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

Habitat suitability modelling results Report (a part of Report of E-flow regime modelling for HPPs cascades)

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ABBREVIATIONS

E-flow – ecological flow

HPP – hydropower plant

LT – Lithuania

LV – Latvia

Optimal habitat – habitat area where selected fish can be found in large density

Optimum flow ($Q_{optimum}$) - a river flow value, at which the area of available habitat reaches its maximum or insignificant habitat suitability increase can be observed

Q_{annual} – annual water discharge

Q_{30_avg} – average water discharge of the summer 30-days low flow period

Q_{30_max} – maximum water discharge of the summer 30-days low flow period

Q_{30_min} – minimum water discharge of the summer 30-days low flow period

Suitable habitat – habitat area where selected fish can be found in small density

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, suitable river habitat modelling were carried out in the project pilot rivers Ciecere, Losis (LV) and Varduva (LT). River habitat modelling has been done to calculate the habitat suitability for selected fish species in different hydrological conditions. Modelling results analysis leads to the ecological flow (E-flow) value estimation in rivers regulated by operating hydropower plant (HPP) in the transboundary Venta catchment. General E-flow calculation principles and approaches are defined by the EU Water Framework Directive (WFD) and CIS Guidance document Nr.31 "Ecological flows in the implementation of the Water Framework Directive".

The River habitat modelling have been carried out for the following case-study sites within transboundary Venta River Basin:

Latvia:

Ciecere River: below Ciecere, Dzirnavnieki and Pakuli HPPs;

Losis River: below Grantini and Lejnieki HPPs.

Lithuania:

Varduva River: below Kušėnai, Renavas, Vadagiai, Ukrinai and Juodeikiai HPPs.

The habitat modelling results have shown that hydromorphological alterations, caused by operating HPP, considerably affect the ecological status of rivers.

2. MESO-SCALE HABITAT SIMULATION MODEL (MesoHABSIM)

2.1. Concept and application

Meso-scale habitat simulation model MesoHABSIM was used for habitat suitability calculations at different flows. It is based on habitat availability for selected fish species during different hydrological conditions.

MesoHABSIM consists of three separate sub-models:

1) Fish conditional model: fish habitat model which describes relationships between abundance of selected fish species and abiotic environment of river (depth, stream velocity, substrate composition, presence of boulders, woody debris or in-stream vegetation, etc.).

2) Hydrological data: flow time series in reference (natural) and altered (impacted by HPP) conditions.

3) Hydromorphic unit (HMU) data: HMU as polygons and hydromorphological data as points based on field measurements, including river depth, channel substrate and stream velocity.

Sim-Stream application was used to implement MesoHABSIM model.

This approach addresses the requirements of river basin management defined in WFD because it takes into account not only hydrological calculations, but also biological response. It predicts how aquatic community (fish in our case study) respond to river habitat modification due to anthropogenic pressures.

Due to the scale of resolution increasing from micro- to meso-scales, the MesoHABSIM takes into account the variations in stream morphology along the river and is applicable to large-scale issues. Habitat and fish measurements at large spatial units are practical and relevant to river management.

The results of MesoHABSIM can be used as for ecosystem analysis and selection of adequate mitigation measures, such as construction of fish bypass channels or changes in HPP operations. It must be taken into account that in natural water bodies ecological flows must be implemented together with measures which decreases impact of connectivity disruption (dam). It creates a basis for balance between water resources use and ecological quality – evaluation of ecological flow.

2.2. Sim-Stream Model

Habitat flow-rating curves, habitat suitability and hydrological impact degree was assessed using SimStream software available at https://mesohabsim.isprambiente.it/. Sim-Stream software combines all three parts of MesoHABSIM (fish model, hydrological data series and HMU) and simulates physical habitat suitability at different flow conditions.

Sim-Stream model is a tool that supports the MesoHABSIM Simulation approach; describes river features that are relevant for aquatic species; calculates habitat suitability; and report on the actual and projected status of investigated river.

The software integrates field collected hydro-morphological data with biologic data (fish). This physical habitat simulation model describes the utility of instream habitat conditions for aquatic fauna, allowing to simulate change in habitat quality and quantity in response to alterations of flows or river morphology.

Since the distribution of hydromorphologocal units (HMUs) changes as a function of flow, the mesohabitats are mapped under multiple flow (at least four) conditions at representative (natural river bed, no artificial obstacles) stretches of the river. The independent biological data (fish) is collected in representative mesohabitats. In Sim-Stream model the relationship between fish abundance and suitable habitat distribution is calculated with multivariate statistics.

3. MODEL INPUT DATA

3.1. Hydromorphic unit maps and Field Survey

Hydromorphological units mapping and field works was done in ice-free period of 2020–2022. Hydromorphological type-specific, mesoscale river stretches were selected downstream of each studied HPP. Depending on river size, these river stretches were 100-500 m long. Only natural sites without channelization were selected in order to assess the ecological impact of water level alterations below HPP. Each river stretch was divided into hydromorphological units (HMU), which were mapped at multiple flow conditions. HMU can be described as lotic mesohabitats (riffles, rapids, glides, pools). HMU were mapped as polygons which allows to assess changes in habitat area under different water levels. Flow velocity, water depth and channel substrate were measured at least in seven points within each HMU in Latvia and at least in ten points in Lithuania. For modelling the spatial information about HMU location and size as well as data of water depth, flow velocity and river bad substrate within HMU have been used.

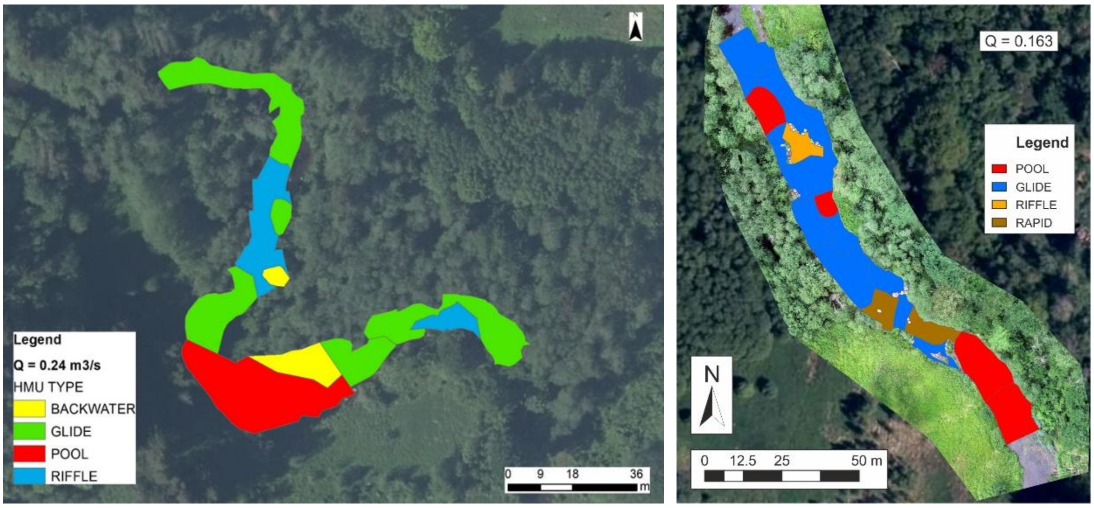


Figure 3.1.1. Example of hydromorphic unit map of the Losis River (Q = 0.24 m^3/s) below Lejnieki HPP (left) and Varduva River (Q = 0.163 m^3/s) below Vadagiai HPP (right)

3.2. Hydrological data

For each case study two hydrological data series were used: daily water flow data in reference (upstream the HPP) and altered conditions (downstream of HPP). Data series have been created for one year (normal hydrological conditions) in order to describe the habitat suitability in typical hydrological conditions.

Before TRANSWAT project hydrological monitoring station was installed only below Pakuli HPP on Ciecere River. During this project additional water level sensors were installed below and above all case studies within Latvia, providing higher quality hydrological calculations. Figure 3.2.1. shows example of the hydrographs used for habitat modelling in Ciecere River.

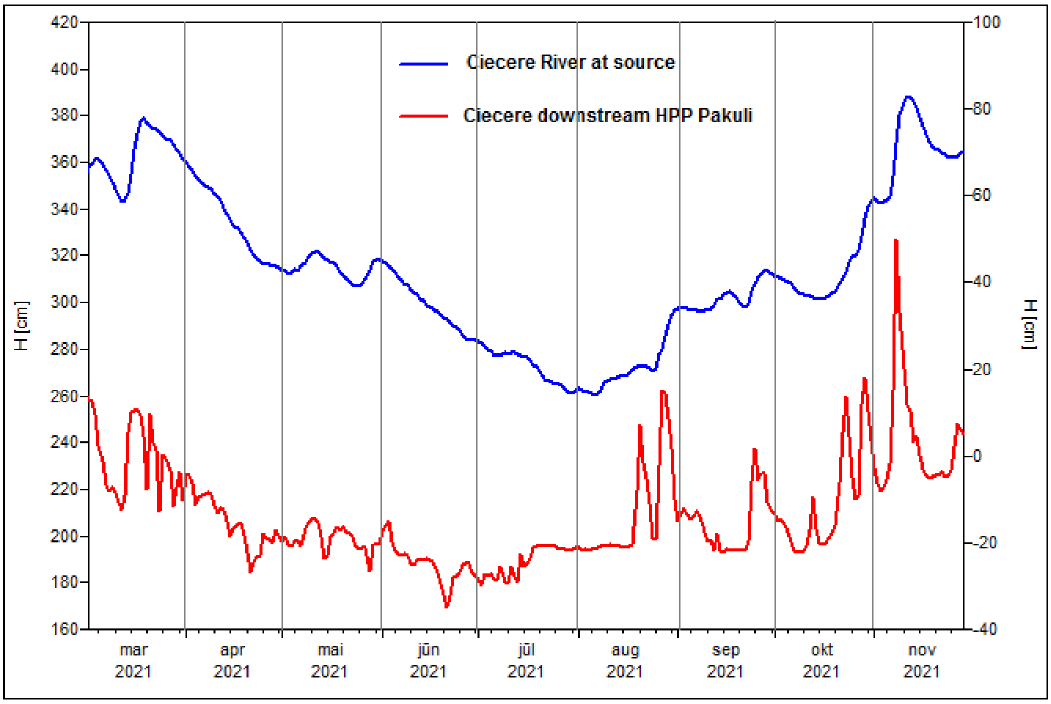


Figure 3.2.1. Example of Ciecere River daily water level at reference (Ciecere River source at Lake Cieceres) and altered (Ciecere River-below Pakuli HPP) conditions

In Lithuania, the water level sensors were installed below each HPP on the Varduva River and at the inflow to the HPP cascade structure. Figure 3.3.1. shows example of the discharge hydrographs used for habitat modelling in Varduva River.

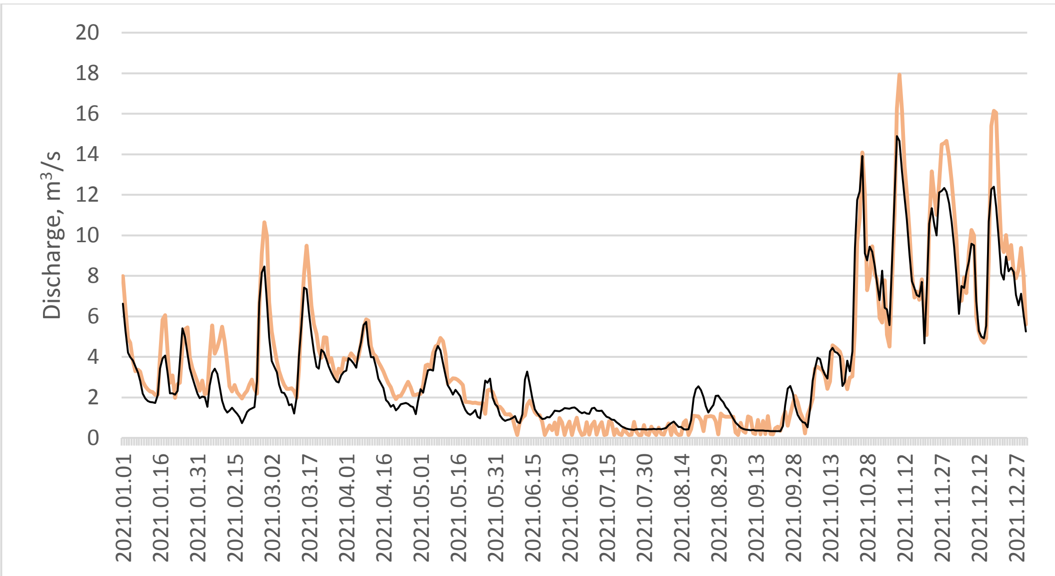


Figure 3.3.1. Example of Varduva River daily water discharge at reference (Varduva River inflow – black curve) and altered (Varduva River below Renavas HPP – orange curve) conditions

3.3. Fish data

Latvia. Fish data have been collected in each case study site where habitat field surveys were done. Fish fauna was sampled in all of HMU and 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.

For habitat modelling a List of specific species of interest has been created for each river within the project area.

Lithuania. Fish data have been collected in each case study site in all of HMUs mapped during field survey. Fish were sampled in accordance with the EU standard EN 14011 (CEN, 2003) by using of the standard backpack pulse current electrofishing device (Hans Grassl GmbH; Germany).

For habitat modelling all sensitive and migratory fish species were selected, which should be present in the rivers like Varduva and which were actually recorded below the lowermost HPP dam.

Figure 3.4.1. Fishing in one of riffles in Ciecere River

4. MODELLING RESULTS FOR LATVIAN CASE STUDIES

4.1. Ciecere River – below Ciecere HPP (Ciecere1)

This stretch of Ciecere River is not included into list of priority fish waters, but habitat is more suitable for salmonid fish species. Ciecere HPP is most upstream of three HPP and only 1.8 km from Lake Ciecere. According to Water use permits, guaranteed water discharge is determined as 0.061 m^3/s. Ecological flow is the same as guaranteed water discharge.

Ciecere1 River List of species of interest:

- Adult common dace (*Leuciscus leuciscus*),
- Adult bullhead (*Cottus gobio*),
- Juvenile brown trout (*Salmo trutta*),
- Adult stone loach (*Barbatulus barbatulus*).

Habitat curves for selected fish species depending on flow rate are shown in Figure 4.1.1. These curves were modelled for each fish species of interest (common dace, bullhead, brown trout, stone loach) that was pre-selected by fish expert especially for Ciecere River, site 1. It is evident that for some of species habitat area increases with increasing water discharge (bullhead, common dace), but for other species available habitat reaches it's maximum (stone loach) or even starts to decrease (brown trout) with increased water discharge.

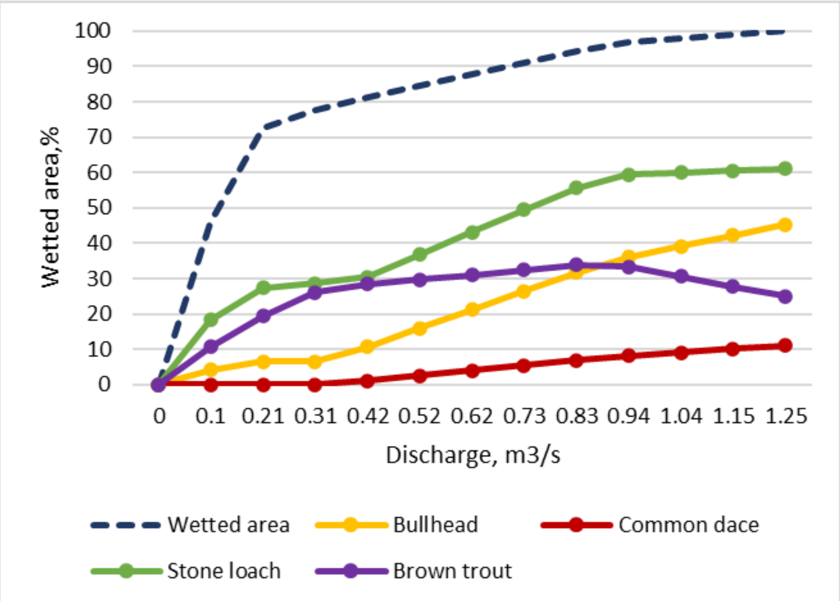


Figure 4.1.1. Habitat-Flow rating curve of Ciecere River downstream Ciecere HPP

Figures 4.1.2 and 4.1.3. show habitat suitability maps for brown trout and bullhead, which are species of high priority for Ciecere River. It is evident that available habitat (optimal and suitable habitats) rapidly increases when discharge increases from Q_{30_min} to Q_{30_avg} and small even increase can be observed until discharge reaches Q_{30_max}. When discharge reaches Q_{annual_avg}, available habitat area starts to decrease because water velocity is too large for juvenile brown trout (Fig. 4.1.2).

Figure 4.1.2. Habitat suitability maps for juvenile brown trout during four different discharges

Different habitat suitability trend can be observed for adult bullhead. Small habitat increase can be observed between Q_{30_min} to $Q_{30\_avg,}$ but optimal and suitable habitat significantly increase when discharge is close to Q_{30_max} (Fig. 4.1.3).

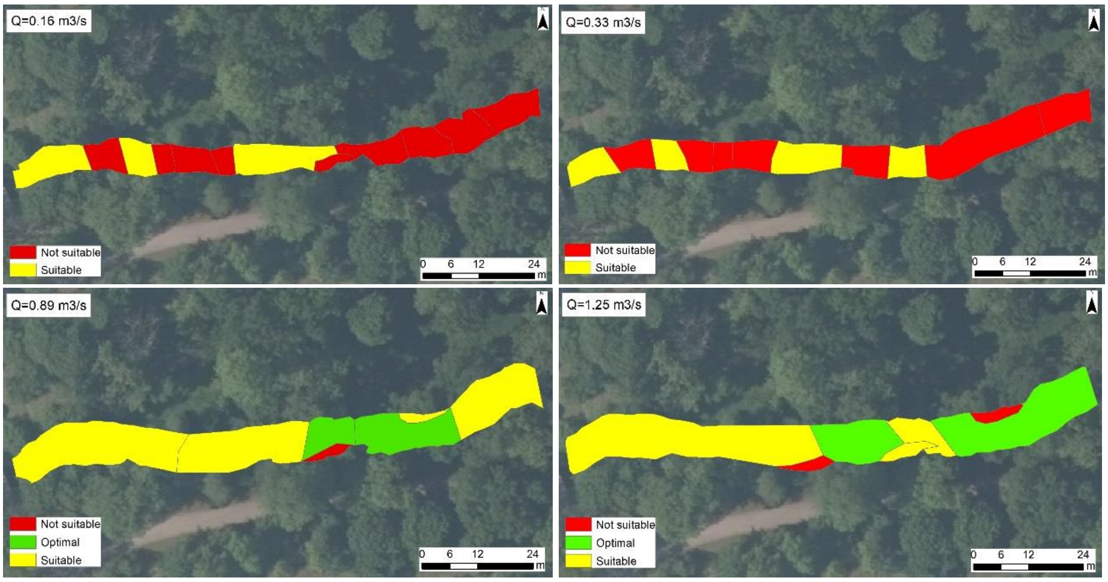


Figure 4.1.3. Habitat suitability maps for adult bullhead during four different discharges

Figures 4.1.4 and 4.1.5. show the habitat distribution in time during 2021 that is a year with normal water runoff. The red line on pictures is a threshold corresponding of habitat area with 97% of probability, and the blue line is an average habitat area. Results show that all modelled fish species are under strong hydromorphological pressure due to habitat loss. For juvenile brown trout most of habitats during summer are below AQ97 threshold (Fig. 4.1.4), indicating that water level in river is too low and summer period ecological flow must be increased. The areas of habitats available to the bullhead have also significantly decreased as a result of the operation of the HPP, but decrease are less intense.

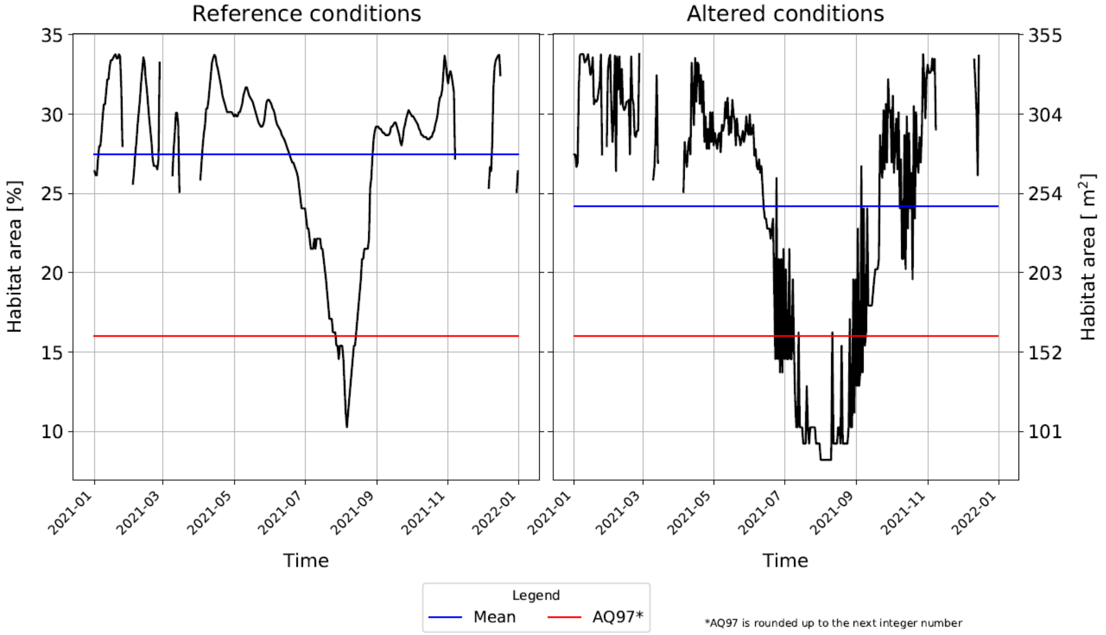


Figure 4.1.4. Habitat time series of the juvenile brown trout in reference and altered conditions

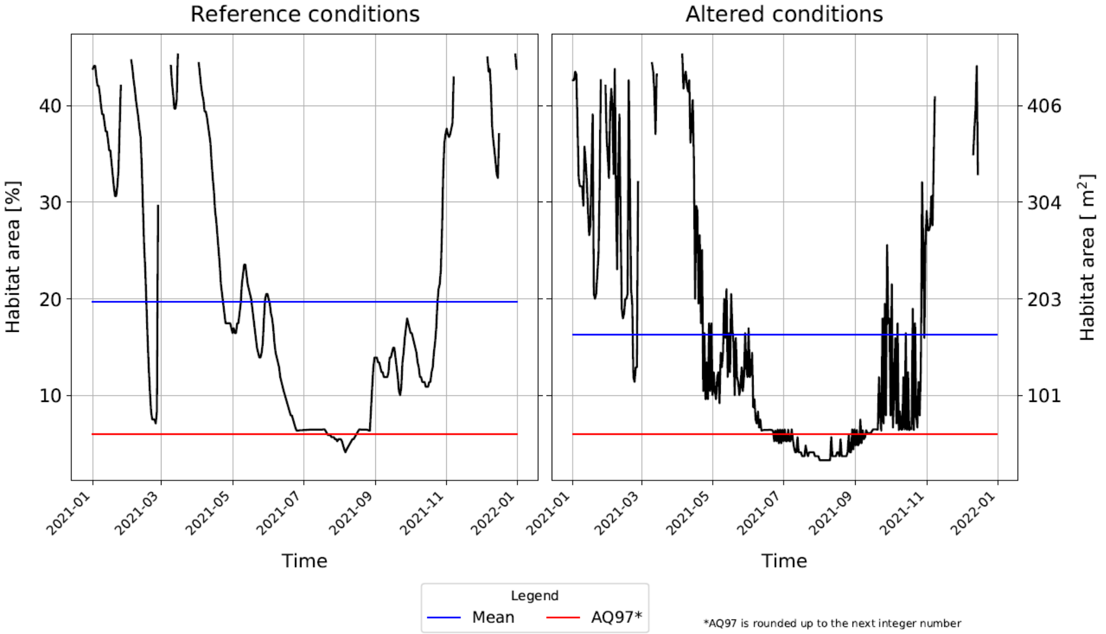


Figure 4.1.5. Habitat time series of the adult bullhead in reference and altered conditions

4.2. Ciecere River – below Dzirnavnieki HPP (Ciecere2)

This stretch of Ciecere River is not included into list of priority fish waters, but habitat is more suitable for salmonid fish species. Dzirnavnieki HPP is middle of three HPPs. According to Water use permits, guaranteed water discharge is determined as 0.30 m^3/s. Ecological flow is the same as guaranteed water discharge.

Ciecere2 River List of species of interest:

- Juvenile brown trout (*Salmo trutta*),
- Adult and juvenile chub (*Squalius cephalus*),
- Adult bullhead (*Cottus gobio*),
- Adult stone loach (*Barbatulus barbatulus*).

Habitat curves for selected fish species depending on flow rate are shown in Figure 4.2.1. These curves were modelled for each fish species of interest (brown trout, chub, bullhead, stone loach) that was pre-selected by fish expert especially for Ciecere River, site 2. It is evident that for some of species habitat area increases with increasing water discharge (bullhead, chub), but for other species available habitat reaches it's maximum or even starts to decrease (stone loach, brown trout) with increased water discharge.

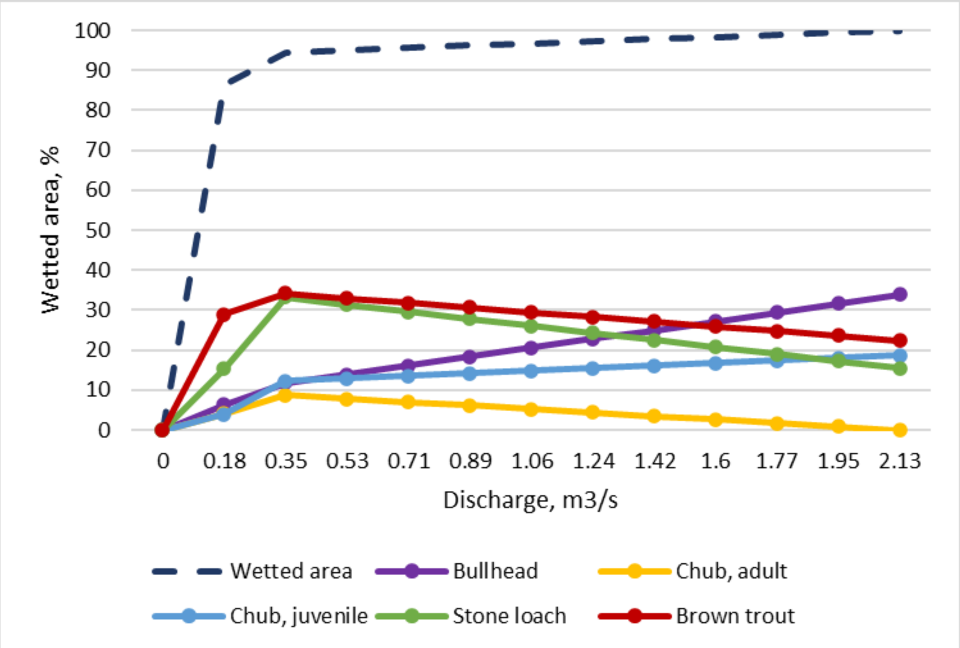


Figure 4.2.1. Habitat-Flow rating curve of Ciecere River downstream Dzirnavnieki HPP

Figures 4.2.2 and 4.2.3. show habitat suitability maps for brown trout and bullhead, which are species of high priority for Ciecere River. In total, Ciecere2 has very suitable habitats for brown trout. Our results shows that there are no significant habitat suitability fluctuations in summer low flow period. Riffle at the end of the stretch is especially suitable for brown trout. When discharge reaches Q_{annual_avg}, available habitat area starts to decrease because water velocity is too large for juvenile brown trout (Fig. 4.2.2).

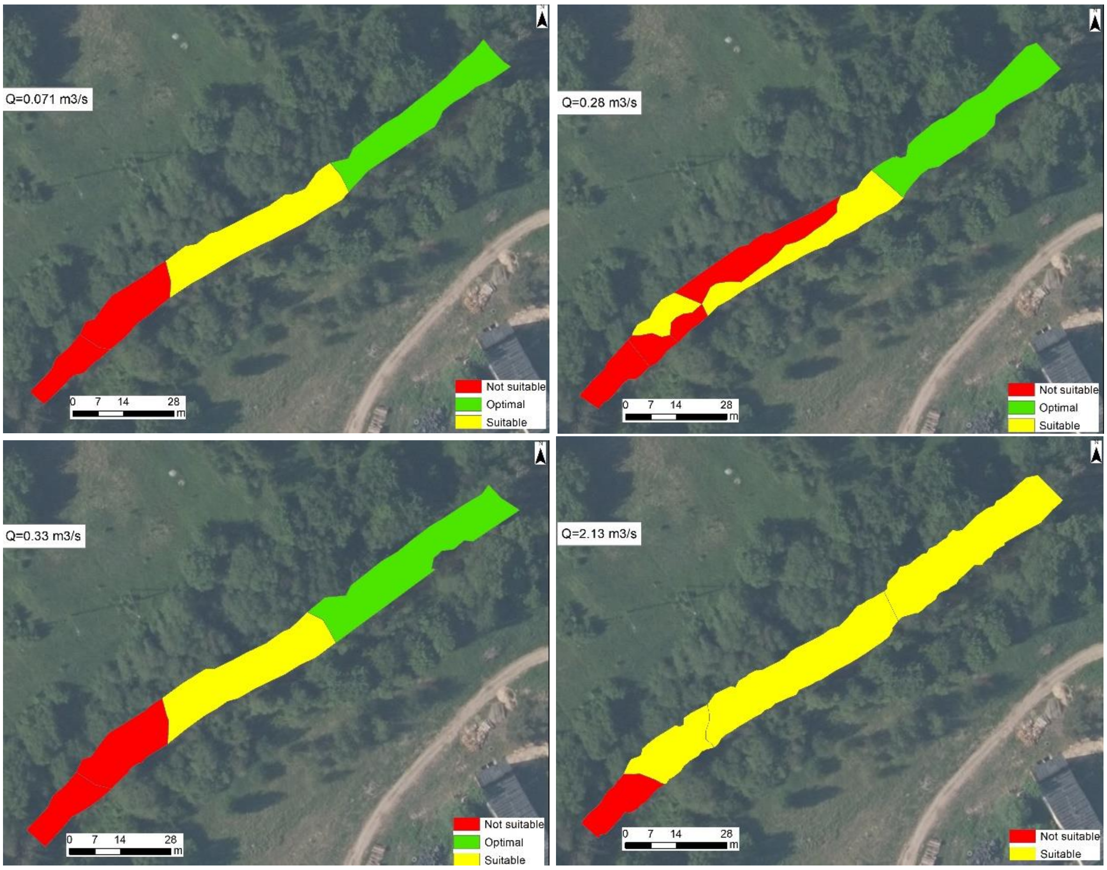
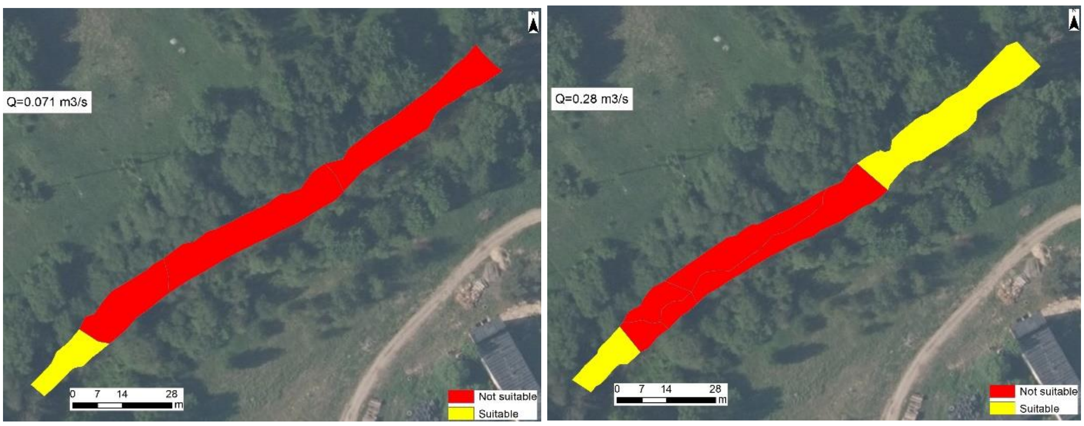


Figure 4.2.2. Habitat suitability maps for juvenile brown trout during four different discharges

For bullhead we observed significant available habitat increase when discharge increased from Q_{30_min} to Q_{30_avg} and small available habitat increase continued until discharge reached Q_{annual_avg} (Fig. 4.2.3).



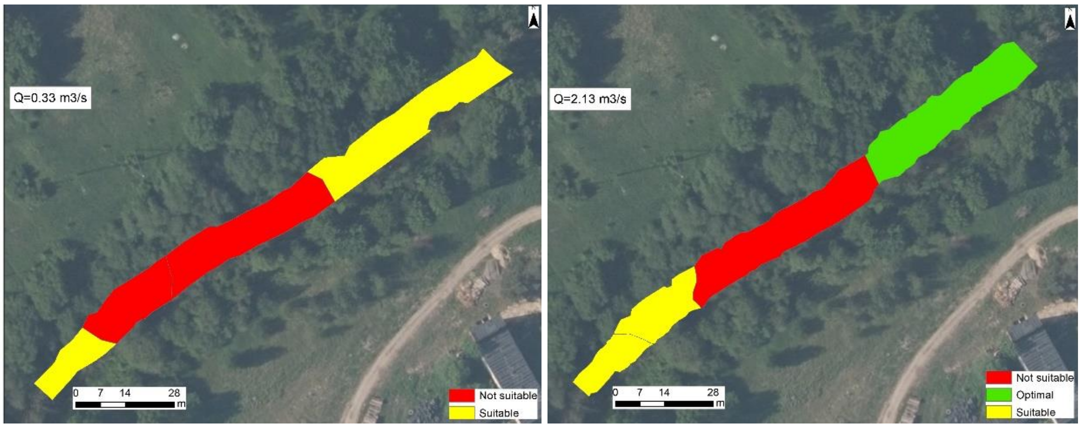


Figure 4.2.3. Habitat suitability maps for adult bullhead during four different discharges

Figures 4.2.4 and 4.2.5. show the habitat distribution in time during 2021 that is a year with normal water runoff. The red line on pictures is a threshold corresponding of habitat area with 97% of probability, and the blue line is an average habitat area. Results are different for the high priority fish species. Obviously the operating HPP don't have significant impact on available habitats for juvenile brown trout (Fig. 4.2.4) because of no obstacles downstream and free access for fish from the downstream.

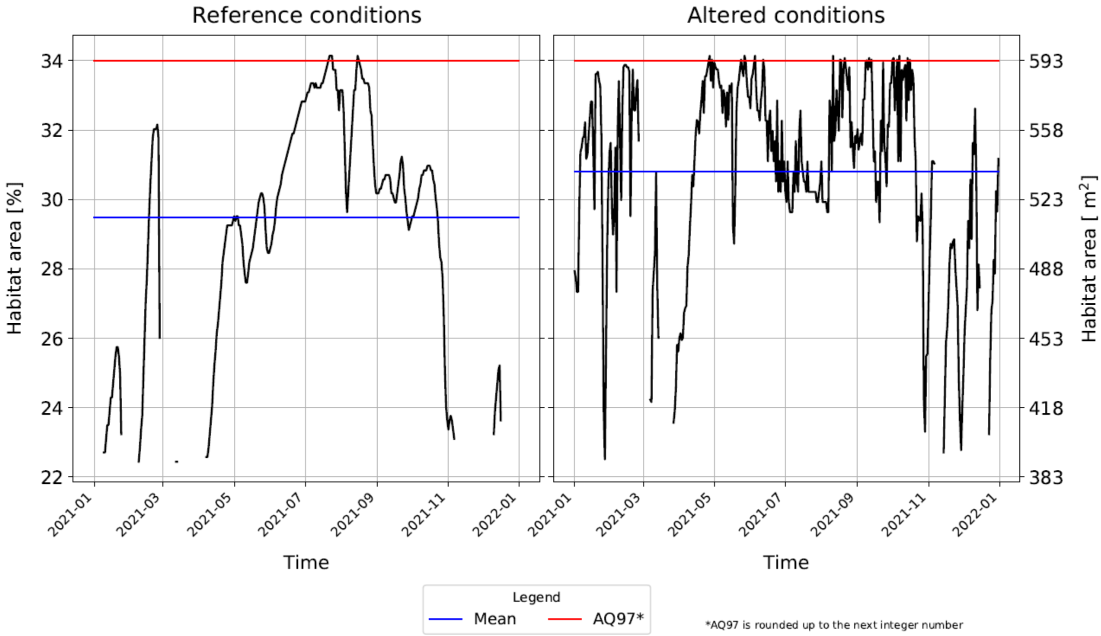


Figure 4.2.4. Habitat time series of the juvenile brown trout in reference and altered conditions

Adult bullhead is more impacted by operating HPP (Fig. 4.2.5). During late summer and autumn the significant continuous suitable habitat decrease can be observed, so fish is under significant hydrological pressure almost half a year.

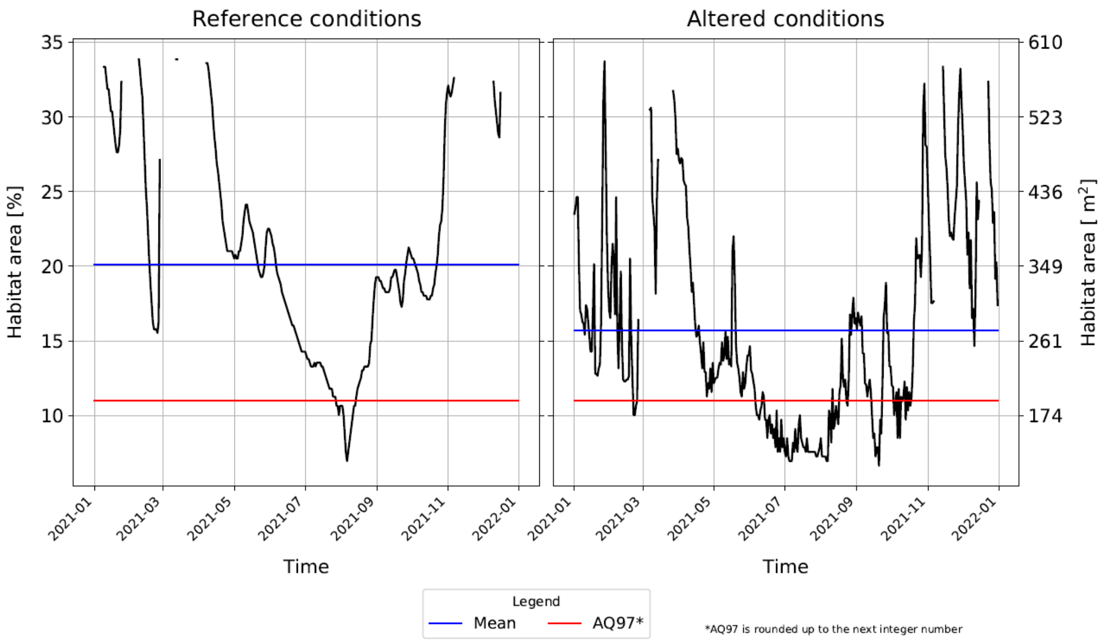


Figure 4.2.5. Habitat time series of the adult bullhead in reference and altered conditions

4.3. Ciecere River – below Pakuli HPP (Ciecere3)

This stretch of Ciecere River is included into list of priority fish waters and belongs to salmonid fish waters. Pakuli HPP is lowest of three HPPs and is located 32 km from river mouth. According to Water use permits, guaranteed water discharge is determined as 0.32 m^3/s. Ecological flow is 0.30 m^3/s.

Ciecere3 River List of species of interest:

- Juvenile brown trout (*Salmo trutta*),
- Adult chub (*Squalius cephalus*),
- Adult spirlin (*Alburnoides bipunctatus*),
- Adult stone loach (*Barbatulus barbatulus*),
- Adult bullhead (*Cottus gobio*).

Habitat curves for selected fish species depending on flow rate are shown in Figure 4.3.1. These curves were modelled for each fish species of interest (juvenile brown trout, adult chub, adult spirlin, adult stone loach, adult bullhead) that was pre-selected by fish expert especially for Ciecere River, site 3. It is evident that for some of species habitat area increases with increasing water discharge (bullhead, chub, spirlin), but for other species available habitat reaches it's maximum or even starts to decrease (brown trout) with increased water discharge.

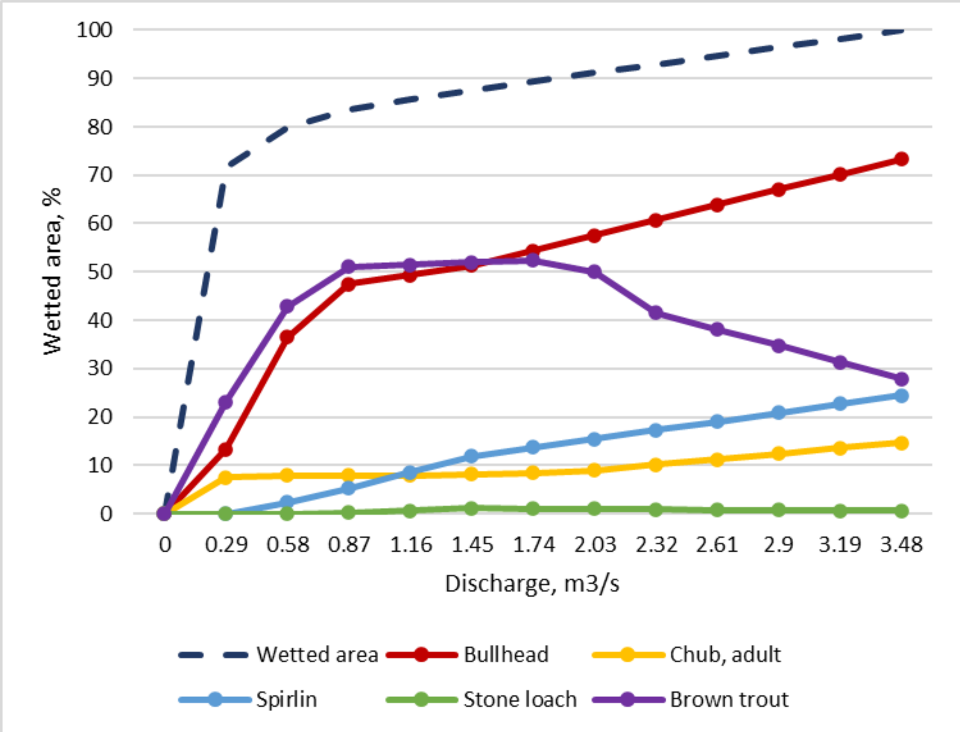
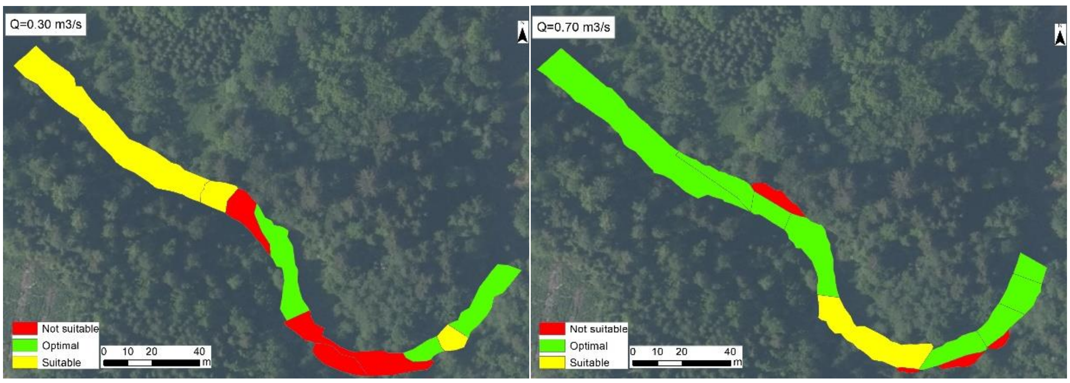


Figure 4.3.1. Habitat-Flow rating curve of Ciecere River downstream Pakuli HPP

Figures 4.3.2 and 4.3.3. show habitat suitability maps for brown trout and chub, which are species of high priority for Ciecere River. Similarly to other salmonid fish waters, brown trout reaches it's maximum available habitat when discharge is close to Q_{30_max}. When discharge reaches Q_{annual_avg}, available habitat area starts to decrease because water velocity is too large for juvenile brown trout (Fig. 4.3.2).



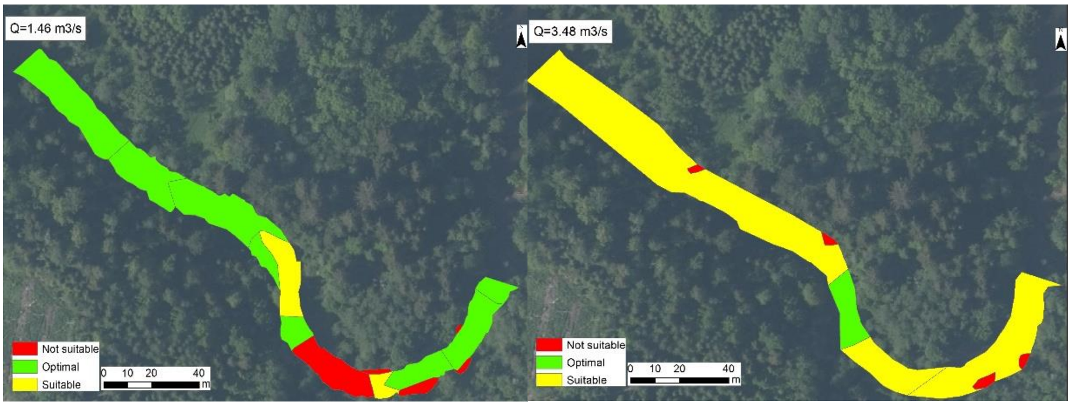


Figure 4.3.2. Habitat suitability maps for juvenile brown trout during four different discharges

Habitat availability for adult chub are very similar for different flow conditions (Fig. 4.3.3), although small habitat increase trend can be observed when discharge is close to Q_{annual_avg}.

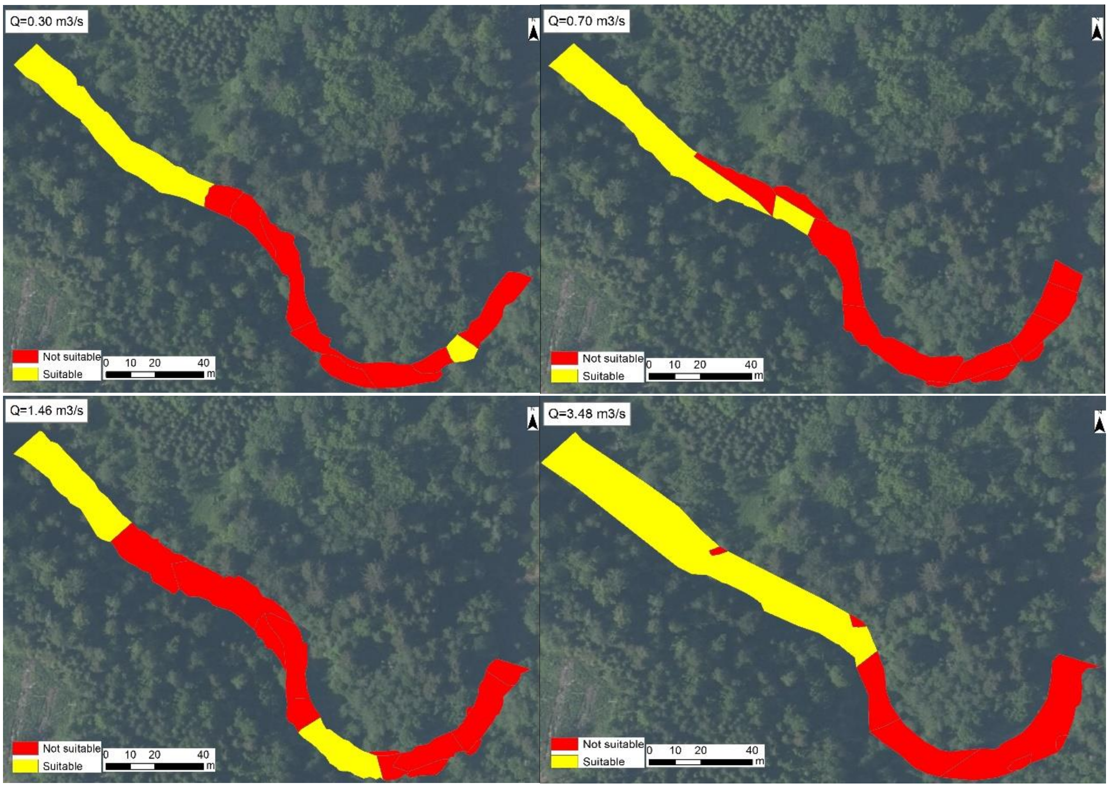


Figure 4.3.3. Habitat suitability maps for adult chub during four different discharges

Figures 4.3.4 and 4.32.5. show the habitat distribution in time particularly during 2021 that is a year with normal water runoff. The red line on pictures is a threshold corresponding of habitat area with 97% of probability, and the blue line is an average habitat area. Results show that operating HPP don't have significant impact on available habitat area for juvenile brown trout (Fig. 4.3.4). This river stretch is naturally suitable for salmonid fish species in most of year, although some habitat decrease in spring and late autumn season can be observed, when water discharge is naturally very high.

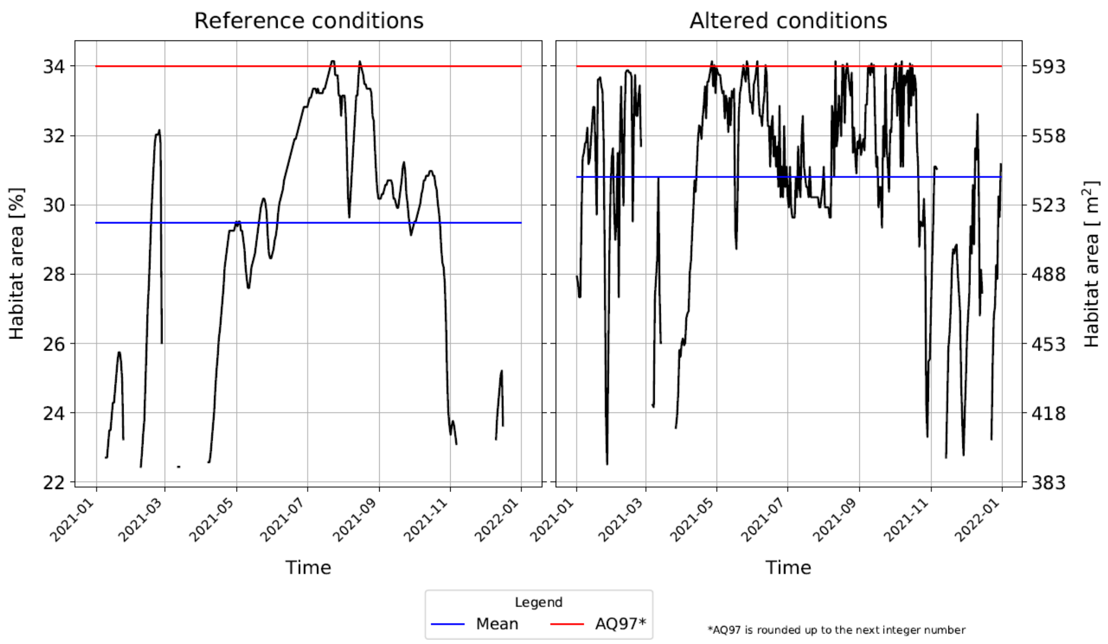


Figure 4.3.4. Habitat time series of the juvenile brown trout in reference and altered conditions

Different situation can be observed for adult chub (Fig. 4.3.5) and operating HPP have significant impact on habitat availability for this relatively large fish. Similar to other projects obtaining in the TRANSWAT project results show that the most critical period is summer and early autumn when almost no habitats are available for chub.

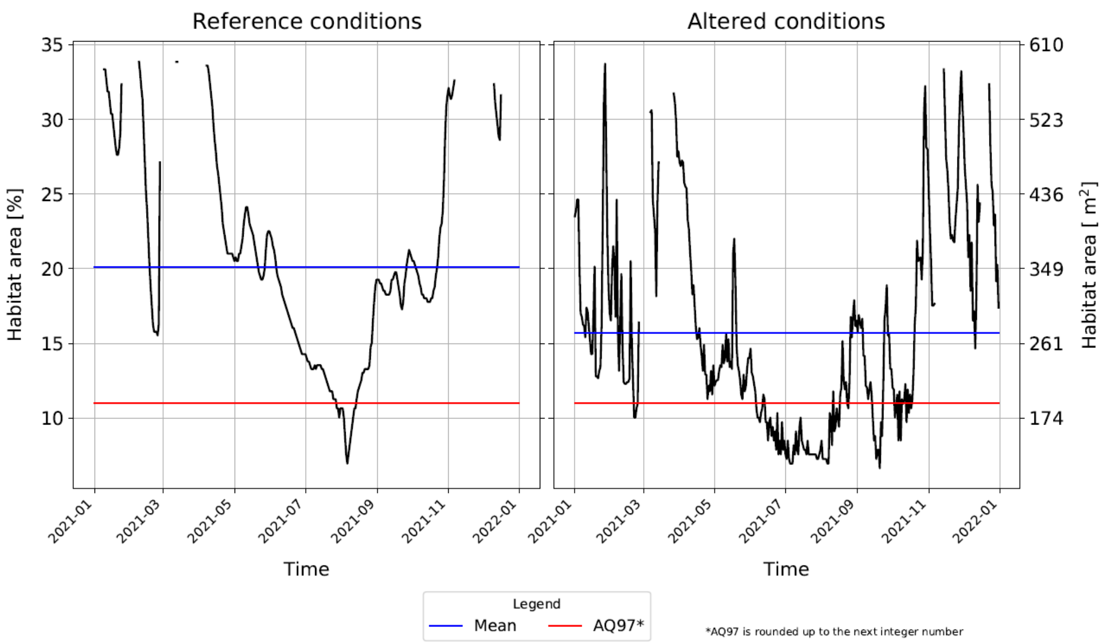


Figure 4.3.5. Habitat time series of the adult chub in reference and altered conditions

4.4. Losis River – below Lejnieki HPP (Losis1)

Losis River is not included into list of priority fish waters, but according to field surveys this site may belong to salmonid fish waters. Lejnieki HPP is lowest of two HPPs and is located 4 km from river mouth. According to Water use permits, guaranteed water discharge is determined as 0.093 m^3/s. Ecological flow is 0.20 m^3/s.

Losis1 River List of species of interest:

- Juvenile brown trout (*Salmo trutta*),
- Adult chub (*Squalius cephalus*),
- Adult common dace (*Leuciscus leuciscus*),
- Adult stone loach (*Barbatulus barbatulus*),
- Adult bullhead (*Cottus gobio*).

Habitat curves for selected fish species depending on flow rate are shown in Figure 4.4.1. These curves were modelled for each fish species of interest (common dace, bullhead, brown trout, stone loach, chub) that was pre-selected by fish expert especially for Losis River, site 1. For most of modelled fish species available habitat area increases with increasing water discharge and optimum flow can be determined only for adult stone loach. Available habitat area for most of modelled fish species are below 20% of river stretch indicating that this part of river is under significant hydromorphological pressure.

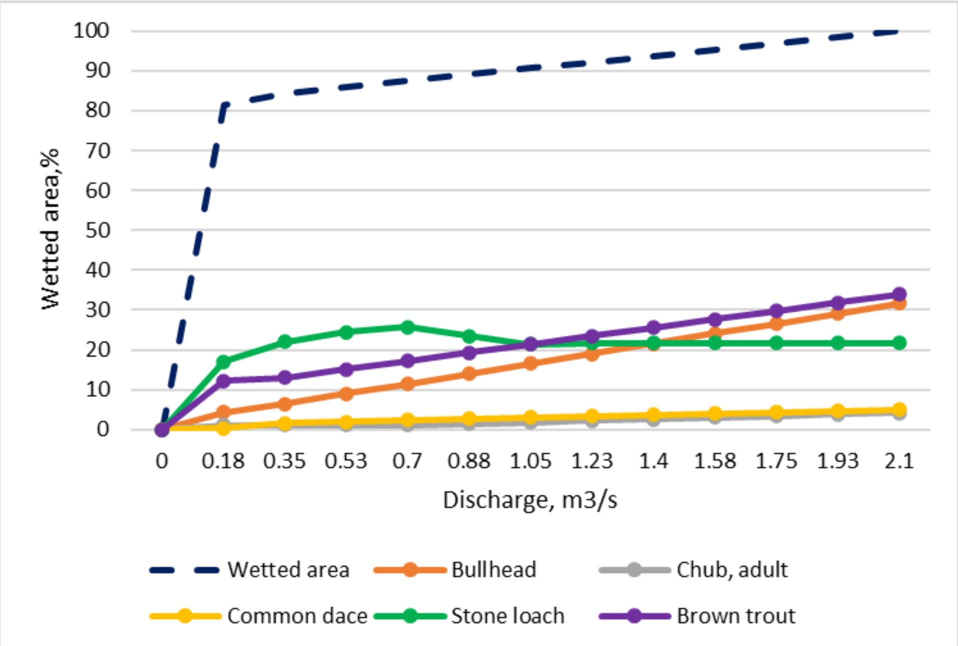


Figure 4.4.1. Habitat-Flow rating curve of Losis River downstream Lejnieki HPP

Figures 4.4.2 and 4.4.3. show habitat suitability maps for brown trout and bullhead, which are species of high priority for Losis River. Habitat availability (sum of suitable and optimal habitats) show only insignificant increase when water discharge increases from Q_{30_min} to Q_{30_max}, but it rapidly reaches it's maximum when discharge is close to Q_{annual_avg}.

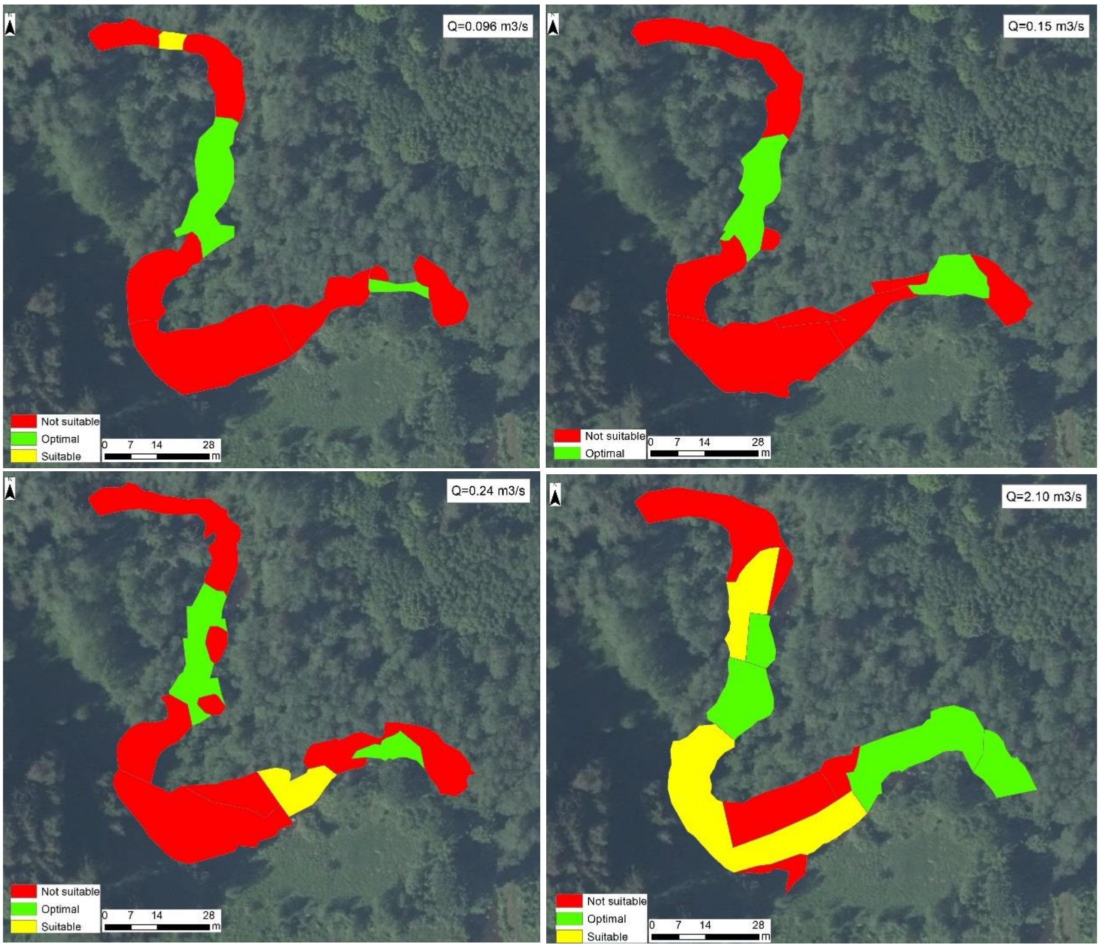
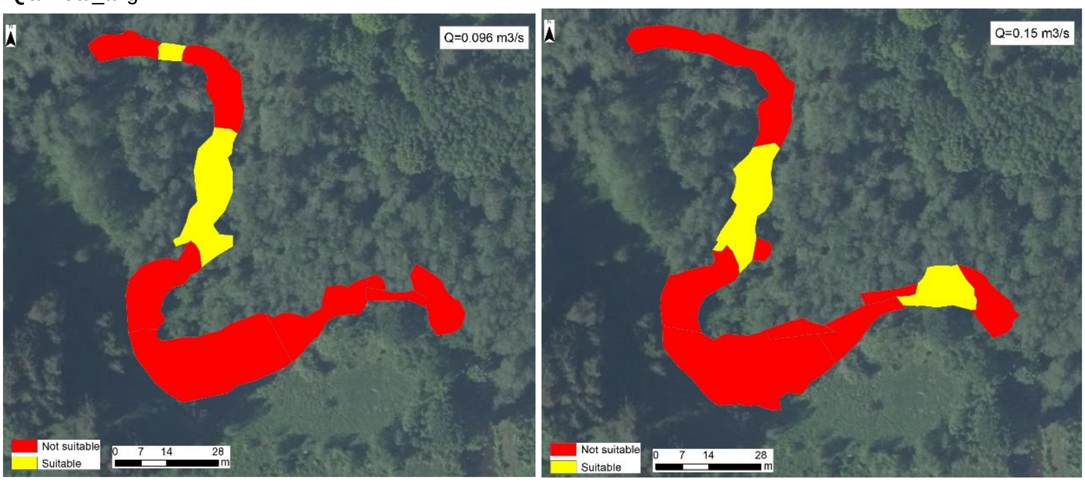


Figure 4.4.2. Habitat suitability maps for juvenile brown trout during four different discharges

Similar trend can be observed also for bullhead (Fig. 4.4.3): insignificant changes in low flow period and rapid available habitat increase during Q_{annual_avg}.



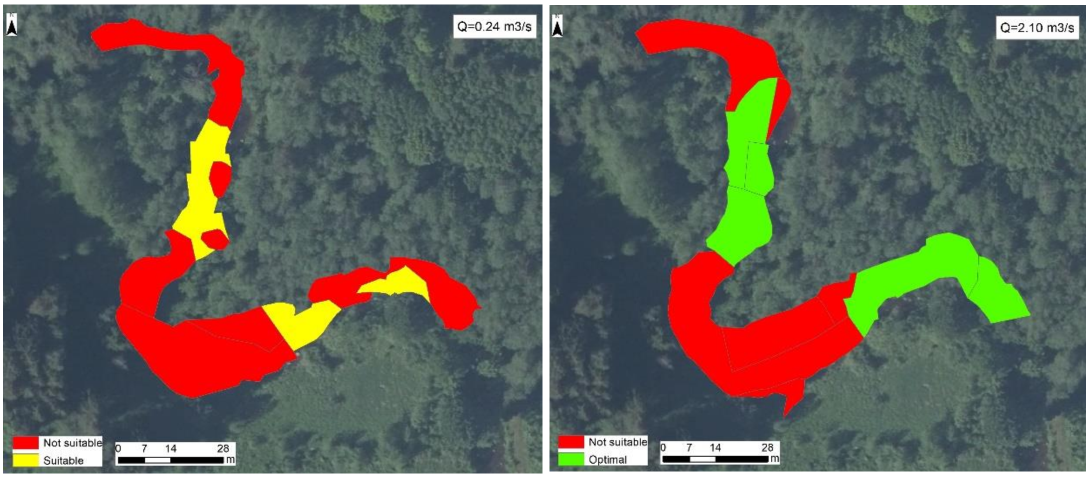


Figure 4.4.3. Habitat suitability maps for adult bullhead during four different discharges

Figures 4.4.4 and 4.4.5. show the habitat distribution in time particularly during 2021 that is a year with normal water runoff. The red line on pictures is a threshold corresponding of habitat area with 97% of probability, and the blue line is an average habitat area. Results are very similar for all modelled fish species in Losis1 and shows that this river stretch is strongly affected by hydrological pressure caused by HPP. Almost half of potential habitats for brown trout and bullhead are lost due too low water level below HPP and available habitat depletion starts already in May, just after spring high flows.

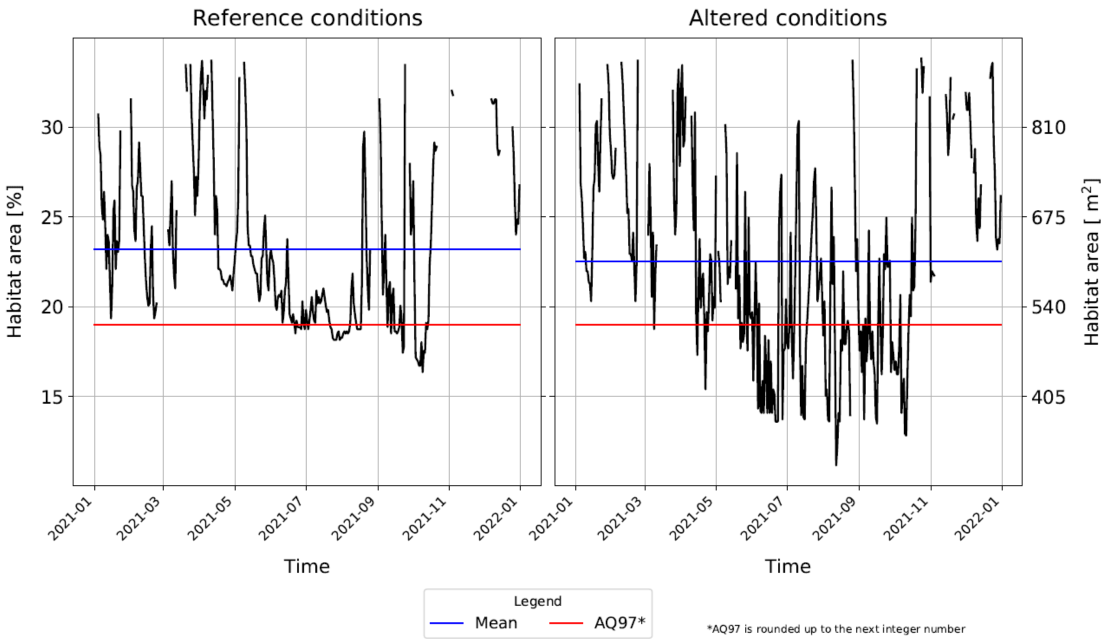


Figure 4.4.4. Habitat time series of the juvenile brown trout in reference and altered conditions

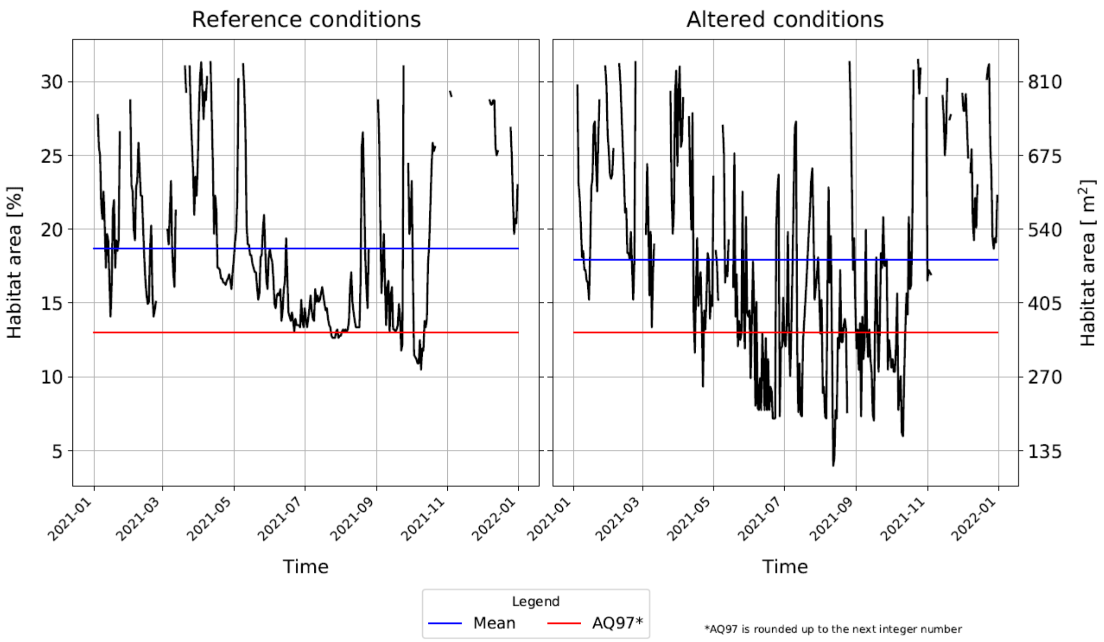


Figure 4.4.5. Habitat time series of the adult bullhead in reference and altered conditions

4.5. Losis River – below Grantini HPP (Losis2)

Losis River is not included into list of priority fish waters, but according to field surveys this particular site may belong to cyprinid fish waters. This site is located between two HPP and have altered habitat conditions. Grantini HPP is highest of two HPPs and is located 7.6 km from river mouth. According to Water use permits, guaranteed water discharge is determined as 0.029 m^3/s. Ecological flow is 0.20 m^3/s.

Losis2 River List of species of interest:

- Juvenile brown trout (*Salmo trutta*),
- Adult chub (*Squalius cephalus*),
- Adult common dace (*Leuciscus leuciscus*),
- Adult stone loach (*Barbatulus barbatulus*),
- Adult bullhead (*Cottus gobio*).

Habitat curves for selected fish species depending on flow rate are shown in Figure 4.5.1. These curves were modelled for each fish species of interest (common dace, bullhead, brown trout, stone loach, chub) that was pre-selected by fish expert especially for Losis River, site 2. For most of modelled fish species available habitat area increases with increasing water discharge and optimum flow can be determined only for adult stone loach. This indicates that this river stretch is strongly affected by operating HPP.

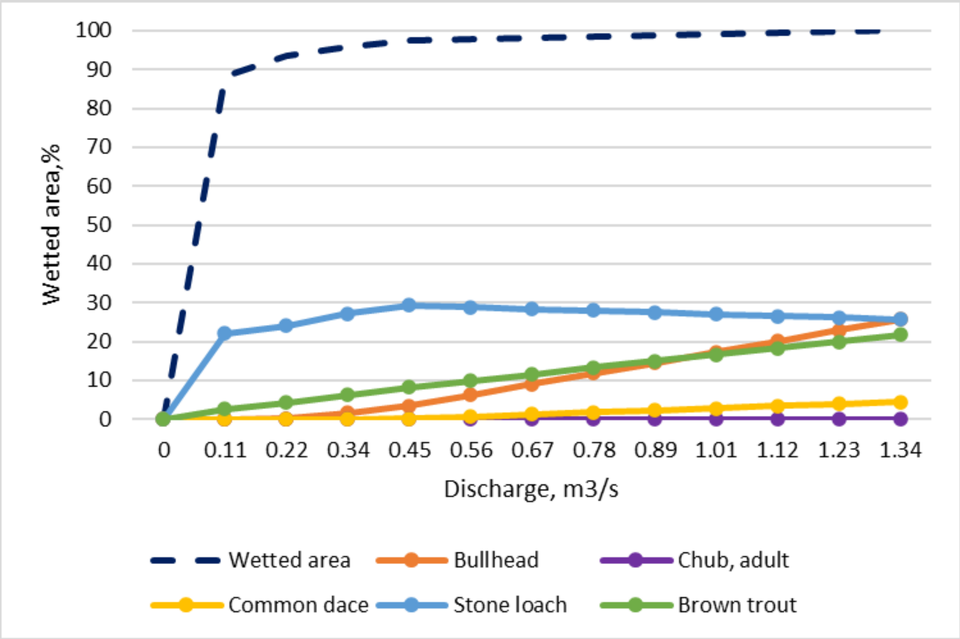


Figure 4.5.1. Habitat-Flow rating curve of Losis River downstream Grantini HPP

Figures 4.5.2 and 4.5.3. show habitat suitability maps for brown trout and stone loach, which are species of high priority for Ciecere River. In general, this particular river stretch of Losis2 is not very suitable for brown trout, probably because of natural reasons and hydromorphological alterations caused by local village and operating HPP. During low flow period Q_{30_min} – Q_{30_max} only habitats in two artificial riffles are available for brown trout (Fig. 4.5.2). The rapid available habitat increase could be observed, when water discharge reaches Q_{annual}, but only in units with hard substrate.

Figure 4.5.2. Habitat suitability maps for juvenile brown trout during four different discharges

Different situation can be observed for adult stone loach. When discharge is the lowest (Q_{30_min} and Q_{30_avg}) no availability changes can be observed and all river stretch is suitable for stone loach. When discharge is close to Q_{30_max}, habitat availability slowly starts to increase and reaches it's maximum when discharge is close to Q_{annual}.

Figure 4.5.3. Habitat suitability maps for adult stone loach during four different discharges

Figures 4.5.4 and 4.5.5. show the habitat distribution in time particularly during 2021 that is a year with normal water runoff. The red line on pictures is a threshold corresponding of habitat area with 97% of probability, and the blue line is an average habitat area. Obtained results are very similar for all modelled fish species, except stone loach. Results show that operating HPP cause enormous decrease of habitat availability for brown trout (Fig. 4.5.4) and habitat depletion starts already in late spring. Situation is different only for adult stone loch whose habitat availability is not particularly affected by operating HPP (Fig. 4.5.5).

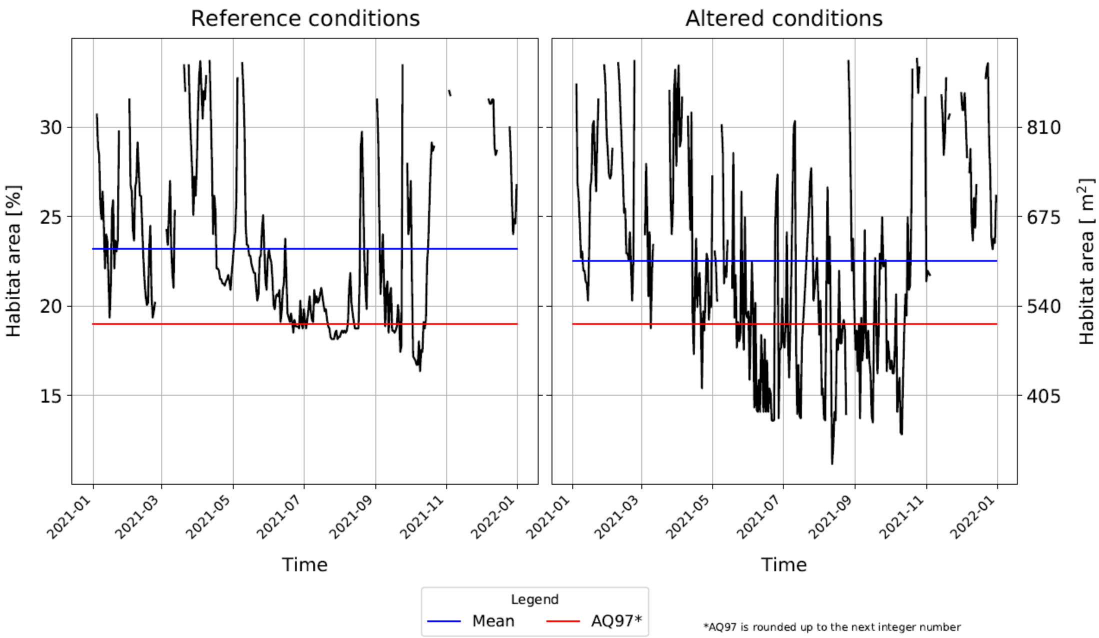


Figure 4.5.4. Habitat time series of the juvenile brown trout in reference and altered conditions

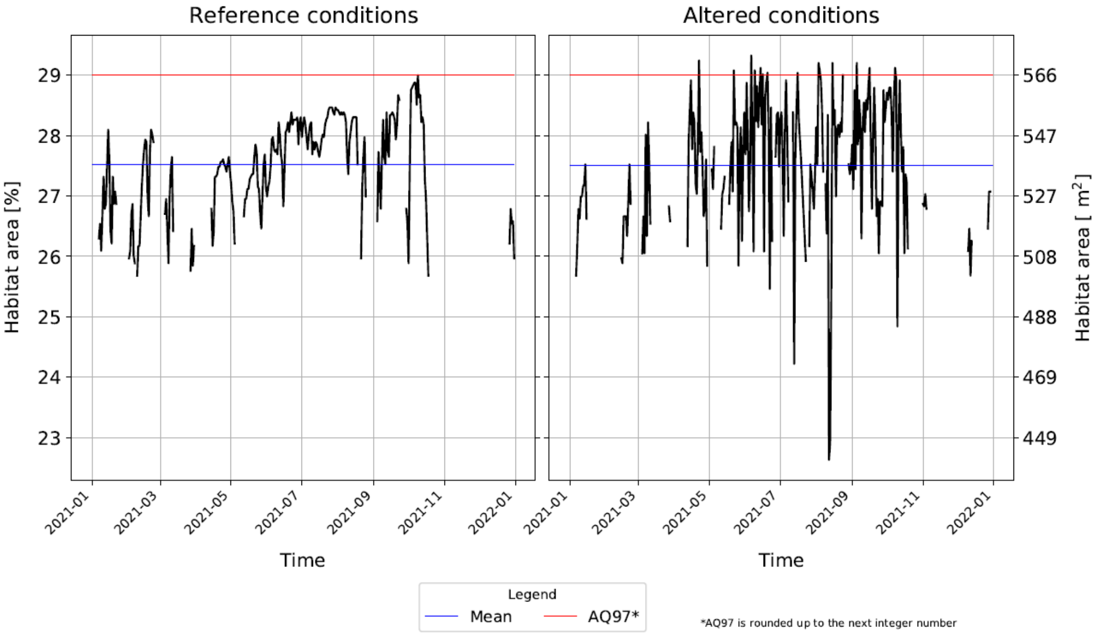


Figure 4.5.5. Habitat time series of the adult stone loach in reference and altered conditions

5. MODELLING RESULTS FOR LITHUANIAN CASE STUDIES

Varduva River List of species of interest:

- Juvenile salmon (*Salmo salar*),
- Juvenile brown trout (*Salmo trutta*),
- Vimba (*Vimba vimba*),
- Spirlin (*Alburnoides bipunctatus*),
- Bullhead (*Cottus gobio*)

5.1. Varduva River – below Kulšėnai HPP

Kulšėnai HPP is most upstream of five HPP in the Varduva. According to the Rules for the operation of the hydropower plants, guaranteed water discharge is determined as 0.2 m^3/s.

Habitat curves for fish species of interest depending on discharge are shown in Figure 5.1.1. The habitat area of bullhead and juvenile brown trout increases significantly up to the discharge of ~0.7 m^3/s and then tends to stabilize. The habitat suitable for juvenile salmon occurs in the stretch at a discharge of 0.4 m^3/s, the most rapid increase being within the discharge of 0.5-0.7 m^3/s. The habitat area of spirlin and vimba increases almost uniformly with increasing flow; however, the river stretch becomes suitable for vimba only at a disharge greater than 0.5 m^3/s.

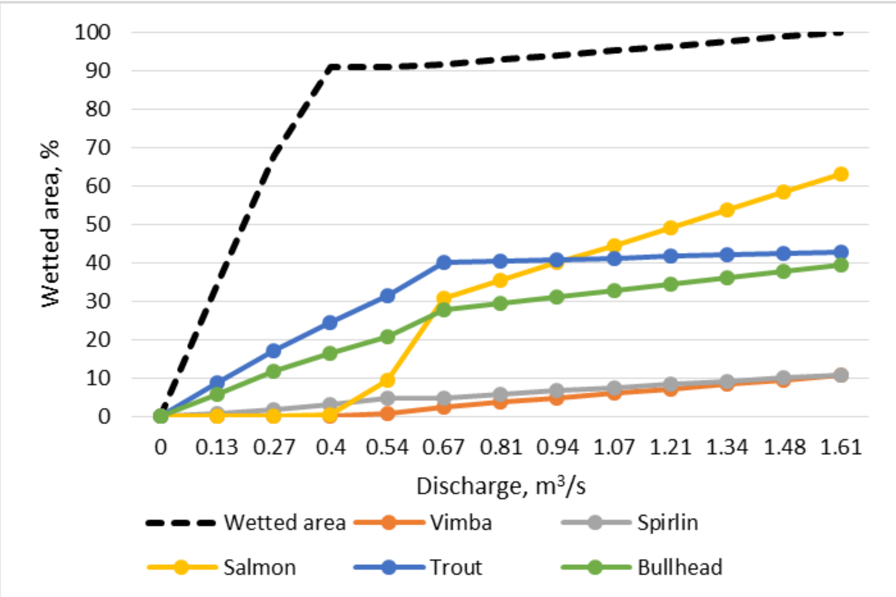


Figure 5.1.1. Habitat-Flow rating curve of Varduva River downstream Kulšėnai HPP

Figure 5.1.2 show habitat suitability maps for spirlin and juvenile brown trout, which are expected to be present in the Varduva downstream Kulšėnai HPP irrespective of migration barriers. At conditions close to very low flow conditions (0.36 m^3/s; Q_{30_min} = 0.20 m^3/s) the area of suitable habitat for spirlin is very small, but at Q_{30_avg} (0.62 m^3/s) it already covers almost twice as much of the reach. Suitable habitats for juvenile brown trout are present even at very low flows, but the maximum area of optimal habitat is reached at Q_{30_avg} and then stabilises.

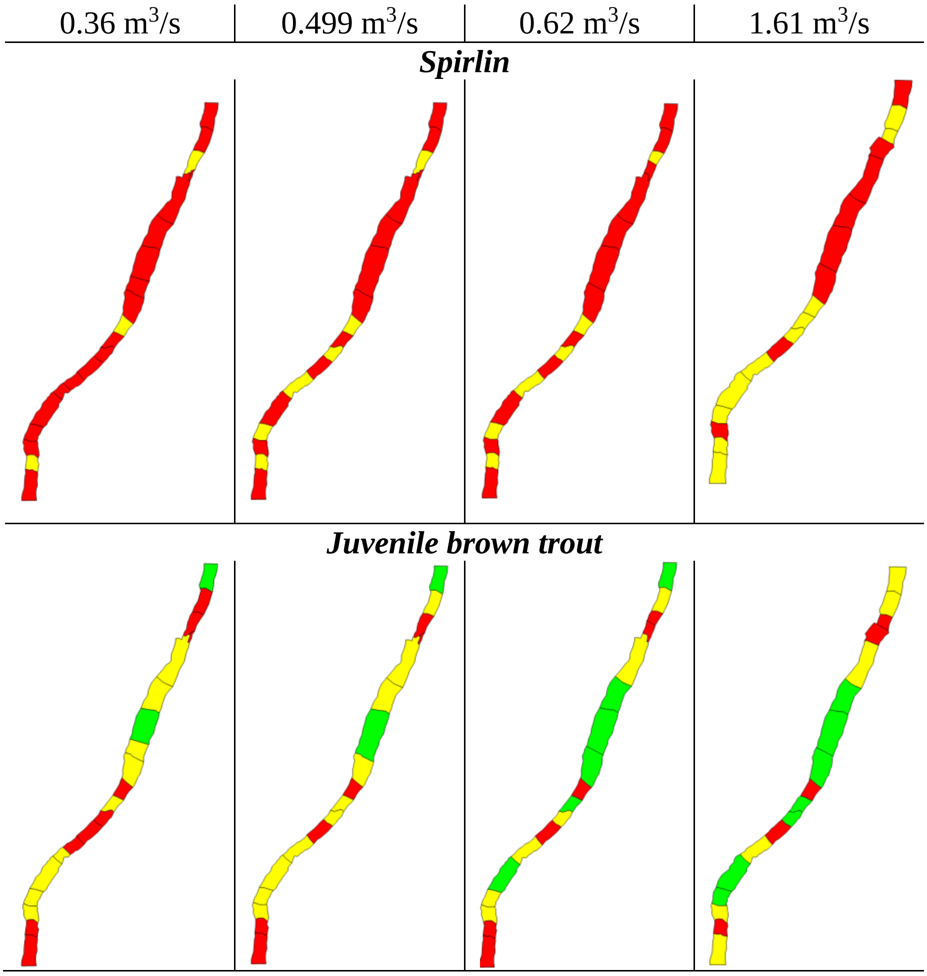


Figure 5.1.2. Habitat suitability maps for juvenile brown trout and spirlin during four different discharges

Figures 5.1.3 and 5.1.4 show the habitat distribution in time during 2021 that is a year with normal water runoff. The red line on pictures is a threshold corresponding of habitat area with 97% of probability, and the blue line is an average habitat area. The results show that the impact of the operation of the Kulšėnai hydropower plant on the habitat availability of the modelled fish species is relatively low. Some reduction in the area of habitats suitable for the species of interest occurs during the low flow period, but this is relatively minor and of short duration. The value of the habitat availability index IH=0.73, which indicates the overall deviation of the spatial and temporal availability of habitats from natural conditions due to the operation of the HPP, indicates that the impact of the Kulšėnai HPP on habitat availability is the lowest in the Varduva HPP chain.

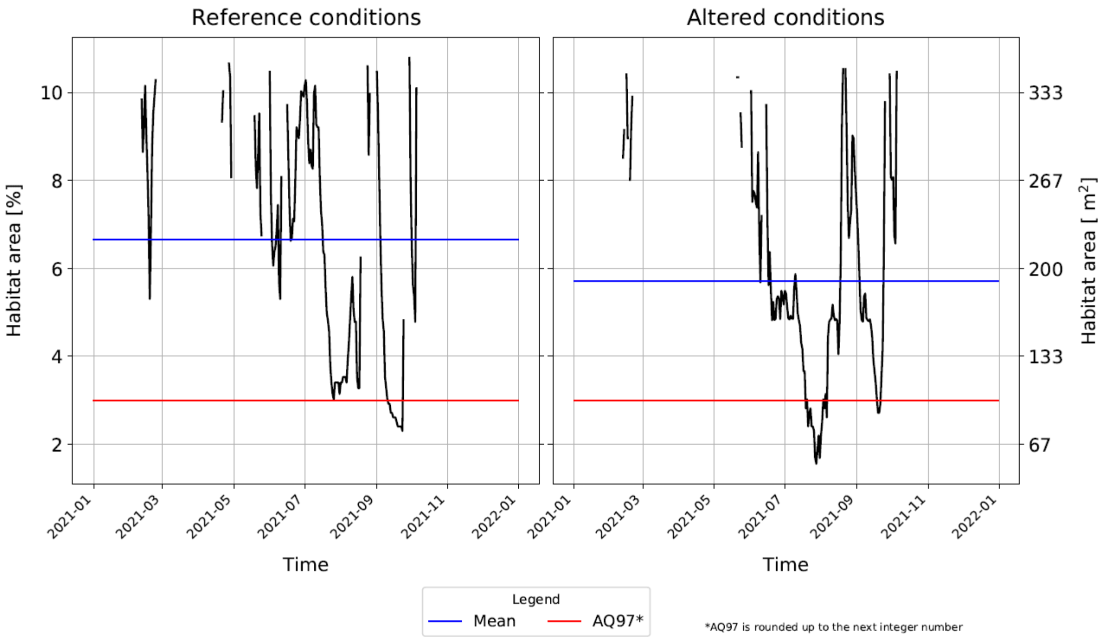


Figure 5.1.3. Habitat time series of the spirlin in reference and altered conditions

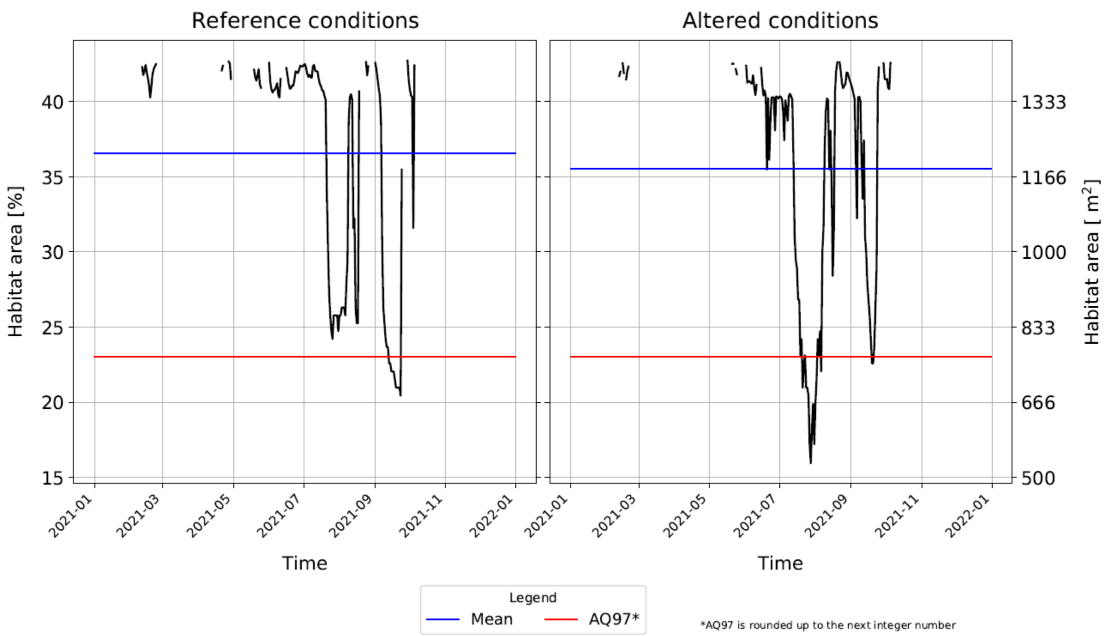


Figure 5.1.4. Habitat time series of the juvenile brown trout in reference and altered conditions

5.2. Varduva River – below Renavas HPP

Renavas HPP is the second from the upstream in the chain of five HPP in the Varduva. According to the Rules for the operation of the hydropower plants, guaranteed water discharge is determined as 0.39 m^3/s.

Habitat curves for fish species of interest depending on discharge are shown in Figure 5.2.1. Due to specific morphology of the river channel, suitable habitats for juvenile salmon and bullhead are almost absent in the studied stretch, occupying only up to 2.3% of the wetted area. Variation of habitat area suitable for juvenile brown with flow is small: it increases slightly up to a discharge of ~0.9 m^3/s and then tends to stabilize. Suitable habitats for vimba only occurs in the stretch at flows above 1.0 m^3/s. At very low flows (<0.2 m^3/s), there is no suitable habitat for spirlin in the studied reach, but as the flow increases above 0.2 m^3/s, the area of habitat suitable for spirlin increases almost continuously.

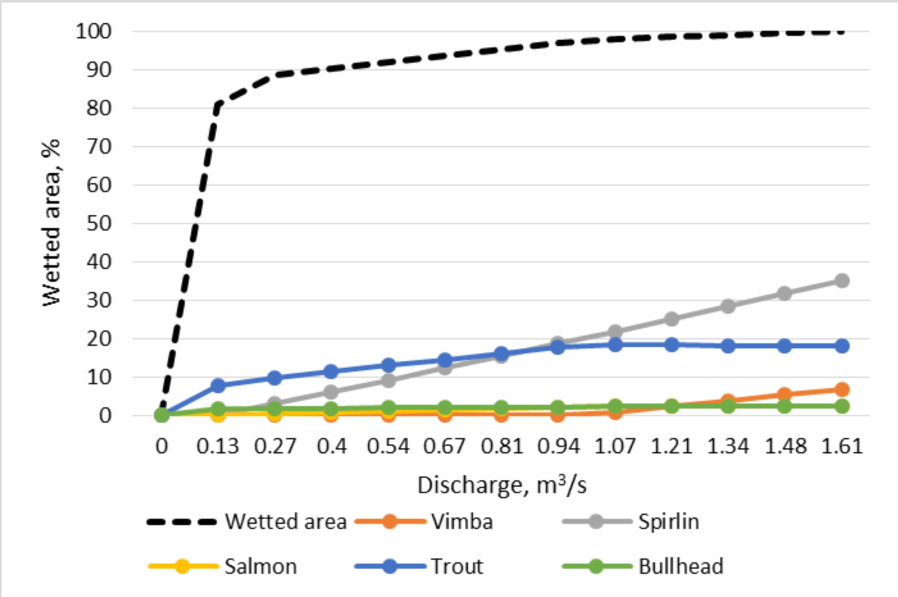


Figure 5.2.1. Habitat-Flow rating curve of Varduva River downstream Renavas HPP

Figure 5.2.2 show habitat suitability maps for spirlin and juvenile brown trout, which are expected to be present in the Varduva downstream Renavas HPP irrespective of migration barriers. At a very low flow (0.162 m^3/s), which twice less than Q_{30_min} (0.39 m^3/s), there are no suitable habitat for spirlin at all. At Q_{30_avg} discharge, it already occupies more than 12% of the wetted area, while at >1 m^3/s it covers most of the reach. Suitable habitat for juvenile brown trout is present even at very low flows, but habitat area increases with increasing flow.

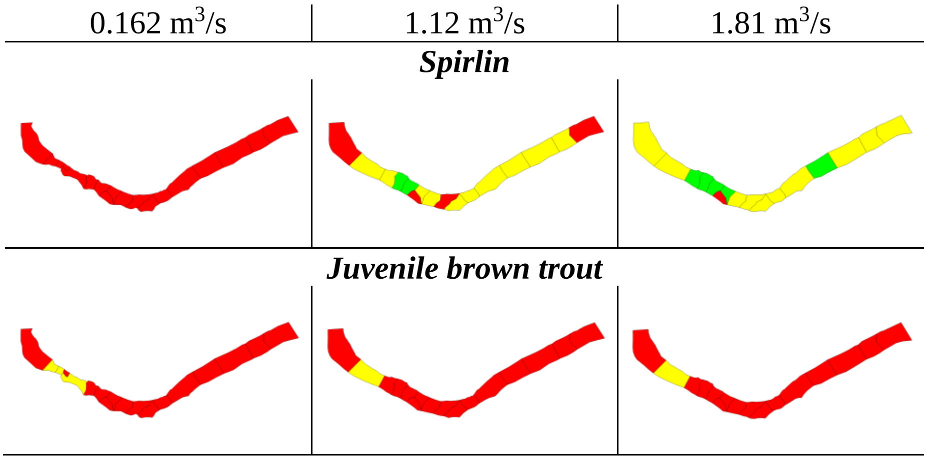


Figure 5.2.2. Habitat suitability maps for juvenile brown trout and spirlin during four different discharges

Figures 5.2.3 and 5.2.4 show the habitat distribution in time during 2021 that is a year with normal water runoff. The red line on pictures is a threshold corresponding of habitat area with 97% of probability, and the blue line is an average habitat area. The results show that the impact of the operation of the Renavas hydropower plant on the habitat availability of the modelled fish species is very strong. When the power plant operates during the dry season, there is almost no suitable habitat for the spirlin and the area of suitable habitat for juvenile brown trout is significantly reduced. The habitat availability index IH=0.40, indicating the total spatial and temporal deviation of habitat availability from natural conditions due to the HPP, shows that the impact of the Renavas HPP on the availability of habitats for the species of interest is very strong, and is the strongest in the Varduva hydropower plant network.

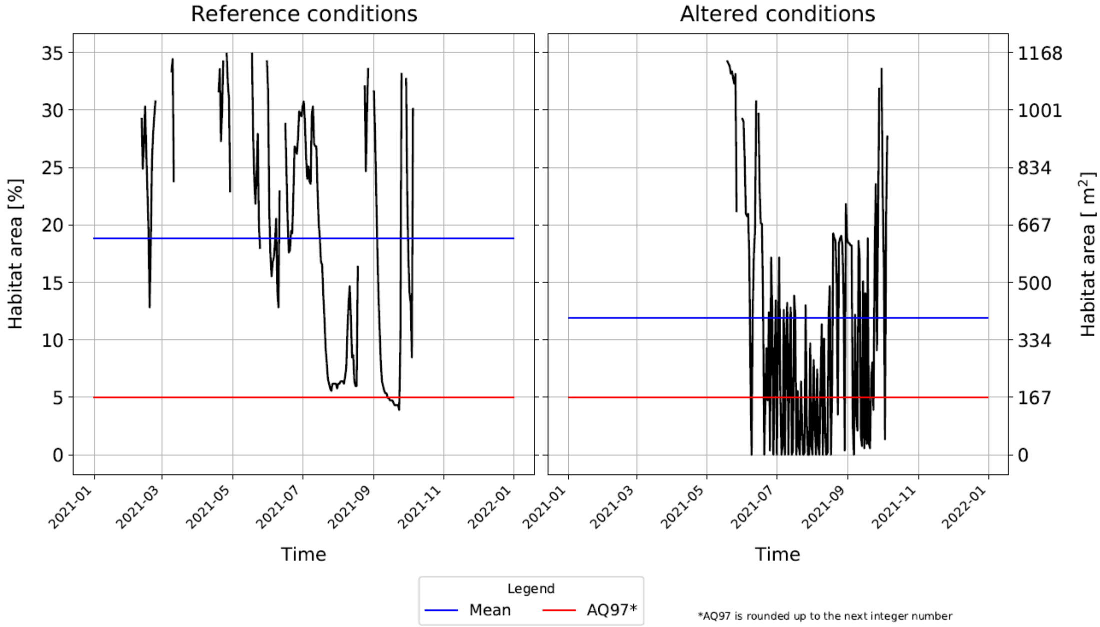


Figure 5.2.3. Habitat time series of the spirlin in reference and altered conditions

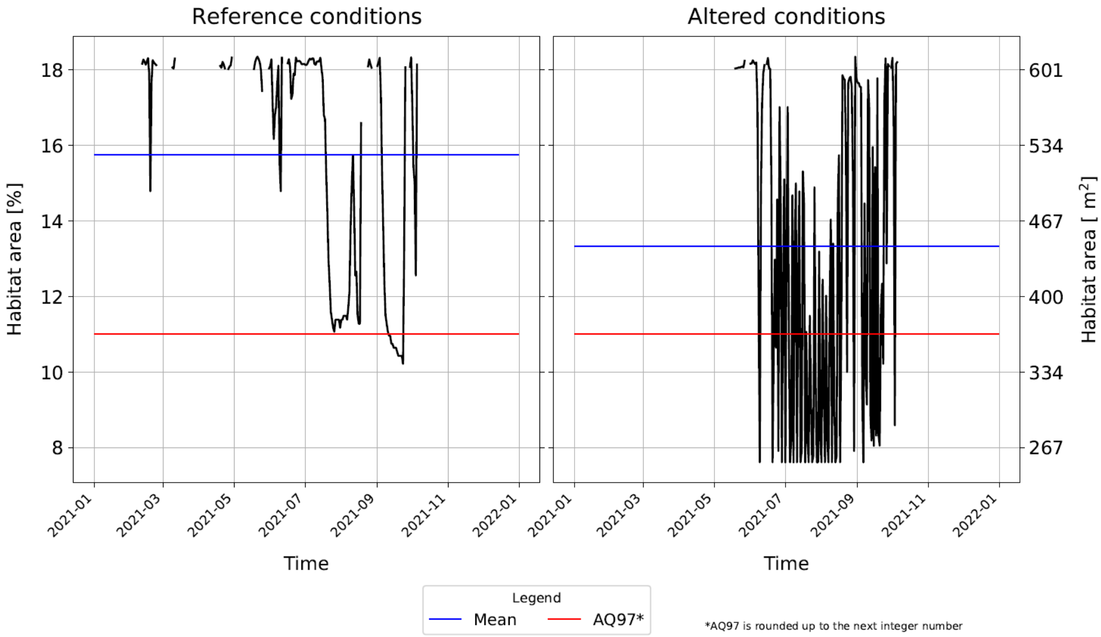


Figure 5.2.4. Habitat time series of the juvenile brown trout in reference and altered conditions

5.3. Varduva River – below Vadagiai HPP

Vadagiai HPP is the third from the upstream in the chain of five HPP in the Varduva. According to the Rules for the operation of the hydropower plants, guaranteed water discharge is determined as 0.41 m^3/s.

Habitat curves for fish species of interest depending on discharge are shown in Figure 5.3.1. The habitat area of spirlin and bullhead increases almost uniformly with increasing flow. The habitat area of juvenile brown trout increases significantly up to the discharge of ~0.8 m^3/s and then tends to stabilize. The river stretch becomes suitable for vimba and juvenile salmon only at a discharge greater than 0.8 m^3/s, but as the flow increases above 0.8 m^3/s, the area of suitable habitat increases almost continuously.

Figure 5.3.2 show habitat suitability maps for spirlin and juvenile brown trout, which are expected to be present in the Varduva downstream Renavas HPP irrespective of migration barriers. At a very low flow (0.163 m^3/s), which more than twice less than Q_{30_min} (0.41 m^3/s), the area of habitat suitable for spirlin covers less than 1% of the wetted area. At a discharge of 0.967 m^3/s, which is quite close to Q_{30_avg} (0.68 m^3/s), it already occupies nearly 8% of the wetted area. Suitable habitat for juvenile brown trout is present even at very low flow, but at a discharge close to Q_{30_avg} it covers most of the river stretch studied.

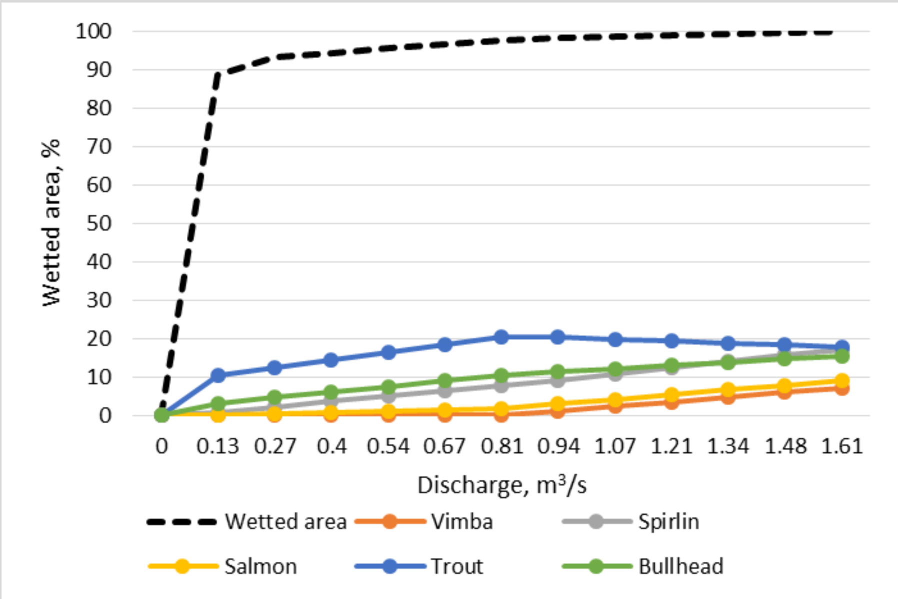


Figure 5.3.1. Habitat-Flow rating curve of Varduva River downstream Vadagiai HPP

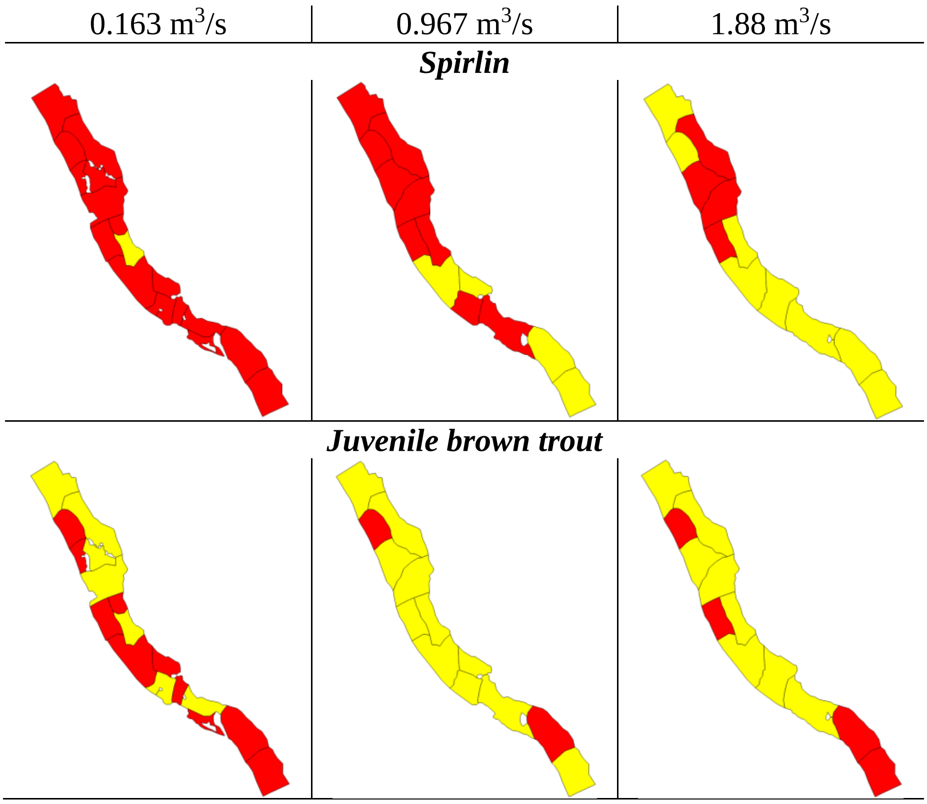


Figure 5.3.2. Habitat suitability maps for juvenile brown trout and spirlin during four different discharges

Figures 5.3.3 and 5.3.4 show the habitat distribution in time during 2021 that is a year with normal water runoff. The red line on pictures is a threshold corresponding of habitat area with 97% of probability, and the blue line is an average habitat area. The results show that spatial and temporal availability of habitats suitable for spirlin and juvenile brown trout is significantly reduced.

However, they reflect the impact of the Renavas hydropower plant, as the Vadagiai HPP does not operate during the low-flow season. The habitat availability index IH=0.45, indicating the overall spatial and temporal deviation of habitat availability from natural conditions due to the HPP, shows once again that the impact of the Renavas HPP on the habitat availability of the species of interest is very strong and can be felt over a large distance from the Renavas HPP, even on the section of the river downstream of the Vadagiai HPP.

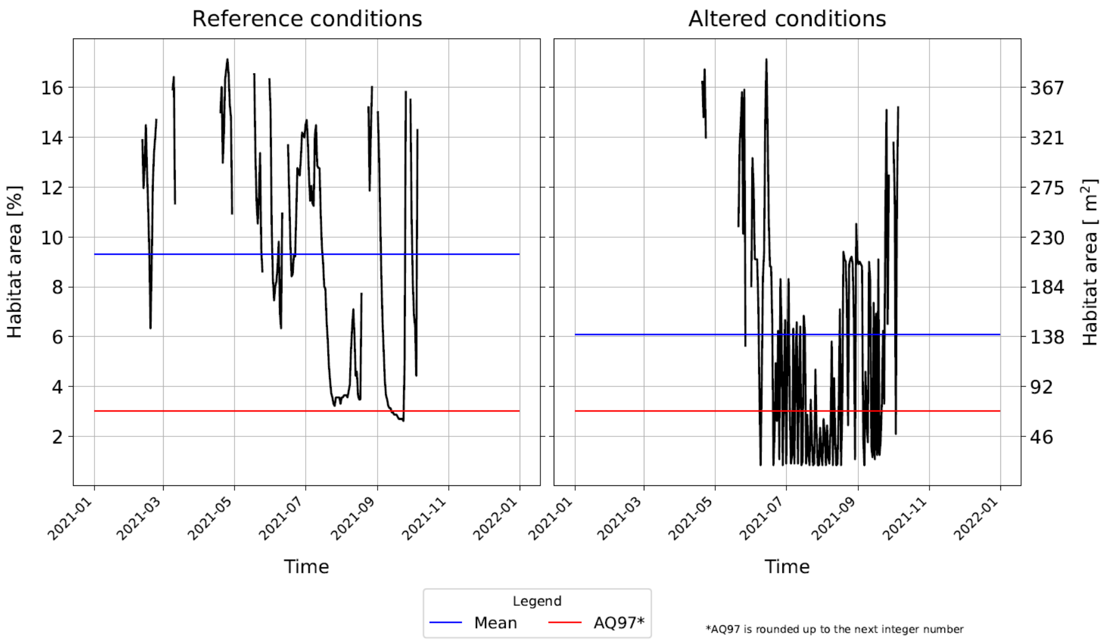


Figure 5.3.3. Habitat time series of the spirlin in reference and altered conditions

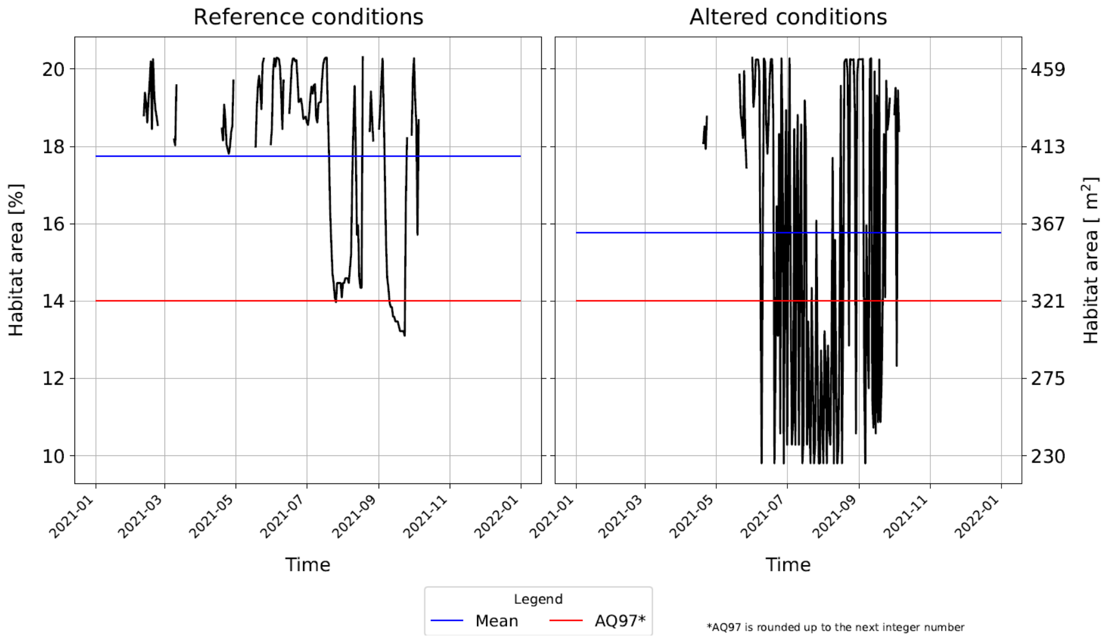


Figure 5.3.4. Habitat time series of the juvenile brown trout in reference and altered conditions

5.4. Varduva River – below Ukrinai HPP

Ukrinai HPP is the fourth from the upstream in the chain of five HPP in the Varduva. According to the Rules for the operation of the hydropower plants, guaranteed water discharge is determined as 0.46 m^3/s.

Habitat curves for fish species of interest depending on discharge are shown in Figure 5.4.1. Due to specific morphology of the river channel, suitable habitats for vimba are absent in the studied stretch. The habitat area of bullhead, juvenile brown trout and juvenile salmon increases up to the discharge of ~0.8 m^3/s and then tends to stabilize. The habitat area of spirlin increases almost uniformly with increasing flow.

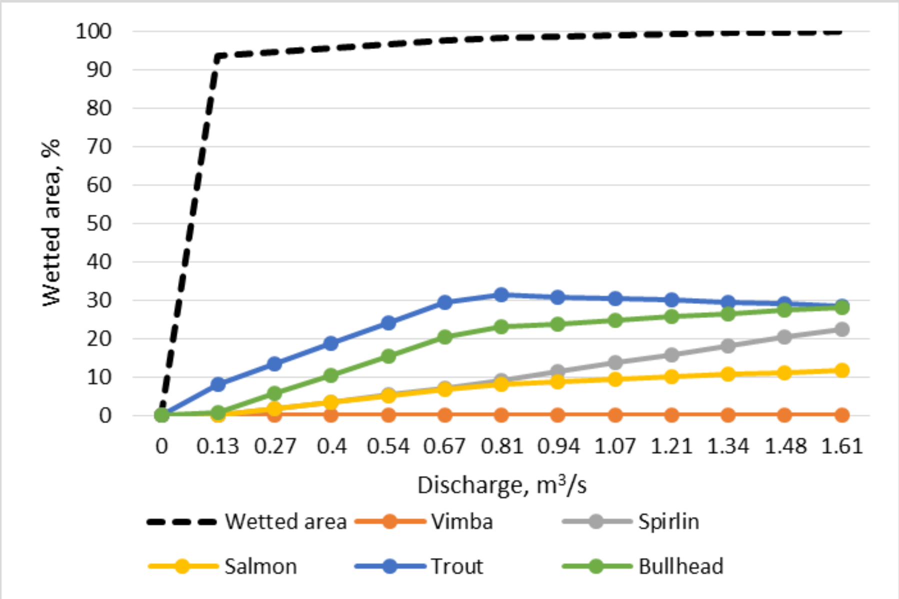


Figure 5.4.1. Habitat-Flow rating curve of Varduva River downstream Ukrinai HPP

Figure 5.4.2 show habitat suitability maps for spirlin and juvenile brown trout, which are expected to be present in the Varduva downstream Kulšėnai HPP irrespective of migration barriers. At a very low flow (0.15 m^3/s), which three times less than Q_{30_min} (0.46 m^3/s), there are no suitable habitat for spirlin at all. At a discharge of 0.82 m^3/s, which is close to Q_{30_avg} (0.71 m^3/s), it already occupies 8% of the wetted area. Suitable habitat for juvenile brown trout is present even at very low flow, but at a discharge close to Q_{30_avg} it covers most of the river stretch studied.

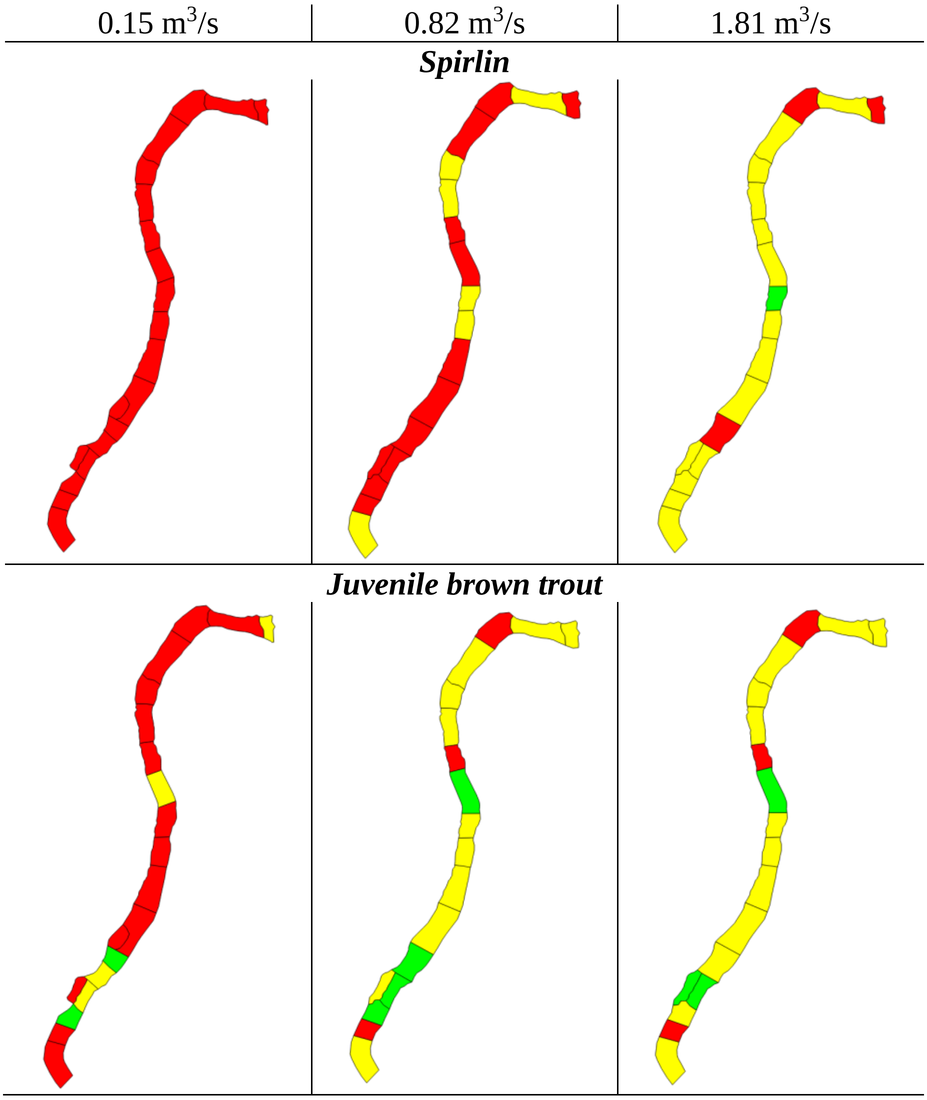


Figure 6.1.2. Habitat suitability maps for juvenile brown trout and spirlin during four different discharges

Figures 5.4.3 and 5.4.4 show the habitat distribution in time during 2021 that is a year with normal water runoff. The red line on pictures is a threshold corresponding of habitat area with 97% of probability, and the blue line is an average habitat area. The results show that the impact of the operation of the Ukrinai hydropower plant on the habitat availability of the modelled fish species is relatively strong. During periods of low water flow, the operation of HPP temporarily deprives both spirlin and juvenile brown trout of some of their suitable habitat. The habitat availability index IH=0.61, indicating the overall spatial and temporal deviation of habitat availability from natural conditions due to the HPP, shows that the impact of the Ukrinai HPP on habitat availability for the species of interest is quite significant.

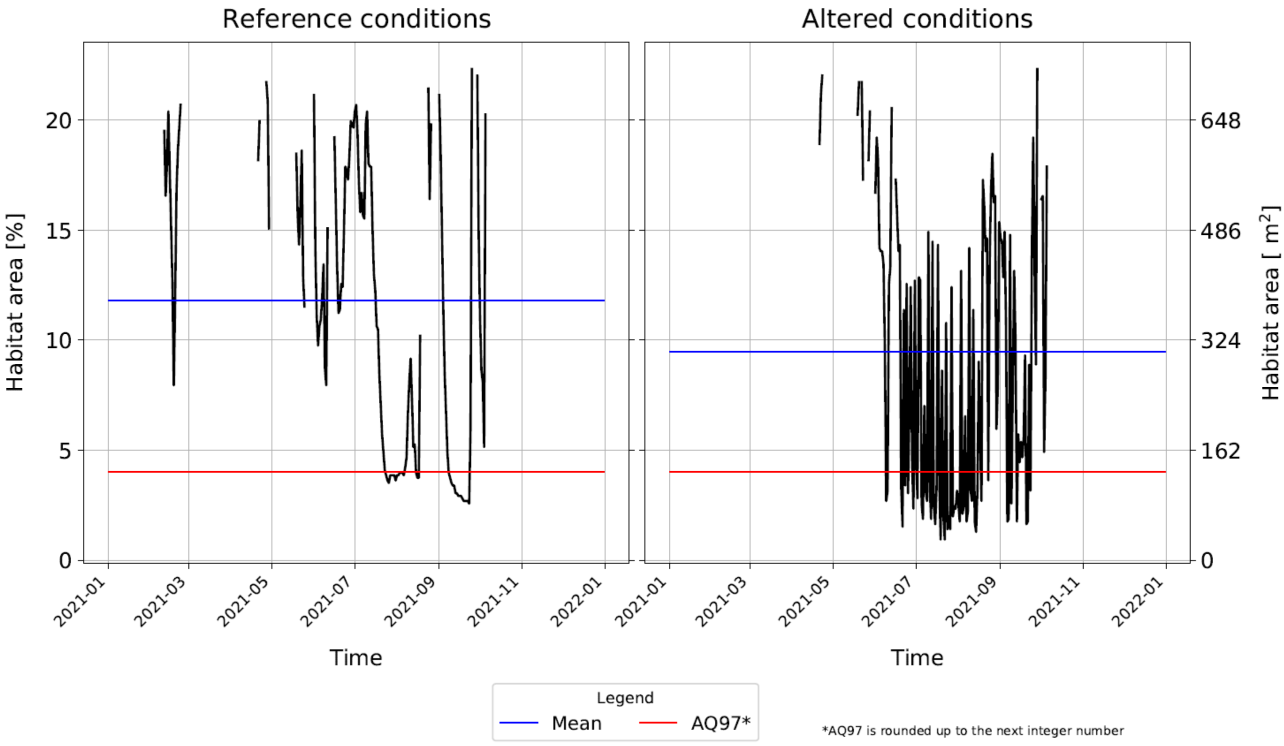


Figure 5.4.3. Habitat time series of the spirlin in reference and altered conditions

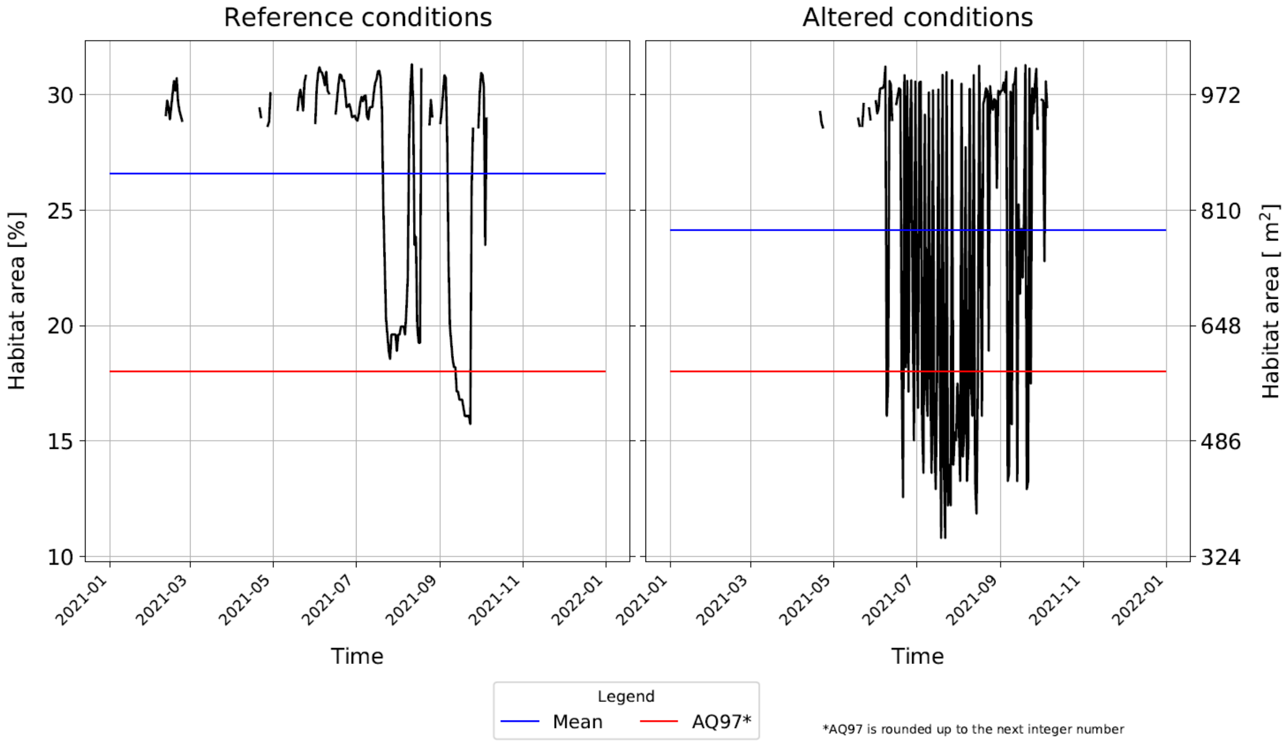


Figure 5.4.4. Habitat time series of the juvenile brown trout in reference and altered conditions

5.5. Varduva River – below Juodeikiai HPP

Juodeikiai HPP is the last from the upstream in the chain of five HPP in the Varduva. According to the Rules for the operation of the hydropower plants, guaranteed water discharge is determined as 0.91 m^3/s.

Habitat curves for fish species of interest depending on discharge are shown in Figure 5.5.1. The habitat area of spirlin and vimba increases almost uniformly with increasing flow; however, the river stretch becomes suitable for vimba only at a discharge greater than 0.5 m^3/s. The habitat area of juvenile salmon increases up to the discharge of ~0.7 m^3/s and then tends to stabilize. The maximum area of habitat for juvenile brown trout peaks at a discharge of ~0.5 m^3/s, and for bullhead at a discharge of ~0.7 m^3/s, with the habitat areas of both species beginning to decline as discharge further increases.

Figure 5.5.2 show habitat suitability maps for spirlin and juvenile brown trout, which are expected to be present in the Varduva downstream Kulšėnai HPP irrespective of migration barriers. At a very low flow (0.274 m^3/s), which three times less than Q_{30_min} (0.91 m^3/s), the area of habitat suitable for spirlin is very small, but at a discharge of 0.998 m^3/s, which is close to Q_{30_avg} (1.07 m^3/s), it covers nearly half of the river stretch studied. Suitable habitat for juvenile brown trout is present even at very low flow, but at a discharge close to Q_{30_avg} the area of habitat, which is optimal for this species, reaches its maximum.

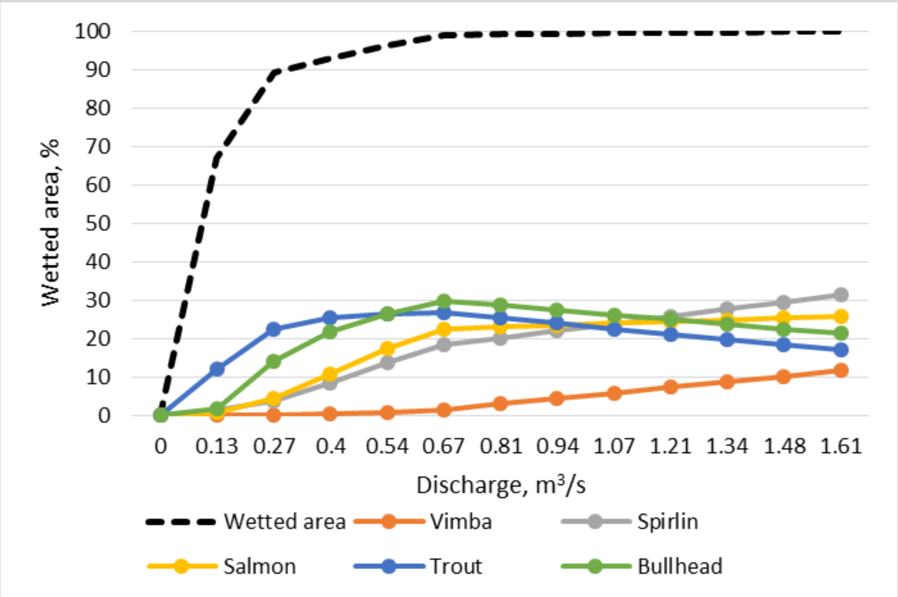


Figure 5.5.1. Habitat-Flow rating curve of Varduva River downstream Juodeikiai HPP

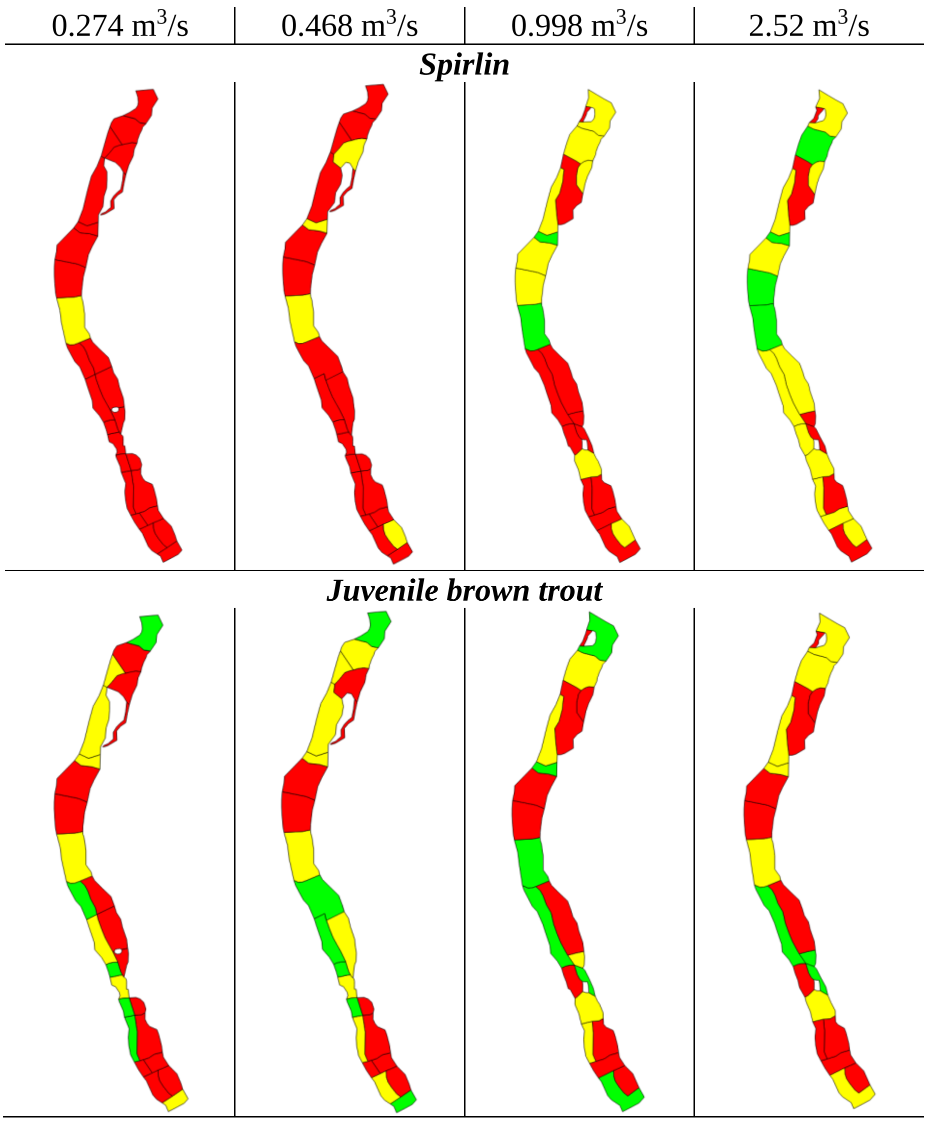


Figure 5.5.2. Habitat suitability maps for juvenile brown trout and spirlin during four different discharges

Figures 5.5.3 and 5.5.4 show the habitat distribution in time during 2021 that is a year of closer to dry water runoff conditions (year of 80% probability). The red line on pictures is a threshold corresponding of habitat area with 97% of probability, and the blue line is an average habitat area. The results show that the impact of the operation of the Juodeikiai hydropower plant on the habitat availability of the modelled fish species is relatively low. Some temporal reduction in the area of habitat suitable for spirlin occurs during the low flow period, while the habitat of the brown trout is not at all affected by the operation of this hydropower plant. However, the habitat availability index IH=0.61, indicating the overall spatial and temporal deviation of habitat availability from natural conditions due to the hydropower plant, shows that the Juodeikiai hydropower plant does have an impact on the availability of habitats suitable for certain species of interest.

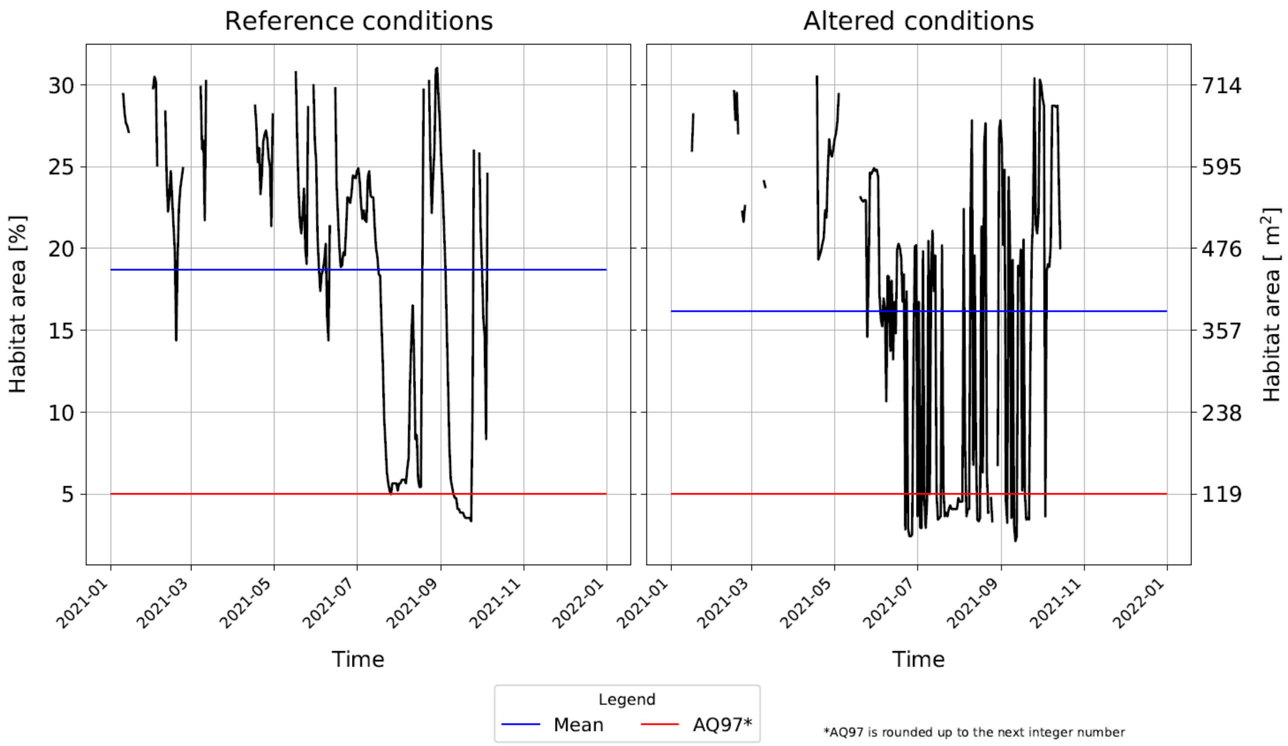


Figure 5.5.3. Habitat time series of the spirlin in reference and altered conditions

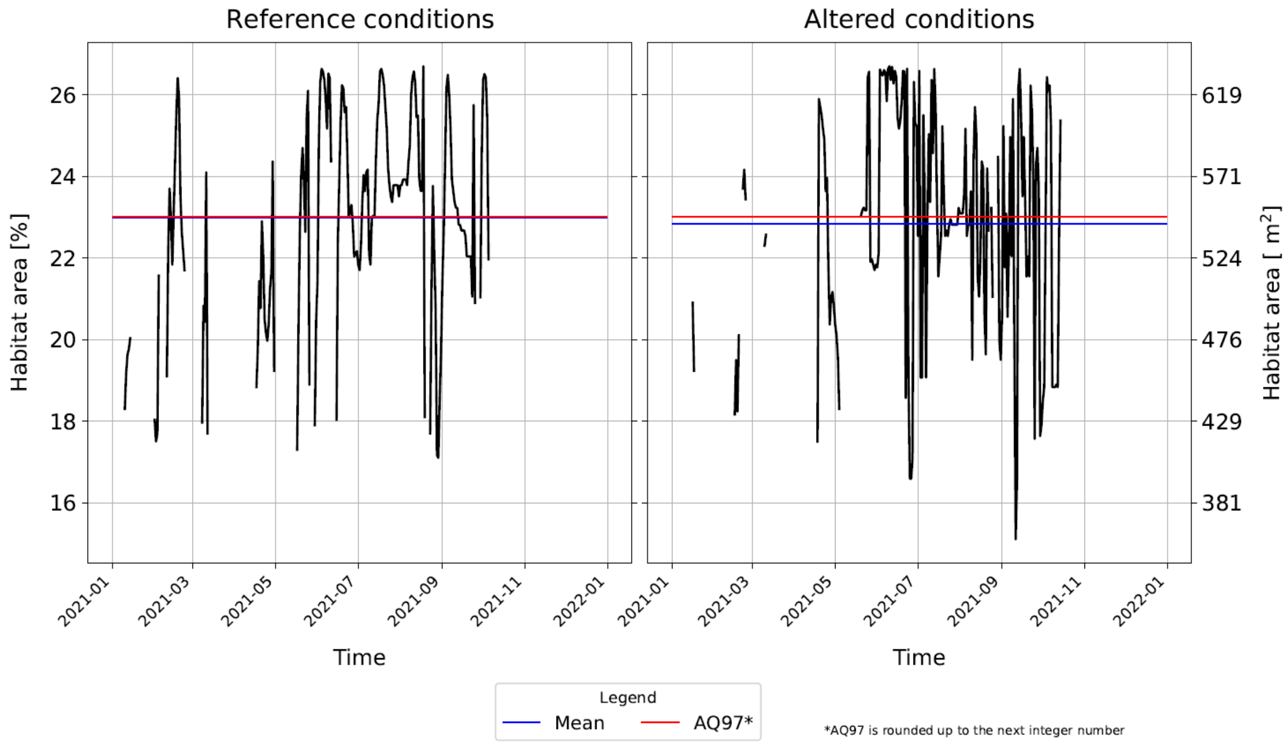


Figure 5.5.4. Habitat time series of the juvenile brown trout in reference and altered conditions

6. ECOLOGICAL FLOW EVALUATION IN LATVIA

Ecological flows (E-flow) were determined using methodology, developed in ECOFLOW project (*Ecological flow estimation in Latvian - Lithuanian transboundary river basins, LLI-249*) and full methodical description can be found in the ECOFLOW project developed materials (ECOFLOW project report, 2019).

According to this methodology, E-flow can be calculated using optimum flow ($Q_{optimum}$) as a key hydrological value. Optimum flow is a river flow value, at which the area of available habitat reaches its maximum or insignificant habitat suitability increase can be observed.

Based on expert judgement and WFD guidelines (EU Guidance Nr.31, 2015) is assumed that 60% of the $Q_{optimum}$ is sufficient value for presence and development of fish fauna during spawning and rearing period (mid October – June). For the rest of a year 30% of the $Q_{optimum}$ is necessary to protect the aquatic fauna and flora during the dry season.

6.1. Ciecere River – below Ciecere HPP (Ciecere1)

Using habitat-flow rating curve (Fig. 6.1.1) the $Q_{optimum}$ was defined as 0.95 m^3/s, which is closed to Q_{annual}. According to the E-flow calculation methodology, the suggested ecological flow regime of Ciecere River below Ciecere HPP is following: 1). water discharge not less than 0.25 m^3/s in period from July to mid-October and 2). water discharge ≥0.50 m^3/s in period from mid-October to June. Proposed minimum E-flow is corresponding to the average flow of the low flow period (Q_{30_avg}).

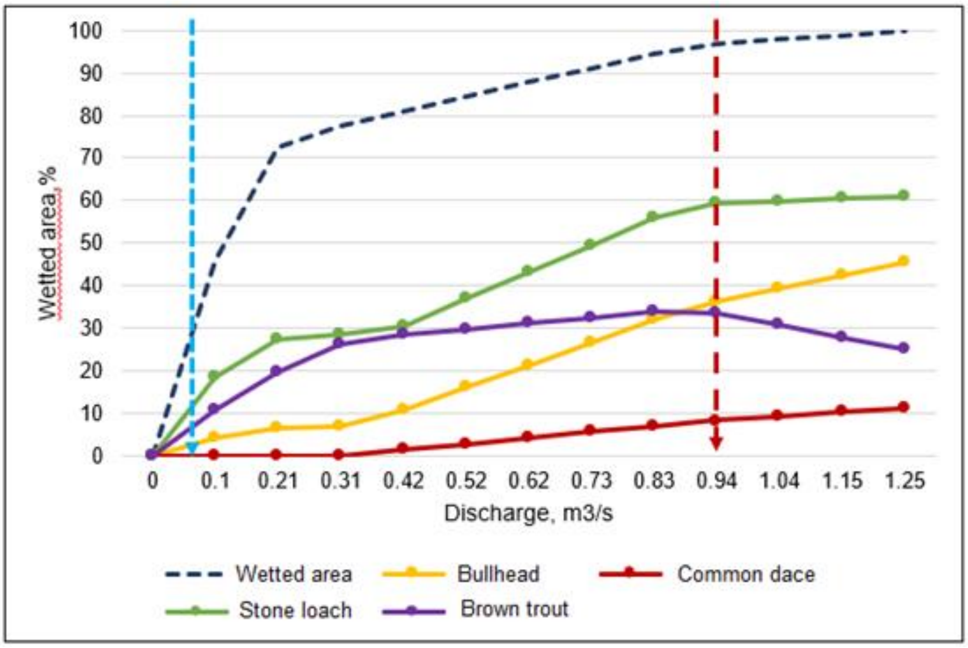


Figure 6.1.1. Habitat flow-rating curve for Ciecere River below Ciecere HPP (red arrow – optimum flow, blue arrow - ecological flow in permit)

To validate the proposed ecological flow regime, E-flow values were compared with daily discharges of year 2021 (normal hydrological conditions). Figure 6.1.2 shows that river had enough water to provide the ecological flow regime during most of year 2021. River Ciecere below Ciecere HPP is located very closed to the river source at the Ciecere Lake. During most of summer days this river stretch has naturally very low discharge values and can't provide sufficient E-flow. Therefore, the Ciecere HPP must stop working during the dry summer.

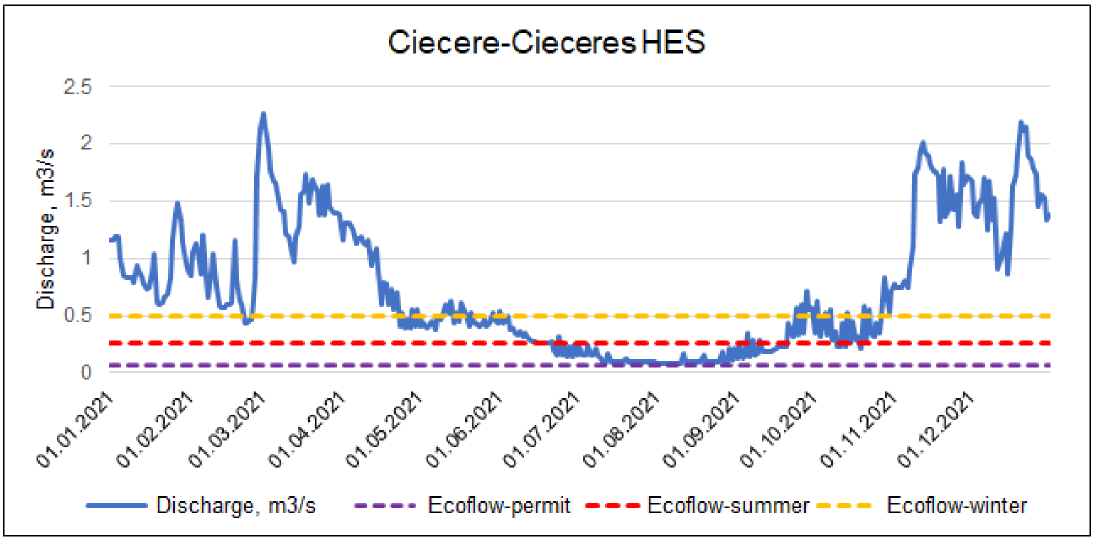


Figure 6.1.2. Comparison of daily discharge and ecological flows specified in water use permits and proposed in TRANSWAT project for Ciecere River below Ciecere HPP

6.2. Ciecere River – below Dzirnavnieki HPP (Ciecere2)

Using habitat-flow rating curve (Fig. 6.2.1), the $Q_{optimum}$ was defined as 0.92 m^3/s which is between Q_{annual} and Q_{30_max}. According to E-flow calculation methodology, the suggested ecological flow regime of the Ciecere River below Dzirnavnieki HPP is following: 1). water discharge not less than 0.27 m^3/s in period from July to mid-October and 2). water discharge ≥0.55 m^3/s in period from mid-October to June. Proposed minimum E-flow is corresponding to the average flow of the low flow period (Q_{30_avg}).This value 0.27 m^3/s matches to the ecological flow value specified in water use permit (0.30 m^3/s) of the Dzirnavnieki HPP. It means that the HPP already has sustainable ecological flow regime during summer season but has to provide the E-flow also during high flow period. Proposed minimum E-flow value is corresponding to the average flow of the low flow period (Q_{30_avg}).

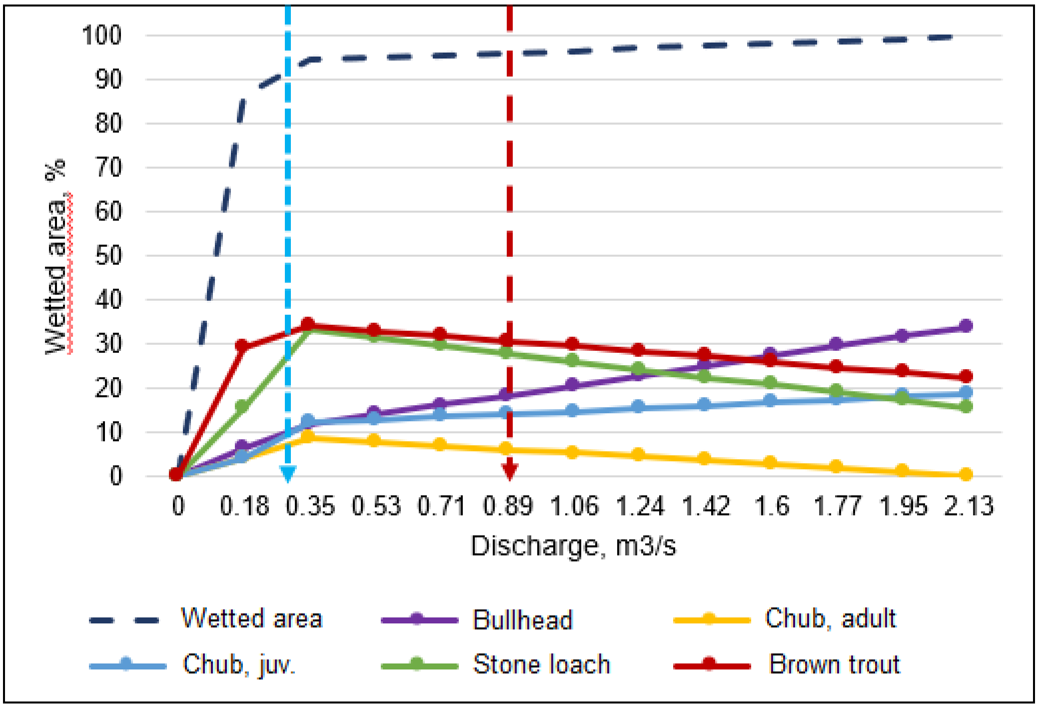


Figure 6.2.1. Habitat flow-rating curve for Ciecere River below Dzirnavnieki HPP (red arrow – optimum flow, blue arrow - ecological flow in permit)

To validate the proposed ecological flow regime, the E-flow values were compared with daily discharges of year 2021 (normal hydrological conditions). Figure 6.2.2 illustrates that river had enough water to provide proposed ecological flow regime during most of year 2021, including summer months.

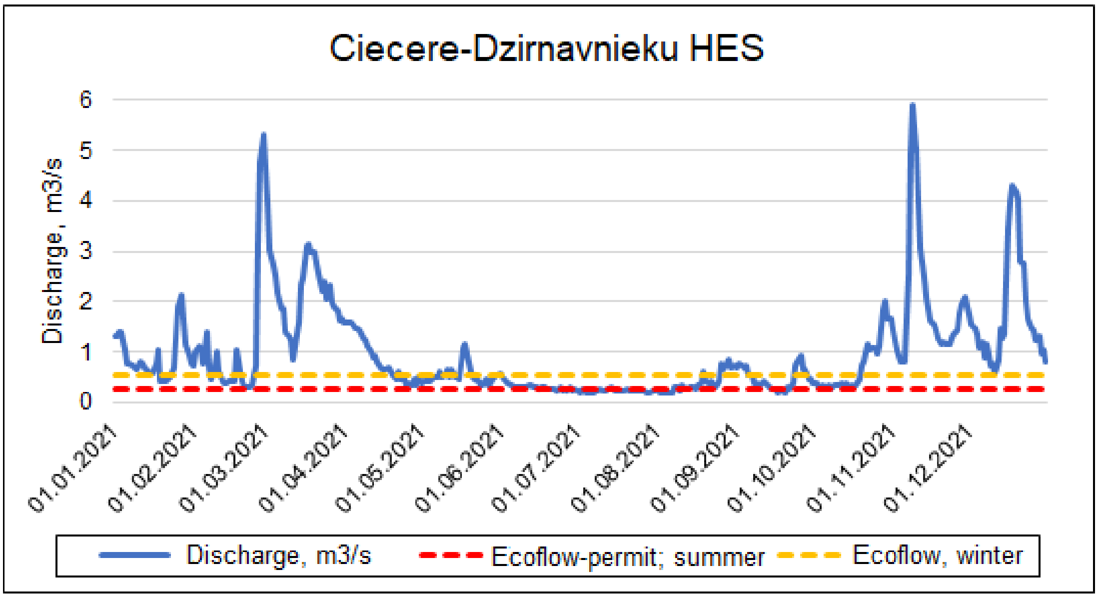


Figure 6.2.2. Comparison of daily discharge and ecological flows specified in water use permits and proposed in TRANSWAT project for Ciecere River below Dzirnavnieki HPP

6.3. Ciecere River – below Pakuli HPP (Ciecere3)

Using habitat-flow rating curve (Fig. 6.3.1), the $Q_{optimum}$ was defined as 3.45 m^3/s, which is closed to the Q_{annual}. According to the E-flow calculation methodology, the suggested ecological flow regime of the Ciecere River below Pakuli HPP is is following: 1) water discharge not less than 1.05 m^3/s in period from July to mid-October and 2) water discharge ≥2.10 m^3/s in period from mid-October to June. The proposed minimum E-flow value is corresponding to the average flow of the low flow period (Q_{30_avg}).These numbers are the same as in previous ECOFLOW project.

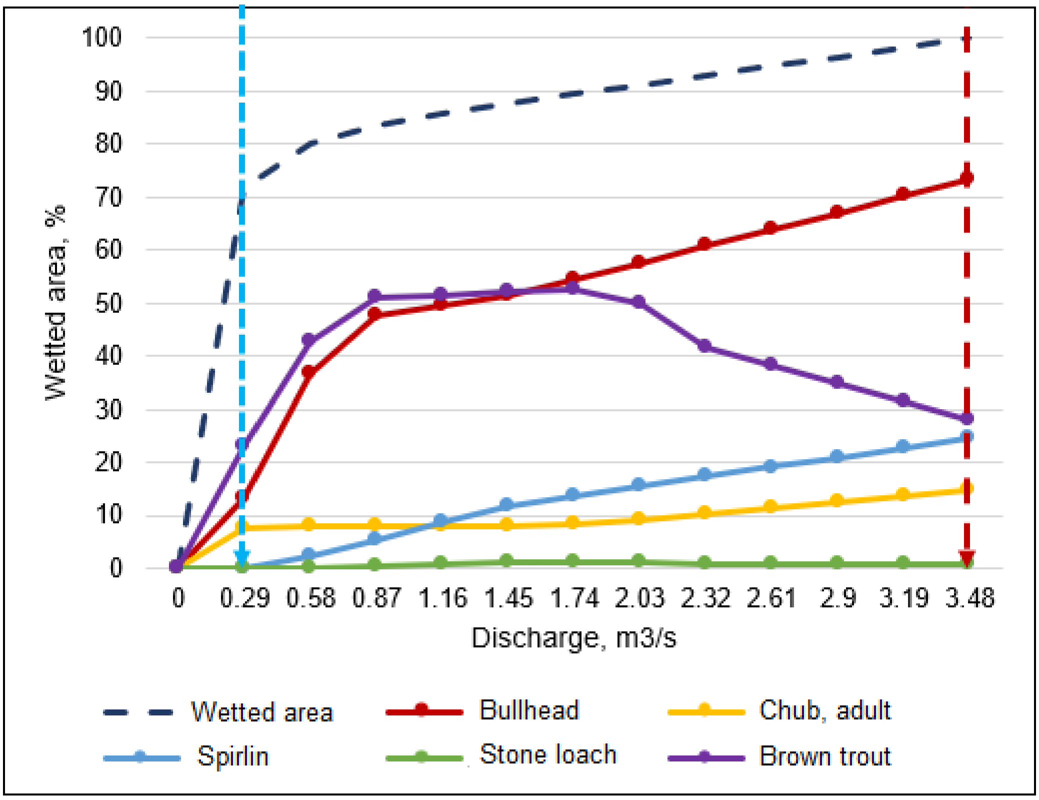


Figure 6.3.1. Habitat flow-rating curve for Ciecere River below Pakuli HPP (red arrow – optimum flow, blue arrow - ecological flow in permit)

To validate the proposed ecological flow regime E-flow values were compared with daily discharges of year 2021 (normal hydrological conditions). Figure 6.3.2 shows that the Ciecere River had enough water to provide the proposed ecological flow regime during most of year 2021 except some low flow periods during dry summer and autumn.

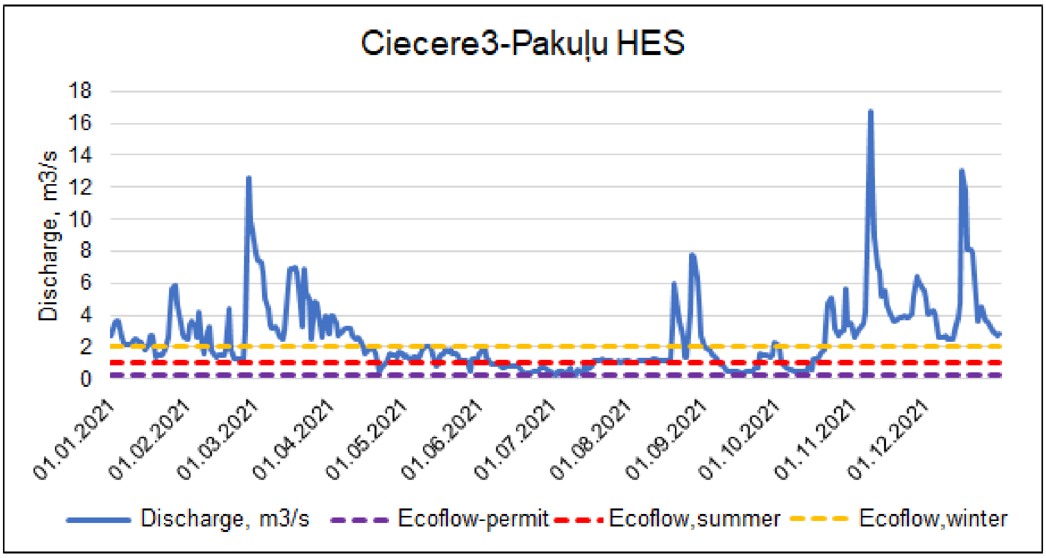


Figure 6.3.2. Comparison of daily discharge and ecological flows specified in water use permits and proposed in TRANSWAT project for Ciecere River below Pakuli HPP

6.4. Losis River – below Lejnieki HPP (Losis1)

Using habitat-flow rating curve (Figure 6.4.1), the $Q_{optimum}$ was defined as 2.1 m^3/s which is closed to Q_{annual}. According to the E-flow calculation methodology, the suggested ecological flow regime of the Losis River below Lejnieki HPP is following: 1) water discharge not less than 0.65 m^3/s in period from July to mid-October and 2) water discharge ≥1.25 m^3/s in period from mid-October to June. The proposed minimum E-flow value is corresponding to the average flow of the low flow period (Q_{30_avg}).

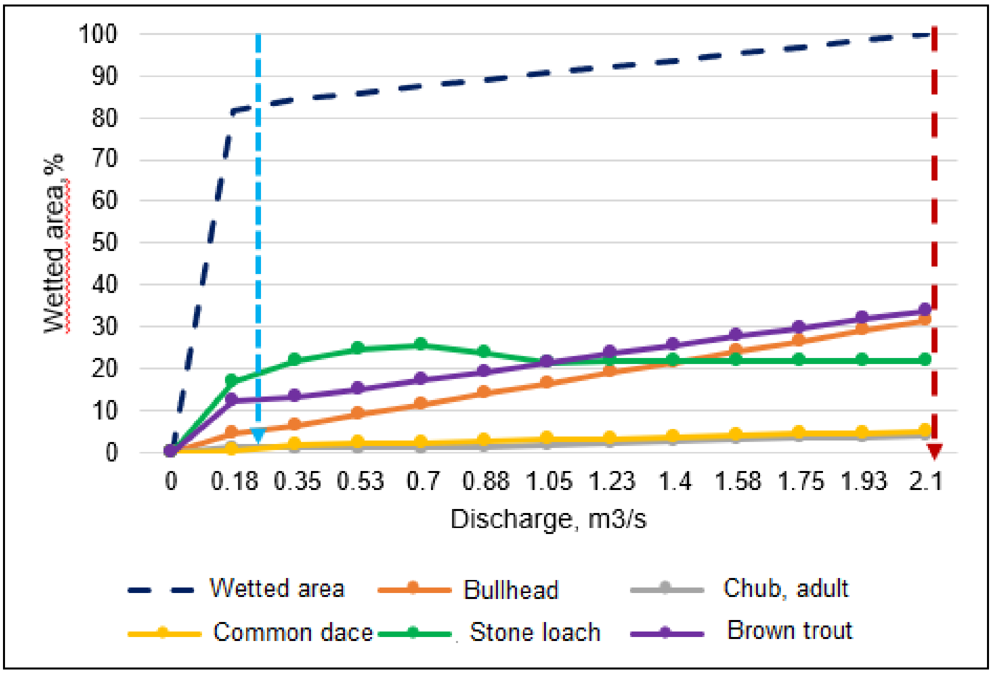


Figure 6.4.1. Habitat flow-rating curve for Losis River below Lejnieki HPP (red arrow – optimum flow, blue arrow - ecological flow in permit)

To validate our proposed ecological flow regime E-flow values were compared with daily discharge of year 2021 (normal hydrological conditions). Figure 6.4.2 shows that river had enough water to provide proposed ecological flow during most of year 2021, except some small low flow events during summer and autumn.

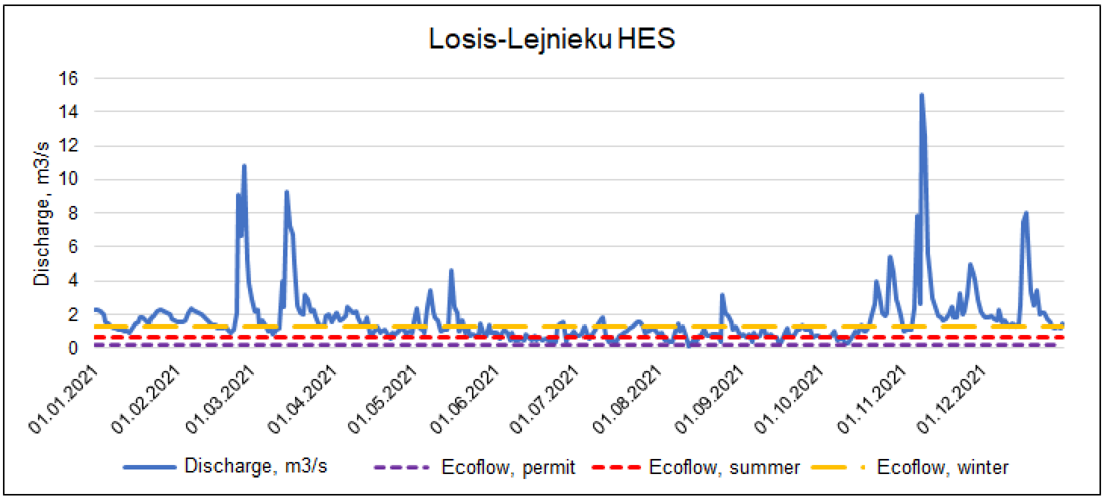


Figure 6.4.2. Comparison of daily discharge and ecological flows specified in water use permits and proposed in TRANSWAT project for Losis River below Lejnieki HPP

6.5. Losis River – below Grantini HPP (Losis2)

Using habitat-flow rating curve (Figure 6.5.1), the $Q_{optimum}$ was defined as 1.30 m^3/s which is closed to the Q_{annual}. According to the E-flow calculation methodology, the suggested ecological flow regime of the Losis River below Grantini HPP is following: 1) water discharge not less than 0.40 m^3/s in period from July to mid-October and 2) water discharge ≥0.80 m^3/s in period from mid-October to June. The proposed minimum E-flow value is corresponding to the average flow of the low flow period (Q_{30_avg}).

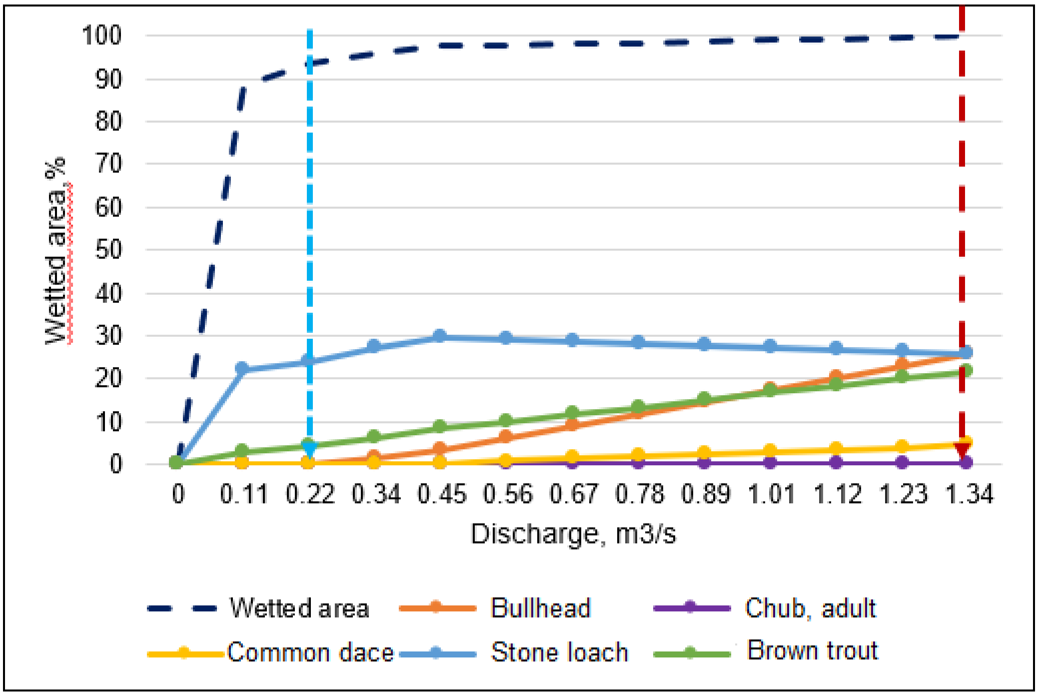


Figure 6.5.1. Habitat flow-rating curve for Losis River below Grantini HPP (red arrow – optimum flow, blue arrow - ecological flow in permit)

To validate our proposed ecological flow regime, the ecological flow values were compared with daily discharge of year 2021 (normal hydrological conditions). Figure 6.5.2 shows that river had enough water to provide proposed ecological flow during most of year 2021, even during summer low flow periods.

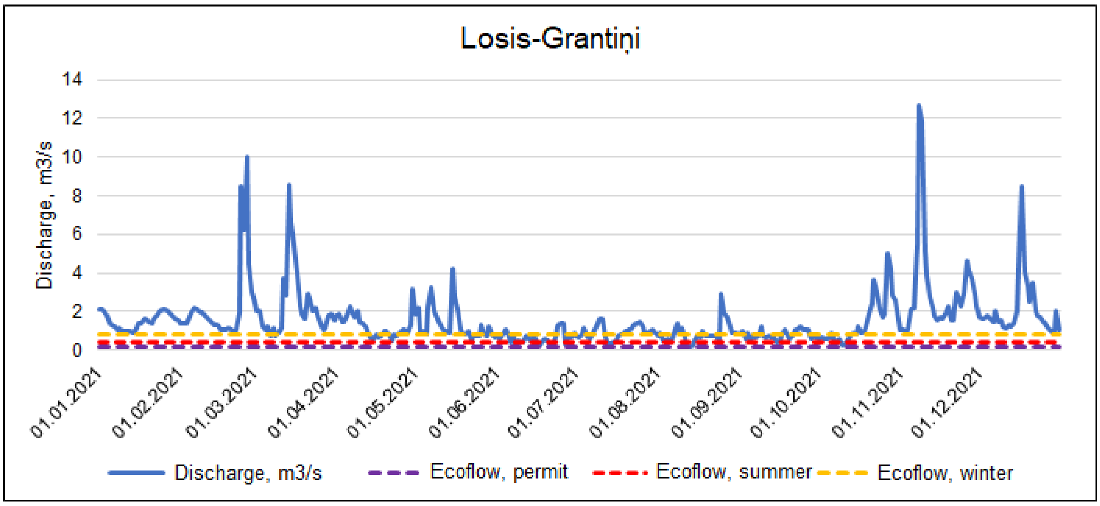


Figure6.5.2. Comparison of daily discharge and ecological flows specified in water use permits and proposed in TRANSWAT project for Losis River below Lejnieki HPP

7. ECOLOGICAL FLOW EVALUATION IN LITHUANIA

In Lithuania, the discharge which corresponds to the concept of ecological flow (E-flow), was determined for the first time during the ECOFLOW project (Interreg V-A Latvian-Lithuanian programme project "*Ecological flow estimation in Latvian - Lithuanian transboundary river basins", LLI-249*) and full methodical description can be found in ECOFLOW deliverable "*Methodology of E-flow evaluation on the base of Venta and Lielupe Latvian-Lithuanian transboundary river basins*". The ecological discharge was repeatedly determined during the ECODAM project (National Research Programme 'Sustainability of agro-, forest and water ecosystems' 2nd call project „Impact assessment of hydrotechnical structures on river runoff and sustainable water management for conservation and restoration of water ecosystems"; Project registration number SIT-20-3, Research Council of Lithuania). During the ECODAM project, the ecological discharge was determined based on the analysis of Uniform Continuous-Under-Threshold (UCUT) curves, and the validation was performed based on the analysis of the habitat area – discharge rating curves (Final Report of ECODAM project, 2022). The ecological flow determined by both methods during mentioned projects is close to Q_{30_avg}.

7.1. Varduva River – below Kulšėnai HPP

Using habitat-flow rating curve (Figure 7.1.1) the unfavourable conditions and insufficient fish habitats were highlighted during the guaranteed flow (0.20 m^3/s) situation. According to the above mentioned E-flow calculation methodology, the suggested ecological flow regime for the Varduva River below Kulšėnai HPP is 0.62 m^3/s. The proposed minimum E-flow value is corresponding to the average flow of the low flow period (Q_{30_avg}).

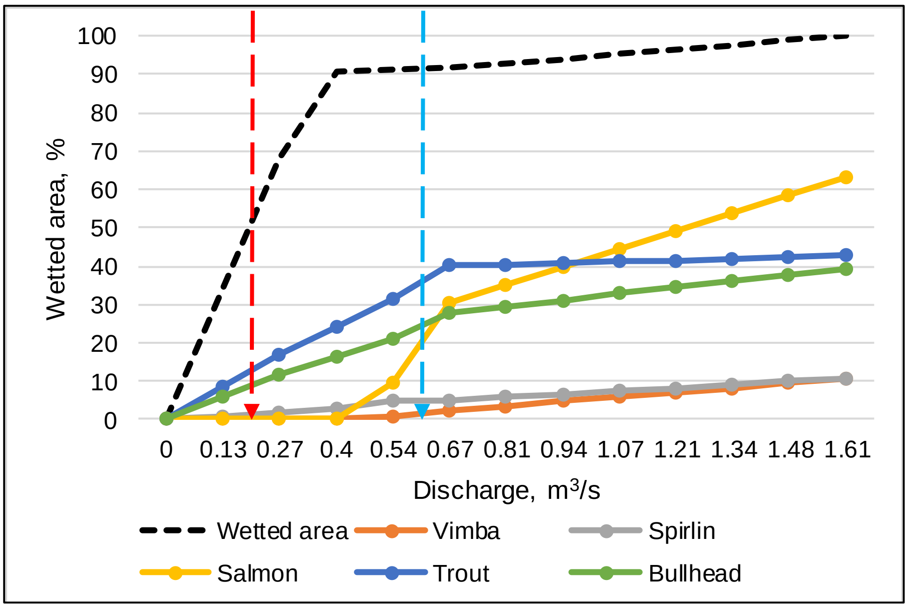


Figure 7.1.1. Habitat flow-rating curve for Varduva River below Kulšėnai HPP (red arrow – guaranteed flow, blue arrow – ecological flow proposed in TRANSWAT)

To validate our proposed ecological flow regime for the Varduva River below Kulšėnai HPP, the ecological flow value was compared with daily discharge of year 2021 (normal hydrological conditions) and existing guaranteed flow. Figure 7.1.2 shows that river had enough water to provide proposed ecological flow during most of year 2021, except end of July and beginning of August.

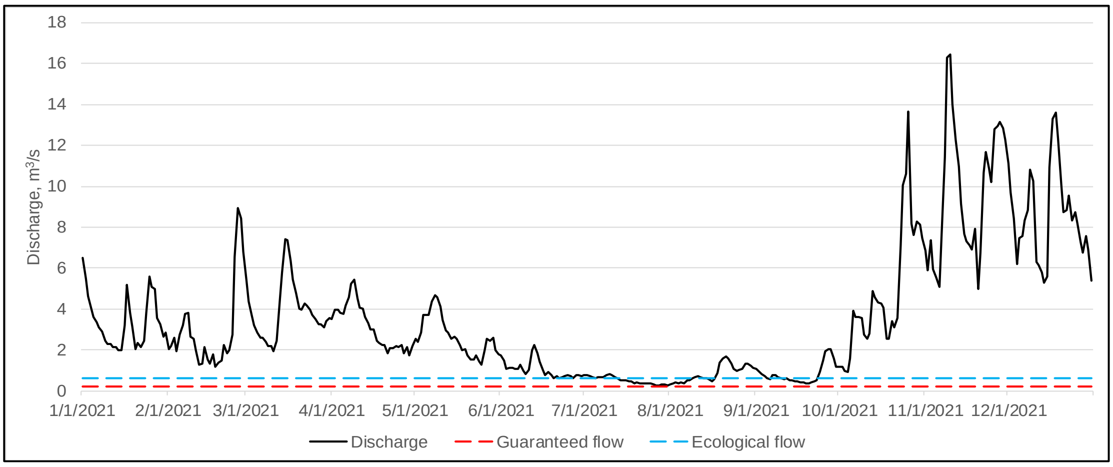


Figure 7.1.2. Comparison of daily discharge and guaranteed discharge specified in reservoir exploitation rules and ecological flow proposed in TRANSWAT project for Varduva River below Kulšėnai HPP

7.2. Varduva River – below Renavas HPP

Using habitat-flow rating curve (Figure 7.2.1) the unfavourable conditions and insufficient fish habitats were highlighted during the guaranteed flow (0.39 m^3/s) situation. According to the above mentioned E-flow calculation methodology, the suggested ecological flow regime for the Varduva River below Renavas HPP is 0.66 m^3/s. The proposed minimum E-flow value is corresponding to the average flow of the low flow period (Q_{30_avg}).

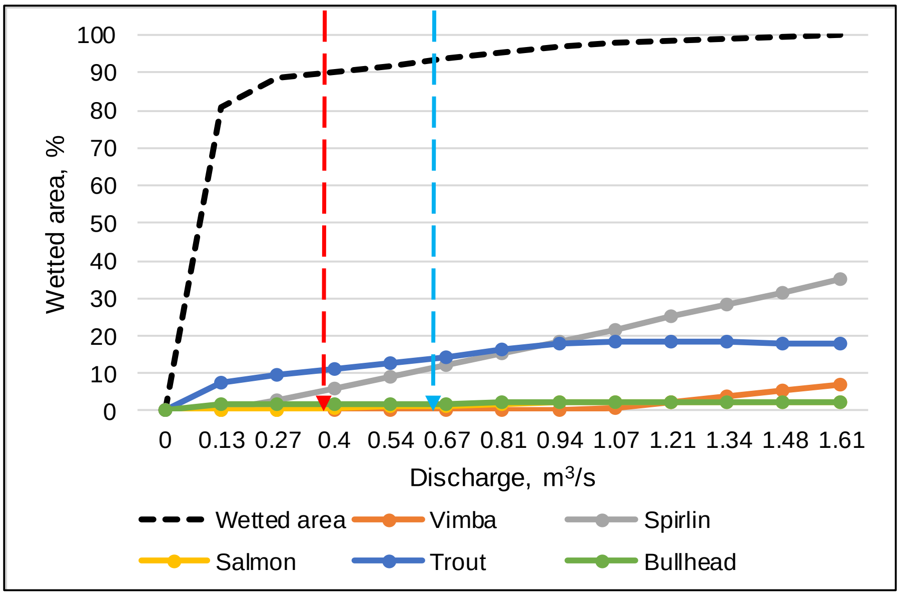


Figure 7.2.1. Habitat flow-rating curve for Varduva River below Renavas HPP (red arrow – guaranteed flow, blue arrow – ecological flow proposed in TRANSWAT)

To validate our proposed ecological flow regime for the Varduva River below Renavas HPP, the ecological flow value was compared with daily discharge of year 2021 (normal hydrological conditions) and existing guaranteed flow. Figure 7.2.2 shows that river had enough water to provide proposed ecological flow during most of year 2021, except warm period from June to October when hydropeaking operation regime below HPP was observed.

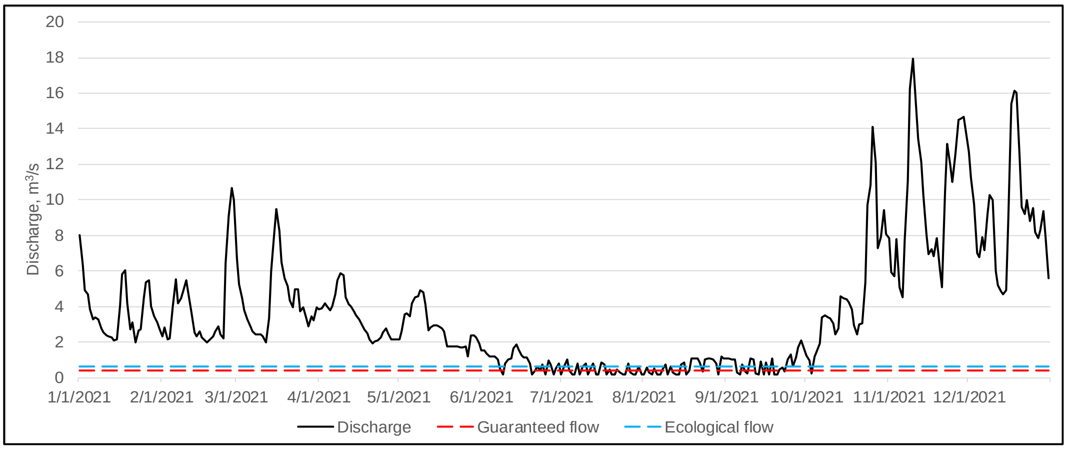


Figure 7.2.2. Comparison of daily discharge and guaranteed discharge specified in reservoir exploitation rules and ecological flow proposed in TRANSWAT project for Varduva River below Renavas HPP

7.3. Varduva River – below Vadagiai HPP

Using habitat-flow rating curve (Figure 7.3.1) the unfavourable conditions and insufficient fish habitats were highlighted during the guaranteed flow (0.41 m^3/s) situation. According to the above mentioned E-flow calculation methodology, the suggested ecological flow regime for the Varduva River below Vadagiai HPP is 0.68 m^3/s. The proposed minimum E-flow value is corresponding to the average flow of the low flow period (Q_{30_avg}).

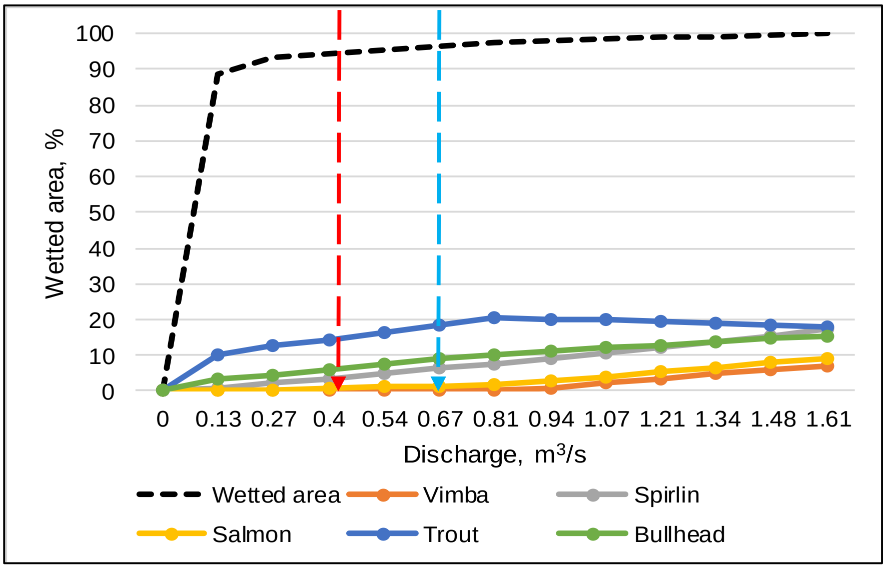


Figure 7.3.1. Habitat flow-rating curve for Varduva River below Vadagiai HPP (red arrow – guaranteed flow, blue arrow – ecological flow proposed in TRANSWAT)

To validate our proposed ecological flow regime for the Varduva River below Vadagiai HPP, the ecological flow value was compared with daily discharge of year 2021 (normal hydrological conditions) and existing guaranteed flow. Figure 7.3.2 shows that river had enough water to provide proposed ecological flow during most of year 2021, except warm period from June to October when hydropeaking operation regime below HPP was observed.

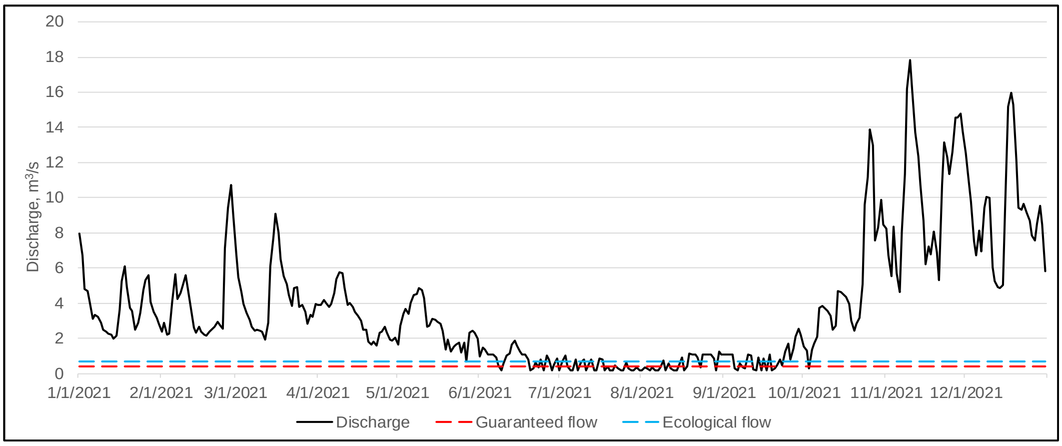


Figure 7.3.2. Comparison of daily discharge and guaranteed discharge specified in reservoir exploitation rules and ecological flow proposed in TRANSWAT project for Varduva River below Vadagiai HPP

7.4. Varduva River – below Ukrinai HPP

Using habitat-flow rating curve (Figure 7.4.1) the unfavourable conditions and insufficient fish habitats were highlighted during the guaranteed flow (0.46 m^3/s) situation. According to the above mentioned E-flow calculation methodology, the suggested ecological flow regime for the Varduva River below Ukrinai HPP is 0.71 m^3/s. The proposed minimum E-flow value is corresponding to the average flow of the low flow period (Q_{30_avg}).

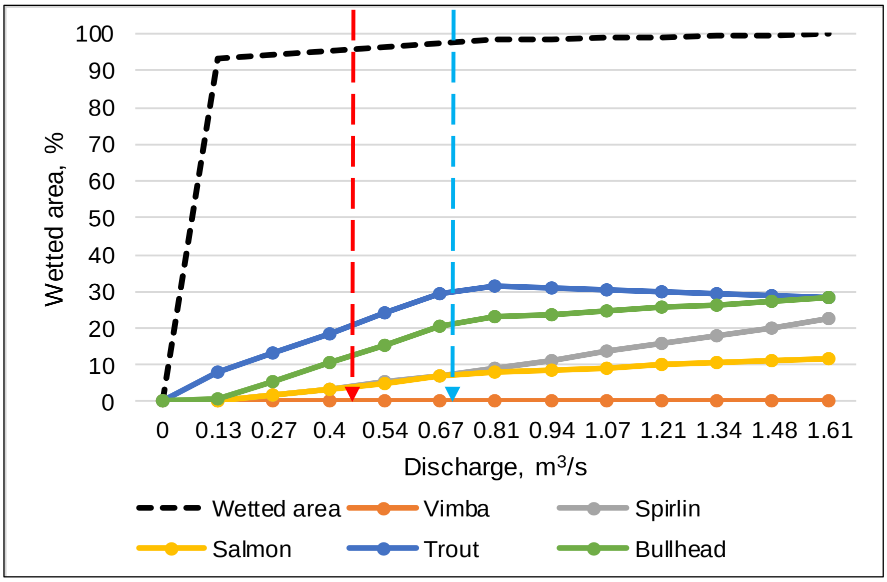


Figure 7.4.1. Habitat flow-rating curve for Varduva River below Ukrinai HPP (red arrow – guaranteed flow, blue arrow – ecological flow proposed in TRANSWAT)

To validate our proposed ecological flow regime for the Varduva River below Ukrinai HPP, the ecological flow value was compared with daily discharge of year 2021 (normal hydrological conditions) and existing guaranteed flow. Figure 7.4.2 shows that river had enough water to provide proposed ecological flow during most of year 2021, except warm period from July to October when hydropeaking operation regime below HPP was observed.

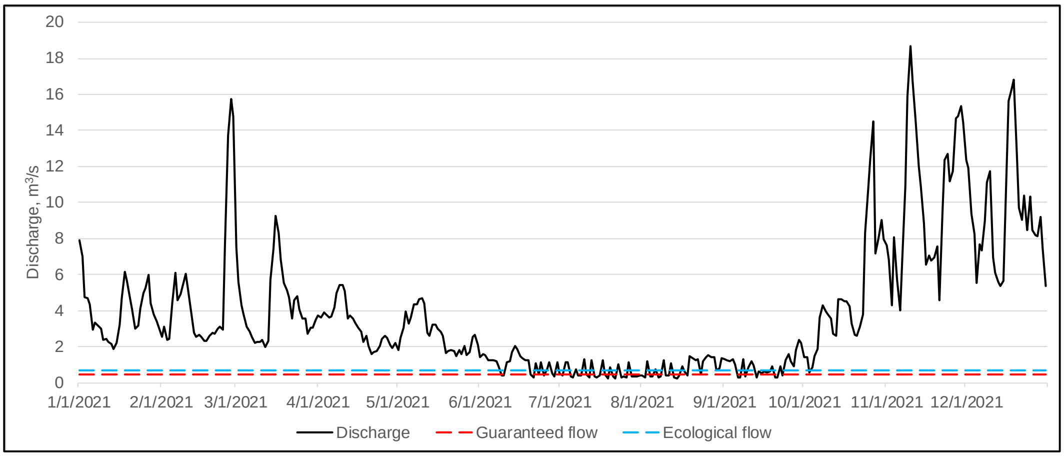


Figure 7.4.2. Comparison of daily discharge and guaranteed discharge specified in reservoir exploitation rules and ecological flow proposed in TRANSWAT project for Varduva River below Ukrinai HPP

7.5. Varduva River – below Juodeikiai HPP

Using habitat-flow rating curve (Figure 7.5.1) the unfavourable conditions and insufficient fish habitats were highlighted during the guaranteed flow (0.91 m^3/s) situation. According to the above mentioned E-flow calculation methodology, the suggested ecological flow regime for the Varduva River below Juodeikiai HPP is 1.07 m^3/s. The proposed minimum E-flow value is corresponding to the average flow of the low flow period (Q_{30_avg}).

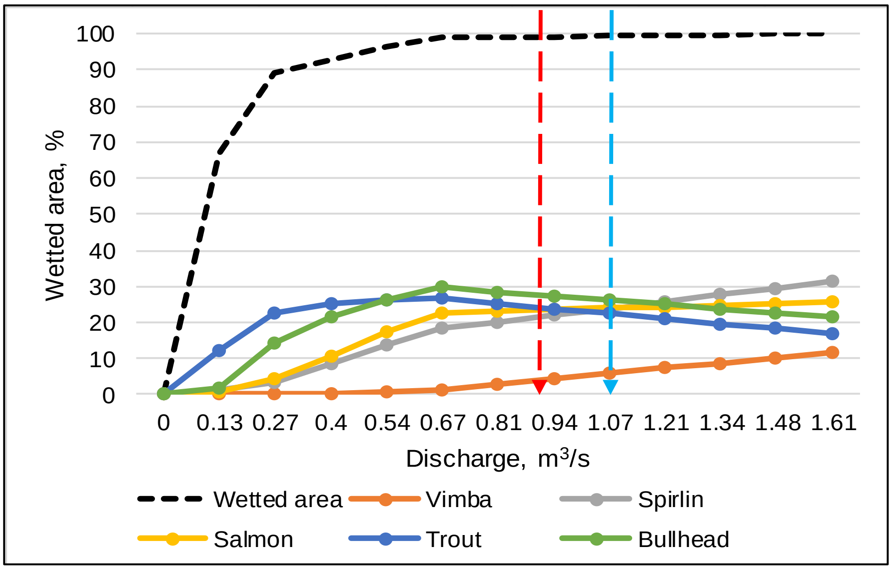


Figure 7.5.1. Habitat flow-rating curve for Varduva River below Juodeikiai HPP (red arrow – guaranteed flow, blue arrow – ecological flow proposed in TRANSWAT)

To validate our proposed ecological flow regime for the Varduva River below Juodeikiai HPP, the ecological flow value was compared with daily discharge of year 2021 (closer to dry hydrological conditions) and existing guaranteed flow. Figure 7.5.2 shows that river had enough water to provide proposed ecological flow during most of year 2021, except occasional periods during warm season from June to October when hydropeaking operation regime below HPP was observed. The overall water balance showed that there would be enough water to maintain E-flow if HPP would operate in the transit regime.

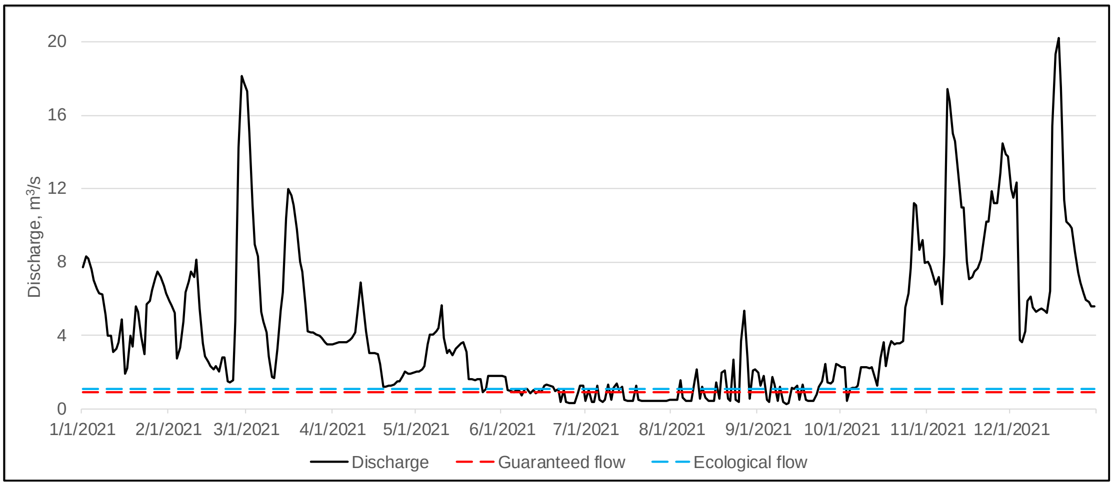


Figure 7.5.2. Comparison of daily discharge and guaranteed discharge specified in reservoir exploitation rules and ecological flow proposed in TRANSWAT project for Varduva River below Juodeikiai HPP

8. CONCLUSIONS

- Ecological flow modelling was done in three sites in Ciecere River and two sites in Losis River in Latvia. Meanwhile in Lithuania, ecological flow modelling was done in five sites of the Varduva River. Most of studied sites belongs to salmonid river type which is especially vulnerable to hydrological alterations caused by operating HPP.
- It was found out that the ecological flows, specified in water use permits, usually are too low and do not guarantee healthy and sustainable management of aquatic resources. The comparison of the proposed ecological flow values with daily discharges of year 2021 (and other years) shows that there is no natural obstacles to not to increase ecological flow values (Table 8.1).

Table 8.1 Comparison of ecological flow values in studied rivers in Latvia

River	HPP name	E-flow in permit, m^3/s	Proposed E-flow summer, m^3/s	Proposed E-flow winter, m^3/s
Ciecere	Ciecere	0.061	0.25	0.50
Ciecere	Dzirnavnieki	0.30	0.27	0.55
Ciecere	Pakuli	0.32	1.05	2.10
Losis	Lejnieki	0.093	0.65	1.25
Losis	Grantini	0.029	0.40	0.80

- The largest deviations from existing and our modelled habitat availability are in the summer season, indicating that summer season ecological flows must be raised even it means that some HPP must stop operating in summer period.
- Modelling of the effects of five HPP on the availability of habitats suitable for fish species of interest in Varduva River in Lithuania has shown that the impact of Kulšėnai HPP which is at the top of the HPP cascade is minimal during low flow period. The impact of the next one, Renavas HPP, is very strong and extends below Vadagiai HPP, which does not operate during dry season. The impact on fish habitats of the Ukrinai HPP and the Juodeikiai HPP is lower than that of the Renavas HPP, but still quite significant.
- The results of the habitat-flow dependence analysis show that the current Q-guarantee specified in the Rules for the operation of the hydropower plants installed in the Varduva River does not ensure the long-term existence of

viable fish populations, and should be increased to Q_{30_avg} to comply with the ecological flow concept (Table 8.2).

Table 8.2 Comparison of guaranteed flow values specified in reservoir exploitation rules and ecological flow proposed in TRANSWAT project for the Varduva Rivers in Lithuania

River	**HPP name**	**Guaranteed flow, m^3/s**	**Proposed E-flow based on Q_{30_avg}, m^3/s**
Varduva	Kulšėnai	0.20	0.62
Varduva	Renavas	0.39	0.66
Varduva	Vadagiai	0.41	0.68
Varduva	Ukrinai	0.46	0.71
Varduva	Juodeikiai	0.91	1.07

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https://circabc.europa.eu/sd/a/4063d635-957b-4b6f-bfd4-b51b0acb2570/Guidance%20No%2031%20-%20Ecological%20flows%20%28final%20version%29.pdf

Impact assessment of hydrotechnical structures on river runoff and sustainable water management for conservation and restoration of water ecosystems: Final Report, 2022. ECODAM project (Project No. S-SIT-20-3) funded by the Research Council of Lithuania (LMTLT), the National Research Programme 'Sustainability of agro-, forest and water ecosystems (2015–2021)'

Methodology of E-flow evaluation on the base of Venta and Lielupe Latvian-Lithuanian transboundary river basins, 2019. ECOFLOW project report. https://www.meteo.lv/fs/CKFinderJava/userfiles/files/Par_centru/ES_projekti/ECOFLOW/DeliverableT3_1_METHODOLOGY.pdf