5

The characteristic of this section is – on the upstream end – defined by the tailwater channel of the HPP, which is a canal with embankments on either side and homogenous water depth. The whole channel below the power plant is about 4,5 km long, although only the lowermost 1 km until the confluence with the residual flow water was sampled. The residual flow stretch follows the “old” Drava riverbed on the right side of the

hydropower channel (see next chapter). From the confluence onwards (below the town of Donja Dubrava), the Drava flows about 5,8 km until it reaches the confluence with the Mura (S4). Although, the morphology in this stretch can be considered near-natural, this segment of the Drava is most severely affected by the hydropower operation, respectively the hydropeaking activity at Donja Dubrava. The water released by the power plant is very clear and the released sediments are mostly fine to coarse gravel (grain sizes approx. 5-30 mm) with fine sediments almost completely lacking. The gravel layer along the shorelines is therefore extremely loose.

The total number of fish caught in this section was low, even when considering the lower sampling intensity. Only 816 total individuals were caught, 80% of those were bleak, making it by far the most frequent species in this section. Most of the bleak were caught in the tailrace channel below the power plant. The chub and the stone loach were 2<sup>nd</sup> and 3<sup>rd</sup> in total catch numbers (~5% each). The chub also accounted for the highest share in total fish biomass (17,5 kg, 36%). Altogether, the catch biomass was relatively low (48 kg). The vast share of the total biomass was added through single larger individuals of chub, nase, cactus roach or asp. It is also noteworthy, that no small or juvenile rheophilic fish (like nase or barbel) were caught in this section. We assume that the main reason for this is the lack of suitable juvenile fish habitat due to the flow fluctuations.

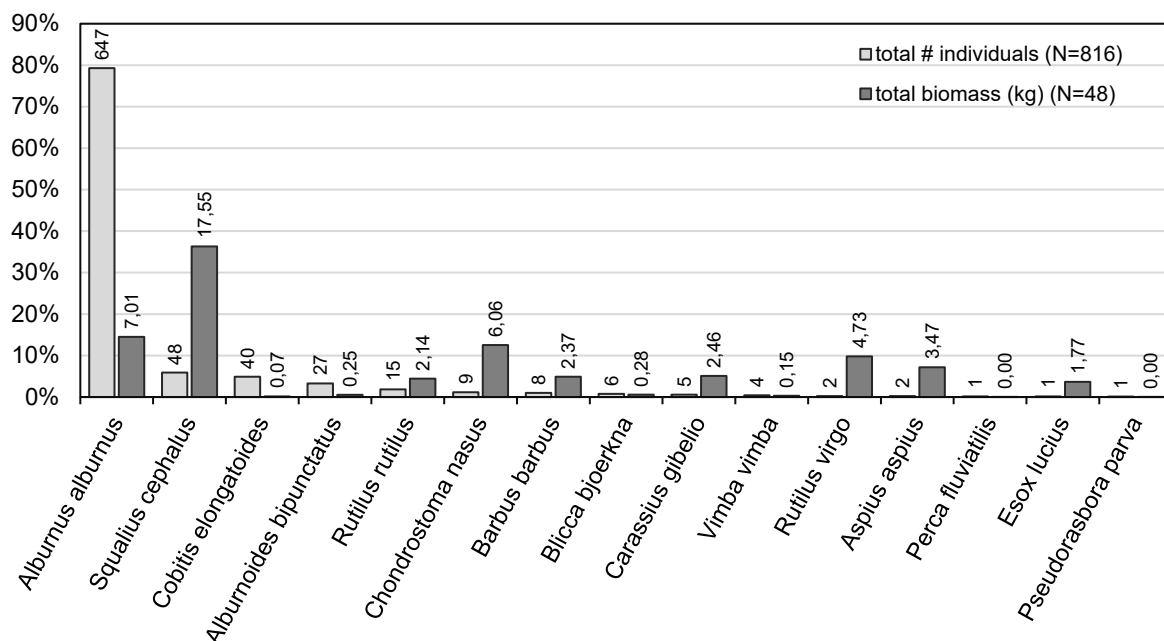


Figure 24: Relative and total numbers of caught fish individuals and fish biomass in kg in section below Donja Dubrava power plant (Drava) per species. Data is arranged in descending order based on relative fish abundance. All caught and identified species are displayed.





Figure 25: Drava in sampling section SD – below power plant Donja Dubrava.

### 3.1.5.2 Residual flow stretch Drava (Section SR)

The residual flow section represents the “old” Drava riverbed that was the main channel before the construction of the hydropower plant Donja Dubrava. It runs south of the tailwater channel of the HPP and is about 11 km long and thereby considerably longer than the 6,5 km long channel. The section also comprises the confluences of two tributaries (the Pltivica and the Bednja). Although the channel morphology in the old Drava bed has only been

changed slightly (occasional embankments and training structures), the characteristic of this section is defined by the amount of water released at the hydropower dam on the upstream end of the section. The baseflow amounts to 20m<sup>3</sup>/s, which is exceeded only during high flow periods that usually occur in late summer/autumn as well

as during snow melting in the alpine catchment (April & May) – i.e. less than 20 days per year on average (Croatian waters, voda.hr). This however means that dynamic river processes linked to seasonal/temporal discharge changes are drastically reduced in this section and the overall habitat availability is much lower compared to the historic state, where discharge in this section was about 10-15 times higher.

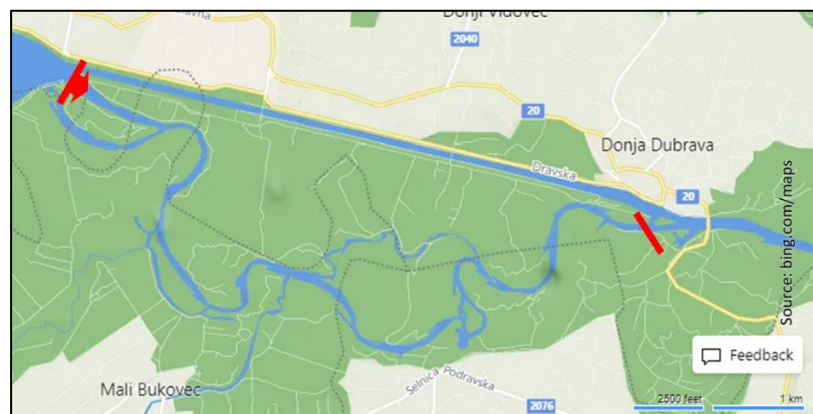


Figure 26: Location of the residual flow section of HPP Donja Dubrava in the Drava above the Mura confluence – sampled via electrofishing on July 17 and July 20, 2021.



The residual flow stretch was sampled on July 17 with the smaller boat and on July 20 with the larger boat. The flow- and weather conditions were comparable on both days. In total, 24 strips were sampled amounting to a fished area of 1,66 ha. The average flow velocity (0,5 m/s) and average water depth (0,8 m) in the sampled strips was considerably lower than in section SD. The total catch number was just shy of 5.000 individuals with a total catch biomass of 202 kg. Overall, 30 species were recorded of which 9 were rheophilic, 3 oligorheophilic, 15 indifferent and 3 limnophilic. 13 of the 30 species are considered rheopar, 15 are euryopar and 3 limnopar.

Table 10: Overview on locality and fishing effort in section SR.

Section "R"		DRAVA		Croatia	
Date:	17 & 19.07.2021				
Starting point:	Sveta Marija, Croatia		46,322802; 16,726586		
End point:	Donja Dubrava, Croatia		46,308355, 16,809227		
Section length: 11,1 km			Discharge: 20 m <sup>2</sup> /s		
Fishing effort					
	small boat		large boat		total
Number of strips fished	15		9		24
total length fished (km)	1,32		2,33		3,65
total area fished (ha)	0,26		1,40		1,66
Average water depth (m)	0,7		1,1		0,8
Average maximum depth (m)	1,1		2,4		1,5
Average flow velocity (m/s)	0,3		1,0		0,5
Total catch					
total fish abundance (# individuals)	1.687		3.304		4.990
total biomass (kg)	31		171		202
total species number: 30					
flow preference:					
# rheophilic	9	# oligorheophilic	3	# indifferent	15
		# limnophilic	3		
spawning preference:					
# rheopar	13	# euryopar	12	# limnopar	5
habitat structure preference:					
# highly structure-bound	9	# medium structure-bound	16	# not structure-bound	5

The most frequently caught fish in the residual flow stretch was the bleak (one third of the total catch, 1.665 individuals). The chub and spiralin combined for another third of the total catch, followed by the bitterling (9%), the vimba bream (8%) and the roach (5%). Barbel and Nase were caught in smaller numbers (4% and 2% of the total catch), but accounted for 50% of the total biomass (76 kg nase, 23 kg barbel). The chub had a biomass share of 30% and the bleak a share of 16%.

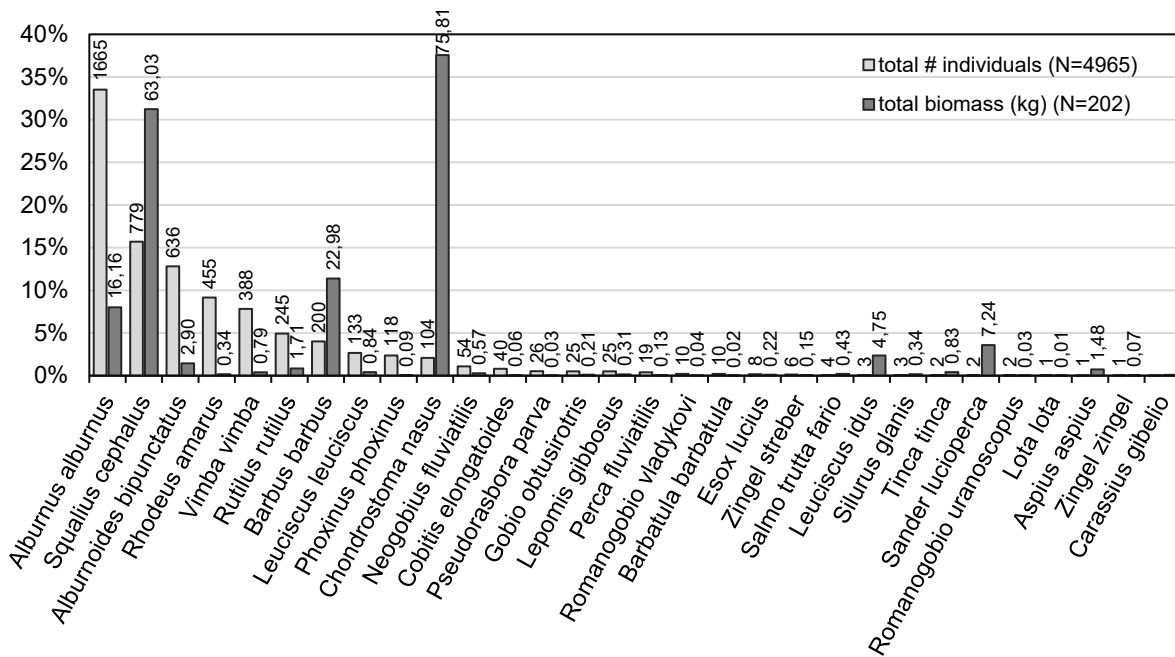


Figure 27: Relative and total numbers of caught fish individuals and fish biomass in kg in the residual flow section (Drava) per species. Data is arranged in descending order based on relative fish abundance. All caught and identified species are displayed.



Figure 28: Sampling section SR – residual flow stretch in old Drava riverbed.

### 3.1.6 Section 5 – Drava – 25km downstream of Mura confluence

Section 5 is located about 25 km downstream of the Mura confluence between the Croatian towns of Gola, Hlebine and Molve. Sampling was carried out on July 21. In total, the section is about 6,5 km long (rkm 214 to rkm 207,5). The morphology of the Drava within this section is described as transitional zone from an anabranching system to a meandering river. The dimension of the Drava from this section onwards is considerably larger than in the sections described above. The shoreline is in part natural or near-natural, in some areas hard embankments and river regulation structures are found. The section also comprises large gravel bars.

After significant rainfall on the evenings of July 18 and 19, the discharge in the Drava was above mean water level for the following sampling days. During sampling in S5, the discharge was about 650 m<sup>3</sup>/s. Thus, a majority of the habitats within the main channel were not visible/accessible during the sampling and the significantly higher turbidity (and lower visibility) of the water made sampling more difficult. The average water depth within the sampling strips was 1,3 m – similar to the sections S4 and S3. The average flow velocity was 0,7 m/s and thereby also similar to the sections upstream.

33 strips were sampled in section 5. The total fished length was 9,1 km and the fished area 4,29 ha. In total, over 12.000 fish were recorded and the total catch biomass was 330 kg. 26 species were detected. The fish community is dominated by indifferent species (15), followed by rheophilic (6), limnophilic (3) and oligorheophilic (2). Regarding spawning habitat, species without clear flow preference (euryopar) are most frequent with 11, followed by rheopar species with 9. 6 limnopar species were recorded.

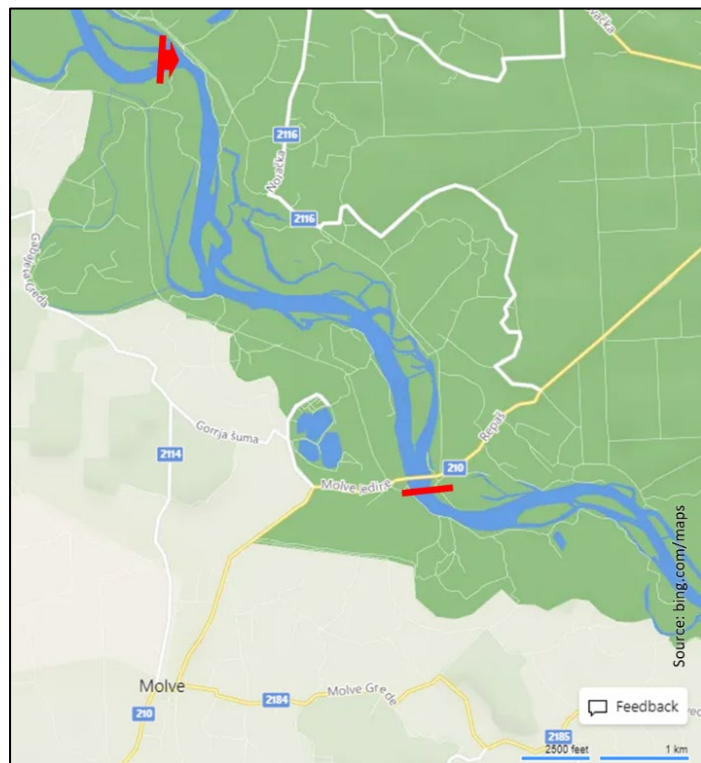


Figure 29: Location of section 5 in the Croatian Drava – sampled via electrofishing on July 20<sup>th</sup>, 2021.

Table 11: Overview on locality and fishing effort in section S5.

Section 5		DRAVA		Croatia			
Date:	21.07.2021						
Starting point:	Gola, Croatia (rkm: 214)	46,170302, 17,037039					
End point:	Molve, Croatia (rkm: 207,5)	46,127958, 17,071185					
Section length: 6,5 km	Water Temperature: 20,4 °C	Discharge (m <sup>3</sup> /s): 650 (Novo Virje skela)					
Conductivity: 235 µS/cm	pH: 7,96	Oxygen: 9,0 mg/L					
Fishing effort							
	small boat	large boat	total				
Number of strips fished	17	16	33				
total length fished (km)	2,9	6,19	9,09				
total area fished (ha)	0,58	3,71	4,29				
Average water depth (m)	0,9	1,7	1,3				
Average maximum depth (m)	1,3	2,6	2,0				
Average flow velocity (m/s)	0,6	0,9	0,7				
Total catch							
total fish abundance (# individuals)	9.681	2.551	12.232				
total biomass (kg)	147	183	330				
total species number: 26							
flow preference:							
# rheophilic	6	# oligorheophilic	2	# indifferent	15	# limnophilic	3
spawning preference:							
# rheopar	9	# euryopar	11	# limnopar	6		
habitat structure preference:							
# highly structure-bound	5	# medium structure-bound	14	# not structure-bound	7		

The total catch numbers in section S5 were high compared to other sections. The vast majority of registered fish were bleak (45%, 5.395 ind.), which also accounted for 14% (45 kg) of the total catch biomass. Other frequent species include the white bream, the vimba bream (10% each), the nase (9%), the roach (8%), the chub (6%) and the bitterling (5%). Other species had shares of less than 2% of the total abundance. Regarding fish biomass, the nase had the highest share with 33% (110 kg), followed by bleak and chub (14% each). Overall, the biomass distribution was more balanced than in other sections, with 11 additional species reaching at least 5 kg of catch biomass.

The relatively high catch numbers and biomasses may in part be a result of the flow- and sampling conditions during this day. It is likely that during higher flow conditions, more fish are seeking and moving to refugial habitats located along the shorelines and in side channels, etc. These habitats were also the ones that were sampled more intensely due to the water turbidity on this day.



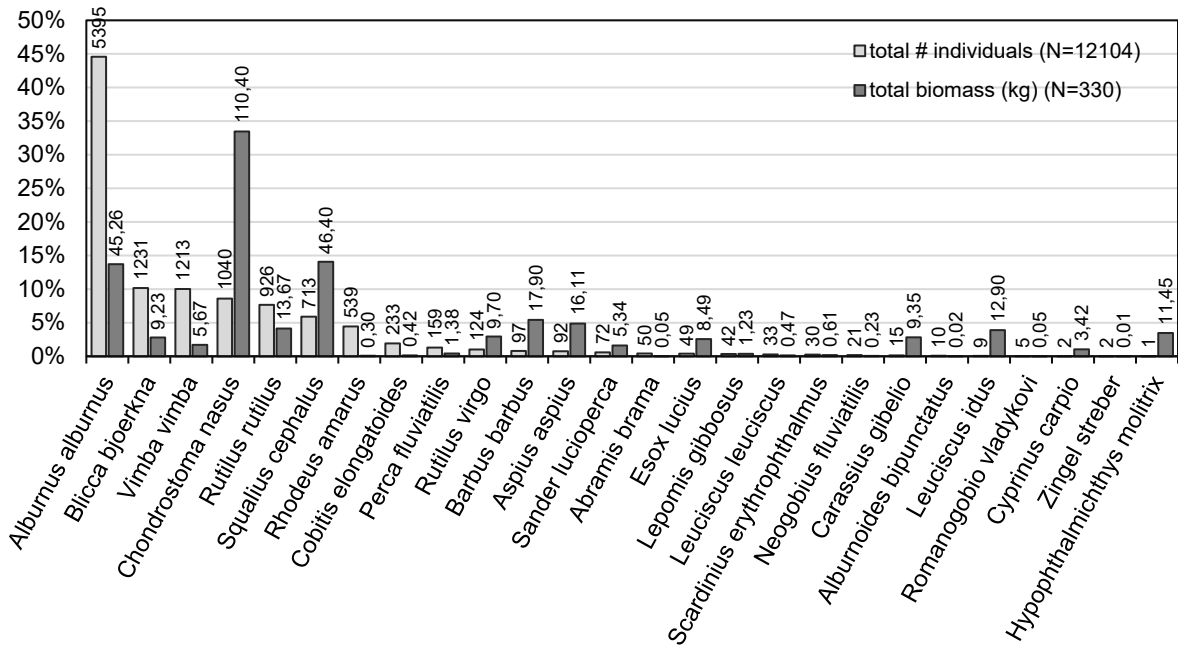


Figure 30: Relative and total numbers of caught fish individuals and fish biomass in kg in section 5 (Drava) per species. Data is arranged in descending order based on relative fish abundance. All caught and identified species are displayed.



Figure 31: Sampling section S5 – Drava.



### 3.1.7 Section 6 – Drava – Border Drava Croatia & Hungary

Section 6 was sampled on July 22. It spans between the towns of Pitomaca (rkm: 173,5) and Lukac/Terezino Polje (rkm: 153) along the Hungarian-Croatian border. The Hungarian town of Barcs is located at the end of this section. This stretch is characterized as the beginning of a single-main channel meandering Drava with several side-channels and floodplain waterbodies. The substrate composition is dominated by sand. Gravel fractions are significantly lower than in sections upstream. The outer banks of the main channel have been altered through training structures. Similar to the situation in section S5, the discharge during sampling was at about annual mean level because of the rainfall in previous days. This also led to a reduced visibility/higher turbidity in the Drava.

Sampling commenced at the pedestrian bridge (Skela Križnica) and finished below the border-bridge between Terezino Polje and Barcs. The sampled stretch is about 20 km long. The total fished length amounts to 7,4 km (28 fishing strips), respectively 5,45 ha.

The average flow velocity in the sampling strips is further reduced from the previous section (from 0,7 m/s to 0,4 m/s). In total, over 5.800 fish were caught. The total catch biomass was 202 kg. 29 species could be detected of which 4 were rheophilic, 4 oligorheophilic, 16 indifferent and 5 limnophilic. Regarding their spawning habitat preference, 9 species are considered rheopar, 15 are euryopar and 5 are limnophilic.

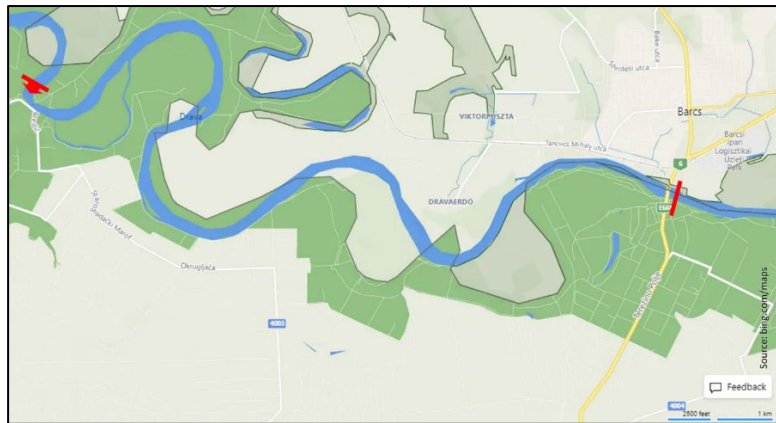


Figure 32: Location of section 6 – Drava between Croatia and Hungary – sampled via electrofishing on July 22, 2021.

Table 12: Overview on locality and fishing effort in section S6.

Section 6		DRAVA		Croatia & Hungary			
Date:	22.07.2021						
Starting point:	Pitomaca, Croatia (rkm: 173,5) 45,964336, 17,312910						
End point:	Lukac, Croatia (rkm: 153) 45,944412, 17,462529						
Section length: 20,5 km	Water Temperature: 20,5°C		Discharge (m <sup>3</sup> /s): 624 (Terezino Polje)				
Conductivity: 239 µS/cm	pH: 7,72		Oxygen: 8,62 mg/L				
Fishing effort							
	small boat	large boat	total				
Number of strips fished	11	17	28				
total length fished (km)	2,18	5,22	7,40				
total area fished (ha)	0,44	3,13	3,57				
Average water depth (m)	0,7	1,3	1,1				
Average maximum depth (m)	1,2	2,3	1,8				
Average flow velocity (m/s)	0,2	0,6	0,4				
Total catch							
total fish abundance (# individuals)	3.626	2.185	5.811				
total biomass (kg)	65	136	201				
total species number: 29							
flow preference:							
# rheophilic	4	# oligorheophilic	4	# indifferent	16	# limnophilic	5
spawning preference:							
# rheopar	9	# euryopar	12	# limnopar	8		
habitat structure preference:							
# highly structure-bound	8	# medium structure-bound	14	# not structure-bound	7		

The most frequent species in section 6 was once again the bleak with 50% of all individuals (nearly 3.000). The chub, nase, roach and barbel followed in descending order (from 13% to 3,5%). The overall catch biomass was made up by almost equal shares of the silver carp and the nase (22%, 44 kg each). Although only few individuals of the silver carp were caught, the large body size of these fish resulted in the high biomass share. Further, the bleak, the chub and the roach had considerable share of the total biomass.

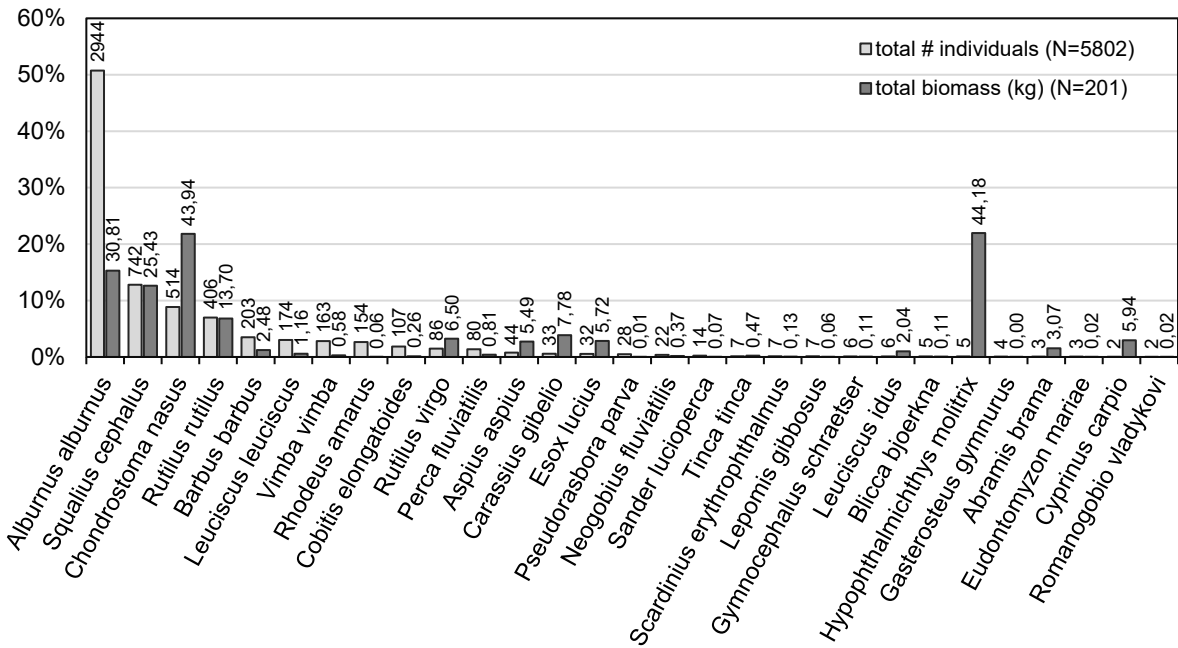


Figure 33: Relative and total numbers of caught fish individuals and fish biomass in kg in section 6 (Drava) per species. Data is arranged in descending order based on relative fish abundance. All caught and identified species are displayed.



Figure 34: Sampling section S6 – Drava.

### 3.1.8 Section 7 – Drava – downstream Donji Miholjac

Section 7 represents the lowermost sampling stretch in the Drava. It extends downstream of Donji Miholjac between river kilometers 80 and 66,5. This section was sampled on July 23. On the upper end of this section, around Donji Miholjac, a large fish farm is established with a total surface area of 975 ha (Opačak et al., 2003). The overall characteristic of this section is comparable to section S6. The flow velocities are reduced compared to sections further upstream and the substrate composition is dominated by finer material. Most outer banks are stabilized through training structures, although the overall channel morphology is still considered near-natural.

The discharge stayed relatively constant compared to the previous two sampling days (slightly above annual mean discharge), resulting in still reduced visibility in the water. In total, 28 strips were sampled. The overall sampled length amounted to 5,76 km covering a surface area of 2,97 ha.

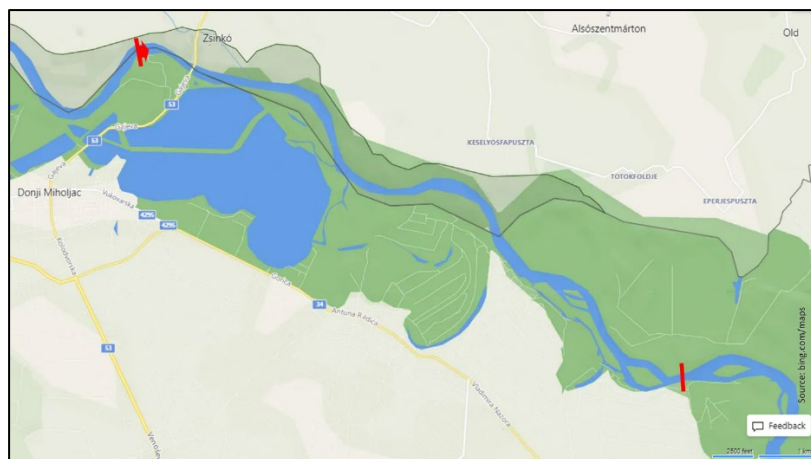


Figure 35: Location of section 7 – sampled via electrofishing on July 23, 2021.

32 species could be recorded. 8 of these 32 species are considered rheophilic or oligorheophilic (4 each), 21 are indifferent and 3 are limnophilic. Regarding spawning preference, 9 species are rheopar, 17 are euryopar and 5 are limnopar. The amount of species that clearly prefer faster flowing conditions is already drastically lower in this section.



Table 13: Overview on locality and fishing effort in section 7.

Section 7		DRAVA		Croatia & Hungary	
Date:	23.07.2021				
Starting point:	Donji Miholjac, Croatia (rkm: 79,5) 45,786066, 18,190581				
End point:	Belisce, Croatia (rkm: 66,5) 45,728733, 18,325597				
Section length: 13 km	Water Temperature: 22,4 °C		Discharge (m <sup>3</sup> /s): 595 (Donji Miholjac)		
Conductivity: 245 µS/cm	pH: 7,95		Oxygen: 8,98 mg/L		
Fishing effort					
	small boat		large boat		total
Number of strips fished	13		15		28
total length fished (km)	1,22		4,54		5,76
total area fished (ha)	0,24		2,72		2,97
Average water depth (m)	0,7		1,4		1,1
Average maximum depth (m)	1,1		2,5		1,8
Average flow velocity (m/s)	0,2		0,4		0,3
Total catch					
total fish abundance (# individuals)	2.247		5.237		7.484
total biomass (kg)	13		139		152
total species number: 32					
flow preference:					
# rheophilic	4	# oligorheophilic	4	# indifferent	21
# limnophilic	3				
spawning preference:					
# rheopar	9	# euryopar	17	# limnopar	5
habitat structure preference:					
# highly structure-bound	11	# medium structure-bound	12	# not structure-bound	8

Although the total species number was relatively high with 32 detected fish species, the fish community was dominated by the bleak – accounting for 70% of the total abundance and 38% of the catch biomass. Regarding total biomass, the asp and the pike – two piscivorous species – had the second- and third highest share with 20% and 13% (30,5 kg and 20,2 kg). In terms of fish abundance, the roach (623 individuals), the bitterling (420 ind.) and the chub (315 ind.) had shares of above 2% of the total catch.



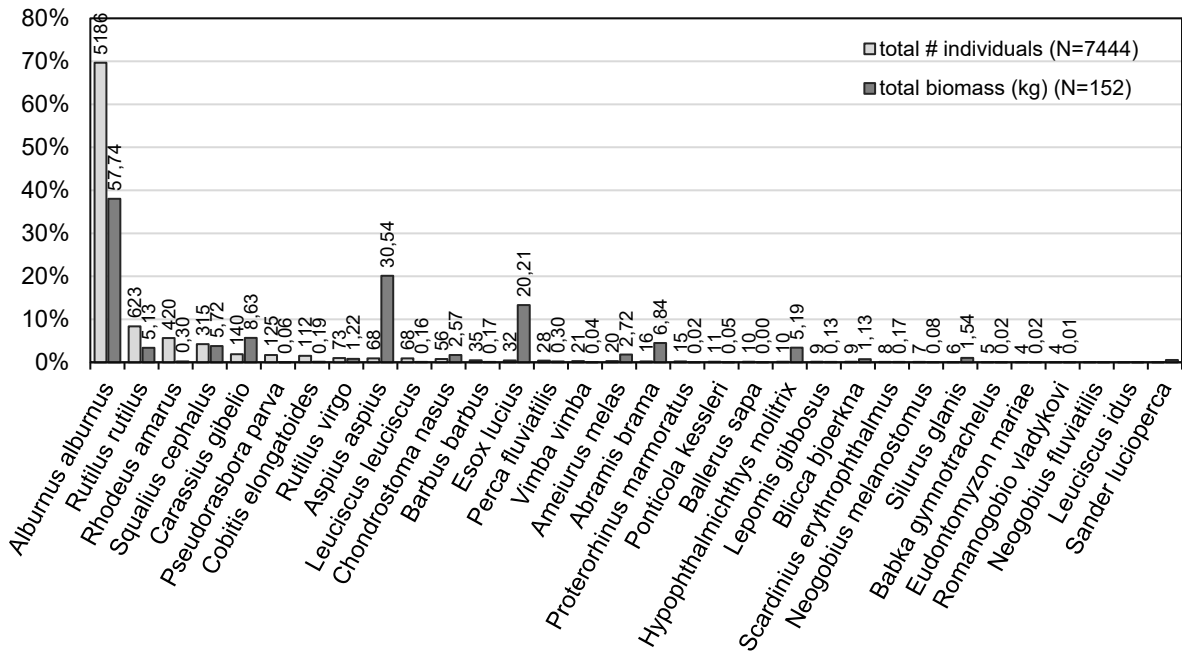


Figure 36: Relative and total numbers of caught fish individuals and fish biomass in kg in section 7 (Drava) per species. Data is arranged in descending order based on relative fish abundance. All caught and identified species are displayed.



Figure 37: Sampling section S7 – Drava.

## 3.2 Comparative Results

To investigate the longitudinal change of the fish cenosis in more detail, this chapter highlights selected results that show differences between the single sections based on species distribution and fish community structure.

### 3.2.1 Selected Species

In this chapter, the longitudinal zonation and differences in population structure of different species shall be highlighted. Detailed catch numbers for each species are provided in the appendix.

#### 3.2.1.1 Nase – *Chondrostoma nasus*

The nase is a member of the cyprinid fish family. It is characterized as a rheophilic fish species that inhabits medium sized and large rivers and reaches sizes of around 55 cm. In spring (between March and May), the nase undertakes migrations of several kilometers up to over 100 km to reach its spawning places. Typical spawning sites for the nase have been described as rather shallow water zones (<50cm) with high flow velocities (0,5-1,5 m/s) and coarse gravel. Suitable spawning sites therefore are mostly found along gravel banks and in tributaries of larger rivers. After spawning, adult specimen will leave the spawning site and migrate downstream to deeper water areas. Young juveniles remain in shallow zones with low flow velocities for rearing. During its lifecycle, the nase is dependent on different riverine habitats (Melcher & Schmutz, 2010; Huber & Kirchhofer, 1998, Peñáz, 1996). The nase is one of the most commonly found species in both the Mura and Drava and due to its different habitat requirements throughout its lifecycle and the migratory behavior, it is considered a flagship species for the TBR MDD.

*Table 14: Overview on catch parameters of nase – Chondrostoma nasus – in sampled section in Mura and Drava. Relative dominance describes share of nase in total catch numbers and biomass per section.*

	S1	S2	S3	S4	S5	S6	S7	SR	SD	Total
Total catch (individuals)	303	139	177	61	1040	514	56	104	9	2403
Relative total dominance (ind)	7%	3%	4%	2%	9%	9%	1%	2%	1%	5%
Total catch biomass (kg)	124	26	44	36	110	44	3	76	6	468
Relative weight dominance (kg)	42%	14%	33%	27%	33%	22%	2%	38%	13%	28%
Mean length (mm)	259	164	211	362	139	132	78	323	375	173
SD length	150	134	131	34	100	98	88	185	44	131
Mean weight (g)	408	184	250	580	106	85	46	732	649	195
SD weight	413	327	315	210	257	166	134	521	222	335

In the Mura and Drava, nase have been caught in all investigated sections. The highest number of nase (1.040 individuals) was caught in section S5 (25km below the Mura

confluence). In sections S5 and S6 the nase accounted for 9% of the total fish abundance. In other stretches of the Drava, this share was much lower (1-2%). In the uppermost section of the Mura (S1), the nase had a share of 7% of all individuals. In sections 2 and 3, the share was lower (3 and 4%). Regarding the total catch biomass, the nase accounted for a relatively high share in almost all sections. The highest biomass dominance was recorded in S1 – the uppermost section of the Mura. 42% (124 kg) of the total catch biomass were allocated to the nase. This share dropped to 14% in section 2 and rose to 33% in section 3. In the Drava, the nase had biomass shares between 22% (S6) and 38% (in the residual flow stretch, SR). In section 7, the share of nase was very low – accounting for only 2% of the total catch biomass. During sampling in Serbia (see chapter 3.3), only 5 individuals of the nase were recorded at one site in the pilot area Karadordevo.

Besides the stated differences in total catch numbers and catch biomass per section, the recorded fish sizes (and consequently also fish weight) of nase differed significantly between the sampled stretches (Figure 37). The average length (in mm) and weight (in g) of nase is displayed in Table 14. In the Mura (S1-3), the average size ranged between 164 and 259 mm. Individuals caught in S1 were larger than in S3 and S2. In section S4 (Drava at Mura confluence), the average size of nase was even bigger (362 mm) although the total abundance of nase was low compared to the Mura sections. In



Figure 38: two examples of caught nase – *Chondrostoma nasus* from the Mura and Drava.

the residual flow stretch (SR) in the Drava, the average size of nase was also high (323 mm). In the Drava upstream of the Mura confluence (SD), the highest average size was recorded. However, the total catch number in SD was very low (only 9 specimen). Nase from lower parts of the Drava (sections 5-7) were considerably smaller than in the upper sections. The average size ranged between 78 and 139 mm.



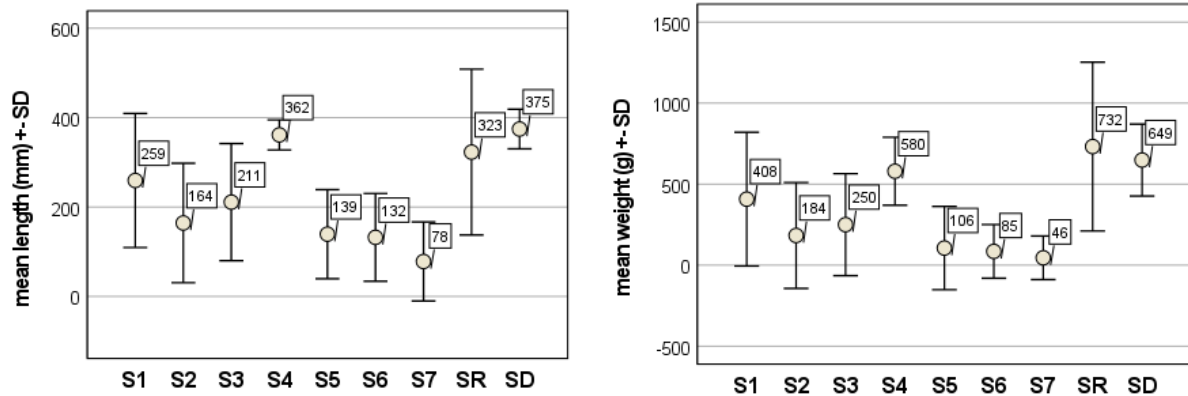
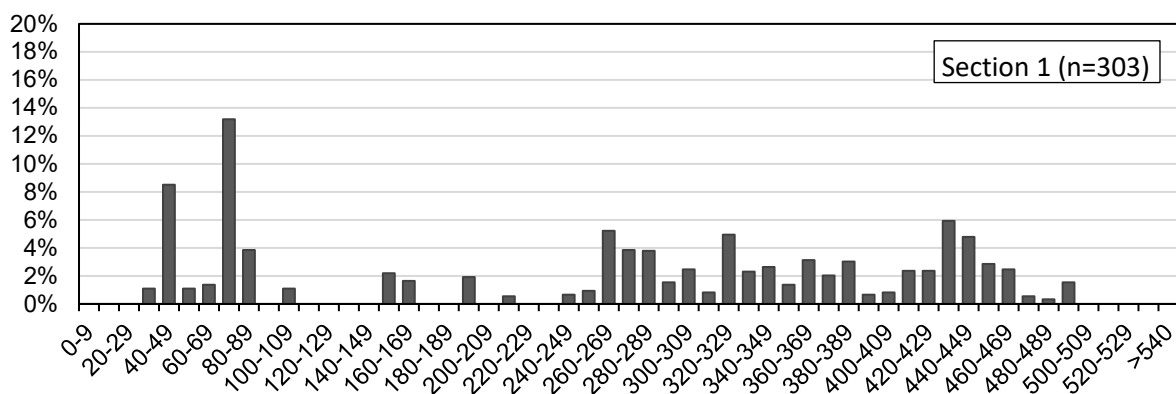


Figure 39: Error bar plot of mean length and mean weight (+/- std. deviation) of nase in sampled sections in the Mura and Drava.

The differences in fish size of nase per investigated section have been analyzed closer by plotting length-frequency graphs displaying the size distribution of nase for each section (Figure 38 and Figure 39).

In the Mura (sections 1-3), nase of all size/age classes were caught. All three sections show distinct juvenile year classes (0+ individuals born in spring 2020 and 1+ fish born in spring of 2019). The size differentiation between these two year classes is not clearly identifiable. 0+ individuals have sizes of about 30-60 mm whereas 1+ fish are about 60-110 mm large. In section S3, the 0+ fish are underrepresented compared to the two upstream sections (~2%). S2 shows the highest share of 0+ individuals (30%) and in S1, about 10% of nase caught were 0+ fish.

The 1+ year class accounts for about 20% of caught individuals in S1, 30% in S2 and 40% in S3. The share of 1+ nase therefore rises from S1 to S3. Subadult ("medium-sized", probably in age class 2+) fish were rarely caught in S1. Only 6% of all nase had sizes between 110 and 240 mm. The share of these fish was higher in S2 (17%) and S3 (16%). Adult specimen were most frequent in section S1, both in terms of absolute catch number (193 individuals) and relative share (63% of all nase). In S2, only 25% of specimen were adult nase and in S3, 40%. Maximum sizes of caught nase in the Mura were at about 500 mm in all three sections.



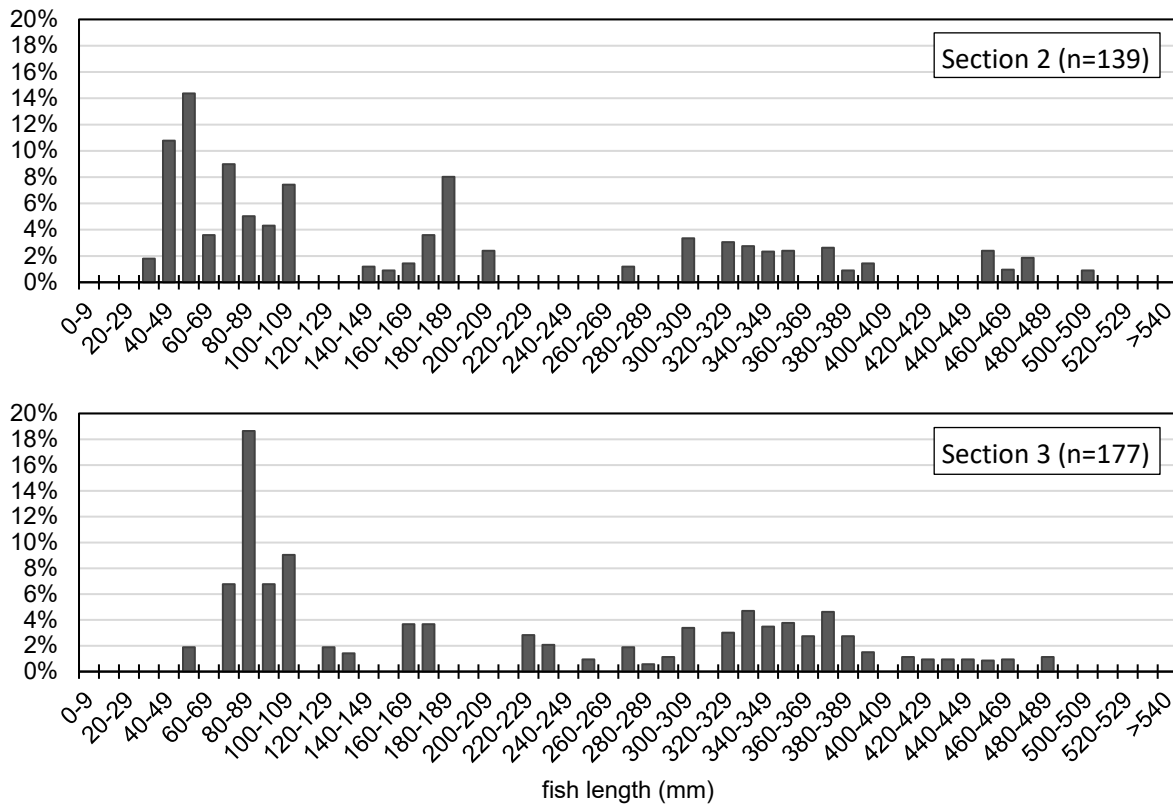
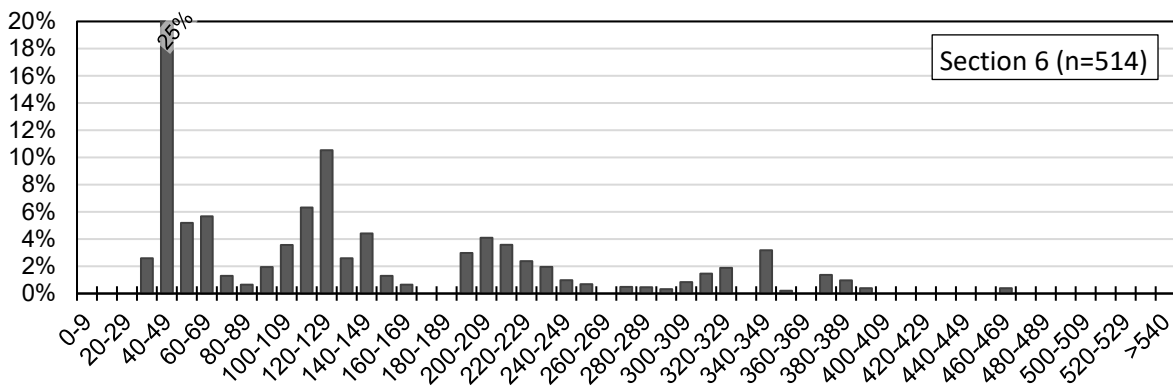
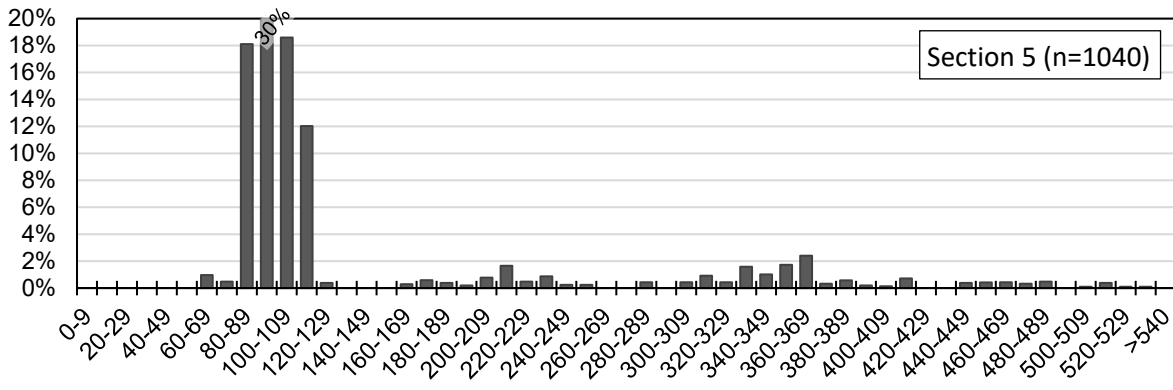
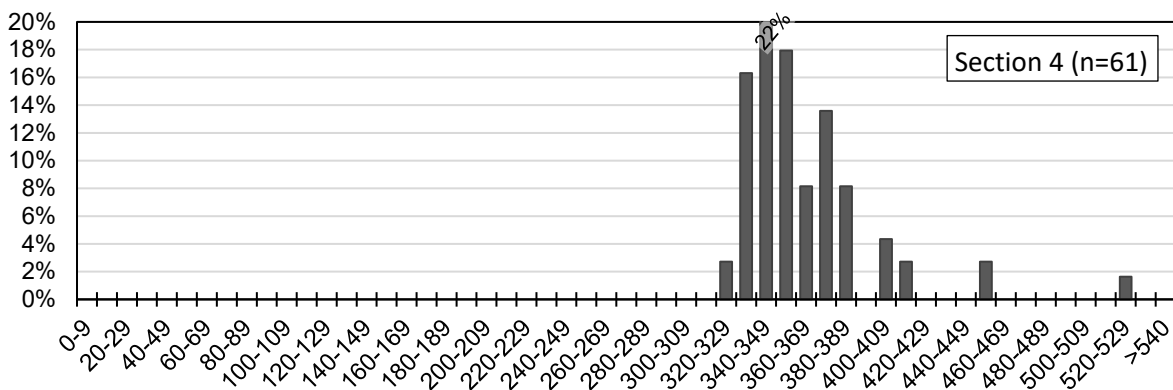
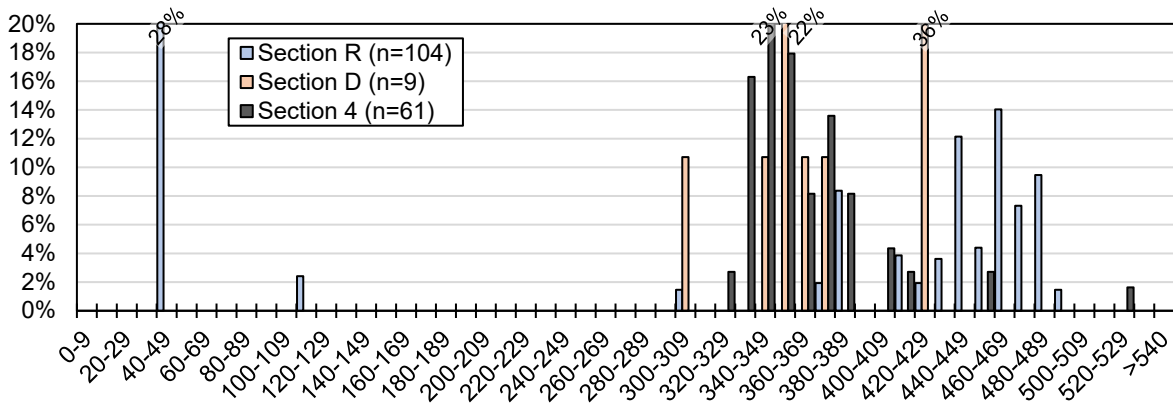


Figure 40: Length-frequency plot of nase (*C. nasus*) displaying the population structure in sampled Mura-sections S1, S2 and S3.

In the Drava the distribution of nase during the sampling in July was more heterogenous. In the uppermost sampled section (S4 – confluence with the Mura and the upstream located sections SR – residual flow stretch and SD – Drava below HPP Donja Dubrava) the total number of nase was relatively low. Also, almost all caught individuals were larger adult fish (>300 mm). Only in the residual flow section, a few juvenile nase could be caught (0+ and 1+) and no juveniles were detected in SD or S4. Compared to upstream sections in the Mura but also to sections further downstream in the Drava, the reach between the hydropowerplant and the Mura confluence shows a clear lack of juvenile nase.





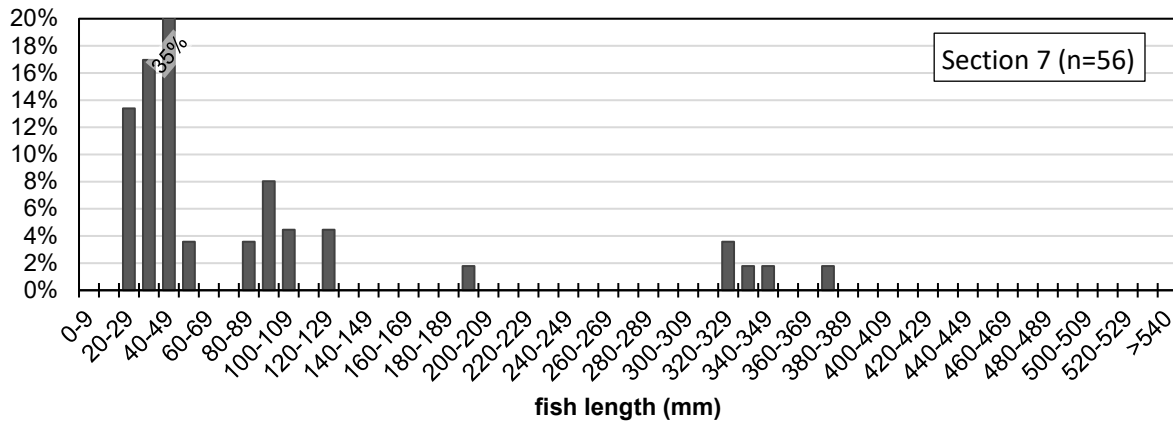


Figure 41: Length-frequency plot of nase (*C. nasus*) displaying the population structure in sampled Drava-sections.

In section 5 –25 km downstream of the Mura, the share of juveniles (0+ and 1+) was by far the highest – with over 80% of nase belonging to that size class. Only 20% of nase in section 5 were subadults and adults, although the total number of individuals in this size class was also high compared with other sections and the population structure in S5 can be considered balanced. In section 6, nase of all size classes were present. The overall picture presents a well-balanced age structure with about 40% 0+ fish, 32% 1+ fish and 28% subadults and adults. Since the maximum sizes of 1+ nase are about 10-15 mm higher in the Drava sections S5 and S6 than in the Mura, young nase obviously grow slightly faster in the Drava compared to the Mura.

In section S7, the total amount (and the relative share) of nase is drastically lower compared to the above described sections. Only 56 nase were caught in total, with adults only caught as single individuals (6 in total). Still, both the 0+ (70%) and 1+ year class (20%) are present.

Overall, a healthy population of nase was assessed in the middle reaches of the Drava (sections S5 and S6) and also in the Mura. In the area of the confluence of Mura and Drava and upstream (sections 4, R and D), juvenile nase were almost completely missing and also adults were caught in lesser frequencies. In section S7 – the number of nase was also lower. This could be also due to the fact that this area is already on the lower end of the natural distribution range of nase in the Drava.

### 3.2.1.2 Barbel – *Barbus barbus*

The barbel is a cyprinid species with a wide distribution range throughout Europe. Similar to the nase, it is characterized as a rheophilic fish species that prefers temperate streams and rivers in mainly lowland areas. It also undertakes spawning migrations in spring (May-July, often slightly later and at warmer temperatures than the nase) to reach suitable spawning habitats in tributaries of larger rivers or along shallow gravel bars. The preferences of flow velocity (~0,4 to 1 m/s), water depth (20-60 cm) and gravel (grain size about 2-6 cm) at the spawning site are similar to the nase. However, adult barbel have less strict habitat requirements and can cope with impounded sections, channelization and/or higher nutrient contents better than the nase (Penaz et al., 2002; Britton & Pegg, 2011).

Barbels often occur in groups and were frequently caught during the sampling in the Mura and Drava. No barbels were caught during sampling Serbia (Danube backwaters).

*Table 15: Overview on catch parameters of barbel – *Barbus barbus* – in sampled section in Mura and Drava. Relative dominance describes share of barbel in total catch numbers and biomass per section.*

	S1	S2	S3	S4	S5	S6	S7	SR	SD	Total
Total catch (individuals)	366	337	189	123	97	203	35	200	8	1558
Relative total dominance (ind)	8%	7%	5%	4%	1%	4%	<1%	4%	1%	3%
Total catch biomass (kg)	77	22	15	4	18	2	0	23	2	164
Relative weight dominance (kg)	26%	12%	11%	3%	5%	1%	<1%	11%	5%	10%
Mean length (mm)	163	84	130	55	164	62	53	171	259	119
SD length	161	109	110	79	147	55	38	97	135	126
Mean weight (g)	212	66	78	31	184	12	5	115	297	105
SD weight	504	286	176	180	505	42	12	335	415	346

Both the total number of caught barbels and their relative dominance within the fish community were highest in the two upper sections of the Mura (~350 ind. and 7-8% of all caught fish). Though the total catch number was comparable in section S1 and S2, much larger barbels were caught in S1 (77 kg total biomass, 26% share) than in S2 (22 kg and 12% share). In the lowest Mura section (S3), the share and total catch number of barbels was slightly lower (189 individuals, 5% share). At the confluence to the Drava, the total number decreased to 123 individuals and just 4 kg catch biomass. Upstream of the confluence, in the Drava below the hydropower plant (SD), only 8 barbels were caught in total. In the residual flow section (SR) further upstream, the number of barbel was much higher (both in terms of total individuals: 200; and biomass: 23 kg).

In section 5- further downstream in the Drava, the total number of caught barbels was below 100, however the total biomass (18 kg; 5% share) was highest compared to other Drava sections (except SR). In section 6, over 200 barbels were recorded, although with a relatively low total biomass of 2 kg (mainly small individuals). In section 7, only 35

barbels were caught making up less than 1% of the total fish community both in terms of individuals and biomass. This is in line with the significant decrease of also nase in the lowermost sampling section.



Figure 42: Barbel (*B. barbus*) caught in the Mura.

The differences in fish size and fish weight between the sampled sections are indicated in Figure 41. Mean length of barbels varied between 5 cm (S7 and S4) to over 250 in SD. However only 8 barbels in total were caught in SD. In sections with total catch numbers of at least 100 individuals, the average length was highest in sections S1, SR and S5 (16-17 cm). The variability in weight was similar between the sections, with an even higher variability within the single sections (high standard deviations for mean weight values).

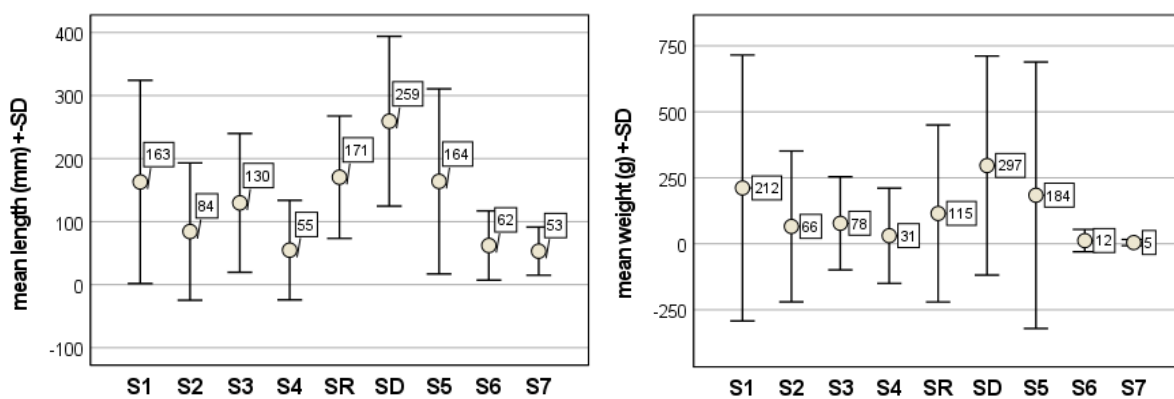


Figure 43: Error bar plot of mean length and mean weight ( $\pm$  std. deviation) of barbel in sampled sections in the Mura and Drava.

The length-frequency distribution of barbel is shown in Figure 42 and Figure 43.

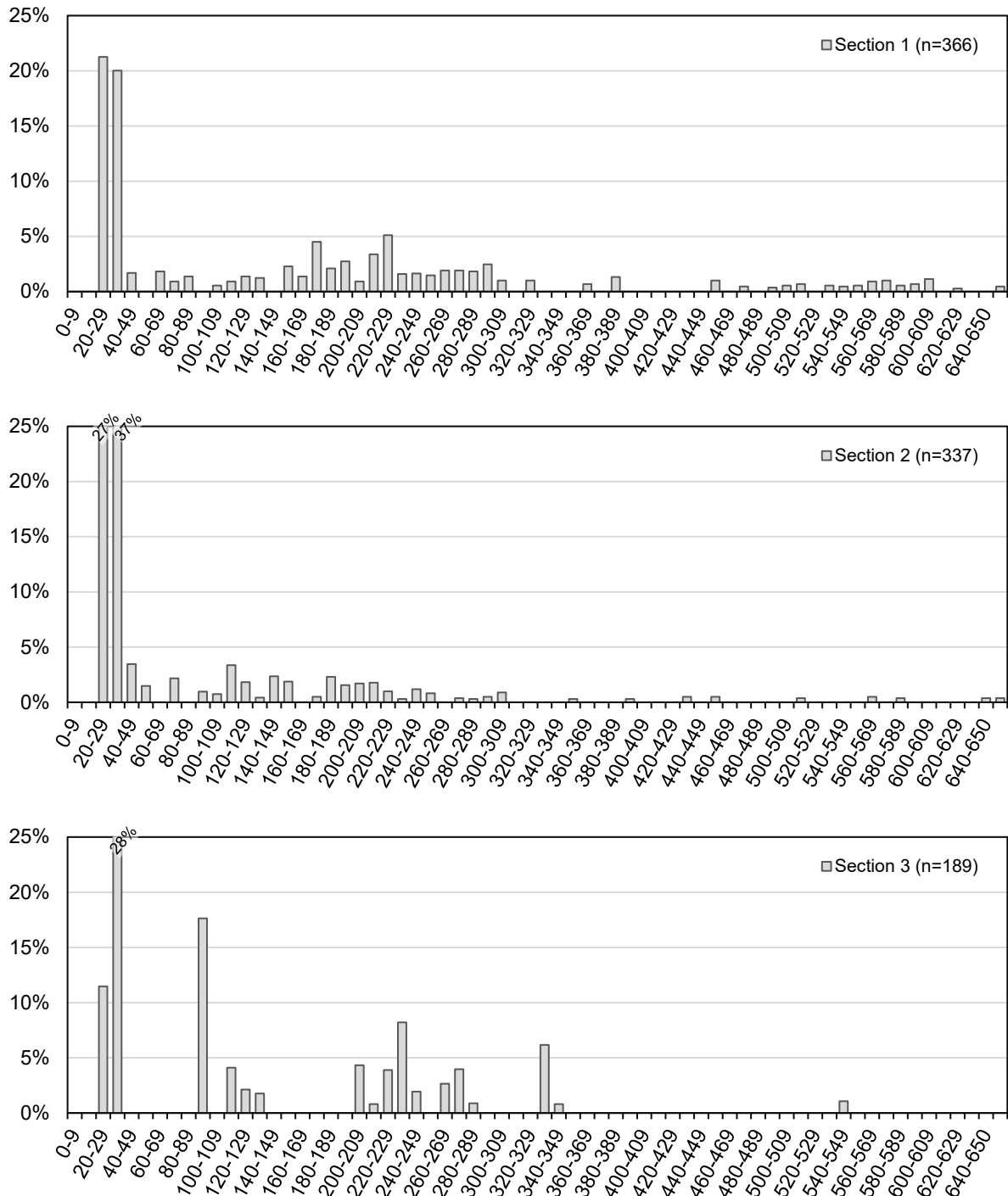
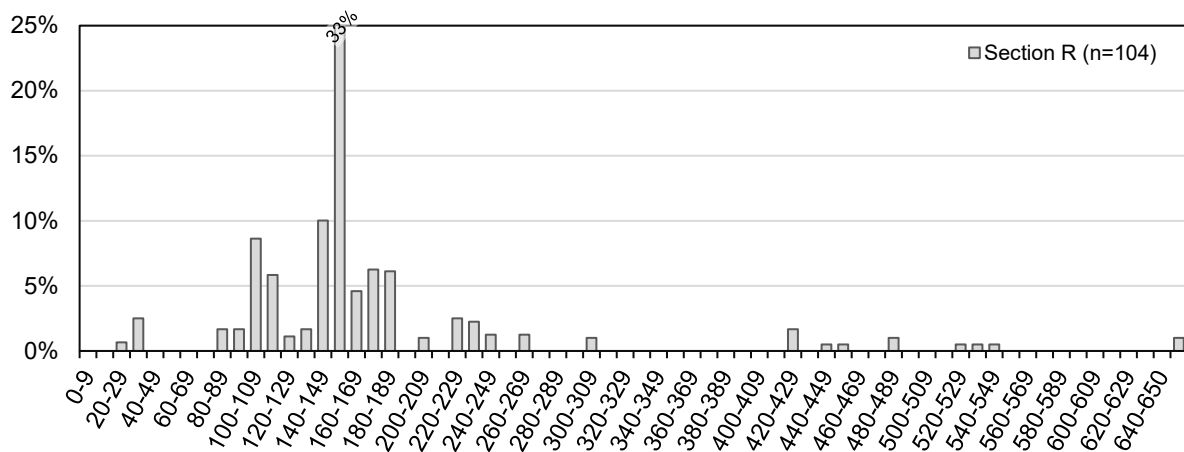
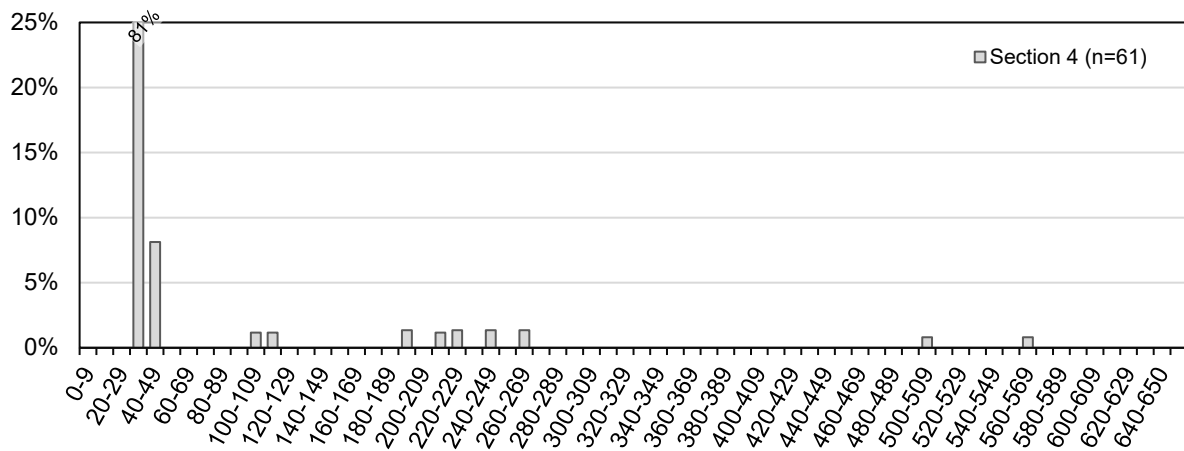


Figure 44: Length-frequency plot of barbel (*B. barbus*) displaying the population structure in sampled Mura-sections.

The age structure of barbel is similar in the two upper investigated Mura sections (S1, S2). In both sections, a distinct 0+ year class is visible (fish with 20-50 mm body length). In S1, the overall share of this size class (41%) is a little lower than in S2 (64%). The size of the



1+ year class (fish that hatched in spring of 2020) is not clearly identifiable. Most likely, barbels with sizes between 60 and 150 mm belong to this age class. The share of larger adult individuals is lower in S2 compared to S1. The largest specimen of barbels had sizes of about 650 mm. In section S3, the overall density of barbels is lower than in upstream sections, but still juvenile (0+, 1+) year classes are present as well as medium sized fish (100-350 mm). Overall, the population structure in the Mura can be summarized as well balanced (lots of juveniles, less larger fish, different size classes present). However, the total catch numbers of barbel were overall lower than initially expected.



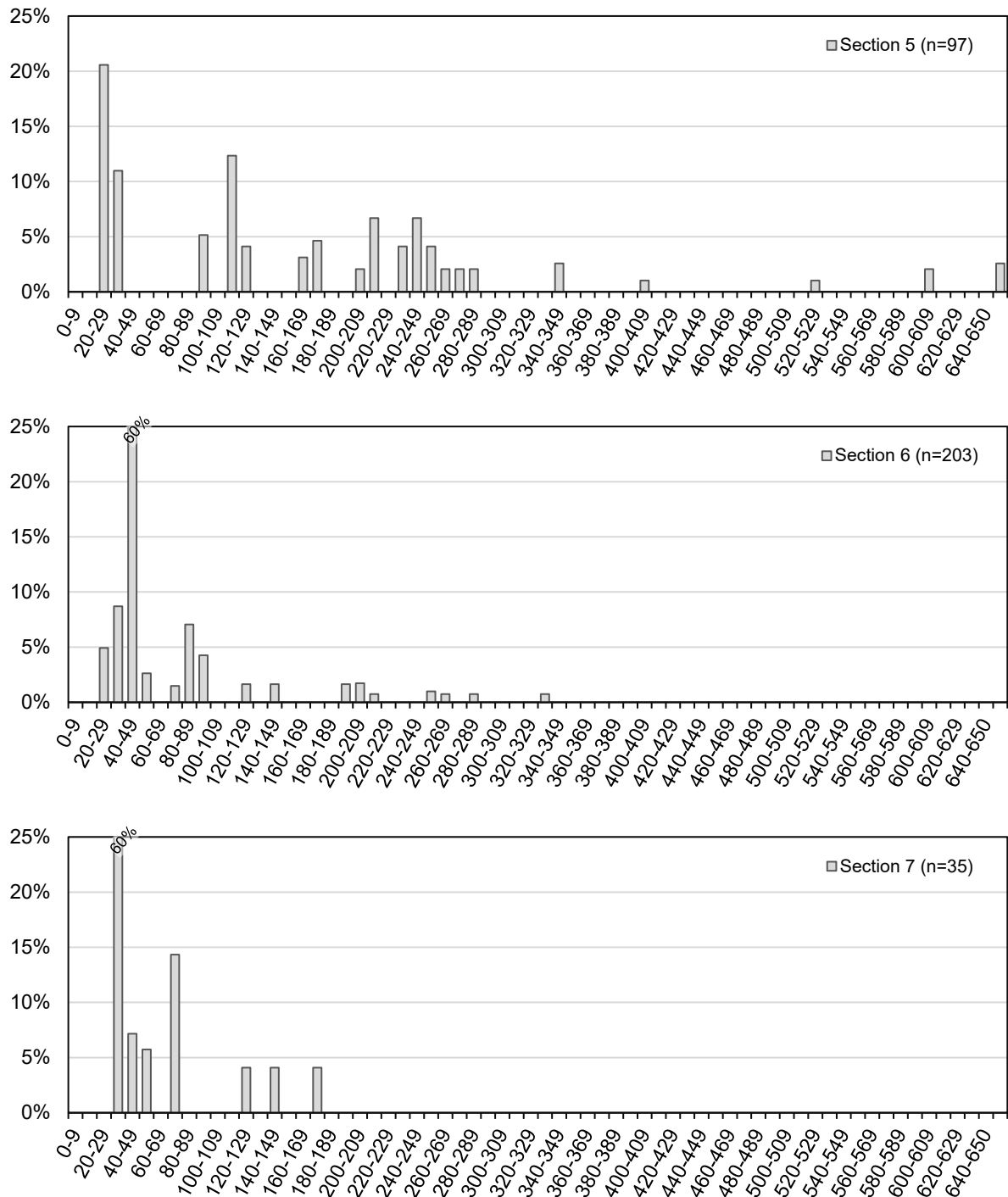


Figure 45: Length-frequency plot of barbel (*B. barbus*) displaying the population structure in sampled Drava-sections.

The density of barbels was generally lower in the Drava compared to the Mura sections. In section SD (below the powerplant and upstream of S4, not displayed), only 8 barbels were caught in total (no 0+ fish). In the residual flow section SR, only very few 0+ barbels were caught, but much more 1+ and subadult specimen were recorded. This stretch obviously has much better habitat conditions than the Drava below the hydropower

outlet. In section S4 (near the Mura confluence), most caught barbels were 0+ fish (90%) and only few subadult and adult fish were caught.

In section S5, 0+ (30%) and 1+ barbels (21%) were caught as well as subadult fish (160-280 mm, 37%), but only few larger individuals. In section S6, the total number of barbels was highest compared to all other Drava sections, mainly due to a large amount of 0+ barbels (~75%). Another 13% of barbels from S6 were in the size class of 70-100 mm, but only few subadult and no large barbels (>340mm) were caught. In section S7, the total density of barbels was low and all of the caught fish were rather small – with about 75% belonging to the 0+ age class.

### 3.2.1.3 Chub – *Squalius cephalus*

The chub, also referred to as common chub, is a species widespread throughout Europe and a member of the cyprinid family. It occurs in medium sized and large rivers as well as in standing or artificial water bodies. The chub is considered a generalist species, and can occur in faster flowing waters as well as in lotic systems. It is frequently found along the shorelines of larger rivers in the barbel zone close to or in deadwood structures. Chub spawn from late spring to summer and can grow up to about 60cm in length. The biggest chub caught during this field survey was 565 mm large.

With an average dominance of 8% and weight dominance of 17%, the chub occurred in all investigated stretches in higher abundances. The total catch numbers of the chub were lowest in section S4 and SD. In the Mura sections, the dominance of chub within the fish community was slightly higher than in the Drava sections. The average size of chub was about 13 cm. Slightly higher size averages were documented in sections S1, S5 and SD. However, also larger individuals (~40-55 cm) were recorded in all investigated sections.

Table 16: Overview on catch parameters of chub – *Squalius cephalus* – in sampled section in Mura and Drava. Relative dominance describes share of chub in total catch numbers and biomass per section.

	S1	S2	S3	S4	S5	S6	S7	SR	SD	Total
Total catch (individuals)	463	434	535	22	713	742	315	779	48	4.051
Relative total dominance (ind)	10%	9%	13%	1%	6%	13%	4%	16%	6%	8%
Total catch biomass (kg)	49	39	38	3	46	25	6	63	18	287
Relative weight dominance (kg)	17%	21%	29%	2%	14%	13%	4%	31%	36%	17%
Mean length (mm)	157	138	110	151	144	123	100	131	193	131
SD length	86	87	83	105	67	53	43	86	179	79
Mean weight (g)	106	90	72	125	65	34	18	81	366	71
SD weight	266	268	292	281	177	52	38	239	553	223

### 3.2.1.4 Predatory fish species

During sampling the Mura and Drava, 5 species were caught that are considered predatory fish: The asp (*A. aspius*), the pike (*E. Lucius*), the perch (*P. fluviatilis*), pike-perch (*S. lucioperca*) and the catfish (*S. glanis*). Predatory in this sense means that these species are piscivorous. Their diet, especially that of larger individuals consist predominantly of other fish. The abundance of predatory species is therefore always dependent on the availability of prey (other fish species occurring within the habitat range).

Table 17: Total/relative abundance and total/relative biomass of predatory species caught in the Mura and Drava sections.

	S1	S2	S3	S4	S5	S6	S7	SR	SD	Total
<b><i>Aspius aspius</i></b>										
Total catch (individuals)	2	6	26	10	92	44	68	1	2	252
Relative total dominance (ind)	<0,1%	0,1%	0,7%	0,3%	0,8%	0,8%	0,9%	<0,1%	0,2%	0,5%
Total catch biomass (kg)	3,6	6,6	2,1	11,6	16,1	5,5	30,5	1,5	3,5	81,1
Relative weight dominance (kg)	1,2%	3,6%	1,6%	8,9%	4,9%	2,7%	20,1%	0,7%	7,2%	4,8%
<b><i>Esox lucius</i></b>										
Total catch (individuals)	3	5	3	2	49	32	32	8	1	135
Relative total dominance (ind)	0,1%	0,1%	0,1%	0,1%	0,4%	0,5%	0,4%	0,2%	0,2%	0,3%
Total catch biomass (kg)	<0,1	0,3	0,1	7,8	8,5	5,7	20,2	0,2	1,8	44,6
Relative weight dominance (kg)	<0,1%	0,1%	0,1%	5,9%	2,6%	2,8%	13,3%	0,1%	3,7%	2,7%
<b><i>Perca fluviatilis</i></b>										
Total catch (individuals)		72	5	61	159	80	28	19	1	425
Relative total dominance (ind)		1,5%	0,1%	1,8%	1,3%	1,4%	0,4%	0,4%	0,2%	0,9%
Total catch biomass (kg)		0,7	0,1	0,3	1,4	0,8	0,3	0,1	<0,1	3,7
Relative weight dominance (kg)		0,4%	<0,1%	0,2%	0,4%	0,4%	0,2%	0,1%	<0,1%	0,2%
<b><i>Sander lucioperca</i></b>										
Total catch (individuals)	1	7	1		72	14	1	2		98
Relative total dominance (ind)	<0,1%	0,1%	<0,1%		0,6%	0,2%	<0,1%	<0,1%		0,2%
Total catch biomass (kg)	3,1	8,8	0,8		5,3	0,1	0,8	7,2		26,2
Relative weight dominance (kg)	1,1%	4,7%	0,6%		1,6%	<0,1%	0,5%	3,6%		1,6%
<b><i>Silurus glanis</i></b>										
Total catch (individuals)	1		4	1			6	3		15
Relative total dominance (ind)	<0,1%		0,1%	<0,1%			0,1%	0,1%		<0,1%
Total catch biomass (kg)	2,7		2,1	1,2			1,5	0,3		7,9
Relative weight dominance (kg)	0,9%		1,6%	0,9%			1,0%	0,2%		0,5%
<b>TOTAL</b>										
Total catch (individuals)	7	88	39	74	372	170	135	34	5	925
Relative total dominance (ind)	0,2%	1,8%	1,0%	2,2%	3,1%	2,9%	1,8%	0,7%	0,6%	1,9%
Total catch biomass (kg)	9,5	16,3	5,3	20,9	31,3	12,1	53,4	9,4	5,2	163,4
Relative weight dominance (kg)	3,2%	8,8%	4,0%	16,0%	9,5%	6,0%	35,2%	4,7%	10,8%	9,7%



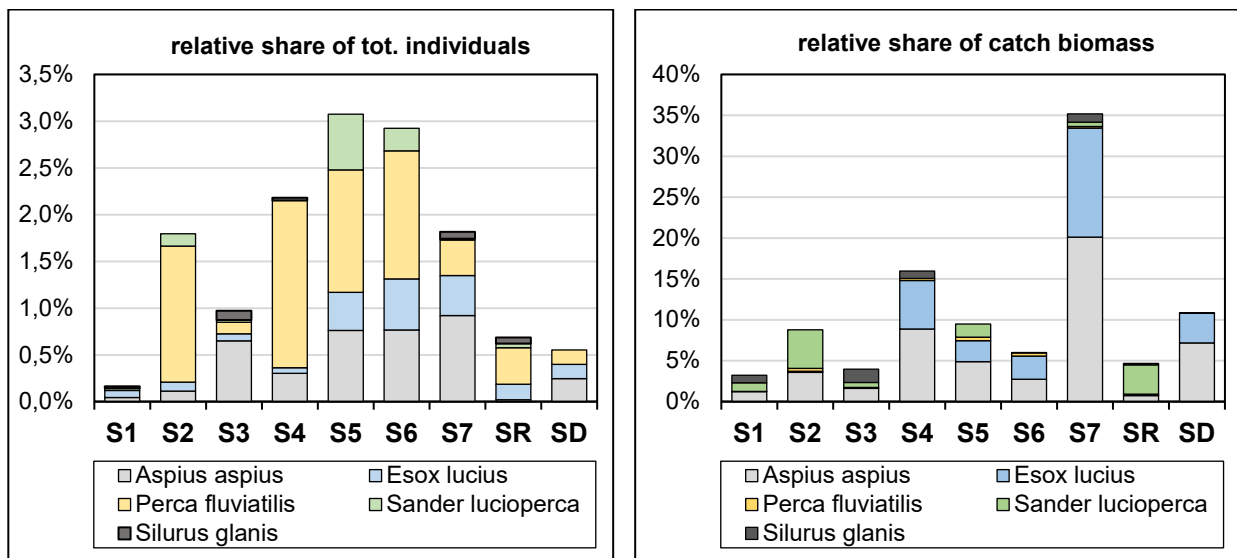


Figure 46: Relative dominance of predatory species within the fish community in the sampled sections. Values based on total catch number (Ind.) and total catch biomass (kg)

Since all of the recorded predatory species are rather large growing, their relative share of catch biomass is higher than their relative share of caught individuals (Figure 44). The perch was the most frequently caught overall (425 individuals), whereby most specimen were caught in section S5. The community share of perch ranges between 0,1 and 1,8%. Most caught perches were however small individuals (mean length: 78mm, maximum length: 21cm and only 35 individuals larger than 15cm). The biomass share of perch is therefore very low (between 0,4 and less than 0,1% in the respective sections).

The asp was the second most frequent predator, although 80% of all 252 individuals were caught in the lower Drava section (S5, S6, S7). In the Mura, only single specimen of the asp were caught. The share of asp in the fish community is below 1% in all sections. However, several larger individuals of asp were caught (about 35% of caught specimen were larger than 35cm, the largest individual was 70cm long). The biomass share of asp is therefore higher than the relative abundance and ranges from 1-3,6% in the Mura to 5-20% in the Drava.

135 individuals of pike were caught in total. Similar to the frequency of asp, the pike most frequently occurred in the Drava (relative dominance about 0,1% in the Mura and 0,5% in the Drava). The weight dominance was consequently also higher in the Drava than in the Mura (about 2,5-13%). The mean length of pike was about 25cm, the two largest individuals (80 and 85cm) were both caught in section S4 (being the only pikes in this section). Overall, the frequency of pike (especially that of larger specimen) was rather low.

The pikeperch was caught most frequently in section S5. About 75% of the 98 total individuals were registered in this section. More specifically, these pikeperch were all from a group of juvenile individuals (<10cm) within a very limited range. The density of pikeperch was overall low in all sampled sections and most individuals were small juveniles. Only 8 fish were larger than 50cm.

The least abundant predator was the catfish, of which only 15 total individuals were recorded. 5 in the Mura, 7 in the Drava and 3 in the old Drava riverbed (residual flow section). The largest individual was just above 70cm.

In total, 925 specimen of predatory fish species were caught. The vast majority of these were juvenile individuals. The relative dominance in the sampled sections ranges from 0,2 to 3% (1,9% overall). The relative biomass share ranges from 3 to 35% (9,7% overall).

### 3.2.1.5 Non-native fish species

Non-native species caught in the Mura and Drava are the black bullhead (*A. melas*), the silver carp (*H. molitrix*), the pumpkinseed (*L. gibbosus*), the stone moroko (*P. parva*), the three-spined stickleback (*G. gymnurus*) and five different species of gobies (racer goby, monkey goby, round goby, bighead goby and tubenose goby). The prussian carp (*C. gibelio*) is considered as non-native in the MDD region by several authors – and also under national guidelines in Croatia, Hungary, Serbia and possibly Slovenia). However, throughout central Europe, it is also often considered native. Since exact data on its historic distribution or time of introduction is not available, the actual status remains unresolved. Within the frame of this chapter, the results for the prussian carp are presented separately for this reason.

Overall, the abundance of caught non-native fish was relatively low (total catch numbers in Table 21). In total, just over 500 Individuals caught are considered non-native (1% of all caught individuals). 206 total individuals of the Prussian carp were caught, 140 of which in section S7. Although over 90% of Prussian carps were caught in the lower sections of the Drava (S5-S7), single specimen were also caught in the Mura.

4,5% of the overall biomass are contributed by non-native fish, in particular by the silver carp (*H. molitrix*), whose 17 caught individuals account for 68 kg of total biomass, and over 90% of the biomass of all non-native fish.

Table 18: Total catch number and total biomass of non-native species caught in the Mura and Drava.

\* status unclear, data on the historic distribution or introduction missing. Often considered non-native in the MDD region.

	S1	S2	S3	S4	S5	S6	S7	SR	SD	Total
<b>Babka gymnotrachelus</b>										
Total catch (individuals)							5			5
Total catch biomass (kg)							<0,1			<0,1
<b>Neogobius fluviatilis</b>										
Total catch (individuals)		9	3	10	21	22	3	54		123
Total catch biomass (kg)		0,1	0,1	<0,1	0,2	0,4	0,1	0,6		1,4
<b>Neogobius melanostomus</b>										
Total catch (individuals)							7			7
Total catch biomass (kg)							0,1			0,1
<b>Ponticola kessleri</b>										
Total catch (individuals)							11			11
Total catch biomass (kg)							<0,1			<0,1

	S1	S2	S3	S4	S5	S6	S7	SR	SD	Total
<b>Proterorhinus semilunaris</b>										
Total catch (individuals)							15			15
Total catch biomass (kg)							<0,1			<0,1
<b>Goby sp.</b>										
Total catch (individuals)							27			27
Total catch biomass (kg)							0,1			0,1
<b>Gobies total</b>										
Total catch (individuals)		9	3	10	21	22	68	54		188
Total catch biomass (kg)		0,1	0,1	0,0	0,2	0,4	0,2	0,6		1,7
<b>Ameiurus melas</b>										
Total catch (individuals)							20			20
Total catch biomass (kg)							2,7			2,7
<b>Gasterosteus gymnurus</b>										
Total catch (individuals)	2					4				6
Total catch biomass (kg)	<0,1					<0,1				<0,1
<b>Hypophthalmichthys molitrix</b>										
Total catch (individuals)			1		1	5	10			17
Total catch biomass (kg)			7,5		11,4	44,2	5,2			68,3
<b>Lepomis gibbosus</b>										
Total catch (individuals)	20	2			42	7	9	25		104
Total catch biomass (kg)	0,1	<0,1			1,2	0,1	0,1	0,3		1,9
<b>Pseudorasbora parva</b>										
Total catch (individuals)	22					28	125	26	1	202
Total catch biomass (kg)	0,1					<0,1	0,1	<0,1	<0,1	0,2
<b>TOTAL</b>										
Total catch (individuals)	44	11	4	10	64	66	233	104	1	537
Total catch biomass (kg)	0,2	0,1	7,6	0,0	12,9	44,6	8,4	0,9	0,0	74,7
<b>Carassius gibelio*</b>										
Total catch (individuals)	10	1			15	33	140	1	5	206
Total catch biomass (kg)	1,3	1,1			9,4	7,8	8,6	0,2	2,5	30,8

Whereas in sections S1 to S6 (Mura and Drava down to Barcs/Terezino Polje), only the monkey goby was recorded, all four other species of gobies could be detected in the lowest sampling reach (S7, close to Donji Miholjac). As a recent study from this reach has stated that the occurrence of the racer goby Drava has not been confirmed to this date (Piria et al., 2021). The result from this sampling campaign therefore very likely represent the first record of the racer Goby in the lower Drava. This is not a particularly big surprise, since all ponto-caspian goby species have extended their range upstream of their historic range (lower Danube) in recent years.

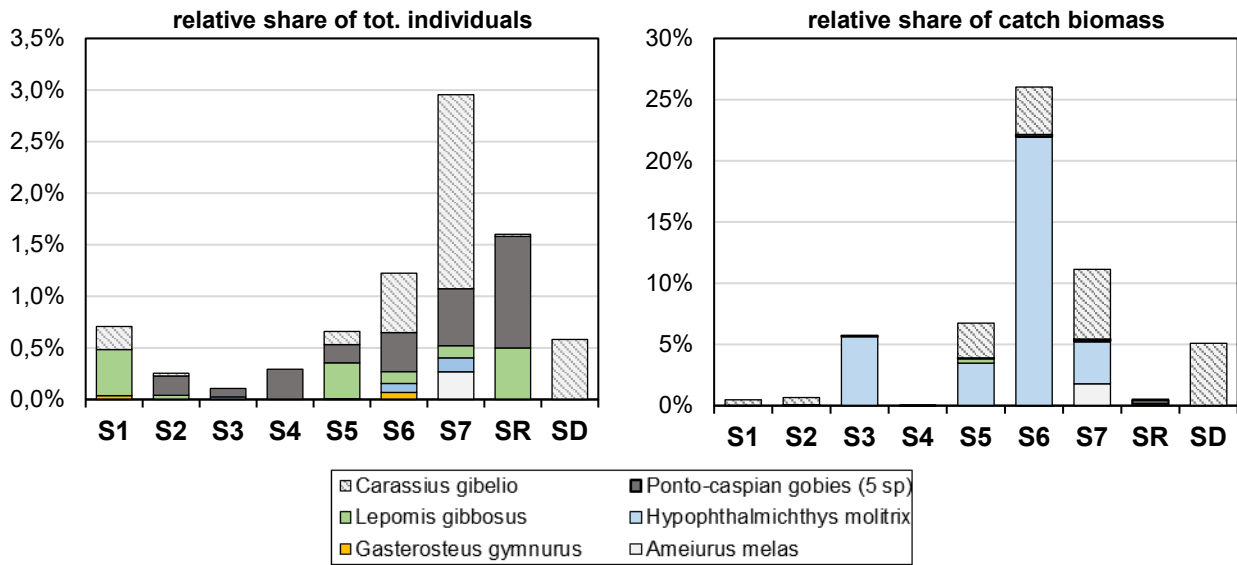


Figure 47: Relative dominance of non-native fish species within the fish community in the sampled sections. Values based on total catch number (Ind.) and total catch biomass (kg). Status of *C. gibelio* in Europe/MDD-region not fully resolved.

Although the amount of non-native fish in the Mura and Drava is considered low within the samples taken, this is differing from some previous samplings conducted in the area. Jelić et al. (2012) have for example found 10% of caught fish in the area around Donji Miholjac to be non-native. Saly (2016) sampled the Drava close to Barcs and found 20% non-native fish (12% gobies). Even in section S7, were the most non-native individuals were caught during this sampling campaign (<3%), the share of gobies was only 0,5%. The reason for this difference is most likely explained with the different sampling approach. Previous sampling probably focused on the river shorelines, where the amount of non-native fish (especially gobies) is much higher, especially in rip-rap-structures. Gobies benefit greatly from the embankment of shorelines in larger rivers. Extended riprap structures serve as ideal habitat for these speleophilic species. Comparable studies from the Danube in Austria have shown that the amount of gobies along riprap structures is extremely high, and (esp. the round goby) being the most frequently found fish species nowadays. Also, results from the Joint Danube Survey revealed that the presence of gobies is much higher in the Danube in Serbia.

The results from sampling in Serbia (Danube backwaters) also yielded high numbers of non-native fish (10%, respectively 30%), however mainly not gobies, but pumpkinseed (*L. gibbosus*) and brown bullhead (*A. melas*). Also, relatively high numbers of prussian carp were caught.



### 3.2.2 Quantitative stock estimations

The applied method of “strip electrofishing” enables the calculation of standardized population estimates (individuals per hectare and biomass per hectare) for each sampling section and fish species. This allows a comparison between sampling sections and also comparisons with future investigations in the TBR MDD. However, the following limitations need to be considered when interpreting the results presented in this chapter:

- The sampling intensity was relatively low compared to the spatial extent of the sections (one day of sampling for sections of 5-20km in a large river) and the high habitat variability in the Mura and Drava. Robust quantitative results are only reachable by sampling each occurring habitat type (including backwaters) at least three times (three strips). This was not the case in either section. Ultimately, also the overall habitat distribution is not known and could therefore not be integrated into the calculation.
- By definition of the “strip fishing method”, the summed length of sampling strips should have been at least as high as the total section length. This would only be possible by sampling about two to three times as many strips (2-3 days per section).
- Sampling is most effective during low flow periods. However, the Drava water level was at or above mean flow level during sampling in sections 5, 6 and 7. This also led to reduced visibility of fish in the water due to higher turbidity.
- Deep areas (mainly in the middle of the river) and deeper pools (water depth >2,5m) could not be sampled due to the limited field effectiveness of the electrofishing gear. Species inhabiting these areas are underrepresented in our results.
- Species that prefer stagnant or very slow flowing areas within a river system (limnophilic species, mainly occurring outside of the main channel) are underrepresented because sampling was limited to the main channel and easily reachable side channels. Oxbows, temporarily connected water bodies in the floodplain areas or other habitat types not directly accessible with the boat from the main channel were not sampled.

Under these prerequisites, the gained results present a comprehensive overview that allows to draw conclusions on the differences between the sampled sections and also on the overall status of the fish fauna in the investigated rivers. Potential future investigations of the fish fauna should aim to cover sampling sections in more detail and also include habitats outside of the main channel. Also, sampling throughout different seasons should be implemented to gain insights to seasonal and/or yearly fluctuations of the fish stocks.

Table 19: Key parameters (mean value, median, Min. and Max.) of standardized fish abundance (ind/ha) and fish biomass (kg/ha) per fishing strip in sampled sections.

Section	S1	S2	S3	S4	S5	S6	S7	SR	SD
<b>Abundance (Ind./ha)/strip</b>									
Mean	3.492	5.688	5.592	5.573	11.051	3.704	6.071	6.102	3.492
Median	1.681	1.599	1.488	2.112	1.747	1.583	3.135	2.234	1.681
Minimum	0	6	6	8	32	61	52	0	0
Maximum	19.091	84.000	29.412	25.000	75.000	20.877	40.357	28.000	19.091
<b>Biomass (kg/ha)/strip</b>									
Mean	85	86	89	114	167	92	58	148	55
Median	63	35	46	32	60	52	40	39	24
Minimum	0	2	0	5	2	2	3	0	4
Maximum	242	473	651	667	926	441	274	760	118

Each sampled fishing strip has a defined area (fished length by effective width of the electric field). Thus, the catch of each sampling strip can be standardized on abundance and biomass per hectare of water surface area. The yielded fish abundances and fish biomass per strip is displayed in Figure 46 and Table 22.

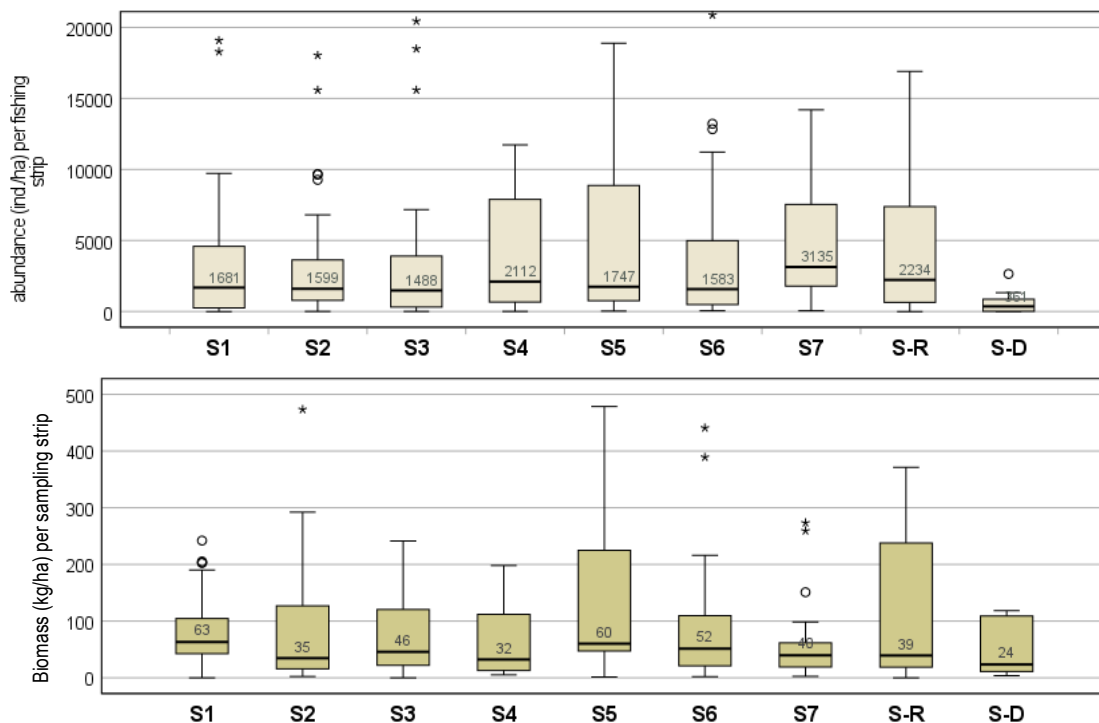


Figure 48: Distribution of standardized fish abundance (upper chart) and fish biomass (lower chart). Outliers and extreme values only displayed if within the range of the Y-Axes. Maximum values are shown in Table 22.

Due to the high variability of fish density and fished strip area, the variability of fish abundance and biomass per strip was high in all sections: Minimum values of fish abundance within a single strip ranged from 0 (no fish caught in this strip) to 61 fish per hectare, whereas maximum values ranged from 20 to over 80-thousand fish per hectare. Variability for biomass was equally high with values per strip ranging from 0 to over 900 kg/ha for the sampled strips.

Median values of fish abundance were around 1.500 ind./ha in the Mura sections (S1-3), over 2.000 in section 4, slightly above 1.500 in sections 5 and 6 and over 3.000 in section 7. Regarding fish biomass, the highest median values were recorded in sections 1 (63 kg/ha) and section 5 (60). In other sections, median values ranged from 32-52 kg/ha.

To calculate one representative value of fish abundance and fish biomass for a sampling section (rather than the variable values for single strips), the strip fishing method requires information on the overall habitat distribution, i.e. the quantification of habitat occurrence within the sampling reach (see 2.2.3). Since this information was not available for the sampled sections, the calculation was done without weighting the values based on the habitat representativeness. The results therefore assume that the distribution and amount of sampling strips was selected according to the overall habitat availability, which is not entirely correct (see limitations at the beginning of this chapter). The following results therefore may be compared with each other and indicate the fish faunistic composition at the time of the sampling, but cannot represent the “absolute”/universally correct fish density or biomass within these sections.

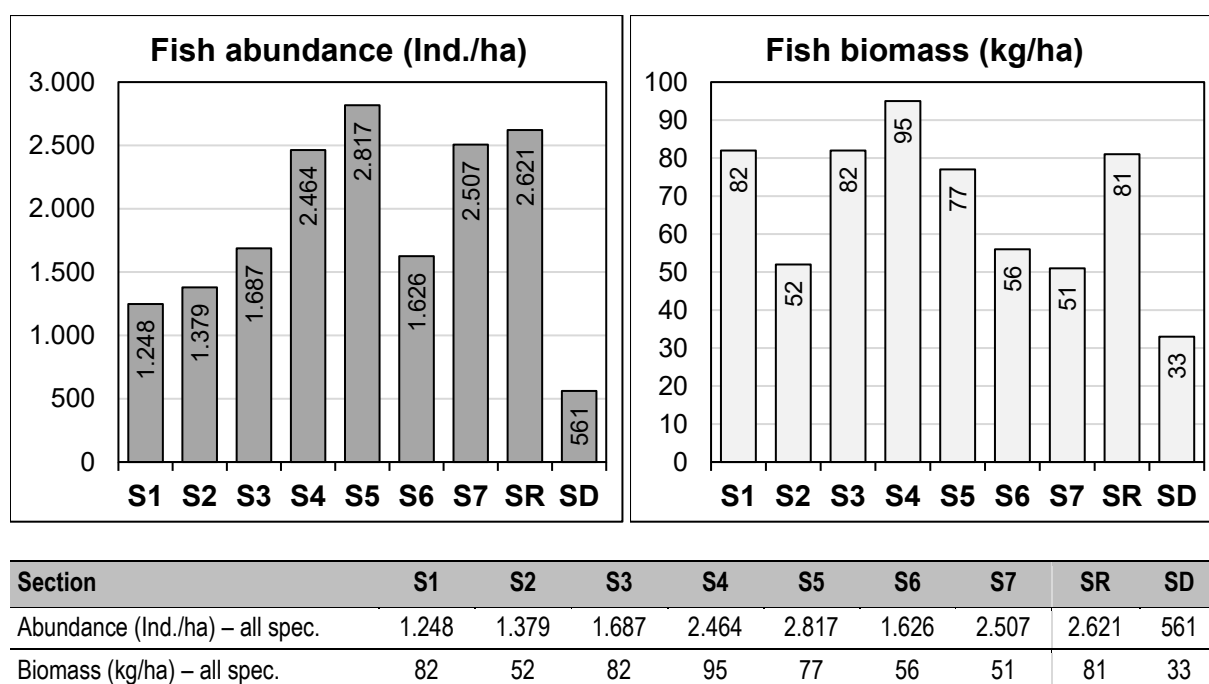


Figure 49: Standardized fish abundance (ind/ha) and fish biomass (kg/ha) per sampling section.

In Figure 49, the standardized fish abundance and fish biomass is presented per sampling section. A table with standardized abundance and biomass values for each species is provided in the appendix. The values for each section represent the amount of individuals and the fish biomass per hectare of water surface area that are occurring. The numbers can be regarded as a weighted mean value calculated from the single fishing strips in each section. The comparison between the fish abundance and the biomass shows that both indicators need to be regarded separately. A high fish density does not necessarily entail a high fish biomass – if for example only small individuals of small growing species were caught. Overall, the fish abundance and fish biomass were a little lower than initially anticipated. Although single species show considerable population sizes throughout the sections (bleak, nase, chub) or in single sections (barbel, spirlin, dace, bitterling, vimba bream, etc.), the assessed overall fish stock is relatively low.

The respective values per sections are displayed separately for the bleak (*A. alburnus*) and other species in the following figures. The bleak was by far the most common and most frequent fish caught. In most sections except S1, S2, S5 and SR, the bleak occurred in higher frequency than all other species combined. The reason for the mass catches of bleak is on the one hand related to the ecology of the bleak (as species building high abundances in lowland rivers), on the other hand because bleak are easily caught through electrofishing since they live in swarms close to the water surface in the open water as opposed to most other species that are more oriented on the river bottom and along shorelines. They are therefore also easily caught even in areas where visibility in the water is reduced turbidity. To display differences in the fish community, it seems reasonable to display selected results without the bleak.

The overall fish abundance was higher in the sections of the Drava than in the Mura, with sections S5, S4 and S7 yielding the highest values, although the abundance in S7 was in large part assigned to the bleak. Overall abundance ranged from about 1.200 to 1.700 ind/ha in the Mura (with the bleak accounting for a little less than half of that). In the Drava, the overall abundance ranged from about 1.600 ind/ha in S6 to about 2.500-2.800 ind/ha in the other sections. Fish abundance in the residual flow section was also high with a total of 2.600 ind/ha. In the Drava below the hydropower plant, fish abundance was very low – of the 560 ind/ha, about 450 where bleak.

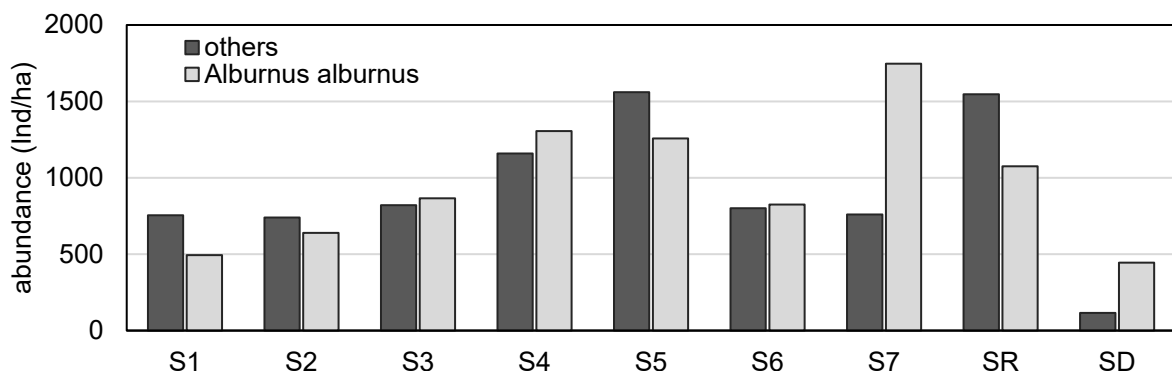


Figure 50: Distribution of fish abundance (Ind/ha) per section separated between bleak (*A. alburnus*) and other species.

The results for the biomass show that in sections S1, S3, S4, S5 and SR, the biomass values range around 80 kg/ha. In sections S2, S6 and S7, the biomass was just above 50 kg/ha and in SD, the fish biomass was 33 kg/ha. As opposed to the fish abundance, the bleak had a much lesser share in total fish biomass in the sampled sections. This is due to the smaller size (and therefore weight) of the bleak, that grows to about 15 cm and therefore accounts for less of the biomass than larger growing species. Interestingly, the bleak had the highest share of biomass in the residual flow stretch (40 kg/ha or about 50% of fish biomass).

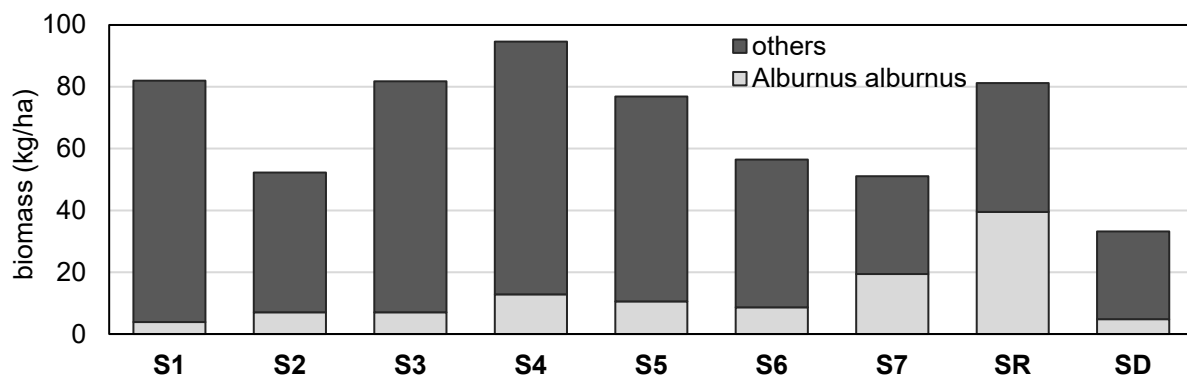


Figure 51: Distribution of fish abundance (Ind/ha) per section separated between bleak (*A. alburnus*) and other species.



### 3.2.3 Comparisons on community level

In this chapter, highlights on the longitudinal differences in fish community will be presented. This comparison is essential for the overall assessment of the status of fish populations in the investigated rivers. Comparisons are drawn on the level of the described ecological guilds (flow preference, spawning site preference and structural preferences as indicated in Table 4). The total number of species attributed to each guild is found in the table below. The number of rheophilic species decreased from the Mura down to the Drava from 9 to 4 species whereas the number of indifferent species tended to increase over the river course. Overall, most caught species are considered to be indifferent fish. Regarding flow conditions at spawning sites, rheopar and euryopar species are most frequent (19, respectively 20 species), whereby rheopar fish decreased with increasing river length and vice versa for euryopar fish. Limnopar species (spawning in areas without flow velocity, e.g. stagnant side waters) are much less frequent.

Table 20: Total number of recorded species per section and ecological guild.

	S1	S2	S3	S4	S5	S6	S7	SR	SD	Total
<b>Flow velocity preference</b>										
rheophilic	9	8	7	5	6	4	4	9	4	12
oligorheophilic	4	4	5	2	2	4	4	3	2	6
indifferent	12	15	11	12	15	16	21	15	9	25
limnophilic	3	2	0	1	3	5	3	3	0	5
<b>Spawning habitat preference</b>										
rheopar	14	13	13	8	9	9	9	13	6	19
euryopar	9	11	9	9	11	12	17	12	7	20
limnopar	5	5	1	3	6	8	5	5	2	8
<b>Structural preference</b>										
high	8	7	7	5	5	8	11	9	3	16
medium	15	16	9	9	14	14	12	16	7	23
low	5	6	7	6	7	7	8	5	5	8
<b>TOTAL SPECIES #</b>	<b>28</b>	<b>29</b>	<b>23</b>	<b>20</b>	<b>26</b>	<b>29</b>	<b>32</b>	<b>30</b>	<b>15</b>	<b>48</b>

Detailed values of the assessed fish abundance and fish biomass per species and the corresponding guilds are included in the appendix.

#### 3.2.3.1 Flow velocity preferences

In general, the fauna in all sections is dominated by rheophilic and indifferent fish – i. e. either species, that prefer areas with high flow velocities (rheophilic) or species that do not have a pronounced preference for certain flow conditions (indifferent). This is somewhat expected, since these two guilds are including most of the caught species in the Mura and Drava (12 respectively 25 out of the 48 total species).

Table 21: Fish abundance (Individuals/ha) and Biomass (kg/ha) per section and flow velocity guild.

Flow velocity preference	S1	S2	S3	S4	S5	S6	S7	SR	SD
<b>Abundance (Ind./ha)</b>									
rheophilic	534	314	497	154	298	226	57	640	32
oligorheophilic	5	25	32	199	335	78	50	135	30
indifferent	703	1030	1158	2067	2043	1272	2253	1764	499
limnophilic	7	10		43	142	50	147	82	
<b>Biomass (kg/ha)</b>									
rheophilic	58	14	38	31	32	15	1	18	9
oligorheophilic	1	<1	1	1	1	<1	<1	1	<1
indifferent	24	37	42	62	43	41	49	61	24
limnophilic	<1	<1		<1	<1	<1	<1	1	

Rheophilic fish account for a much higher community share in the Mura compared to the Drava (mainly due to the presence of the spiralin – *A. bipunctatus* in the Mura). Other species accounting for a larger part of this guild are the barbel (*B. barbus*), the nase (*C. nasus*) and to a slightly lesser extent also the cactus roach (*R. virgo*). A gradual decrease of rheophilic fish can be observed from up- to downstream sections (from ~40% in section 1 to 2% in section 7). The residual flow stretch in the Drava (SR) shows a higher share of rheophilic fish (~25%) compared to other Drava sections. This is no surprise, since it represents the uppermost sampled section in the Drava. In the section below the hydropower plant (SD), which is located right below the residual flow section, rheophilic fish are on the other hand rare (6% of the community).

Regarding the fish abundance, the indifferent guild dominates the community share in all sections (56% in section S1 up to 90% in section S7). The majority of these fish are bleak (which account for about half of the fish abundance in all sections, compare Figure 48). Without the mass occurring bleak, the rheophilic guild would account for a much larger share in the fish community, respectively the indifferent guild would be less dominant. Besides the bleak, the chub (*S. cephalus*), roach (*R. rutilus*), dace (*L. leuciscus*) are frequently occurring indifferent fish.

The share of oligorheophilic and limnophilic fish is low compared to the two main guilds. Both are almost exclusively present in the Drava. The share of oligorheophilic fish is highest in section S4 and S5. This guild is almost exclusively represented by the presence of vimba bream (*V. vimba*), to a lesser extent also by the stone loach (*C. elongatoides*). The limnophilic guild has the highest shares in sections S4, S5 and S6. Even in these sections, the overall abundance of limnophilic fish is less than 5%. The only species of this guild with significant abundance is the bitterling (*R. amarus*), which also occurs frequently in the residual flow section. The limnophilic guild was not expected to be represented in major shares, since sampling focused on the main stem of the river and habitats, where limnophilic fish would be expected in higher shares (stagnant water bodies) were underrepresented.

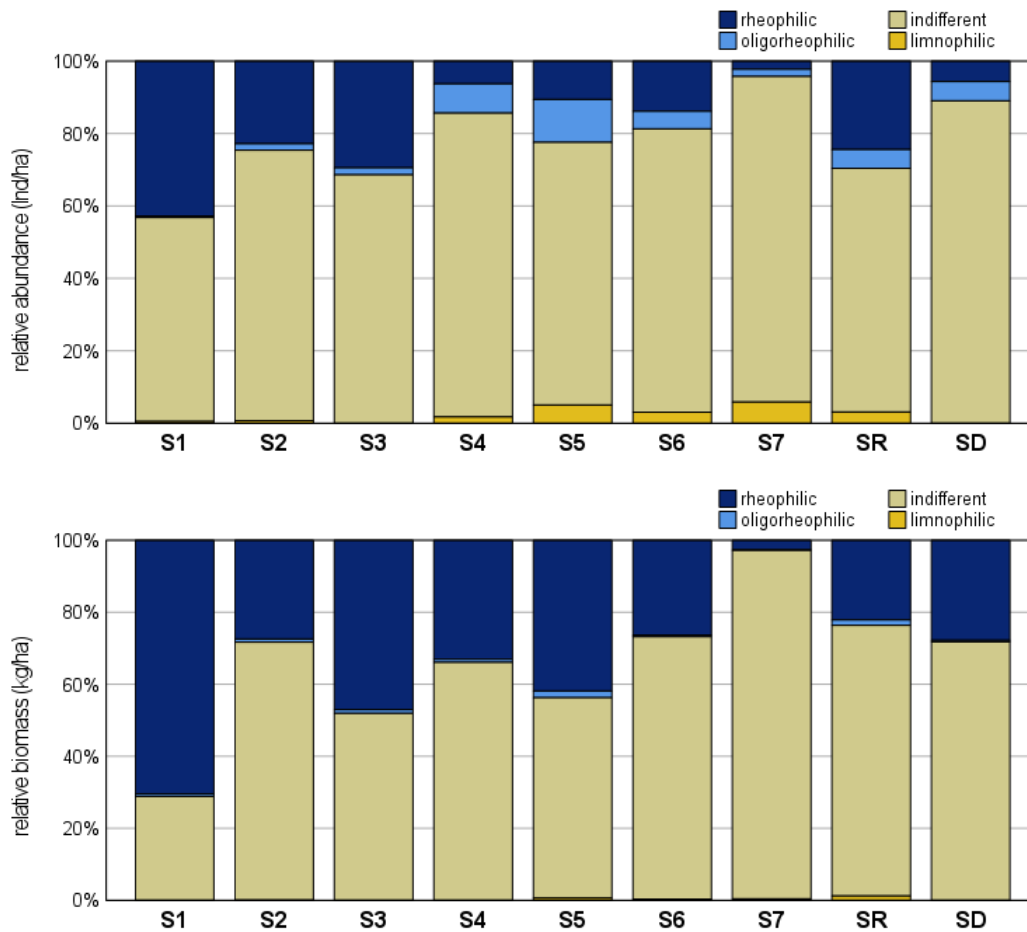


Figure 52: Relative share of fish abundance (Ind/ha) – upper chart, and relative biomass (kg/ha) – lower chart, per flow velocity preference and sampled section. Underlying values are based on quantitative stock calculations:

In terms of community composition based on the fish biomass, the dominance of indifferent fish shifts toward the rheophilic guild. In general, less species account for a larger share of the community structure when considering biomass compared to fish abundance, because only larger growing species (which are less frequent) account for the major stake in total fish biomass.

In the uppermost Mura-section, 70% of the fish biomass was contributed by rheophilic species (mainly nase and barbel). The main contribution for indifferent fish comes from the chub. In section S2, the share of indifferent species is about 70%, whereas rheophilic fish account for only 30%. This is due to the presence of the indifferent carp (*C. carpio*) as well as due to higher shares of bleak and chub. Nase and barbel on the other hand were much rarer encountered in S2 compared to S1. In section S3, the share of rheophilic fish is again higher (~50%), due to an increased nase biomass. Indifferent fish accounting for the other 50% of biomass are mainly the carp, chub and bleak. In the Drava sections S4, S5 and S6, the share of rheophilic species lies between 25 and 40%, with the nase accounting for the vast majority of biomass. For indifferent fish, the carp has a high share in S4, but only accounts for very minor share in S5 and S6. The chub however, has a lower

share in S4 than in S5 and S6. The bleak has a share of 15% of the total biomass in all three of these sections. In section S7, the bleak has a share of almost 40% of the biomass, by far the highest value in all investigated reaches. The two predatory species asp (*A. aspius*) and pike (*E. Lucius*) make up for about one third of the total biomass in S7. Rheophilic species are almost missing in S7, with a total of only 3% of the biomass.

In the residual flow stretch (SR), the rheophilic guild accounts for a total of about 25%. The spiralin (*A. bipunctatus*) has a share of 10% of the biomass, nase and barbel account for a total of 12%. In SD, the nase (13%) and the cactus roach (10%) are the two dominating rheophilic species, although the total biomass in this section was the lowest overall. The indifferent guild dominates in these two sections, accounting for about 75% of the biomass (mainly bleak and chub).

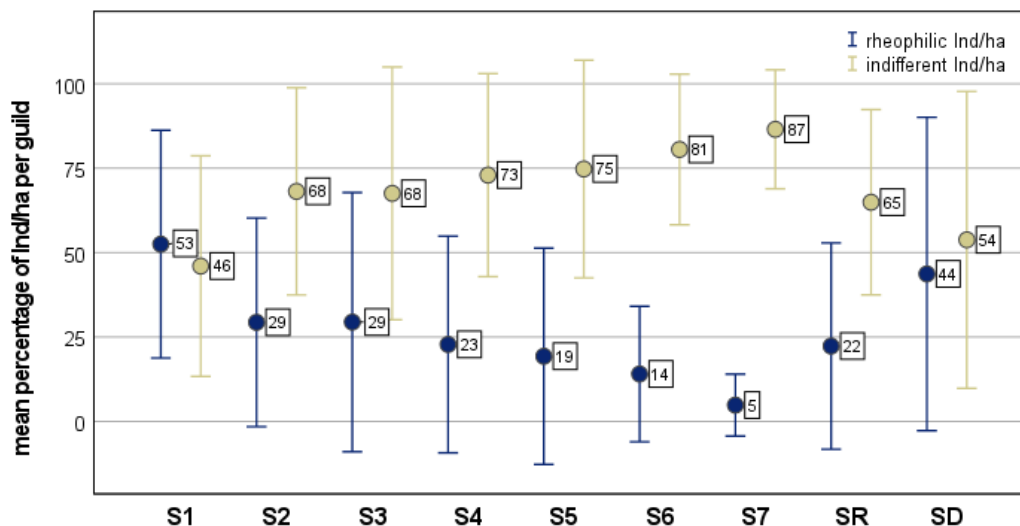


Figure 53: Average percentage of fish density (Ind/ha) of rheophilic and indifferent species in sampled fishing strips in each section. Error bars indicate  $\pm$  std. deviation of the mean.

Overall, there is a rather clear pattern of decreasing amount of rheophilic fish with increasing river length (or distance from the source). This can be most clearly seen in Figure 53, where the mean share of fish density in all strips and sections is displayed. From section S1 to S7, the mean share of rheophilic fish density drops from 53 to 5%, whereas the share of indifferent fish rises from 46% in S1 to 87% in S7. Sections SR and SD need to be regarded separately. In SR, the share of rheophilic and indifferent fish was in the same range as in sections S4 or S3, whereas in SD, rheophilic fish were even more dominant. It has to be considered though, that the main reason for this is that the total fish density in SD was very low overall.

### 3.2.3.2 Spawning habitat preferences

The preferred flow conditions at spawning habitats are categorized as rheopar (requiring spawning habitats with constant flow velocity), euryopar (no preference for flow velocity) and limnopar (preferring standing/stagnant areas in the river or sidearms/oxbows).

All rheophilic species are also considered rheopar. Additionally, all oligorheophilic species are also rheopar, except for the stone loach, who is considered euryopar. From the guild of indifferent fish, the dace and the asp are classified as rheopar (they prefer areas of higher flow velocities as spawning habitats, whereas they are not bound to flowing waters throughout their lifecycle). Most indifferent species are also considered euryopar and thereby considered to be “generalist” species that may cope with a variety of different habitat conditions. The guild of limnopar species require lentic conditions at their spawning habitat. All limnophilic species and the indifferent species carp, pike, and prussian carp are categorized as limnopar.

Since the categorization of spawning requirements is in many cases in line with the above described flow velocity preferences, the results for the sampled sections are quite similar as well. The total values of fish abundance and fish biomass per spawning habitat guild are indicated in Table 27.

Table 22: Fish abundance (Individuals/ha) and Biomass (kg/ha) per section and spawning habitat guild.

Flow velocity preference	S1	S2	S3	S4	S5	S6	S7	SR	SD
<b>Abundance (Ind./ha)</b>									
rheopar	601	526	596	636	607	335	115	823	35
euryopar	638	841	1.086	1.778	2.053	1.222	2.180	1.706	521
limnopar	10	13	4	51	157	69	205	92	4
<b>Biomass (kg/ha)</b>									
rheopar	61	18	41	41	37	17	12	23	12
euryopar	21	24	27	21	34	34	29	57	19
limnopar	0	10	15	32	5	6	10	1	3

In terms of relative share of each spawning guild within the fish community in the sampled sections, a gradual decrease of rheopar species from 50% to 5% (of the total fish abundance – Ind./ha) is observed from section S1 to S7. Besides barbel, nase and spirlin, the dace accounts for a considerable share of this guild in the Mura sections. At the same time, the share of euryopar fish increases from 50% to 87%. In the Drava sections, also the guild of limnopar species accounts for a minor share of the community – 2to 8% of fish (mainly bitterling) belong to this guild.

When evaluating the relative dominance of spawning guilds based on the biomass, rheopar and limnopar species account for a larger share in most sections and the share of euryopar species is reduced. In S1, 75% of the biomass are rheopar species (mainly nase and barbel). Whereas the biomass share of barbel drops in consecutive sections (12% in S2, 8% in S3 and 1-5% in S4, S5 and S6), the share of nase is higher (14% in S2, 37% in



S3, 27, 33 and 22% in S4-6). The biomass of euryopar species is mainly set up by chub and bleak, whereas the amount of bleak is higher in lower sections (esp. S7) and the amount of chub higher in upstream sections. The biomass share of limnopar species is also higher due to the presence of carp in sections S2, S3 and S4. In sections S5, S6 and S7, the limnopar species pike and prussian carp replace the biomass share of carp.

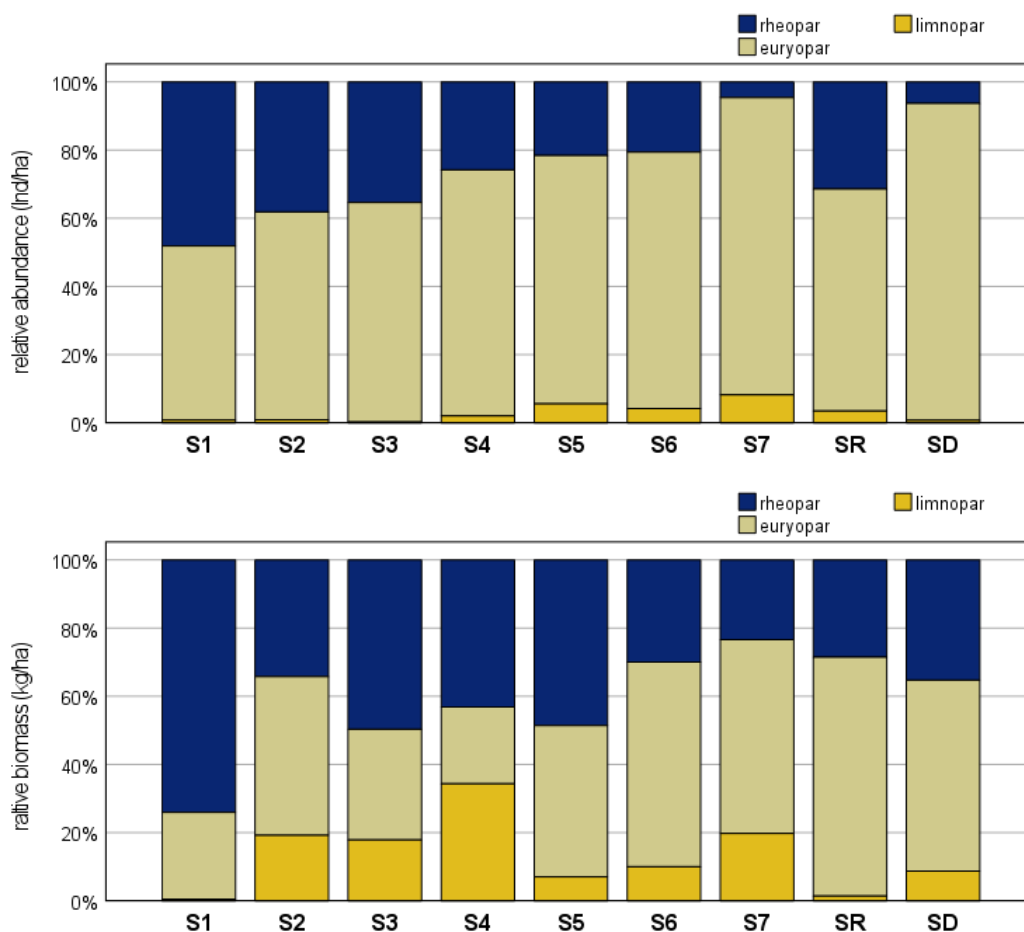


Figure 54: Relative share of fish abundance (Ind/ha) – upper chart, and relative biomass (kg/ha) – lower chart, per spawning habitat preference and sampled section. Underlying values are based on quantitative stock calculations:

### 3.2.3.3 Habitat-structure preferences

Species preference for structural features in a river is a more or less imprecise categorization since it may refer to a variety of different structural features (woody structures, specific grain sizes, presence of gravel bars, presence of macrophytes, etc.). Overall, this categorization enables only limited informative value, since only limited conclusions on the habitat availability may be drawn. The values for assessed abundance (Ind/ha) and biomass (kg/ha) for each structure-guild are provided in the table below.

Table 23: Fish abundance (Individuals/ha) and Biomass (kg/ha) per section and spawning habitat guild.

Structure preferences	S1	S2	S3	S4	S5	S6	S7	SR	SD
<b>Abundance (Ind./ha)</b>									
High structural pref,	140	145	230	76	246	258	174	472	61
Medium str. pref,	609	542	561	543	747	346	318	906	40
Low str. pref.	500	692	896	1845	1823	1022	2009	1243	459
<b>Biomass (kg/ha)</b>									
High structural pref,	14	12	16	9	13	9	9	13	13
Medium str. pref,	61	29	54	59	42	20	5	26	11
Low str. pref.	7	11	11	27	22	28	36	42	9

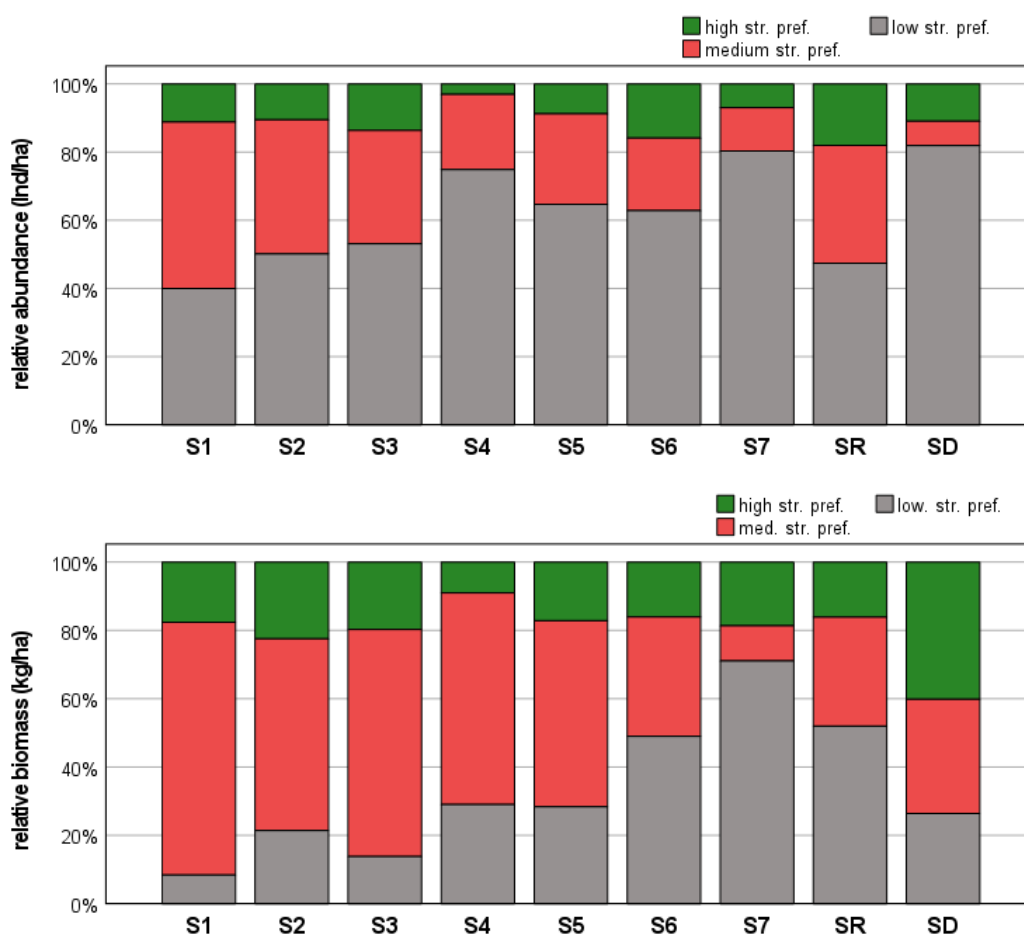


Figure 55: Relative share of fish abundance (Ind/ha) – upper chart, and relative biomass (kg/ha) – lower chart, per structural preference and sampled section. Underlying values are based on quantitative stock calculations.

Overall, species with low structure preferences account for the major share in terms of fish abundance. This is the case although most caught species are attributed to the other two guilds. The bleak however, which is considered to have low structural preferences, is significantly increasing the overall share of this guild. Also, the roach accounts for a significant share of this guild. The share of bleak is increasing with river length and in

upper sections of the Mura, species with “medium” structure preference are more dominant.

Many of the frequently caught species (except for the bleak and the chub) are included in the guild with “medium” structural preferences. This includes species like the nase, barbel or spirlin, They account for the largest biomass share in section S1-S5.

The amount of fish with high structure preferences is relatively low both in terms of abundance share and biomass share. This is due to the fact that the chub is the only species out of this guild that accounts for significant shares of both abundance and biomass (in part also vimba bream, which was however caught in much lower frequencies).

Many of the frequently caught species (except for the bleak and the chub) are therefore included in the guild with “medium” structural preferences.

### 3.3 Environmental DNA sampling

Sampling of eDNA was performed at ten different locations throughout the sections that were also sampled via electrofishing. The sections SR and SD (upstream of the Mura confluence) were combined by sampling below the confluence of the outlet channel of the HPP Donja Dubrava and the residual flow stretch. At two sections (S1 and S5), two eDNA samples were taken (up- and downstream of the section).

For each sample/location, 12 PCR replicates were conducted by the laboratory. The submitted results include the number of positive replicates (out of a maximum of 12) and the total number of DNA sequences.

With higher DNA concentrations (higher abundance of this species), the probability for a detection is consequentially higher as well. Detections with only one positive replicate (like for example for the sterlet – *A. ruthenus*) need to be interpreted with caution. There is a small chance of mis-identification. To reduce these uncertainties and get more robust results, it would be advisable to take two field replicates at each sampling site (two samples instead of one for each location).

The community composition according to the eDNA results is analyzed based on the total number of DNA sequences per species and sampling location.

#### 3.3.1 Species detection

The following table indicates the identified species at each sampling location. For each species and location, the number of positive replicates is summarized for easier interpretation. Some taxa could not be identified to species level. This is common in eDNA sampling and can be caused either by the genetic similarities on genus level (e.g. in *Romanogobio* sp. or *Gymnocephalus* sp.) or genetic similarities between species (e.g. nase – *C. nasus* and ruffle dace – *T. souffia*). Explanatory notes on the single taxa are included in the table description.

Table 24: List of recorded taxa with eDNA sampling at ten sampling locations in the Mura (S1-S3) and Drava (SD-S7) in July 2021. Values are based on positive PCR-replicates out of 12 cycles:

■ =1 positive replicate; ■ =2-5 positive replicates; ■ =6-9 positive replicates; ■ =10-12 positive replicates

	S1 a	S1 b	S2	S3	SD	S4	S5 a	S5 b	S6	S7
<i>Abramis brama</i>	■	■	■	■	■	■	■	■	■	■
<i>Acipenser ruthenus</i>										■
<i>Alburnoides bipunctatus</i>	■	■	■	■	■	■	■	■	■	■
<i>Alburnus alburnus</i>	■	■	■	■	■	■	■	■	■	■
<i>Ameiurus melas</i>		■	■							■
<i>Aspius aspius</i>	■	■	■	■	■	■	■	■	■	■
<i>Barbatula barbatula</i>	■	■	■			■	■	■	■	■
<i>Barbus barbus</i>	■	■	■	■	■	■	■	■	■	■
<sup>a</sup> <i>Barbus balcanicus</i>		■								
<sup>b</sup> <i>Bsapa_Bbjoernkna_Vvimba</i>			■		■	■	■	■	■	■
<sup>c</sup> <i>Carassius</i> sp.	■		■	■	■	■	■	■	■	■

	S1 a	S1 b	S2	S3	SD	S4	S5 a	S5 b	S6	S7
Cobitis elongatoides										
<sup>d</sup> Cobitis sp.										
Cottus gobio										
<sup>e</sup> Cyprinidae - Complex 1										
Cyprinus carpio										
<sup>f</sup> Eudontomyzon mariae										
Esox lucius										
Gasterosteus gymnurus										
<sup>g</sup> Gobio_Ralbi_Rkess_Rvld										
<sup>h</sup> Gymnocephalus sp.										
Hucho hucho										
Hypophthalmichthys molitrix										
Lepomis gibbosus										
<sup>i</sup> Lidus_Lleuciscus_Pcultratus										
Lota lota										
Neogobius fluviatilis										
Neogobius melanostomus										
Oncorhynchus mykiss										
Perca fluviatilis										
Phoxinus phoxinus										
Ponticola kessleri										
Proterorhinus semilunaris										
Pseudorasbora parva										
Rhodeus amarus										
Romanogobio carpathorossicus										
<sup>j</sup> Romanogobio sp.										
Romanogobio uranoscopus										
<sup>k</sup> R_virgo_pigus										
<sup>k</sup> Rutilus pigus										
Rutilus rutilus										
Sabanejewia balcanica										
Salmo trutta										
Salvelinus sp.										
<sup>l</sup> Sander sp.										
Scardinius erythrophthalmus										
Silurus glanis										
Squalius cephalus										
Thymallus thymallus										
Tinca tinca										
Zingel streber										
Zingel zingel										
Ammodytidae*										
Trachurus sp.*										
Oncorhynchus gorboscha*										
<b>Total taxa</b>	<b>40</b>	<b>31</b>	<b>46</b>	<b>30</b>	<b>30</b>	<b>36</b>	<b>39</b>	<b>39</b>	<b>39</b>	<b>36</b>

a: Identified as *Barbus carpathicus* or *B. peloponnesius*. Since neither occur in the MDD region, it is likely that this detection is attributable to *B. balcanicus* (balcanian barbel).

b: No genetic differentiation possible between *Ballerus sapa*, *Blicca bjoerkna* and *Vimba vimba*.

c: Likely *C. gibelio*, however genetics of *Carassius* are complex, and therefore no determination to species level.

d: Likely *C. elongatoides*, but insufficient genetic match.

e: No genetic differentiation possible between *Chondrostoma nasus* and *Telestes souffia*.

f: Identified as *Lampetra planeri* which does not occur in the MDD region (probable imprecision in reference database). Likely that this detection is attributable *E. mariae*.



*g: No genetic differentiation possible between *Gobio gobio*, *Romanogobio albipinnatus*, *R. kesslerii* and *R. vladykovi*.*

*h: No genetic differentiation possible between *Gymnocephalus baloni*, *G. cernua* and *G. schraetser*.*

*i: No genetic differentiation possible between *Leuciscus idus*, *L. leuciscus* and *Pelecus cultratus*.*

*j: Genus *Romanogobio*, insufficient genetic match on species level.*

*k: Likely *Rutilus virgo* since *R. pigus* not native in Danube catchment. However, genetics of *Rutilus* are complex and not fully understood yet.*

*l: No genetic differentiation possible between *Sander lucioperca* and *S. volgensis*.*

*\*: DNA probably inserted through wastewater drainage after human consumption.*

The eDNA analysis resulted in a total number of 55 identified taxa (species or groups of species). The most frequently detected species were the bleak, the spiralin, the barbel, several gudgeon species (only *R. uranoscopus* and *R. carpatorossicus* can be identified on species level), the bullhead and the so called “Cyprinid complex 1” which includes the nase as well as the potentially occurring riffle dace (*T. souffia*). Unfortunately, the analysis can not distinguish between these two species. We assume that most of the DNA for this complex is stemming from nase, since nase was also frequently caught with electrofishing. If and where the riffle dace was present can therefore not be answered via the eDNA analysis.

**Species that could not be caught with electrofishing but were detected with eDNA sampling are:** the sterlet (*A. ruthenus*; single detection in S7), the balcanian barbel (*B. balcanicus*; single detection in S1), the Danube salmon (single detections in sections S1, S2 and S5), the golden spined loach (*S. balcanica*, detected in all Mura-sections and in S7), the grayling (*T. thymallus*, detected in S1, S2, and single detections in S5 and S6). All of these species are protected under the EU habitats directive.

Additionally, the non-native rainbow trout (*O. mykiss*, detected in all sections except S3), one or several species of char (*Salvelinus* sp.), the pink salmon (*O. gorbuscha*), and DNA of Ammodytidae and *Trachurus* sp. Were detected. The rainbow trout is expected to occur more or less regularly in the Mura and Drava. Possibly also some form of *Salvelinus* (potentially hybrids from fish farms) may occur. However, we think it is highly unlikely that any of the latter three taxa are found in the Mura or Drava and their detected DNA is assumed to be stemming from waste-water influxes.

It is important to note that the detected species have been identified through the comparison of DNA in the sample with so called reference databases. The detection of a particular species is therefore not only dependent on the actual occurrence of the fish in the sampling area, but also on the used genetic database (DNA reference material).

### 3.3.2 Community composition and comparison with electrofishing

The total number of detected DNA sequences allows an estimation of the community composition since the amount of DNA in the river is correlated with the total number of fish occurring (Pont et al., 2022). Uncertainties remain because the amount of DNA that is emitted by a single fish depends also on the species, the size of the fish or the “activity” of the fish. Additionally, the amount of detectable DNA is diluted with further distance from the “source” (the fish emitting the DNA). These factors, and the fact that several species cannot be distinguished with eDNA, are considered major limitations of the method compared to “classic” electrofishing.

The relative abundance of all samples and species/taxa are presented in Table 25.

The community shares detected through eDNA sampling generally correspond well with the result from electrofishing. The community trends from both eDNA and electrofishing exhibit a longitudinal change of the fish community from the Mura to the lower Drava reaches, with rheophilic species occurring in higher frequencies in upstream reaches and species preferring less flow more frequent in lower reaches. Bottom dwelling fish (and/or fish generally preferring deeper areas within the river) are generally detected in higher shares when applying eDNA, whereas species bound to the littoral zone and/or surface-oriented species are easier caught with electrofishing.

Table 25: Relative abundance of recorded taxa with eDNA sampling at ten sampling locations in the Mura (S1-S3) and Drava (SD-S7) in July 2021. Results from site S1 b are not listed (unreliable quantification of DNA amount due to trouble during sampling). Explanatory notes on species and taxa are included in the table above. Values based on total number of DNA sequences:   =<1% ;   =1-5% ;   =5-20% ;   =>20%

	S1 a	S2	S3	SD	S4	S5 a	S5 b	S6	S7
Abramis brama	<1	3%	2%	7%	7%	5%	5%	1%	4%
Acipenser ruthenus									<1
Alburnoides bipunctatus	25%	17%	22%	5%	6%	4%	4%	1%	<1
Alburnus alburnus	5%	7%	8%	7%	9%	8%	11%	8%	7%
Ameiurus melas		<1							<1
Aspius aspius	<1	<1	<1	<1	1%	<1	<1	<1	<1
Barbatula barbatula	<1	1%			<1	<1	<1	<1	
Barbus barbus	32%	26%	16%	12%	12%	14%	14%	7%	2%
Barbus balcanicus									
Bsapa_Bbjoernkna_Vvimba		<1		13%	10%	7%	9%	5%	4%
Carassius sp.	<1	<1	<1	<1	<1		<1	<1	<1
Cobitis elongatoides	<1	<1	<1	<1	<1	<1	<1	<1	<1
Cobitis sp.		<1				<1	<1		
Cottus gobio	<1	<1	2%	<1	2%	<1	1%	1%	
Cyprinidae - Complex 1	16%	11%	14%	11%	13%	16%	18%	13%	3%
Cyprinus carpio	<1	<1	<1	<1	<1	<1	<1	<1	<1
Eudontomyzon mariae		<1							
Esox lucius	<1	<1	<1	2%	2%	<1	<1	3%	<1
Gasterosteus gymnurus	<1	<1							
Ggobio_Ralbi_Rkess_Rvld	2%	3%	1%	4%	3%	3%	3%	1%	<1
Gymnocephalus sp.	<1	<1	<1	5%	1%	1%	<1	<1	<1
Hucho hucho	<1	<1					<1		
Hypophthalmichthys molitrix	<1	<1	<1	<1	1%	<1	2%	4%	2%

	S1 a	S2	S3	SD	S4	S5 a	S5 b	S6	S7
Lepomis gibbosus	<1	<1	<1			<1	<1	<1	<1
Lidus_Lleuciscus_Pcultratus	<1	2%	<1		<1	<1	<1	<1	<1
Lota lota			<1						
Neogobius fluviatilis		2%	8%	3%	5%	11%	6%	24%	7%
Neogobius melanostomus									42%
Oncorhynchus mykiss	<1	<1		9%	3%	<1	2%	<1	<1
Perca fluviatilis	<1	1%	<1	2%	<1	<1	<1	2%	1%
Phoxinus phoxinus	<1	<1		1%	1%	<1	<1	<1	
Ponticola kessleri							<1		2%
Proterorhinus semilunaris				6%	4%	5%	6%	9%	7%
Pseudorasbora parva	<1	<1			<1	<1	<1	<1	
Rhodeus amarus	<1	<1	<1	1%	2%	2%	2%	<1	<1
Romanogobio carpathorossicus	2%	4%	4%		2%	2%	2%	4%	<1
Romanogobio sp.				<1		<1			
Romanogobio uranoscopus	<1	<1			<1				
R_virgo_pigus	<1	<1	<1	2%	2%	4%	2%	5%	4%
Rutilus pigus			<1		<1	<1		<1	<1
Rutilus rutilus	<1	<1	<1	3%	2%	2%	2%	1%	2%
Sabanejewia balcanica	<1	<1	<1						<1
Salmo trutta	<1	<1		<1	<1	<1	<1	<1	
Salvelinus sp.	<1	<1		<1	<1	<1	<1		
Sander sp.	<1	<1	<1	<1	<1	<1	<1	<1	<1
Scardinius erythrophthalmus	<1	<1						<1	<1
Silurus glanis	<1	<1	2%	3%	3%	<1	2%	1%	6%
Squalius cephalus	14%	14%	13%	2%	4%	7%	2%	4%	<1
Thymallus thymallus	<1	<1				<1		<1	
Tinca tinca		<1					<1	<1	
Zingel streber	<1	<1	<1		<1	<1	<1	<1	
Zingel zingel	<1	<1	<1	<1	<1	<1	<1	<1	<1
Ammodytidae	<1								
Trachurus sp.		<1							
Oncorhynchus gorboscha	<1	<1				<1		<1	<1
<b>Total taxa</b>	40	46	30	30	36	39	39	39	36

The **bream** was detected in all sections and in much higher shares with eDNA compared to electrofishing (especially in sections SD, S4 and S5).

The **bleak** was occurring in high densities throughout all sampling locations (5-11%), although the share was lesser than with electrofishing.

The **spiralin** was detected in much higher shares in the Mura (17-25%) but also in the Drava, the spiralin was recorded in all sections (in decreasing amount). With electrofishing, the spiralin could only be detected in the Drava down to section S4 and generally in much lesser frequency (except for section SR).

The **barbel** was recorded in high shares throughout all sampling sections. Particularly high values were recorded in the Mura sections S1 (32%) and S2 (26%). The relative community share of barbel was about 4 times less with electrofishing. Barbels are bottom-oriented fish that often occur in larger groups in the middle of rivers – areas that are ineffectively covered with electrofishing.

One complex of species (including *B. sapa* – the **white eyed bream**, *B. bjoerkna* – the **white bream** and *V. vimba* – the **vimba bream**) was detected in higher frequencies in the Drava (sections SD-S7, decreasing share from 13 to 4%). Although it is not possible to distinguish which of the three species accounts for this share, it is very likely that the vimba bream and the white bream contributed considerably, because these species were also frequently (in part in even higher community shares) caught with electrofishing.

The **spined loach** (*C. elongatoides*) was detected in all sections and also the **golden spined loach** (*S. balcanica*) which could not be caught during electrofishing was recorded in the Mura and in the lowest Drava section (S7). Although the community shares of these species are low, their presence is important since they are protected under Annex II of the habitats directive.

Interestingly, the **bullhead** (*C. gobio*, a species also protected under Annex II of the habitats directive) was detected in all sections except for S7. Although the community shares are only 2% or less, the bullhead has not been encountered in any other recent surveys neither in the Mura nor in the Drava. Also during electrofishing, we could only catch single specimen of bullhead (in S1 and in S3).

A taxa group including both the **nase** (*C. nasus*) and the **riffle dace** (*T. souffia*), termed “Cyprinidae Complex 1” was detected in rather high shares throughout all sections (11-18% in sections S1 to S6, 3% in S7). Although we cannot rule out that the riffle dace also was present during sampling, the major share of DNA from this group is provided by the nase. The nase was also frequently caught with electrofishing, although their community share was lower (~6% abundance share on average) compared to the eDNA sampling.

The **carp** (*C. carpio*) was detected in all sections (densities <1%), as well as the pike (densities of up to 3%).

A taxa group of several **gudgeons** were detected in rather high shares (compared to electrofishing) in all sections but S7. Although most gudgeons cannot be distinguished on species level, their overall community share was about 5% (4-7%) in sections S1 to S6, and 2% in S7. Since gudgeons are bottom oriented fish, it is no surprise that they were detected in much higher shares with eDNA sampling.

The **Danube salmon** (*H. hucho*) was detected in the Mura (S1-S3) and in section S5 in the Drava. Whereas the detections from the Mura are considered plausible and likely, the detection from section S5 shall be interpreted with care. This section is probably below (or on the lower edge) of the native range of Danube salmon. The community shares of this species are low, which is no surprise since the Danube salmon, as a top predator, does naturally not occur in high densities. However, it was not caught during electrofishing and its confirmed presence is considered a strong indication for the protection necessity of the TBR MDD. The Danube salmon is endemic to the Danube catchment and considered endangered by the IUCN.

The taxa complex containing the **ide** (*L. idus*), the **dace** (*L. leuciscus*) and the **chekhon** (*P. cultratus*) was recorded in all sections except SD. Unfortunately, it is not possible to

distinguish these to species level via eDNA. The ide and the dace were also regularly caught with electrofishing, with the dace even accounting for considerably larger community shares than with eDNA. The checkon on the other hand, could not be detected through electrofishing.

The **perch** (*P. fluviatilis*) was detected in all sections in shares of about 1%. The **minnow** (*P. phoxinus*) was also detected in all sections except S3. Through electrofishing, the minnow could only be caught in the residual flow stretch of the Drava (SR).

The **bitterling** was detected in all sections, but in much lesser shares compared to electrofishing.

The **roach** (*R. rutilus*) was detected in all samples taken. The community share of roach was higher in the Drava (~2%) than in the Mura (~0,5%) but generally less than with electrofishing (1% in Mura, 7% in Drava). The **cactus roach** (*R. virgo*) on the other hand was detected in higher quantities (and in all sections) with eDNA than with electrofishing: In the Drava, the share of cactus roach was about 3% (1% with electrofishing). In the Mura, the share was below 0,5%.

The **brown trout** (*S. trutta*), which was caught only in the residual flow section (SR) with electrofishing, was detected in all sections except S3 and S7 with eDNA. The overall community share was rather low throughout.

The **grayling** (*T. thymallus*) was detected only with eDNA sampling and occurred in section S1 and S2 in the Mura and S5 and S6 in the Drava. Similar to the Danube salmon, the presences of grayling in the Mura is no surprise, the detections in the Drava need to be questioned, since (especially in S6), the habitat conditions are generally not suitable for the grayling who prefers clear and flowing water with gravel/rocky bottoms.

The **chub** (*S. cephalus*) was detected in all sections and accounts for a considerable community share in the Mura (~14%). In the Drava, the share drops to about 3%. With electrofishing, similar shares of chub were detected in the Mura, but higher shares in the Drava (~7%).

The **rudd** (*S. erythrophthalmus*) was detected in four section (S1, S2, S6 and S7). The community share of this species is rather low, which is most likely a consequence of the rudd occurring primarily in side waters and backwaters but not in the main channel. The same is true for the **tench** (*T. tinca*), which was detected in sections S2, S5 and S6 in also low quantity. With electrofishing, these species were recorded in similar shares.

The **zingel** (*Z. zingel*) and the **streber** (*Z. streber*) were both detected frequently (all sections except streber in SD and S7) but in rather low shares. The shares of streber were higher in the Mura whereas the zingel was more abundant in the Drava. Compared to electrofishing, both species were detected “better” through eDNA. Both species occur almost exclusively in deeper, faster flowing section of the river middle making them hard to catch with electrofishing.



Various **predatory/piscivorous species** were recorded in nearly all sections (asp, pike, pike-perch, Danube salmon, perch and catfish). The community share was relatively low for most species, with the tendency towards higher shares in the Drava (~5%) compared to the Mura (~1%). Perch, catfish and pike accounted for the larger part of the share of predators – opposed to electrofishing, where the asp had considerable community shares especially in the lower Drava.

The **non-native** silver carp (*H. molitrix*) and pumpkinseed (*L. gibbosus*) were caught in almost all sections. Additionally, the brown bullhead (*A. melas*), the stickleback (*G. gymnurus*), the stone moroko (*P. parva*) and the non-native salmonids rainbow trout (*O. mykiss*) and char (*Salvelinus* sp.) were detected – both salmonids were not caught during electrofishing. The rainbow trout (and the silver carp in the lower Drava) was the only of these species with higher community shares. In section SD (below Donja Dubrava), 9% of the detected fish DNA is contributed by the rainbow trout. It is possible that this higher share is a consequence of stocking activity of rainbow trout into the Donja Dubrava reservoir for recreational angling.

Four species of **gobies** were detected through eDNA sampling: the monkey goby (*N. fluviatilis*), the round goby (*N. melanostomus*), the tubenose goby (*P. semilunaris*) and the bighead goby (*P. kessleri*). Generally, the community share of gobies was much higher in the eDNA samples than with electrofishing - again caused mainly by the fact that gobies are bottom dwelling fish that are underestimated with electrofishing. An exception to this would be the electrofishing sampling in regulated shoreline areas (rip-rap), where gobies can be caught in extremely high frequencies as well. The monkey goby was detected in all sections except S1 (uppermost Mura stretch). It's relative share ranges from 2% in S2 up to 24% in S6. The tubenose goby was detected in all section of the Drava (shares between 4 and 9%), but not in the Mura. The bighead goby was detected only in S7 (2% share). The round goby was also only detected in S7 but had by far the highest community share of all species in this section (42%).

Overall, the share of gobies is increasing with river length: no gobies in S1, 2% in section S2, about 8% in sections S3, SD and S4, 14% in S5, 33% in S6 and 57% in S7. This is rather surprising since the overall share of gobies based on the result of electrofishing is considered to be below 5%. More gobies (species and individual number) were generally recorded in section S7 also with electrofishing but the dominance of these species is probably higher than what we concluded through electrofishing. The gobies therefore also account for the highest amount of non-native fish DNA detected through eDNA sampling. In any case, the future development and spread of invasive gobies in the TBR MDD shall be closely monitored.

## 3.4 Danube

The results of the sampling in Serbia have been copied to this document and partly aggregated from the full report provided by the University of Novi Sad. The full report of the Serbian sampling effort is provided as annex to this report.

Table 26: List of recorded species in the pilot areas Gornje Podunavlje (GP) and Karadorđevo (K) with reference to ecological and reproductive guilds.

Species	English name	flow guild	area GP	area K
<i>Abramis brama</i>	Bream	indifferent	X	X
<i>Alburnus alburnus</i>	Bleak	indifferent	X	X
<i>Ameiurus melas</i>	Black bullhead	indifferent	X	X
<i>Aspius aspius</i>	Asp	indifferent	X	X
<i>Ballerus ballerus</i>	Blue bream	indifferent	X	
<i>Blicca bjoerkna</i>	White bream	indifferent	X	X
<i>Carassius gibelio</i>	Prussian carp	indifferent	X	X
<i>Chondrostoma nasus</i>	Nase	rheophilic		X
<i>Cobitis elongatoides</i>	Spined loach	oligorheophilic		X
<i>Cyprinus carpio</i>	Carp	indifferent	X	X
<i>Esox lucius</i>	Northern pike	indifferent	X	X
<i>Gymnocephalus cernua</i>	Ruffe	indifferent		X
<i>Hypophthalmichthys molitrix</i>	White bighead	indifferent		X
<i>Lepomis gibbosus</i>	Pumpkinseed	limnophilic	X	X
<i>Leuciscus idus</i>	Ide	indifferent	X	X
<i>Micropterus salmoides</i>	Largemouth black bass	n.a.	X	
<i>Neogobius fluviatilis</i>	Monkey goby	indifferent	X	
<i>Perca fluviatilis</i>	European perch	indifferent	X	X
<i>Proterorhinus semilunaris</i>	Western tubenose goby	n.a.	X	X
<i>Pseudorasbora parva</i>	Stone moroko	indifferent	X	X
<i>Rhodeus amarus</i>	Bitterling	limnophilic	X	X
<i>Rutilus rutilus</i>	Roach	indifferent	X	X
<i>Sander lucioperca</i>	Pike-perch	indifferent	X	X
<i>Scardinius erythrophthalmus</i>	Rudd	limnophilic	X	X
<i>Silurus glanis</i>	Wels catfish	indifferent		X
<i>Squalius cephalus</i>	Chub	indifferent		X
<i>Tinca tinca</i>	Tench	limnophilic	X	X

### 3.4.1 Pilot area Gornje Podunavlje

#### 3.4.1.1 Physico-chemical parameters

Physico-chemical parameters within the pilot area Gornje Podunavlje are presented in Table 32. Main differences are found between the two sampling dates, rather than throughout sampling localities. Specifically, during the 1st round, high water temperatures were recorded (26-28°). At Mrtva Baračka, the highest temperature within one single mesohabitat was recorded (29 °C). During the second round, the average temperatures were significantly lower and ranged from 19 to 22 °C. Conductivity did not vary significantly between the sampling dates, but rather between localities. It was highest at the Mrtva Baračka. This indicates the possibility of increased leaching of minerals from the surrounding soil and/or weaker water exchange cycles in this water body. This is also indicated by the transparency of the water, which was constantly the lowest in the locality of Mrtva Baračka. Oxygen saturation and oxygen content was higher in the first sampling round, whereas at the localities Bajski kanal and Mrtva Baračka, the levels were about twice as high compared to Sakajtaš. O<sub>2</sub> values dropped in the second sampling period and levelled throughout all sampling localities, accompanied by the drop in water temperature. This indicates that with the drop in temperature, the production of phytoplankton most likely decreased.

Table 27: Average values of physical and chemical parameters within the pilot area Gornje Podunavlje

Locality	Round	Temp (°C)	Cond (µS/cm)	O <sub>2</sub> sat. (%)	O <sub>2</sub> cont. (mg/l)	pH	Transparency (cm)	Depth (cm)
Sakajtaš	1	26.08	372.40	34.60	2.89	7.87	113.00	184
Mrtva Baračka	1	27.90	577.60	74.50	5.84	8.31	43.00	125
Bajski kanal	1	27.90	379.60	75.08	5.81	8.30	123.80	233
<b>Total sampling rd. 1</b>	<b>1</b>	<b>27.29</b>	<b>443.20</b>	<b>61.39</b>	<b>4.85</b>	<b>8.16</b>	<b>93.27</b>	<b>180</b>
Sakajtaš	2	19.78	362.80	34.40	3.16	8.32	73.00	145
Mrtva Baračka	2	20.52	573.00	40.75	3.57	8.11	46.18	130
Bajski kanal	2	21.68	398.18	34.51	2.93	8.01	125.91	211
<b>Total sampling rd. 2</b>	<b>2</b>	<b>20.82</b>	<b>459.28</b>	<b>36.94</b>	<b>3.23</b>	<b>8.12</b>	<b>83.25</b>	<b>165</b>

#### 3.4.1.2 Fish fauna of pilot area Gornje Podunavlje

Overall, 21 fish species were recorded in the pilot area Gornje Podunavlje. Most species (9) are eurytopic, meaning that they do not have special preferences for water flow. It is also noticed that 7 recorded species are rheophilic (preferring lentic water bodies, seasonally/occasionally inhabiting floodplains). It is important to note that some of the species that inhabit the waterbodies within this floodplain area and have been regularly

recorded in previous surveys, were not registered. These are *Misgurnus fossilis*, *Barbus barbus*, *Hypophthalmichthys molitrix*, *Neogobius melanostomus* and *Silurus glanis*.

Total and relative catch numbers and biomasses are presented in Table 33. The fish fauna is dominated by cyprinid species (members of the carp family - Cyprinidae). The most frequent species are *Alburnus alburnus* and *Rutilus rutilus* with over 36% and over 16% share in the total catch. The high abundance of two invasive species - *Ameiurus melas* (15%) and *Lepomis gibbosus* (12%) – is evident.

In the biomass share, the dominant species is *Carassius gibelio* with almost 20% of the total biomass, while *Rutilus rutilus* and *Alburnus alburnus* follow with 14% and 11%. The relatively high share of *Micropterus salmoides* (17%) is due to the catch of one large individual (1.300 g).

Table 28: Total catch and catch biomass within pilot area Gornje Podunavlje.

Species	Total catch (ind.)	In %	Total Biomass (g)	In %
<i>Abramis brama</i>	22	2,62	147	1,50
<i>Alburnus alburnus</i>	309	36,79	1.083	11,01
<i>Ameiurus melas</i>	129	15,36	792	8,05
<i>Aspius aspius</i>	11	1,31	971	9,87
<i>Ballerus ballerus</i>	6	0,71	7	0,07
<i>Blicca bjoerkna</i>	1	0,12	9	0,09
<i>Carassius gibelio</i>	43	5,12	1.941	19,73
<i>Cyprinus carpio</i>	1	0,12	15	0,16
<i>Esox lucius</i>	3	0,36	569	5,79
<i>Lepomis gibbosus</i>	101	12,02	880	8,95
<i>Leuciscus idus</i>	9	1,07	30	0,30
<i>Micropterus salmoides</i>	10	1,19	1.719	17,47
<i>Neogobius fluviatilis</i>	2	0,24	5	0,05
<i>Perca fluviatilis</i>	2	0,24	3	0,03
<i>Proterorhinus semilunaris</i>	4	0,48	2	0,02
<i>Pseudorasbora parva</i>	8	0,95	7	0,07
<i>Rhodeus amarus</i>	12	1,43	20	0,21
<i>Rutilus rutilus</i>	140	16,67	1.337	13,59
<i>Sander lucioperca</i>	2	0,24	87	0,88
<i>Scardinius erythrophthalmus</i>	24	2,86	186	1,89
<i>Tinca tinca</i>	1	0,12	26	0,27
<b>TOTAL</b>	<b>840</b>	<b>100</b>	<b>9.836</b>	<b>100</b>

Catch numbers for each sampling locality are presented in Table 34. It was noted that some species are observed in higher frequency in localities closer to the main course of the Danube. *Alburnus alburnus*, for example, accounts for almost 50% of the catch in the locality Sakajtaš. Its abundance decreases with further distance from the Danube. On the other hand, in the same locality, its biomass is the smallest, which implies that there were more younger specimen located there. *Ballerus ballerus* was detected only in the locality Sakajtaš, with a significant mass share of 15%. Roach is present in all localities, but its abundance and biomass are the least in the Sakajtaš locality. The tench was detected only at the Mrtva Baračka site (which has the most characteristic habitats for limnophilic fish). Only 8 species were detected in all three localities, which implies that the connection

between habitats is not at the highest level, or that that living conditions in habitats differ to a greater extent.

Table 29: Catch total- and biomass shares by sampling localities in the pilot area GP.

Species	Sakajtaš (closest to Danube)		Mrtva Baračka (medium distance)		Bajski kanal (furthest)	
	Tot. catch (%)	Biomass (%)	Tot. catch (%)	Biomass (%)	Tot. catch (%)	Biomass (%)
<i>Abramis brama</i>	1,94	0,27	2,36	1,15	3,23	2,48
<i>Alburnus alburnus</i>	49,03	2,91	40,88	13,33	25,51	11,91
<i>Ameiurus melas</i>			13,85	4,73	25,81	15,83
<i>Aspius aspius</i>	3,40	1,01	1,35	21,75		
<i>Ballerus ballerus</i>	4,37	15,48				
<i>Blicca bjoerkna</i>					0,29	0,24
<i>Carassius gibelio</i>	14,08	63,53	4,05	3,42	0,59	12,53
<i>Cyprinus carpio</i>	0,49	0,73				
<i>Esox lucius</i>			0,34	0,55	0,59	14,75
<i>Lepomis gibbosus</i>	12,14	11,61	2,36	3,36	20,23	13,28
<i>Leuciscus idus</i>	2,43	0,56	1,35	0,41		
<i>Micropterus salmoides</i>			2,36	33,42	0,88	7,02
<i>Neogobius fluviatilis</i>					0,59	0,13
<i>Perca fluviatilis</i>					0,59	0,08
<i>Proterorhinus semilunaris</i>	0,49	0,04	0,34	0,01	0,59	0,02
<i>Pseudorasbora parva</i>	3,88	0,34				
<i>Rhodeus amarus</i>	1,46	0,24	1,35	0,21	1,47	0,17
<i>Rutilus rutilus</i>	4,85	2,50	24,66	12,78	16,72	19,66
<i>Sander lucioperca</i>	0,49	0,22	0,34	1,88		
<i>Scardinius erythrophthalmus</i>	0,97	0,55	4,05	2,40	2,93	1,88
<i>Tinca tinca</i>			0,34	0,60		

## 3.4.2 Pilot area Karadorđevo

### 3.4.2.1 Physico-chemical parameters

Recorded physico-chemical parameters are presented in Table 35. Variability between sampling localities during the first sampling round were due to a fast rise in water levels during survey. In the second sampling round, a quick drop of the water level led to differences between the localities. During both sampling rounds, the Lovrenac site showed the largest variations in conductivity, as well as in terms of oxygen concentration (between sampled habitats, data not displayed). In the first round, both the highest and the lowest oxygen concentration were measured at this locality (14.99 mg/l and 2.38 mg/l). This suggests that there is little water exchange processes, while some zones tend to have anoxic conditions, which can be detrimental to fish populations. At the Lovrenac - Račva locality significantly lower oxygen concentrations were record during both rounds, especially during round 2 (1,44 mg/l).



Table 30: Average values of physical and chemical parameters within the SRP " Karadorđevo "

Locality	Round	Temp (°C)	Cond (µS/cm)	O2 sat (%)	O2 (mg/l)	pH	Transparency (cm)	Depth (cm)
Dunavac	1	<b>24.96</b>	<b>354.80</b>	<b>77.74</b>	<b>6.37</b>	<b>8.63</b>	<b>50.80</b>	<b>156.60</b>
Lovrenac - Račva	1	<b>24.58</b>	<b>359.20</b>	<b>56.92</b>	<b>4.73</b>	<b>8.34</b>	<b>39.20</b>	<b>67.60</b>
Lovrenac	1	<b>27.20</b>	<b>575.80</b>	<b>93.78</b>	<b>7.02</b>	<b>8.70</b>	<b>33.60</b>	<b>68.90</b>
<b>Total sampling rd. 1</b>	<b>1</b>	<b>25.58</b>	<b>429.93</b>	<b>76.15</b>	<b>6.04</b>	<b>8.55</b>	<b>41.20</b>	<b>97.70</b>
Dunavac	2	<b>25.56</b>	<b>380.20</b>	<b>38.52</b>	<b>3.11</b>	<b>7.85</b>	<b>45.20</b>	<b>174.00</b>
Lovrenac - Račva	2	<b>23.10</b>	<b>405.20</b>	<b>17.10</b>	<b>1.44</b>	<b>7.72</b>	<b>36.00</b>	<b>44.80</b>
Lovrenac	2	<b>23.94</b>	<b>512.60</b>	<b>56.30</b>	<b>4.63</b>	<b>8.26</b>	<b>36.80</b>	<b>69.40</b>
<b>Total sampling rd. 2</b>	<b>2</b>	<b>24.20</b>	<b>432.67</b>	<b>37.31</b>	<b>3.06</b>	<b>7.94</b>	<b>39.33</b>	<b>96.07</b>

### 3.4.2.2 Fish fauna of pilot area Karadorđevo

A total of 24 species were recorded in the pilot area Karadorđevo. 10 species are eurytopic, 9 species are rheophilic. Some of the species recorded regularly in previous monitorings in this area were not recorded. These are: *Ballerus ballerus*, *Misgurnus fossilis*, *Gymnocephalus schraetser*. *Ballerus ballerus* and *Gymnocephalus schraetser* are less common in floodplains, while *Misgurnus fossilis* is a species that is rarely caught in this area by electrofishing.





Figure 56: Two caught fish from the pilot area Karadordevo (*C. elongatoides* – top; and juvenile specimen of *T. tinca* – bottom)

Overall, the pilot area is dominated by species from the carp family (Cyprinidae). The most common are *Alburnus alburnus* and *Rutilus rutilus* with 34% and over 14% share of the total catch (Table 36). The presence of *Carassius gibelio* with almost 12% is also significant, while *Blicca bjoerkna* (slightly above 7%) and *Abramis brama* with 6% follow. Carp (*Cyprinus carpio*) dominates in the mass share with 29%, while *Carassius gibelio* has a slightly lower value of mass share (26%). The presence of a large predator (*Esox lucius*) with over 12% share in the total mass of the sample is noticeable, while *Rutilus rutilus* is present with over 9% (Table 8).

Table 31: Total catch and catch biomass within pilot area Karadordevo

Species	Total Abundance	In %	Total Biomass (g)	In %
<i>Abramis brama</i>	72	6,05	269	1,15
<i>Alburnus alburnus</i>	400	33,61	1.210	5,19
<i>Ameiurus melas</i>	6	0,50	105	0,45
<i>Aspius aspius</i>	47	3,95	331	1,42
<i>Blicca bjoerkna</i>	85	7,14	774	3,32
<i>Carassius gibelio</i>	139	11,68	6.141	26,35
<i>Chondrostoma nasus</i>	5	0,42	28	0,12
<i>Cobitis elongatoides</i>	13	1,09	47	0,20
<i>Cyprinus carpio</i>	29	2,44	6.734	28,89
<i>Esox lucius</i>	8	0,67	2.815	12,08
<i>Gymnocephalus cernuus</i>	1	0,08	3	0,01
<i>Hypophthalmichthys molitrix</i>	9	0,76	4	0,02
<i>Lepomis gibbosus</i>	58	4,87	1.554	6,67
<i>Leuciscus idus</i>	35	2,94	507	2,18
<i>Perca fluviatilis</i>	5	0,42	93	0,40
<i>Proterorhinus semilunaris</i>	5	0,42	2	0,01
<i>Pseudorasbora parva</i>	41	3,45	76	0,33
<i>Rhodeus amarus</i>	30	2,52	30	0,13
<i>Rutilus rutilus</i>	170	14,29	2.113	9,07
<i>Sander lucioperca</i>	5	0,42	59	0,25

Species	Total Abundance	In %	Total Biomass (g)	In %
<i>Scardinius erythrophthalmus</i>	20	1,68	225	0,97
<i>Silurus glanis</i>	1	0,08	10	0,04
<i>Squalius cephalus</i>	3	0,25	117	0,50
<i>Tinca tinca</i>	3	0,25	55	0,23
<b>TOTAL</b>	<b>1.190</b>	<b>100</b>	<b>23.304</b>	<b>100</b>

When interpreting the catch and biomass shares by localities within the area Karadžorđevo, some species are observed more frequently in localities closer to the main course of the Danube (Table 37). *Chondrostoma nasus* and *Gymnocephalus cernuus* were detected only at the Dunavac site, which is also closest to the main course of the Danube. This is to be expected since both species are rheophilic. On the other hand, the tench was found in both localities that are further away from the main course of the Danube River, which is also expected considering that it is a limnophilic species.

Table 32: Catch total- and biomass shares by sampling localities in the pilot area Karadžorđevo

Species	Dunavac (closest)		Lovrenac – Račva (medium)		Lovrenac (furthest)	
	Tot. catch (%)	Biomass (%)	Tot. catch (%)	Biomass (%)	Tot. catch (%)	Biomass (%)
<i>Abramis brama</i>	13,91	2,46	3,77	0,78	0,97	0,18
<i>Alburnus alburnus</i>	33,86	5,58	39,70	6,56	27,49	3,56
<i>Ameiurus melas</i>					1,46	1,32
<i>Aspius aspius</i>	5,77	1,55	0,75	1,03	5,35	1,64
<i>Blicca bjoerkna</i>	0,52	0,44	12,31	7,70	8,27	2,28
<i>Carassius gibelio</i>	8,66	38,24	8,79	19,00	17,27	21,00
<i>Chondrostoma nasus</i>	1,31	0,35				
<i>Cobitis elongatoides</i>	1,05	0,13	2,26	0,50		
<i>Cyprinus carpio</i>	1,57	18,44	3,02	36,84	2,68	32,28
<i>Esox lucius</i>	1,05	18,65	0,25	16,62	0,73	1,36
<i>Gymnocephalus cernuus</i>	0,26	0,04				
<i>Hypophthalmichthys molitrix</i>	2,10	0,04			0,24	0,01
<i>Lepomis gibbosus</i>	0,79	1,21	0,75	1,51	12,65	16,83
<i>Leuciscus idus</i>	3,67	2,47	3,77	1,27	1,46	2,70
<i>Perca fluviatilis</i>	0,79	0,48	0,25	0,22	0,24	0,49
<i>Proterorhinus semilunaris</i>	1,05	0,02			0,24	0,00
<i>Pseudorasbora parva</i>	2,36	0,21	5,28	0,43	2,68	0,35
<i>Rhodeus amarus</i>	0,26	0,06	4,02	0,20	3,16	0,14
<i>Rutilus rutilus</i>	18,90	8,13	13,82	6,67	10,46	12,17
<i>Sander lucioperca</i>	0,79	0,29	0,25	0,29	0,24	0,17
<i>Scardinius erythrophthalmus</i>	1,05	1,07	0,50	0,02	3,41	1,71
<i>Silurus glanis</i>	0,26	0,12				
<i>Squalius cephalus</i>					0,73	1,46
<i>Tinca tinca</i>			0,50	0,38	0,24	0,34

### 3.5 Previous fish population assessments

Since the sampling effort conducted for this project can only reflect the fish stock characteristics at the actual time of the sampling, it is crucial to set the results into perspective by comparing the outcome with the samplings conducted in previous assessments and studies. As described in chapter 2.4, various sources were screened for their potential usability. The most recent and comprehensive overview on past fish surveys and data compilations from the Croatian-Hungarian Drava is provided by Saly (2019). Intensive literature analysis and the integration of information from fishermen and anglers is also provided by Sallai & Kontos (2008). An overview on native fish in the Slovenian Mura is provided by Povž (2016), but comprehensive historic reports on catches of rare species was not easily available. For the Danube, publicly available data on fish stocks are available from several “Joint Danube Surveys” (coordinated by the ICPDR – [www.icpdr.org](http://www.icpdr.org)).

It turned out that the (relative/absolute) number of caught fish individuals was the most consistent available parameter throughout the analyzed surveys. However, not all suitable surveys were included entirely. For example, the fish assessment in the Slovenian Mura for the hydropower plant in Hrastje Mota would include several more sampling occasions and sites/seasons. For various sources, biomass values (absolute catch, standardized kg/ha) would be available, but have not been included in this report.

The analyzed samplings were conducted between 2006 and 2021 and include electrofishing-surveys from 34 occasions (including the lifelineMDD sampling) in the TBR MDD. 17 samplings were conducted in the Mura, 8 in the Drava and 7 in the Serbian Danube. All surveys (except for the lifelineMDD assessment in the Serbian Danube-backwaters) were conducted in the main river or in connected side-arms. Backwaters or disconnected waterbodies within the floodplain areas are not included. Although some samplings stated to have included these habitats, the information on the selected water bodies as well as data availability was scarce. For the sampled areas in Serbia, rather recent reports and management plans exist that include detailed data on fish. However, precise information on the quality and availability of the data were not available for this current report.

Table 33: Overview of included data sources of recent surveys investigating the fish fauna of the TBR MDD

RIVER	YEAR	SEASON	SITE/SECTION	R-KM	SURVEY
Mura	2010	fall	Spielfeld	142	GZÜV - Austrian national Database
Mura	2013	fall	Spielfeld	142	GZÜV - Austrian national Database
Mura	2019	fall	Spielfeld	142	GZÜV - Austrian national Database
Mura	2019	fall	Cersak	140	GZÜV - Austrian national Database
Mura	2010	fall	Radkersburg	115	GZÜV - Austrian national Database
Mura	2019	fall	Radkersburg	115	GZÜV - Austrian national Database
Mura	2013/14	spring	Bakovci-Verzej	96	HE Hrastje Mota - fish assessment
Mura	2013/14	fall	Bakovci-Verzej	96	HE Hrastje Mota - fish assessment
Mura	2013/14	spring	Verzej-G.Bistrica	90	HE Hrastje Mota - fish assessment
Mura	2013/14	fall	Verzej-G.Bistrica	90	HE Hrastje Mota - fish assessment

RIVER	YEAR	SEASON	SITE/SECTION	R-KM	SURVEY
Mura	2013/14	spring	Gibina-Petisovci	75	HE Hrastje Mota - fish assessment
Mura	2013/14	fall	Gibina-Petisovci	75	HE Hrastje Mota - fish assessment
Mura	2013/14	spring	Petisovci-Izliv Ledave	62	HE Hrastje Mota - fish assessment
Mura	2013/14	fall	Petisovci-Izliv Ledave	62	HE Hrastje Mota - fish assessment
Mura	2021	summer	S1	89	lifelineMDD (BOKU)
Mura	2021	summer	S2	61	lifelineMDD (BOKU)
Mura	2021	summer	S3	7	lifelineMDD (BOKU)
Mura	2021	summer	S1-S3	90-0	lifelineMDD (BOKU)
Drava	2021	summer	SR	250	lifelineMDD (BOKU)
Drava	2021	summer	SD	240	lifelineMDD (BOKU)
Drava	2021	summer	S5	210	lifelineMDD (BOKU)
Drava	2021	summer	S6	160	lifelineMDD (BOKU)
Drava	2021	summer	S7	74	lifelineMDD (BOKU)
Drava	2021	summer	SD-S7	253-65	lifelineMDD (BOKU)
Drava	2006		Donji Miholjac	75	Jelić et al 2012
Drava	2016	fall	Barcs	152	Saly 2016
Danube	2007	summer/fall	Mohacs	1446	JDS2 - ICPDR
Danube	2007	summer/fall	Batina	1430	JDS2 - ICPDR
Danube	2007	summer/fall	Aljmas	1380	JDS2 - ICPDR
Danube	2013	summer/fall	Hercegszanto	1434	JDS3 - ICPDR
Danube	2013	summer/fall	Aljmas	1434	JDS3 - ICPDR
Danube (BW)	2021	Summer/fall	Gornje Podunavlje	(1430)	lifelineMDD (INCVP)
Danube (BW)	2021	Summer/fall	Karadorđevo	(1310)	lifelineMDD (INCVP)

### 3.5.1 Analysis of species occurrence

In total, 66 fish species were detected during all analyzed surveys (including eDNA sampling in 2021). 64 species were caught with electrofishing throughout recent years - 46 species in the Mura, 52 species in the Drava and 42 in the Danube. A list of caught species and their detection frequency is provided below.

Table 34: List of recorded fish species during various samplings in Mura (17 surveys), Drava (8 surveys) and Danube (7 surveys) between 2006 and 2021. "current study" indicates the detection through eDNA (\*only presence/absence, not counted in detection frequency) and electrofishing in the Mura and Drava in July 2021 and in the Danube backwaters in Serbia (sampling conducted by INCVP). Column "detection frequency" includes the total number of samplings in which the species was caught. Column "detection frequency" indicates the share of samplings in which the species was recorded.

	current study		detection frequency (total)			detection frequency (%)			
	Mu & Dr	Danube Serbia	Mu	Dr	Da	Mu	Dr	Da	Total
<b>Total species count</b>	<b>54</b>	<b>27</b>	<b>46</b>	<b>52</b>	<b>42</b>				<b>66</b>
Abramis brama	X	X	5	5	7	29%	63%	100%	53%
Acipenser ruthenus	*								
Alburnoides bipunctatus	X		15	6		88%	75%		66%
Alburnus alburnus	X	X	15	8	7	88%	100%	100%	94%
Ameiurus melas	X	X		2	4		25%	57%	19%
Anguilla anguilla					2			29%	6%
Aspius aspius	X	X	7	7	7	41%	88%	100%	66%
Babka gymnotrachelus	X			1	1		13%	14%	6%



	current study		detection frequency (total)			detection frequency (%)			
	Mu & Dr	Danube Serbia	Mu	Dr	Da	Mu	Dr	Da	Total
<b>Total species count</b>	<b>54</b>	<b>27</b>	<b>46</b>	<b>52</b>	<b>42</b>				<b>66</b>
Ballerus ballerus		X			5			71%	16%
Ballerus sapa	X		1	2	4	6%	25%	57%	22%
Barbatula barbatula	X		4	2		24%	25%		19%
Barbus balcanicus	*		1			6%			3%
Barbus barbus	X		17	8	4	100%	100%	57%	91%
Blicca bjoerkna	X	X	1	6	5	6%	75%	71%	38%
Carassius carassius				1			13%		3%
Carassius gibelio	X	X	8	7	5	47%	88%	71%	63%
Chondrostoma nasus	X	X	17	7	4	100%	88%	57%	88%
Cobitis elongatoides	X	X	5	8	2	29%	100%	29%	47%
Cottus gobio	X		2			12%			6%
Ctenopharyngodon idella				1			13%		3%
Cyprinus carpio	X	X	4	4	4	24%	50%	57%	38%
Esox lucius	X	X	8	8	7	47%	100%	100%	72%
Eudontomyzon mariae	X		3	3	3	18%	38%	43%	28%
Gasterosteus gymnurus	X		2	1		12%	13%		9%
Gobio gobio			6			35%			19%
Gobio obtusirostris	X		3	2		18%	25%		16%
Gymnocephalus baloni			1	1	5	6%	13%	71%	22%
Gymnocephalus cernua	X	X		2	3		25%	43%	16%
Gymnocephalus schraetser	X			1	3		13%	43%	13%
Hucho hucho	*		4			24%			13%
Hypophthalmichthys molitrix	X	X	1	3	1	6%	38%	14%	16%
Hypophthalmichthys nobilis				1			13%		3%
Lepomis gibbosus	X	X	5	6	3	29%	75%	43%	44%
Leuciscus idus	X	X	3	5	7	18%	63%	100%	47%
Leuciscus leuciscus	X		14	6		82%	75%		63%
Lota lota	X		9	2	5	53%	25%	71%	50%
Micropterus salmoides		X			1			14%	3%
Misgurnus fossilis				1	1		13%	14%	6%
Neogobius fluviatilis	X	X	2	7	4	12%	88%	57%	41%
Neogobius melanostomus	X			1	5		13%	71%	19%
Oncorhynchus mykiss	*								
Perca fluviatilis	X	X	8	8	7	47%	100%	100%	72%
Pelecus cultratus					2			29%	6%
Phoxinus phoxinus	X			1			13%		3%
Ponticola kessleri	X			1	5		13%	71%	19%
Proterorhinus semilunaris	X	X		3	6		38%	86%	28%
Pseudorasbora parva	X	X	6	6	4	35%	75%	57%	50%
Rhodeus amarus	X	X	5	7	4	29%	88%	57%	50%
Romanogobio carpathorossicus	X		11			65%			34%
Romanogobio uranoscopus	X		7	1		41%	13%		25%
Romanogobio vladykovi	X		12	7	3	71%	88%	43%	69%
Rutilus rutilus	X	X	5	8	7	29%	100%	100%	63%
Rutilus virgo	X		3	6	2	18%	75%	29%	34%
Salmo trutta fario	X		4	1		24%	13%		16%
Sander lucioperca	X	X	5	6	6	29%	75%	86%	53%
Sander volgensis					1			14%	3%
Scardinius erythrophthalmus	X	X	2	4	4	12%	50%	57%	31%
Sebanjewa balcanica	*			1			13%		3%
Silurus glanis	X	X	2	4	3	12%	50%	43%	28%
Squalius cephalus	X	X	17	8	4	100%	100%	57%	91%

	current study		detection frequency (total)			detection frequency (%)			
	Mu & Dr	Danube Serbia	Mu	Dr	Da	Mu	Dr	Da	Total
<b>Total species count</b>	<b>54</b>	<b>27</b>	<b>46</b>	<b>52</b>	<b>42</b>				<b>66</b>
Telestes souffia			1			6%			3%
Thymallus thymallus	*		4			24%			13%
Tinca tinca	X	X	1	3	2	6%	38%	29%	19%
Vimba vimba	X		5	8		29%	100%		41%
Zingel streber	X		5	3		29%	38%		25%
Zingel zingel	X		10	2		59%	25%		38%

The most commonly found species in the TBR MDD is the bleak, which was detected in 94% of the analyzed surveys (30 out of 32). Only in two samplings in the Mura (at the upper border of the TBR MDD), the bleak was not recorded. The second most common species is the chub tied with the barbel. Both occur in 29 samples (91%) and are missing only in the two samples from the Serbian Danube-backwaters and in one sample of the JDS3 from the Serbian Danube. Other common species include the nase (88%), the pike and the perch (72% of samples each). On the other hand, species caught in only one of the 32 samples are the riffle dace (*T. souffia*), the Danube whitefin gudgeon (*R. vladkyovy*), the balcan spined loach (*S. balcanica*), the Volga pikeperch (*S. volgensis*), the Eurasian minnow (*P. phoxinus*), the balkanian barbel (*B. balcanicus*), the crucian carp (*C. carassius*) and three non-native species (largemouth bass, bighead carp, grass carp). Other rare species include the chekhon (*P. cultratus*), the weather loach (*M. fossilis*), the bullhead (*C. gobio*) – all caught in two samples only. Two species detected exclusively with eDNA in 2021 are the sterlet (*A. ruthenus*) and the non-native rainbow trout (*O. mykiss*). The occurrence of both is documented from historic literature.

For the areas sampled in Serbia, the regular occurrence of *M. fossilis*, *B. barbus*, *G. schraetser* and *N. melanostomus* is mentioned, however these species were not detected in 2021.

### 3.5.1.1 Rare species

Particularly rare species that have not been caught in the analyzed recent surveys include the fringebarbel sturgeon (*Acipenser nudiiventris*) and the sterlet (*A. ruthenus*). Both sturgeons are considered native in the Drava and lower Mura and although reports of catches from local older fishermen exist, recent confirmed catches – at least from the fringebarbel sturgeon – are missing. Two sterlet catches have been reported by fishermen (mentioned by Pengal, 2021) in the Slovenian Mura and Drava. The sterlet was also detected through eDNA sampling in the lowest Drava in 2021. However, the DNA density was very low and there is a small chance of mis-identification. Nevertheless, possible sturgeon populations in the Mura and Drava (and also Danube) within the TBR MDD shall be investigated further in the future.

The balcanian barbel (*B. balcanicus*) is considered native in the Slovenian Mura and reports from the Drava also exist. Confirmed catches are very rare in all analyzed river sections. Very likely, the balcanian barbel was confirmed through eDNA sampling in 2021 (see chapter 3.3.1). The Danube bleak (*Alburnus chalcoides*, formerly *Chalcalburnus chalcoides*) is listed as occurring in the Drava by Jelic (2012), however no recent catches have been reported. The riffle dace (*T. souffia*) was caught in the Slovenian Mura, recent confirmed catches from the Drava are however lacking, although it may occasionally occur there as well.

The mudminnow (*Umbra krameri*) is a species that is highly adapted to stagnant and infrequently connected water bodies in the floodplain area. Although this species is considered native in the TBR MDD and its occurrence/presence is confirmed in several areas (e.g. through the DRAVALIFE project - [www.drava-life.hr](http://www.drava-life.hr)), the analyzed reports have not included recent catches. This is most likely the consequence of the focus on riverine habitats when performing electrofishing. Stagnant and often hard-to-access water bodies cannot be sampled with the same methodology as open water areas within the main river complex.

The same is true for other limnophilic species like the weather loach (*Misgurnus fossilis*), the belica (*Leucaspis delineatus*), the crucian carp (*C. carassius*) or to a lesser extent also for the the rudd (*S. erythroptalmus*), the tench (*T. tinca*) or the bitterling (*R. amarus*). All of whose abundances are much higher in (temporarily disconnected) side arms, oxbows and generally stagnant areas compared to the main river. Although some of these species have been recorded frequently, the abundances of these species are likely underestimated when sampling the main channel of a river. Nevertheless, their presence is an important indicator for the occurrence of specific habitat conditions that are part of a natural river system. Future investigations should attempt to better integrate the fauna of stagnant water bodies.

The presence of salmonid fish species was confirmed via electrofishing in 2021 only by single catches of the brown trout in the residual flow stretch of the Drava (SR). Additionally to the brown trout, the Danube salmon (*H. hucho*) and the grayling (*T. thymallus*) are considered native in both the Mura and the Drava. Whereas in the Mura, recent catches of Danube salmon and grayling are reported (yet rare), there are no recent catches of these species in the Drava. Both species are restricted to the upstream reaches of the TBR MDD area, their catch in the Drava is therefore considered rather unlikely. The non-native rainbow trout (*Oncorhynchus mykiss*), that has established self-reproducing populations throughout many European rivers, has also been caught in the in the Mura and in the Drava river. Additionally, the presence of the brook trout (*Salvelinus fontinalis*) was reported by Jelic (2012). With eDNA sampling, we were able to detect all of the above-mentioned species in both the Mura and Drava!

### 3.5.1.2 Non-native species

The presence of non-native species in the TBR MDD has been confirmed in almost every study carried out in recent years. Recent reportings include the presence of the grass carp (*Ctenopharyngodon Idella*), the silver carp and bighead carp (*Hypophthalmichthys molitrix* and *H. nobilis*), the black and brown bullhead (*Ameiurus meals* and *A. nebulosus*), rainbow trout and brook trout (*O. mykiss*, *S. fontinalis*), the pumpkinseed (*L. gibbosus*), the largemouth bass (*Micropterus salmoides*), the three-spined stickleback (*Gasterosteus gymnurus*) and several ponto-caspian goby species. These gobies represent a major share of the fish faunistic composition in the Danube (especially in regulated stretches). Up to 50% of caught fish were gobies during selected samplings in the Danube. Also in the lower Drava, considerable amounts of gobies have been recorded (e.g. 12% of caught individuals near Barcs by Saly, 2019).

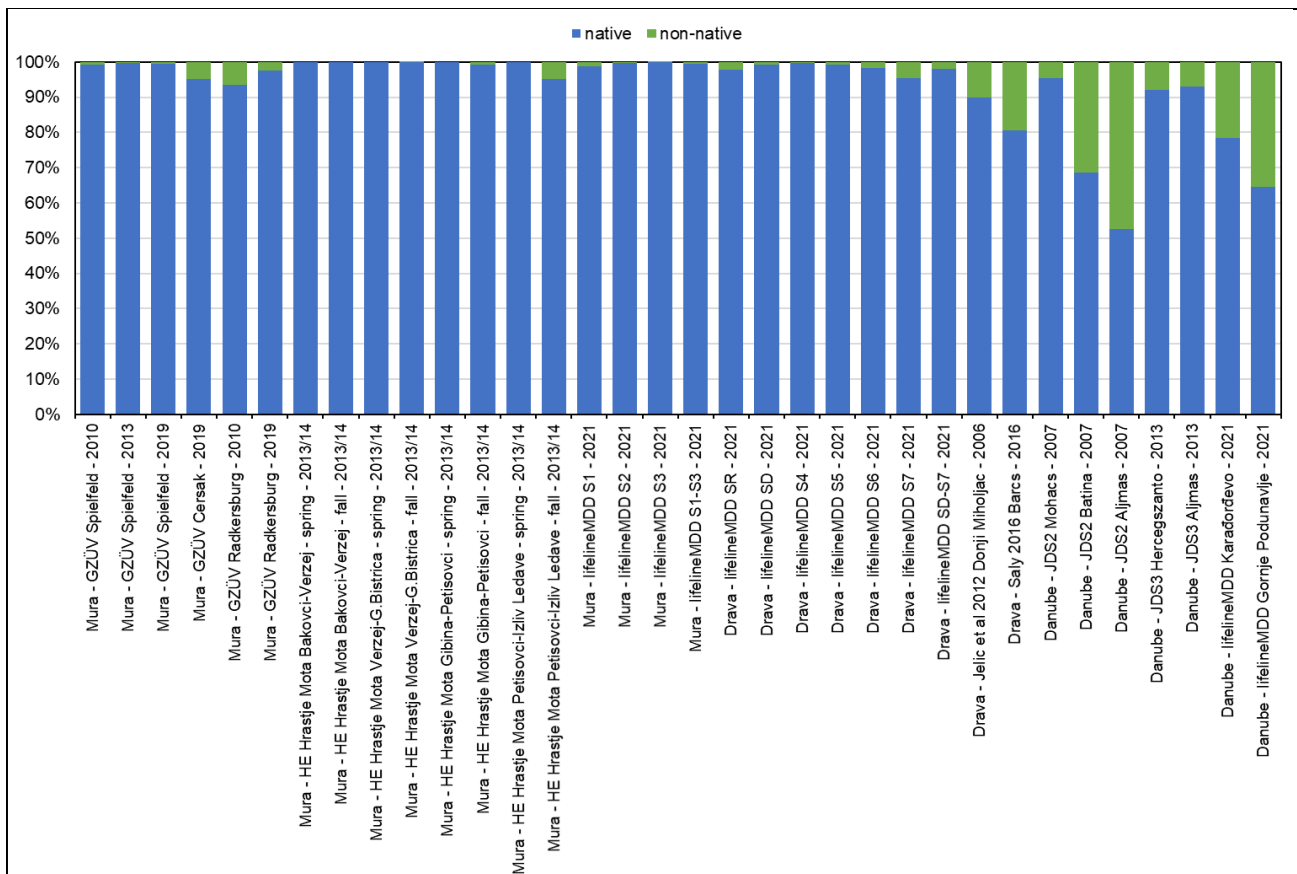


Figure 57: Share of native and non-native fish (percentage of total catch number/total fish abundance) for all analyzed recent surveys.

Within the sampling for this report, 5 ponto-Caspian-goby species have been detected: monkey goby (*Neogobius fluviatilis*), bighead goby (*Ponticola kessleri*), round goby (*Neogobius melanostomus*), racer goby (*Babka gymnotrachelus*) and western tubenose goby (*Proterorhinus semilunaris*). Reported catches of the monkey goby, the bighead goby and the tubenose goby date back to at least 15 years. In fact, the bighead goby is even

considered a native species in Croatia (Jakovlić et al. 2015) – although probably exclusively in the Danube and not in the Drava river.

The range expansion of the ponto-caspian goby species from the Danube reaches upstream is well documented for the Drava (e.g. Piria et al., 2021, Saly, 2019). During sampling in 2021 it was well described that the presence of gobies is increasing in further downstream stretches – especially through eDNA sampling, in which the gobies had major community shares in the lower Drava. Prior to this survey, the racer goby (*B. gymnotrachelus*) was not caught in the Drava river (Piria et al, 2021). However, five specimen were detected in July 2021 in the reach below Donji Miholjac. The range expansion is very much driven by the habitat suitability for these species. Although still too little is known about the dominant drivers for their invasion in many parts of European rivers, the presence of hard embankments, artificial shorelines and rip-rap structures enhances the reproduction success of these “speleophilic” species (hiding spaces inbetween larger rocks serve as optimal spawning habitats).

The categorization of the prussian carp (*C. gibelio*) is not fully reconstructible due to the lack of sound historic information on its native range. This species is considered and treated as non-native in Croatia, Hungary, Serbia and Slovenia and therefore in most countries of the TBR MDD except for Austria. The reason for this different view is that the historic development and presence of the prussian carp is (and will likely remain) unsolved. In many cases/countries, publications and guidelines have been published on minimizing adverse effects and impacts of Prussian carp.

Oddly, the eel (*A. anguilla*) is categorized as a native species in several lists. Although the eel is native in both Slovenia and Croatia (in river draining to the Adriatic Sea), it is considered non-native for the Danube river basin and therefore also records from the Mura and Drava are likely stemming exclusively from human introduction into these systems.

### **3.5.1.3 Nase and Barbel**

The nase and barbel are two species that are frequently caught in the TBR MDD. As two rheophilic, relatively large growing species with distinct migratory behavior and relatively high fish densities, the populations of these species are very suitable to indicate the functioning of rivers.



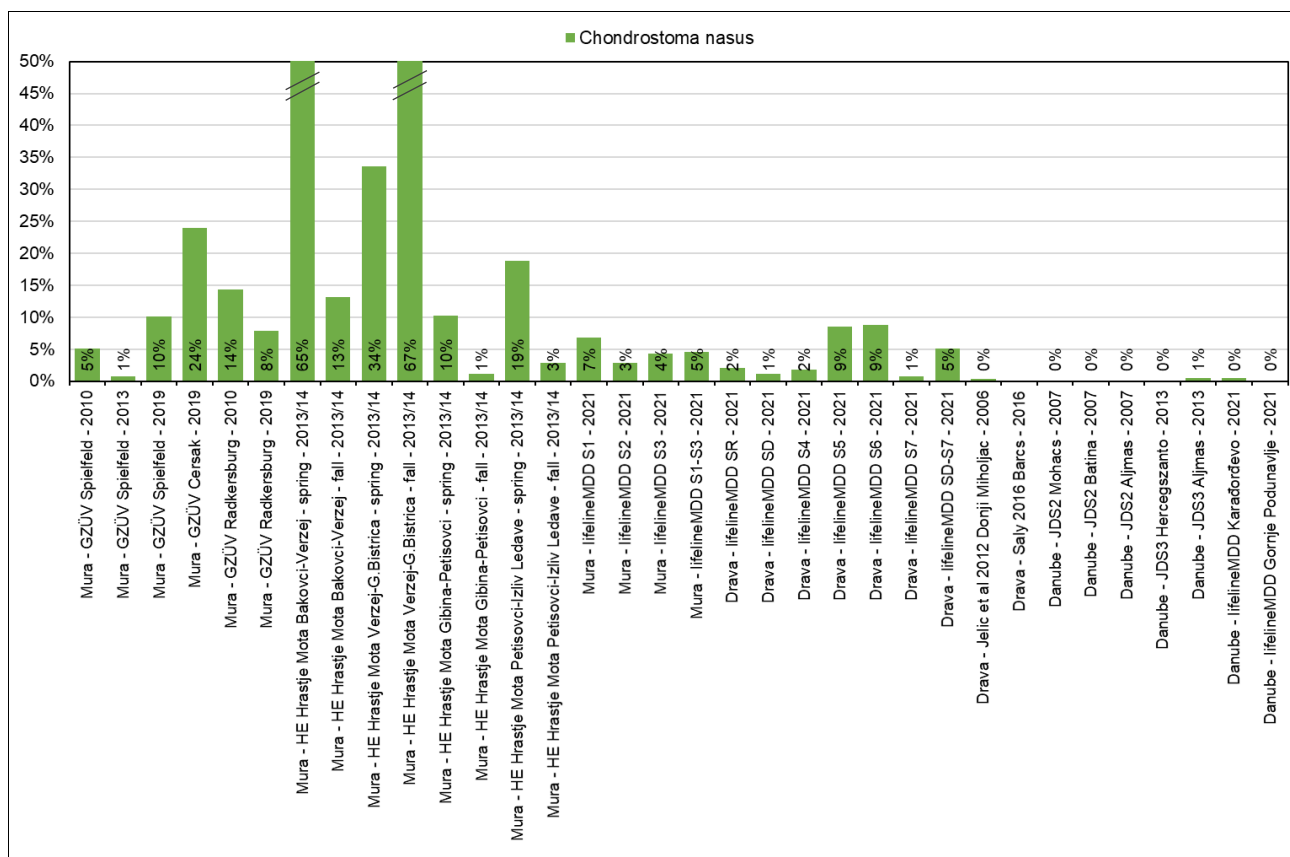


Figure 58: Relative share of nase (*C. nasus*) in recent fish surveys in TBR MDD.

The relative frequency of nase in previous samplings is indicated in Figure 58. Overall, the share of nase is higher in upstream sections of the TBR MDD (Mura and upstream parts of the Drava). On average, the nase accounts for about 10% of the fish community in the Mura. Two very high shares of nase were recorded during sampling in the Mura (Podgornik et al., 2015). In the Drava, this share drops to below 5%. In the Danube, only very few single individuals of the nase can be encountered. However, single specimen were also caught in the floodplain backwaters of the Serbian Danube in 2021.

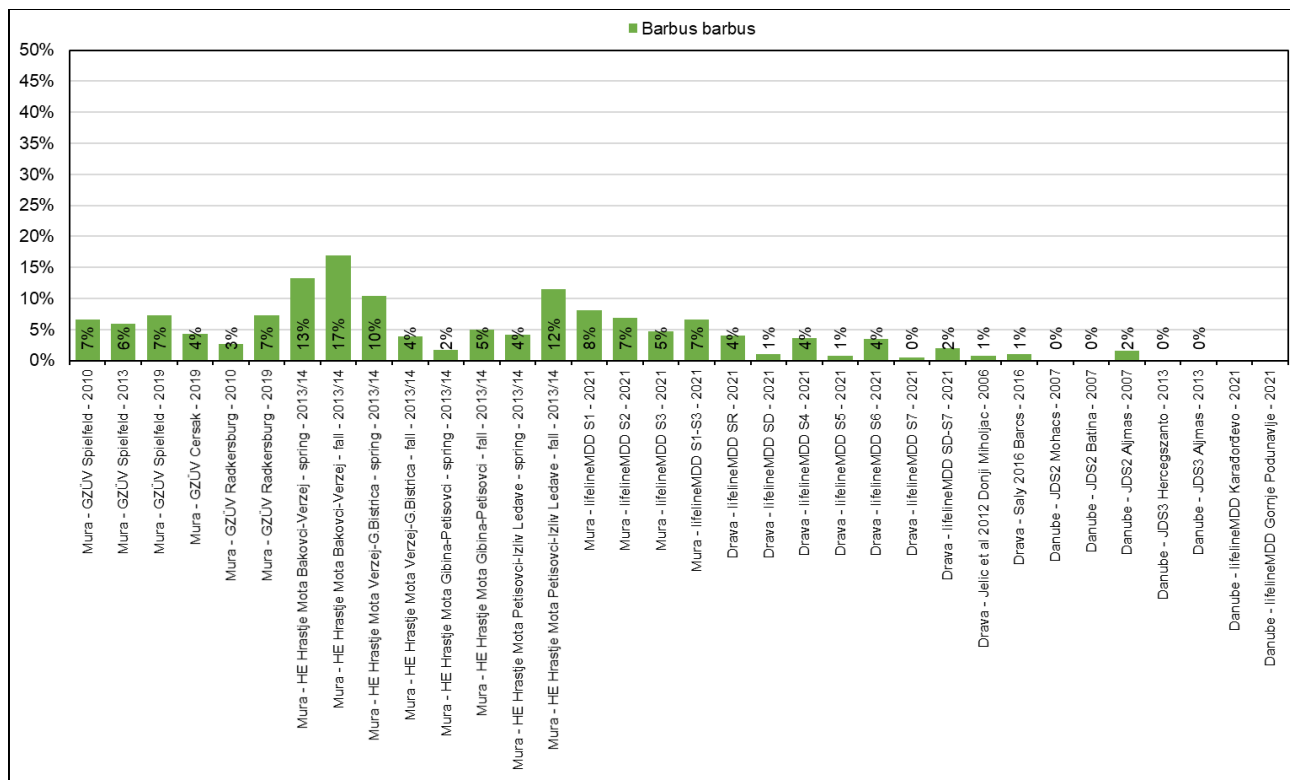


Figure 59: Relative share of barbel (*B. barbus*) in recent fish surveys in TBR MDD.

The barbel had an average community share of slightly below 10% in the Mura in previous samplings as well as in 2021. The result from sampling in 2021 is therefore very much in line with previous assessments. In the Drava, barbel occur in lesser dominance shares (below 5%). However, the barbel was also recorded further downstream and was caught in the Danube as well. No individuals of the barbel were recorded in the Danube backwaters in Serbia.

### 3.5.2 Analysis of fish community structure

As mentioned above, the analysis of the fish community throughout the different surveys is accomplished via the relative catch number and/or standardized fish abundances. A full list of the relative frequencies for each sampling occasion is included in the appendix.

The authors are aware that the relative fish frequency is a parameter that can only incompletely describe the status of the fish community at the time of the sampling. One major issue is that the fish frequency does not contain information on the population structure and/or fish sizes that were recorded. Therefore, critical information on the age distribution as well as spawning- and recruitment success is missing. Nevertheless, we conclude that the overall target of comparing community trends and fish community changes throughout the river course can be achieved with the analyzed data.

One excellent indicator of the changing fish community along the river course is the analysis of flow velocity preferences. Since most of the 64 total species that were recorded during the surveys are categorized as either rheophilic (preferring conditions with higher flow velocities and constant current) or indifferent (occurring in both stagnant and flowing conditions), these two guilds account for the major share within the fish community.

In Figure 56, it is clearly shown, that the amount of rheophilic fish decreases with continuing river length. In the Mura, a decrease of rheophilic dominance can be observed from the Austrian-Slovenian border Mura down to the confluence with the Mura can be observed.

In the most upstream sections of the Mura (border Mura between Austria and Slovenia), the rheophilic guild accounts for roughly 70-80% of caught fish. In the Slovenian Mura down to the confluence with the Drava, this share gradually drops to about 30-40%. In the Drava sections analyzed (all of them close to or downstream of the Mura confluence), the share of rheophilic fish ranges between 5 and 15%. Additionally, oligorheophilic species and limnophilic species account for notable shares of the community. In the Serbian Danube sections, the indifferent guild accounts for over 90% of the fish community with occasional shares of oligorheophilic species. Rheophilic and limnophilic species are almost completely missing. In the Danube backwaters in Serbia, the share of limnophilic fish is slightly increased again (10-15%).

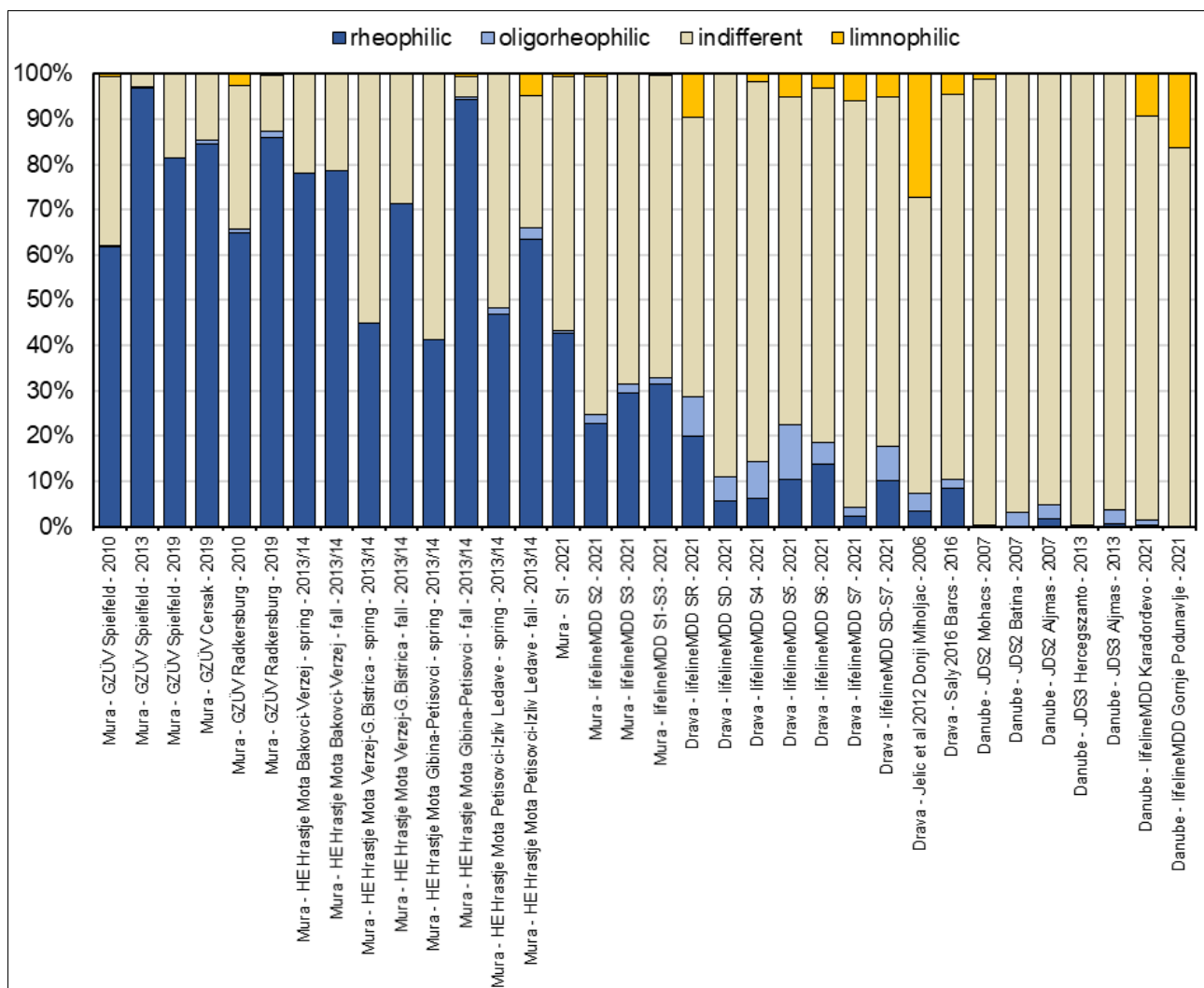


Figure 60: Share of caught fish (percentage of total catch number/total fish abundance) by flow preference and analyzed survey.

Interestingly, at three of four sampling sites that were investigated in both spring and fall (2013/14) in the Slovenian Mura, a significant seasonal difference of the fish community was assessed. During the samplings in fall, the dominance of rheophilic fish was greater than during samplings in spring. This strongly suggests that the seasonal fluctuation of the fish community is significant. To analyze this pattern in more detail and also considering the results for the fish biomass, the share of the most frequent species was plotted in Figure 57. Although the share of rheophilic and indifferent fish was almost equal in the section Bakovci – Veržej, the detailed species structure reveals that there was a pronounced difference in the relative density of spirilin (*A. bipunctatus*) and nase (*C. nasus*) between spring and fall – the nase had a much higher share during sampling in spring and vice versa for the spirilin. In the other sections, the share of rheophilic fish is higher in fall than in spring. In the section Veržej - G. Bistrica for example, the amount of chub decreased from spring to fall, whereas the amount of nase increased.

The difference between spring and fall regarding biomass was generally much less pronounced – a pattern visible in most sections except for Petišovci - izliv Ledave (high biomass share of *Abramis brama* in fall, data not plotted). Overall, differences in the fish community composition occur not only between seasons, but also significantly between adjacent stretches within the Mura.

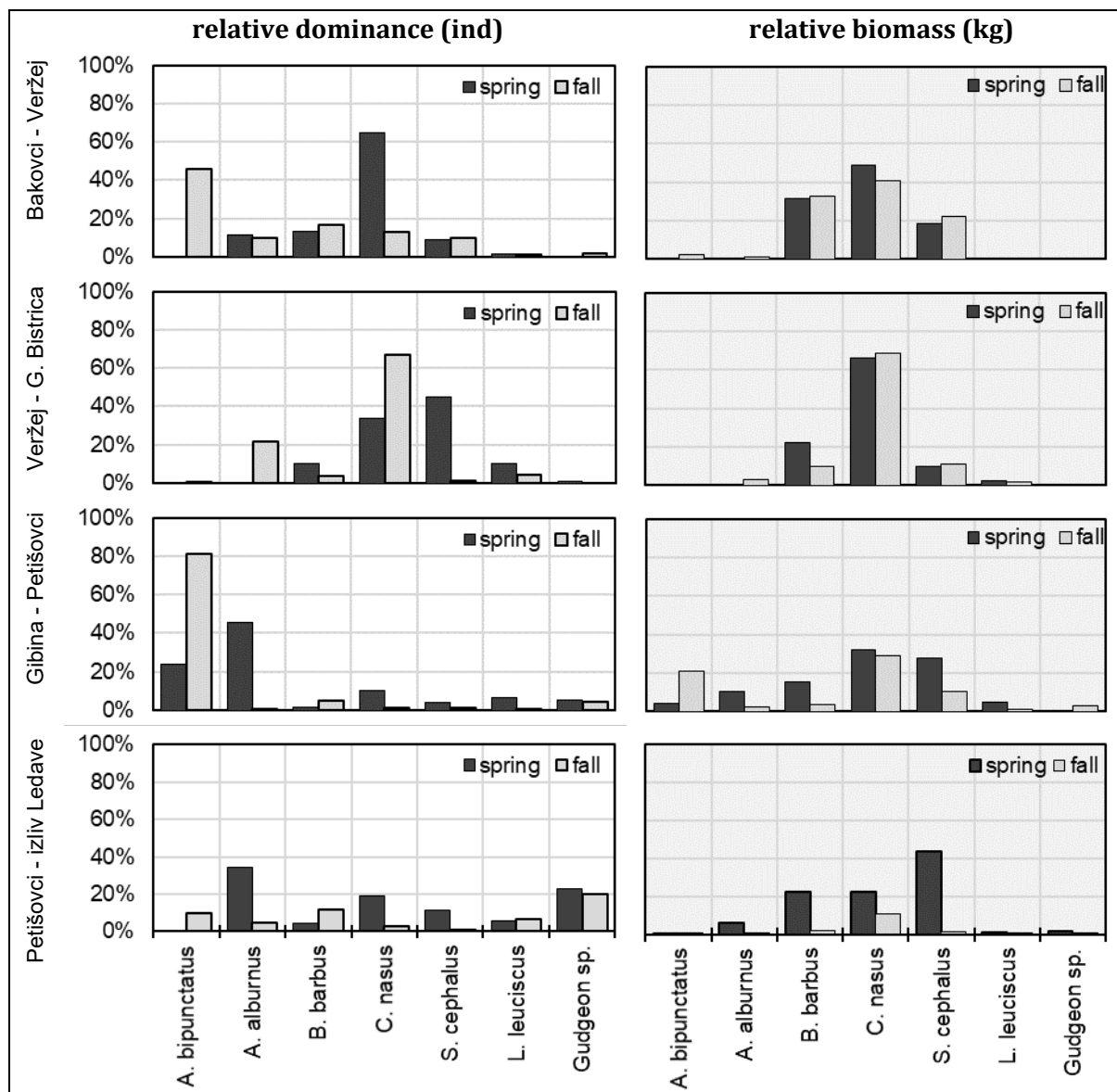


Figure 61: relative share of fish individuals and fish biomass in four sampled Mura section and two different seasons. Data is derived from Podgornik et al. (2012). Only 7 most common species/groups are displayed. The bleak (*A. alburnus*), chub (*S. cephalus*) and dace (*L. leuciscus*) are characterized as indifferent species, others as rheophilic. Total frequencies for the sampled sections are<sup>1</sup>: Bakovci – Veržej (spring: 188 ind., 80 kg; fall: 303 ind., 55 kg); Veržej - G. Bistrica (spring: 127 ind., 41 kg; fall: 205 ind., 39 kg); Gibina – Petišovci (spring: 175 ind., 13 kg; fall: 1850 ind., 13 kg); Petišovci - izliv Ledave (spring: 77 ind., 9 kg; fall: 193 ind., 36 kg)

<sup>1</sup> Stated values have been taken from the report by Podgornik et al. (2012). However, values for fish abundance do not seem plausible. Possibly, only larger specimen were caught.



Strong seasonal fluctuations in the density of different fish species have also been described for the middle and lower Drava river by Sallai & Kontos (2005). These results also suggest that the variability of the fish community within several years is presumed to be high. The authors assume that due to the open longitudinal continuum between the Danube and the Mura, natural population and community dynamics induced by fish migration (i.e. location changes of fish of different age classes and for different purposes) are the most important factors for the faunistic composition.

## 4 Conclusions & action recommendations

The conducted field research in the Mura and Drava as well as in Danube backwaters contributes greatly to an up to date overview on the current situation of fish stocks in these rivers. Together with information from other recent fish surveys and sampling activities, a comprehensive picture of the status of the fish fauna in the TBR MDD can be drawn. Additionally, knowledge gaps have been identified that should be addressed in future surveys to better understand the possible implications of river management decisions and/or possible future measures implemented in the TBR MDD.

### 4.1 Current status of the fish fauna at a glance

The current status of the fish fauna was assessed via a sampling survey conducted in July 2021. During this survey, 7 sections along the Mura and Drava in Slovenia, Croatia and Hungary were sampled on one day each via electrofishing using two boats. In all sections, environmental DNA samples were taken to identify/verify species occurrence. Additionally, sampling of two Danube backwater systems was conducted in Serbia (areas of Gornje Podunavlje and Karađorđevo) in July and September of 2021 via electrofishing.

The sampling of the Mura and Drava using electrofishing proved to be effective to get insights into the current species distribution and population characteristics. A clear change of the fish community was observed from up- to downstream sections. Whereas in upstream sections (Mura), rheophilic fishes (species that prefer fast flow, like nase, barbel, spirlin, several gudgeons) are dominating, a shift to indifferent species (more generalist, no strict ecological requirements for flow conditions; species like the bleak, the chub, roach, perch) in the lower sections is visible. In lower sections, the share of limnophilic (species that prefer stagnant conditions) is also higher.

During the sampling for this project in the Mura and Drava with electrofishing and eDNA, a total of 53 species was recorded. Comparing this result to other recent surveys, it is acknowledged that only 5 species caught in other recent surveys in the Mura and Drava were “missing” in 2021 (or have been mis-identified or cannot be distinguished by eDNA detection): the gudgeon (*G. gobio*, identification in the field sometimes difficult, taxonomic discussion on gudgeons is ongoing), crucian carp (*C. carassius*, eDNA cannot distinguish between *C. gibelio* and *C. carassius*), weather loach (*M. fossilis*), riffle dace (*T. souffia*, not distinguishable from the nase via eDNA) and Balon’s ruffe (*G. baloni*, not distinguishable from other species of genus *Gymnocephalus* via eDNA ).

On the other hand, we were able to record species that have very rarely been caught during other studies. In the Mura, the white-eyed bream (*B. sapa*), the white bream (*B. bjoerkna*), the bullhead (*C. gobio*), the lamprey (*E. mariae*), the catfish (*S. glanis*) as well

as the non-native (alien species) monkey goby (*N. fluviatilis*) and silver carp (*H. molitrix*) were recorded during the sampling in 2021 but not in other recent surveys. Additionally, through eDNA, we were able to detect the presence of the balcanian barbel (*B. balcanicus*), the brown bullhead (*A. melas*), the minnow (*P. phoxinus*), the golden spined loach (*S. balcanica*) and the tench (*T. tinca*) in the Mura.

In the Drava, the minnow (*P. phoxinus*) and brown trout (*S. trutta*) were caught in the residual flow section of the HPP Donja Dubrava through electrofishing. Sallai & Kontos (2008) have also reported catches of these two species in this section in 2004. Through eDNA, these species were also detected in further downstream reaches of the Drava. eDNA analysis further documented detections of the sterlet, the bullhead, the Danube salmon, the grayling, the stickleback and the sand gudgeon in the Drava, all of which could be caught with electrofishing in any recent surveys. The presence of five ponto-caspian goby species has been confirmed for the lower Drava (four species through eDNA, 5 through electrofishing). The record of the non-native racer goby (*B. gymnotrachelus*) in the Drava near Donji Miholjac appears to be the first documented catch of this species in the Croatian Drava (compare Piria et al. 2021).

Although the overall amount of fish (expressed as fish abundance and fish biomass) was lower than initially expected, the faunistic composition showed vital populations of typical species occurring in the area (e.g. nase, barbel, chub, bleak). Especially the presence of large numbers of juvenile individuals of nase and barbel in most sections indicates that a sufficient amount of suitable riverine habitat is available. These species require areas with sediment dynamics (suitable gravel and grain sizes for successful reproduction) as well as gravel bars that are available in all investigated sections. The near natural morphodynamics that are still in effect in many parts of the TBR MDD are essential to sustainably protect the populations of these species. Since for example the nase requires different habitat conditions throughout its life-cycle, also many other fish species (that occur in lesser frequency or/and are harder to catch via electrofishing), will find suitable habitats in areas where nase populations are intact.

Especially, compared to other larger European rivers that are hydromorphologically modified to a much higher extent (like the Austrian sections of the Mura and Drava), the rivers of the TBR MDD have preserved a near natural state and river characteristic dynamics to this date.

The sampling in the Mura and Drava focused on the description of the longitudinal change of the fish community. Water bodies aside of the main channel like disconnected side arms, temporarily connected bays, oxbows, but also tributaries could not be sampled sufficiently. Sampling in the floodplain areas in Serbia showed that the fish community greatly differs from the main channel (other species occurring – more limnophilic species). We assume that also in backwaters and oxbows in the Mura and Drava, the fish fauna is composed differently to the main channel and that typical “floodplain-species” are probably greatly underestimated not only in this survey, but also in results from other fish investigations. Exchange processes and the connectivity between the main river and

the floodplain (lateral connectivity) however play an integral role in riverine ecology and several fish species are also depending on riverine habitats that are only temporarily connected to the main channel (e.g. the carp during spawning and egg development). The authors strongly suggest to put future efforts into investigating biotic interactions between these habitat types and the spatial distribution of species throughout their lifecycle/different seasons.

## 4.2 Temporal dynamics of fish stocks

The composition of the fish fauna in the TBR MDD is highly dynamic. Without being able to quantify seasonal or annual fluctuations during this survey, a quick analysis of other recent samplings conducted in comparable river stretches of Mura and Drava has shown that the abundance (and biomass) of the most common/important species like nase and barbel can fluctuate considerably between different seasons (Podgornik et al., 2001, Sallai & Kontos, 2008). This underlines the fact that results from single sampling efforts generally need to be interpreted with caution. Although this is true for any river system, we assume that seasonal/annual fluctuations in fish densities are more pronounced in the TBR MDD as the river corridor is open and fish can migrate without barriers or obstacles. Fish inhabiting the Mura and Drava are able to “choose” and move between a larger variety of habitats compared to rivers that are more severely altered. Additionally, fish can migrate freely within the axis between the Danube and the Slovenian Mura, spanning over 300 km. Within this system, it is very likely that extensive movements of fish (or even parts of whole populations) occur. At least for nase and barbel, migration distances to reach spawning habitats of over 100 km have been documented (e.g. Steinmann, 1937). This pattern cannot be observed nowadays in other larger central European rivers, since the migration routes have been blocked with the construction of hydropower plants.

To get a profound idea about the extent and causes of stock fluctuations, it would be required to conduct consecutive sampling efforts over multiple seasons and/or years. The sampling effort (electrofishing surveys) would be rather extensive of course. Based on the results of this survey, we can recommend to apply a combination of electrofishing and eDNA sampling for future surveys. Whereas electrofishing can give quite precise information on the current population sizes and age structures, eDNA sampling will complement community composition and possible shifts thereof. Also, eDNA sampling is much cheaper and can be applied in higher spatial and temporal density than electrofishing.

To gain more insights into the migration- and behavioral pattern of fish in the Mura and Drava, a study using (radio- /acoustic) telemetry would be very suited. This would also greatly contribute to gain more knowledge about the ecological requirements of European riverine fish species and thereby make conservation and river restoration efforts in general more profound.

## 4.3 Sampling effectiveness

The electrofishing survey in the Mura and Drava was conducted during a relatively high flow situation, especially the second half of sampling (in the lower Drava reaches). If possible, the river discharge should be below average discharge levels because fish are distributing within a much lesser area within the river and are therefore usually easier to catch. Also, during higher flow periods, the visibility in the river is reduced (due to higher turbidity of the water) – a factor that also reduces the effectivity of electrofishing, because stunned fish are not easily spotted and caught with the hand held dip nets. On the other hand however, some areas or habitats within the river corridor are potentially much harder to sample or not at all accessible, because sampling with an electrofishing boat requires a minimum water depth of usually 30-50cm (simply to be able to navigate the boat). This is especially true for rivers/sections with high habitat variability like parts of the Mura and Drava. Some side arms, gravel bars, shorelines, etc. might not be easy to sample during low flow periods.

The sampling was scheduled and carried out during the Covid-19 pandemic. Due to various travel restrictions in the years 2020 and 2021, the initially planned sampling in autumn of 2020 could not be realized. The optimal time frame for an electrofishing survey that attempts to characterize the fish community would be in autumn. The main reason being that at this time, the juvenile fish that hatched in spring/summer of the same year already have a body length of a few centimeters and are therefore easier to catch and identify. Also, during autumn, the hydrological conditions are often most stable and longer periods of low flow make it easier to plan surveys. Nevertheless, sampling in other seasons may as well gain valuable additional information, like seasonal variabilities and distribution patterns of the fish community.

Electrofishing using two boats proved to be effective to get a good overview on the fish community in a relatively short timeframe (approximately one day to characterize a river stretch of ~15km). Nevertheless, the following limitations of the sampling approach need to be considered when interpreting the results and when planning possible future investigations:

- Even though the sampling was carried out with a team of 8+ people, the fish biocenosis of the lower Mura or Drava over a stretch over several kilometers cannot be covered completely during a one-day-sampling. The high (fish-)habitat diversity, which is found in most parts of the investigated rivers, indicates that a sampling effort to cover the whole community would require more fishing strips and possibly additional sampling methods (like netting).
- Consecutive sampling efforts over longer timespans would be required to better quantify and validate species occurrence and variability in community structure and stock sizes.
- The results regarding quantitative parameters of the fish population (abundance, biomass) have to be interpreted with caution. The values are based on a single



sampling day and the varying visibility had a major influence on the results. Generally, quantitative parameters can only represent a rough estimation of the current faunistic composition and the assessed values are rather an under- than overestimation of the actual stock sizes. The collected data shall be used as a basis for future and more in-depth analysis.

The results from eDNA sampling present a good addition to the “traditional” electrofishing method. With a relatively low effort, critical information on the fish community can be gathered. First and foremost, a comprehensive species/taxa list. It is evident that eDNA records bottom dwelling and/or bottom oriented species in much higher quantities compared to electrofishing. Similar to electrofishing however, the species list contains primarily species that live in the main channel of the river. Species bound to side channels, oxbows etc. either occur in minor community shares (rudd, tench) or were not detected at all (weatherfish – *M. fossilis* or mudminnow – *U. krameria*). The major disadvantages of eDNA sampling are that several taxa cannot be distinguished to species level and their presence (or absence) can hence not be confirmed. Also, information on the population structure of the detected species (fish sizes, total abundance) can not be derived. Although the total quantity of detected DNA may give an estimation on the number of individuals occurring (as proxy for population size), the current state-of-the-art eDNA sample “only” allows for an estimation of the overall community composition.

Sampling in Danube backwaters in Serbia with CPUE electrofishing in Serbia proved to be effective to determine the fish community. However, several challenges that are particularly encountered in backwaters exist:

- Accessibility of different water bodies (often no road and densely vegetated areas). Water bodies often not connected so accessibility by boat not possible.
- Accumulations of deadwood or macrophytes on the water surface can make boat navigation difficult and may reduce visibility/catch efficiency of fish.
- Habitat conditions strongly vary with different water levels. Sound knowledge of the sampling area and situation at different water levels is a prerequisite for targeted and effective sampling effort.

To get more detailed insights into the fish community structure and overall dynamics of the fish stocks in the TBR MDD, recommendations on potential other/additional samplings can be drawn:

- Future samplings should increase the number of total fishing strips for single sections to account for the high habitat variability and increase the validity of sampling results. Details on the habitat conditions and habitat distribution within the sampling stretch should be assessed (via mapping of aerial pictures, drone footage or physical habitat

mapping) and known before the sampling is planned to identify the necessary sampling intensity.

- Additional sampling methods like net sampling (especially in areas too deep for electrofishing) and/or targeted eDNA sampling can give valuable further insights on the fish community (detection of rare species, insights in habitat usage and potential ecologically important habitats).
- Targeted sampling of backwater systems, oxbows, temporarily connected side arms, tributaries (all areas not within the main channel of the Mura and Drava) should be implemented. In a best case scenario, the lateral dynamic of the fish community could be assessed by sampling habitats along a lateral gradient that are connected at different temporal and spatial scales during various discharge situations.
- Potential spawning sites of typical riverine fish species could be assessed via mapping during the spawning period (in tributaries, but also along gravel bars with suitable grain sizes, water depth and flow velocity).
- To assess the density of juvenile (rheophilic) fish, targeted electrofishing of gravel bars and shorelines (using boats and/or backpack generators) can be conducted (CPUE electrofishing) in the future.
- Future sampling surveys should be carried out in clear water situations to reduce uncertainties that are influenced by varying visibility and related catch probabilities.

#### **4.4 Effects of hydropower plants and -operation**

Besides the open longitudinal axis between the Mura and the Danube, the Croatian Drava upstream of the Mura confluence is heavily modified by the presence of three large hydropower plants with large reservoirs. The lowest of the three is the Donja Dubrava powerplant. It is located approximately 8 km upstream of the Mura confluence and was built in 1989. The reservoir (lake Jezero Dubrava) has a surface area of about 17 km<sup>2</sup> making it the second largest lake in Croatia.

The hydropower plants in Croatia have heavily altered the appearance and ecology of the Drava. Although sections further upstream were not sampled in 2021 during the sampling campaign (sampling in the residual flow stretch of HPP Varazdin was not possible due to elevated water level), it is undoubted that the habitat conditions in the Drava upstream of the Mura confluence are totally different from the formerly free flowing and unregulated Drava. Although the HPP are equipped with fish migration facilities, these facilities are far too small and do not meet current state-of-the-art criteria for functional migration aids. Additionally, the migration aids lead directly into the large reservoirs, which do not serve as suitable habitat for riverine fish. The power plants (and reservoirs) also present massive obstacles for downstream migration and dispersal of the fish fauna.

The change of the river appearance (including change of sediment dynamics, habitat diversity, morphology, flow, temperature, oxygen conditions, etc.) in general has resulted in major ecosystem changes that cannot be reversed and are also difficult to mitigate.

Although we definitely recommend to further investigate the fish fauna in the Drava between the Slovenian-Croatian border and the Mura-confluence in future samplings, we also call to evaluate this section decoupled from the rest of the Drava within the TBR MDD and to elaborate tailored mitigation measures (like the adaption of hydropower operation schemes) for these heavily altered water bodies.

The powerplant in Donja Dubrava operates as a run-of-river powerplant that also uses the storage capacity of the reservoir for “flexible” production of electric energy. This means, that during times of high discharge in the Drava, the turbines of the powerplant work at full capacity, but during lower flow periods, the turbines can (partly) be switched off to fill up the reservoir and release the water (and produce more electric energy) during periods of higher energy demand and higher energy prices. This scheme is very common among hydropower operators since it enables higher energy flexibility (compared to a conventional run-of-river power plant) and higher economic efficiency. However, the periodic reduction of discharge below the power plant in combination with the later following release of relatively high amounts of water, creates artificial flow fluctuations in the river sections below the power plant. This phenomenon is called hydropeaking or hydrofibrillation (Greimel et al., 2018). Powerplants with usually most severe flow fluctuations in terms of frequency and intensity are high-head storage power plants (typically located in mountainous areas with high slopes).

The ecological effects of these artificial flow fluctuations have been under thorough investigation in the last years. Although riverine biota are generally very well adapted to riverine (and discharge) dynamics, artificial fluctuations may severely affect aquatic organisms. Due to the periodic and often very rapid rise and fall of the water level in the riverbed, fish and benthic invertebrates may drift away or strand along the shorelines of the affected river reaches. A comprehensive overview on research regarding hydropeaking impacts is provided by Greimel et al., 2018.

The periodicity and the duration of water storage and targeted release times at the power plant Donja Dubrava depend mainly on the hydrological situation in the Drava. Therefore, the hydropeaking at this powerplant does not follow a strict periodic/operational pattern, but is more heterogenous. The analysis of the gauging station below the power plant Donja Dubrava revealed that during low flow conditions, the discharge increase between base flow and peak flow is about 130% (increase from  $\sim 120\text{m}^3/\text{s}$  to  $250\text{-}350\text{m}^3/\text{s}$ ). During medium flow conditions, the peak discharge is about 80% higher than the base flow (increase from  $\sim 280\text{m}^3/\text{s}$  to  $\sim 500\text{m}^3/\text{s}$ ) and at high flow conditions (Drava discharge  $\sim 500\text{m}^3/\text{s}$  and higher), the powerplant operates as run-of-river plant with permanent maximum energy output (full turbine capacity). In summary, the operational scheme at the power plant Donja Dubrava produces artificial flow fluctuations at a Drava discharge of up to  $500\text{m}^3/\text{s}$ . The amplitude of these peaks is about 100%. That means that during water release, the discharge of the Drava is twice as high as during “storage” periods. The peaks/water release happens irregularly and up to three times per day. At the gauging station in Terezino Polje ( $\sim 90\text{km}$  further downstream), the flow fluctuations are still visible on the hydrograph (although with much lesser intensity). Although the

inflow of the Mura (which is not affected by artificial flow fluctuations) is partly buffering the hydropeaks produced by the HPP Donja Dubrava, the effects of the flow fluctuations are significant for an extensive stretch of the Croatian-Hungarian Drava.

It is out of question, that the flow fluctuations potentially have a severe effect on the biotic community in the Drava reaches below the power plant. Although, the detailed effects have not been the main focus of the current study and further investigations would be necessary to quantify adverse effects and make recommendations on how to improve the situation, some insights can already be provided by the current results.

The overall fish density (560 Ind/ha) and fish biomass (33 kg/ha) was by far the lowest (compared to all other sampling sites) in the section directly below the power plant (SD, see Figure 47). 80% of all caught individuals were bleak, with the majority of those caught directly in the outlet channel of the hydropower plant. Additionally, it was obvious that the density of juvenile rheophilic fish was extremely low in this section. In fact, no juvenile individuals of nase were caught (only 9 nase in total) and only 4 juvenile barbel (out of 8 total). Also in the section S4 (at the confluence with the Mura), no juvenile specimen of nase were caught. This lack of juvenile nase is noteworthy, since in all other investigated sections, juvenile nase could be caught.

The authors recommend to put more focus on the assessment of the impacts of hydropeaking at Donja Dubrava. This would include regular samplings of the fish fauna (with standardized electrofishing) as well as the benthic invertebrate fauna. In terms of abiotic assessments, a closer investigation of the operational schemes of the power plant and the analysis of sediment balance and sediment turnover would be crucial.

## **4.5 Absence of predators – fisheries management**

Very low catch rates of predatory fish were conspicuous along the entire study area. Even though predators always make up only small proportions of the species distribution, the densities of predatory fish fell far short of expectations. The low populations of pike, pike-perch and catfish are particularly striking (see chapter 3.2.1.7). Large individuals, some of which also use deep areas (pools) as habitats, were generally expected to be caught in lower numbers. Deep areas (>2.5m water depth) cannot be sampled effectively with boat electrofishing, so it was clear from the beginning that large predators (or also sturgeons), which prefer these deep areas, would be underrepresented or caught only sporadically.

However, predatory fish species also form populations consisting of different age classes, with juveniles generally dominating in terms of absolute abundance. Thus, if a significant adult fish population would exist (which admittedly cannot be mapped quantitatively), we expected to be able to catch juvenile specimen of predatory fish species in typical juvenile habitats/areas that can be covered by electrofishing. In our view, the widespread absence of juvenile pike, catfish, and pike-perch primarily indicates that adult specimen, and thus potential mother fish, are present only at very low densities.

In any case, the Drava and Mura rivers provide extensive suitable reproductive habitats for the predators considered, and reproduction should function. In addition, the high densities of small fish species and juvenile fish should guarantee an excellent basis (food source) for the successful growth of predatory fish. Therefore, the question arises why the densities - in all age classes - of pike perch, catfish and pike are low. This question can admittedly not be answered on the basis of the present single sampling of the study area. From the authors' point of view, the most likely reason could be found in the fishing exploitation of the stocks. During the fieldwork, a relatively high density of recreational fishermen was observed along the entire study area. At least from the perspective of the Austrian fishing team, the number of recreational fishers is very high. The fish stocks in the Mur and Drava rivers also allow for a satisfactory catch result and a successful pursuit of this recreational activity. We do not know or have analyzed the fishing regulations in the area, and are not informed about catch numbers, harvest regulations, fishing pressure, etc., but it is in any case conceivable that fishing/harvest pressure and the low predator densities correlate. Especially the three mentioned fish species (pike-perch, pike and catfish) are usually also target species of angling and are particularly sought after by anglers because of their tasty and low-bone meat. The only predator that occurs in good densities and whose population has a healthy age structure is the asp. However, as a particularly bone-rich representative of the carp fish, this predatory species is also certainly subject to the least harvest pressure. Selective fishing for few predatory fish and the harvest of large numbers can lead to recruitment overfishing. This means that the number of spawners is so low that the number of juveniles also remains low because there are no longer sufficient numbers of eggs being laid to compensate for the removal by surplus production.

In any case, from our point of view, it is advisable to shed more light on the fishery use of the Mura and Drava rivers in the future and to integrate the stakeholder group of recreational fishermen into targeted studies. The use of fish stocks and sustainable fisheries management should always support rather than counteract conservation efforts of fish populations.

## **4.6 Presence of non-native species**

The presence of several non-native fish species has been confirmed within this survey and previous surveys. In total, 15 non-native fish species were recorded in the last 20 years through various electrofishing surveys. With eDNA sampling, we were able to detect at least 11 non-native fish species in the Mura and Drava. Non-native species have been either introduced by human activities (e.g. spreading from fish farms, introduction via stocking) or they have expanded their occurrence-range due to changed environmental conditions (e.g. warming of water temperatures and change of riverine habitat conditions).

The number and density of non-native species occurring in the TBR MDD is increasing with river length. Generally, less non-native fish are caught in the Mura compared to the



Drava. Only five non-native species have regularly been recorded in the Mura: the stickleback (*G. gymnasium*), the silver carp (*H. molitrix*), the pumpkinseed (*L. gibbosus*), the monkey goby (*N. fluviatilis*) and the stone moroko (*P. parva*).

In the Drava, an additional 7 invasive species have been caught: the brown bullhead (*A. melas*), the grass carp (*C. idella*), the bighead carp (*H. nobilis*) and four goby species (racer goby, round goby, tubenose goby, bighead goby).

In the Danube, the eel (*A. anguilla*) has been caught during the JDS surveys. In the Danube backwaters, the largemouth bass (*M. salmoides*) was also caught in 2022. For the Danube, the tubenose goby (*P. semilunaris*) is considered native. Also, the classification of the recorded other goby species as non-native can be questioned for the Danube, although the historic native range of these species does not include the Danube in the area of the TBR MDD.

Table 35: List of recorded non-native fish species during various electrofishing samplings in Mura (17 surveys), Drava (8 surveys) and Danube (7 surveys) between 2006 and 2021. # of records indicates the share of samples in which the species was recorded, average relative share indicates the mean relative abundance/total catch number of each species in all samples. \*species detected exclusively with eDNA sampling.

	# of records			Average relative share in % (min-max)		
	Mu	Dr	Da	Mura	Drava	Danube
<i>Ameiurus melas</i>	*	2/8	4/7		0,56% (0,27-0,85)	4,06% (0,14-15,36)
<i>Anguilla anguilla</i>			2/7			0,03% (0-0,05)
<i>Babka gymnotrachelus</i>		1/8	1/7		0,06%	0,11%
<i>Ctenopharyngodon idella</i>		1/8			0,04%	
<i>Gasterosteus gymnasium</i>	2/17	1/7	1/7	0,13% (0,04-0,21)	0,07%	
<i>Hypophthalmichthys molitrix</i>	1/17	3/8	1/7	0,02%	0,08% (0,01-0,13)	0,38%
<i>Hypophthalmichthys nobilis</i>		1/8			0,39% (0,39-0,39)	
<i>Lepomis gibbosus</i>	5/17	6/8	3/7	1,66% (0,04-4,91)	0,41% (0,11-1,16)	5,76% (0,39-12,02)
<i>Micropterus salmoides</i>			1/7			1,19%
<i>Neogobius fluviatilis</i>	2/17	7/8	4/7	0,13% (0,08-0,19)	1,29% (0,05-6,54)	1,89% (0-5,96)
<i>Neogobius melanostomus</i>		1/8	5/7		0,09%	9,6% (0,69-20,85)
<i>Oncorhynchus mykiss</i>	*	*				
<i>Ponticola kessleri</i>		1/8	5/7		0,15%	6,67% (0,78-18,47)
<i>Proterorhinus semilunaris</i>		3/8	6/7		2,39% (0,2-5,27)	0,54% (0,17-1,27)
<i>Pseudorasbora parva</i>	6/17	6/8	4/7	0,87% (0,25-2,28)	1% (0,12-2,79)	1,18% (0,05-3,45)
<i>Salvelinus</i> sp.	*	*				
<i>Carassius gibelio</i>	8/17	7/8	5/7	0,12% (0,03-0,22)	1,82% (0,02-6,96)	4,16% (0,34-11,68)
TOTAL (all)				1,31% (0,00-6,39)	4,94% (0,29-19,41)	22% (4-47)
Total (gobies)				0,02% (0,00-0,19)	2,06% (0,00-11,81)	13,4% (0,4-47)

The prussian carp (*C. gibelio*) is listed in the table above because it is considered non-native by most countries in the TBR MDD (all except Austria). However, the authors of this report point out that the status of this species is not resolved in our opinion and may stay unresolved due to the lack of historical distribution data. For the sake of comparability, the prussian carp has been included in lists and tables of non-native species. It is the most commonly found non-native species in the TBR MDD (occurring in 20 of 32 samples). Also, it occurs throughout the whole region (Mura, Drava and Danube)

in rather similar abundances. The highest shares have been documented in the Danube backwaters (12 and 5%, investigation from 2021) as well as in lower Drava reaches (3-7%, investigations from 2012 and 2016).

The relative abundances of non-native species is generally much higher in the Danube than in the Drava and Mura. Whereas in the Mura, on average 1,3% individuals were non-native, about 5% of fish in the Drava and 22% in the Danube are considered non-native. Without the Prussian carp, these values would be slightly lower (0,8% in the Mura, 3,4% in the Drava and 18% in the Danube), the overall trend would however be unaffected. The amount of ponto-caspian gobies is much higher in the Danube as well. Whereas in the Mura, the share of gobies was very low in all investigations (<0,1%), their amount increases in the Drava – more specifically in the lower Drava reaches. During sampling in 2021, the share of gobies was highest in the lowest sampling reach (S7; 0,55% gobies). Two former investigations recorded much higher shares of gobies in the lower Drava (2,2 respectively 11,8%). In the Danube, between 4 and 47% of the fish community are gobies. In the Danube backwaters in Serbia (sampled in 2021), their share drops to below 1% (0,4 and 0,7%).

Overall, the amount and occurrence of non-native fish in the Mura and Drava is rather low when analyzing results from electrofishing campaigns. The eDNA analysis however revealed much higher shares of non-native fish in the Drava – especially of ponto-caspian gobies. Although large uncertainties remain regarding the validity of quantifying the amount of fish DNA collected and we would recommend to rely more on electrofishing results, the future development of the fish fauna especially in the lower Drava shall be closely investigated. Some principles and recommendations can be formulated:

- The introduction of non-native species either via direct stocking efforts or introduction from fish ponds or aquaculture should be prevented and avoided wherever possible. The grass carp, bighead carp and silver carp are believed to have no self-reproducing populations in the Mura and Drava (Saly, 2019), their occurrence is therefore a consequence of stocking and/or escaped from fish farms and ponds.
- Ponto-caspian gobies have colonized the Danube and are expanding their range upstream into the Drava and Mura. In 2021, 5 different goby species have been detected in the lower Drava through electrofishing, although their abundances are still considered relatively low. eDNA sampling indicated much higher community shares of ponto-caspian gobies. The occurrence and abundance of gobies is driven significantly (but not exclusively) by the presence of river training structures like rip rap or groynes. It is out of question, that these species will greatly benefit from potential further channelization measures or bank protection/stabilization. This may lead to a shift in the fish community composition. To protect and strengthen the native fish community structure in the TBR MDD, emphasis should be put on maintaining and promoting natural riverine habitat conditions and river dynamics – either through protection of existing near-natural sections or through river restoration.

## 4.7 Summary of threats for fish and conclusions

The outcomes of the fish study for the lifelineMDD project underpin the importance of the TBR MDD as a biodiversity hotspot. Over 60 fish species are known to occur in the Mura, Drava and Danube, amongst them many protected species. The sampling of fish populations in the Mura, Drava and Danube backwaters focused on several river sections to characterize the longitudinal gradient of the fish community as well as the fish community in Danube backwaters (lateral gradient). No “complete” overview can be drawn for the whole TBR MDD in terms of prioritizing single river sections – since only single sections were analyzed. However, in a following synthesis report, the findings of the fish study shall contribute, together with findings from other studies, to identify areas of particular importance.

The authors strongly accentuate that the main reason for the occurrence of a large number of fish species, with many building healthy, self-reproducing populations, is a factor of the open continuum between the Mura and the Drava and the hydromorphologic dynamics (habitat diversity) in these rivers.

The ability for fish to migrate freely within this river corridor (~300km) is a prerequisite for a wide dispersal and distribution for many species. Especially fish that need open migration routes to fulfill their lifecycle or are bound to specific habitat features (like the need of gravel as substrate for nase and barbel during spawning) would be severely affected by migration barriers. Additionally, the dynamic morphological features along widespread areas of the investigated river corridors are unique for this river dimension in central Europe. (Further) morphological degradation – like the cut off of side channels/meanders, bank stabilization measures, channel regulation etc. – shall be prevented and at the same time, morphological improvements can be implemented/initiated wherever possible. Two pilot sites are currently improved within the lifelineMDD project: one in Slovenia and one the Special Nature Reserve Karadjordjevo in Serbia (dredging and sediment removal in order to improve the hydrological regime and also fish migration).

From a fish-ecological viewpoint, it was obvious that the presence of hard embankments and morphological regulations had a negative impact on the riverine fish community. The average dominance of rheophilic species in sampling strips along rip-rap structures and hard embankments was just 7% (compared to e.g. 38% along gravel bars). All river sections with a high degree of hard embankments are eligible for ecologically oriented measures. A relatively high degree of hard embankments was observed in the sampled sections S2 (only in upper half, downstream of Mursko Sredisce), in S3 (the lowest Mura-stretch) and in S6 (close to Barcs/Terezino Polje).

Potential migration barriers (new hydropower plants) and morphological degradation are considered the greatest risks for the fish fauna of the TBR MDD. In addition, the ecological effects of the hydropower operation at the power plant Donja Dubrava shall receive more attention in future investigations. The collected data suggests that the

artificial flow fluctuations caused by the HPP drastically reduce the amount of typical riverine fish in sections below the power plant. The occurrence of non-native/invasive species shall also be closely followed in the future. Especially the potential mass reproduction of ponto-caspian gobies extending further upstream from the Danube and lower Drava may cause severe ecological instabilities or community shifts.

## 5 References

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## 6 Appendix

Table 36: Total catch numbers (total individuals incl. catch efficiency estimation) for each section.

Species	S1	S2	S3	S4	S5	S6	S7	SR	SD	tot
Abramis brama	4	8		2	50	3	16			84
Alburnoides bipunctatus	1119	575	572	2	10			636	27	2941
Alburnus alburnus	1772	2278	2047	1805	5395	2944	5186	1665	647	23738
Ameiurus melas							20			20
Aspius aspius	2	6	26	10	92	44	68	1	2	252
Babka gymnotrachelus							5			5
Ballerus sapa			2				10			12
Barbatula barbatula	42		33					10		85
Barbus barbus	366	337	189	123	97	203	35	200	8	1558
Blicca bjoerkna		47			1231	5	9		6	1298
Carassius gibelio	10	1			15	33	140	1	5	206
Chondrostoma nasus	303	139	177	61	1040	514	56	104	9	2403
Cobitis elongatoides	9	55	3	70	233	107	112	40	40	670
Cottus gobio	2		33							35
Cyprinus carpio		6		8	2	2				18
Esox lucius	3	5	3	2	49	32	32	8	1	135
Eudontomyzon mariae	2	8	1			3	4			19
Gasterosteus gymnurus	2					4				6
Gobio obtusirotris	63	10						25		98
Gymnocephalus cernua				20						20
Gymnocephalus schraetser						6				6
Hypophthalmichthys molitrix			1		1	5	10			17
Lepomis gibbosus	20	2			42	7	9	25		104
Leuciscus idus	5	1			9	6	3	3		27
Leuciscus leuciscus	228	714	147	450	33	174	68	133		1947
Lota lota		4						1		5
Neogobius fluviatilis		9	3	10	21	22	3	54		123
Neogobius melanostomus							7			7
Perca fluviatilis		72	5	61	159	80	28	19	1	425
Phoxinus phoxinus								118		118
Ponticola kessleri							11			11
Proterorhinus semilunaris							15			15
Pseudorasbora parva	22					28	125	26	1	202
Rhodeus amarus	2	32		60	539	154	420	455		1661
Romanogobio carpathorossicus	13	30								43
Romanogobio uranoscopus	5							2		7
Romanogobio vladykovi	3	8	2	20	5	2	4	10		53
Rutilus rutilus	13	80	7	468	926	406	623	245	15	2781
Rutilus virgo		17	185	7	124	86	73		2	494
Salmo trutta fario								4		4
Sander lucioperca	1	7	1		72	14	1	2		98
Scardinius erythrophthalmus					30	7	8			45
Silurus glanis	1		4	1			6	3		15
Squalius cephalus	463	434	535	22	713	742	315	779	48	4051
Tinca tinca						7		2		9
Vimba vimba	4	21	35	205	1213	163	21	388	4	2053
Zingel streber		3			2			6		11
Zingel zingel	5	5	41					1		51
Various	9	68	1		128	9	40	25		281
<b>TOTAL</b>	<b>4480</b>	<b>4913</b>	<b>4051</b>	<b>3407</b>	<b>12104</b>	<b>5802</b>	<b>7444</b>	<b>4965</b>	<b>816</b>	<b>47983</b>

Table 37: Total catch biomass (sum of fish weight incl. catch efficiency estimation) for each section.

Species	S1	S2	S3	S4	S5	S6	S7	SR	SD	Tot.
Abramis brama	6,1	5,1		3,0	<0,1	3,1	6,8			24,2
Alburnoides bipunctatus	5,1	2,5	2,5	<0,1	<0,1			2,9	0,3	13,3
Alburnus alburnus	13,9	25,1	16,3	17,8	45,3	30,8	57,7	16,2	7,0	230,1
Ameiurus melas							2,7			2,7
Aspius aspius	3,6	6,6	2,1	11,6	16,1	5,5	30,5	1,5	3,5	81,1
Babka gymnotrachelus							<0,1			<0,1
Ballerus sapa			0,5				<0,1			0,5
Barbatula barbatula	0,1		<0,1					<0,1		0,2
Barbus barbus	77,4	22,2	14,7	3,8	17,9	2,5	0,2	23,0	2,4	164,0
Blicca bjoerkna		1,3			9,2	0,1	1,1		0,3	12,0
Carassius gibelio	1,3	1,1			9,4	7,8	8,6	0,2	2,5	30,8
Chondrostoma nasus	123,7	25,6	44,3	35,6	110,4	43,9	2,6	75,8	6,1	468,0
Cobitis elongatoides	<0,1	0,1	<0,1	0,1	0,4	0,3	0,2	0,1	0,1	1,3
Cottus gobio	<0,1		<0,1							0,1
Cyprinus carpio		34,4		37,1	3,4	5,9				80,8
Esox lucius	<0,1	0,3	0,1	7,8	8,5	5,7	20,2	0,2	1,8	44,6
Eudontomyzon mariae	<0,1	0,1	<0,1			<0,1	<0,1			0,1
Gasterosteus gymnurus	<0,1					<0,1				<0,1
Gobio obtusirotris	0,6	<0,1						0,2		0,8
Gymnocephalus cernua				0,1						0,1
Gymnocephalus schraetser						0,1				0,1
Hypophthalmichthys molitrix			7,5		11,4	44,2	5,2			68,3
Lepomis gibbosus	0,1	<0,1			1,2	0,1	0,1	0,3		1,9
Leuciscus idus	<0,1	2,3			12,9	2,0	0,1	4,8		22,0
Leuciscus leuciscus	4,9	4,5	1,2	0,6	0,5	1,2	0,2	0,8		13,8
Lota lota		2,0						<0,1		2,0
Neogobius fluviatilis		0,1	0,1	<0,1	0,2	0,4	0,1	0,6		1,4
Neogobius melanostomus							0,1			0,1
Perca fluviatilis		0,7	0,1	0,3	1,4	0,8	0,3	0,1	<0,1	3,7
Phoxinus phoxinus								0,1		0,1
Ponticola kessleri							<0,1			<0,1
Proterorhinus semilunaris							<0,1			<0,1
Pseudorasbora parva	0,1					<0,1	0,1	<0,1	<0,1	0,2
Rhodeus amarus	<0,1	<0,1		<0,1	0,3	0,1	0,3	0,3		1,1
Romanogobio carpathorossicus	0,1	0,3								0,4
Romanogobio uranoscopus	0,1							<0,1		0,1
Romanogobio vladykovi	<0,1	<0,1	<0,1	0,2	<0,1	<0,1	<0,1	<0,1		0,4
Rutilus rutilus	0,1	1,9	0,3	4,3	13,7	13,7	5,1	1,7	2,1	42,9
Rutilus virgo		0,5	0,3	3,7	9,7	6,5	1,2		4,7	26,5
Salmo trutta fario								0,4		0,4
Sander lucioperca	3,1	8,8	0,8		5,3	0,1	0,8	7,2		26,2
Scardinius erythrophthalmus					0,6	0,1	0,2			0,9
Silurus glanis	2,7		2,1	1,2			1,5	0,3		7,9
Squalius cephalus	48,9	39,2	38,4	2,7	46,4	25,4	5,7	63,0	17,6	287,4
Tinca tinca						0,5		0,8		1,3
Vimba vimba	1,0	0,4	0,4	1,0	5,7	0,6	<0,1	0,8	0,2	10,1
Zingel streber		<0,1			<0,1			0,1		0,2
Zingel zingel	1,0	1,1	1,3					0,1		3,4
Various	<0,1	0,1	<0,1		<0,1	<0,1	0,1	0,1		0,2
<b>TOTAL</b>	<b>294,1</b>	<b>186,1</b>	<b>133,1</b>	<b>130,8</b>	<b>330,0</b>	<b>201,3</b>	<b>151,8</b>	<b>201,8</b>	<b>48,3</b>	<b>1677,4</b>

Table 38: Standardized fish abundance (Individuals/ha) per species, guild and each section. Values based on strip-fishing assessment.

☐ Low structural preference; ☐ medium str. pref.; ☐ high str. pref.

	S 1	S 2	S 3	S 4	S 5	S 6	S 7	S R	S D
<b>Rheophilic - rheopar</b>									
<i>Cottus gobio</i>	<1		13						
<i>Salmo trutta fario</i>								7	
<i>Alburnoides bipunctatus</i>	312	161	225	1	2			472	18
<i>Barbatula barbatula</i>	12		13					9	
<i>Barbus barbus</i>	102	95	77	89	23	57	12	83	5
<i>Chondrostoma nasus</i>	85	39	93	44	242	144	19	49	6
<i>Gobio obtusirostris</i>	18	3							
<i>Romanogobio carpathorossicus</i>	4	8							
<i>Romanogobio uranoscopus</i>	1							3	
<i>Romanogobio vladkovi</i>	<1	2	<1	14	1	<1	1	9	
<i>Rutilus virgo</i>		5	74	5	29	24	25		1
<i>Zingel streber</i>		<1			<1			8	
<b>Oligorheophilic - rheopar</b>									
<i>Eudontomyzon mariae</i>	<1	2	<1			<1	1		
<i>Gymnocephalus schraetser</i>						2			
<i>Zingel zingel</i>	1	1	16					<1	
<i>Ballerus sapa</i>			<1				3		
<i>Vimba vimba</i>	1	6	14	148	280	46	7	98	2
<b>Oligorheophilic - euryopar</b>									
<i>Cobitis elongatoides</i>	2	15	1	51	54	30	38	36	27
<b>Indifferent - rheopar</b>									
<i>Leuciscus leuciscus</i>	63	200	58	325	8	49	23	84	
<i>Aspius aspius</i>	<1	2	10	7	21	12	23	<1	1
<b>Indifferent - euryopar</b>									
<i>Babka gymnotrachelus</i>							2		
<i>Lota lota</i>		1						1	
<i>Neogobius fluviatilis</i>		3	1	7	5	6	1	13	
<i>Neogobius melanostomus</i>							2		
<i>Ponticola kessleri</i>							4		
<i>Proterorhinus semilunaris</i>							5		
<i>Silurus glanis</i>	<1		2	<1			2	3	
<i>Squalius cephalus</i>	129	122	211	16	166	207	105	387	33
<i>Blicca bjoerkna</i>		13			287	1	3		4
<i>Gymnocephalus cernua</i>				14					
<i>Leuciscus idus</i>	1	<1			2	2	<1	2	
<i>Phoxinus phoxinus</i>								106	
<i>Pseudorasbora parva</i>	6					8	42	11	<1
<i>Sander lucioperca</i>	<1	2	<1		17	4	<1	2	
<i>Abramis brama</i>	1	2		1	12	<1	5		
<i>Alburnus alburnus</i>	493	639	866	1.305	1.257	825	1.747	1.075	444
<i>Hypophthalmichthys molitrix</i>			<1		<1	1	3		
<i>Perca fluviatilis</i>		20	2	44	37	22	10	9	<1
<i>Rutilus rutilus</i>	3	22	3	338	216	114	210	60	10
<b>Indifferent - limnepar</b>									
<i>Esox lucius</i>	<1	1	1	1	11	9	11	9	<1
<i>Carassius gibelio</i>	3	<1			4	9	47	1	3
<i>Cyprinus carpio</i>		2	3	6	<1	<1			
<i>Ameiurus melas*</i>							7		
<b>Limophilic - limnepar</b>									
<i>Gasterosteus gymnurus</i>	<1					1			
<i>Lepomis gibbosus</i>	6	<1			10	2	3	15	
<i>Tinca tinca</i>						2		2	
<i>Rhodeus amarus</i>	<1	9		43	125	43	142	65	
<i>Scardinius erythrophthalmus</i>					7	2	3		
<b>TOTAL</b>	<b>1.248</b>	<b>1.379</b>	<b>1.687</b>	<b>2.464</b>	<b>2.817</b>	<b>1.626</b>	<b>2.507</b>	<b>2.621</b>	<b>561</b>



Table 39: Standardized fish biomass (kg/ha) per species, guild and each section. Values based on strip-fishing assessment.  
 Low structural preference;  medium str. pref.;  high str. pref.

	S 1	S 2	S 3	S 4	S 5	S 6	S 7	SR	SD
<b>Rheophilic - rheopar</b>									
<i>Cottus gobio</i>	<1		<1					<1	
<i>Salmo trutta fario</i>									
<i>Alburnoides bipunctatus</i>	1	<1	<1	<1	<1			8	<1
<i>Barbatula barbatula</i>	<1		<1					<1	
<i>Barbus barbus</i>	22	6	7	3	4	<1	<1	6	2
<i>Chondrostoma nasus</i>	34	7	30	26	26	12	<1	4	4
<i>Gobio obtusirostris</i>	<1	<1							
<i>Romanogobio carpathorossicus</i>	<1	<1							
<i>Romanogobio uranoscopus</i>	<1							<1	
<i>Romanogobio vladykovi</i>	<1	<1	<1	<1	<1	<1	<1	<1	
<i>Rutilus virgo</i>		<1	<1	3	2	2	<1		3
<i>Zingel streber</i>		<1			<1			<1	
<b>Oligorheophilic - rheopar</b>									
<i>Eudontomyzon mariae</i>	<1	<1	<1			<1	<1		
<i>Gymnocephalus schraetser</i>						<1			
<i>Zingel zingel</i>	<1	<1	<1					<1	
<i>Ballerus sapa</i>			<1				<1		
<i>Vimba vimba</i>	<1	<1	<1	<1	1	<1	<1	<1	<1
<b>Oligorheophilic - euryopar</b>									
<i>Cobitis elongatoides</i>	<1	<1	<1	<1	<1	<1	<1	<1	<1
<b>Indifferent - rheopar</b>									
<i>Leuciscus leuciscus</i>	1	1	<1	<1	<1	<1	<1	3	
<i>Aspius aspius</i>	1	2	<1	8	4	2	10	<1	2
<b>Indifferent - euryopar</b>									
<i>Babka gymnotrachelus</i>							<1		
<i>Lota lota</i>		<1						<1	
<i>Neogobius fluviatilis</i>		<1	<1	<1	<1	<1	<1	<1	
<i>Neogobius melanostomus</i>							<1		
<i>Ponticola kessleri</i>							<1		
<i>Proterorhinus semilunaris</i>							<1		
<i>Silurus glanis</i>	<1		<1	<1			<1	<1	
<i>Squalius cephalus</i>	14	11	15	2	11	7	2	12	12
<i>Blicca bjoerkna</i>		<1			2	<1	<1		<1
<i>Gymnocephalus cernua</i>				<1					
<i>Leuciscus idus</i>	<1	<1			3	<1	<1	3	
<i>Phoxinus phoxinus</i>								<1	
<i>Pseudorasbora parva</i>	<1					<1	<1	<1	<1
<i>Sander lucioperca</i>	<1	2	<1		1	<1	<1	<1	
<i>Abramis brama</i>	2	1		2	<1	<1	2		
<i>Alburnus alburnus</i>	4	7	7	13	11	9	19	39	5
<i>Hypophthalmichthys molitrix</i>			3		3	12	2		
<i>Perca fluviatilis</i>		<1	<1	<1	<1	<1	<1	<1	<1
<i>Rutilus rutilus</i>	<1	<1	<1	3	3	4	2	<1	1
<b>Indifferent - limnepar</b>									
<i>Esox lucius</i>	<1	<1	<1	6	2	2	7	<1	1
<i>Carassius gibelio</i>	<1	<1			2	2	3	<1	2
<i>Cyprinus carpio</i>		10	15	27	<1	2			
<i>Ameiurus melas*</i>							<1		
<b>Limophilic - limnepar</b>									
<i>Gasterosteus gymnurus</i>	<1					<1			
<i>Lepomis gibbosus</i>	<1	<1			<1	<1	<1	<1	
<i>Tinca tinca</i>						<1		<1	
<i>Rhodeus amarus</i>	<1	<1		<1	<1	<1	<1	<1	
<i>Scardinius erythrophthalmus</i>					<1	<1	<1		
<b>TOTAL</b>	<b>82</b>	<b>52</b>	<b>82</b>	<b>95</b>	<b>77</b>	<b>56</b>	<b>51</b>	<b>81</b>	<b>33</b>

Table 40: Relative community composition for all analyzed recent samplings (electrofishing). **All values in %**  
 See chapters 2.4 and 3.5 for details. Data from Mura and Drava 2021 (detailed tables above) are summarized into Sections S1-S3 (Mura) and SD-S7 (Drava).

	MU-Spielfeld-2010	MU-Spielfeld-2013	MU-Spielfeld-2019	MU-Cersak-2019	MU-Radkersburg-2010	MU-Radkersburg-2019	MU-Bakovci-Verzej-2013/14 (s)	MU-Bakovci-Verzej-2013/14 (f)	MU-Verzej-G.Bistrica-2013/14 (s)	MU-Verzej-G.Bistrica-2013/14 (f)	MU-Gibina-Petisovci-2013/14 (s)	MU-Gibina-Petisovci-2013/14 (f)	MU-Petisovci-I. Ledave-2013/14 (s)	MU-Petisovci-I. Ledave -2013/14 (f)	MU-S1 to S3-2021 - lifelineMDD	DR-SD to S7-2021 - lifelineMDD	DR-Donji Miholjac-2006	DR-Barcs-2016	DA-Mohacs-2007	DA-Batina-2007	DA-Aljimas-2007	DA-Hercegzsanto-2013	DA-Aljimas-2013	DA BW-Karadordevo-2021 - lifelineMDD	DA BW-G. Podunavlje-2021 lifelineMDD	
Abramis brama	0,3			0,2									12,1	0,1	0,2	4,6			1,3	2,7	0,7	0,2	4,4	6,1	2,6	
Alburnoides bipunctatus	46,9	89,4	61,2	54,5	36,5	68,8		45,9		0,3	23,9	81,0	0,9	9,8	16,9	2,0	1,9	3,0								
Alburnus alburnus	1,6	0,3		3,1	0,1	0,9	11,7	9,9		21,8	45,5	0,7	34,2	4,9	45,3	51,1	6,8	41,6	79,0	45,5	38,7	67,9	50,6	33,6	36,8	
Ameiurus melas																0,1	0,8		0,1	0,3				0,5	15,4	
Anguilla anguilla																			0,0	0,1						
Aspius aspius	0,2	0,2		0,1						0,7					0,3	0,6	1,0		1,5	1,9	0,9	7,2	10,5	3,9	1,3	
Babka gymnotrachelus																0,0						0,1				
Ballerus ballerus																			0,0	0,1		2,1	0,9		0,7	
Ballerus sapa															0,0	0,0	0,0		0,0	0,1	0,2		0,3			
Barbatula barbatula			0,1		0,2										0,6	0,0	0,1									
Barbus balcanicus		0,1																								
Barbus barbus	6,6	5,9	7,3	4,4	2,7	7,3	13,3	16,9	10,5	3,9	1,7	4,9	4,2	11,5	6,6	1,9	0,7	1,1	0,0	0,0	1,6	0,1				
Blicca bjoerkna															0,4	3,6	7,4	0,2	0,9	5,7	1,8				7,1	0,1
Carassius carassius																	0,2									
Carassius gibelio	0,3	0,2		4,1	3,3	0,1				0,1					0,1	0,6	2,6	7,0	0,3	2,9	0,8				11,7	5,1
Chondrostoma nasus	5,1	0,8	10,1	24,0	14,4	7,8	64,7	13,1	33,6	67,1	10,3	1,1	18,9	2,8	4,6	5,2	0,4		0,0		0,1		0,5	0,4		
Cobitis elongatoides					0,2	1,0									0,5	1,7	2,7	0,6					2,6	1,1		
Cottus gobio															0,3											
Ctenopharyngodon idella																	0,0									
Cyprinus carpio	0,3				0,2	0,1									0,0	0,0	0,6		0,0	0,0				2,4	0,1	
Esox lucius		0,1	0,1	0,2	0,1							0,1			0,1	0,4	1,5	0,8	0,3	0,1	0,0	1,6	6,5	0,7	0,4	
Eudontomyzon mariae															0,1	0,0		0,2	0,0	0,1	0,5					
Gasterosteus gymnurus	0,2														0,0	0,0										
Gobio gobio	1,5	0,3	2,7	0,4	1,0	0,2																				
Gobio obtusirostris													1,4		0,5	0,1		0,2								

	MU-Spielfeld-2010	MU-Spielfeld-2013	MU-Spielfeld-2019	MU-Cersak-2019	MU-Radkersburg-2010	MU-Radkersburg-2019	MU-Bakovci-Verzej-2013/14 (s)	MU-Bakovci-Verzej-2013/14 (f)	MU-Verzej-G.Bistrica-2013/14 (s)	MU-Verzej-G.Bistrica-2013/14 (f)	MU-Gibina-Petisovci-2013/14 (s)	MU-Gibina-Petisovci-2013/14 (f)	MU-Petisovci-I.Ledave-2013/14 (s)	MU-Petisovci-I.Ledave-2013/14 (f)	MU-S1 to S3-2021 - lifelineMDD	DR-SD to S7-2021 - lifelineMDD	DR-Donji Miholjac-2006	DR-Barcs-2016	DA-Mohacs-2007	DA-Batina-2007	DA-Aljmas-2007	DA-Hercegszanto-2013	DA-Aljmas-2013	DA BW-Karadorjevo-2021 - lifelineMDD	DA BW-G. Podunavlje-2021 lifelineMDD
Gymnocephalus baloni											0,3						1,3		0,0	2,3	2,2	0,2	0,3		
Gymnocephalus cernua																0,1	1,0		0,1	2,8				0,1	
Gymnocephalus schraetser																0,0			0,0	0,5	0,1				
Hucho hucho	0,5	0,1			0,2	0,1																			
Hypophthalmichthys molitrix															0,0	0,0									0,8
Hypophthalmichthys nobilis																	0,4								
Lepomis gibbosus					2,3							0,6		4,9	0,2	0,2	1,2	0,2	0,4					4,9	12,0
Leuciscus idus		0,1													0,0	0,1	1,3		0,9	1,5	0,7	8,1	11,8	2,9	1,1
Leuciscus leuciscus	4,3			1,1	2,1		1,5	1,2	10,2	4,5	6,6	0,1	5,6	6,4	8,1	2,5	0,0								
Lota lota		0,1	0,1	0,2	0,1	0,0					3,0	2,3		3,2	0,0	0,0	0,6		0,5	2,8	2,0	0,7	0,5		
Micropterus salmoides																									1,2
Misgurnus fossilis																	0,2		0,0						
Neogobius fluviatilis															0,1	0,3	0,5	6,5	1,9	1,3	6,0				0,2
Neogobius melanostomus																0,0			0,7	16,4	20,9	5,7	4,4		
Perca fluviatilis	0,9	0,1	0,3	0,7	1,6	0,1									0,6	1,0	7,3	3,4	1,4	0,2	1,0	0,3	0,8	0,4	0,2
Pelecus cultratus																			0,0		0,0				
Phoxinus phoxinus																0,3									
Ponticola kessleri																0,0			0,8	10,0	18,5	1,8	2,3		
Proterorhinus marmoratus																0,0	1,7	5,3	0,2	0,5	1,3	0,5		0,4	0,5
Pseudorasbora parva	0,3		0,5	0,8	0,8	2,3									0,2	0,5	2,8	0,4	0,1				0,3	3,4	1,0
Rhodeus amarus			0,1		0,1	0,2									0,3	4,7	22,9	4,4	0,8		0,0			2,5	1,4
Romanogobio carpathorossicus		0,1		0,7	1,9	0,8	0,7				2,8	3,9	1,8	14,8	0,3										
Romanogobio uranoscopus				0,1	0,1	0,2					2,0	0,1	3,6		0,0	0,0									
Romanogobio vladkyovi	0,3				4,2	0,5	1,1	0,7			0,3	0,1	16,3	4,9	0,1	0,1	0,1	4,0	0,1	0,0	0,1				
Rutilus rutilus			0,7											2,5	0,7	7,8	23,7	0,8	8,5	1,7	1,8	3,3	3,3	14,3	16,7
Rutilus virgo				0,1											1,5	0,8	0,1		0,0				0,0		
Salmo trutta fario	0,5	0,2			0,2			1,0								0,0									
Sander lucioperca					0,4					0,2					0,1	0,3	0,1	0,4	0,1	0,4	0,3		0,0	0,4	0,2

	MU-Spielfeld-2010	MU-Spielfeld-2013	MU-Spielfeld-2019	MU-Cersak-2019	MU-Radkersburg-2010	MU-Radkersburg-2019	MU-Bakovci-Verzej-2013/14 (s)	MU-Bakovci-Verzej-2013/14 (f)	MU-Verzej-G.Bistrica-2013/14 (s)	MU-Verzej-G.Bistrica-2013/14 (f)	MU-Gibina-Petisovci-2013/14 (s)	MU-Gibina-Petisovci-2013/14 (f)	MU-Petisovci-I. Ledave-2013/14 (s)	MU-Petisovci-I. Ledave -2013/14 (f)	MU-S1 to S3-2021 - lifelineMDD	DR-SD to S7-2021 - lifelineMDD	DR-Donji Miholjac-2006	DR-Barcs-2016	DA-Mohacs-2007	DA-Batina-2007	DA-Aljmas-2007	DA-Hercegszanto-2013	DA-Aljmas-2013	DA BW-Karadordevo-2021 - lifelineMDD	DA BW-G. Podunavlje-2021 lifelineMDD	
Sander volgensis																			0,0							
Scardinius erythrophthalmus	0,4				0,1											0,1	2,1		0,0	0,1					1,7	2,9
Sebanjewa balcanica																	0,0									
Silurus glanis															0,0	0,0	0,1		0,0		0,0				0,1	
Squalius cephalus	29,4	1,8	16,7	4,3	23,1	8,9	8,8	10,1	44,9	1,4	3,7	1,3	11,7	0,2	10,7	7,6	0,8	18,6	0,0			0,1	0,0		0,3	
Telestes souffia	0,4																									
Thymallus thymallus				0,2	1,0	0,0					0,1															
Tinca tinca					0,1											0,0	0,4							0,3	0,1	
Vimba vimba		0,1												2,5	0,4	5,8	0,0	0,4								
Zingel streber				0,2	2,5							3,0		19,5	0,0	0,0		0,2								
Zingel zingel	0,3	0,3		0,8	0,7	0,5						0,4	1,4		0,4	0,0		0,6								

**LifelineMDD fish protocol**

**Section:..... Strip #:.....**

Editor: ..... date: ..... time: ..... boat: .....

GPS waypoint: Start:.....middle:.....end:.....

Fishing Strip Information (Strip type, habitat description, etc): .....

Water depth (m): Min..... Max..... Med..... Flow velocity (m/s): ..... visibility (cm): .....

Fishing gear:

electrofishing  unit power (kw):..... Voltage (V)..... Hand-anode Anode-Rake

duration [min.]:..... Catch estimation [%]:.....

Net  net size (dimensions)..... mesh size.....

Substrate conditions (dominant substrate): .....

Shoreline structure: .....

Comments (Photos, peculiarities, etc):

**Sketch of sampling site/sampling strip** (quick drawing of sampling strip in the river, + shoreline structures):



