Rapport de stage individuel

4ème année

Habitat assessment of juvenile Danube Salmon (Hucho hucho) in the River Pielach

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Acknowledgements

First of all, I want to thank Kurt Pinter for giving me the opportunity to do an internship in his research team within the University of Natural Resources and Life Sciences (BOKU) in Vienna. Supervised by Kurt Pinter and Gabriel Gruber, I was well surrounded and learnt a lot. I also want to thank Joselyne who took care of us during our first days in the project team, and in the field. She was really helpful.

This internship was my first professional research experience, my first foreign experience, and my first field work experience too, and it was full of wonderful moments shared with the project team.

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Introduction

Freshwater ecosystems represents 0,8% of the Earth's surface (Dudgeon et al., 2006), and 51% of all the fish species known are living in those habitats, which represents more than 18 000 species (Férard, 2021). Varius threats are impacting freshwater ecosystems in different ways. For instance, habitats can be destroyed by humans owing to their use of the river: they can add groynes to make sailing easier for example. Those changes impact biodiversity and many species are endangered or threatened today. Regarding fish, a decrease of 76 % of the migratory fish populations since 1970 has been observed (Férard, 2021), and the Danube salmon is one of them. According to Fishbase, this species is on the IUCN Red list of endangered species.
As part of my 4th-year internship carried out during the engineering program at the Department of Planning and Environment (DAE) in Polytech Tours, with a specialization in Aquatic Environments Engineering (IMA), I was welcomed at the University of Natural Resources and Life Sciences located in Vienna, Austria. Surrounded by researchers from the Institute of Hydrobiology, I had the opportunity to join a project on habitat assessment for Danube Salmon larvae (*Hucho hucho*) – as you can see on the picture below (Figure 1).

I chose to undertake this internship with the aim of exploring the world of research by participating in an ambitious project that has received European funding for its realization. The Danube salmon is an endangered species, and this study aims to help its persistence by understanding the favourable habitats for juveniles. I was enthusiastic about being able to work towards the protection of a species, and having the opportunity to do so while deepening my knowledge of aquatic environments and discovering new waterways has only increased my motivation.

Participating in the development of protocols, having the chance to be involved in decisive exchanges regarding the project's continuity, facing the realities of the field and adapting to them, are situations I wish to experience and become competent in. It happened through different missions: spawning redds mapping, larvae mapping, and the data treatment. This internship opportunity has given me a glimpse of a chance to enrich myself greatly with diverse tasks and competent supervisors to guide me through this journey of discovery.

Figure 1 : Picture of a Hucho hucho taken during the spawning redd mapping (@Illona Doyon)

1. Hosting structure presentation

The University of Natural Resources and Life Sciences, Vienna (BOKU) welcomed me to take part in this project (Figures 2 and 3). Founded in 1872, BOKU specializes in the fields of natural resources, life sciences, and sustainability, with six competence areas: Ecosystem Management and Biodiversity, Agricultural Production and Food, Renewable Raw Materials and New Technologies, Biotechnology, Landscape, Water, Habitat and Infrastructure, Resources and social dynamics. Composed of fifteen departments, BOKU has 360 international partner universities and welcomes 10 374 students.

Figure 2 : Picture of BOKU University (@ Illona Doyon)

The habitat assessment of juvenile Danube salmon (*Hucho hucho*) project is driven by the Institute of Hydrobiology and Aquatic Ecosystem Management. At BOKU, this is a renowned institute focused on the study and management of freshwater ecosystems. The Institute of Hydrobiology and Aquatic Ecosystem Management conducts cutting-edge research in various areas of hydrobiology, including limnology, aquatic ecology, and water resource management. Its mission is to advance understanding of freshwater ecosystems, their biodiversity, functioning, and responses to environmental changes. The institute's research projects tackle pressing issues related to water quality, aquatic biodiversity conservation, ecosystem restoration, and the sustainable management of aquatic resources.

Figure 3 : Picture of BOKU University (@ Illona Doyon)

2. Missions and problematics

"The Danube salmon (Hucho Hucho) is one of the most endangered freshwater species in Europe suffering from severe population declines due to anthropogenic impacts" (Schöfbenker, 2018). In 2016, Michael Schöfbenker lead a project for his Master thesis.

Entitled *Population size, reproduction & fry habitats of Danube salmon (Hucho hucho) in the river Pielach, Austria*, it is about getting all the information he was able to get concerning the Danube salmon population in the river Pielach. As you can see on figure 4, this river is located in lower Austria and it is a Danube tributary. The Pielach is one of the main rivers used by the Danube salmon to spawn.

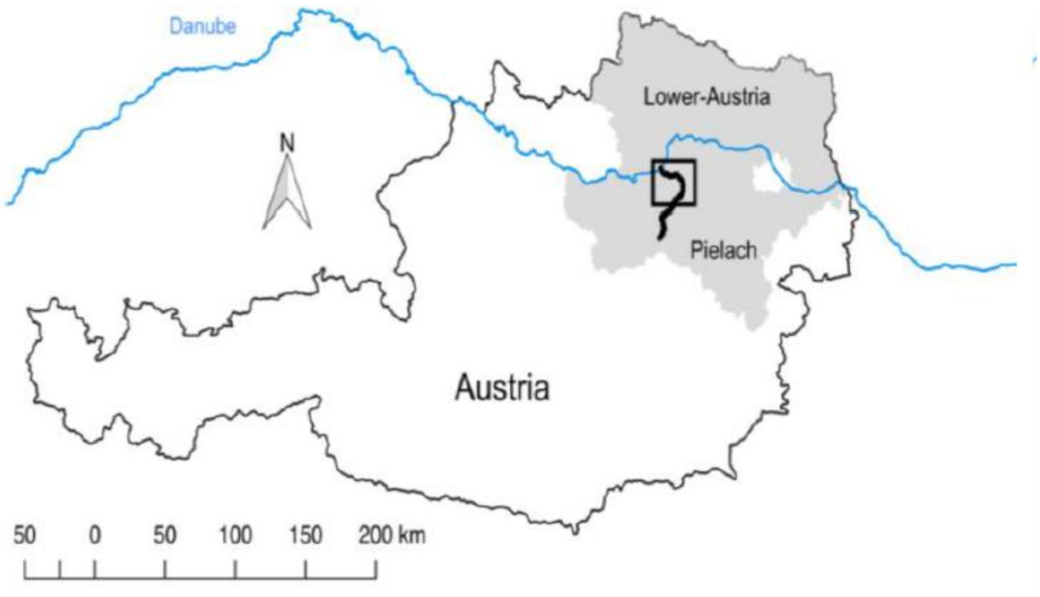


Figure 4 : Location of the Pielach (@ Schöfbenker, 2018)

In his study, Schöfbenker is focusing on "*the population size of individuals > 20 cm, the reproduction activity and the fry habitat selection of Danube salmon*" (Schöfbenker, 2018). To assess of the reproduction activity, he did a spawning redd mapping, investigated the population by snorkelling, characterized fry habitats by flow velocity, water depth, coverage, and the substrate composition (Schöfbenker, 2018). That research had been done along 32 km of the river, from Weinburg to the Danube (Figure 5).

Figure 5 : Mapping investigation area of the Pielach (@ Schöfbenker, 2018)

This year, the project aims at repeating and comparing the same research to see how the situation has changed: is there the same number of spawning sites? Are they still at the same location? Is there the same number of larvae?
The goal is also to be more accurate and to improve the data assessment, with a better description of fry habitats, a global characterisation of the available habitats in the river, and to produce a data set bigger enough to be published. This project should be useful is the Danube salmon population following up.

Furthermore, like most of the rivers in Austria, "*the Pielach had been impacted by hydroelectric power development*" (Schmutz et al., 2002). Hydroelectric turbines need a strong flow velocity to produce more electricity, which means that the natural slope of the river is not enough. That is why diversion arms had been created in the river. Owing to those arms, some of the water of the river is diverted from its natural bed, and a river section impacted by flow abstraction is called a residual flow stretch (Schmutz and Sendzimir, 2018). Another purpose of the project is to see how much those infrastructures are impacting the fish behaviour, if they are creating a difference between full flow and residual flow, and if so, what are the consequences.

To achieve these goals, the main missions are the spawning redd mapping, the larvae mapping, and the data treatment. Transects data have been collected and snorkelling has been done too for the project, but they won't be treated in this report because they were not already finished at the end of the internship.

3. Material and methodology

3.1. Spawning redd mapping

A spawning redd is like a nest, created by a fish to spawn. The Danube salmons relocate the sediments by excavating the spawning redds and leave a large light spot without algae cover behind. Thanks to its colour, it is easier to recognise (Figure 6).

Figure 6 : Picture of a spawning redd located in the Pielach (@ Gabriel Gruber)

The Danube salmon spawning period takes place during spring (Table 1). The spawning activity depends on the environmental conditions like the water temperature (between 8°C and 12°C), the water depth, and the flow velocity.

Table 1: Guild classification and mains characteristics of the Danube salmon (@ Schöfbenker, 2018)

Attributes	Danube salmon
Flow velocity guild	rheophilic [1, 11]
Temperature guild	oligo - stenothermal [1,2]
Reproduction guild	gravel hiders [5]
Feeding guild	piscivorous [4,2]
Migration guild / length	potamodromous / medium [2]
Life span	up to 20 years [6,7,8]
Optimal temperature	9 - 19 °C [2,3]
Structure dependent	Minor [12]
Spawning period	Spring [6,10,13]
Spawning behaviour	rheopar [11]

The Pielach is monitored by three stations and thanks to the data collected, the spawning activity was identified. The graph below (Figure 7) shows the temperature and the discharge of the Pielach at each station and the corresponding time. Through that information, a daily investigation of the study area was conducted from the 19th of March to the 22nd of April. During this time, the river had to face a big discharge characterized by 76,3 m^3/s (Table 2) in the middle of April. The discharge was too high to continue looking for spawning sites, the water was too turbid (it is not possible to see properly through the water if the discharge is higher than 10 m^3/s), and we finally found out that this event destroyed all the spawning redds.

The spawning redd mapping has been carried out by walking along the river closed to the shoreline, fighting against the vegetation. We used polarized glasses to see better through the water.

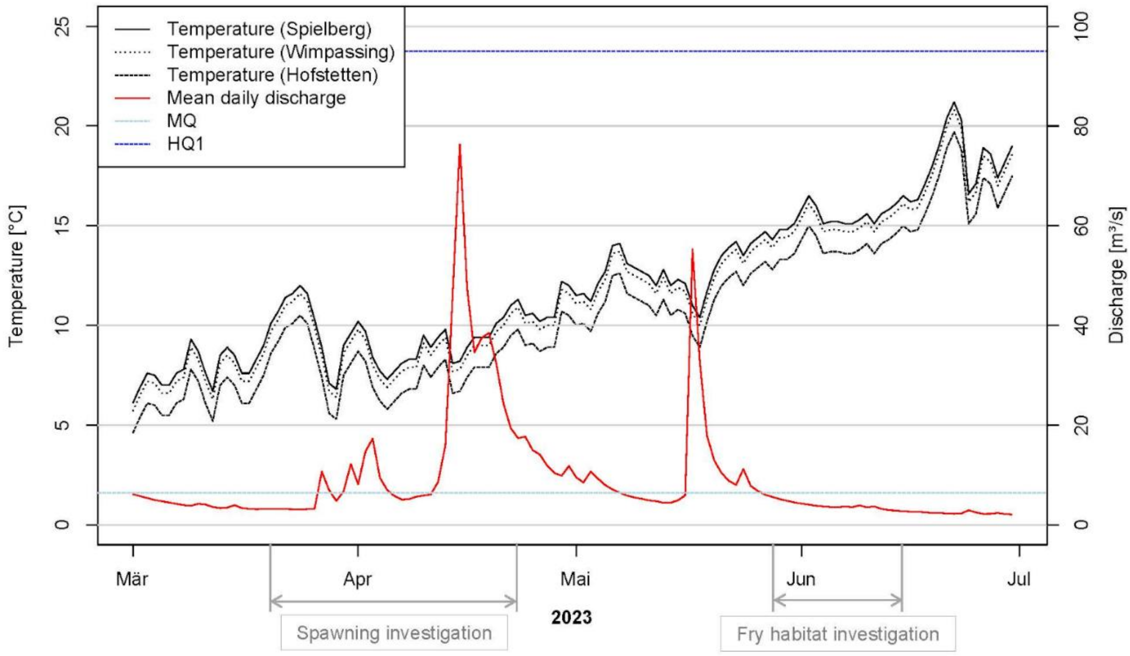


Figure 7 : The temperature and the discharge of the PIelach (@Gabriel Gruber)

Table 2 : Environmental conditions in the Pielach from 19/03/2023 to 22/04/2023 (@Gabriel Gruber)

	Discharge [m^3/s]	Temperature_Hofstetten [°C]	Temperature_Wimpassing [°C]	Temperature_confluence [°C]
Mean	15,4	7,8	8,9	9,3
Median	7,0	7,9	9,0	9,4
Std. Dev.	16,9	1,3	1,3	1,3
Min	3,1	5,3	6,4	6,8
Max	76,3	10,5	11,6	12,0

3.2. Larvae mapping

The mapping of fry habitats started on the 9th of May, the first fry was found on the 27th of May, and it ended on the 14th of June. The calculated dates in the following table refer to spawning redds 1 and 2 which have been found on the 19th of March 2023. Based on those results, it was not relevant to start looking for larvae before the beginning of May.

Table 3 : Expected day-degrees and calculated dates until hatching, emerging and exogenous feeding after Jungwirth & Winkler (1984), and Bajic et al. (2015) (@Gabriel Gruber).

	Day-degrees (Jungwirth & Winkler, 1984; Schöfbenker, 2018)	Calculated date for first redd	Day-degrees (Bajic et al., 2015)	Calculated date for first redd
Hatching	280	19.04.2023	288	20.04.2023
Emerging	440	04.05.2023	463	06.05.2023
Start exogenous feeding	448	05.05.2023	494	09.05.2023

Based on those data, the larvae mapping started around 490 – 520 day-degrees regarding spawning redds 1 and 2, which is late to assume that everything was caught. However, as the figure shows, the discharge was too important to be able to look for larvae before the beginning of May, and then another high flow period happened. The mapping started again when the discharge was more appropriate to investigate as it is showed in table 4.

Table 4 : Environmental conditions in the Pielach from 27/05/2023 to 14/06/2023 (@Gabriel Gruber)

	Discharge [m³/s]	Temperature_Hofstetten [°C]	Temperature_Wimpassing [°C]	Temperature_confluence [°C]
Mean	4,0	13,8	14,9	15,3
Median	3,7	13,7	14,8	15,2
Std. Dev.	0,9	0,5	0,5	0,5
Min	2,9	12,8	13,9	14,3
Max	6,1	15,0	16,1	16,5

The larvae mapping was also carried out by walking along the shoreline of the river at the beginning, then, when the discharge was under 8 m3/s, it was possible to walk in the river. We used waders, polarized glasses, nets to catch larvae, a small container to look easily at larvae, measurement sticks, a flowmeter, and a ruler to measure larvae length. The distance of mapping start to the next spawning redd was about 300 m minimum (Table 5).

Table 5 : Distance of mapping downstream spawning redds [m] (@ Illona Doyon)

Minimum	274
Maximum	1209
Mean	510

To determine the fry species, taxonomic characteristics were used: large adipose fin as larvae, big and long head, fry length, number of dorsal spines. Then the fry was measured and released in its habitat. The fry position under the surface, its distance to the shoreline, the water depth at its position, the cover under 50 cm and above 50 cm, and the flow velocity at 100%, 40% of the water depth and at the nose of the fry, were collected. The habitat measurement was done afterwards. It includes the habitat length and width, mean water depth, substrate, compactness, river side, if it is located in a residual flow stretch, coordinates, cover above 50 cm, if there is xylal, and finally, water depth and flow velocity (100% and 40% of the water depth) at the shoreline, at 50 cm from the shoreline, at 100 cm from the shoreline, and at 150 cm from the shoreline. An example of the protocol sheet is in appendix (Appendix 1).

3.3. Data treatment

After developing the spawning redd methodology, the larvae habitat protocol, and their implementation in the field, we took part in the data treatment. Remotely, with our own computers, we cleaned and ordered the data to prepare the results. We used Qgis to locate the spawning redds and the larvae habitats with maps, and we also used Excel to prepare statistic results.
To sum up, we were involved in all the data process: from the development of the protocol sheet to the data treatment, including their collection.

4. Results and discussion

4.1. Spawning redds

4.1.1. Maps of spawning redds and number

During the spawning redds investigation, 58 spawning sites were found (their mapping is in appendix 2). 14,385 km were mapped in full flow, 18 spawning sites were in it, which represents 1,25 spawning redd per kilometre, and it is equivalent to 31 % of the full flow stretch.
In the residual flow, 18,157 km were mapped with 40 spawning redds in it, so there were 2,2 redds per kilometre, which corresponds to 69 % of the residual flow stretch.
There is a difference of spawning redd density, but the statistical analysis of the spawning redd densities (redds/km) between full water and residual flow stretches did not show a significant difference (p-value(Chi²) : $p = 0.609$). The mapped spawning redds within the sub-populations (ID: 1 - 2) consisted of 47 spawning redds from the Danube to Salau and 11 redds from Salau to Weinburg, respectively (table 6). Sub-population 1 contained more spawning redds and the spawning redd density is higher than between Salau and Weinburg (sub-population 2). The amount of detected spawning redds within the nine sub-reaches (ID: 3 - 11) ranged from maximum 18 redds in Salau to zero redds in the Spielberger, Neuhofen, and Weinburg sub-reaches. A mean of ~ 6 spawning redds were detected within the sub-reaches.

Table 6 : Number and density of spawning redds in the Pielach in 2023 in each sub-populations (ID : 1-2) and each sub-reach (ID : 3-11) (@ Emmanuelle Waguette)

	ID	Continuum interruption	Number of spawning redds	Density of spawning redds (Redds/km)
Sub-populations	1	Salau	47	2.04
	2	Weinburg	11	1.16
Sub-reach	3	Spielberg	0	0
	4	Albrechtsberg	1	0.26
	5	Neuhofen	0	0
	6	Eibelsau	6	1.18
	7	Doppel	5	2.93
	8	Mühlau	17	7.2
	9	Salau	18	3.42
	10	Engelsdorf	11	1.43
	11	Weinburg	0	0
Total			58	1.78

To compare with 2016's results, 69 spawning redds were mapped (Schöfbenker, 2018). We can see on the graph below (Figure 8) that the repartition of spawning sites is less homogeneous in 2023. In 3 locations, no redds were found to only 1 in 2016.

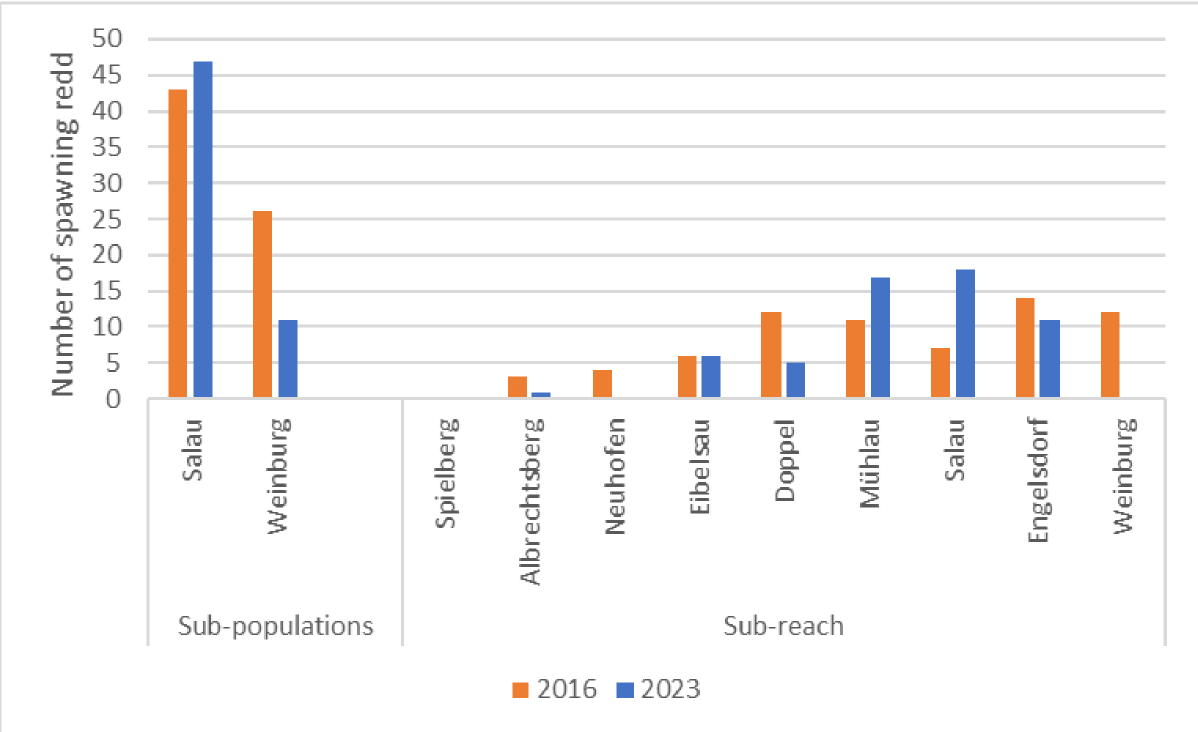


Figure 8 : Number of spawning redds in the sub-populations and the sub-reaches in 2016 and 2023 (@ Emmanuelle Waguette)

In some cases, it was possible to see adult fish. In total, 44 fish have been observed on spawning redds during the spawning redd mapping. Their distribution is showed in table 7.

Table 7 : Distribution of fish that have been observed on spawning redds during the spawning redd mapping (@ Gabriel Gruber)

Redd type	**number of redds**
Redds with 0 ind.	35
Redds with 1 ind.	5
Redds with 2 ind.	11
Redds with 3 ind.	3
Redds with 4 ind.	2
Redds with no fish data	2
Sum	*58*

The recorded spawning fish length ranged from 500 to 1 000 mm, with a mean total length of 810 mm. To compare to the fish length observed in 2016, the fish are smaller (2016: min length = 600 mm; max length = 1 100 mm; mean length = 840 mm; Schöfbenker, 2018).

4.1.2. Spawning redds characteristics

The estimated mean of spawning redd length was 3,1 m and the redd width average was 1,7 m. The majority of the spawning redds (n = 43) were in run sections. Five spawning redds were allocated to riffle sections and three spawning redds were found in the transition zone between run and riffle. The estimated mean of spawning redd water depth was 30 cm. The optimum water depths for Danube salmon spawning redds in the river Pielach range from 30 – 40 cm (UI = 1) and 40 – 50 cm (UI = 0.9; Figure 9). Water depths classes 20 – 30 cm and 50 – 60 cm both show a suitable utility index of 0.4 (Schöfbenker, 2018). 14 spawning redds don't have information about the water depth, so the data for the graph below comes from 45 out of 59 spawning redds. The more used water depth is 20 – 40 cm (Figure 10). In 2016, spawning sites were mostly found in areas with 25 – 50 cm of water depth (@ Schöfbenker, 2018).

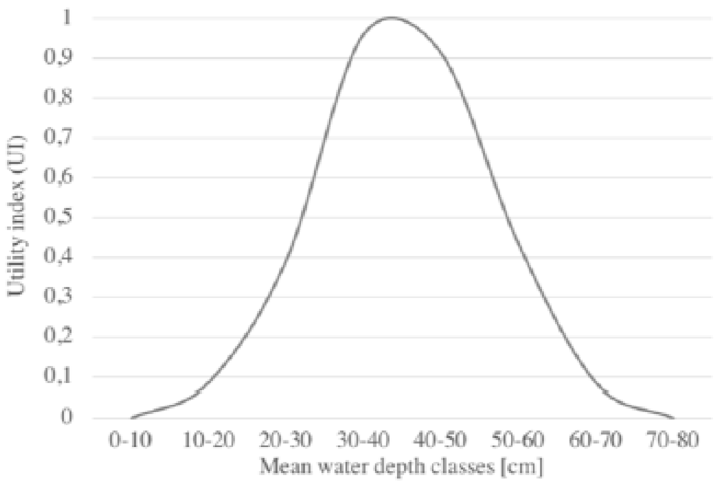


Figure 9 : Utility index (UI) curve of the mean water depth classes [cm] for Danube salmon spawning redds (@ Schöfbenker, 2018)

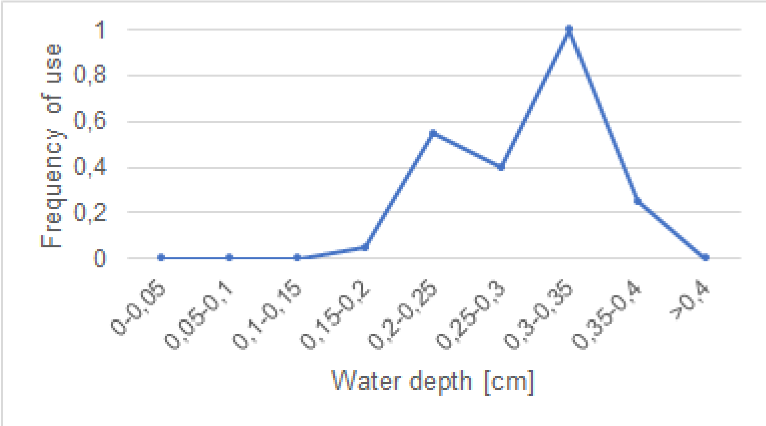


Figure 10 : Frequency of used water depth for spawning redds (@ Gabriel Gruber)

4.2. Larvae habitats

4.2.1. Maps of larvae and number of individuals

During the fry habitat investigation, 89 individuals were detected within the study area (Figure 11; detailed view of larvae and redds mapping: appendix 3). In full flow, 5,14 km were prospected, and 5, 95 km in residual flow. 83 and 6 larvae were respectively found in those river stretches. So, in full flow, larvae density is 16 time more important than in residual flow: 16,14 larvae per kilometre of the mapped area to 1,01 larvae per kilometre of the mapped area in the residual flow. Thanks to the Chi² test, we can say that there is a statistically significant difference between residual and full flow for larvae, and that the larvae occurrence was higher in the full flow (p-value (Chi²) = 0,0003 < 0,05).

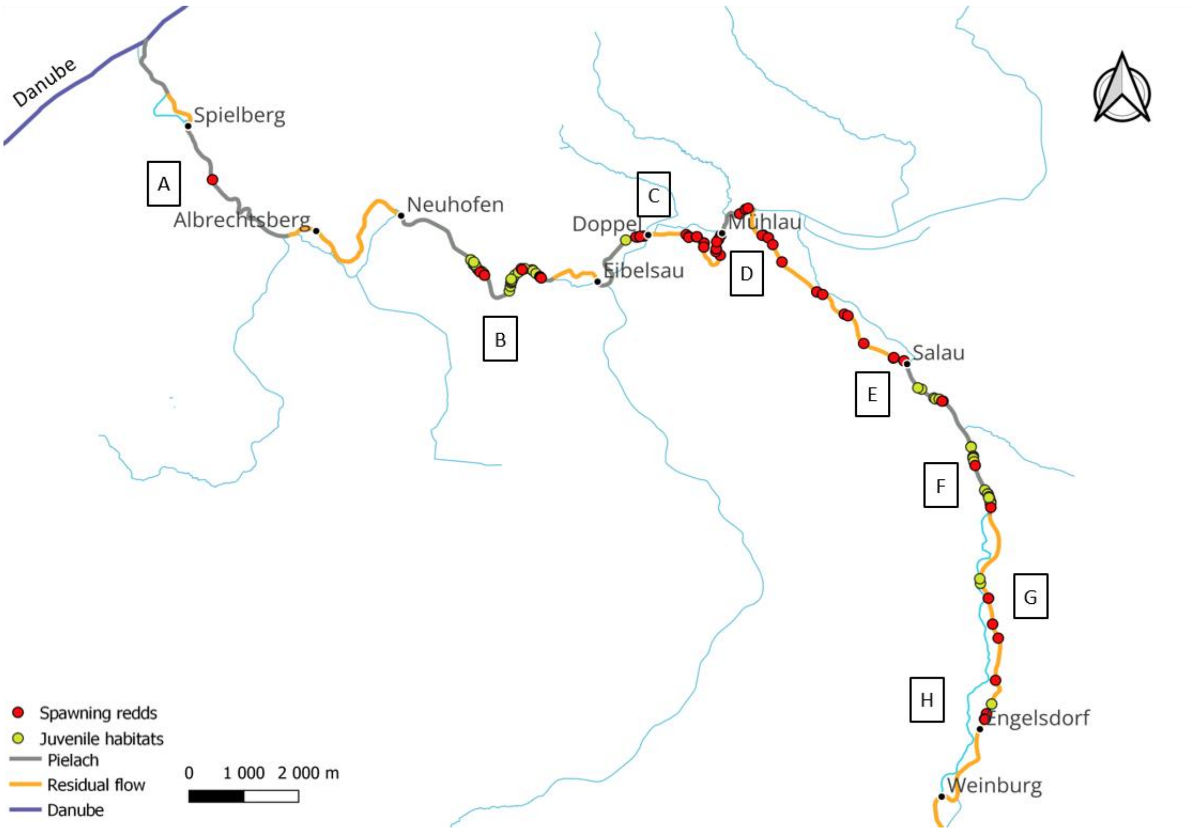


Figure 11 : Investigated Danube Salmon (Hucho hucho) juvenile habitats (n=69) from Weinburg to the Danube with both spawning redds and flow stretches (@ Emmanuelle Waguette, Illona Doyon)

According to the previous part about spawning redd investigation, 18 spawning sites were found in full flow, and 40 in residual flow. At the beginning of larvae prospection, because of redds density (Appendix 4), we supposed that we were going to find more larvae in residual flow than is full flow. Because results were different, we thought it was due to the high flow in April that damaged all spawning redds and since the ones located in full flow were older than the ones in residual flow, larvae were bigger enough to survive to the discharge. However, the age difference was not so big, so we believed that maybe some spawning redds were stronger than others thanks to their structure, and so to the substrate. To determine if the substrate was responsible for larvae density, we looked at the compactness when we did the transects and hit the riverbed with a metal stick to see how far it was penetrating the ground. Finally, the results are showing a significant difference between full flow and residual flow (Figure 12).

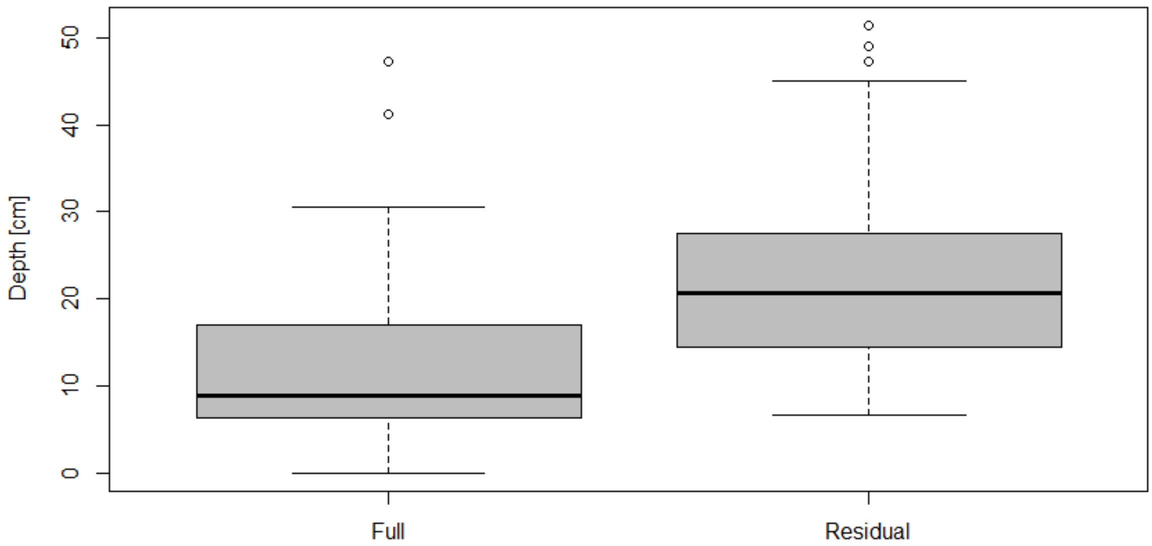


Figure 12 : Compactness difference between full flow and residual flow in transects (@Gabriel Gruber)

The recorded fry habitat density is decreasing with increasing distance to the closest upstream spawning redd (Figure 13). Over 50 % of the investigated fry habitats were located within the first 0 - 200 m downstream of the next spawning redds and around eighty % were located within the first 350 m downstream of the next spawning redd (Appendix 5). Ninety-eight percent of the observed fry habitats (n = 88) were found on the first 450 - 500 m downstream of the next spawning redd. One fry was recorded in 503 m distance downstream to the next mapped spawning redd.
On the graph below, we can also see that the most common distance to find larvae is 150 – 200 m downstream of the next spawning site. It was about 75 – 100 m in 2016 (Schöfbenker, 2018). This year, larvae are overall more far away from the next closest upstream spawning redd (about 250 m more sometimes). It can be a consequence of the high flow that happened during April. Larvae may have been taken by the flow and moved in new habitats.

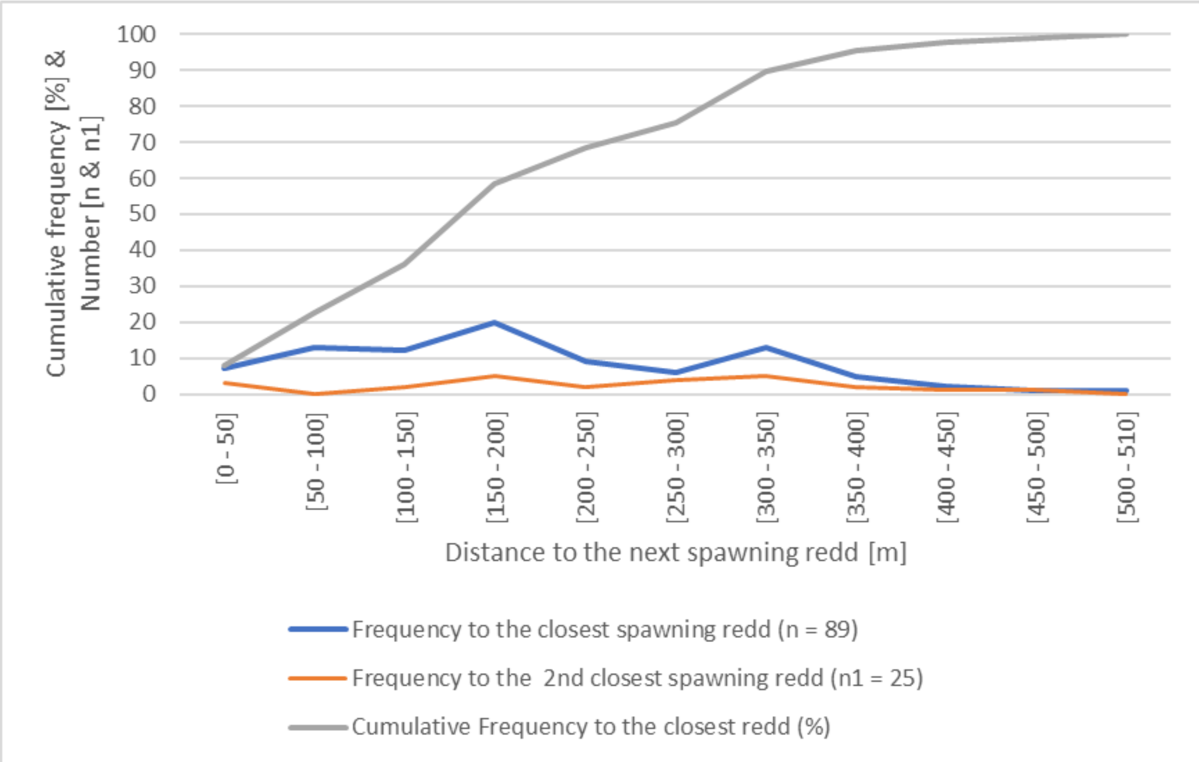


Figure 13 : Distance of the fry habitats to the closest spawning redd upstream [m] (@ Illona Doyon, Emmanuelle Waguette)

4.2.2. Larvae length

The measured total length of the majority of the examined individuals (n = 59) ranged from 25 to 30 mm (Figure 14), whereby the smallest fry had a total length of 23 mm and the largest 37 mm (Appendix 6). The mean total fish length of the investigated Danube salmon fry was 29 mm. Due to the long investigation period of almost four weeks, a certain growth of the individuals could be observed. Compared to 2016 investigation, larvae are bigger than in 2023 (in 2016: the fry length majority was included between 23 mm and 28 mm, the smallest fry was 17 mm long and the biggest one was 35 mm long, and the mean length was 25,6 mm; Schöfbenker, 2018).

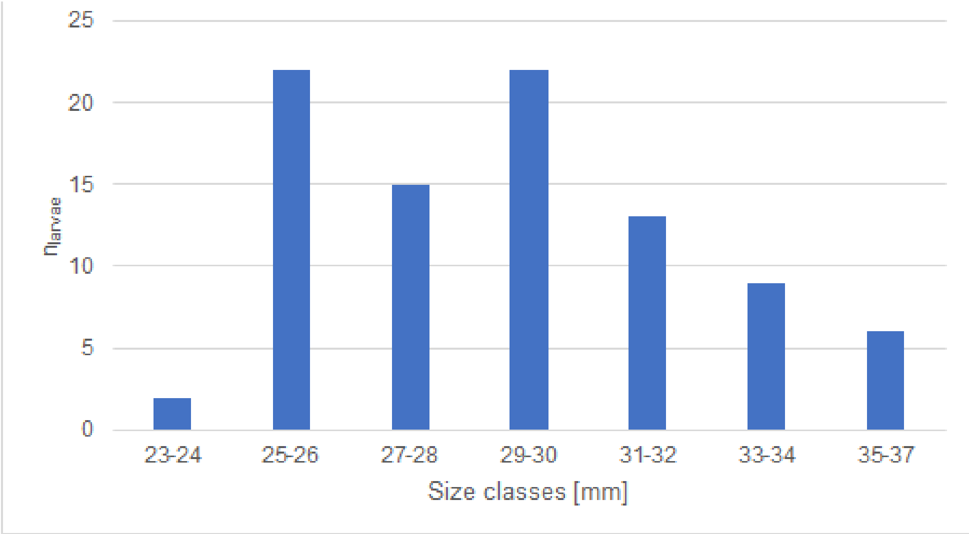


Figure 14 : Length frequency diagram [mm] of the detected larvae (n_{larvae} = number of individuals) (@ Gabriel Gruber)

4.2.3. Habitat characteristics

The investigated fry habitats were located along the shoreline, downstream of the detected spawning redds. The Danube salmon fry habitats are characterized by their appearance and key parameters like flow velocity, water depth, cover and substrate. Some habitats shared similar parameters, and it was also observed that sometimes they are home to several larvae.
The grouped fries were occasionally detected in distances of a few centimetres next to each other. In that case, independent habitat parameters were measured at the exact position for every single individual. 57 Danube salmons were individualists (64 %), while the remaining 36 % shared their first occupied habitat with at least another conspecific (Appendix 7). On average, around 1 individual was found per microhabitat ($\bar{x}$ = ~ 1 Ind./m2) (Appendix 8). The largest group of fries within a single habitat consisted of 5 individuals, which results in a maximum of around 13 individuals per square meter. 17 individuals were observed together with another conspecific (19,1 %). 9 fries occupied their first habitat together with two conspecifics (10,1 %) and 6 individuals formed groups of five specimen per habitat (6.7 %). The main difference with 2016's data, is that Danube fries were mostly living in groups: 71,3 % of them were sharing their first habitat, whereas only 28,7 % were individualists (Schöfbenker, 2018).

Then, regarding the fish position, the preferred water depth class for the Danube fry is about 11 to 21 cm (Figure 15). All prospected habitats were seen in shallow water ranging from less than 1 cm deep, to 101 cm. The mean water depth for the recorded habitats is 23,8 cm which is closed to 2016 value (20,8 cm; Schöfbenker, 2018; Appendix 9).

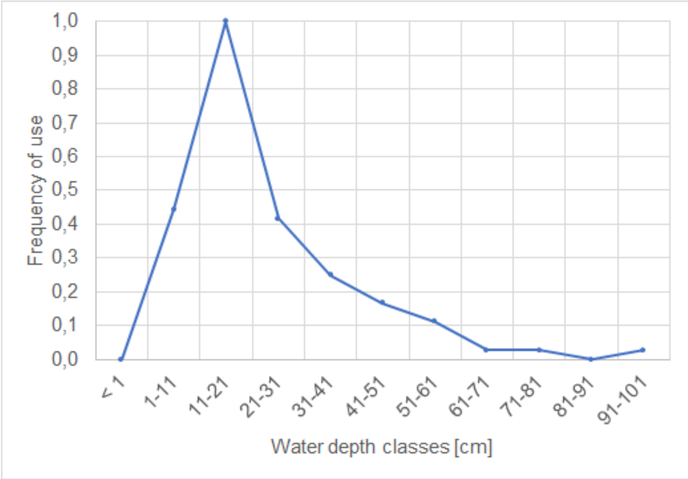


Figure 15 : Frequency of used water depth (@Emmanuelle Waguette, Illona Doyon)

Still at the fish position, the flow velocity recorded is ranged from less than 30 cm/s to 30 cm/s, and the one larvae like the most is around 0 to 10 cm/s (Figure 16). Furthermore, the flow velocity along the vertical line at the fish position is statistically similar, as we can see with the figure 17, and corresponds to a slow discharge. Danube fries are small and fragile fish, so they need a flow velocity strong enough to always move and find food, but also smooth enough in order to go wherever they want and survive.

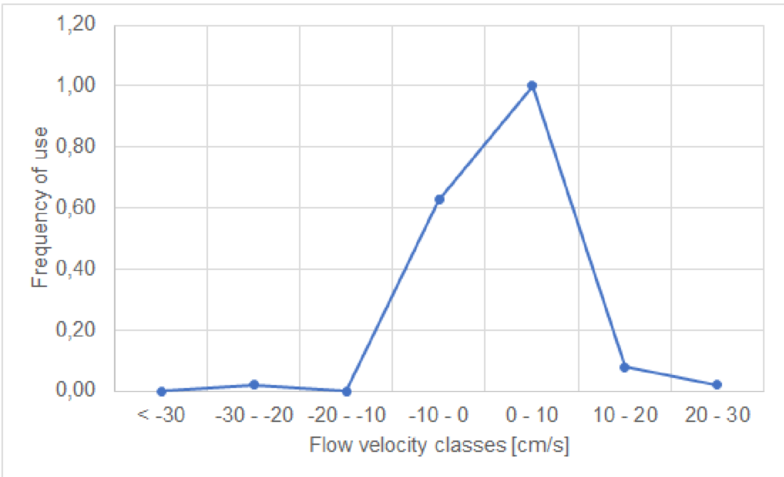


Figure 16 : Frequency of used flow velocity (@ Gabriel Gruber)

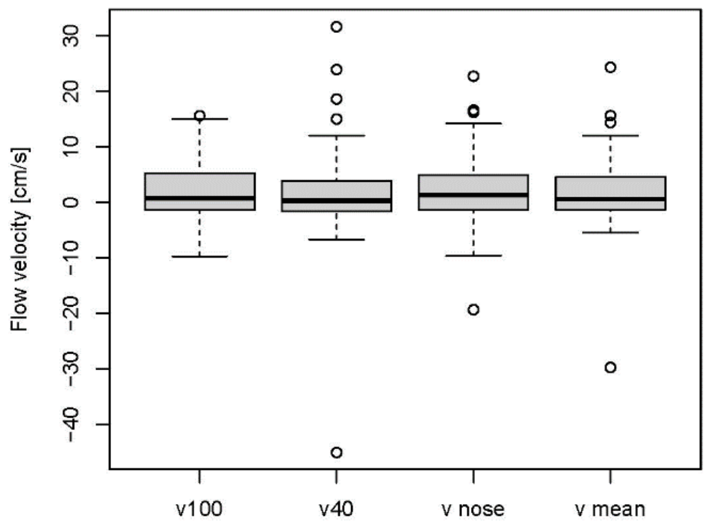


Figure 17 : Flow velocity along vertical line at the fish position (@ Gabriel Gruber)

Now, regarding water depth and flow velocity parameters around to the fry position, at 50 cm, at 100 cm, and at 150 cm from the shore, we can see on figure 18 that the velocity is increasing with the distance to the shore. Apart of some extreme values, the mean flow velocity for each category is between 0 and 0,2 m/s, so it is a slow velocity, but it is not without any velocity. Those measurements have been done owing to the beginning of larvae investigation. We observed that Danube fries were usually located in shallow position where it was possible to see small waves on the shoreline. Since we made this observation, it was decided to collect some more information about flow velocity about larvae habitats (the data table is in appendix 10).

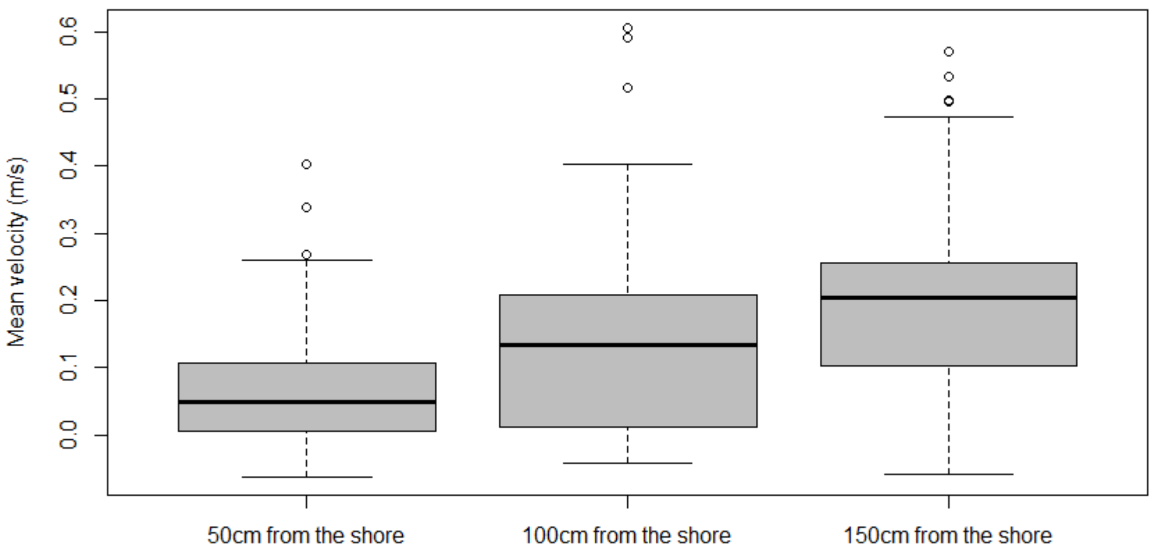
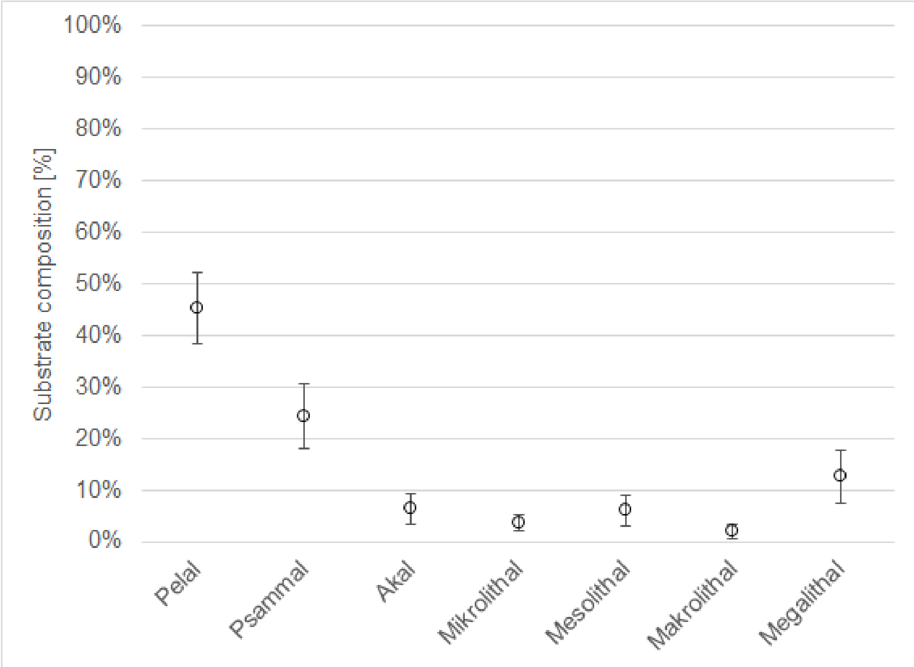


Figure 18 : Flow velocity around the fish position (@Gabriel Gruber)

To continue the description, larvae habitat substrate was analysed, and the preferred fry habitat is mostly composed of pelal (45 %, see table in appendix 11), which is characterised as fine predominantly inorganic substrate, and psammal (24 %) which is sand. Then we can find megalithal

(13 %). We can see on figure 19 that the substrate composition is very similar to 2016 results (Schöfbenker, 2018), based on arithmetic averages.



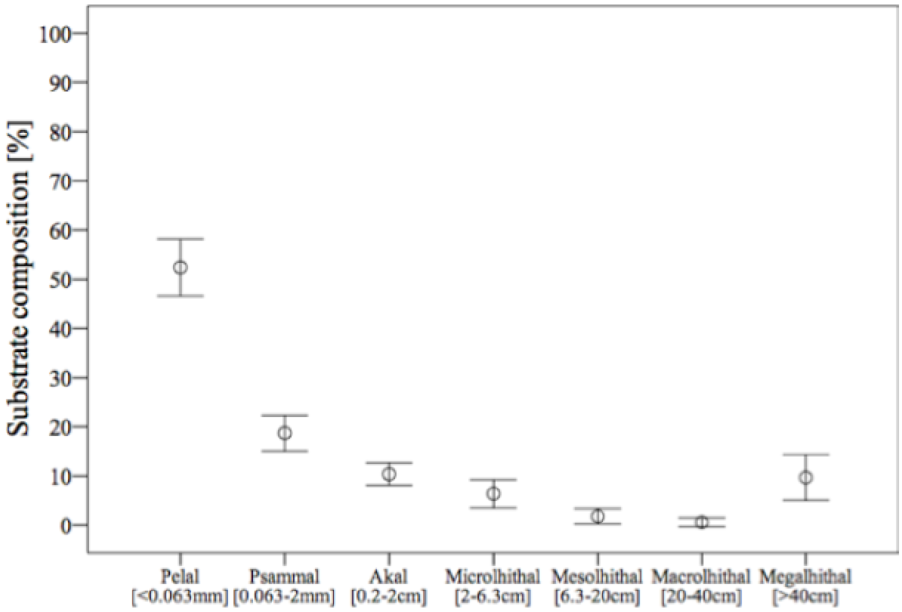


Figure 19 : Average substrate composition of larvae habitats with 95% confidence intervals in 2023 (top, Gabriel Gruber) and in 2016 (bottom, Schöfbenker, 2018)

Finally, we looked at the cover of the fish position, which means under 50 cm above the water surface, and at the habitat cover, so above 50 cm above the river surface (Figure 20). Fish are in average less covered than the entire habitat (31,30 % to 50,07 %; see table in appendix 12), but both are covered most of the time. Larvae were often discovered under grass, and because they like to live where there are psammal and pelal, vegetation can not take root, grow, and became dense enough to protect fries. However, the entire habitat is covered by trees in general since habitats are located close to the shore.

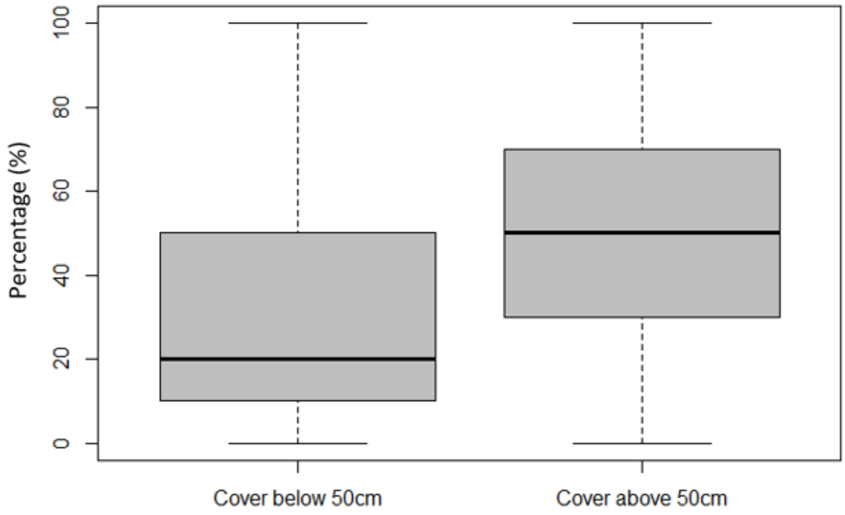


Figure 20 : Cover of the fish position (below 50 cm) and of the entire habitat (above 50 cm) (@Gabriel Gruber)

4.3. Personal impressions

This internship was rich in knowledge and skills. First, it took place in a foreign country, so I had to express myself and work in another language. Everything in work went well so I am proud of myself for that. Then I discovered "real" field work in Austria. I had to follow the river, fighting against the vegetation all along the day, and I had never experiment that before in France. Sometimes, it could be quite dangerous because of the river, the relief, the vegetation, or the weather, and it would have been better if someone was there as a frame, just to feel safer. Emmanuelle and I were always together when we were in the field because of that, since we thought it was safer. Moreover, field work is not an activity everybody can do because it can be very intense physically.
Our tutors gave us a lot of autonomy. Thanks to that, we were able to organise our work as we wanted. However, I sometimes had the feeling that we were not totally involved in protocol establishments. Everything was very clear when they were explaining it to us, but I would have enjoyed being part of the reflexion.

Conclusion

Compared to 2016, less spawning redds were mapped and they are more located in the upstream part of the river, but as it was in 2016, residual flow stretches were used as often as full flow stretches for spawning. The detection of Danube salmon fries reveals the reproduction success of the population and the availability of habitats with suitable conditions. Larvae habitats were scattered than in 2016, and less abundant.

To ensure the long-term viability in the hyporhithral*,* as it was suggested by Schöfbenker, "*the construction of functional fish-bypass channels at the weir in Salau and Weinburg would be necessary"* but they are still not implemented. However, the Danube salmon population in the Pielach still has a reproduction activity and the investigated characteristics of fry habitats will contribute to the understanding about early developmental stages of the Danube salmon. Thanks to this study, the more relevant action that could be implemented to protect larvae would be to give the full flow back to the Pielach. We had a close look to the substrate, and especially to the compactness, and the results are showing a significant difference between full and residual flow. So, giving the full flow back to the Pielach seems to be the right decision for the Danube salmon, which is at the top of the food chain, so many other species must be impacted too by the residual flow. This residual flow is used to create electricity thanks to turbines. Around 9 or 10 turbines are implemented on the Pielach, and it was showed that the quantity of produced energy could be the same with only one or two windmill (K. Pinter, personal communication). The ecological impact would be less effective than the hydroelectric turbines' one.

This internship was a wonderful experience which gave me new skills and knowledge. Even if it is satisfying to do this work to help a species to survive and finally discovered something new (here it's the compactness difference in full and residual flow) that could really change something, I am not sure that I will work in the research field later as a professional. However, this experience confirms that I enjoy working outside.

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Wasser-Atmosphäre-Umwelt (WAU) Institute of Hydrobiology and Aquatic Ecosystem Management Institut für Hydrobiologie und Gewässermanagement (IHG).

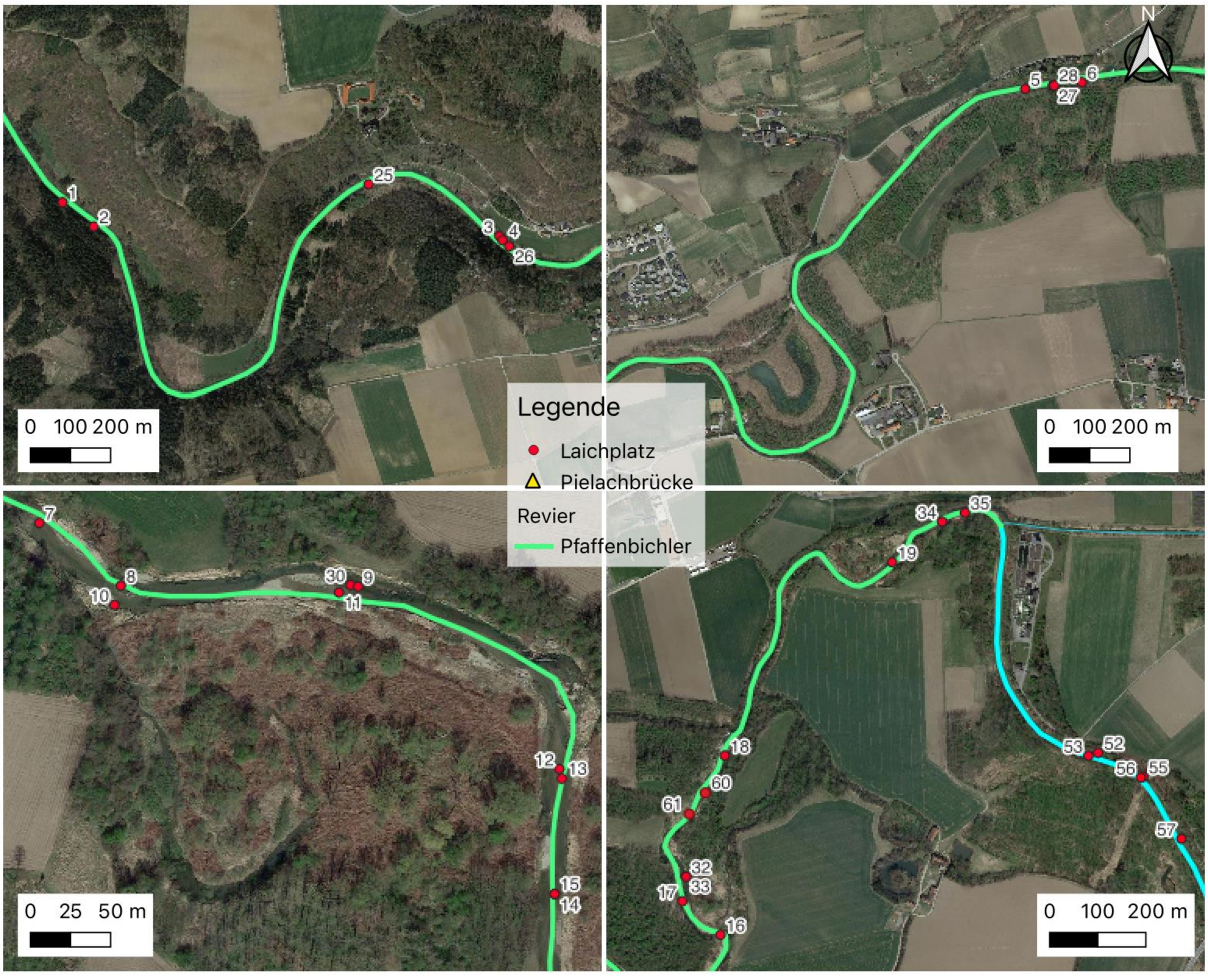
Appendix

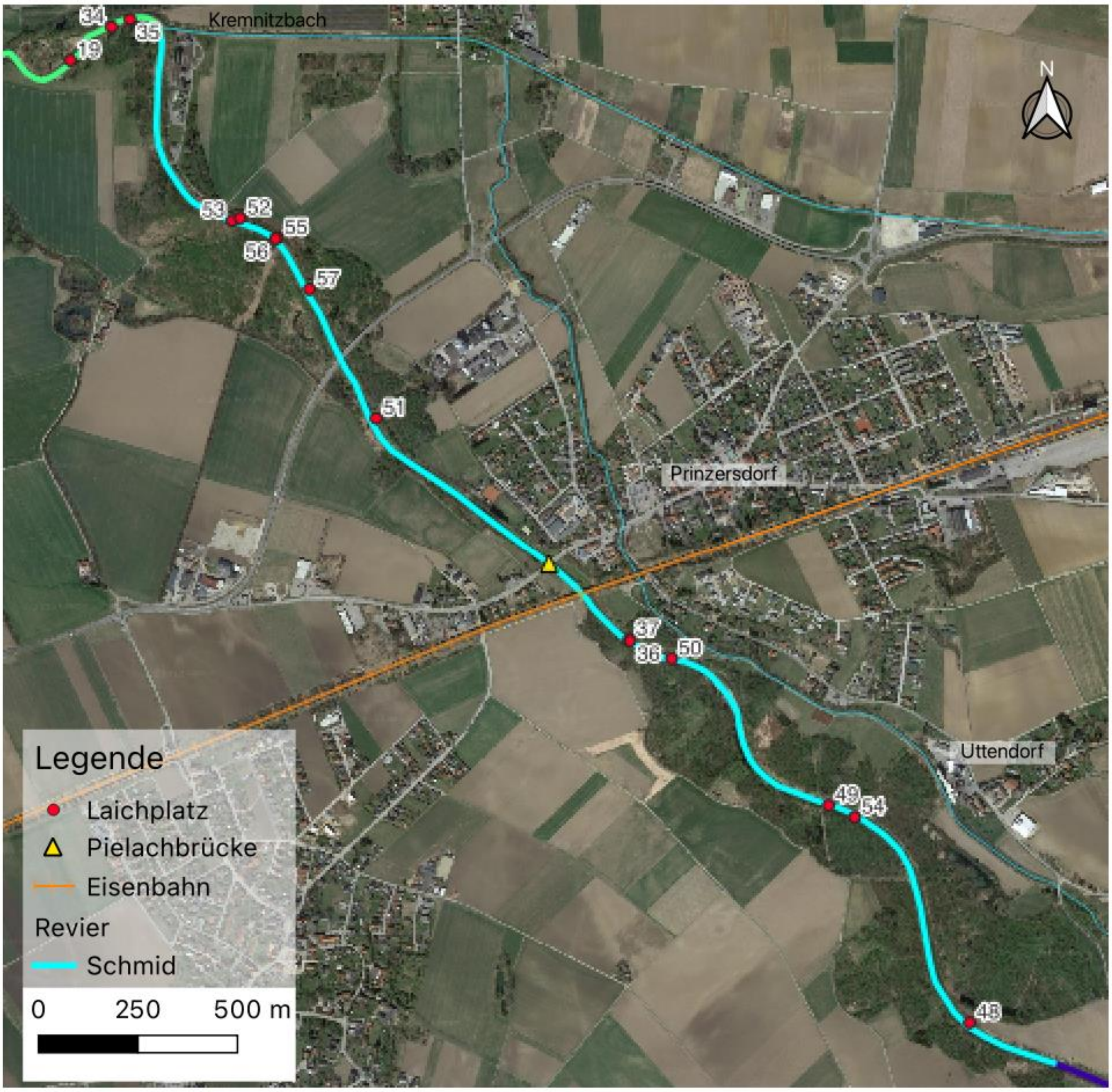
<u>Appendix 1 :</u> Larvae habitats' protocol sheet

	Date					
	Time					
	Larvae number					
	$Size_{larvae}$ [mm]					
Larvae position	Position under surface [cm]					
	Water $depth_{Fish\ position}$ [cm]					
	Distance to shore [cm]					
	$Cover_{Fish\ position}$ (< 50 cm)					
	v_{100} (fish position) [m/s]					
	v_{40} (fish position) [m/s]					
	v_N (fish position) [m/s]					
Habitat	Average water $depth_{Habitat}$ [cm]					
	Pelal					
	Psammal					
	Akal					
	Mikrolithal					
	Mesolithal					
	Makrolithal					
	Megalithal					
	Compactness					
	Side of river					
	Residual flow					
	$Length_{Habitat}$ [cm]					
	Max. $width_{Habitat}$ [cm]					
	$Coordinate_N$ [°]					
	$Coordinate_E$ [°]					
	$Cover_{Habitat}$ (> 50 cm)					
	Xylal					
	Larva uses same habitat as larva(e) ...					
50 cm from shore	Water $depth_{50cm}$ [cm]					
	v_{100} (50cm) [m/s]					
	v_{40} (50cm) [m/s]					
100 cm from shore	Water $depth_{100cm}$ [cm]					
	v_{100} (100cm) [m/s]					
	v_{40} (100cm) [m/s]					
	Water $depth_{150cm}$ [cm]					

150 cm from shore	v_{100} (150cm) [m/s]					
	v_{40} (150cm) [m/s]					
	Investigator					
	Comments					

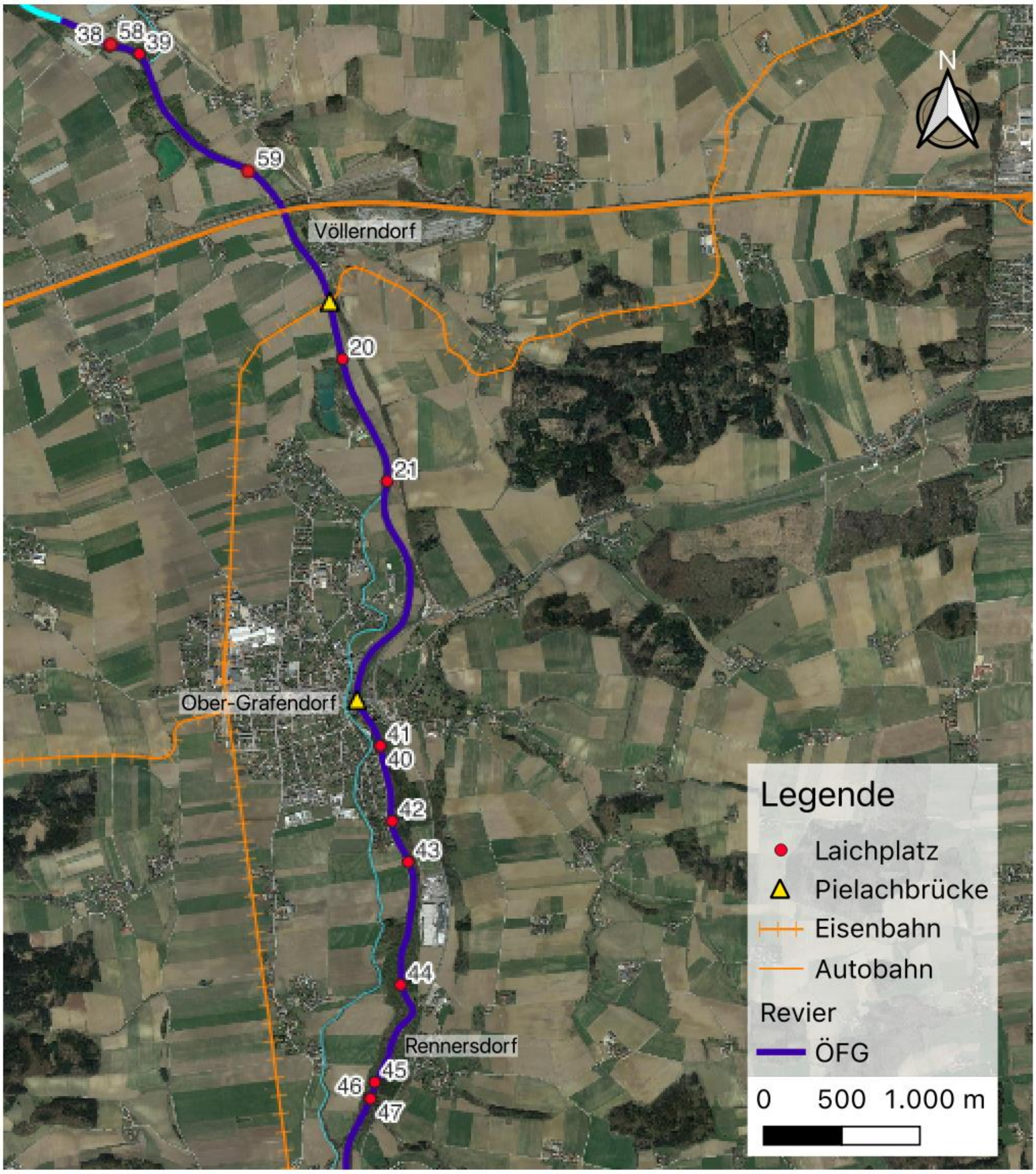
Appendix 2: Spawning redds' maps (@ Emmanuelle Waguette)





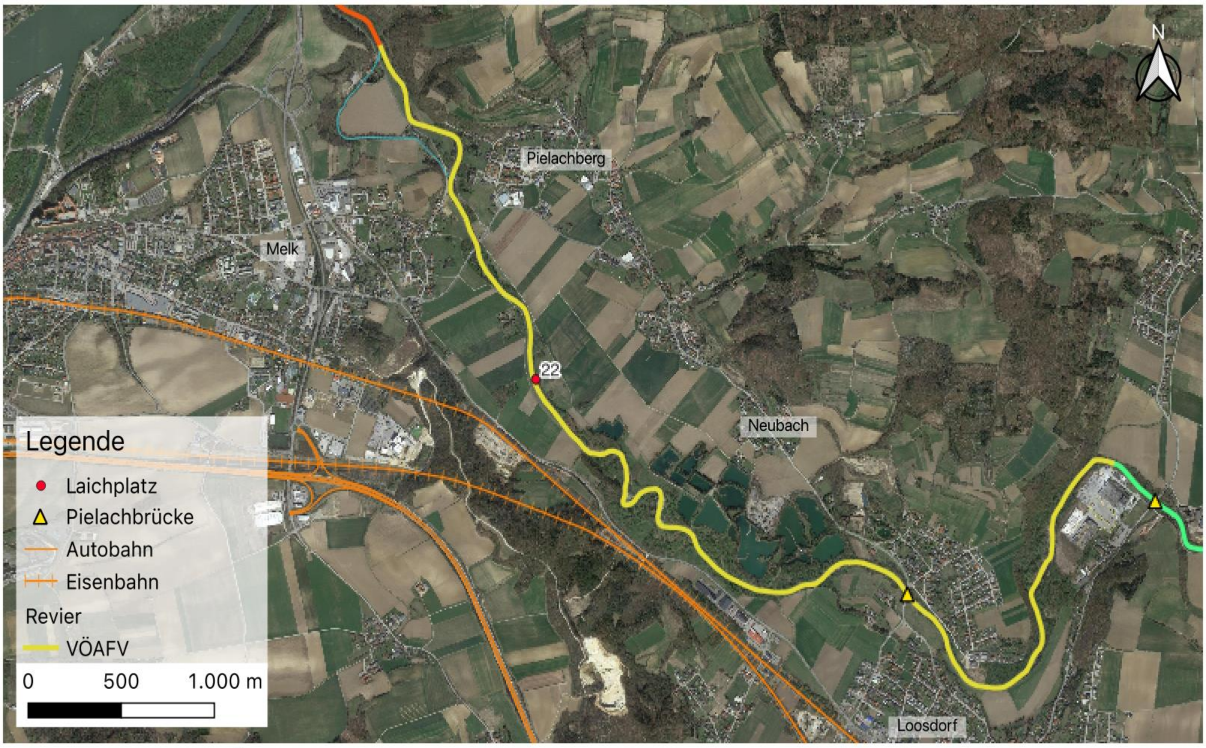
Anzahl der Laichplätze im Revier „Schmid“: 12
Gesamte Anzahl der auf Laichplätzen angetroffenen Huchen: 6

(Bei den weiß unterlegten Nummern in der Karte handelt es sich um Laichplatz-IDs)



Anzahl der Laichplätze im Revier „ÖFG": 14
Gesamte Anzahl der auf Laichplätzen angetroffenen Huchen: 13

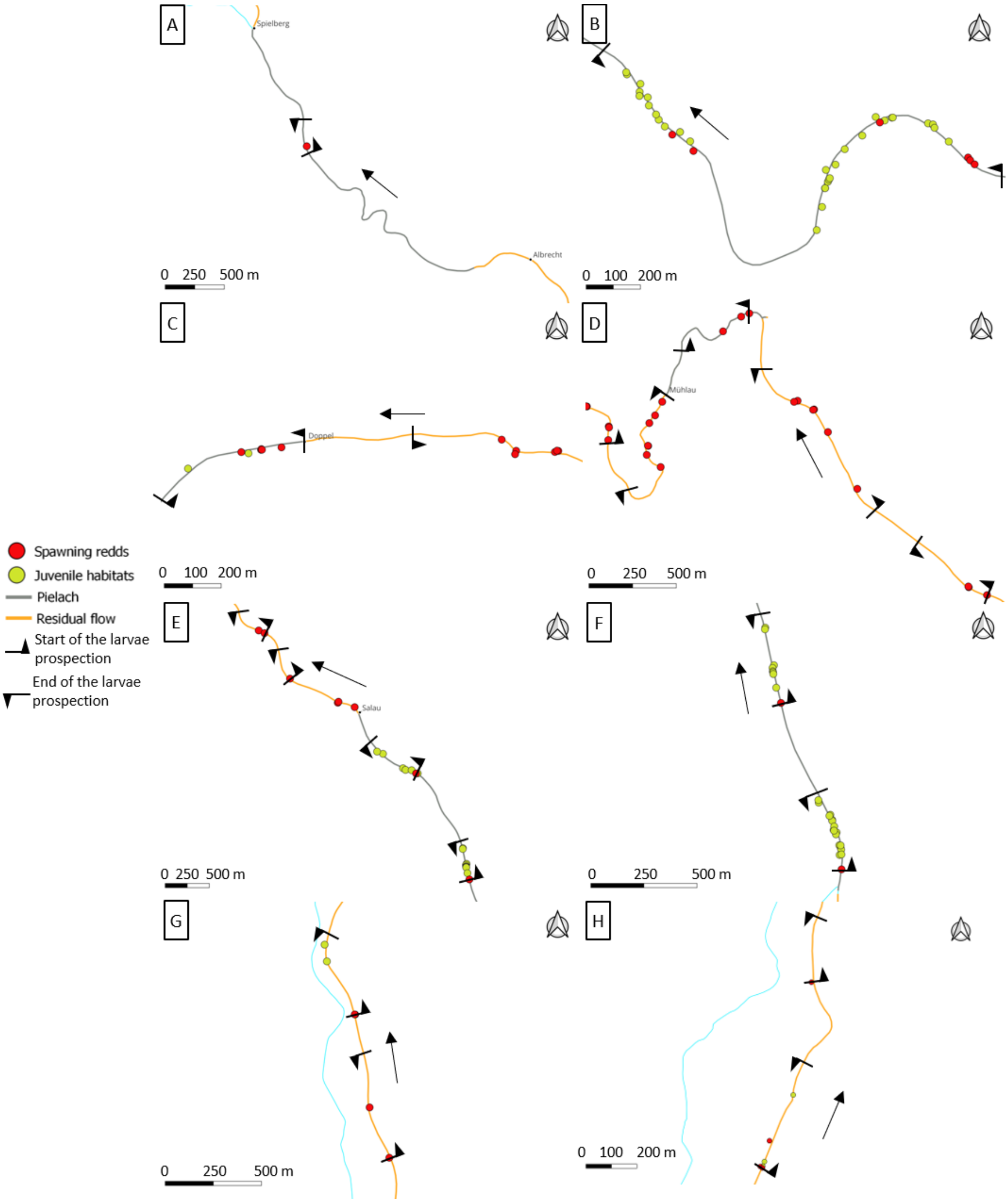
(Bei den weiß unterlegten Nummern in der Karte handelt es sich um Laichplatz-IDs)



Anzahl der Laichplätze im Revier „VÖAFV“: 1
Gesamte Anzahl der auf Laichplätzen angetroffenen Huchen: 0

(Bei den weiß unterlegten Nummern in der Karte handelt es sich um Laichplatz-IDs)

Appendix 3: Detailed view of the larvae and redds mapping along the river course from downstream sites (A) to Weinburg (H). Arrow = flow direction



Appendix 4: Number and density of spawning redds and larvaes in the Pielach in 2023 in each sub-populations (ID : 1-2) and sub-reach (ID : 3-11). The density of the spawning redd is calculated on 32km of the study whereas the density of the larvae is calculated on the 11km of larvae prospection.

	ID	Continuum interruption	Number of Spawning redds	Density of Spawning redd (Redds/km)	Number of larvaes	Density of larvae (larvaes/km)
Sub-population	1	Salau	47	2,04	42	5,42
	2	Weinburg	11	1,16	47	14,03
Sub-reach	3	Spielberg	0	0	0	0
	4	Albrechtsberg	1	0,26	0	0
	5	Neuhofen	0	0	0	0
	6	Eibelsau	6	1,18	40	17,30
	7	Doppel	5	2,93	2	3,86
	8	Mühlau	17	7,20	0	0
	9	Salau	18	3,42	0	0
	10	Engelsdorf	11	1,43	47	14,03
	11	Weinburg	0	0,00	0	0
Total			58	1,78	89	8,02

Appendix 5: Statistical overview about the distances of fry habitats to the closest spawning redd [n=89]

Distance to the spawning redd [m]	Frequency [n]	Cumulative frequency [n]	Cumulative frequency [%]
0 - 50	7	7	7,9
50 - 100	13	20	22,5
100 - 150	12	32	36,0
150 - 200	20	52	58,4
200 - 250	9	61	68,5
250 - 300	6	67	75,3
300 - 350	13	80	89,9
350 - 400	5	85	95,5
400 - 450	2	87	97,8
450 - 500	1	88	98,9
500 - 510	1	89	100

Appendix 6 : Larvae length results

	Larvae size [mm]
Mean	29
Median	29
Std. Deviation	3
Minimum	23
Maximum	37

Appendix 7: Frequency analysis of fry per habitat

Fry per habitat	Number of larvae [n=89]	Frequency [%]
1	57	64,0
2	17	19,1
3	9	10,1
5	6	6,7

Appendix 8: Statistical overview of fry per habitat and per square meter

	Fry/m²	Fry/Habitat
Mean	0.69	1.35
Standard Deviation	1.76	0.18
Minimum	0.04	1
Maximum	12.5	5

Appendix 9: Water depth at fish position

Values at fish position	[cm]
Mean	23,8
Median	18
Std. Deviation	16,6
Minimum	5,5
Maximum	101

Appendix 10: Flow velocity around the fish position

Flow velocity [m/s]													
	Fish position				0,5 m from the shore			1,0 m from the shore			1,5 m from the shore		
	v_{mean}	v_{100}	v_{40}	v_{nose}	v_{mean}	v_{100}	v_{40}	v_{mean}	v_{100}	v_{40}	v_{mean}	v_{100}	v_{40}
Mean	0,02	0,02	0,02	0,02	0,06	0,07	0,07	0,14	0,16	0,14	0,20	0,23	0,20
Median	0,01	0,01	0,00	0,01	0,05	0,05	0,04	0,13	0,16	0,10	0,20	0,23	0,20
Std. Deviation	0,06	0,05	0,08	0,06	0,09	0,09	0,11	0,15	0,16	0,16	0,14	0,18	0,14
Minimum	-0,30	-0,10	-0,45	-0,19	-0,06	-0,11	-0,08	-0,04	-0,05	-0,05	-0,06	-0,08	-0,05
Maximum	0,24	0,16	0,32	0,23	0,40	0,35	0,47	0,61	0,77	0,59	0,57	0,81	0,58

Appendix 11 : Substrat composition of fry habitats

	Pelal	Psammal	Akal	Mikrolithal	Mesolithal	Makrolithal	Megalithal
Average	45%	24%	6%	4%	6%	2%	13%
Std. Deviation	33%	31%	14%	7%	14%	7%	25%

Appendix 12: Cover of fish position (< 50 cm) and of the entire habitat (> 50 cm)

	Cover (<50cm)	Cover (>50cm)
Mean	31,30	50,07
Standard Deviation	27,99	24,87
Max	100	100
Min	0	0

35 ALLÉE FERDINAND DE LESSEPS
37200 TOURS

Illona Doyon
2022-2023

Habitat assessment of juvenile Danube Salmon (Hucho hucho) in the River Pielach

Résumé : The Danube salmon (*Hucho hucho*) is one of the most endangered species. This study aims to help it to survive by understanding juvenile preferred habitats, as it has already been done by Schöfbenker in 2016 in his master theses. Repeating his experimentations are helpful in the population follow-up and to compare how the situation changed. By improving the data assessment, this study could be published to help the Danube salmon in its prosperity.

Mots Clés : Danube salmon, Hucho hucho, Pielach, spawning redd, fry habitats, larvae, investigation, field work

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