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Joint management of Latvian – Lithuanian trans-boundary river and lake water bodies (TRANSWAT) LLI-533

RIVER HABITAT SURVEY REPORT

2022

LVĢMC

UNIVERSITY OF LATVIA

BIOR

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ABBREVIATIONS

E-Flow	Ecological Flow
EU	European Union
HPP	Hydropower Plant
GU	Geomorphic Unit
LAS	Latvian Elevation System
LEGMC	Latvian Environment, Geology and Meteorology Centre
MS	Monitoring station
RB	River Basin
RBD	River Basin District
WFD	Water Framework Directive

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1. INTRODUCTION

In the frame of the “Joint management of Latvian – Lithuanian trans-boundary river and lake water bodies” project (TRANSWAT) LLI-533 financed by the Interreg V-A Latvia–Lithuania Programme 2014-2020, field surveys were carried out in the project pilot rivers Ciecere, Losis (LV) and Varduva (LT).

The main objective of the those field surveys (FS) was to collect biological (fish), hydrological and morphological data in order to assess the river habitat changes due to water regime regulation by HPPs and to evaluate the ecological flow (E-flow) based on the principles and approaches of the EU Water Framework Directive (WFD).

Field surveys were organized in the following pilot rivers:

Ciecere River: regulated by three HPPs, three work sites downstream each HPP;

Losis River: regulated by two HPPs, two work sites downstream each HPP;

Varduva River: regulated by five HPPs, five work sites downstream each HPP.

The survey program included hydrological measurements (water discharge, water depth, flow velocity) and substrate description in each measurement point within a given geomorphic unit, as well as geomorphic unit mapping and fish data collecting.

It is clear that HPP operation considerably affects the water regime and river morphology. The most significant pressure identified within the scope of the field works is interruption of the river continuity by dams’ construction itself. No one fish has built in HPPs of the project case studies. Bank erosion process due to hydropeaking is essential for Losis River downstream HPP Grantini.

On the base of FSs the River Habitat – Water Flow rating curves for the case studies will be designated.

Fish survey results are included in the present report as additional chapter.

E-flow will be evaluated for all case studies using MESOHABSIM model.

2. OBJECTIVES OF THE FIELD SURVEYS

The main objective of the Field Survey is the collecting of the empirical data in order to assess an impact of the HPP on the rivers' ecosystem. The specific ofjectives of the field surveys in the frame of the TRANSWAT project are:

- To collect hydro-morphological data downstream of each HPP along the pilot rivers regulated by HPPs cascade and to create a map of habitats;
- To collect fish data in the pilot rivers in order to describe the presence and abundance of fish species.

As already mentioned, the main objective of the FSs will be collecting the missing data for habitat mapping and creating the rating curve of water flow and river habitat. Taking into account the natural flow fluctuation during the year, the field measurements have to be carried out in different flow conditions.

3. SITES OF MEASUREMENTS, SURVEYS TIMELINE

The measurements' sites have been selected during the Initial field survey in the October 2020. The key principle of this selection comes from the main objective – to assess the influence of the each HPP operation on the hydrological regime and aquatic ecosystem.

3.1. Ciecere River measurements sites

River has small U- shaped valley, 150 – 200 m wide. River banks are sandy loam, moderate slope, overgrown with shrubs. In some places, there are outcrops of bedrock.

Floodplain is also sandy loam, covered by shrub and meadow vegetation, inundated. Channel is sinuous, 10 m width in average and 0.3-0.6 m depth.

River bed substrate: boulders, cobbles, gravel and mud.

3 small hydropower plants are constructed in the Ciecere River within Latvian part of the tronsboundary Venta Riber Basin (RB). Two of these HPPs (HPP Dzirnavnieki and HPP Ciecere) are located in the upper stretch of the river at a distance of 5.9 km from each other.

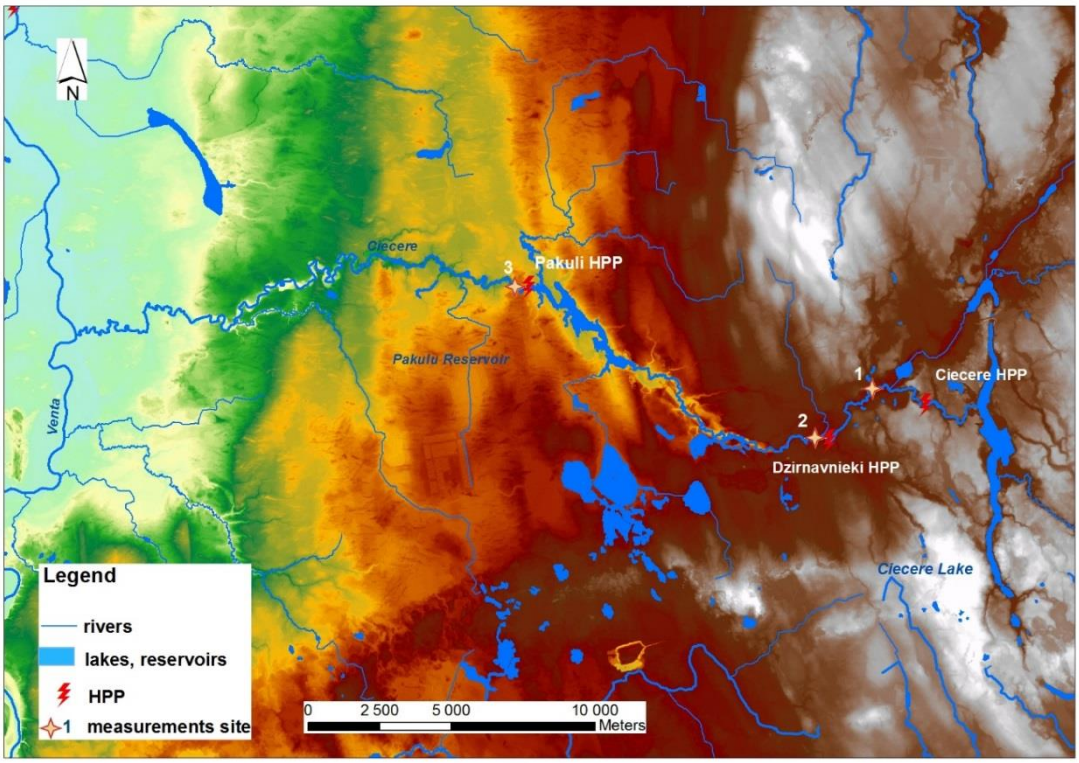

Figure 3.1.1. HPPs and measurements sites in Ciecere River

Third one is located in the middle river stretch at a distance of 17.4 km from the second HPP. The measurements sites have been designed downstream each of the HPP. (Fig. 3.1.1).

3.2. Losis River measurements sites

River has small U- shaped and V-shaped (in upper searches) valley, 100 – 250 m wide. River banks are sandy loam, moderate slope, overgrown with shrubs and trees.

Channel is sinuous, 8 m width in average and 0.3-0.6 m depth.

River bed substrate: boulders, cobbles and gravel.

2 small hydropower plants are constructed in the Losis River within Latvian part of the tronsboundary Losis RB: HPP Grantini and HPP Lejnieki. Both of them are located in the lower river stretch. The measurements sites have been designed downstream each of the HPP. (Fig. 3.2.1).

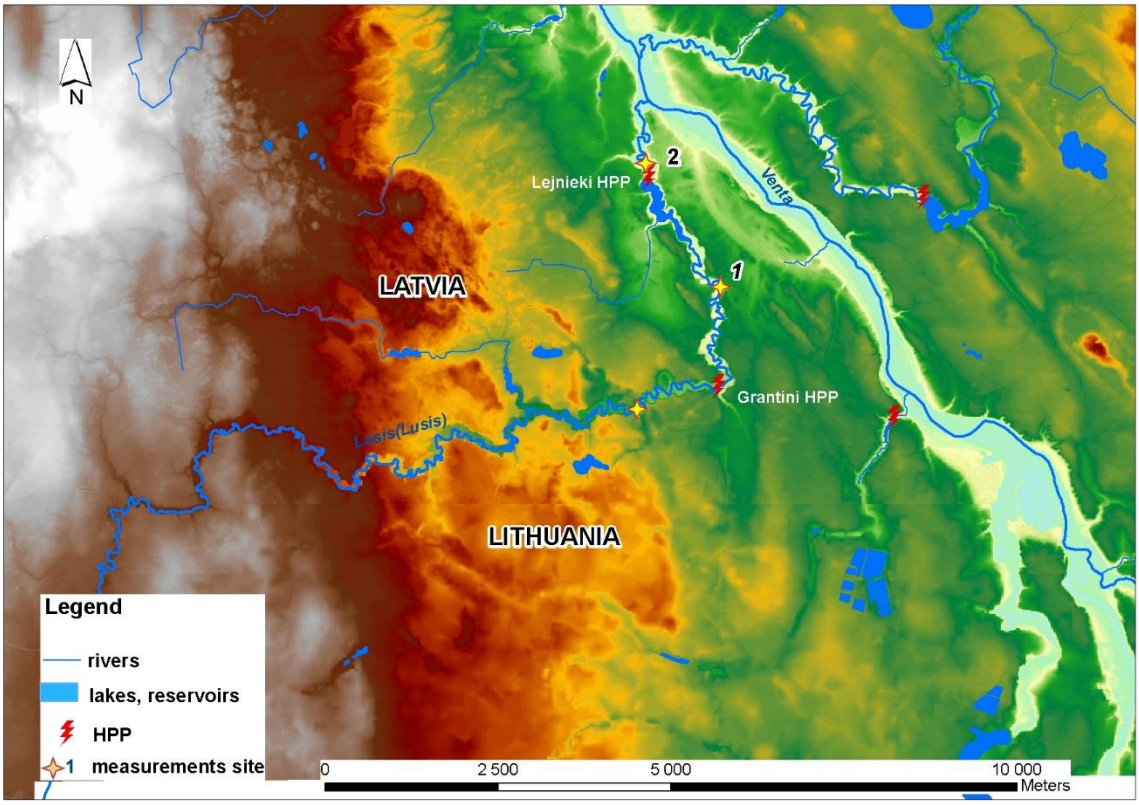

Figure 3.2.1. HPPs and measurements sites in Losis River

3.3. Varduva River measurements sites

Varduva River consists of the cascade of 5 small hydropower plants. All HPPs are located in the middle and lower reaches of the Varduva River. From the upstream, the first Kulšėnai HPP is located on the 59.8 kilometre from the river mouth. Whereas, the nearest Renavas HPP is constructed 17.8 km downstream. Vadagiai HPP is a third hydrotechnical structure located only 4.6 km downstream Renavas HPP. Another hydropower plants of Ukrinai and Juodeikiai are located further on 25.6 (11.8 km downstream Vadagiai HPP) and 7.1 (18.5 km downstream Ukrinai HPP) kilometre respectively from the river mouth. The measurements sites have been selected downstream each of the studied HPP. (Fig. 3.3.1).

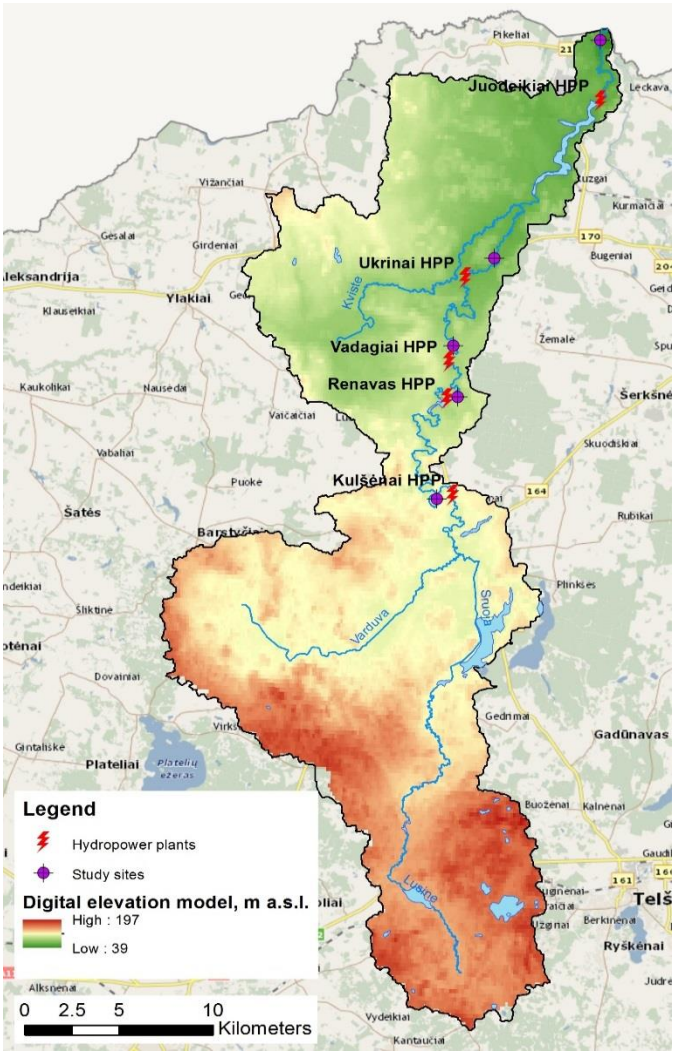

Figure 3.3.1. HPPs and measurements sites in Varduva River

3.4. Survey timeline

Field Surveys mainly were carried during 2021 but it started in October 2020. At

least four field measurements were intended to carry out under different hydrological conditions corresponding to the following water discharge:

- minimum of low flow period;
- average of low flow period;
- maximum of low flow period;
- annual water discharge.

Tables 3.4.1. and Table 3.4.2. show the dates of measurements and corresponding water flow ranges in Latvia and Lithuania.

Table 3.4.1.Field measurements in Latvia, 2020-2021

Latvian case studies					
Flow range	Ciecere River			Losis River	
	Ciecere HPP	Dzirnavnieki HPP	Pakuli HPP	Grantini HPP	Lejnieki HPP
low flow min	23.09.2021	12.11.2020	13.11.2020	28.09.2021	20.10.2020
low flow average	12.11.2020	23.09.2021	23.09.2021	27.04.2021	27.04.2021
low flow max	03.06.2021	03.06.2021	03.06.2021	11.08.2021	-
annual mean	25.11.2021	03.06.2021	25.11.2021	20.10.2020	08.10.2021

Table 3.4.2. Field measurements in Lithuania, 2020-2021

Lithuanian case studies					
Flow range	Varduva River				
	Kulšėnai HPP	Renavas HPP	Vadagiai HPP	Ukrinai HPP	Juodeikiai HPP
low flow min	02.08.2021	15.07.2021	15.07.2021	04.08.2021	03.08.2021
low flow average	20.06.2022	02.08.2021	13.07.2021	21.06.2022	15.09.2021
low flow max	15.12.2020	18.11.2020	18.11.2020	13.07.2021	14.07.2021
annual mean	-	-	-	-	-

In Latvia, fish data collection for the Fish Model validation was carried out by BIOR in Losis River and and Ciecere rivers.

In Lithuania, fish data collection for the Fish Model validation was carried out by Nature Research Centre (NRC) in the Varduva River.

4. SURVEY RESULTS

This chapter includes information about FS results, as well as short information about methods and equipment used for the field measurements in Latvia and Lithuania.

4.1. Latvian Habitat mapping and hydrological measurements

Geomorphic units were mapped altogether in 5 sites: 3 in the Ciecere River and 2 in the Losis River. Surveyed reach length varied from 120 m to 280 m in Ciecere River and from 195 m to 215 m in Losis River. In both rivers it was in accordance with MesoHABSIM model requirements (reach length at least > 10 river widths). For all five sites, mapped river reach had constant length, and changes in mapped area are related to changes in water level. Total mapped area depends on the length of the reach and river width. For example, side bars and mid-channel bars can appear in low flows and disappear in higher flows. Depending on site and discharge, mapped area varied from 710 m^2 to 3860 m^2 in Ciecere River and from 1700 m^2 to 2700 m^2 (Table 4.1.1.).

Table 4.1.1.Case studies, geographical characteristics

River site	Length of surveyed reach, m	Mapped area, m^2	Distance to HPP, km
Ciecere 1	120	710-1015	1.40
Ciecere 2	160	1394-1745	0.45
Ciecere 3	280	2860-3860	0.35
Losis 1	215	2034-2700	0.18
Losis 2	195	1700-1952	2.5

In total, six different hydromorphological units were surveyed in both rivers: aquatic vegetation, backwater, glide, pool, rapid and riffle. Meander pools were denoted as simple pools, runs as fast flowing glides, and forced riffles as riffles, in accordance with available options of the used mapping software. Due to low river bed slope the most frequent geomorphic units were glides and riffles (Fig. 4.1.1. a and 4.1.1. b) that were observed in all studied stretches at all water levels. In natural river stretches the proportion of fast-flowing HMU (riffles and rapids) increases with increasing of water flow. It was not true in Ciecere 1 at Kalnsetas

parks where artificial rived bed structures (stone piles) can be observed. Ciecere 2 below Saldus city was impacted by large beaver' dam which was built in the period between third and fourth survey. Riffles and rapids occupy from 34% to 65% of a total mapped area in Ciecere 1 (Fig. 1-4 in Annex I), 32% to 37% in Ciecere 2 (Fig. 5-8 in Annex III) and 29% to 47% in Ciecere 3 (Fig. 9-12 in Annex I), indicating the Ciecere River as the rithral type river. Fast flowing riffles and rapids occupy from 16% to 31% of a total mapped area in Losis 1 (Fig. 13-16 in Annex I) and 8% to 18% in Losis 2 (Fig. 17-20 in Annex I), indicating the upper stretch of the Losis River as a rithral type river and the lower stretch of the Losis River as a potamal type river.

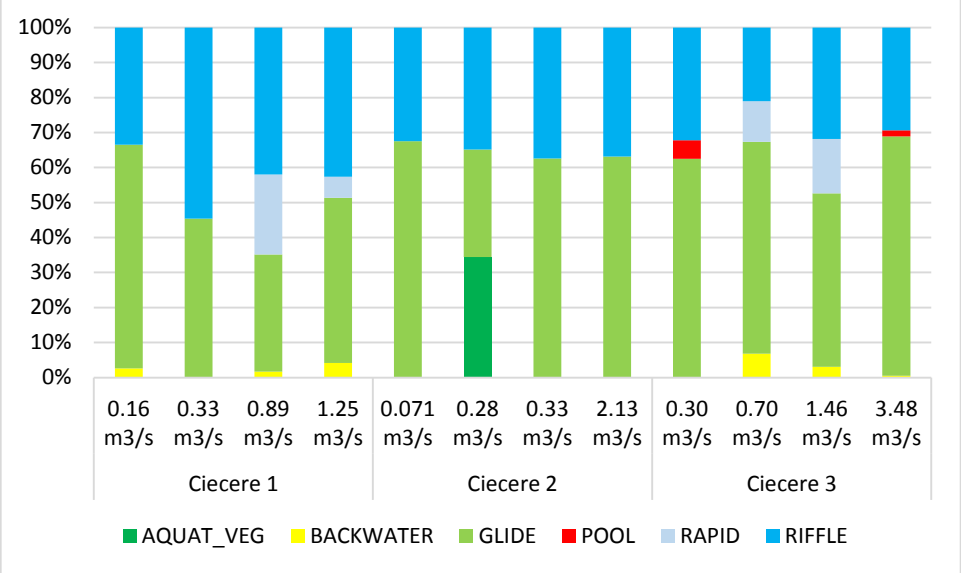

Figure 4.1.1.a Distribution of geomorphic units in surveyed sites within Ciecere River

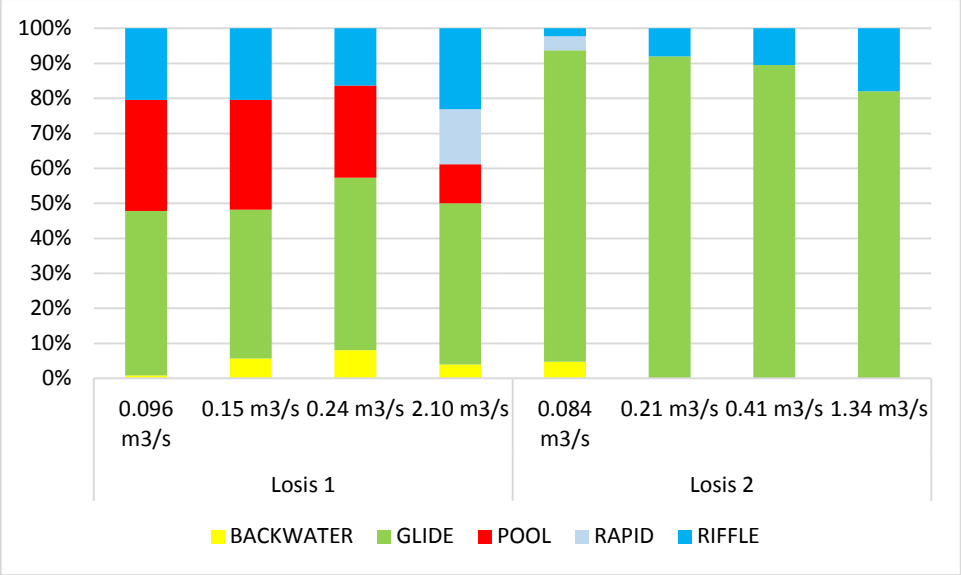

Figure 4.1. 1.b Distribution of geomorphic units in surveyed sites within Losis River

According to distribution of geomorphic units, the most homogeneous was Ciecere 2 River site, where only 2 (3 in the middle of summer) different units per site were found and Losis 2 (2 units in most of surveys). Other river sections were also relatively uniform and mostly no more than 4 different units were observed (Fig. 4. 1.2.). The exception is Losis 1, which is located downstream reach close to river mouth in a scenic location, where 5 units were detected in one season.

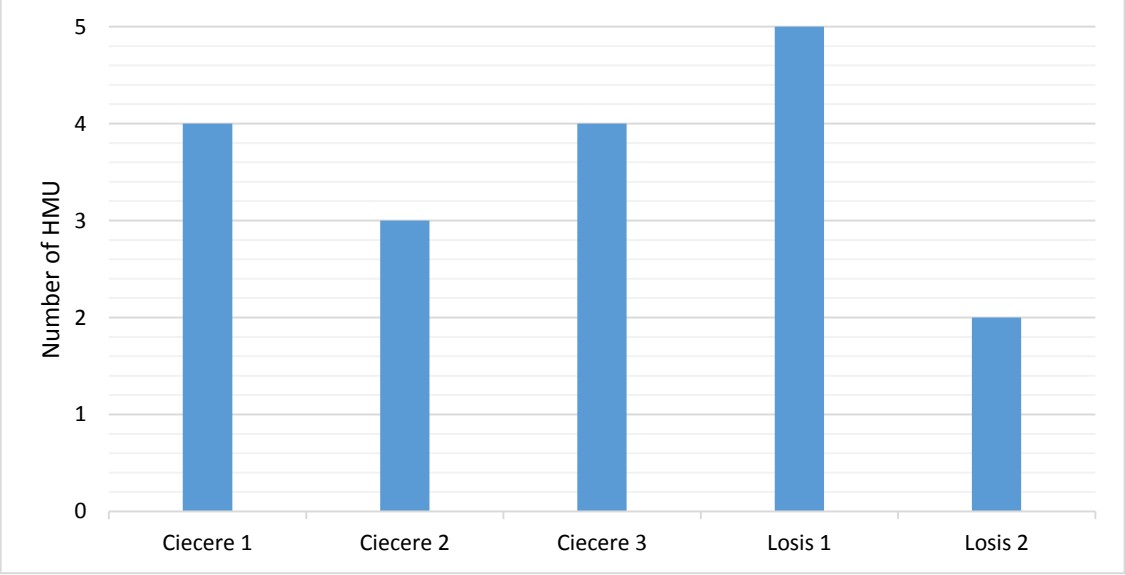

Figure 4. 1.2. Maximum number of different geomorphic units per surveyed site in selected case studies

Glide was a largest HMU with average mapped area 1200 m^2, size of other river units was significantly smaller (Fig. 4.1.3.). Average size of riffles was 510 m^2 and pools 407 m^2. Smallest HMU was backwater with average size 71 m^2. In comparison to the Ecoflow and WBWB projects, only HMUs with an area of more than 5m^2 were mapped in this project. We fallowed the principle that if the HMU occupies less than 1% of the total area, it does not significantly affect the habitat suitability distribution results and it is not worth spending time on its mapping.

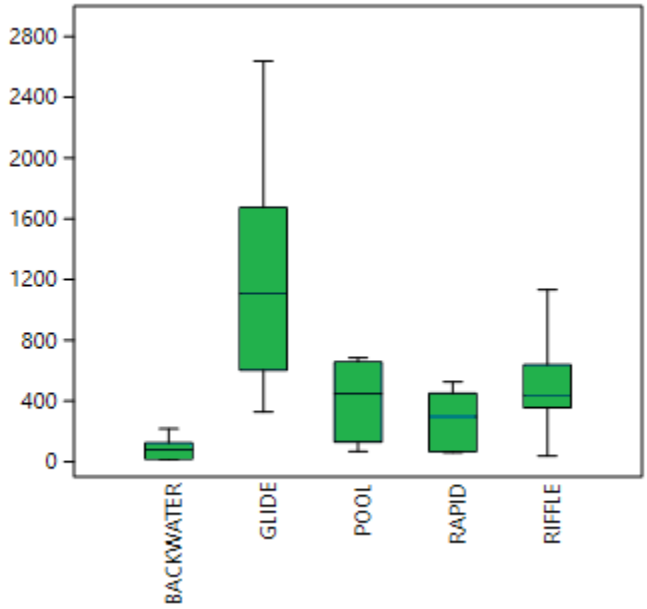

Figure 4.1.3. Area variation of geomorphic units within all studied rivers

In addition to the habitat mapping, point measurements have been carried out in all 5 case study rivers during river habitat survey. This part of surveys included water depth and flow velocity measurements as well as substrate size determination in representative points located proportionally within each HMU. Number of measured points depends on the size of HMU, however, it was not less than 5 measurements in small backwaters and 7 measurements in all other units. During field surveys in for occasions largest number of point measurements was done in Ciecere 3 (327 measurements in total) and Losis 1 (313 measurements), also in Ciecere 1 (225 measurements) and Losis 2 (225 measurements). Lowest number of measurements was done in Ciecere 2 (173 measurements in 4 surveys) because this site had very simple hydromorphological structure (on average 5

HMU). Water discharge measurements (cross-sections) have been carried out in the beginning of each survey and in every site. In some cases additional discharge was measured also in the end of survey.

4.2. Fish data collecting in Latvian rivers

Fish fauna of two rivers – Ciecere and Losis was surveyed. Survey in both rivers has been carried out downstream each HPP in the same stretches where measurements for MesoHABSIM is done. Fish fauna of each type of geomorphological unit (GU) represented in the stretch was sampled yet if there were several units of the same type (pool, riffle etc.) sampling was performed in only one of them.

Fish were sampled in accordance with the EU standard EN 14011 (CEN, 2003) by using of the standard KC Denmark electrofishing device powered by 2 kW generator (National permit for electrofishing surveys No ZD21ZI005). All captured fishes were detected to species level, measured and after recovery released in the river. Results for each GU was registered separately but also pooled results for all surveyed stretch was calculated. Ecological quality of the surveyed stretch was estimated by using of the Latvian Fish index (LVFI)[1]. To give broader look on status of fish fauna of both surveyed rivers, the data from electrofishing surveys performed within other projects (both 2021 and previously) and results of state-wide project for evaluation of importance of Latvian rivers in the protection of fish fauna[2] were also used.

4.2.1. Ciecere River and its fish fauna

In the evaluation of importance of Latvian rivers in protection of fish fauna Ciecere was listed among rivers which has a national scale importance. Models developed during this project shows that in general hydromorphological condition of Ciecere is suitable for such ecologically vulnerable species as bullhead (*Cottus gobio*), grayling (*Thymallus thymallus*) and both river and brook lampreys (*Lampetra*

[1] Description available at https://circabc.europa.eu/sd/a/203dd096-18fc-400e-bd77-b9ff5ffdc19d/LV%20-%20FISH%20-%20RIVERS%20-%20Nov%202016%20final%20accepted.pdf

[2] Project results available at https://bior.lv/lv/par-mums/jaunumi/noskaidrotas-zivim-nozimigakas-latvijas-upes-un-svarigakie-tajas-esosie-zivju-migracijas-skersli

fluviatilis and *L. planeri*) and at some extent also for the spawning of sea trout and brown trout (*Salmo trutta*).

In surveyed stretches downstream the Cieceres, Dzirnavnieku and Pakuļu HPP in total 13 fish species were recorded – schneider (Alburnoides bipunctatus), bleak (Alburnus alburnus), stone loach (Barbatula barbatula), silver bream (Blicca bjoerkna), spined loach (Cobitis taenia), bullhead, gudgeon (Gobio gobio), dace (Leuciscus leuciscus), perch (Perca fluviatilis), minnow (Phoxinus phoxinus), bitterling (Rhodeus sericeus), roach (Rutilus rutilus) and chub (Squalius cephalus). Most abundant and widespread specie downstream all three power plants and in almost all GU was roach (Table 4.2.1.1). Other species found downstream all HPP were bleak and stone loach. Gudgeon, perch, dace and bitterling were found downstream two of three HPP while other species were recorded only downstream one of power plants.

Table 4.2.1.1. Density of different fish species in different geomorphic units and pooled density of individuals of different fish species in Ciecere River downstream each HPP (GU – geomorphological unit; G – glide; B - backwater; Ra – rapid; Ri – riffle)

Site, GU		Alburnoides bipunctatus	Alburnus alburnus	Barbatula barbatula	Blicca bjoerkna	Cobitis taenia	Cottus gobio	Gobio gobio	Leuciscus	Perca fluviatlis	Phoxinus	Rhodeus sericeus	Rutilus rutilus	Squalius cephalus	Total
Cieceres HPP	G							5.1	1.7	5.1			44.4		56.4
	B		6.7			13.3	6.7			33.3			240.0		300.0
	Ra						5.6						2.2		7.8
	Ri						3.2								3.2
	Pooled		***0.4***			***0.9***	***3.5***	**1.3**	***0.4***	***3.5***			***28.4***		***38.6***
Dzirnavnieku HPP	G		1.1			3.3		42.2		5.6		6.7	36.7		95.6
	Ri					0.9		25.0					0.9		26.8
	Pooled		***0.5***			***2.0***		***32.8***		***2.5***		***3.0***	***17.2***		***58.0***
Pakuļu HPP	G		1.2			4.8			7.1						13.1
	B		2.9		2.9	5.8						8.7	173.9	8.7	202.9

	Ra		7.9	0.7					15.0		0.7		2.9		27.1
	Ri	0.9										0.9	1.9		3.7
	Pooled	***0.3***	***3.5***	***0.3***	***0.3***	***1.6***			***7.4***		***0.3***	***1.1***	***18.0***	***0.8***	***33.6***

Largest number of species and greatest density of individuals was found in slower flowing GU (backwater and glide) while in rapids and riffles number of species and density of individuals was lower. Only exception is the stretch downstream the Pakuļu HPP where number of species and density of individuals in rapid was higher than in glide. Noteworthy that in backwaters increase of density was registered not only for roach, perch and other species preferring slow flowing waters but also for such rheophilic species as bullhead and chub. In general, it can be concluded that distribution of species and specimens during the survey of 2021 most probably was altered by very high water temperature (26.8°C) what caused fishes to seek for cooler water in shaded backwaters and other deeper places.

In the sampling station located only 700 m from the rivermouth 17 fish and lamprey species were registered – bleak, silver bream, spined loach, pike (Esox lucius), three-spined stickleback (Gasterosteus aculeatus), gudgeon, sunbleak (Leucaspius delineatus), dace, perch, minnow, bitterling, roach, chub, tench (Tinca tinca), nine-spined stickleback (Pungitius pungitius), vimba bream (Vimba vimba) and lamprey larvae (most probably brook lamprey). Larger number of cyprinid species characteristic for slow-flowing waters can be linked with proximity to Venta River.

Most of fish and lamprey species registered in previous years was recaptured also in 2021. The exceptions are bream (Abramis brama), eel (Anguilla anguilla), Prussian carp (Carassius gibelio), crucian carp (Carassius carassius), ruff (Gymnocephalus cernua), brown trout / sea trout, pikeperch (Sander lucioperca) and rudd (Scardinius erythrophthalmus). Most of these species previously were registered at only a few sampling sites and in minor abundance. Most probably in 2021 these species were not recaptured due to relatively small survey area confined to stretches where measurements for MesoHABSIM was performed. Most of these species are characteristic for slow-flowing rivers and their

occurrence can be linked with proximity of Venta River or HPP reservoirs. Only exception is brown trout / see trout which has a population downstream Dzirnavnieki and Pakuli HPPs.

In the sampling site **Ciecere River downstream Ciecere HPP** seven fish species have been recorded. Information on abundance of different species and their assignment to metrics used for calculation of LVFI is compiled in Table 4.2.1.2. Dominant fish species with the share of more than 70% from the total number of specimens was roach. Only three species used for calculation of LVFI was registered (bullhead, gudgeon and dace) and their total abundance was very low.

Table 4.2.1.2. Abundance (ind./100 m2) of fish species downstream Ciecere HPP and their assignment to groups used for calculating of the LVFI (IntolO2 – species intolerant to oxygen depletion; Lithophils – species requiring lithophilic reproduction habitat; STspecies – species belonging to salmonid waters).

Species		Ind./100 m^2	Groups of species		
			IntolO$_2$	Lithophils	STspecies
Bleak	*(Alburnus alburnus)*	0.4			
Spined loach	*(Cobitis taenia)*	0.9			
Bullhead	*(Cottus gobio)*	3.5	+		+
Gudgeon	*(Gobio gobio)*	1.3	+		
Dace	*(Leuciscus leuciscus)*	0.4		+	
Perch	*(Perca fluviatilis)*	3.5			
Roach	*(Rutilus rutilus)*	28.4			

Due to the dominance of roach and perch which are ecologically tolerant eurytopic fish species and very low number of intolerant species and species with intermediate tolerance, the value of LVFI is only 0.13 what corresponds to bad ecological quality (Table 4.2.1.3).

Table 4.2.1.3. Abundance (ind./100 m2) of fish species downstream Ciecere HPP and their assignment to groups used for calculating of the LVFI (IntolO2 – species intolerant to oxygen depletion; Lithophils – species requiring lithophilic reproduction habitat; STspecies – species belonging to salmonid waters).

Fish metric	Reference level	Measured value	EQR	LVFI value
N100m^2 INTOLO$_2$	118	4.9	0.04	*0.13*
LITHspecies%	100	14.3	0.14	
STspecies	5	1	0.2	

Dominance of roach in the section downstream the Cieceres HPP was registered also in previous years. Noteworthy difference from previous years is that in 2021 two rheophilic species (stone loach and chub) was not recaptured and that in 2021 the total number of recorded species (7 species) was slightly smaller than in previous years (7 to 9 species in one survey). Despite two more rheophilic species recorded in previous years, the value of LVFI (0.12 to 0.17) previously was close to that of 2021 and also corresponded to bad ecological quality. Difference in species composition in 2021 and in previous surveys at some extent can be related to the different location of sampling sites. But it is also possible that very high water temperature during the survey of 2021 influenced the distribution of different species and thus also the results of survey.

In sampling site **Ciecere River downstream Dzirnavnieki HPP** six fish species have been recorded. Only one species assignated for calculation of LVFI was recorded in this stretch (Table 4.2.1.4). But in the same time, it should be noted that share of ecologically tolerant fish species as well as abundance of these species downstream Dzirnavnieki HPP is lower than downstream the Ciecere HPP.

Table 4.2.1.4. Abundance (ind./100 m^2) of fish species downstream Dzirnavnieku HPP and their assignment to groups used for calculating of the LVFI (IntolO_2 – species intolerant to oxygen depletion; Lithophils – species requiring lithophilic reproduction habitat; STspecies – species belonging to salmonid waters).

Species		Ind./100 m^2	Groups of species		
			IntolO_2	*Lithophils*	*STspecies*
Bleak	*(Alburnus alburnus)*	0.5			
Spined loach	*(Cobitis taenia)*	2.0			
Gudgeon	*(Gobio gobio)*	32.8	+		
Perch	*(Perca fluviatilis)*	2.5			
Bitterling	*(Rhodeus sericeus)*	3.0			
Roach	*(Rutilus rutilus)*	17.2			

Due to the presence of only one species belonging to groups assigned for calculation of LVFI (Table 4.2.1.5) the calculated index for river stretch downstream of the Dzirnavnieki HPP is only 0.09 what corresponds to the bad ecological quality.

Table 4.2.1.5. Abundance (ind./100 m^2) of fish species downstream Dzirnavnieku HPP and their assignment to groups of fish species used for calculating of the LVFI (IntolO_2 – species

intolerant to oxygen depletion; Lithophils – species requiring lithophilic reproduction habitat; STspecies – species belonging to salmonid waters).

Fish metric	Reference level	Measured value	EQR	LVFI value
N100m^2 INTOLO$_2$	118	32.8	0.28	*0.09*
LITHspecies%	100	0	0	
STspecies	5	0	0	

Dominance of roach and gudgeon in stretch downstream the Dzirnavnieki HPP was recorded also in previous years. Number of species in previous years was higher (7 to 14 species in one site). In addition of species recorded in 2021 previously in this stretch such ecologically intolerant species as brown trout and brook lamprey were captured. One of reasons for such differences is very high temperature during survey of 2021 yet important role most may be played also by different allocation of sampling sites – in 2021 sampling site was located ~0,5 km downstream Dzirnavnieki HPP while in previous years distance from the HPP reached several kilometres.

In sampling site **Ciecere River below HPP Pakuli** ten fish species have been recorded and five of them is assignated to the groups of species used for calculation of LVFI (Table 4.2.1.6). Dominant fish species in this reach was roach but in the same time this was the only reach where such rheophilic species as schneider, chub, minnow and stone loach was recorded. In the same time, it should be noted that this was the only stretch where such ecologically tolerant species as silver bream was recorded. Half of the species captured in this sampling station belonged to groups of species assigned for calculation of the LVFI.

Table 4.2.1.6. Abundance (ind./100 m^2) of fish species downstream Pakuļu HPP and their assignment to groups used for calculating of the LVFI (IntolO$_2$ – species intolerant to oxygen depletion; Lithophils – species requiring lithophilic reproduction habitat; STspecies – species belonging to salmonid waters).

Species		Ind./100 m^2	Groups of species		
			IntoloO$_2$	*Lithophils*	*STspecies*
Schneider	*(Alburnoides bipunctatus)*	0.3	+	+	+
Bleak	*(Alburnus alburnus)*	3.5			
Stone loach	*(Barbatula barbatula)*	0.3		+	
Silver bream	*(Blicca bjoerkna)*	0.3			
Spined loac	*(Cobitis taenia)*	1.6			

Dace	*(Leuciscus leuciscus)*	7.4		+	
Minnow	*(Phoxinus phoxinus)*	0.3	+	+	+
Bitterling	*(Rhodeus sericeus)*	1.1			
Roach	*(Rutilus rutilus)*	18.0			
Chub	*(Squalius cephalus)*	0.8		+	

Due to higher number of species belonging to groups designated for calculation of value of LVFI also the value of the index downstream the Pakulu HPP was slightly higher than downstream the Cieceres and Dzirnavnieku HPP. Nevertheless, the value of the LVFI in this stretch is still very low and lies below the boundaries (0.31) of poor/bad ecological quality (Table 4.2.1.7).

Table 4.2.1.7. Abundance (ind./100 m^2) of fish species downstream Dzirnavnieku HPP and their assignment to groups of fish species used for calculating of the LVFI (IntolO_2 – species intolerant to oxygen depletion; Lithophils – species requiring lithophilic reproduction habitat; Stspecies – species belonging to salmonid waters.

Fish metric	Reference level	Measured value	EQR	LVFI value
N100m^2 INTOLO_2	118	0.55	0.005	*0.20*
LITHspecies%	100	40	0.4	
STspecies	5	1	0.2	

If compared to the previous surveys in 2021 much greater proportion of roach and subsequently – smaller proportion schneider and other ecologically vulnerable and species and species of intermediate ecological vulnerability. Noteworthy that in 2021 such vulnerable species as brown trout and bullhead was not recorded. Likewise stretches downstream other HPP there are two potentially most important factors for different fish survey results in 2021 – possible impact of a very high water temperature during the fish survey on fish distribution and different allocation of the sampling sites.

Although some differences in distribution and abundance of specific species, the fish fauna downstream of all three HPP has common features (Table 4.2.1.8). Despite some differences in occurrence and abundance of specific species, in general fish fauna downstream the Ciecere HPP and Pakuli HPP is corresponding. Both stretches of river are dominated by roach yet also species particularly sensitive to littoral zone flushing as well as ecologically tolerant species and

species of intermediate tolerance were recorded. Slightly different situation was observed downstream the Dzirnavnieki HPP. Ecologically intolerant species were not recorded in this stretch yet the abundance of species of intermediate tolerance (gudgeon) was higher ant thus the proportion of roach – lower than downstream both other HPP. Noteworthy that in these aspects (no intolerant species and greater abundance of species of intermediate tolerance) fish fauna in the stretch downstream the Dzirnavnieki HPP was more similar to the fish fauna in the sampling site located 700 m from the Venta River.

The similarities and differences of fish fauna can be linked to different hydromorphology of surveyed sites. Greatest proportion of roach was recorded in sites with the pools. Bullhead was recorded in stone dominated relatively shallow stretch downstream the Ciecere HPP while schneider – in deeper stretch downstream the Pakuli HPP. Such potadromous species as brook lamprey and chub was captured only downstream the Pakuli HPP. It may be partly linked with the impact of migration barriers yet it must be taken into account that in previous years chub was recorded both downstream the Ciecere and Dzirnavnieki HPP but brook lamprey – downstream Dzirnavnieki HPP.

However also the relatively high abundance of species with intermediate ecological tolerance recorded in sampling site located 700 m from the Venta River and relatively higher value) of LVFI (0.4 corresponding to poor ecological quality) for this site should be noted. This indirectly confirms that results of fish survey were dependant not only on the hydromorphological features of the sampling site and very high water temperature during the survey but most probably also on the distance from the HPP.

Table 4.2.1.8. Abundance (ind. 100/m^2) of key species of different groups of species typical to rhithral middle-sized warmwater rivers similar to the Ciecere River in the river stretches downstream of each of HPP and in sampling site located close to Venta River.

Group of species	Species	Downstream Ciecere HPP	Downstream Dzirnavnieki HPP	Downstream Pakuli HPP	700 m from the river mouth
	Lampetra planeri[1]				0.4

Species particularly sensitive to littoral zone flushing or level fluctuation	*Cobitis taenia*	0.9	2.0	1.6	0.4
Intolerant species	*Alburnoides bipunctatus*			0.3	
	Cottus gobio	3.5			
Species of intermediate tolerance typical for small and medium size warmwater rhithral streams	*Barbatula barbatula*			0.3	
	Phoxinus phoxinus			0.3	48.1
	Gobio gobio	1.3	32.8		8.6
	Leuciscus leuciscus	0.4		7.4	0.4
	Squalius cephalus[1]			0.8	13.2
Tolerant eurytopic species	*Perca fluviatilis*	3.5	2.5		1.2
	Rutilus rutilus	28.4	17.2	18.0	26.6

[1] Potadromous species

4.2.2. Losis River and its fish fauna

In the project for evaluation of importance of Latvian rivers in protection of fish fauna Losis was listed among rivers which has an importance of local scale. Models developed during this project shows that in general hydromorphological condition of Losis River downstream both HPP is suitable for such ecologically vulnerable species as bullhead, grayling, river and brook lampreys and at some extent also for the spawning of sea trout and brown trout. In the same time created models predicts also high negative anthropogenic impact (mostly the exploitation of HPP and damming of rivers) which considerably reduces the suitability for all mentioned species. Impact of each single HPP dam on fish migration is relatively small, however cumulative impact of both dams is much larger and is approximately equal to the impact of Pakuli HPP in Ciecere River.

In surveyed stretches downstream the Grantini and Lejnieki HPP 15 fish species were recorded – bleak, eel, stone loach, spined loach, bullhead, pike, three-spined stickleback, gudgeon, sunbleak, perch, minnow, bitterling, roach, chub and tench (Table 4.2.2.1). Different species was dominating in different GU and in general species composition and distribution was closer to typical fish fauna of middle-sized rhithral warmwater stream as in Ciecere River. Also, the water temperature during the survey (24.2°C) in Losis River was closer to normal than in Ciecere River.

Downstream the Grantini HPP six species were recorded. Such rheophilic species like stone loach and bullhead was captured only in riffle, chub was recorded in both riffle and glide while gudgeon perch and roach – only in glide. Downstream Lejnieki HPP very high number of individuals was reached in both backwater (mostly

minnow and spined loach) and riffle (mostly stone loach but also minnow). Relatively high density of individuals was recorded also in the pool (mostly spined loach) while number of species and density of individuals in the glide was relatively small.

No additional species was recorded in the sampling site located 200 m from the rivermouth. Dominant species in this site was stone loach and minnow and fish fauna in general was close to that at the site downstream of the Lejnieki HPP.

Table 4.2.2.1. Density of different fish species in different geomorphic units and pooled density of individuals of different fish species in Ciecere River downstream each HPP (GU – geomorphological unit; G – glide; B - backwater; P - pool; Ri – riffle)

Site, GU		Alburnus alburnus	Anguilla anguilla	Barbatula barbatula	Cobitis taenia	Cottus gobio	Esox lucius	Gasterosteus aculeatus	Gobio gobio	Leucaspius delineatus	Perca fluviatlis	Phoxinus phoxinus	Rhodeus sericeus	Rutilus rutilus	Squalius cephalus	Tinca tinca	Total
Grantiņu HPP	G								1.1		1.1			4.3	4.3		10.7
	Ri			5.1		12.8									2.6		20.5
	Pooled			***1.5***		***3.8***			***0.8***		***0.8***			***3.0***	***3.8***		***13.6***
Lejnieku HPP	G				15.6		2.2					2.2		2.2	2.2		24.4
	B	5.6		11.1	55.6	5.6			11.1	5.6	5.6	77.8			22.2		200.0
	P	1.3			72.4			3.9		6.6	21.1		21.1	13.2		1.3	140.8
	Ri		2.2	204.4	11.1				4.4			86.7		2.2			311.1
	Pooled	***1.1***	***0.5***	***51.1***	***41.8***	***0.5***	***0.5***	***1.6***	***2.2***	***3.3***	***9.2***	***29.3***	***8.7***	***6.5***	***2.7***	***0.5***	***159.8***

In previous surveys 20 fish species were recorded and 8 of them was captured also in 2021. Abundance of most of species recorded previously and not captured in 2021 was small (<5 ind./100 m^2) and great part these species (silver bream, crucian carp, rudd etc.) are not typical for medium size rhithral streams. However, such species as brown trout / sea trout and dace should be highlighted. These are rheophilic and lithophilic species typical for middle-size rhithral streams and their absence is indirectly confirming the deterioration of ecological situation in Losis River during the last years. The same can be said regarding failing of capture of lamprey larvae which can be found in most other tributaries of Venta River. In the

same time, it is possible also that smaller number of registered species in 2021 is linked to the relatively short stretch of river surveyed and low density of most of species not captured in this year.

In the sampling site **Losis River downstream Grantini HPP** six fish species have been recorded. Information on abundance of different species and their assignment to metrics used for calculation of LVFI is compiled in Table 4.2.2.2. Four of these species (stone loach, bullhead, gudgeon and chub) are used for calculation of LVFI yet abundance of these and other species was very low (<5 ind./100 m^2).

Table 4.2.2.2. Abundance (ind./100 m^2) of fish species downstream Grantiņu HPP and their assignment to groups used for calculating of the LFI (IntolO$_2$ – species intolerant to oxygen depletion; Lithophils – species requiring lithophilic reproduction habitat; STspecies – species belonging to salmonid waters).

Species		Ind./100 m^2	*Groups of species*		
			IntoloO$_2$	*Lithophils*	*STspecies*
Stone loach	*(Barbatula barbatula)*	1.5		+	
Bullhead	*(Cottus gobio)*	3.8	+		+
Gudgeon	*(Gobio gobio)*	0.8	+		
Perch	*(Perca fluviatilis)*	0.8			
Roach	*(Rutilus rutilus)*	3.0			
Chub	*(Squalius cephalus)*	3.8		+	

Due to very low abundance of species used for calculation of fish index and presence of only one sentinel species the calculated value of LVFI for this stretch is only 0.19 what corresponds to bad ecological quality (Table 4.2.2.3).

Table 4.2.2.3. Abundance (ind./100 m^2) of fish species downstream Grantiņu HPP and their assignment to groups of fish species used for calculating of the LVFI (IntolO$_2$ – species intolerant to oxygen depletion; Lithophils – species requiring lithophilic reproduction habitat; Stspecies – species belonging to salmonid waters).

Fish metric	Reference level	Measured value	EQR	LVFI value
N100m^2 INTOLO$_2$	118	4.5	0.04	*0.19*
LITHspecies%	100	33.3	0.33	
Stspecies	5	1	0.2	

In previous surveys much greater number of species was registered in this stretch of river. We suppose that differences in results of 2021 and previous surveys can be explained mostly by different placement of sampling sites and relatively short

reach of river surveyed in 2021. However, it is also possible that fish fauna of this stretch of river is influenced also by exploitation of Grantiņu HPP and relatively short stretch of river (~4 km) confined between the reservoir of Lejnieku HPP and dam of Grantini HPP.

In the sampling site **Losis River downstream Lejnieki HPP** 15 fish species have been recorded and five of them is assigned to metrics used for calculation of LVFI (Table 4.2.2.4).

Relatively large abundance of stone loach and minnow as well as presence of such rheophilic species typical for middle-sized rhythral as bullhead, gudgeon and chub must be noted. From this perspective fish fauna of surveyed stretch is close to typical ichthyofauna of similar rivers. In the same time this stretch of river was hosted also by large number of ecologically tolerant species and species often found in pothamal waters – silver bream, eel, pike, belica, perch, roach etc.

Table 4.2.2.4. Abundance (ind./100 m^2) of fish species downstream Lejnieku HPP and their assignment to groups used for calculating of the LVFI (IntolO_2 – species intolerant to oxygen depletion; Lithophils – species requiring lithophilic reproduction habitat; STspecies – species belonging to salmonid waters).

Species		**Ind./100 m^2**	***Groups of species***		
			IntolO_2	***Lithophils***	***STspecies***
Bleak	*(Alburnus alburnus)*	1.1			
Eel	*(Anguilla anguilla)*	0.5			
Stone loach	*(Barbatula barbatula)*	51.1		+	
Spined loach	*(Cobitis taenia)*	41.8			
Bullhead	*(Cottus gobio)*	0.5	+		+
Pike	*(Esox lucius)*	0.5			
Three-spined stickleback	*(Gasterosteus aculeatus)*	1.6			
Gudgeon	*(Gobio gobio)*	2,2	+		
Belica	*(Leucaspius delineatus)*	3.2			
Perch	*(Perca fluviatlis)*	9.2			
Minnow	*(Phoxinus phoxinus)*	29.3	+	+	+
Bitterling	*(Rhodeus sericeus)*	8.7			
Roach	*(Rutilus rutilus)*	6.5			
Chub	*(Squalius cephalus)*	2.7		+	
Tench	*(Tinca tinca)*	0.5			

Despite the noteworthy abundance of fishes which are typical for middle-sized rhythral stream, the metrics used for calculation of LVFI (abundance of species

intolerant to oxygen depletion as well as proportion of lithophile and sentinel specie) calculated value of LFI for this stretch (0.29) was low and corresponded to bad ecological quality (Table 4.2.2.5).

If compared to previous surveys relatively large difference of survey results can be observed. First of all, in previous research spined loach was not registered but also the proportion of minnow and stone loach was smaller than in 2021. Taking into account that exploitation of HPP and other anthropogenic pressure often reduces abundance of these species it can be put forward that observed differences can be linked mostly to different allocation of sampling sites and different GU sampled. On other hand absence of brown trout / see trout and brook lamprey should be noted. These species are found in most of tributaries of Venta River and failing to capture it in Losis River can be linked with a relatively small length of surveyed stretch of river but in the same time it is also possible that this species is absent due to operation of HPP and other anthropogenic impact

Table 4.2.2.5. Abundance (ind./100 m^2) of fish species downstream Lejnieku HPP and their assignment to groups of fish species used for calculating of the LVFI (IntolO_2 – species intolerant to oxygen depletion; Lithophils – species requiring lithophilic reproduction habitat; Stspecies – species belonging to salmonid waters).

Fish metric	Reference level	Measured value	EQR	LVFI value
N100m^2 INTOLO_2	118	32.1	0.27	*0.29*
LITHspecies%	100	20	0.2	
STspecies	5	2	0.4	

Comparing results of surveys in different stretches of Losis river several differences and similarities can be found (Table 4.2.2.6). Abundance of most common ecologically tolerant species (roach and perch) in all three stretches was relatively low and in all stretches almost all most common species with intermediate ecological tolerance was represented, including such potadromous species as chub. In the same time large abundance of such species as spined loach which is vulnerable to littoral zone flushing was registered only downstream of Lejnieki HPP. The site downstream of this HPP hosted also largest number of stone loach and minnow.

[1] Potadromous species

Table 4.2.2.6. Abundance (ind. 100/m^2) of key species of different groups of species typical to rhithral middle-sized warmwater rivers similar to the Losis River in the river stretches downstream of each of HPP and in sampling site located close to Venta River.

In general, it can be concluded that most probably the relatively small number of species and abundance of specimens downstream the Grantini HPP as well as

Group of species	Species	Downstream Grantiņu HPP	Downstream Lejnieku HPP	200 m from the rivermouth
Species particularly sensitive to littoral zone flushing or level fluctuation	*Cobitis taenia*		41.8	4.8
Intolerant species	*Cottus gobio*	3.8	0.5	
Species of intermediate tolerance typical for small and medium size warmwater rhythral streams	*Barbatula barbatula*	1.5	51.1	19.2
	Phoxinus phoxinus		29.3	16.0
	Gobio gobio	0.8	2.2	2.4
	Squalius cephalus[1]	3.8	2.7	4.4
Tolerant eurytopic species	*Perca fluviatilis*	0.8	9.2	0.4
	Rutilus rutilus	3.0	2.7	0.4

larger number of species of intermediate tolerance downstream Lejnieki HPP can be related mostly to hydromorphic features of the surveyed stretches. There is great possibility that increasing the number of sampling sites and diversity of surveyed reaches of the river will give the better picture on actual status of fish fauna in stretches downstream both HPP. It should be also noted that such relatively common species for rhithral tributaries of Venta River as brook lamprey and brown trout / see trout was not recorded in 2021 and additional research is needed to confirm absence or presence of these species.

4.3. Lithuanian Habitat mapping and hydrological measurements

During the field surveys (FSs) in Varduva River, the geomorphic units were mapped 17 times: 4 at Kušėnai HPP, 3 at Renavas HPP, 3 at Vadagiai HPP, 3 at Ukrinai HPP, and 4 times at Juodeikiai HPP. According to the MESOHABSIM model requirements (site length at least >10 river widths), the surveyed sites lengths varied from 162 m below Vadagiai HPP to 314 m below Kulšėnai HPP. During field surveys, the length of the section was equal for each case study. The selection of lengths itself was related to the diversity of geomorphic units. Total mapped area depended on the hydrological conditions (discharge) and the length

of the reach. The mapped area varied from 2074.0 m^2 to 3336.4 m^2. The largest relative increase in the mapped area due to an increase in river discharge was obtained below Renavas HPP (432.1 m^2). Whereas the smallest increase was determined below Ukrinai HPP (213.8 m^2) (Table 4.3.1).

Table 4.3.1.Case studies, geographical characteristics

River site	Length of surveyed reach, m	Mapped area, m^2	Distance to HPP, km
Kulšėnai HPP 1	314	3028.3	1.80
Kulšėnai HPP 2	314	3028.3	1.80
Kulšėnai HPP 3	314	3036.8	1.80
Kulšėnai HPP 4	314	3332.3	1.80
Renavas HPP 1	254	2904.3	0.04
Renavas HPP 2	254	3259.6	0.04
Renavas HPP 3	254	3336.4	0.04
Vadagiai HPP 1	164	2117.1	0.54
Vadagiai HPP 2	164	2244.6	0.54
Vadagiai HPP 3	164	2295.8	0.54
Ukrinai HPP 1	311	3027.1	2.93
Ukrinai HPP 2	311	3181.0	2.93
Ukrinai HPP 3	311	3240.9	2.93
Juodeikiai HPP 1	209	2074.0	5.41
Juodeikiai HPP 2	209	2146.0	5.41
Juodeikiai HPP 3	209	2356.6	5.41
Juodeikiai HPP 4	209	2380.9	5.41

Distributions of geomorphic units (GU) surveyed below each of HPP of Varduva River are illustrated in Fig. 4.3.1. At least 7 GUs (pool, glide, riffle, rapid, cascade, secondary channel and backwater) were mapped only in one site. These GUs were identified at low-flow average and low-flow maximum discharge situations during the field surveys below Juodeikiai HPP. The most frequent geomorphic unit was glide. Glides occupied from 40.2% to 68.0% of a total mapped area for 5 selected sites of Varduva River. The second most frequent GU was pool (indicated during all 17 field surveys). Only for the site below Kulšėnai HPP, the second largest GU was riffle. Depending on the discharge situation, riffles occupied 27.5% to 32.3% of total mapped area. The GU of rapid was found almost during all field surveys except very low discharge situation below Renavas and Ukrinai hydropower plants. The area of rapids tended to increase together with an increase in discharge.

Cascade, secondary channel and backwater were the rarest geomorphic units, and they were indicated only several times below Juodeikiai HPP. Accordingly, the mentioned GUs consisted only from 0.6% to 5.3% of total mapped area. The maps of GUs can be found in ANNEX II, Fig. 1–5.

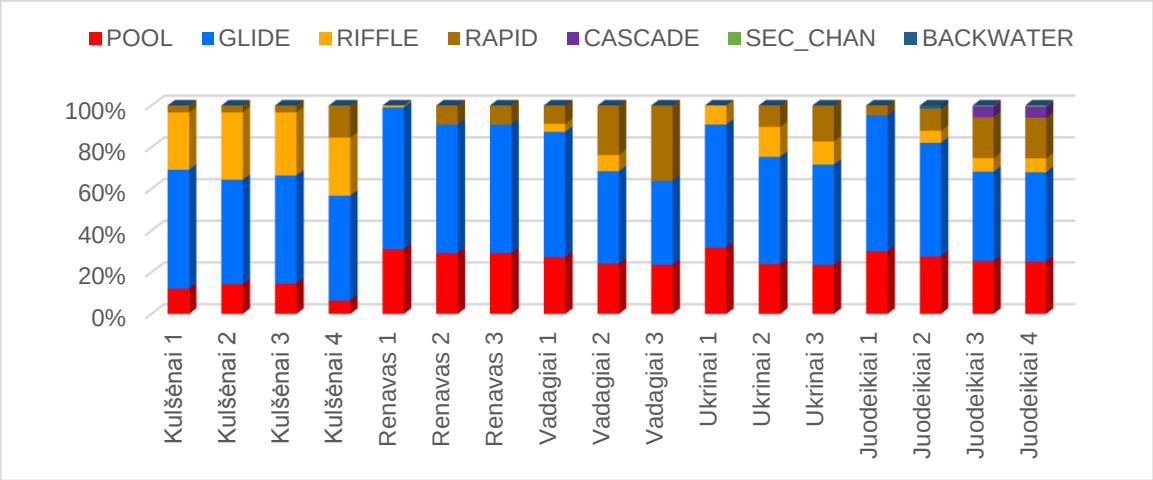

Figure 4.3.1. Distribution of geomorphic units in surveyed sites within Varduva River HPPs (a number after HPP name corresponds to survey number)

According to the number of types of geomorphic units, the most homogeneous case studies were sites below Kulšėnai HPP and Renavas HPP, where 4 and 3 GU types were found respectively. Meanwhile, 3-4 GU types were obtained during the fiels surveys below HPPs of Vadagiai and Ukrinai. The most number (5-6) of GU types was mapped below Juodeikiai HPP. The number of GUs polygons varied from 12 to 26. Nevertheless, that the site below Juodeikiai HPP was only the second shortest, the number of GUs was the highest (21-26). On average the number of GUs polygons was 18 (Fig. 4.3.2.).

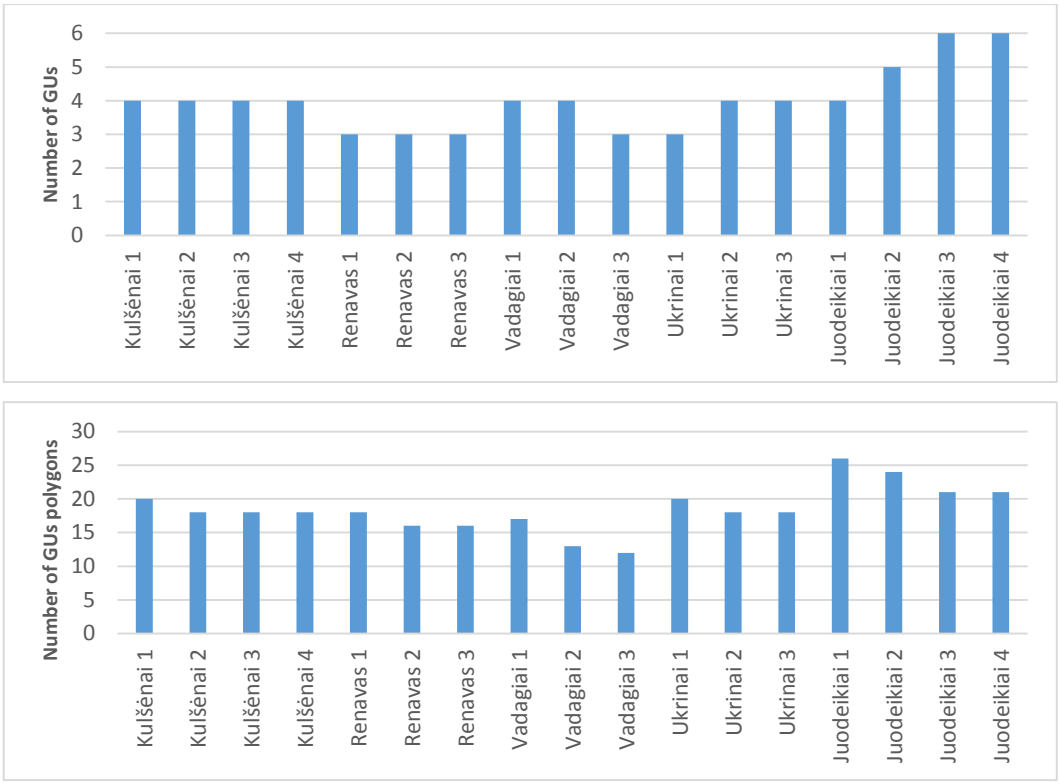

Figure 4.3.2. Number of geomorphic units (GUs) per surveyed site in selected case studies

Seven different areas of GUs were identified during the FSs (Fig. 4.3.3). According to the average area, GUs of riffle (195.4 m^2), glide (153.2 m^2), pool (142.6 m^2) and rapid (134.4 m^2) were the largest. The average area of remaining three GUs (cascade, secondary channel and backwater) was less than 62 m^2. The highest amplitude for GUs polygons area variation was estimated for glide (between 11.9 and 528.5 m^2) and riffle (between 27.6 and 471.7 m^2).

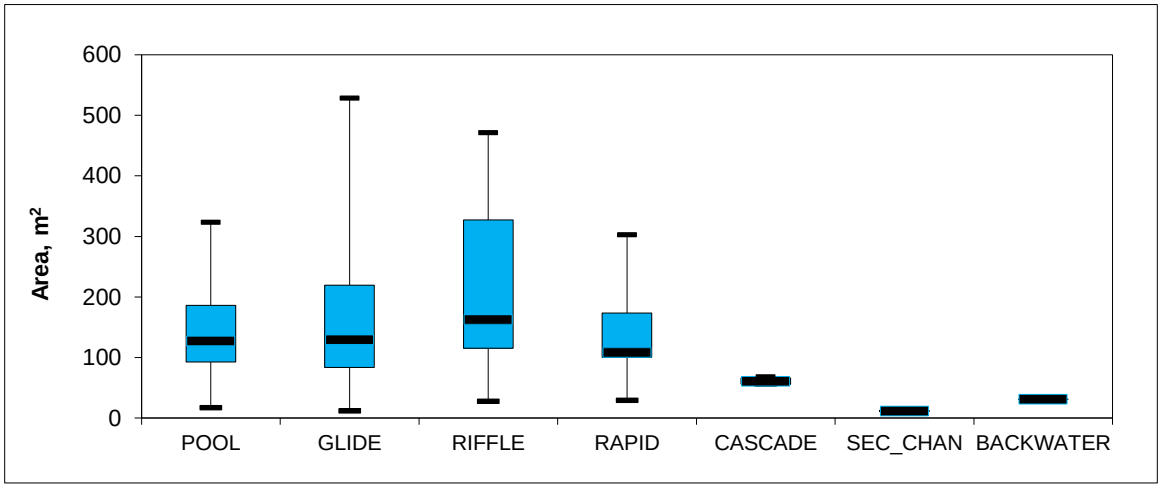

Figure 4.3.3. Area variation of geomorphic units within all studied sites of Varduva River

In addition to the habitat mapping, the hydrological measurements have been carried out in the selected sites of the Varduva River during FS. The hydrological part of surveys consisted of measurements of water depth, flow velocity and discharge as well as determination of substrate type of riverbed (granulometry). Determination of water depth, flow speed and substrate were made in at least 10 representative points of each GU polygon. In the selected cross-sections, the measurements of water discharge were carried out once in each site per survey. Table 4.3.2 shows the measured water flow conditions during the FSs comparing with the corresponding discharges calculated according to historical observations at Ruzgai WGS. Most of measured discharges and the mapped geomorphic units cover the amplitude of low-flow fluctuations (low min – low max) during the warm period. However, the annual mean discharges have not been obtained due to natural variability and anthropogenic activity that regulates river runoff.

Table 4.3.2.Water flow below Varduva River HPPs during FSs vs calculated value according to historical observations at Ruzgai WGS

Q m^3.s		low min	low average	low max	annual mean
Kulšėnai HPP	Calculated	0.227	0.607	1.59	3.16
	Measured 1.80 km downstream	0.360	0.620	1.61	-
Renavas HPP	Calculated	0.244	0.652	1.71	3.40
	Measured 0.04 km downstream	0.162	1.12	1.81	-
Vadagiai HPP	Calculated	0.251	0.673	1.77	3.51
	Measured 0.54 km downstream	0.163	0.967	1.88	-
Ukrinai HPP	Calculated	0.260	0.696	1.83	3.63
	Measured 2.93 km downstream	0.150	0.820	1.81	-
Juodeikiai HPP	Calculated	0.393	1.052	2.76	5.49
	Measured 5.41 km downstream	0.274	0.998	2.52	-

Habitat mapping have been carried out by using the rangefinder *TruPulse 360R* and field tablet *xTablet Flex 10A*, the DJI Phantom 4 RTK drone together with GeoMax Zenith40 GNSS receiver and Pix4Dmapper photogrammetry software were used for areal mapping. The flow velocity measurements have been done

with electromagnetic flow meters, and water depth measurements have been done with a hydrological ruler.

4.4. Fish data collecting in Lithuanian rivers

Fish surveys were carried out in the stretches of the river below each of the 5 HPPs on the Varduva River. Fish were sampled in accordance with the EU standard EN 14011 (CEN, 2003), using IG200/2B pulsed current electric fishing gear powered by a 12 V battery. The electrofishing was carried out by wading. Fish species individuals were counted separately in each geomorphological unit (GU) delineated in the river stretch on a mesohabitat scale. To calculate Lithuanian fish-based index for assessment of ecological status of rivers, fish counts from all GUs we pooled in each of the surveyed stretches. The catchment size of the entire studied river stretch (covering all 5 studied stretches below each of the HPPs) ranges from 342 to 580 km2, and the slope of the river bed ranges from 0.96 to 1.3 m/km in the different stretches.

According to the national typology of Lithuanian rivers, all the studied stretches belong to river type 3, and therefore the ecological status in terms of fish was assessed using the fish metrics and their reference values characteristic of this type of rivers (TAR, 2016-08-09, Nr. 21813). The position of the HPPs in the longitudinal gradient of the Varduva River is shown in Figure 4.4.1.

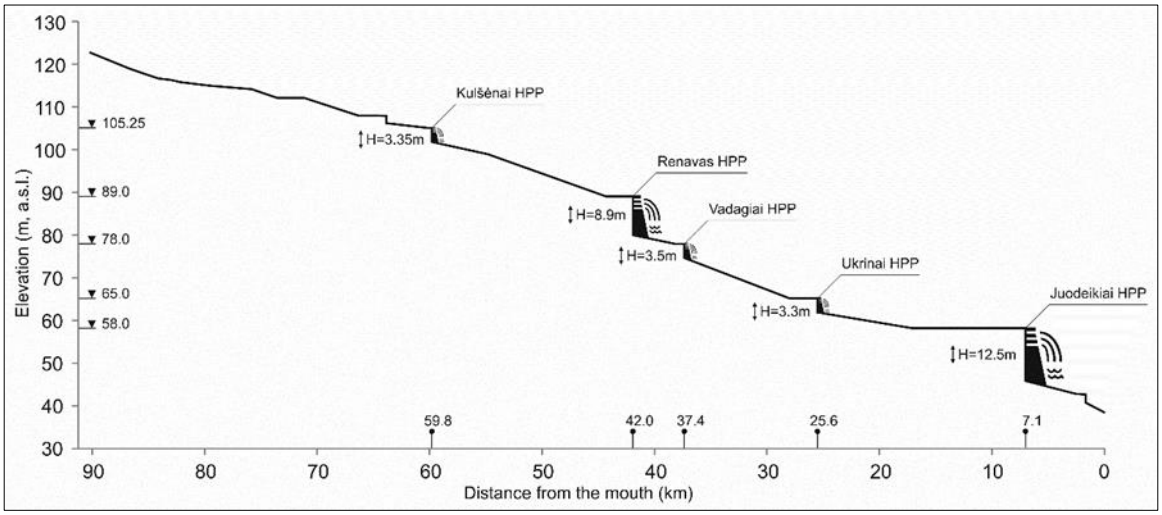

Figure 4.4.1. The position of the HPPs in the longitudinal gradient of the Varduva River

None of the hydropower plants has fish passes, therefore fish migration through the hydropower plants is not possible. Only the stretch of the river below the lowermost Juodeikiai HPP dam is accessible for migratory fish species.

A total of 19 species were recorded in the river, ranging from 8 to 15 species in different stretches (Table 4.4.1). Only 4 fish species were present in the river stretches below all 5 HPPs: stone loach (Barbatulus barbatulus), gudgeon (Gobio gobio), chub (Squalius cephalus) and roach (Rutilus rutilus). The other 2 species, the bleak (Alburnus alburnus) and the bullhead (Cottus gobio), were present in 4 of the 5 studied stretches. Six fish species – spined loach (Cobitis taenia), ruff (Gymnocephalus cernua), burbot (Lota lota), salmon (Salmo salar), brown trout (Salmo trutta) and vimba (Vimba vimba) - were present only in one of the surveyed stretches, with the latter five species recorded only in the river stretch below the lowermost HPP dam. The species diversity of fish, as well as the number of individuals, was the largest in the GUs of glides in all 5 surveyed stretches of the river. The smallest abundance and diversity was in the GUs of rapids and riffles, which under natural conditions are usually preferred by typical rheophilic fish species.

Table 4.4.1. Number of individuals of different fish species in different geomorphic units and total number of individuals of different fish species in the surveyed stretches of the Varduva River below each HPP dam (GU – geomorphological unit; G – glide; P – pool; Ra – rapid; Ri – riffle; Tot – total number of individuals).

Site, GU		Alburnoides bipunctatus	Alburnus alburnus	Barbatula barbatula	Cobitis taenia	Cottus gobio	Esox lucius	Gobio gobio	Gymnocephalus cernua	Leuciscus leuciscus	Lota lota	Perca fluviatlis	Phoxinus phoxinus	Rhodeus sericeus	Rutilus rutilus	Salmo salar	Salmo trutta	Squalius cephalus	Tinca tinca	Vimba vimba
Kulšėnai HPP	G	148	108	5		10		206					165	2	8			8	1	
	P	2	26	2				8					5		13			5		
	Ra					3		1					8							
	Ri	3		5		17		57					81							
	Tot	***153***	***134***	***12***		***30***		***272***					***259***	***2***	***21***			***13***	***1***	
Ren avas	G		263	2				193	2	6		5			409				1	

	P		198					1		2		1			286			3		
	Ra		25	3				13				2			36					
	Tot		***486***	***5***				***207***	***2***	***8***		***8***			***731***			***3***	***1***	
Vadagiai HPP	G	2	104	16				46		8			25	1	19					
	P		102				1	6					5	5	27			1		
	Ra	10	12	14		6		11					129		18					
	Ri	1	30	8		2		27					4							
	Tot	***13***	***248***	***38***		***8***	***1***	***90***		***8***			***163***	***6***	***64***			***1***		
Ukrinai HPP	G		1			17		69			1	115			9			1		
	P					3		4				13			4					
	Ri			1		6						8								
	Tot		***1***	***1***		***26***		***73***			***1***	***136***			***13***			***1***		
Juodeikiai HPP	G	4		28	4	1		53		1		3	20	7	36	1		34		5
	P						2	2				10	3		2			3		2
	Ra			2		3		5					8				4			
	Tot	***4***		***30***	***4***	***4***	***2***	***60***		***1***		***13***	***31***	***7***	***38***	***1***	***4***	***37***		***7***

The fish communities in the river stretches studied differed in structure and composition as well as in status. The descriptions of the fish assemblages in the studied stretches below each of the HPP are given in the following sub-sections below in order from uppermost to lowermost HPP.

Ten fish species have been recorded in the **Varduva River below Kulšėnai HPP** stretch of the river. The share of abundance of different fish species and the assignment of species to ecological guilds (FAME CONSORTIUM 2004), which are used to calculate the Lithuanian fish index for rivers (WFD Intercalibration Report 2011; TAR, 2016-08-09, Nr. 21814), are presented in Table 4.4.2. Several type-specific intolerant fish species are present in the river stretch; rheophilic fish predominate in the fish assemblage. However, the abundance and diversity of intolerant and lithophilic species is much less than under natural conditions (Table 4.4.3). According to fish metrics, the ecological status of the studied stretch is moderate, although close to the good/moderate status boundary.

Table 4.4.2. Relative abundance (N%) of fish species in the stretch of the Varduva River below the Kulšėnai HPP and their assignment to ecological guilds for calculating the fish index (INTOL – intolerant to habitat degradation; TOLE – tolerant to habitat degradation; RH – rheophilic; LITH – lithophilic; OMNI – omnivorous).

Species		N%	Ecological guld			
			Tolerance	Rheophily	Spawning	Feeding
Schneider	*(Alburnoides bipunctatus)*	17.1	INTOL	RH	LITH	
Bleak	*(Alburnus alburnus)*	14.9	TOLE			OMNI
Stone loach	*(Barbatula barbatula)*	1.3		RH	LITH	
Bullhead	*(Cottus gobio)*	3.3	INTOL	RH	LITH	
Gudgeon	*(Gobio gobio)*	30.3		RH		
Minnow	*(Phoxinus phoxinus)*	28.9		RH	LITH	
Bitterling	*(Rhodeus sericeus)*	0.2	INTOL			
Roach	*(Rutilus rutilus)*	2.3	TOLE			OMNI
Chub	*(Squalius cephalus)*	1.4		RH	LITH	OMNI
Tench	*(Tinca tinca)*	0.1	TOLE			OMNI

Table 4.4.3. Reference and measured values of fish metrics that are used in the Lithuanian fish-based method for assessing the ecological status of medium-sized rhithral rivers (national type 3), metrics EQR values, fish index value and the corresponding class of ecological status.

Fish metric	Reference	Measured value	Metric EQR*	Fish index*
INTOL abundance (%)	≥45	20.6	0.46	**0.70**
LITH abundance (%)	≥93	52.1	0.6	
LITH number of species (%)	≥72	50	0.69	
INTOL number of species	≥5	3	0.6	
RH number of species	≥8	6	0.75	
TOLE abundance (%)	≤2	17.4	0.84	
OMNI abundance (%)	≤4	18.8	0.85	
TOLE number of species (%)	≤14	30	0.81	

*Green-good status class, yellow-moderate

In total, 9 species of fish were present in the **Varduva River below Renavas HPP** stretch of the river (Table 4.4.4). No intolerant fish species were recorded. The fish assemblage is dominated by species that are resistant to general habitat degradation (84.5% of all fish individuals), and typical riverine species (rheophilic lithophils) make up only a small part of all fish. More than half of all fish species are not specialized in food objects (omnivorous). The values of none of the type-specific metrics of fish do not meet at least good status criteria, most of the metrics

indicate either bad or poor ecological status (Table 4.4.5). According to the fish index, the ecological status of the studied stretch is poor.

Table 4.4.4. Relative abundance (N%) of fish species in the stretch of the Varduva River below the Renavas HPP and their assignment to ecological guilds for calculating the fish index (INTOL – intolerant to habitat degradation; TOLE – tolerant to habitat degradation; RH – rheophilic; LITH – lithophilic; OMNI – omnivorous).

Species		**N%**	**Ecological guld**			
			Tolerance	Rheophily	Spawning	Feeding
Bleak	*(Alburnus alburnus)*	33.5	TOLE			OMNI
Stone loach	*(Barbatula barbatula)*	0.3		RH	LITH	
Gudgeon	*(Gobio gobio)*	14.3		RH		
Ruff	*(Gymnocephalus cernua)*	0.1				
Dace	*(Leuciscus leuciscus)*	0.6		RH	LITH	OMNI
Perch	*(Perca fluviatilis)*	0.6	TOLE			
Roach	*(Rutilus rutilus)*	50.4	TOLE			OMNI
Chub	*(Squalius cephalus)*	0.2		RH	LITH	OMNI
Tench	*(Tinca tinca)*	0.1	TOLE			OMNI

Table 4.4.5. Reference and measured values of fish metrics that are used in the Lithuanian fish-based method for assessing the ecological status of medium-sized rhithral rivers (national type 3), metrics EQR values, fish index value and the corresponding class of ecological status.

Fish metric	**Reference**	**Measured value**	**Metric EQR***	**Fish index***
INTOL abundance (%)	≥45	0	0	**0.24**
LITH abundance (%)	≥93	1.1	0.01	
LITH number of species (%)	≥72	33.3	0.46	
INTOL number of species	≥5	0	0	
RH number of species	≥8	4	0.5	
TOLE abundance (%)	≤2	84.5	0.16	
OMNI abundance (%)	≤4	84.7	0.16	
TOLE number of species (%)	≤14	44.4	0.65	

*Yellow-moderate status class, brown-poor, red-bad

In the **Varduva River below Vadagiai HPP** section of the river, 11 species of fish were found, of which 7 were rheophilic (Table 4.4.6). There were also some fish species especially sensitive to habitat degradation, but their share in the fish community is insignificant (4.2%). Half of all fish individuals (50.2%) are tolerant and/or omnivorous fish species. Thus, although the metric of the relative number

of tolerant fish species even meets the criteria for high status, the relative abundance of individuals of tolerant as well as omnivorous species is significantly higher than would be expected under natural conditions, and indicates moderate ecological status (Table 4.4.7).

Table 4.4.6. Relative abundance (N%) of fish species in the stretch of the Varduva River below the Vadagiai HPP and their assignment to ecological guilds for calculating the fish index (INTOL – intolerant to habitat degradation; TOLE – tolerant to habitat degradation; RH – rheophilic; LITH – lithophilic; OMNI – omnivorous).

Species		N%	Ecological guld			
			Tolerance	Rheophily	Spawning	Feeding
Schneider	*(Alburnoides bipunctatus)*	2.0	INTOL	RH	LITH	
Bleak	*(Alburnus alburnus)*	38.8	TOLE			OMNI
Stone loach	*(Barbatula barbatula)*	5.9		RH	LITH	
Bullhead	*(Cottus gobio)*	1.3	INTOL	RH	LITH	
Pike	*(Esox lucius)*	0.2				
Gudgeon	*(Gobio gobio)*	14.1		RH		
Dace	*(Leuciscus lauciscus)*	1.3		RH	LITH	OMNI
Minnow	*(Phoxinus phoxinus)*	25.5		RH	LITH	
Bitterling	*(Rhodeus sericeus)*	0.9	INTOL			
Roach	*(Rutilus rutilus)*	10.0	TOLE			OMNI
Chub	*(Squalius cephalus)*	0.2		RH	LITH	OMNI

Table 4.4.7. Reference and measured values of fish metrics that are used in the Lithuanian fish-based method for assessing the ecological status of medium-sized rhithral rivers (national type 3), metrics EQR values, fish index value and the corresponding class of ecological status.

Fish metric	Reference	Measured value	Metric EQR*	Fish index*
INTOL abundance (%)	≥45	4.2	0.09	**0.59**
LITH abundance (%)	≥93	36.1	0.39	
LITH number of species (%)	≥72	54.5	0.76	
INTOL number of species	≥5	3	0.6	
RH number of species	≥8	7	0.88	
TOLE abundance (%)	≤2	48.8	0.52	
OMNI abundance (%)	≤4	50.2	0.52	
TOLE number of species (%)	≤14	18.2	0.95	

*Blue-high status class, green-good, yellow-moderate, brown-poor, red-bad

The opposite is true for lithophilic species: although the species diversity is relatively high, the relative abundance of individuals is low. According to the fish

index, the ecological status of the stretch of the Varduva River below the Vadagiai HPP is moderate.

In total, 8 fish species were recorded in the **Varduva River below Ukrinai HPP** stretch of the river (Table 4.4.8). Individuals of tolerant species (perch) make up the major part (54.2%) of all fish in the assemblage. Among the intolerant species, only the bullhead is present. Most of river type-specific metrics of fish indicate either poor or moderate ecological status (Table 4.4.9). According to the fish index, the ecological status of the studied stretch is moderate.

Table 4.4.8. Relative abundance (N%) of fish species in the stretch of the Varduva River below the Ukrinai HPP and their assignment to ecological guilds for calculating the fish index (INTOL – intolerant to habitat degradation; TOLE – tolerant to habitat degradation; RH – rheophilic; LITH – lithophilic; OMNI – omnivorous).

Species		**N%**	**Ecological guld**			
			Tolerance	Rheophily	Spawning	Feeding
Bleak	*(Alburnus alburnus)*	0.4	TOLE			OMNI
Stone loach	*(Barbatula barbatula)*	0.4		RH	LITH	
Bullhead	*(Cottus gobio)*	10.4	INTOL	RH	LITH	
Gudgeon	*(Gobio gobio)*	29.1		RH		
Burbot	*(Lota lota)*	0.4			LITH	
Perch	*(Perca fluviatilis)*	54.2	TOLE			
Roach	*(Rutilus rutilus)*	5.2	TOLE			OMNI
Chub	*(Squalius cephalus)*	0.4		RH	LITH	OMNI

Table 4.4.9. Reference and measured values of fish metrics that are used in the Lithuanian fish-based method for assessing the ecological status of medium-sized rhithral rivers (national type 3), metrics EQR values, fish index value and the corresponding class of ecological status.

Fish metric	**Reference**	**Measured value**	**Metric EQR***	**Fish index***
INTOL abundance (%)	≥45	*10.3*	0.23	**0.48**
LITH abundance (%)	≥93	11.5	0.12	
LITH number of species (%)	≥72	50	0.69	
INTOL number of species	≥5	1	0.2	
RH number of species	≥8	4	0.5	
TOLE abundance (%)	≤2	59.5	0.41	
OMNI abundance (%)	≤4	6.0	0.98	

TOLE number of species (%)	≤14	37.5	0.73	

*Blue-high status class, green-good, yellow-moderate, brown-poor

The fish assemblage in the stretch of the **Varduva River below** the lowermost of dams **Juodeikiai HPP** is the most diverse in comparison with the rest of the surveyed stretches. Fifteen species of fish have been recorded here, most of them are typical riverine fish (Table 4.4.10). Migratory fish species can access the stretch, therefore the total number of species as well as the number of intolerant species is higher compared to stretches of the river with the barriers for migration. In terms of abundance, individuals of rheophilic fish species make up the majority of fish assemblage (73.7%), but specialized gravel-spawners (lithophilic species) are less numerous. The proportion of individuals of lithophilic species, as well as intolerant species, is much less than would be expected under natural conditions (Table 4.4.11). But the diversity of type-specific riverine species corresponds (intolerant and rheophilic species) or only slightly deviates (lithophilic species) from the reference values. According to fish index, the status of the stretch of the Varduva River downstream of the Juodeikiai HPP is good, although close to good/moderate status boundary.

Table 4.4.10. Relative abundance (N%) of fish species in the stretch of the Varduva River below the Juodeikiai HPP and their assignment to ecological guilds for calculating the fish index (INTOL – intolerant to habitat degradation; TOLE – tolerant to habitat degradation; RH – rheophilic; LITH – lithophilic; OMNI – omnivorous).

Species		**N%**	**Ecological guld**			
			Tolerance	Rheophily	Spawning	Feeding
Schneider	*(Alburnoides bipunctatus)*	1.6	INTOL	RH	LITH	
Stone loach	*(Barbatula barbatula)*	12.3		RH	LITH	
Spined loach	*(Cobitis taenia)*	1.6				OMNI
Bullhead	*(Cottus gobio)*	1.6	INTOL	RH	LITH	
Pike	*(Esox lucius)*	0.8				
Gudgeon	*(Gobio gobio)*	24.7		RH		
Dace	*(Leuciscus lauciscus)*	0.4		RH	LITH	OMNI
Perch	*(Perca fluviatilis)*	5.3	TOLE			
Minnow	*(Phoxinus phoxinus)*	12.8		RH	LITH	
Bitterling	*(Rhodeus sericeus)*	2.9	INTOL			
Roach	*(Rutilus rutilus)*	15.6	TOLE			OMNI

Chub	*(Squalius cephalus)*	15.2		RH	LITH	OMNI
Salmon	*(Salmo salar)*	0.4	INTOL	RH	LITH	
Brown trout	*(Salmo trutta)*	1.6	INTOL	RH	LITH	
Vimba	*(Vimba vimba)*	2.9		RH	LITH	

Table 4.4.11. Reference and measured values of fish metrics that are used in the Lithuanian fish-based method for assessing the ecological status of medium-sized rhithral rivers (national type 3), metrics EQR values, fish index value and the corresponding class of ecological status.

Fish metric	Reference	Measured value	Metric EQR*	Fish index*
INTOL abundance (%)	≥45	8.2	0.18	**0.76**
LITH abundance (%)	≥93	49.0	0.53	
LITH number of species (%)	≥72	60.0	0.83	
INTOL number of species	≥5	5	1	
RH number of species	≥8	10	1	
TOLE abundance (%)	≤2	21.0	0.81	
OMNI abundance (%)	≤4	32.9	0.70	
TOLE number of species (%)	≤14	13.3	1	

*Blue-high status class, green-good, yellow-moderate, brown-poor

According to the results of State monitoring, the metrics of all water quality elements meet the criteria of high or good ecological status in the Varduva River. The presence of HPPs is.the only pressure affecting fish assemblages (see Deliverable T1.1.1 “Review of existing hydro-morphological data and HPPs technical specification”). However, the structure and composition of fish assemblages, as well as ecological status in terms of fish metrics, differ in stretches of the river downstream of different HPPs.

In stretch of the river downstream of the Kulšėnai HPP, which is the uppermost in the cascade of HPPs, there are no species sensitive to water level fluctuations, migratory species are also absent. However, some intolerant species are still found, and the number of individuals of tolerant species is relatively small (Table 4.4.12). The fish index score corresponds to the moderate status, however, it is quite close to the boundary of the moderate and good status. The situation is much worse in the stretch of the Varduva River below the Renavas HPP, which is the second in the chain of HPPs. The distance to the next HPP is the shortest (see Figure 4.4.1), which means that semi-migratory and typical rheophilic species have less space to survive compared to stretches of the rivers below other HPPs.There are no water level fluctuation-sensitive and intolerant species here. Over 83% of all fish in the community are roach and bleak, which are the most resistant to habitat degradation. According to the fish index, the status is poor. The third in the chain is the Vadagiai HPP. This hydropower plant does not operate in the summer,

thereforethe fluctuation of discharge is slightly less than below the Renavas HPP. In addition, the distance to the next impoundment is greater. Some of the intolerant fish species are still present here; however, almost half of all fish are individuals of tolerant species. According to the fish index, the status is moderate, which is one class of status better than in the the stretch below the Renavas HPP. The fourth is the Ukrinai HPP, which operates all year round. The distance to the next impoundment is relatively long, but the fish community is significantly altered. Among the intolerant species, only the sculpin is present, while the tolerant species, mainly perch, make up almost 60% of all fish individuals. According to fish index, the status is moderate.

The situation is different in the lower reaches of the Varduva River, below the Juodeikiai HPP, which is accessible to migratory fish. Fifteen species of fish were recorded here, which is almost twice as many as in other surveyed stretches. Almost all type-specific intolerant species of fish, as well as migratory species are present, including salmon, trout and vimba. Tolerant species no longer dominate, but still make up approximately 20% of all individuals in the assemblage. Lamprey larvae, which are particularly sensitive to littoral washout, are absent, but spined loach is already found in small numbers. According to the fish index, good status has been achieved, but the index value is close to the boundary of good/moderate status.

Table 4.4.12. Key species of the different ecological guilds that should be present in rivers of the Varduva type and the actual relative abundance (in %) of the species in the river stretches downstream of each of HPP. Species that make up >30% of the total abundance in certain stretches are indicated in bold.

Main characteristics of the species group	Species	Kulšėnai HPP	Renavas HPP	Vadagiai HPP	Ukrinai HPP	Juodeikiai HPP
Particularly sensitive to littoral zone flushing or level fluctuation	*Lampetra sp.*					
	Cobitis taenia					1.7
Intolerant and/or long distance migratory	*Salmo salar* [1, 2]					0.4
	Salmo trutta [1, 2]					1.7
	Vimba vimba [2]					2.9
	Alburnoides bipunctatus [1]	17		13		4
	Rhodeus sericeus [1]	0.2		0.9		2.9
	Cottus gobio [1]	3.3		1.3	10	1.7
Intermediate tolerance, Lithophilic	*Phoxinus phoxinus*	29		25		13
	Leuciscus leuciscus		0.6	1.3		0.4
	Squalius cephalus	1.4	0.2	0.2	0.4	15
	Barbatula barbatula	1.3	0.3	5.9	0.4	12
Tolerant, Eurytopic	*Rutilus rutilus*	2.3	**50**	10	5.2	16

	Alburnus alburnus	15	**33**	**39**	0.4	
	Perca fluviatiluis		0.6		**54**	5.4

[1] – intolerant; [2] – long distance migratory

The change in the situation in the river gradient, both in terms of the diversity and abundance of the main ecological guilds, and in terms of the ecological status according to the fish index, is visualized in Figure 4.4.2.

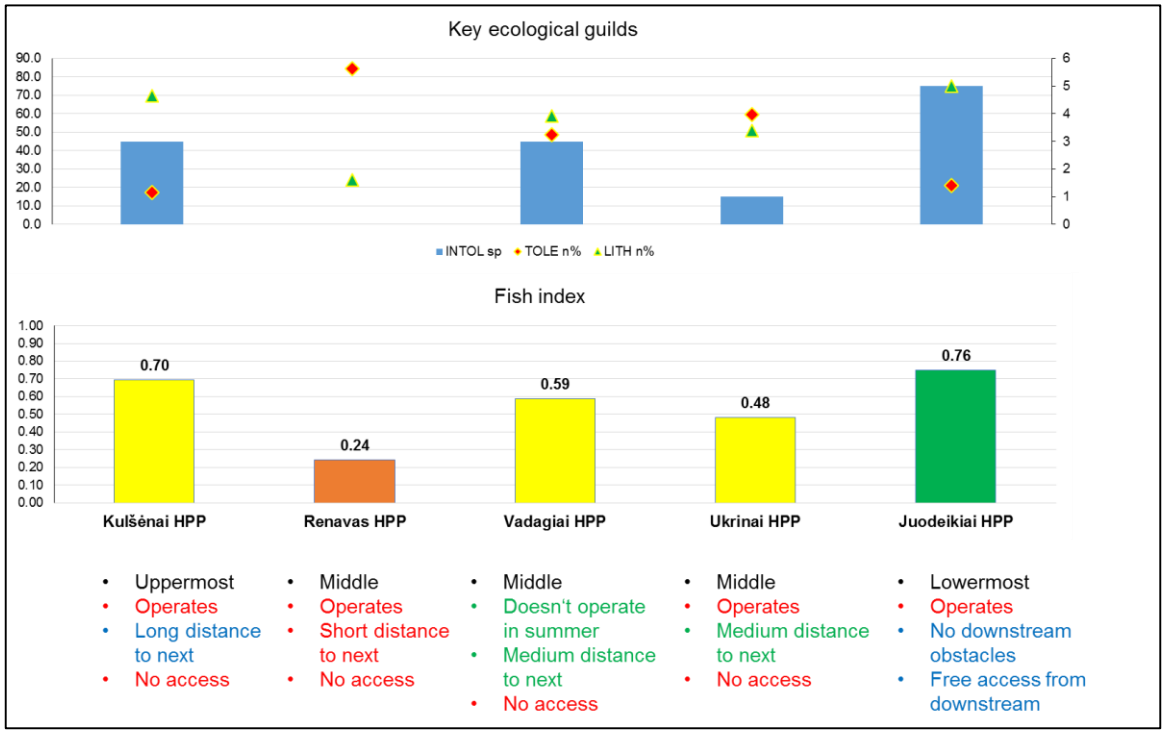

Fig. 4.4.2. Values of metrics of key ecological guilds (upper graph), fish index values and the corresponding class of ecological status (brown – poor, yellow – moderate, green – good) (lower graph) and a description of the position of HPP in the cascade of HPPs, operation, distance to the next HPP and accessibility for migratory fish.

It can be seen that if the HPP is operating, migration of fish is disrupted at both ends, but the distance to the next obstacle is relatively large (Kulšėnai HPP), the impact of connectivity disturbance is smaller compared to the situation where the distance between obstacles to migration is relatively short. The latter scenario is the worst one (Renavas HPP). Accordingly, if the distance to the next impoundment is relatively medium, but the HPP does not operate during the low flow period (Vadagiai HPP), the situation is better compared to the situation when the HPP operates all year round (Ukrinai HPP). However, in both cases, good status is not achieved. And, finally, if the access of fish from the lower reaches is

free, the situation is better than in other cases, despite the fact that the HPP is operating. But the difference in the value of the fish index in the stretches of the river below the lowermost and uppermost HPPs is small.

5. CONCLUSIONS AND RECOMMENDATIONS

- In Latvia surveys have been conducted in 5 case studies within regulated rivers on 159 HMUs with total length of about 1 km and total maximum area 11275 m^2.
- In Lithuania surveys have been conducted in 5 case studies on 101 HMUs with total length of about 1.3 km and total maximum area 14586 m^2.
- It's important to do hydromorphological surveys in type-specific reaches. Our findings show that an incorrectly chosen survey site significantly affects the results of habitat suitability distribution and characteristics of habitat-flow rating curve. For example, if salmonid site is selected, then slow slowing reaches with silt must be avoided.
- Fish surveys results indicate that the cumulative effect of HPP and connectivity disturbance is much stronger than any of these effects taken separately. However, it implies that only the introduction of ecological flow without opening migration routes will only slightly improve the situation in the cascade of HPP, and a good ecological status in terms of fish may not be achieved.
- Provisionally the following species for MesoHABSIM model should be used: Ciecere HPP – spined loach, bullhead, gudgeon and dace; Dzirnavnieki HPP – spined loach, gudgeon, dace and brown trout; Pakuli HPP – schneider, bullhead, dace and brown trout; Grantini HPP – bullhead, chub and gudgeon; Lejnieki HPP – spined loach, bullhead, chub and gudgeon. In the Varduva River, all migratory and disturbance-sensitive (intolerant) fish species characteristic of the river type, which are expected to be present under natural conditions, and which have been recorded in the river section downstream of the Juodeikiai HPP (salmon, trout, vimba, schneider and bullhead), have to be selected to simulate the effects of flow modification on habitat availability.
- To get better understanding of fish fauna of different stretches of Ciecere and Losis rivers as well as impact of HPP of distribution and abundance of different species we recommend to perform additional survey. In this survey general hydromorphologic features of Ciecere River should be surveyed in at least several kilometres long stretch downstream all HPP and hydromorphologic features of Losis River should be surveyed in the stretch from Grantini HPP to

the river mouth. In this survey at least general hydromorphologic features of the river should be registered and several electrofishing sites surveyed to get broader information on distribution of ecologically vulnerable fish species and impact of HPP.

- Special attention should be paid to the evaluation of presence of populations of the brown trout / sea trout and brook lamprey. If necessary additional methods (bottom sampling for lamprey larvae etc.) can be applied.

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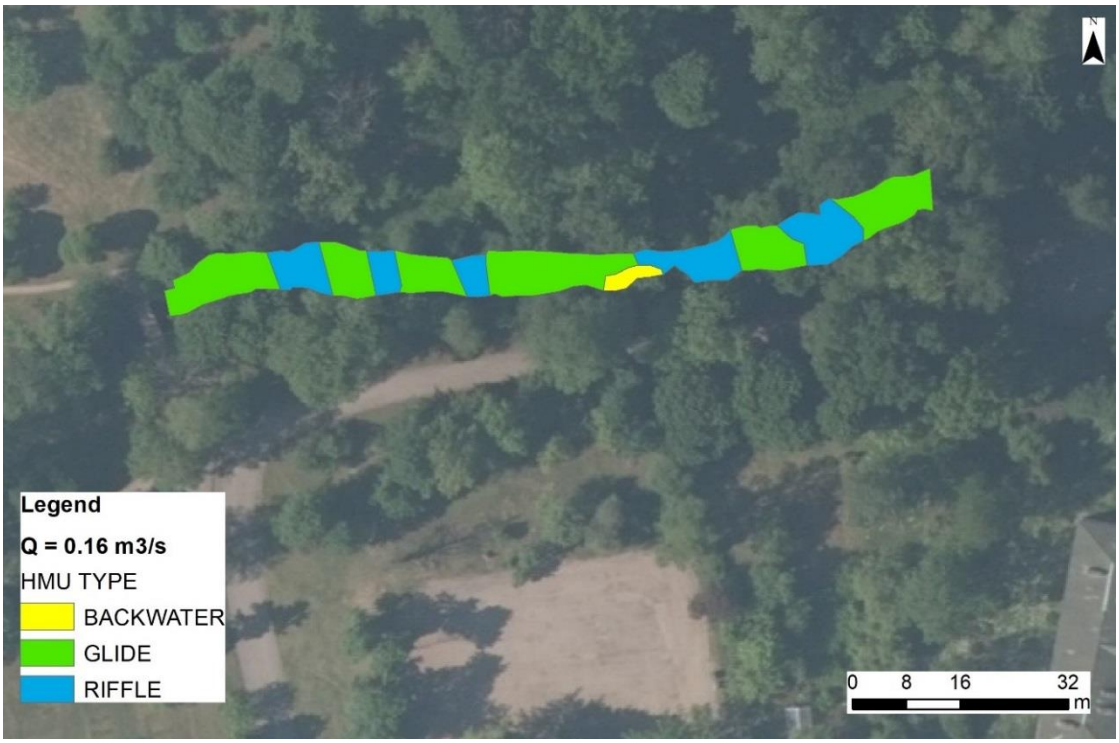

Figure 1. Hydromorphic unit map of the Ciecere 1 (at Kalnsetas parks) River below Ciecere HPP (Q = 0.16 m^3/s)

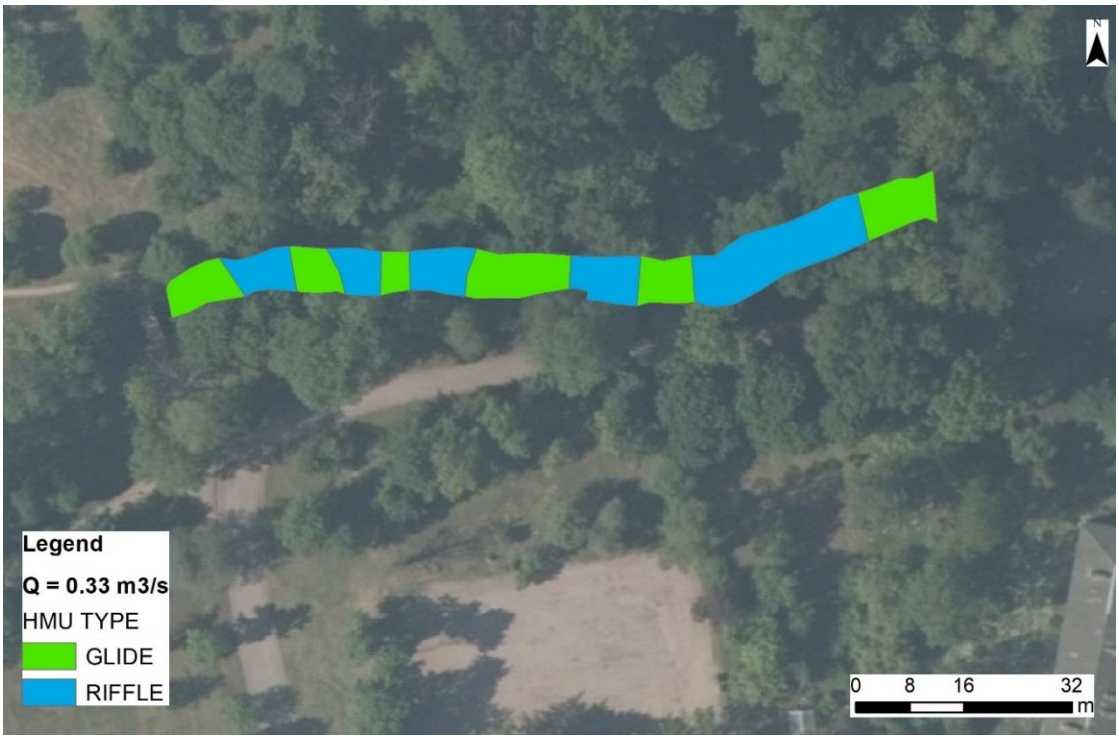

Figure 2. Hydromorphic unit map of the Ciecere 1 (at Kalnsetas parks) River below Ciecere HPP (Q = 0.33 m^3/s)

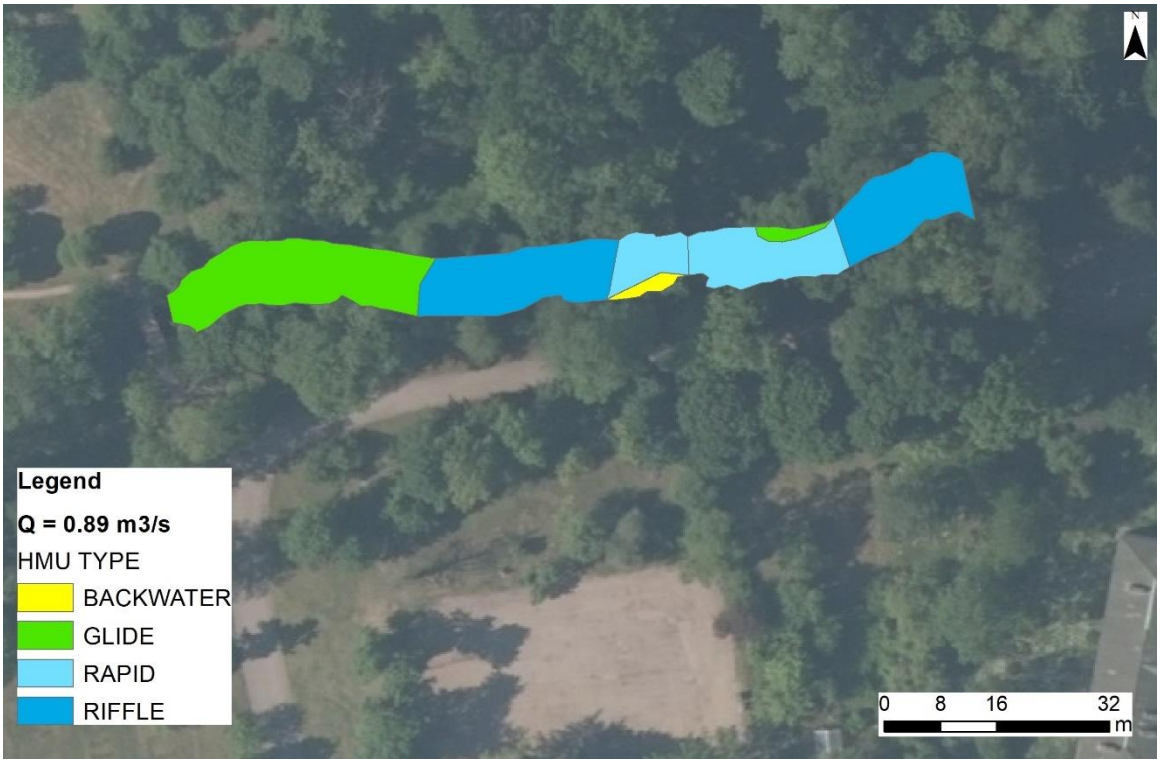

Figure 3. Hydromorphic unit map of the Ciecere 1 (at Kalnsetas parks) River below Ciecere HPP (Q = 0.89 m^3/s)

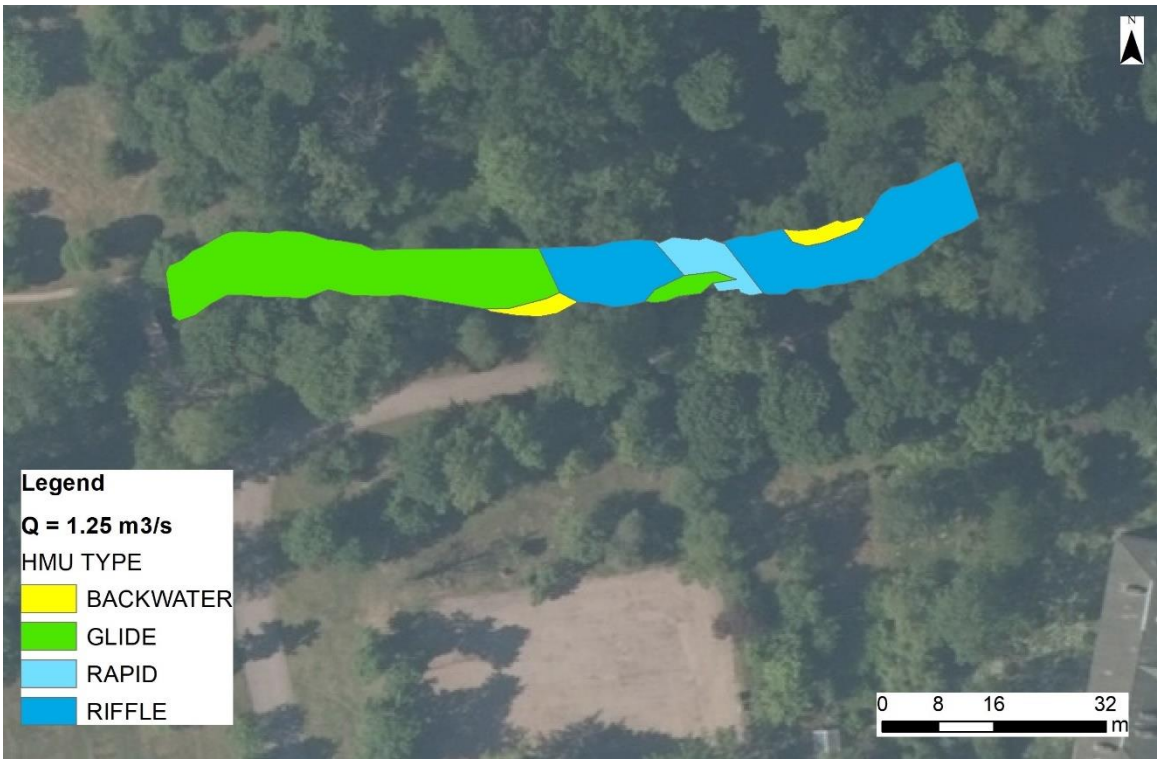

Figure 4. Hydromorphic unit map of the Ciecere 1 (at Kalnsetas parks) River below Ciecere HPP (Q = 1.25 m^3/s)

Figure 5. Hydromorphic unit map of the Ciecere 2 (below Saldus city) River below Dzirnavnieki HPP (Q = 0.071 m^3/s)

Figure 6.. Hydromorphic unit map of the Ciecere 2 (below Saldus city) River below Dzirnavnieki HPP (Q = 0.28 m^3/s)

Figure 7. Hydromorphic unit map of the Ciecere 2 (below Saldus city) River below Dzirnavnieki HPP (Q = 0.33 m^3/s)

Figure 8. Hydromorphic unit map of the Ciecere 2 (below Saldus city) River below Dzirnavnieki HPP (Q = 2.13 m^3/s)

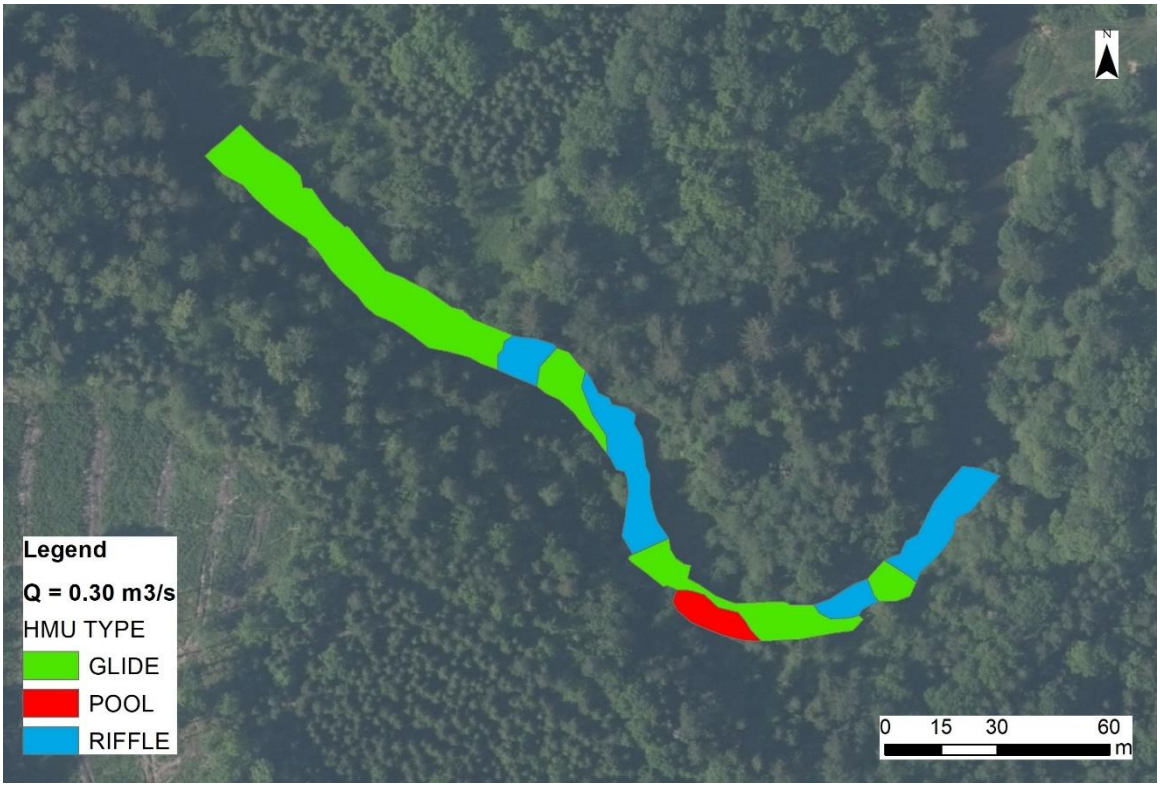

Figure 9. Hydromorphic unit map of the Ciecere 3 River below Pakuli HPP (Q = 0.30 m^3/s)

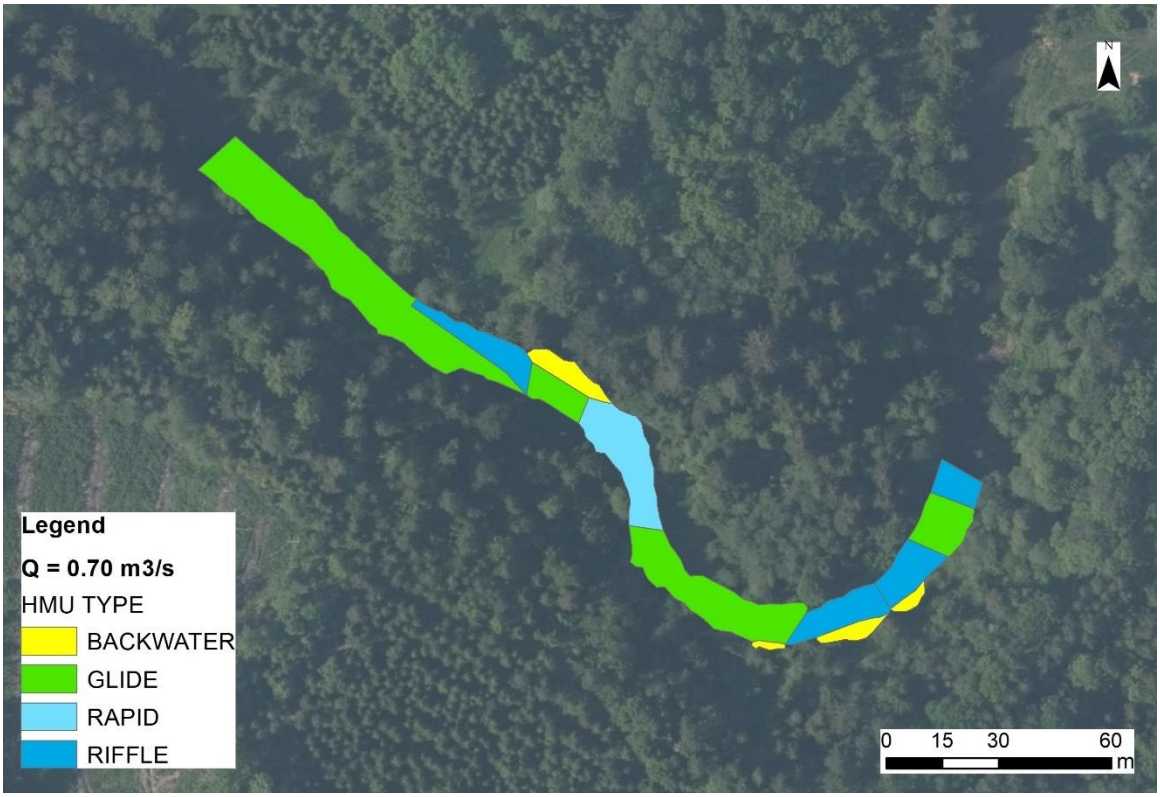

Figure 10. Hydromorphic unit map of the Ciecere 3 River below Pakuli HPP (Q = 0.70 m^3/s)

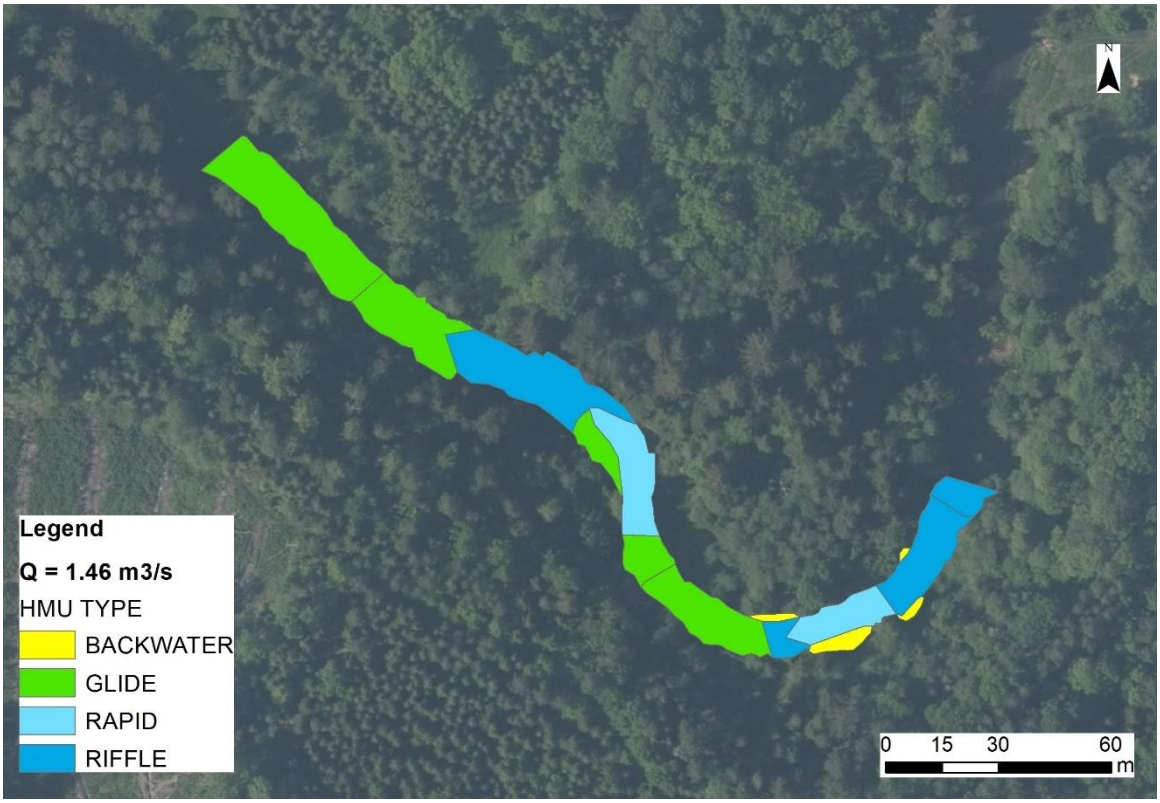

Figure 11. Hydromorphic unit map of the Ciecere 3 River below Pakuli HPP (Q = 1.46 m³/s)

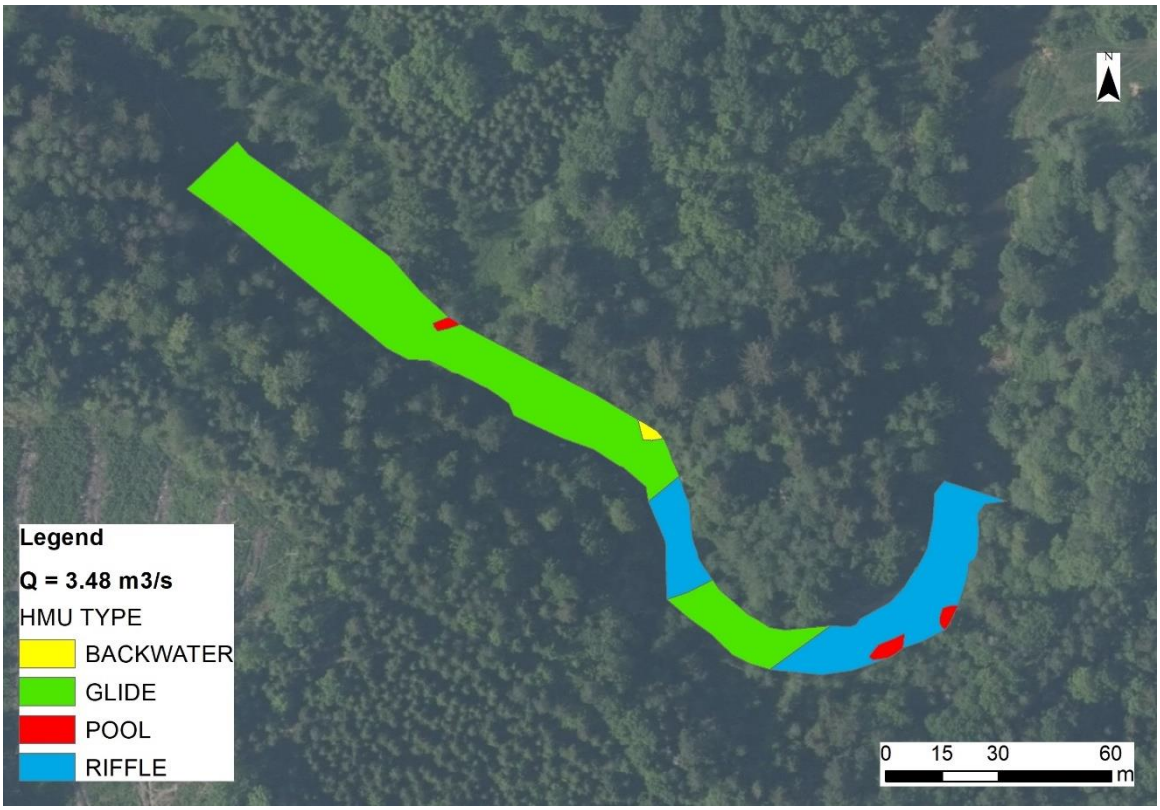

Figure 12. Hydromorphic unit map of the Ciecere 3 River below Pakuli HPP (Q = 3.48 m³/s)

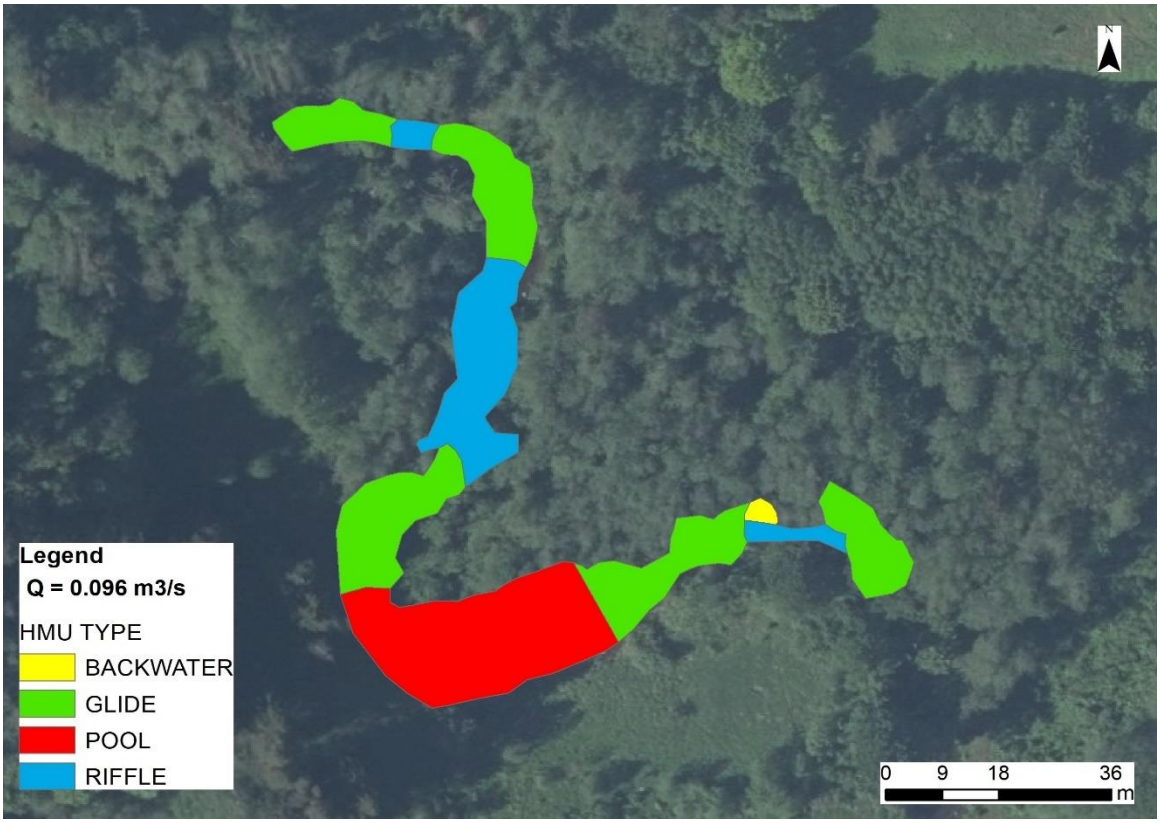

Figure 13. Hydromorphic unit map of the Losis 1 River below Lejnieki HPP (Q = 0.096 m^3/s)

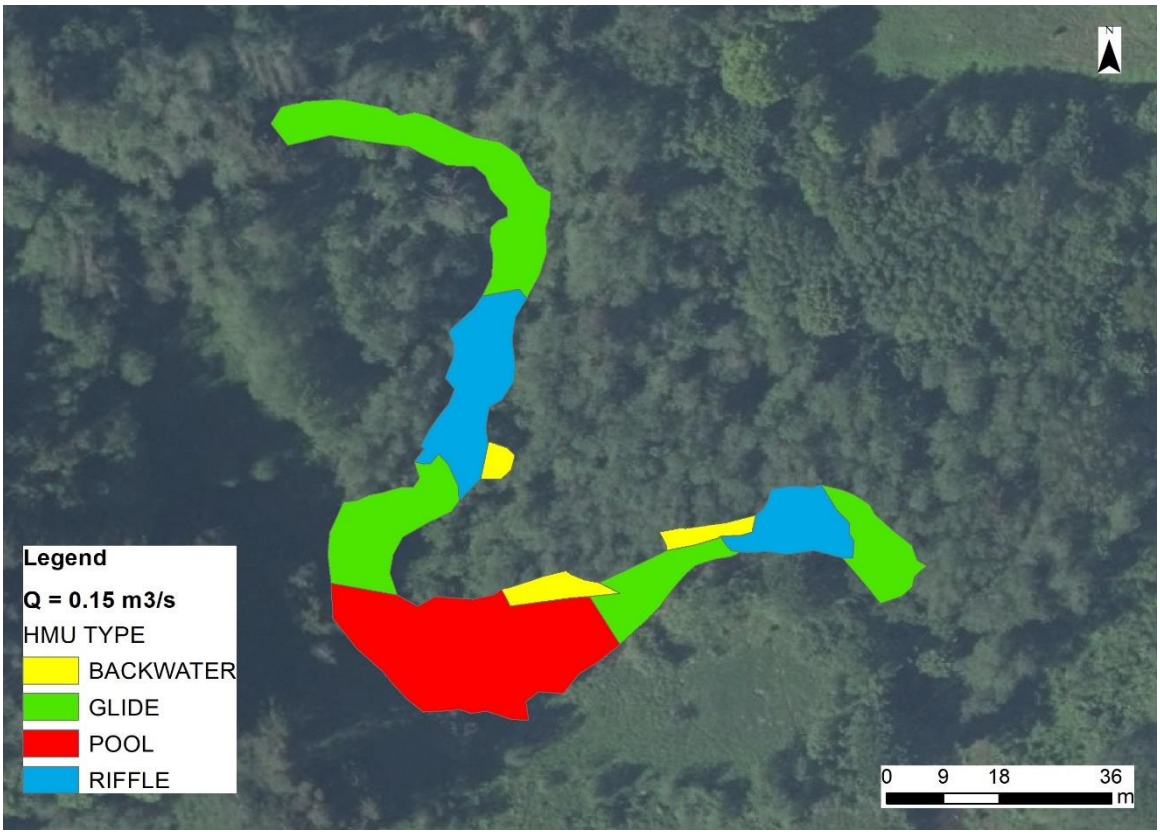

Figure 14. Hydromorphic unit map of the Losis 1 River below Lejnieki HPP (Q = 0.15 m^3/s)

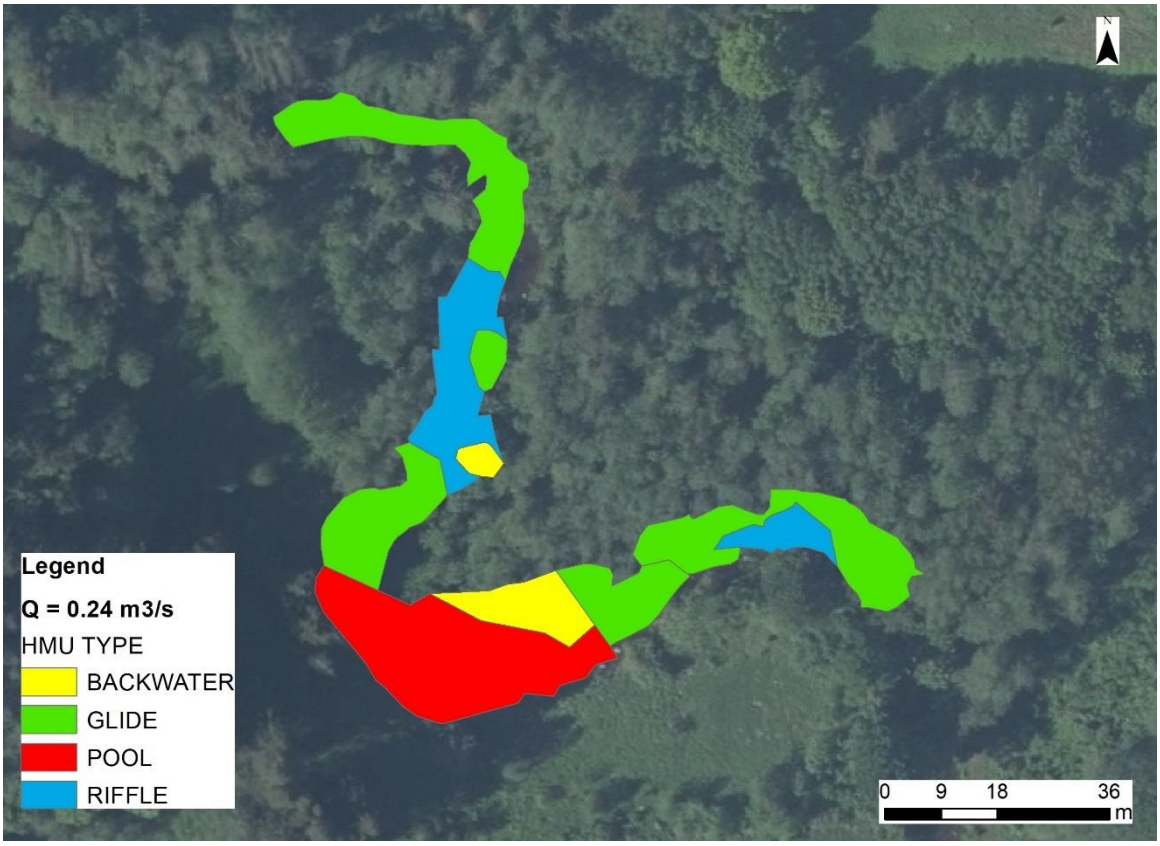

Figure 15. Hydromorphic unit map of the Losis 1 River below Lejnieki HPP (Q = 0.24 m^3/s)

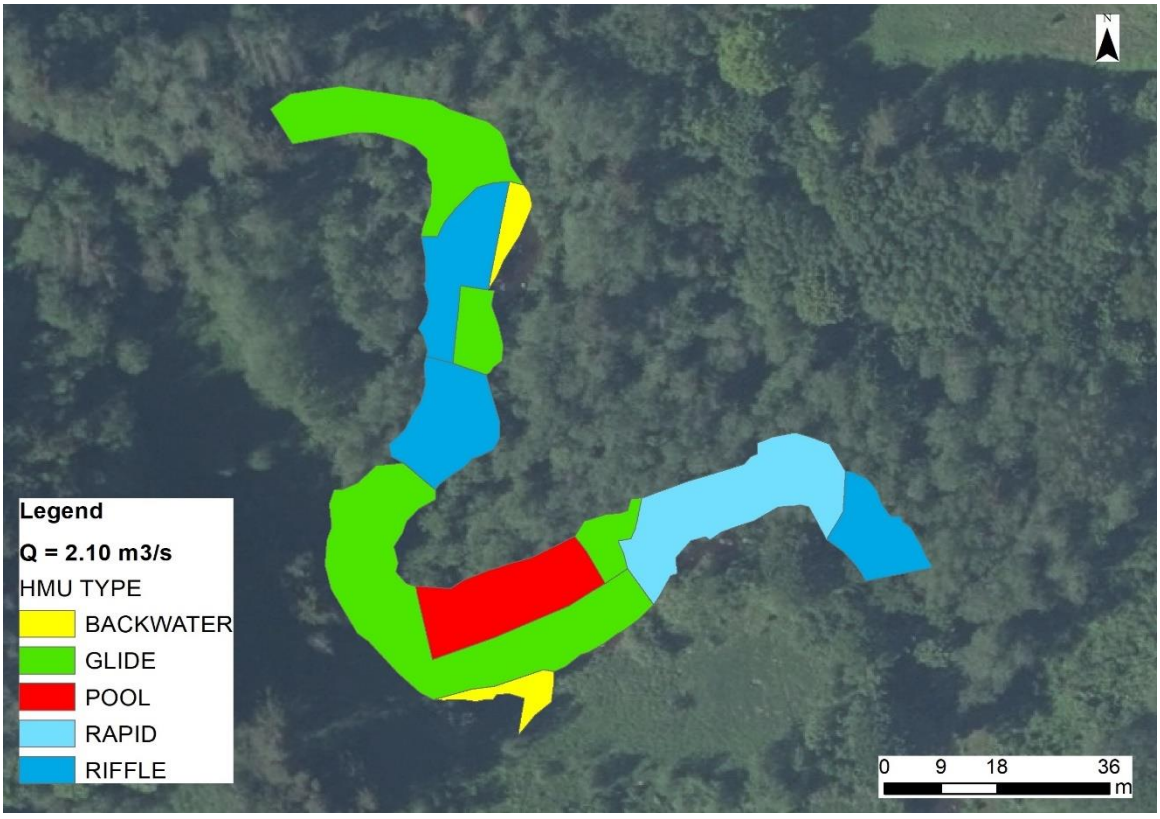

Figure 16. Hydromorphic unit map of the Losis 1 River below Lejnieki HPP (Q = 2.10 m^3/s)

Figure 17. Hydromorphic unit map of the Losis 2 River below Grantini HPP (Q = 0.084 m^3/s)

Figure 18. Hydromorphic unit map of the Losis 2 River below Grantini HPP (Q = 0.21 m^3/s)

Figure 19. Hydromorphic unit map of the Losis 2 River below Grantini HPP (Q = 0.41 m^3/s)

Figure 20. Hydromorphic unit map of the Losis 2 River below Grantini HPP (Q = 1.34 m^3/s)

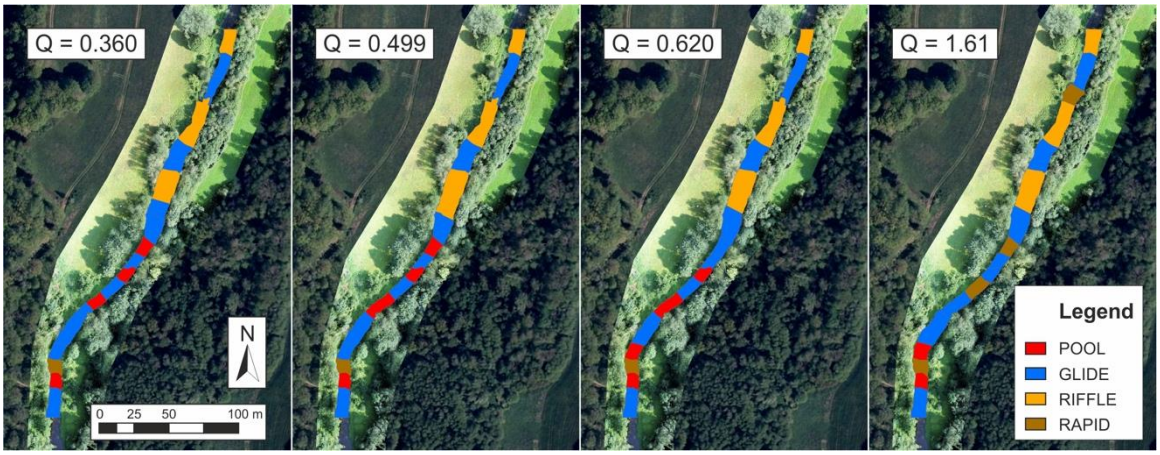

Figure. 1. Map of geomorphic units of the Varduva River below Kulšėnai HPP at corresponding discharges

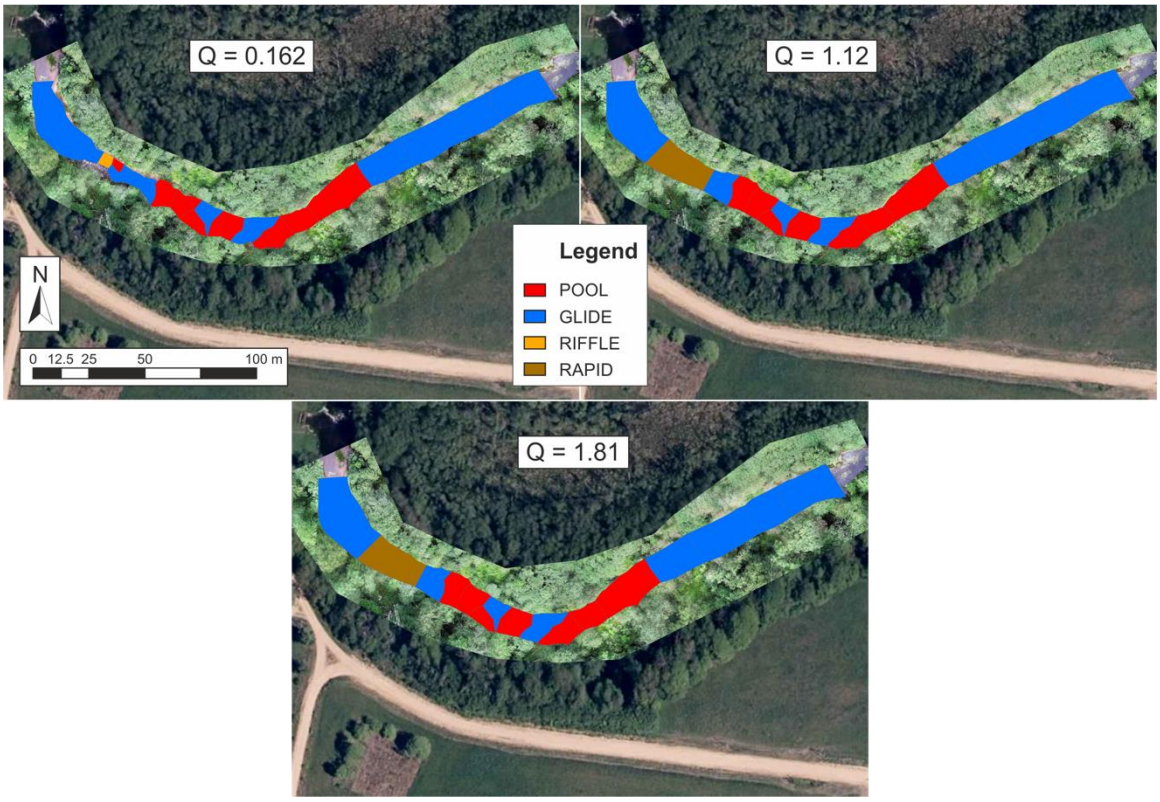

Figure. 2. Map of geomorphic units of the Varduva River below Renavas HPP at corresponding discharges

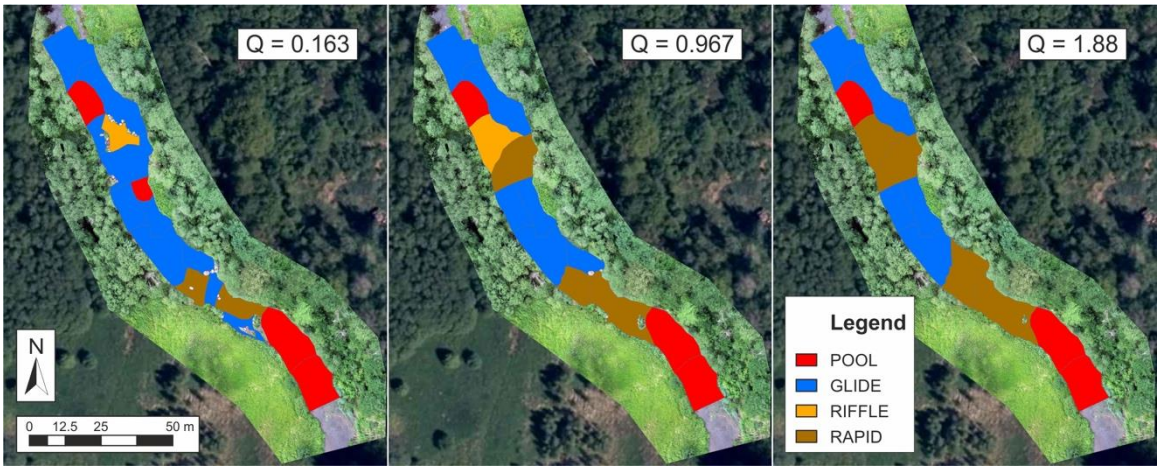

Figure. 3. Map of geomorphic units of the Varduva River below Vadagiai HPP at corresponding discharges

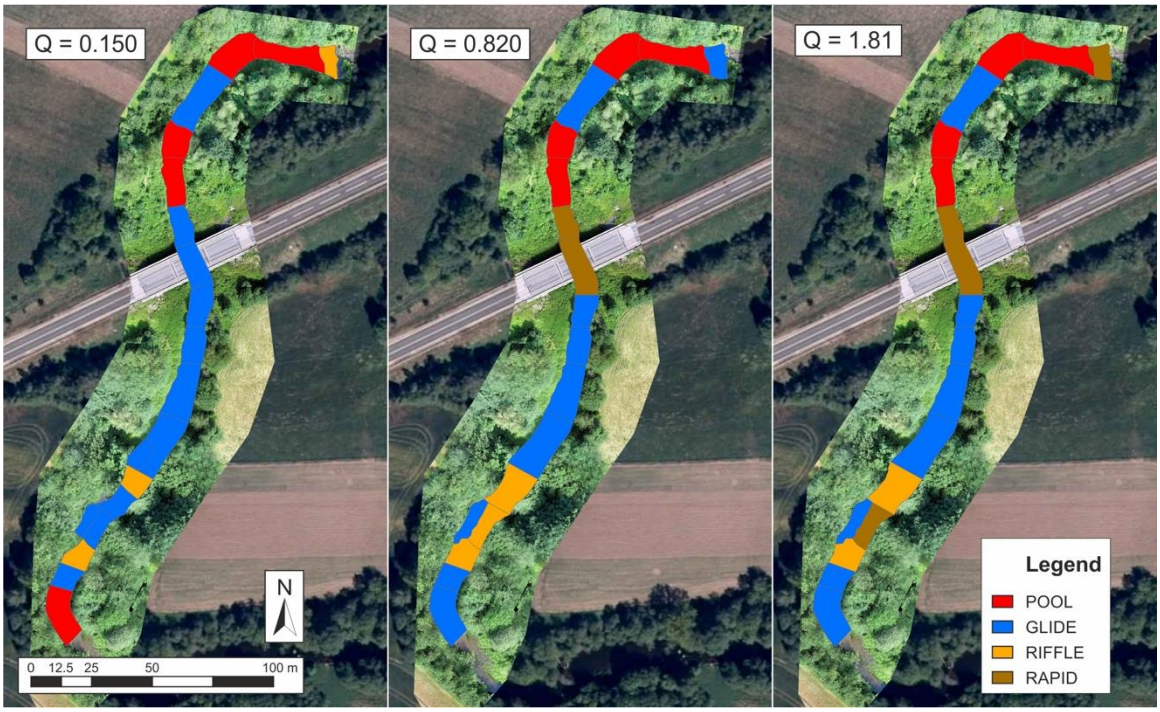

Figure. 4. Map of geomorphic units of the Varduva River below Ukrinai HPP at corresponding discharges

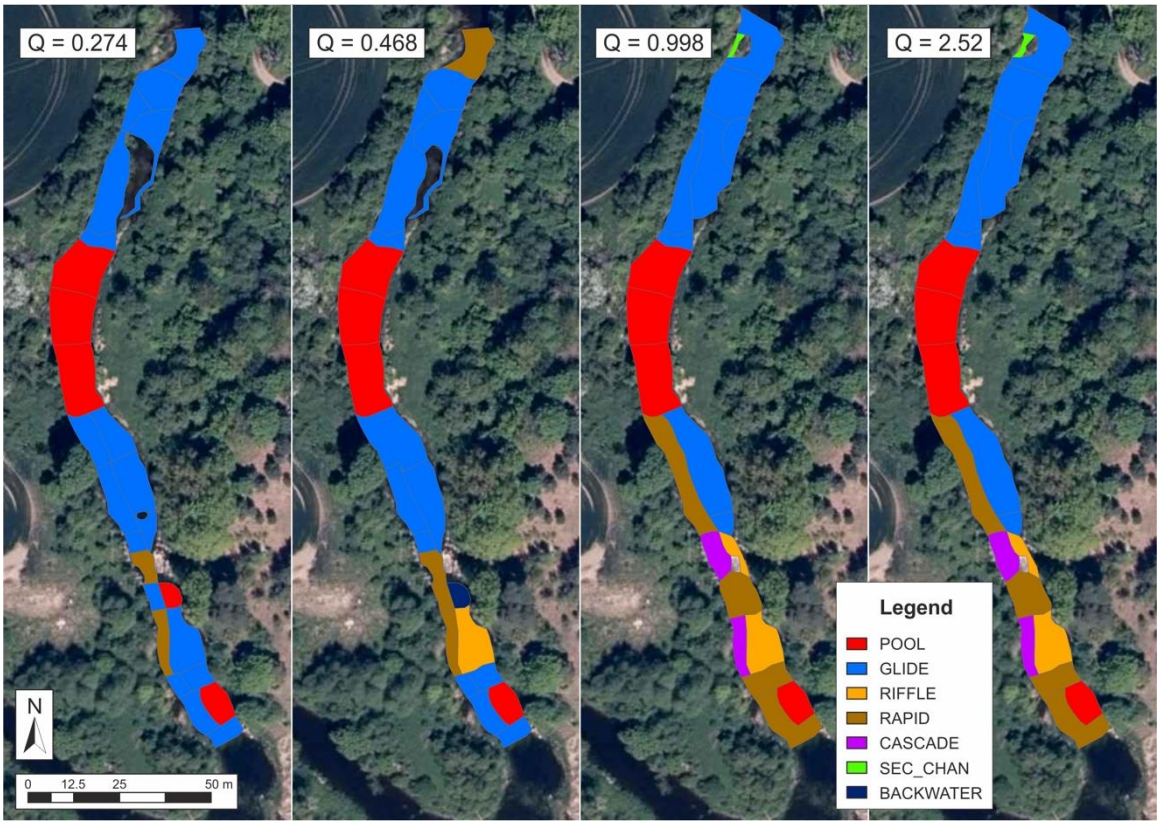

Figure. 5. Map of geomorphic units of the Varduva River below Juodeikiai HPP at corresponding discharges