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Ecological flow estimation in Latvian – Lithuanian transboundary river basins (ECOFLOW), LLI-249

River Habitat modelling results Report: Venta & Lielupe River Basin Districts 2017-2018

Latvia and Lithuania

ECOflow

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ABBREVIATIONS

WFD	Water Framework Directive
CIS	Common Implementation Strategy
EU	European Union
HPP	Hydropower Plant
GU	Geomorphic Unit
WGS	Water Gauging Station
e-flow	ecological flow
MesoHABSIM	Meso-scale Habitat Simulation
l/sec	litres per second
m^3/sec	cubic meters per second
Q	water discharge
LV-LT	Latvian - Lithuanian

1. INTRODUCTION

The main objective of the River habitat modelling is to calculate the habitat suitability for aquatic species (fish) in different hydro-morphological conditions. Modelling results analysis leads the e-flow values estimation in regulated rivers of Venta and Lielupe river basins, based on the principles and approaches 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 Venta and Lielupe river basins in project countries:

Lithuania:

- Venta River – Papile WGS, downstream Rudikiai HPP;
- Venta River – Leckava WGS, downstream Kuodziai HPP;
- Bartuva River – Skuodas WGS, downstream Skuodas HPP;
- Musa River – Ustukiai WGS, downstream Dvariukai HPP;
- Levuo River - Bernatoniai WGS, downstream Akmeniai HPP;
- Suosa River - downstream Stirniskiai HPP.

Due to distinctive climatic conditions of 2018 (very drought summer) and certain management of reservoir resources, when the inflow was lower than outflow and in some cases the values get closer to 1 l/sec. Meanwhile outflow discharge was even during the whole observing period (18-21 l/sec), only several times Stirniskiai HPP was in operating mode. Such conditions provided an opportunity to measure only low min and low average situations below HPP. The dramatic decrease of water level (~76cm) in the reservoir of Stirniškiai HPP with evident impact on the wealth of ecosystem was caused. Due to absence of discharges of low maximum and annual mean values below HPP the project experts were not be able to collect all necessary hydromorphological and hydrological data, which are required for habitat modelling. Therefore, the modelling wasn’t carried out in the case study of Suosa River.

Latvia:

- Vanka River – downstream Edole HPP;

- Eda River – downstream Skede HPP;
- Ciecere River – downstream Pakuli HPP;
- Berze River – downstream Bikstu-Paleja HPP;
- Auce River - downstream Bene HPP;
- Islice River - downstream Rundale HPP.

The habitat modelling results have shown that hydro-morphological alterations considerably affect the ecological status of rivers. The most significant pressures in the pilot basins are the interruption of the river continuity by dams' construction and hydrological regime regulations by HPP.

2. MESO-SCALE HABITAT SIMULATION MODEL (MESOHABSIM)

2.1. Concept and application

The Meso-scale Habitat Simulation Model (MesoHABSIM) addresses the requirements of river basin management. It builds to predict an aquatic communities' response to river habitat modification due to anthropogenic pressures.

The variable spatial distribution of the physical characteristics of the river, resulting from flow fluctuations and biological reactions of the aquatic species (fish) to these changes, is the basis for simulating the effects of changes in the ecosystem and, accordingly, justification for mitigation measures.

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 is a background for integrative analyses of many aspects of the ecosystem. It allows to recreate reference habitat conditions and evaluate possible instream and river basin restoration measures, such as fish-pass construction or changes in HPP operations. From the perspective of water resource management, it not only allows for quantitative measures of ecosystem' sustainability, but also creates a basis for balance between water resources use and ecological quality – evaluation of ecological flow.

2.2. Sim-Stream Model

Sim-Stream Model is a tool that supports the Mesohabitat 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 geomorphic units (GUs) changes as a function of flow, the mesohabitats are mapped under multiple flow conditions at representative stretches of the river. The independent biological data (fish) is collected in selected mesohabitats, and are imported to Sim-Stream Model where the relationship between fish and habitat distribution is calculated with multivariate statistics.

The habitat suitability in areas that have not been biologically sampled is computed. The wetted area suitable for a species is determined for all surveyed flows (4 in case of ECOFLOW project) and interpolated for unmeasured conditions. The Sim-Stream Model performs habitat time series analyses that describe spatial and temporal habitat patterns necessary to support selected fauna as well as number of indices for river ecological quality assessment.

3. MODEL INPUT DATA

3.1. Geomorphic Unit maps and Field Survey

Habitat types are defined by their hydro-morphological or geomorphic units (GUs), such as pools and rapids, geomorphology, land cover and hydrological characteristics. Mesohabitats are mapped under multiple flow conditions at case-study sites along the river. For modelling the spatial information about GUs location and size as well as data of water depth, flow velocity and river bad substrate within GU have been used.

3.2. Hydrological data

The hydrological data is performed as a daily water flow data in reference (upstream the HPP) and altered conditions (downstream HPP). Data series have been created for 3 different years (wet, normal and dry) in order to describe the habitat suitability in all possible hydrological conditions.

In the absence of flow data in reference conditions, the data series of river-analogue were used for modelling.

In Lithuania almost all (5 of 6) case-study sites have hydrological monitoring stations below HPPs. However, only 2 of Latvian case-study sites have hydrological monitoring stations downstream the determined small HPPs (Ciecere River – Pakuli HPP & Berze River – Bikstu-Paleja HPP), and downstream the Bikstu-Paleja HPP well three small HPPs are located. It leads to additional difficulties in calculation of flow data for altered conditions. The energy production data series and turbines technical specifications have been used for these purposes.

Figures 3.2.1. and 3.2.2. show some of the hydrographs used for habitat modelling.

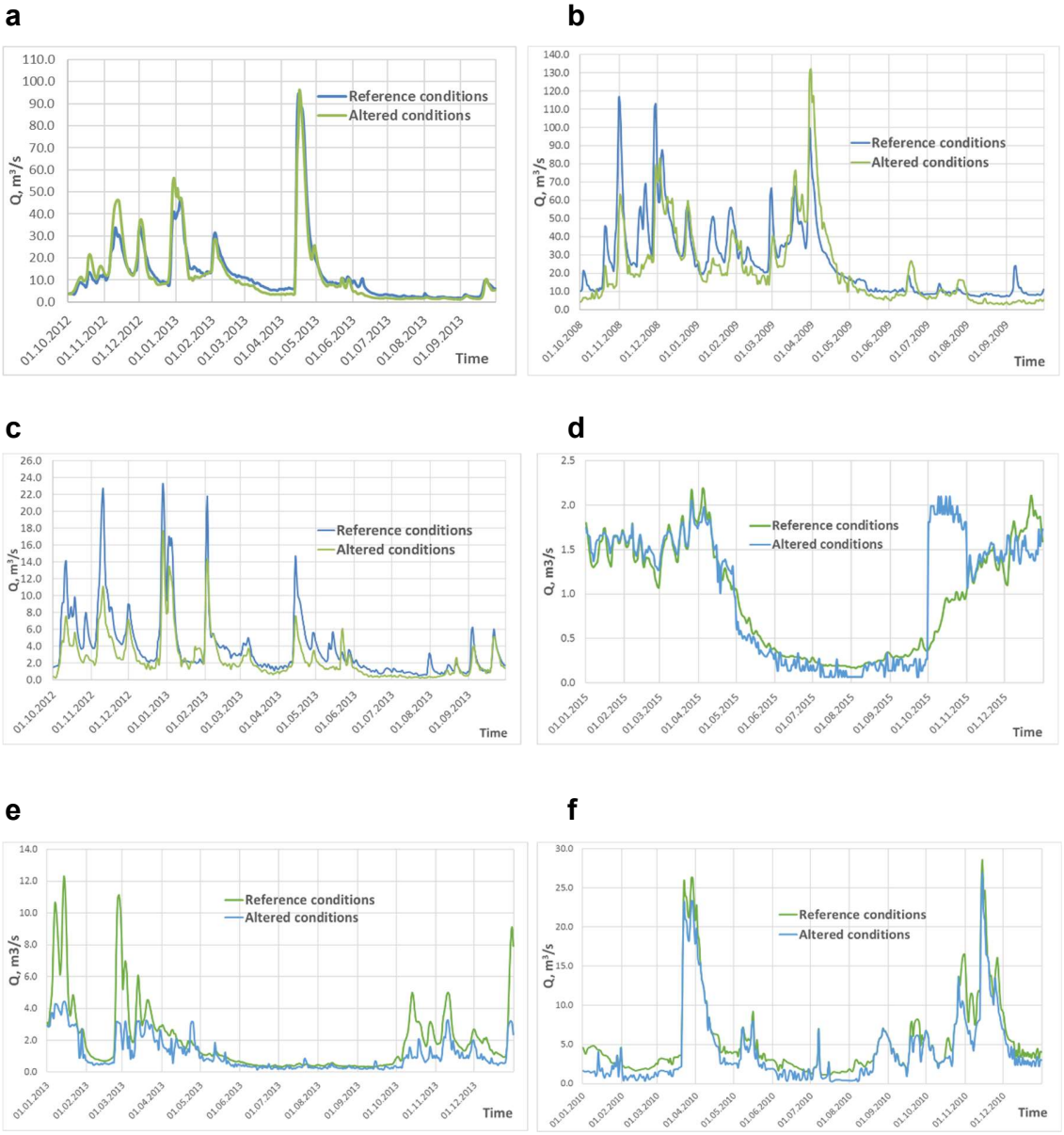
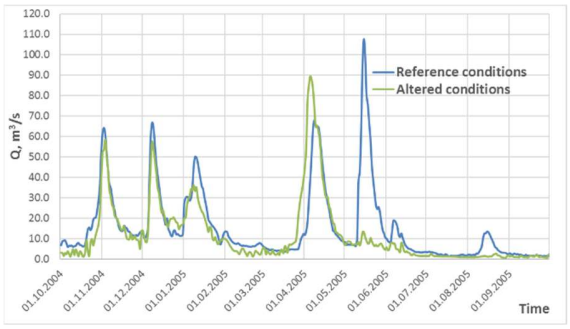


Figure 3.2.1. Hydrographs of Venta River basin (normal year)

a) Venta River – Papile WGS, downstream Rudikiai HPP; b) Venta River – Leckava WGS, downstream Kuodziai HPP; c) Bartuva River – Skuodas WGS, downstream Skuodas HPP; d) Vanka River – downstream Edole HPP; e) Eda River – downstream Skede HPP; f) Ciecere River – downstream Pakuli HPP

a



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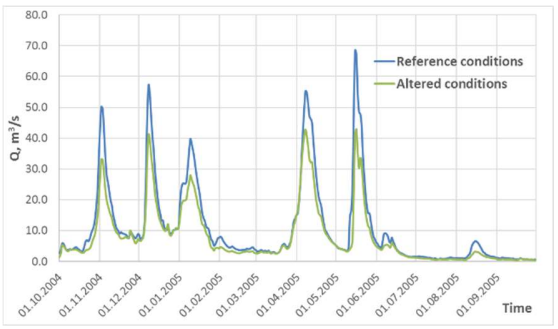

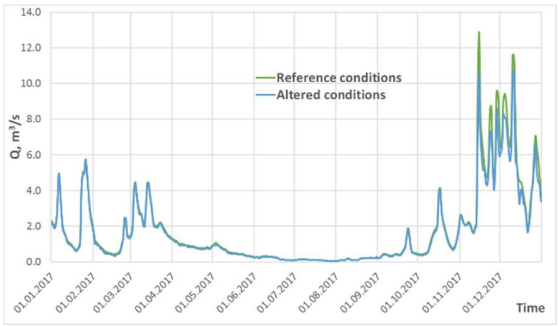

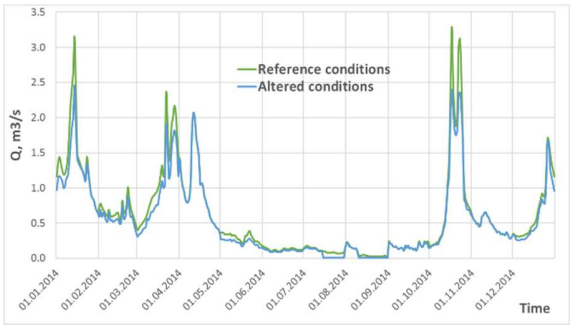

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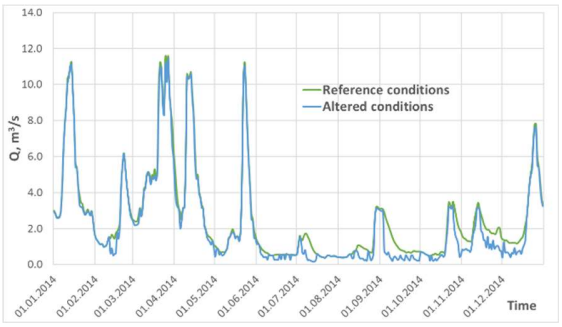


Figure 3.2.2. Hydrographs of Lielupe River basin (normal year)

a) Musa River – Ustukiai WGS, downstream Dvariukai HPP; b) Levuo River - Bernatoniai WGS, downstream Akmeniai HPP; c) Berze River – downstream Bikstu - Paleja HPP; d) Auce River - downstream Bene HPP; e) Islice River - downstream Rundale HPP

3.3. Fish data

Fish data have been collected in each case-study site, where habitat Field surveys were conducted in order to validate the developed Conditional Fish Model. For habitat modelling a *List of specific species of interest* has been created for each river within the project area. The order of species shows their priority.

All of those data are used for developing mathematical models that describe which mesohabitats are used by fish more frequently. This allows evaluating habitat availability at a range of flows.

4. MODELLING RESULTS FOR VENTA RIVER BASIN DISTRICT

4.1. Venta River - Papilė WGS

Venta below Rudikiai HPP is a cyprinid type river. The migration of anadromous fish from the lower reaches to the modelled river stretch is partially limited by a natural obstacle (Kuldiga Waterfall) and several HPP dams with installed fish ladders, but the anadromous vimba (Vimba vimba) is still found in the Venta downstream the Rudikiai HPP. Thus, Venta River stretch in the territory of Lithuania is important for the reproduction of vimba. The river is also inhabited by spirlin (*Alburnoides bipunctatus*) and bullhead (Cottus gobio), the fish species, which are protected in accordance with the EU Species and Habitat Directive.

List of species of interest in the Venta River downstream Rudikiai HPP

1. Vimba (Vimba vimba);
2. Spirlin (Alburnoides bipunctatus);
3. Bullhead (Cottus gobio)

Habitat-flow rating curve

The dependence of the proportion of the area of suitable habitat on the amount of flow was modelled for the species of interest. The habitat-flow rating curve is presented in Figure 4.1.1. It shows that the flow at which the habitat area of vimba reaches the point, at which further increase in habitat depends solely on the increase in the wetted area of the stretch, is about 4.40 m^3/s. Optimum flow for adult and juvenile spirlin and bullhead is about 1.8 m^3/s. With a further increase in flow, the habitat area decreases (juvenile Vimba), remains unchanged (juvenile and adult spirlin), or further increases depending solely on the increase in the wetted area of the stretch (bullhead).

Habitat suitability

The simulated changes in habitat suitability for vimba, spirlin and bullhead at different flows are shown in Figure 4.1.2. At the minimum of low discharge, the studied stretch is not suitable for adult vimba and spirlin. At high flows, the area of habitat suitable for vimba increases significantly and becomes optimal at average annual runoff. The habitat area suitable for spirlin increases slightly, but remains fairly limited regardless of the increase in the amount of flow. The area suitable for bullhead is present even at the minimum low flow, but increases significantly with increasing runoff.

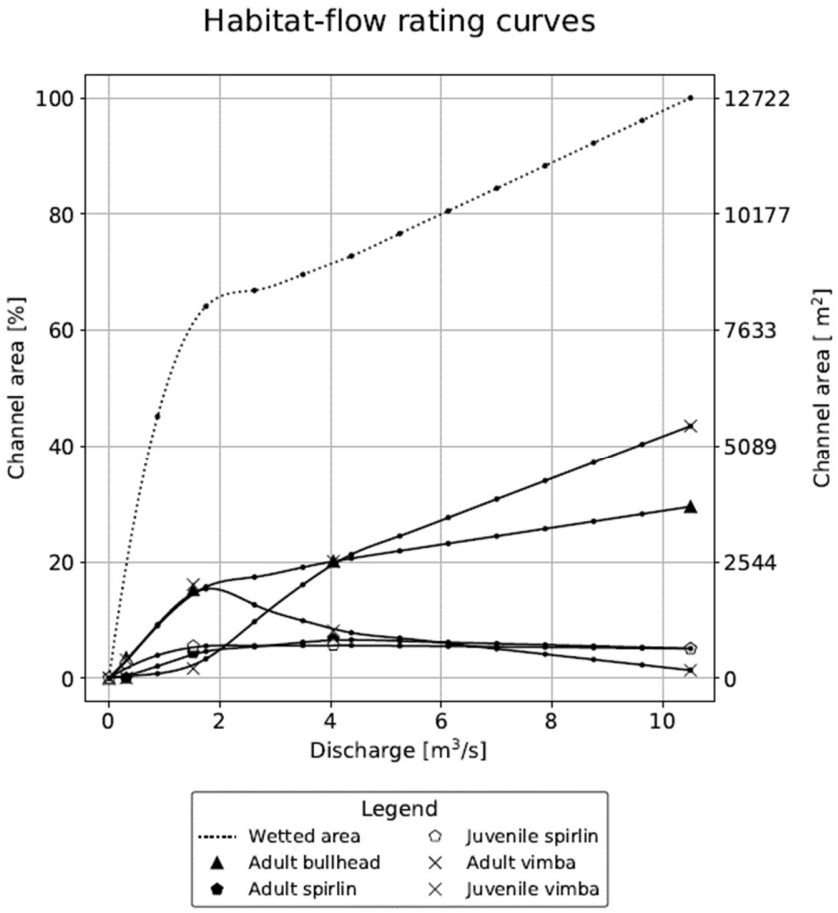


Figure 4.1.1. Habitat-flow rating curve of Venta River downstream Rudikiai HPP

Habitat availability

Changes in the flow lead to changes in both habitat suitability and availability. Figure 4.1.3 shows a temporal variation in habitat available for fish species of interest at reference conditions (if HPP would be absent), and altered conditions (i.e. when HPP functions) during the year with normal runoff. The red line in the pictures is the threshold corresponding to the habitat area with a probability of 97% and the blue line is the average habitat area. It can be seen that, at altered conditions, the line representing the area of effective habitat of spirlin and bullhead drops significantly below the threshold of 97% habitat probability for a continuous duration of almost 3 months. In other words, there is a probability of 97%, that at altered conditions, the habitat area available for spirlin and bullhead is significantly smaller continuously for 3 months than the minimum habitat area at reference conditions. The difference between habitat area at reference and altered

conditions may become particularly large in dry years. The same is valid for vimba, but the difference between the minimum area of suitable habitat at reference and altered conditions is much smaller, because at low flow, the area suitable for vimba in the Venta below Rudikiai HPP is very small even at natural conditions.

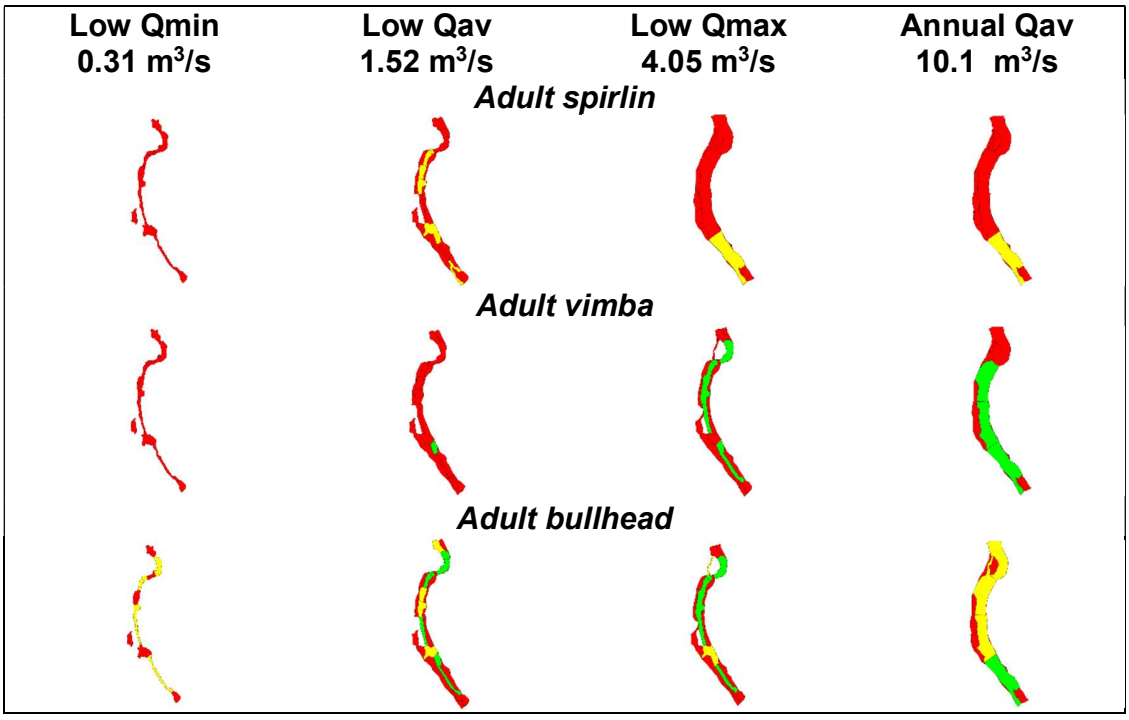


Figure 4.1.2. Habitat suitability for adult spirlin, vimba and bullhead at different runoff in the modelled stretch of Venta River below Rudikiai HPP (Not suitable Suitable Optimal **).**

The Rudikiai HPP leads to a significant decrease in habitat area suitable for protected fish species (vimba, spirlin and bullhead) in the Venta River stretch below HPP. The negative impact is particularly strong in dry years, when the area of suitable habitat is 3-4 months continuously less than the area at reference conditions with a probability of 97%.

The optimal water flow, which provides the sufficient area of suitable habitat for adult vimba is Q=4.41 m^3/s. The lowest threshold of optimal flow for the remaining species and juveniles is ~1.8 m^3/sec.

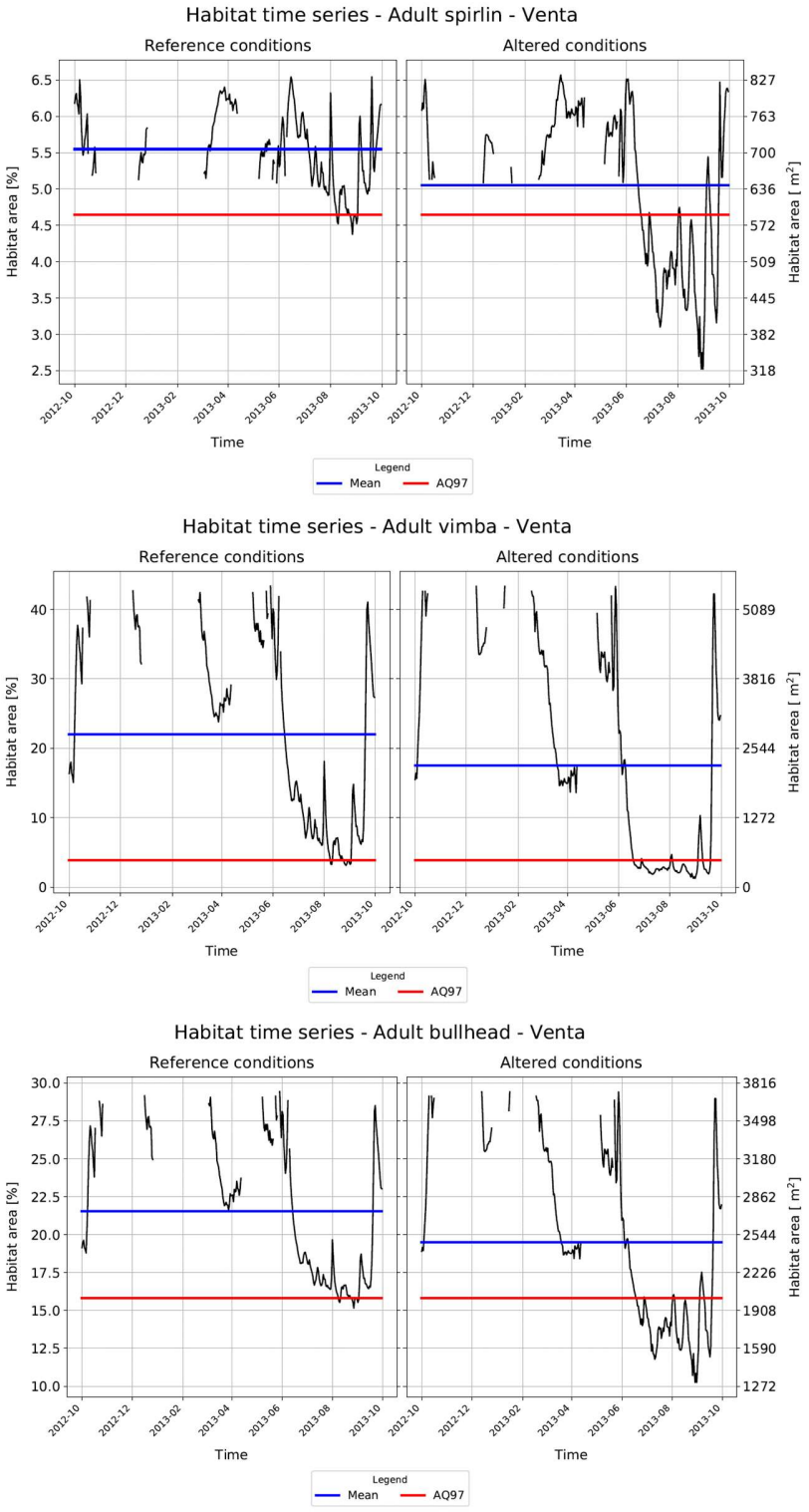


Figure 4.1.3. Time series of habitat availability for spirlin, vimba and bullhead at reference and altered conditions (the year with normal flow).

4.2. Venta River - Leckava WGS

Venta downstream Kuodžiai HPP is a cyprinid type river, but salmonids are also present in some natural tributaries. Due to the natural obstacle (Kuldiga waterfall) downstream Lithuanian/Latvian border, anadromous salmonid species only rarely access Lithuanian part of Venta River. But during spring floods Venta downstream Kuodžiai becomes accessible for another anadromous fish species, the vimba (*Vimba vimba*). Thus modelled stretch of the Venta River is important for vimba's reproduction. The stretch is also inhabited by spirlin (*Alburnoides bipunctatus*) and bullhead (Cottus gobio), the fish species, which are protected under EU Species and Habitat Directive.

List of species of interest in the Venta River downstream Kuodžiai HPP

1. Vimba (Vimba vimba);
2. Spirlin (Alburnoides bipunctatus);
3. Bullhead (Cottus gobio)

Habitat-flow rating curve

The dependence of the proportion of the area of suitable habitat on the amount of flow was modelled for the species of interest, as well as some other anadromous fish that would have been present in the absence of Kuldiga waterfall (anadromous salmonids and lampreys). The habitat-flow rating curve is presented in Figure 4.2.1. It shows that the flow at which the habitat area of adult vimba reaches its maximum, and that of spirlin reaches the point, at which further increase in habitat depends solely on the increase in the wetted area of the stretch, is about 13.38 m^3/s. Optimum flow for juvenile vimba and bullhead is about 4.2 m^3/s. With a further increase in flow, the habitat area decreases, or further increases depending solely on the increase in the wetted area of the stretch (adult spirlin).

Habitat suitability

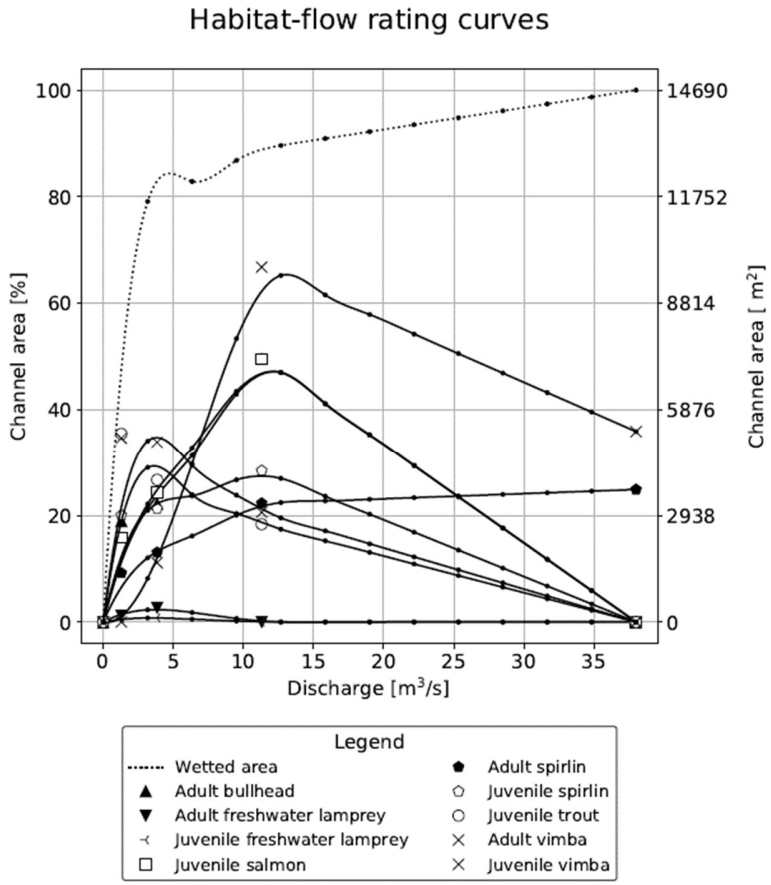


Figure 4.2.1. Habitat-flow rating curve of Venta River downstream Kuodžiai HPP

The simulated changes in habitat suitability for vimba, spirlin and bullhead at different flows are shown in Figure 4.2.2. At the minimum of low discharge, the studied stretch is not suitable for adult vimba and only partly suitable for spirlin. At higher flows, the area of habitat suitable for both fish species increases significantly, particularly that of spirlin. The area suitable for bullhead, on opposite, is present at the minimum low flow, while at high flow it becomes unsuitable. Bullhead is a small benthic fish species. It is a typical inhabitant of salmonid streams, therefore increase in the water level together with the flow is not favorable for this species.

Habitat availability

Temporal changes in the flow result in variation of availability of suitable habitat. Figure 4.2.3 shows a temporal variation in habitat available for fish species of interest at reference conditions (if HPP would be absent), and altered conditions (i.e. when HPP functions) during the year with normal runoff. The red line in the pictures is the threshold corresponding to the habitat area with a probability of 97% and the blue line is the average habitat area. It can be seen that, at altered conditions, the line representing the area of effective habitat of spirlin and vimba drops significantly below the threshold of 97% habitat probability for a continuous duration of about 2 months. In other words, there is a probability of 97%, that at altered conditions, the habitat area available for spirlin and vimba is significantly smaller continuously for 2 months than the minimum habitat area at reference conditions. The difference between habitat area at reference and altered conditions may become particularly significant in dry years. But functioning of Kuodžiai HPP doesn't have negative impact on habitat suitability for bullhead. This species is adapted to live in the shallow water, so a decrease in the water level in Venta downstream Dvariukai HPP may even be beneficial for the latter species.

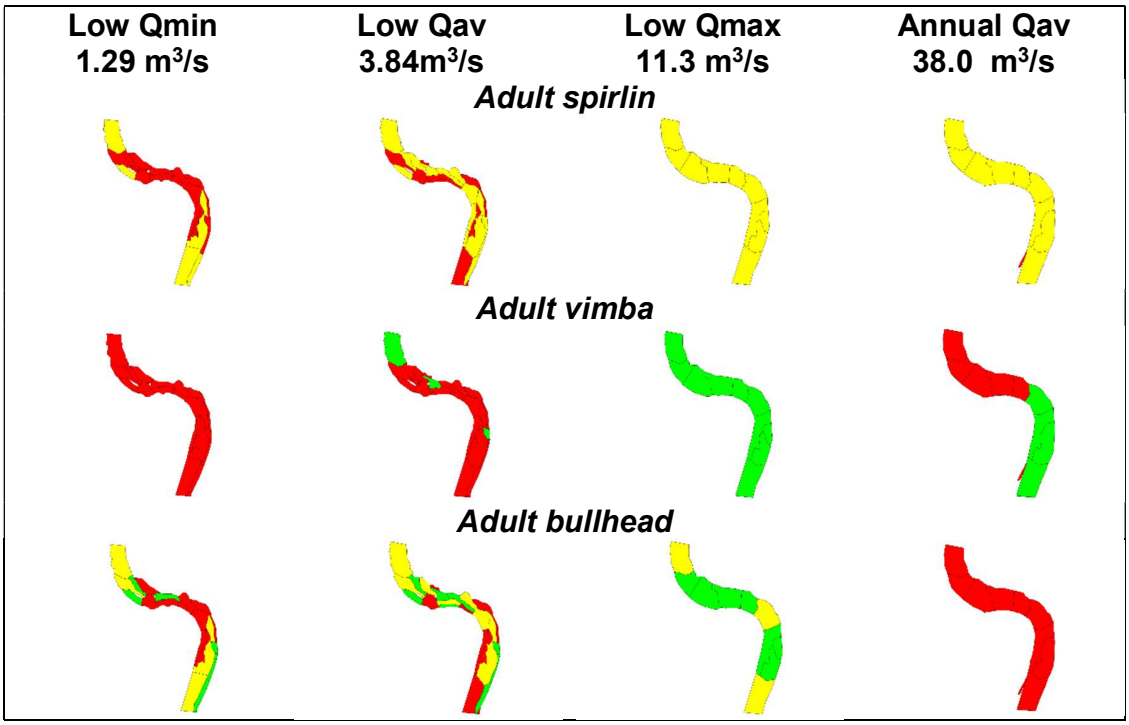
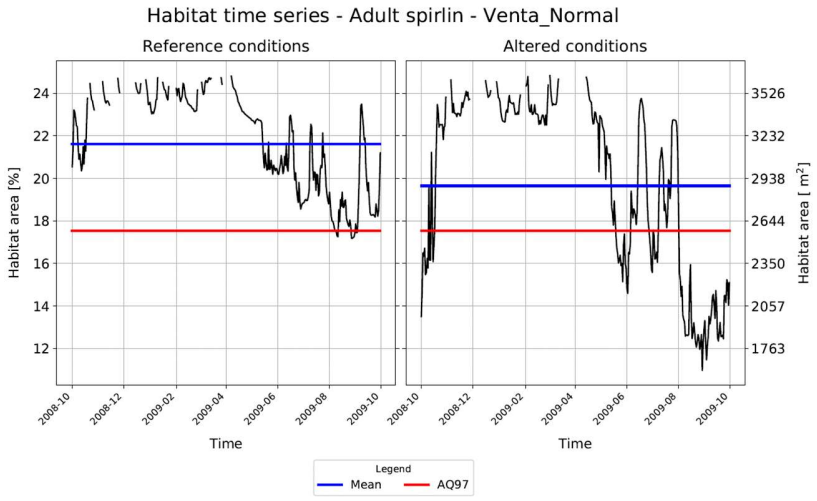


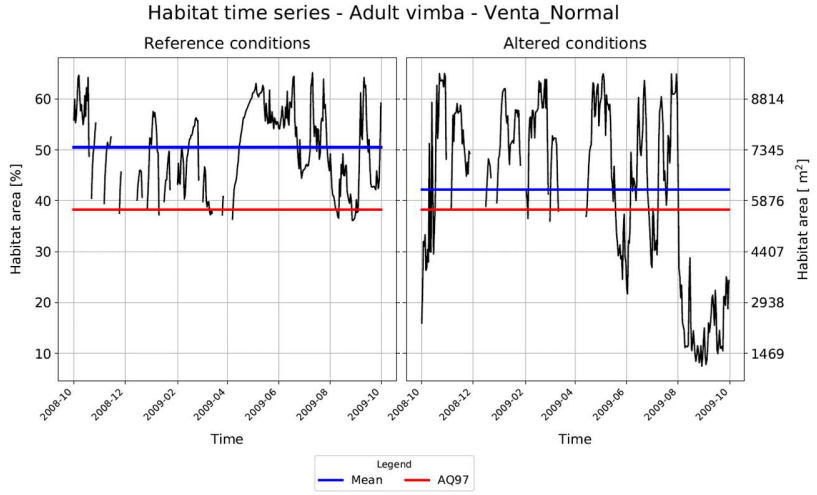
Figure 4.2.2. Habitat suitability for adult spirlin, vimba and bullhead at different runoff in the modelled stretch of Venta River below Kuodžiai HPP

(Not suitable | Suitable | Optimal)

It is evident that in the late summer-autumn, the functioning of the Kuodžiai HPP leads to a significant continuous decrease in habitat area suitable for vimba and spirlin in the Venta River stretch below HPP. The negative impact is particularly strong in dry years. But HPP doesn't pose significant impact on the bullhead, which is adapted to live in shallow water.

The optimal water flow, which provides the sufficient area of suitable habitat for adult vimba and adult and juvenile spirlin is Q=13.38 m^3/s. The lowest threshold of optimal flow for the remaining species and juveniles is ~4.2 m^3/s.





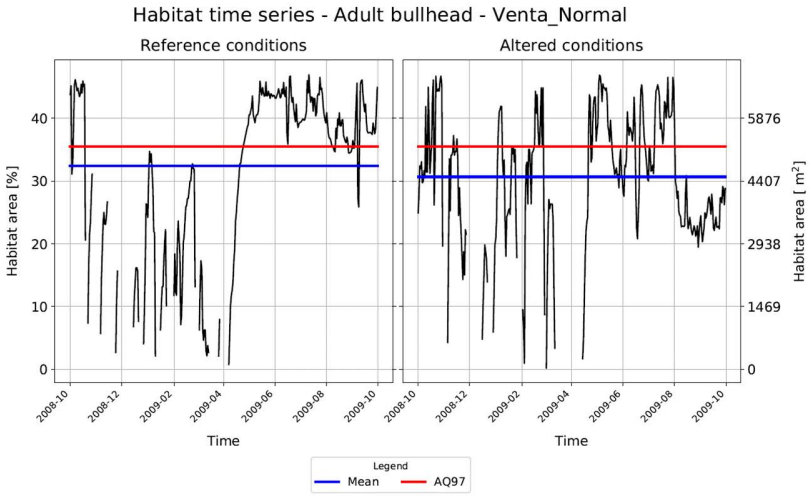


Figure 4.2.3. Time series of habitat availability for spirlin, vimba and bullhead at reference and altered conditions (the year with normal flow).

4.3. Bartuva River - Skuodas WGS

The Bartuva downstream of the Skuodas is a cyprinid type river, but anadromous salmonids also access to the river, as well as to larger tributaries. There are also spawning grounds of vimba (Vimba vimba) in the Bartuva river stretch close to the Lithuanian-Latvian border. The river is also inhabited by spirlin (*Alburnoides bipunctatus*) and bullhead (Cottus gobio), the fish species, which are protected in accordance with the EU Species and Habitat Directive. However, among these species, only spirlin was registered in the Bartuva River stretch close to the Skuodas HPP.

List of species of interest in the Bartuva River downstream Skuodas HPP

1. Spirlin (Alburnoides bipunctatus);
2. Bullhead (Cottus gobio)

Habitat-flow rating curve

The dependence of the proportion of the area of suitable habitat on the amount of flow was modelled for the species of interest as well as for ordinary species and rare species that could theoretically be present in the modelled river stretch. The habitat-flow rating curve is presented in Figure 4.3.1. It shows that the flow at which the habitat area of all modelled species reaches its maximum is about 1.24 m^3/s.

With a further increase in flow, the habitat area remains unchanged (bullhead), or further slightly increases depending solely on the increase in the wetted area of the stretch (spirlin).

Habitat suitability

The simulated changes in habitat suitability for spirlin and bullhead at different flows are shown in Figure 4.3.2. At the minimum of low discharge, the studied stretch is not suitable for either spirlin or bullhead. At higher flows, the area of habitat suitable for spirlin increases significantly, whereas the area of habitat suitable for bullhead increases only slightly and remains fairly limited, regardless of the increase in flow.

Habitat availability

Changes in the flow lead to changes in both habitat suitability and availability. Figure 4.3.3 show a temporal variation in habitat available for fish species of interest at reference conditions (if HPP would be absent), and altered conditions (i.e. when HPP functions) during the year with normal runoff. The red line in the pictures is the threshold corresponding to the habitat area with a probability of 97% and the blue line is the average habitat area. It can be seen that, at altered conditions, the line representing the area of effective habitat of spirlin and bullhead drops significantly below the threshold of 97% habitat probability for a continuous duration of almost 4 months. In other words, there is a probability of 97%, that at altered conditions, the habitat area available for spirlin and bullhead is significantly smaller continuously for 4 months than the minimum habitat area at reference conditions. The difference between habitat area at reference and altered conditions may become particularly large in dry years. However, the proportion of area suitable for bullhead in the Bartuva below Skuodas HPP is very small even at natural conditions. Therefore, this species is naturally rear in the modelled river stretch.

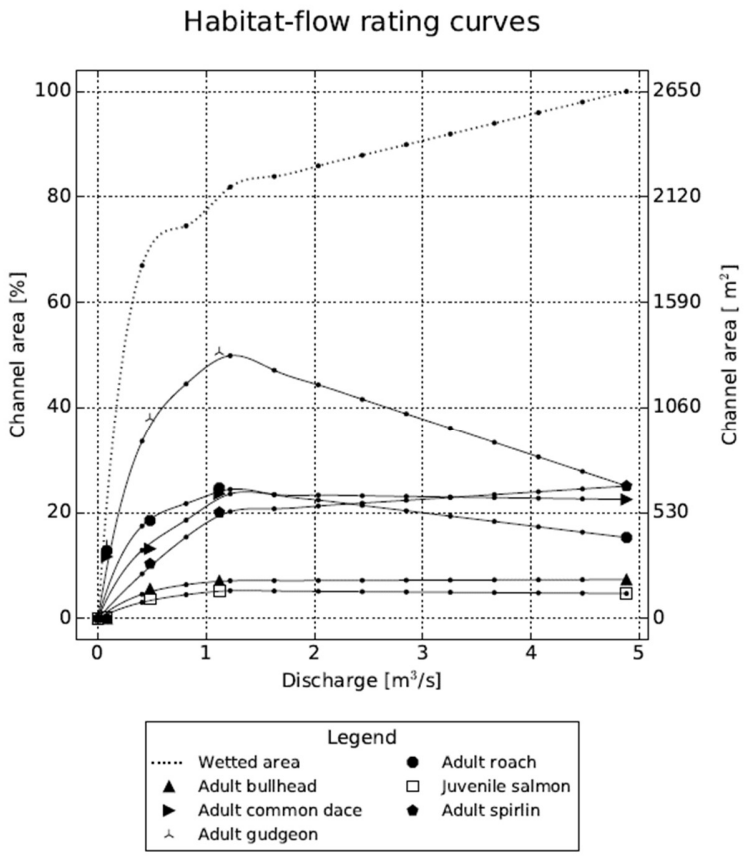


Figure 4.3.1. Habitat-flow rating curve of Bartuva River downstream Skuodas HPP

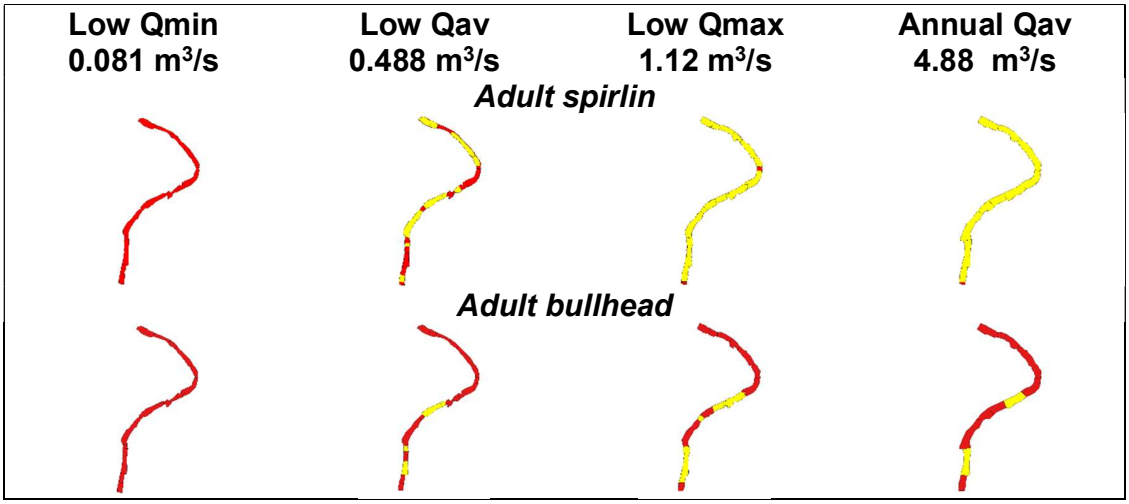


Figure 4.3.2. Habitat suitability for adult spirlin and bullhead at different runoff in the modelled stretch of Bartuva River below Skuodas HPP

Not suitable | Suitable | Optimal

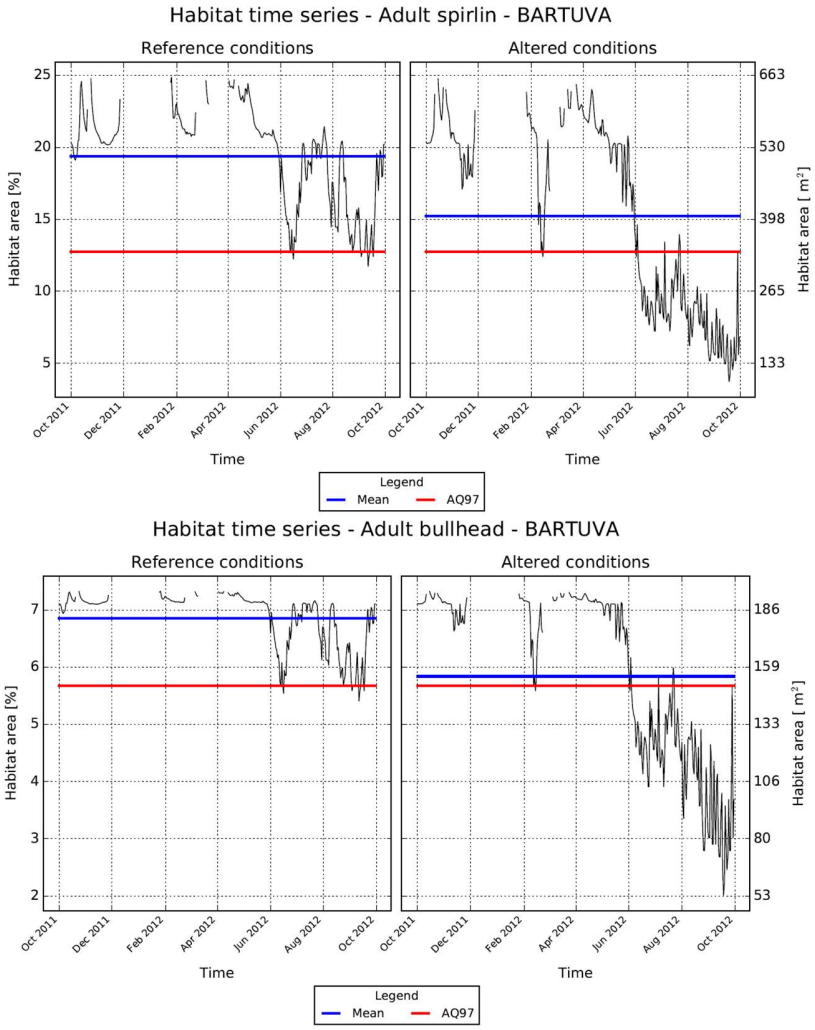


Figure 4.3.3. Time series of habitat availability for spirlin and bullhead at reference and altered conditions (the year with normal flow).

The functioning of the Skuodas HPP in the summer-autumn leads to a significant decrease in habitat area suitable for protected fish species (spirlin and bullhead) in the Bartuva River stretch below HPP. The negative impact is particularly strong in dry years. However, the proportion habitat area that is suitable for bullhead and juvenile salmonids is very small even at reference conditions.

The optimum water flow, which provides the maximum area of suitable habitat for most species, is Q=1.24 m^3/s.

4.4. Vanka River - downstream Edole HPP

Vanka is a salmonid type river that officially is not included in CR for priority fish waters. Edole HPP is the only hydropower plant in Vanka River. Additionally, there are two impoundments upstream the Edole HPP. The guaranteed water discharge that is required by Permission Act is 0.058 m^3/sec.

Vanka River List of species of interest:

1. Brown trout (*Salmo trutta*), juveniles & adult;
2. Northern spined loach (*Cobitis taenia*), adult;
3. Common dace (*Leuciscus leuciscus*), juveniles & adult;

4 Stone loach (*Barbatula barbatula*), juveniles & adult.

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 (brown trout, northern spined loach, stone loach) that was pre-selected by fish expert especially for Vanka River. It is evident that for some of species habitat area increases with increasing water discharge (brown trout), for others especially for juveniles the maximum habitat area is available at the average discharge of low flow period. Taking into account the guaranteed water discharge (0.058 m^3/sec), we can conclude that this discharge is too low, because available habitat for selected fish species varied from 0.40% (adult spirlin) to 34% (juvenile Eurasian minnow) of studied river stretch. During guaranteed discharge only 18% of river is available for juvenile trout. In general, guaranteed water discharge in Vanka River provides habitats that is suitable for small and juvenile fish.

Habitat – Flow rating curve:

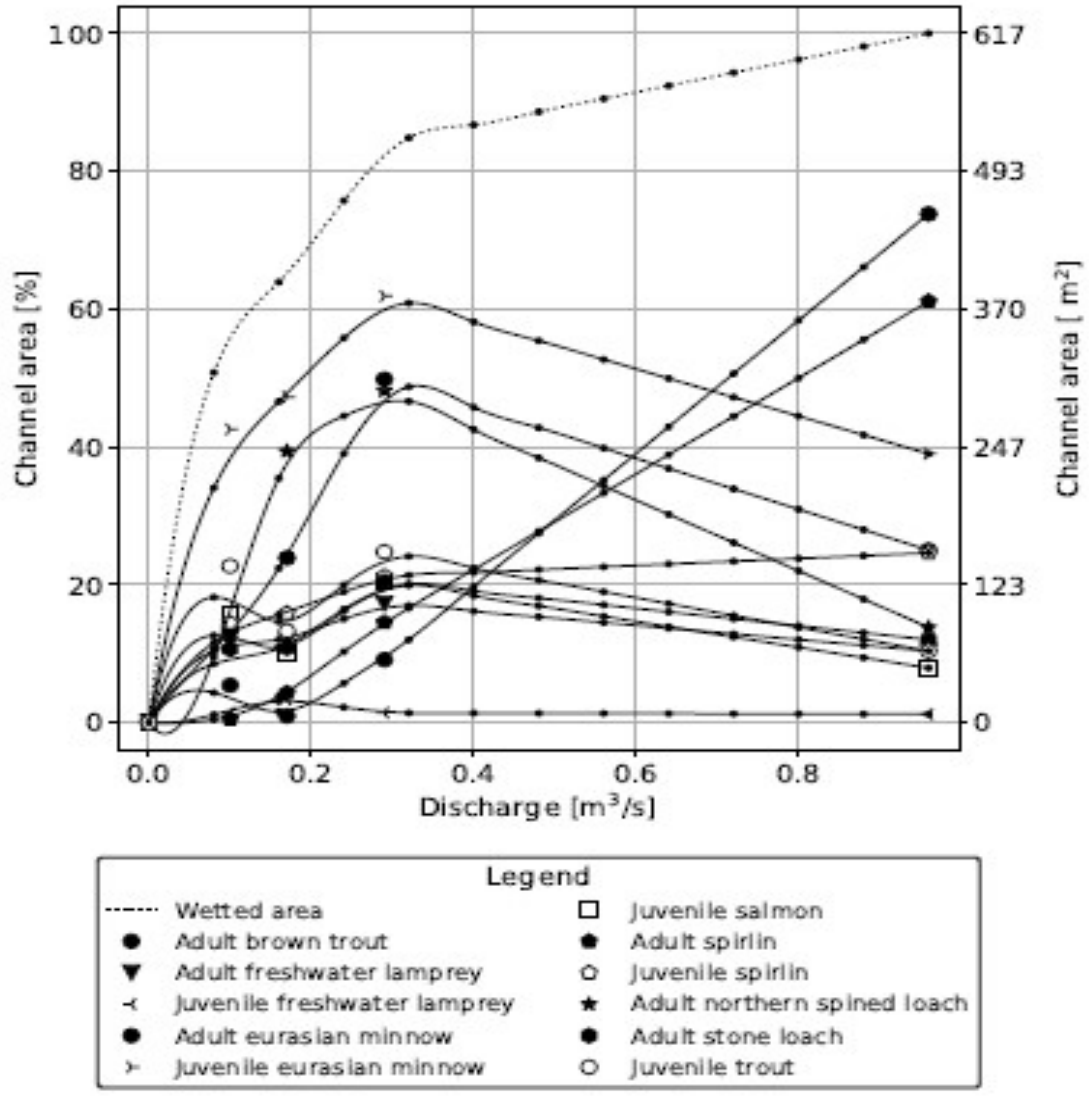
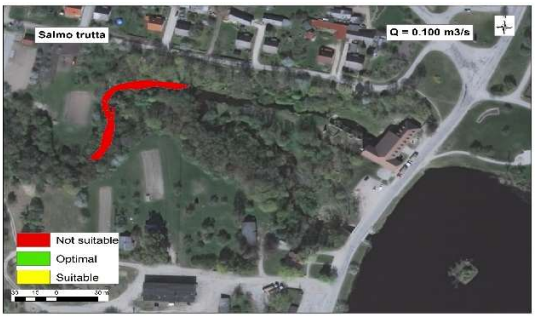


Figure 4.4.1. Habitat-Flow rating curve of Vanka River downstream Edole HPP

Vanka River Habitat Suitability maps:



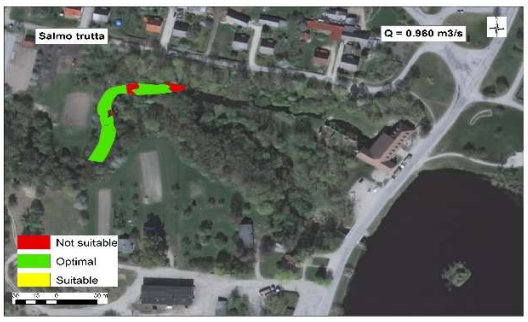
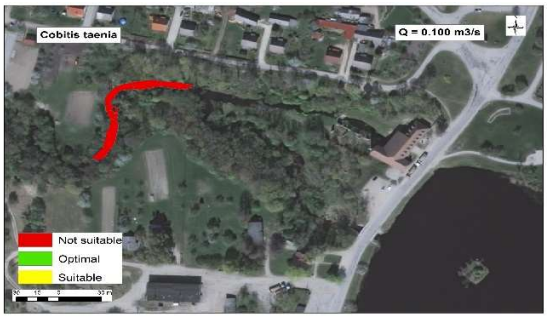


Figure 4.4.2. Habitat suitability maps for brown trout (adult) in presence of min low flow (above), max low flow (centre) and annual mean flow (below).



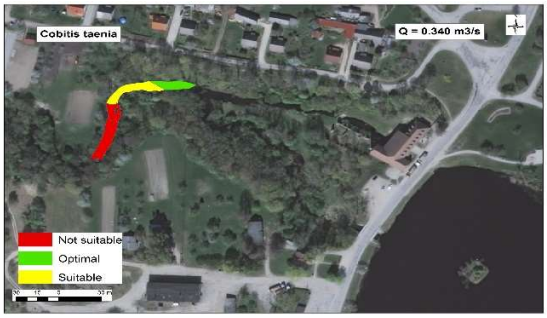


Figure 4.4.3. Habitat suitability maps for northern spined loach (adult) in presence of min low flow (above), max low flow (centre) and annual mean flow (below).

Figures 4.4.2 and 4.4.3. show habitat suitability maps for brown trout and northern spined loach, which are species of high priority for Vanka River. On both graphs the habitat suitability significantly increases with increasing discharge (water depth and stream velocity). For example, during min low flow no were suitable for adult brown trout. Habitat suitability started to increase during max low flow (32% were suitable) and during annual mean flow conditions most of river stretch (87%) were suitable for the brown trout. Also, for northern spined loach habitat availability increased during max low flow (suitable 52%) and annual mean flow (68%).

Habitat availability:

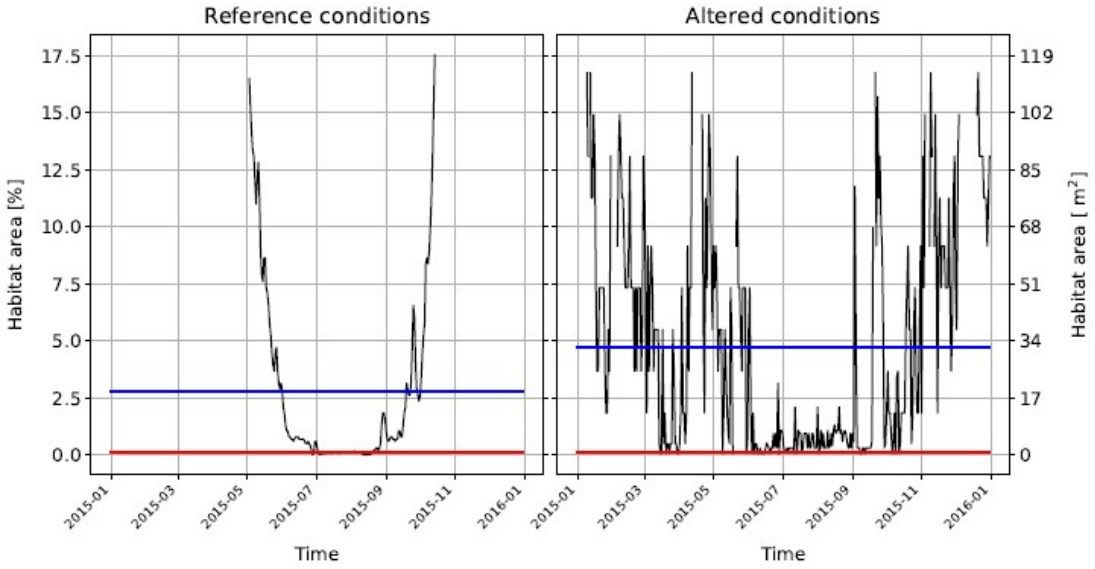


Figure 4.4.4. Habitat time series of the brown trout (adult) in reference and altered conditions

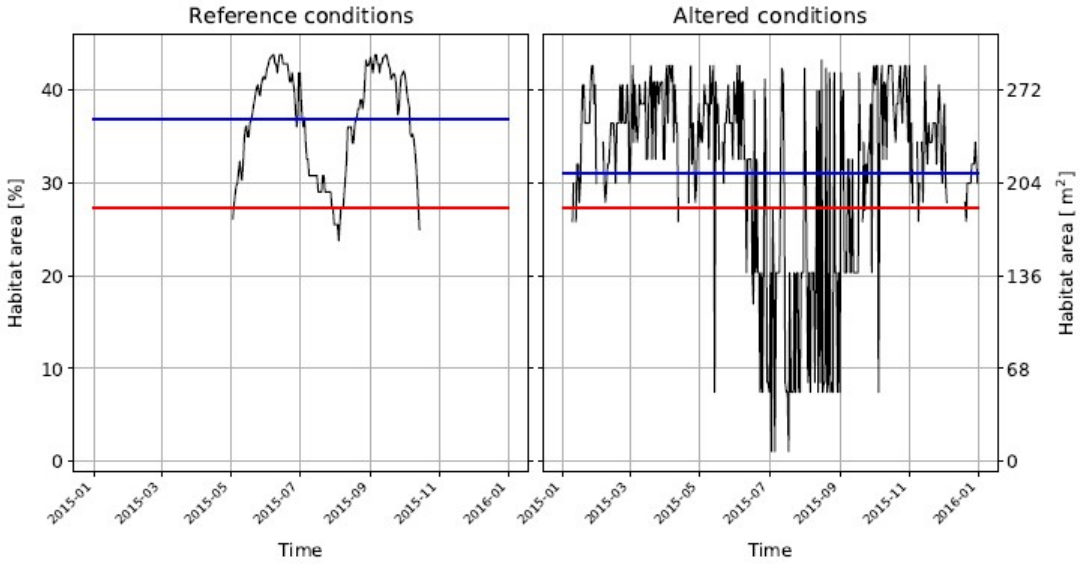


Figure 4.4.4. Habitat time series of the northern spined loach (adult) in reference and altered conditions

Figures 4.4.4 and 4.4.5. show the habitat distribution in time particularly during 2015 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. For the brown trout there aren't any habitats below red line that means presence of fish supported conditions. However, for the northern spined loach in altered conditions during summer low flow period about 30% of the habitat area are below threshold that leads increasing of fish stress days.

4.5. Eda River - downstream Skede HPP

Eda is a salmonid type river that outflow to the Baltic Sea. Skede HPP is one of two hydropower plants in Eda River. Spiku HPP is located about 2 km upstream, both are operated as cascade. The guaranteed water discharge of the Skede HPP that is required by Permission Act is 0.049 m^3/sec and the ecological water discharge is 0.18 m^3/sec.

Eda River List of species of interest:

1. Brown trout (*Salmo trutta*), juveniles & adult;
2. Freshwater lamprey (*Lampetra fluviatilis*), juveniles;
3. Bullhead (*Cottus gobio*), adult;
4. Spined loach (*Cobitis taenia*), adult.

Habitat – Flow rating curve:

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 (brown trout, freshwater lamprey, northern spined loach, etc.) that was pre-selected by fish expert especially for Eda River. It is evident that for some of species habitat area increases with increasing of water discharge (brown trout), for others especially for juveniles the maximum habitat area is available at the average discharge of low flow period.

Habitat – Flow rating curve:

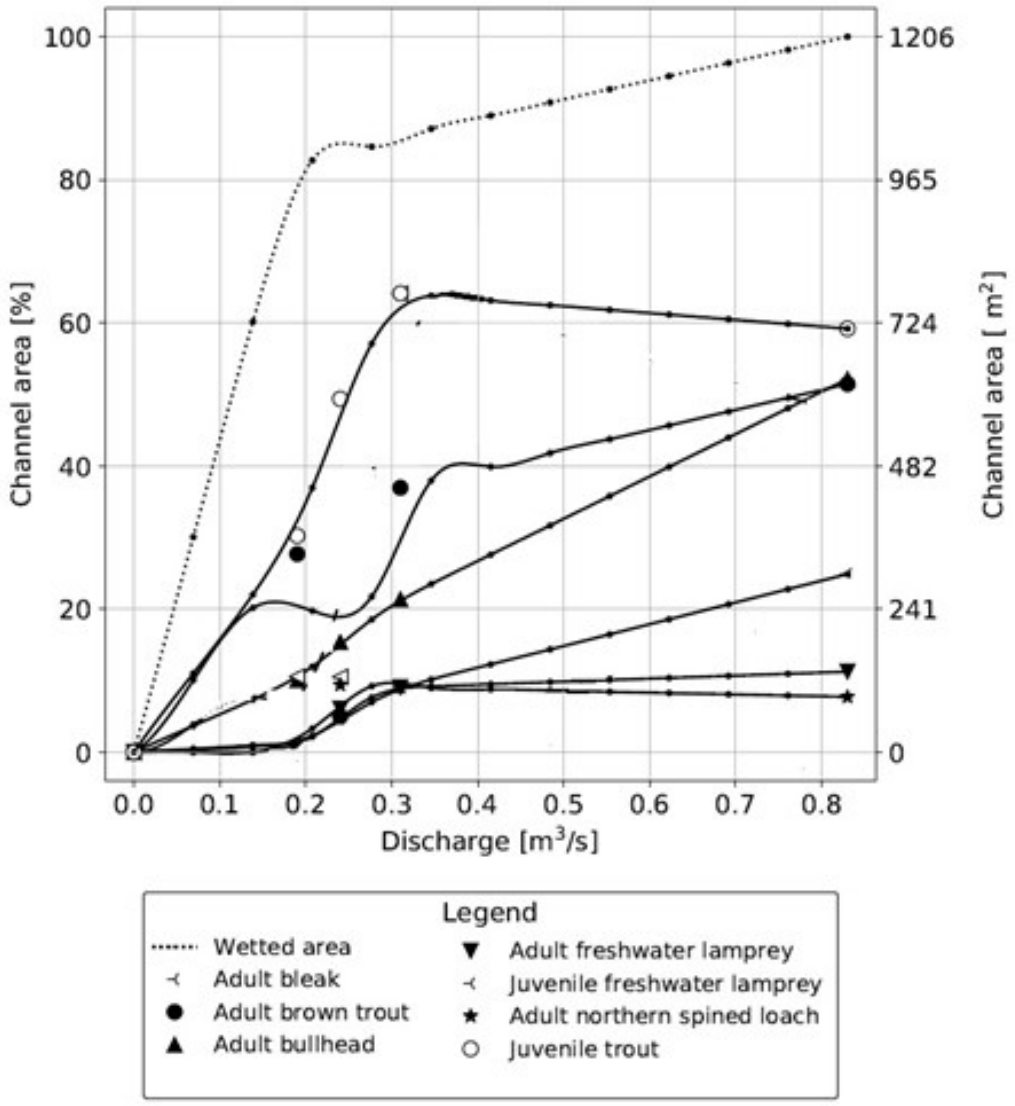
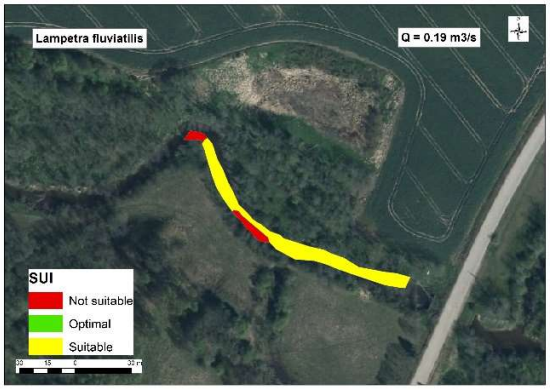


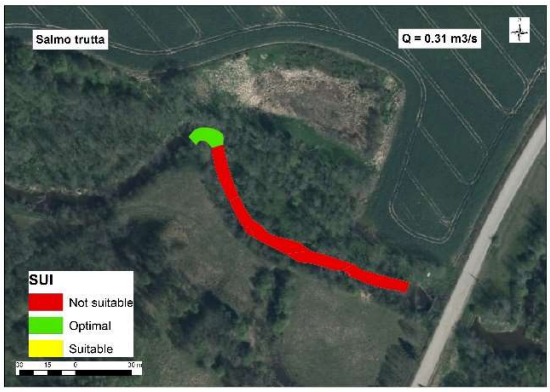
Figure 4.5.1. Habitat-Flow rating curve of Eda River downstream Skede HPP

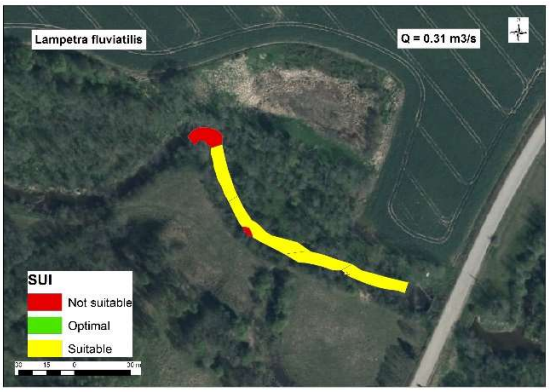
These curves were modelled for each fish species of interest (e.g. brown trout, bullhead, freshwater lamprey) that was pre-selected by fish expert especially for Eda River. It is evident that for all species habitat area increases with increasing water discharge, only for juvenile trout and adult northern spined loach the maximum habitat area is available at the max discharge of low flow period. Taking into account our modelling results, the guaranteed water discharge (0.049 m^3/sec) can't provide more than 11% (juvenile trout) of suitable habitats for target fish species. During ecological discharge (0.18 m^3/s), available habitats within river stretch increases to maximum 19.8% (adult brown trout) and 37% (juvenile trout).

For all other selected fish species available habitats during ecological discharge is less than 12% of total measured river stretch. Maximum available habitat in Eda River is 63.8% of river stretch (juvenile trout), existing guaranteed water discharge can provide only maximum 58% of potential available habitat for juvenile trout in Eda River. For other fish species ecological discharge can provide less than 40% of potential habitat.

Eda River Habitat Suitability maps:







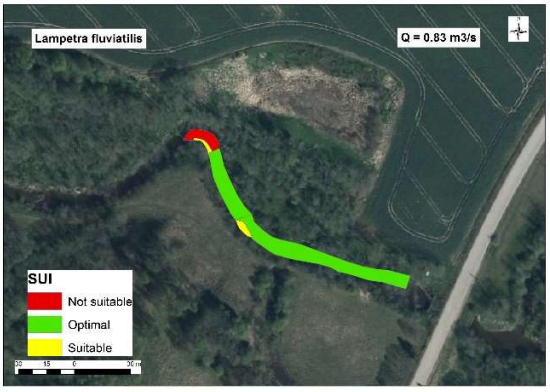


Figure 4.5.2. Habitat suitability maps for brown trout (adult) in presence of min low flow (above), max low flow (centre) and annual flow (below).

Figure 4.5.3. Habitat suitability maps for freshwater lamprey (adult) in presence of min low flow (above), max low flow (centre) and annual flow (below).

Figures 4.5.2 and 4.5.3. show habitat suitability maps for the adult brown trout and adult freshwater lamprey, which are species of high priority for Eda River. On both graphs the habitat suitability significantly increases with increasing discharge (water depth and stream velocity). For example, during min low flow no GU were suitable for adult brown trout. During annual mean flow conditions most of river stretch (95%) were suitable for the brown trout.

Habitat availability:

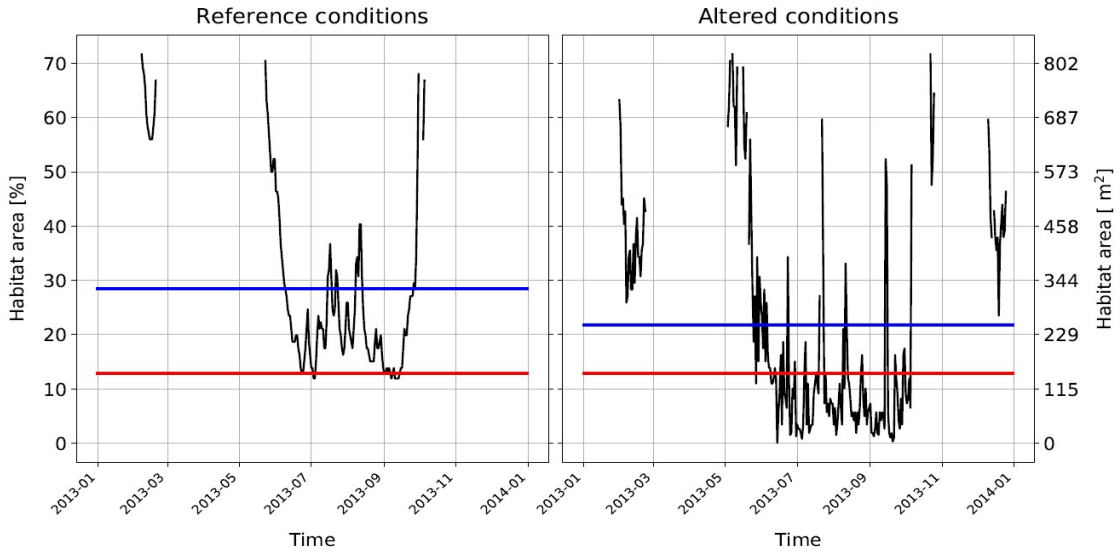


Figure 4.5.4. Habitat time series of the brown trout (adult) in reference and altered conditions

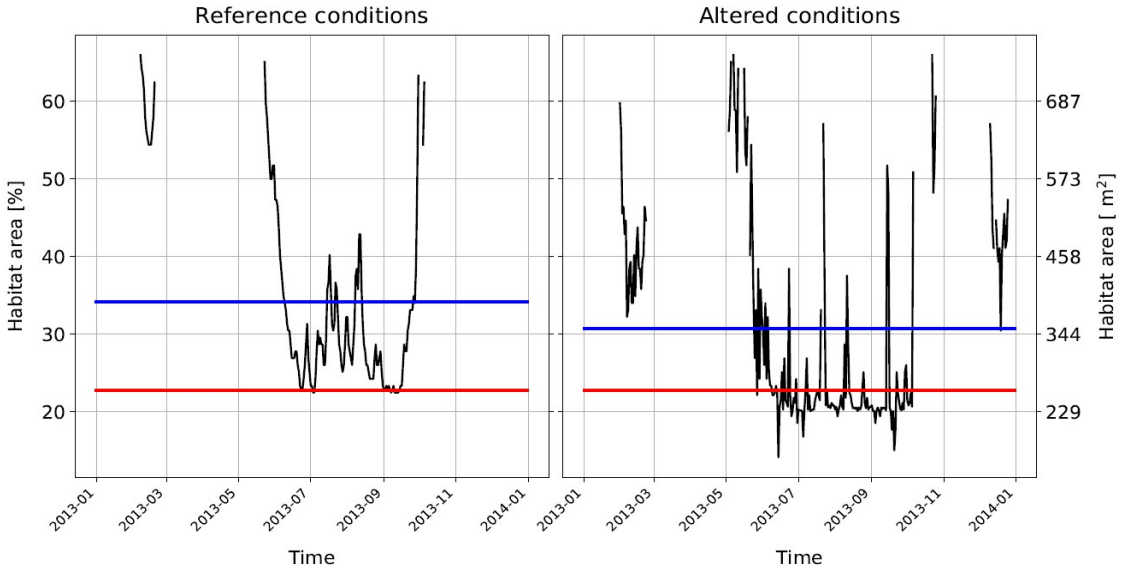


Figure 4.5.5. Habitat time series of the freshwater lamprey (adult) in reference and altered conditions

Figures 4.5.4 and 4.5.5. show the habitat distribution in time particularly during 2013 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 identical for the high priority fish species. As for the brown trout as for the freshwater lamprey in altered conditions during summer low flow period respectively 13% and 23% of the habitat area are below threshold that leads increasing of fish stress days.

4.6. Ciecere River - downstream Pakuli HPP

Ciecere is a salmonid type river. Three hydropower plants are built in the Ciecere River. Pakuli HPP is in the river lower stretch and Ciecere HPP and Dzirnavnieki HPP are located upstream. The guaranteed water discharge of Pakuli HPP that is required by Permission Act is 0.32 m^3/sec.

Ciecere River List of species of interest:

1. Brown trout (*Salmo trutta*), juveniles & adult;

2. Spirlin (*Alburnoides bipunctatus*), juveniles & adult;

3. Chub (*Squalius cephalus*), juveniles & adult;

4. Northern spined loach (*Cobitis taenia*), adult;

5. Common dace (*Leuciscus leuciscus*), adult.

Habitat – Flow rating curve:

Habitat curves for selected fish species depending on flow rate are shown in Figure 4.6.1. These curves were modelled for each fish species of interest (e.g. brown trout, spirlin, common dace) that was pre-selected by fish expert especially for Ciecere River. It is evident that for all species habitat area increases with increasing water discharge, only for adult northern spined loach the maximum habitat area is available at the average discharge of low flow period. Taking into account the guaranteed water discharge (0.32 m^3/sec), we can conclude that this discharge is too low, because available habitat for selected fish species varied from 0.60% of total studied river stretch (adult brown trout) to 16.3% (juvenile trout).

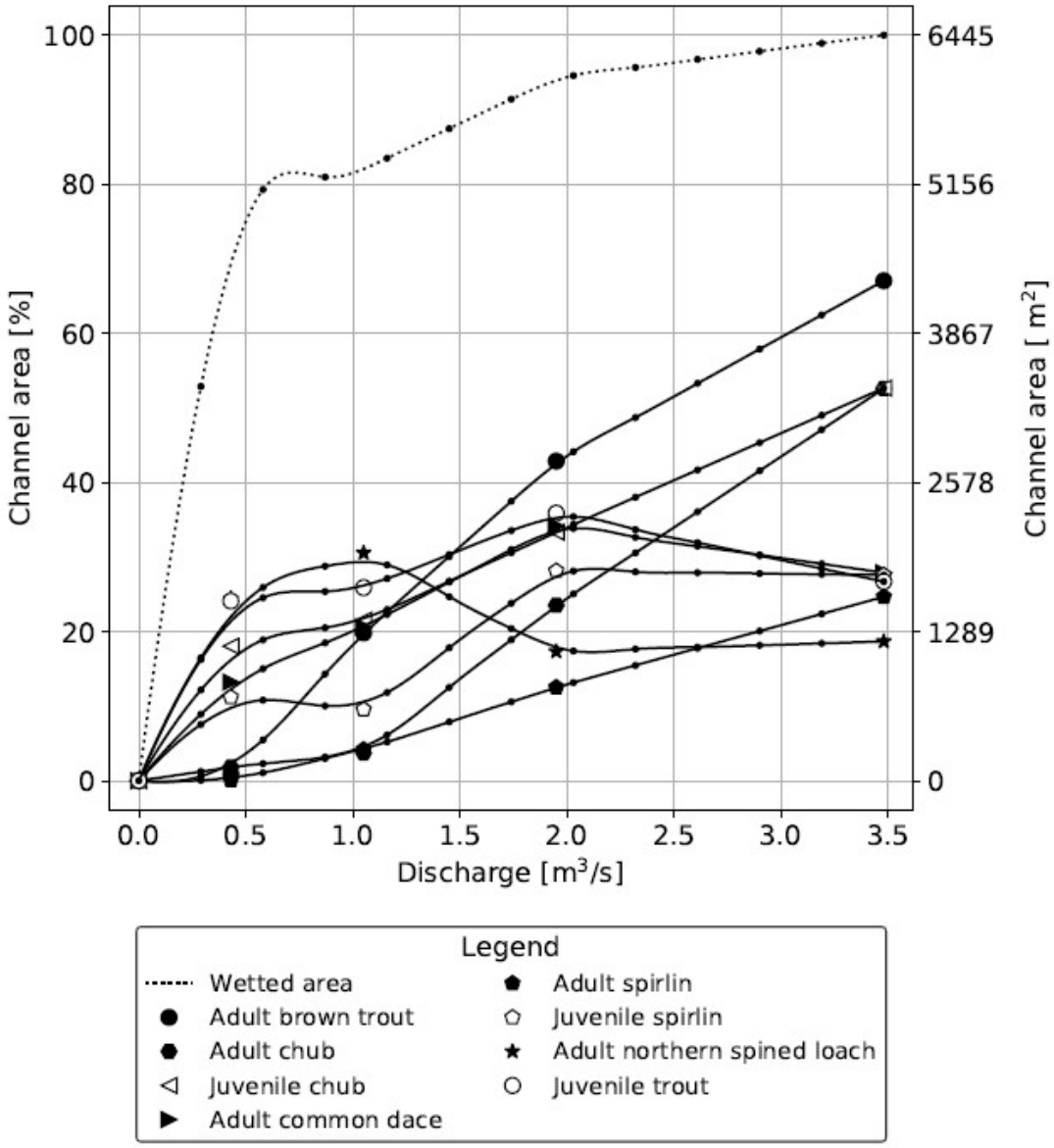
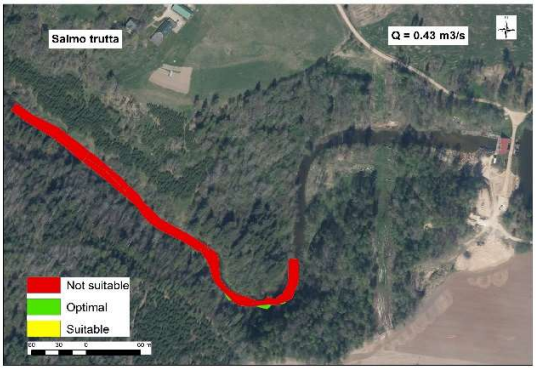
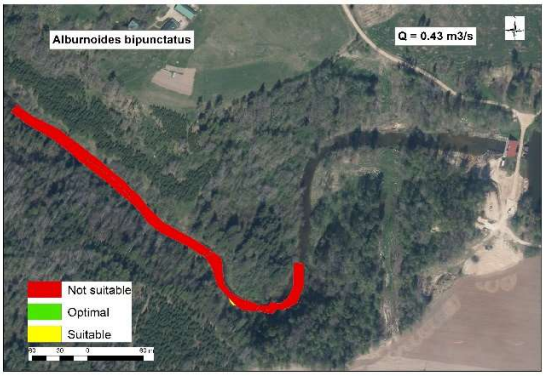
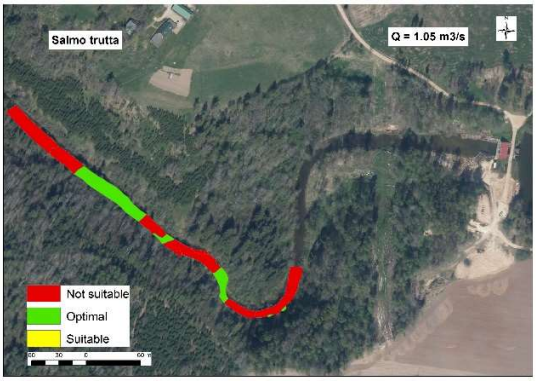


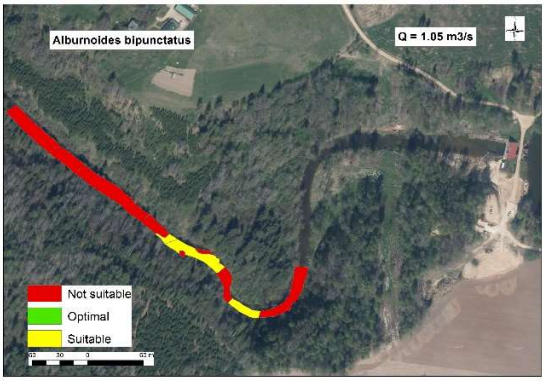
Figure 4.6.1. Habitat-Flow rating curve of Ciecere River downstream Pakuli HPP

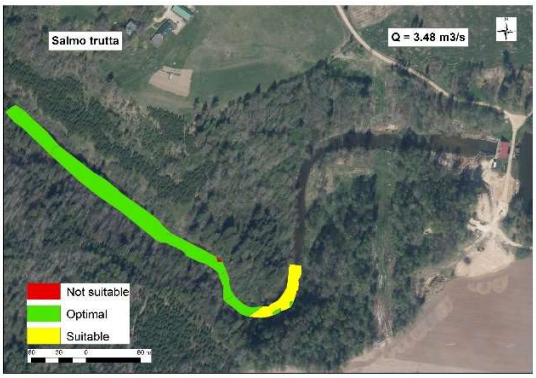
Ciecere River Habitat Suitability maps:











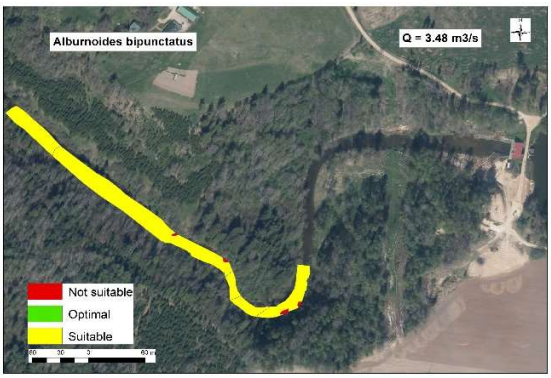


Figure 4.6.2. Habitat suitability maps for brown trout (adult) in presence of min low flow (above), average low flow (centre) and annual flow (below).

Figure 4.6.3. Habitat suitability maps for spirlin (adult) in presence of min low flow (above), average low flow (centre) and annual flow (below).

Figures 4.6.2 and 4.6.3. are showing habitat suitability maps for the adult brown trout and adult spirlin, which are species of high priority for Ciecere River. On both graphs the habitat suitability significantly increases with increasing discharge. During min low flow only 1.5% of river stretch were suitable for adult brown trout.

Habitat availability significantly increased during max low flow (32.2% available) and annual flow (99%) conditions. Similar situation can be observed also for adult spirlin.

Habitat availability:

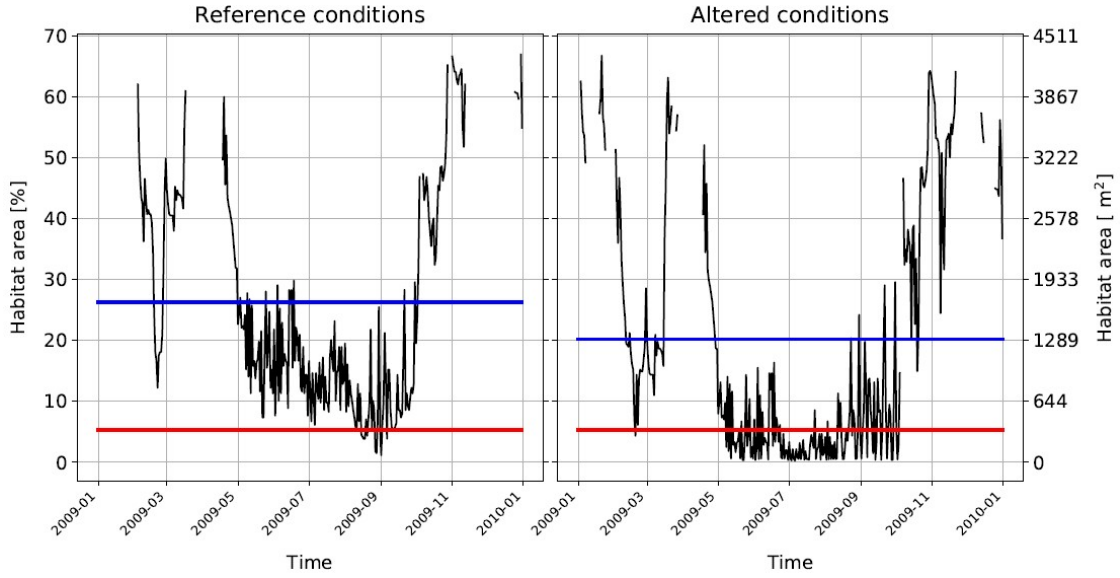


Figure 4.6.4. Habitat time series of the brown trout (adult) in reference and altered conditions

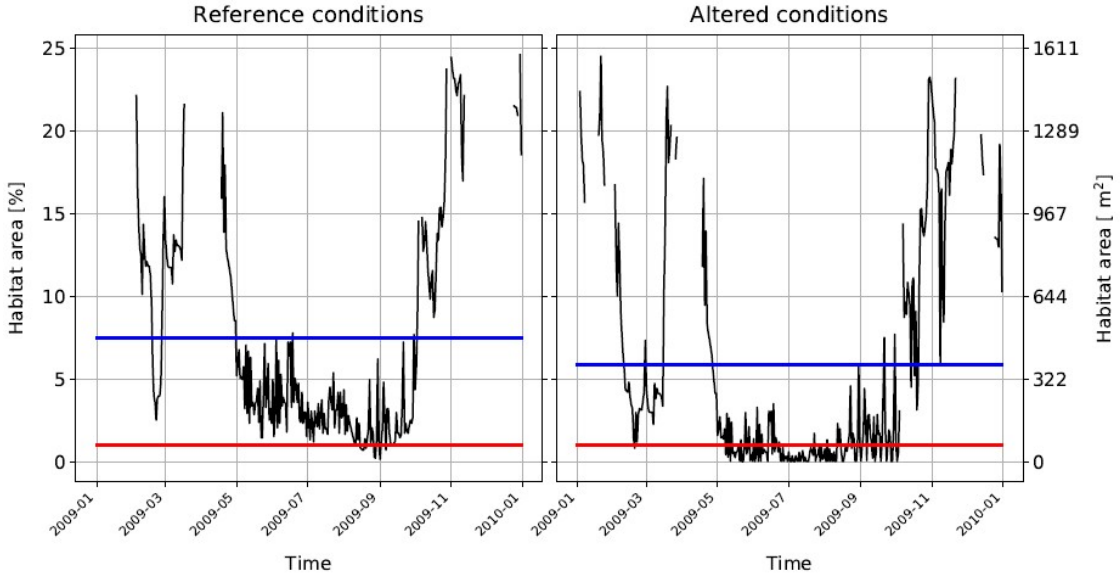


Figure 4.6.5. Habitat time series of the spirlin (adult) in reference and altered conditions

Figures 4.6.4 and 4.6.5. show the habitat distribution in time particularly during 2009 that is a dry year. 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 identical for the high priority fish species. As for the brown trout as for the spirlin in altered conditions during summer low flow period there are habitat areas below threshold that leads increasing of fish stress days.

5. MODELLING RESULTS FOR LIELUPE RIVER BASIN DISTRICT

5.1. Musa River - Ustukiai WGS

Musa is a cyprinid type river, important for reproduction of anadromous vimba (*Vimba vimba*). The river is also inhabited by spirlin (*Alburnoides bipunctatus*), the potamodromous fish species, which is protected in accordance with the EU Species and Habitat Directive. However, migration of fish to the modelled river stretch is limited by another artificial obstacle, the Švobiškis dam, which is situated 7 km downstream Dvariukai HPP. Therefore, both vimba and spirlin are absent from the modelled stretch. For this reason, another two typical rheophilic fish species, dace (Leuciscus leuciscus) and chub (Squalius cephalus) were selected to model the impact of the Dvariukai HPP on habitat availability for the rheophilic fish.

Musa River List of species of interest

1. Dace (Leuciscus leuciscus);
2. Chub (Squalius cephalus).

Habitat-flow rating curve

The dependence of the proportion of the area of suitable habitat on the amount of flow was modelled for the species of interest, as well as for some other fish species that are common in Musa downstream Dvariukai HPP. The habitat-flow rating curve is presented in Figure 5.1.1. It shows that the optimum flow at which the habitat area of most species reaches its maximum is about 2.60 m^3/s. With a further increase in flow, the habitat area decreases, with the exception of the adult chub habitat, which increases further depending solely on the increase in the wetted area of the stretch.

Habitat suitability

The simulated changes in habitat suitability for dace and chub at different flows are shown in Figure 5.1.2. At the minimum of low discharge, most of the studied stretch is not suitable either for dace ore chub because of the small depth and slow current velocity. At higher flows, the area of suitable habitat increases significantly. Certain areas of the studied stretch become even optimal for the fish species of interest.

Habitat availability

Changes in the flow lead to changes in both habitat suitability and availability. Figures 5.1.3a and 5.1.4a show a temporal variation in habitat available for dace and chub at reference conditions (if HPP would be absent), and altered conditions (i.e. when HPP functions) during the year with normal runoff. The red line in the pictures is the threshold corresponding to the habitat area with a probability of 97% and the blue line is the average habitat area. It can be seen that, at altered conditions, the line representing the area of effective habitat crosses the threshold of 97% habitat probability, or in other words, there is a probability of 97%, that at altered conditions, the habitat area available for dace and chub is significantly smaller than the minimum habitat area at reference conditions. The difference between habitat area at reference and altered conditions may become particularly large in dry years (Figures 5.1.3 b and 5.1.4 b).

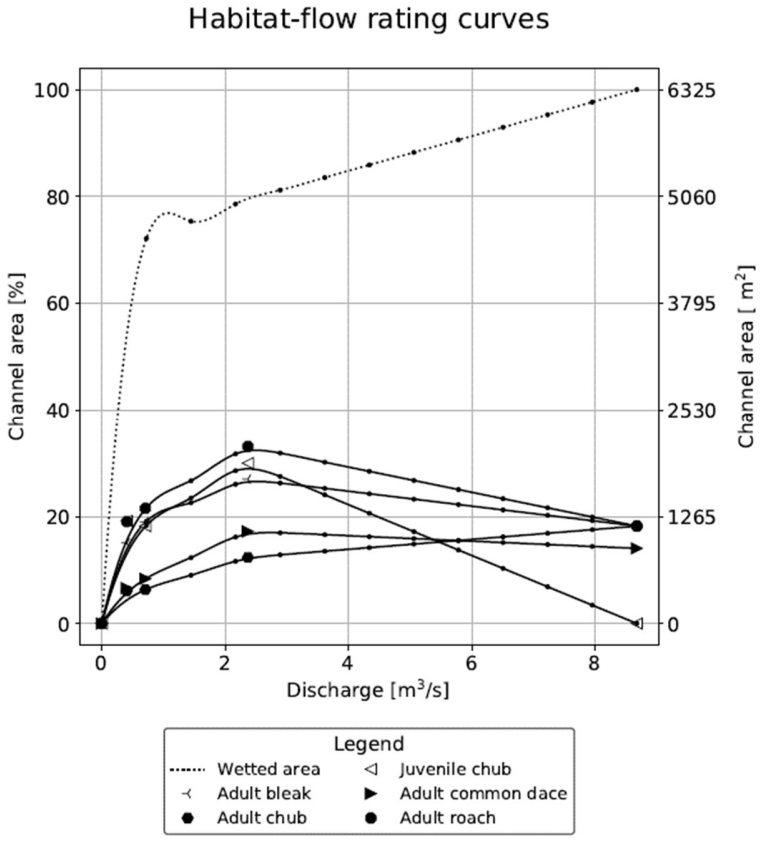


Figure 5.1.1. Habitat-flow rating curve of Musa River downstream Dvariukai HPP

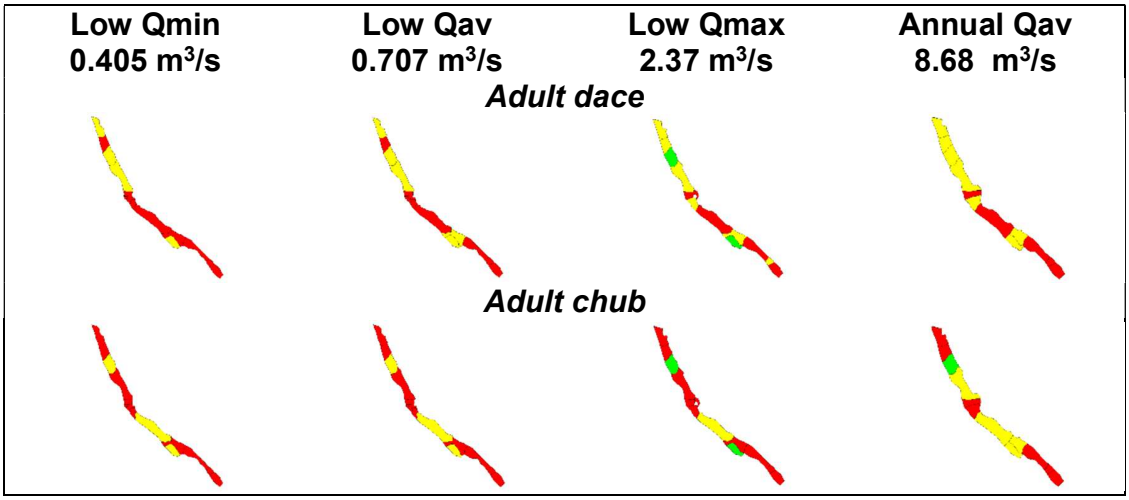
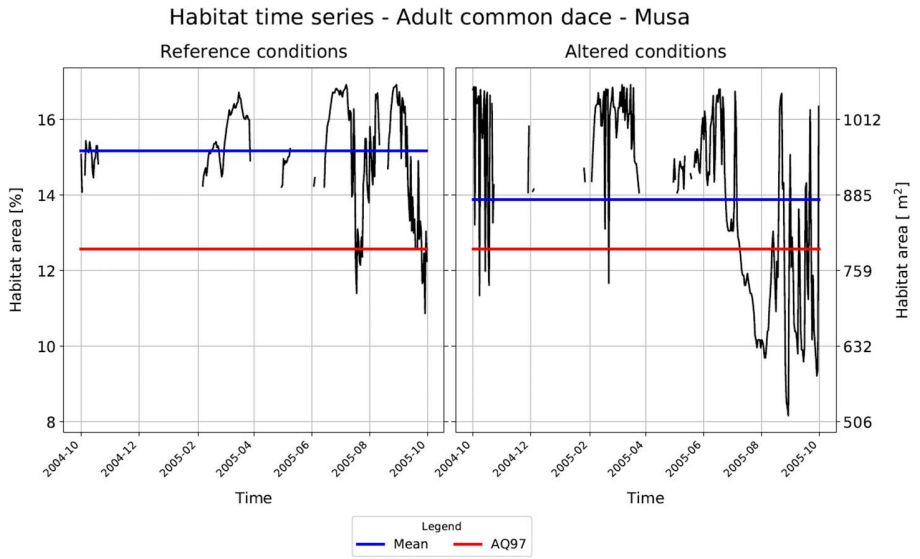


Figure 5.1.2. Habitat suitability for dace and chub at different runoff in the modelled stretch of Musa River below Dvariukai HPP (Not suitable Suitable Optimal **).**

a



b

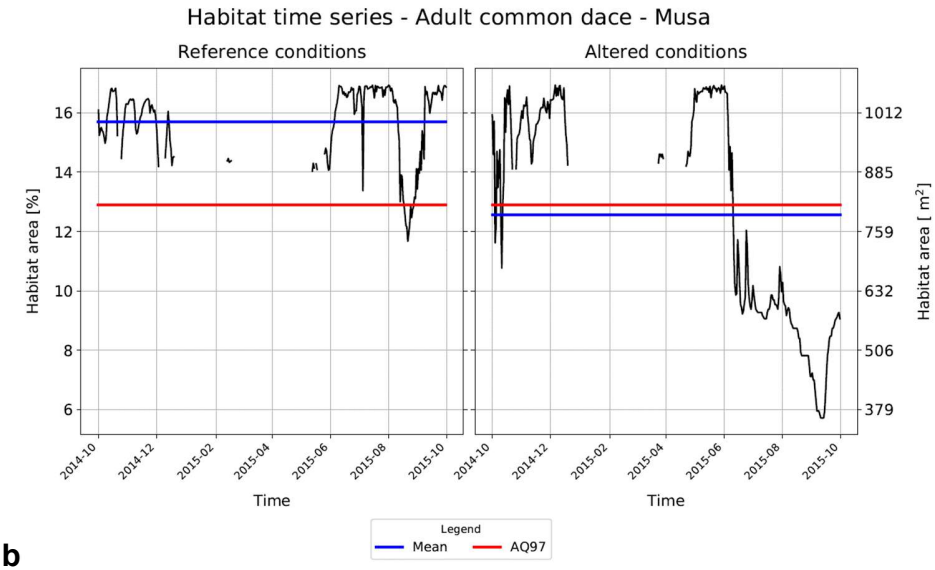
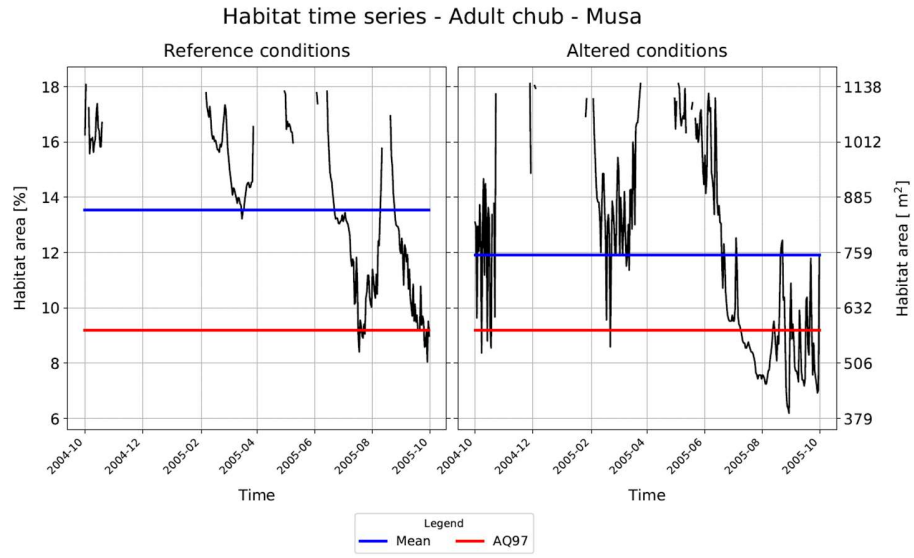


Figure 5.1.3. Time series of habitat availability for dace at reference and altered conditions (a – normal year, b – dry year).

a



b

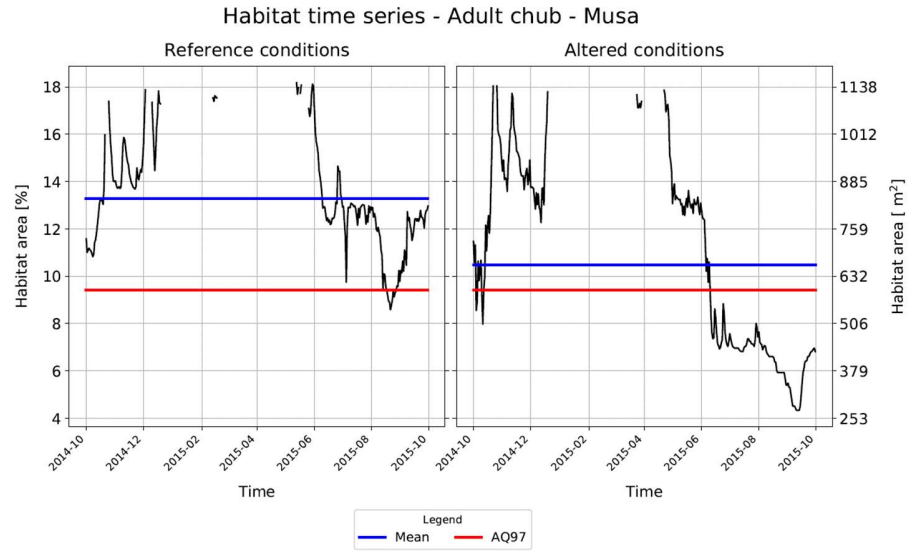


Figure 5.1.4. Time series of habitat availability for chub at reference and altered conditions (a – normal year, b – dry year).

The functioning of the Dvariukai HPP in the summer-autumn leads to a significant decrease in habitat area suitable for typical riverine fish (dace and chub) in the Musa River stretch below HPP. The negative impact is particularly strong in dry years, when the area of suitable habitat is four months continuously less than the area at reference conditions with a probability of 97%.

The optimal water flow, which provides the maximum area of suitable habitat for most fish species, is Q=2.60 m^3/sec.

5.2. Lėvuo River - Bernatoniai WGS

Lėvuo is a cyprinid type river. Previously it was important for reproduction of anadromous vimba (*Vimba vimba*), but after construction of Pasvalys dam close to the river mouth, migration way to Lėvuo River for anadromous fish has been closed. The river also suffers from diffused pollution coming from agricultural lands. Therefore, fish species diversity in the river stretch below Akmeniai HPP nowadays is less than could be expected in the absence of diffused pollution and artificial obstacle for migration. In addition, the studied river stretch is rather homogeneous and small-grained substrate (mainly sand) covers the major part of the river bottom. Anadromous fish species as well as rheophilic fish species which are protected by EU Species and Habitat Directive are absent from this river stretch. For this reason, other typical rheophils, dace (Leuciscus leuciscus) and chub (Squalius cephalus) were selected to model the impact of Akmeniai HPP on habitat availability for rheophilic fish.

Lėvuo River List of species of interest

1. Dace (Leuciscus leuciscus);
2. Chub (Squalius cephalus).

Habitat-flow rating curve

The dependence of the proportion of the area of suitable habitat on the amount of flow was modelled for the species of interest, as well as for some other fish species that are common in Lėvuo downstream Akmeniai HPP. The habitat-flow rating curve is presented in Figure 5.2.1. It shows that the optimum flow at which the habitat area of adult chub, as well as bleak and roach reaches its maximum is about 1.74 m^3/s, that of dace is ~0.56 m^3/s, while the conditions for juvenile chub are not suitable, mainly due to the lack of coarse bottom substrate. With a further increase in flow, the habitat area decreases, with the exception of the adult dace habitat, which increases further depending solely on the increase in the wetted area of the stretch.

Habitat suitability

The simulated changes in habitat suitability for dace and chub at different flows are shown in Figure 5.2.2. It can be seen that the changes in the flow do not have a significant impact on the area of habitat which is suitable for dace. But the area

of habitat of the chub is closely related to the flow. It increases significantly with higher flows and appears to reach an optimum with maximum of low flow.

Habitat availability

Temporal changes in the flow may result in variation of availability of suitable habitat. Figure 5.2.3 shows variation in habitat of dace and chub at reference conditions, and altered conditions (i.e. when HPP functions) during the year with normal runoff. The red line in the pictures is the threshold corresponding to the habitat area with a probability of 97% and the blue line is the average habitat area. It can be seen that, at altered conditions, the line representing the area of effective habitat only at solitary instances crosses the threshold of 97% habitat probability. Therefore, at altered conditions, the decrease in area of effective habitat of dace and chub is insignificant. The differences between habitat area at reference and altered conditions in dry years are also insignificant.

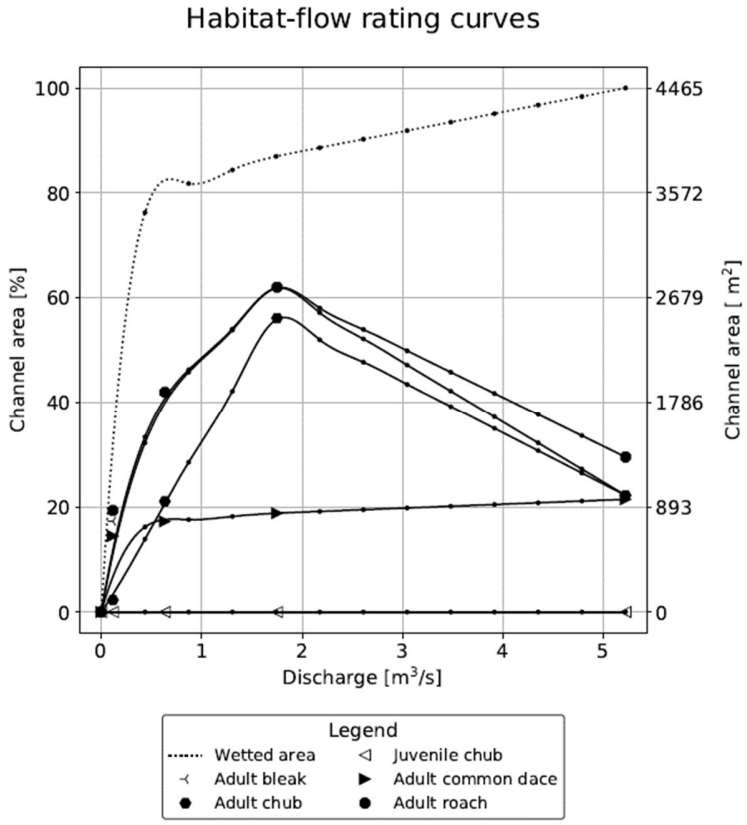


Figure 5.2.1. Habitat-flow rating curve of Lėvuo River downstream Akmeniai HPP

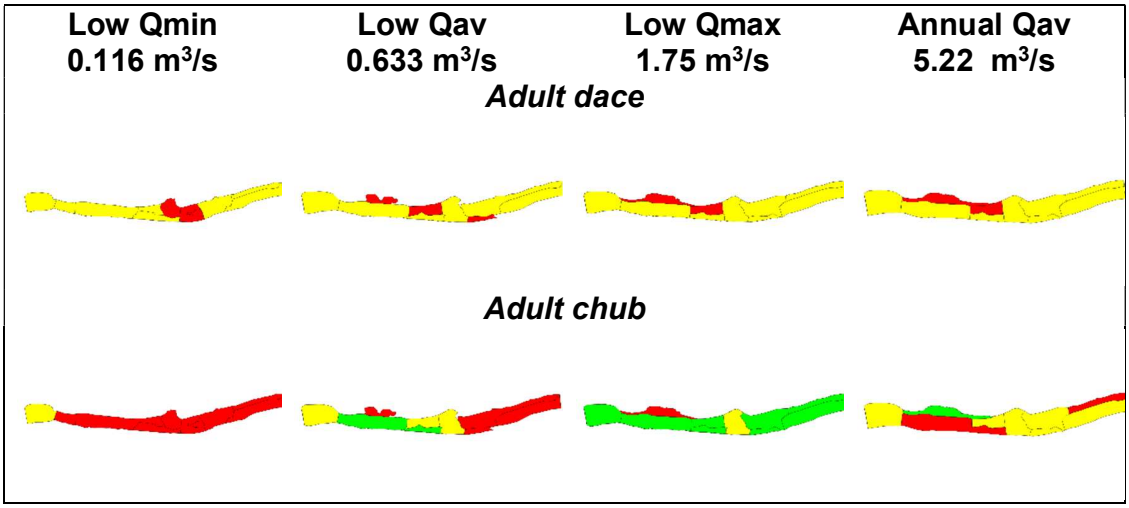
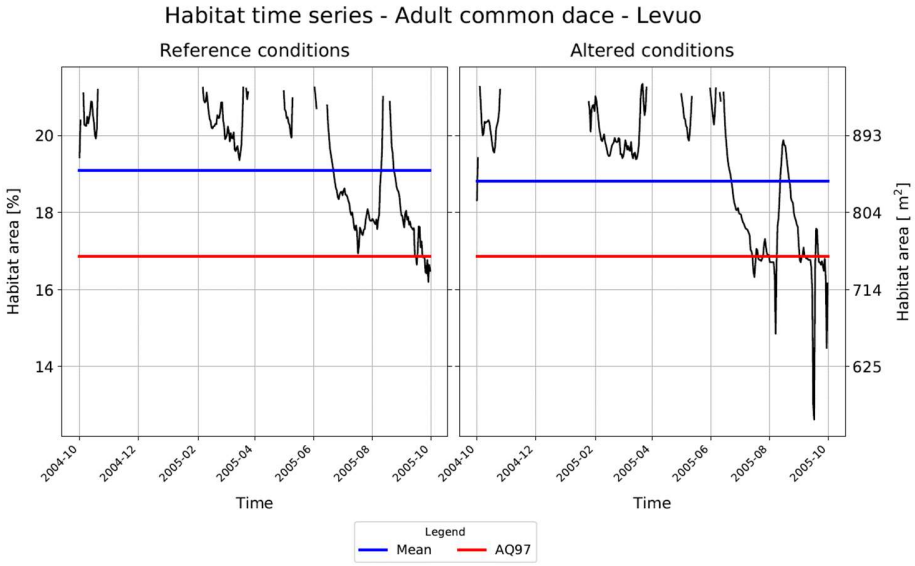


Figure 5.2.2. Habitat suitability for Dace (*Leuciscus leuiscus*) and Chub (*Squalius cephalus)* in presence of different flows in the modelled stretch of Lėvuo River downstream Akmeniai HPP (Not suitable Suitable Optimal).



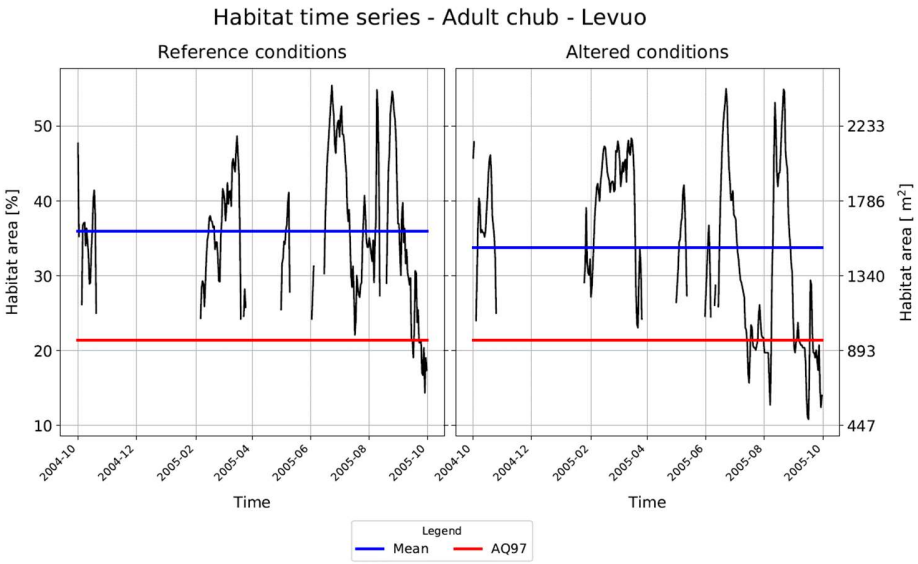


Figure 5.2.3. Time series of habitat availability for Dace and Chub at reference and altered conditions (the year with normal flow).

The functioning of the Akmeniai HPP doesn't have significant impact on the habitat area suitable for typical riverine fish (dace and chub), which live in the Lėvuo River stretch below HPP.

The optimal water flow, which provides the maximum area of suitable habitat for chub is Q=1.74 m^3/s. The lowest threshold of optimal flow for dace is ~0.56 m^3/sec. With a further increase in flow, the habitat area increases further depending solely on the increase in the wetted area of the stretch.

5.3. Berze River - downstream Bikstu-Paleja HPP

Berze is a cyprinid type river. Four hydropower plants are built along the Berze River. Habitat assessment have been carried out downstream of Bikstu-Paleja HPP that is the first HPP of Berze River (upper stretch). Annenieki, Dobele and Berze HPPs are located below it. The guaranteed water discharge of the Bikstu-Paleja HPP that is required by Permission Act is 0.031 m^3/sec.

Berze River List of species of interest:

1. Bullhead (*Cottus gobio*), adult;
2. Chub (*Squalius cephalus*), juveniles & adult;

3. Gudgeon (*Gobio Gobio*), juveniles & adult.

Habitat – Flow rating curve:

Habitat curves for selected fish species depending on flow rate are shown in Figure 5.3.1. These curves were modelled for each fish species of interest (bullhead, chub, gudgeon) that was pre-selected by fish expert specially for Berze River. As it can be seen, for most of species habitat area increases with increasing water discharge, only for juvenile gudgeon the maximum habitat area is available at the average discharge of low flow period. Maximum available habitat area in Berze River was 37.8% of total studied river stretch (adult bullhead and juvenile chub). During existing guaranteed water discharge (0.031 m^3/sec), Berze River was not suitable for any fish species.

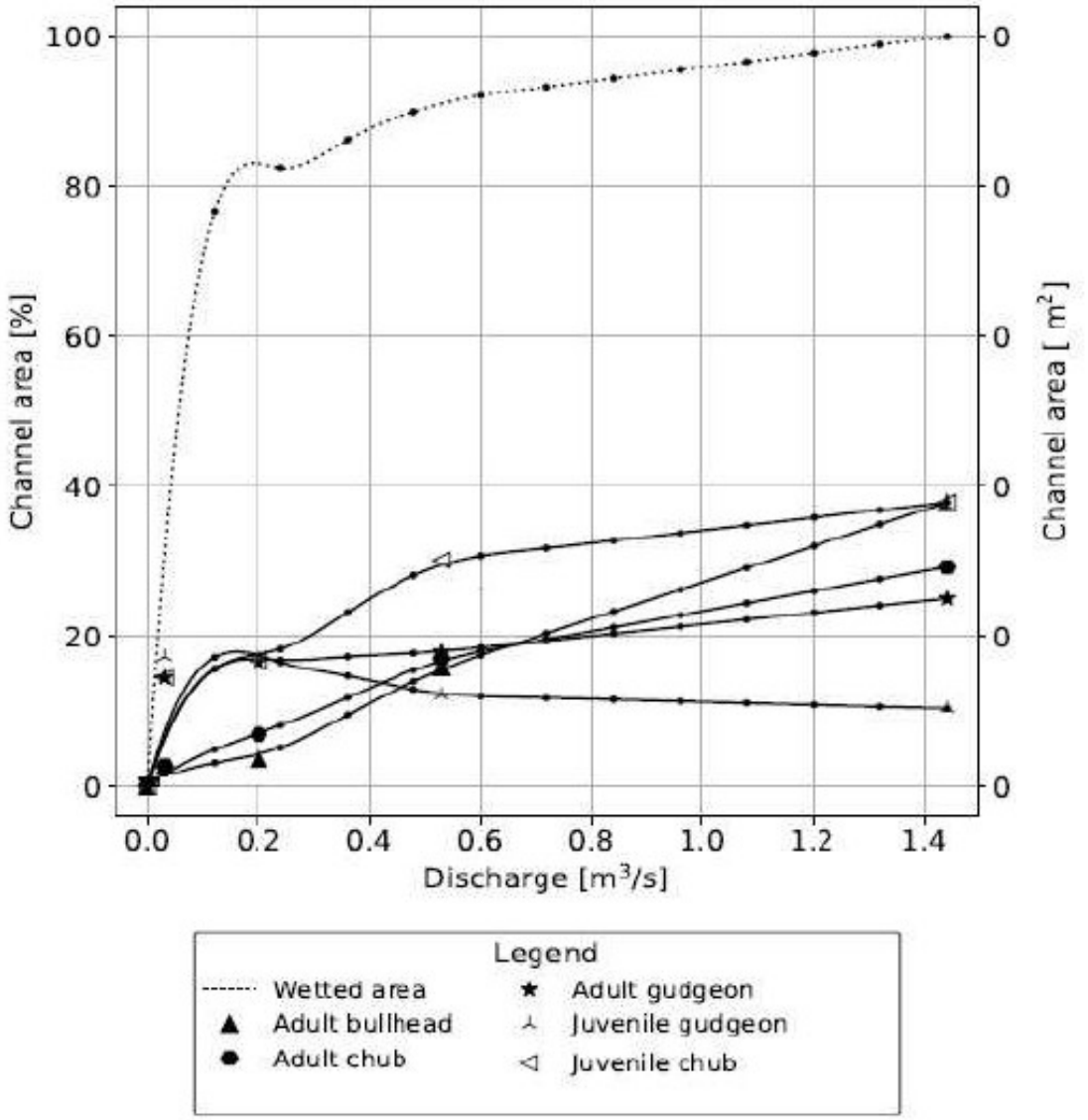


Figure 5.3.1. Habitat-Flow rating curve of Berze River downstream Bikstu-Paleja HPP

Berze River Habitat Suitability maps:

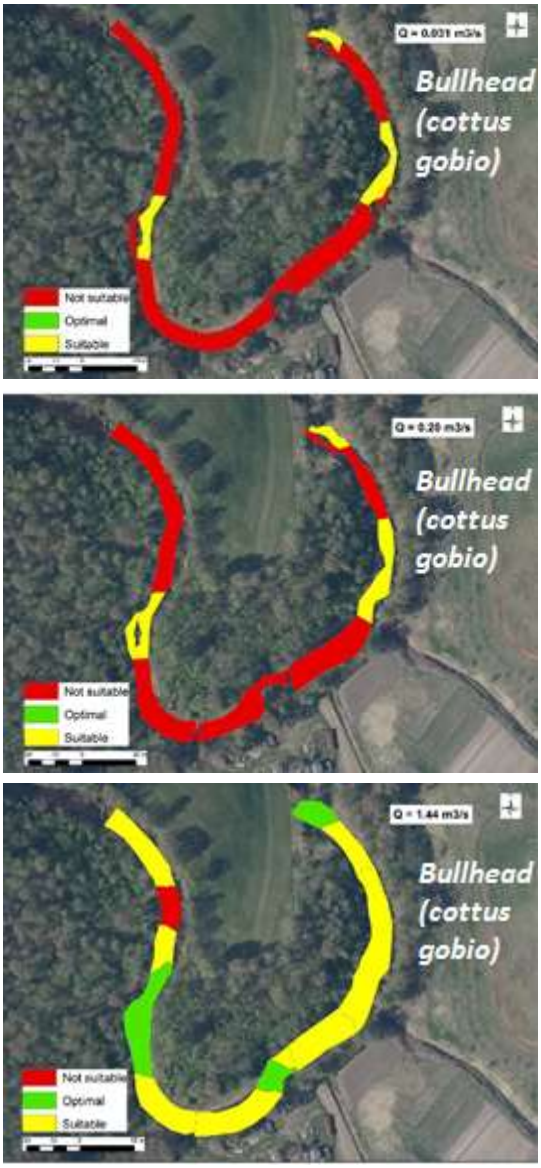


Figure 5.3.2. Habitat suitability maps for bullhead (adult) in presence of min low flow (above), max low flow (centre) and annual flow (below).

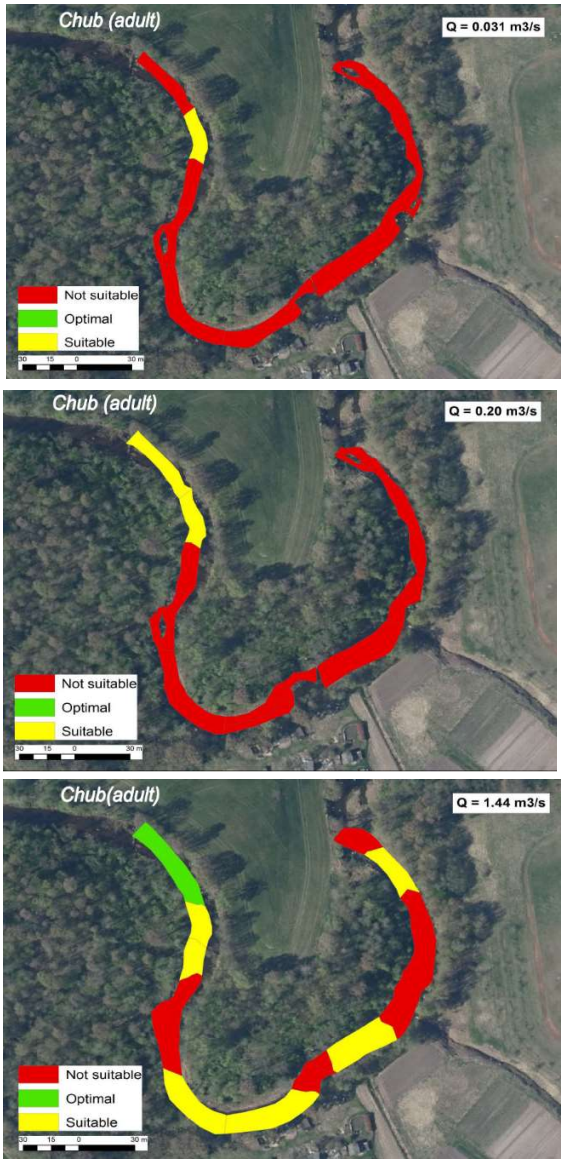


Figure 5.3.3. Habitat suitability maps for chub (adult) in presence of min low flow (above), max low flow (centre) and annual flow (below).

Figures 5.3.2 and 5.3.3. show habitat suitability maps for bullhead and chub which are species of high priority for Berze River. On both graphs the habitat suitability significantly increases with increasing discharge. During min low flow only 16% of studied Berze River stretch was available for adult bullhead, in annual mean flow available habitats for bullhead increased to 96% (Fig. 5.3.2.). For adult chub

available habitat area increased from 6% during min low flow to 63% during annual mean flow (Fig. 5.3.3).

Habitat availability

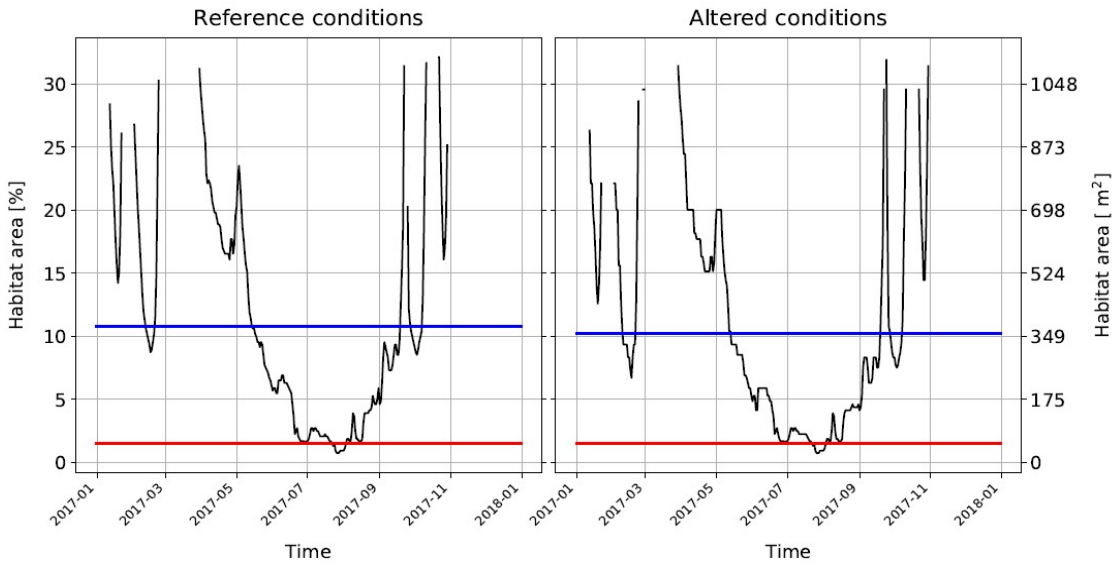


Figure 5.3.4. Habitat time series of the bullhead (adult) in reference and altered conditions

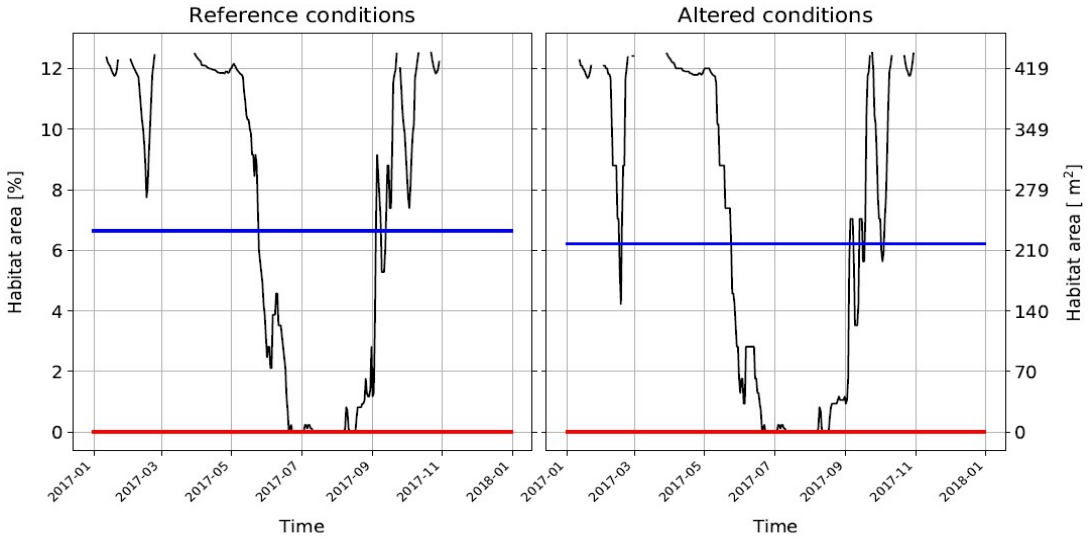


Figure 5.3.5. Habitat time series of the chub (adult) in reference and altered conditions

Figures 5.3.4 and 5.3.5. show the habitat distribution in time particularly during 2017 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. There aren't any habitats below red line that means presence of fish supported conditions.

5.4. Auce River - downstream Bene HPP

Auce is a cyprinid type river. Two hydropower plants are built along the Auce River. Habitat assessment have been carried out downstream of Bene HPP that is the first HPP of Auce River (upper stretch). Kronauce HPP is located in about 25 km below it.

The guaranteed water discharge of the Bene HPP that is required by Permission Act is 0.007 m^3/sec.

Auce River List of species of interest:

1. Northern spined loach (*Cobitis taenia*), adult;
2. Stone loach (*Barbatula barbatula*), adult;
3. European brook lamprey (*Lampetra fluviatilis*), juveniles;
4. Roach (*Rutilus rutilus*), juveniles & adult.

Habitat – Flow rating curve:

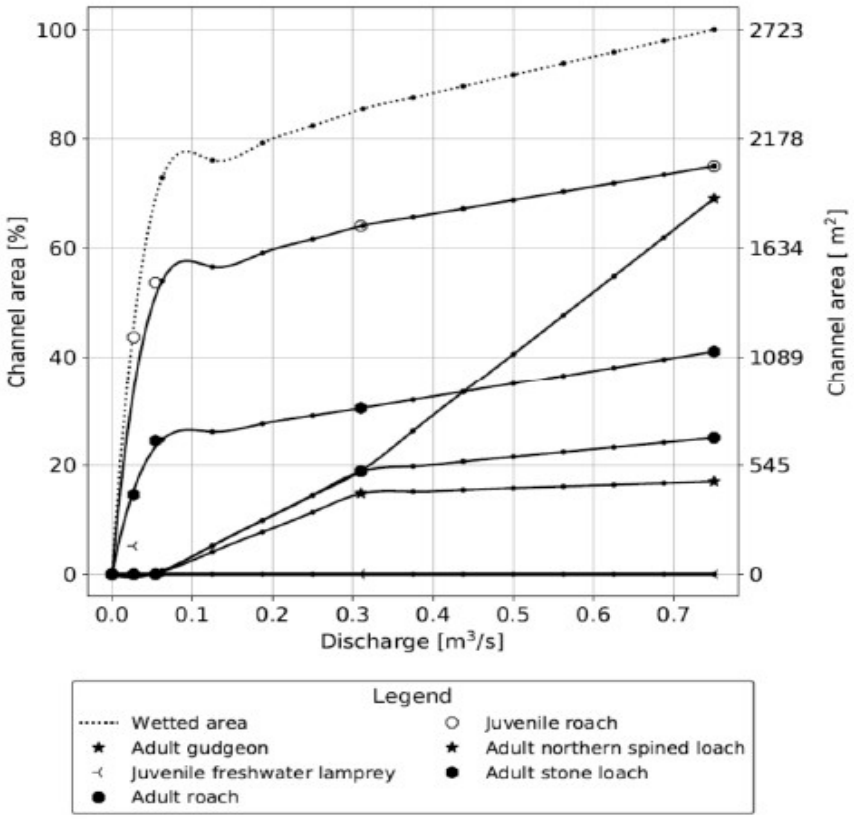
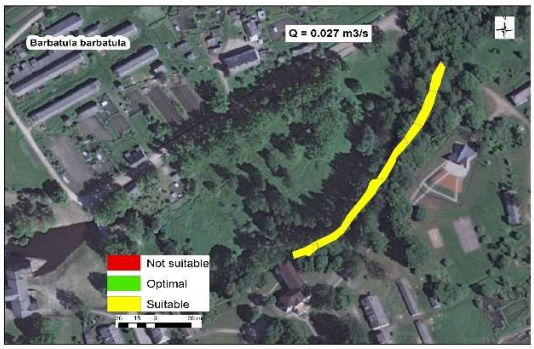


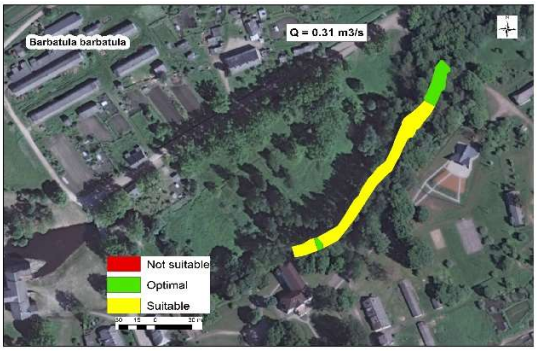
Figure 5.4.1. Habitat-Flow rating curve of Auce River downstream Bene HPP

Habitat curves for selected fish species depending on flow rate are shown in Figure 5.4.1. These curves were modelled for each fish species of interest (bullhead, chub, gudgeon, etc.) that was pre-selected by fish expert especially for Berze River. As it can be seen, for most of species habitat area increases with increasing water discharge, only for juvenile gudgeon the maximum habitat area is available at the average discharge of low flow period. Maximum available habitat in Auce River was 73.5% (juvenile roach) which was observed during annual average flow. During existing guaranteed water discharge (0.007 m^3/sec), Auce River was not suitable for any fish species.

Auce River Habitat Suitability maps:

Figure 5.5.2. Habitat suitability maps for northern spined loach (adult) in presence of min low flow (above), max low flow (centre) and annual flow





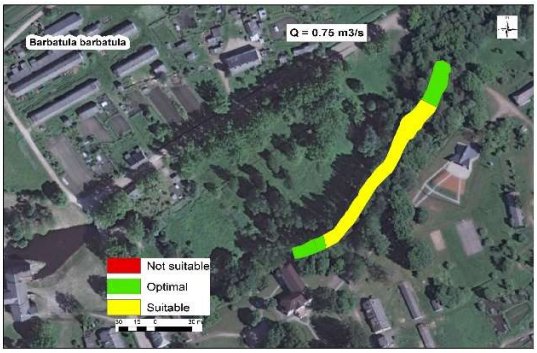


Figure 5.5.3. Habitat suitability maps for stone loach (adult) in presence of min low flow (above), max low flow (centre) and annual flow (below).

Habitat suitability are modelled for each *species of interest* that are showed on the Habitat-Flow rating curve. Northern spined loach and stone loach are species of high priority for Auce River. It is evident that the habitat suitability for both of fish species is increasing with water flow increase. As it can be seen in Figure 5.5.2., during min low flow no habitat is suitable for northern spined loach. During max

low flow and annual mean flow habitat suitability increases to ~ 68-69% of total studied river stretch.

Habitat availability

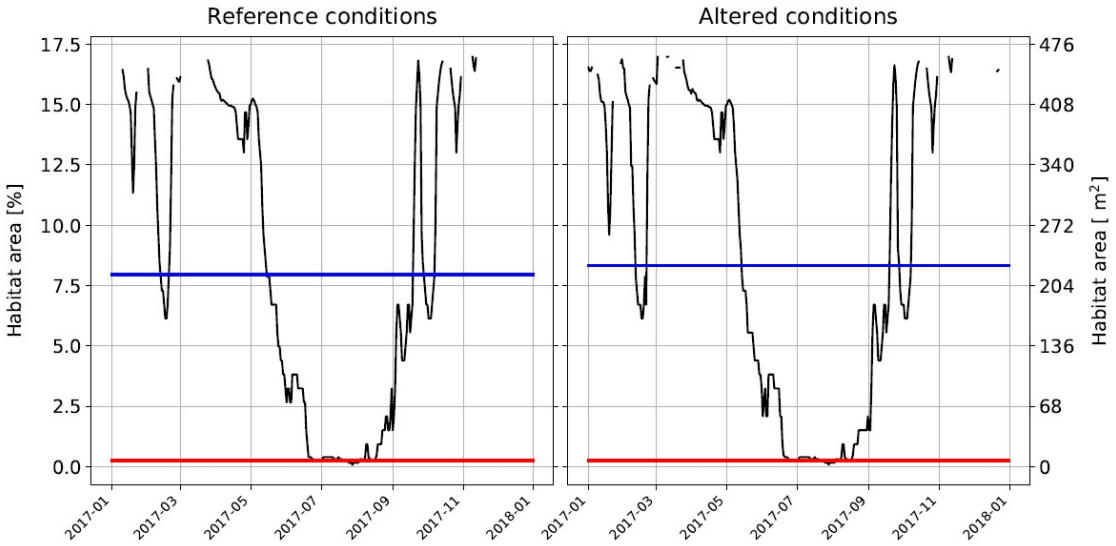


Figure 5.5.4. Habitat time series of the northern spined loach (adult) in reference and altered conditions

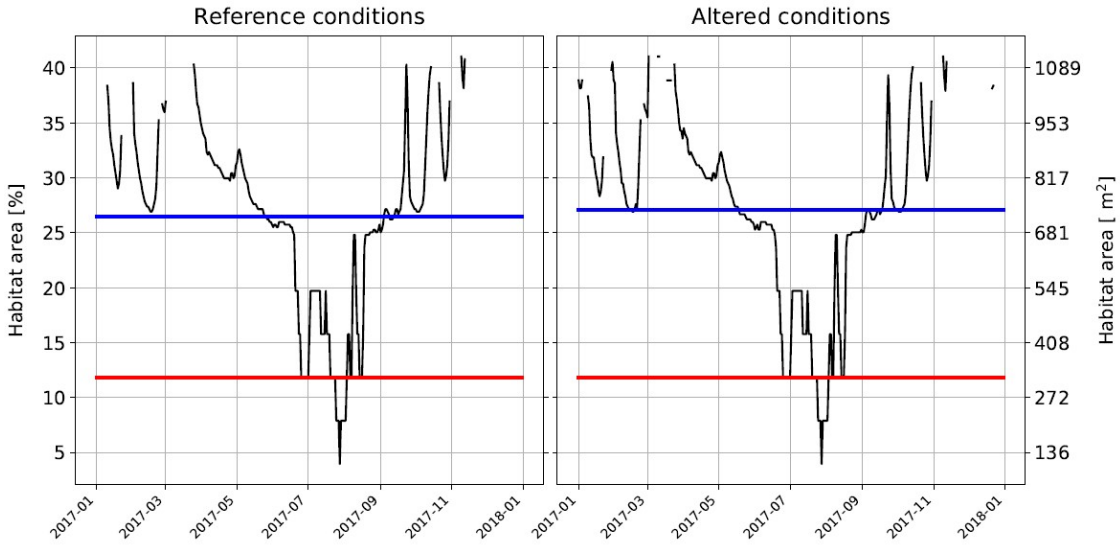


Figure 5.5.5. Habitat time series of the stone loach (adult) in reference and altered conditions

Figures 5.5.4 and 5.5.5. show the habitat distribution in time particularly during 2017 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.

There are only small habitat areas below red line that means presence of fish supported conditions.

5.6. Islice River - downstream Rundale HPP

Islice is a cyprinid type river. Rundale HPP is the only hydropower plant located on this river. The guaranteed as well as ecological water discharge that is required by Permission Act is 0.16 m3/sec.

Islice River List of species of interest:

1. Chub (*Squalius cephalus*), juveniles & adult;
2. Stone loach (*Barbatula barbatula*), adult;
3. Northern spined loach (*Cobitis taenia*), adult;
3. Bleak (*Alburnus alburnus*), adult;
4. Common dace (*Leuciscus leuciscus*), adult.

Habitat – Flow rating curve:

Habitat curves for selected fish species depending on flow rate are shown in Figure 5.6.1. These curves were modelled for each fish species of interest (bleak, chub, common dace, etc.) that was pre-selected by fish expert especially for Islice River. Visible for most of species habitat area increases with increasing water discharge, only for the northern spined loach the maximum habitat area is available at the max discharge of low flow period. Maximum area of suitable habitats in Islice River was observed for adult bleak (57.7%), but during ecological and guaranteed (0.16 m^3/sec) flow maximum available habitat was 25.4% of studied river stretch for adult stone loach, also for all other selected target fish species available habitat was at least 10% (adult chub) from all river reach. Existing ecological discharge provides about 29%-83% of maximum available habitats in Islice River.

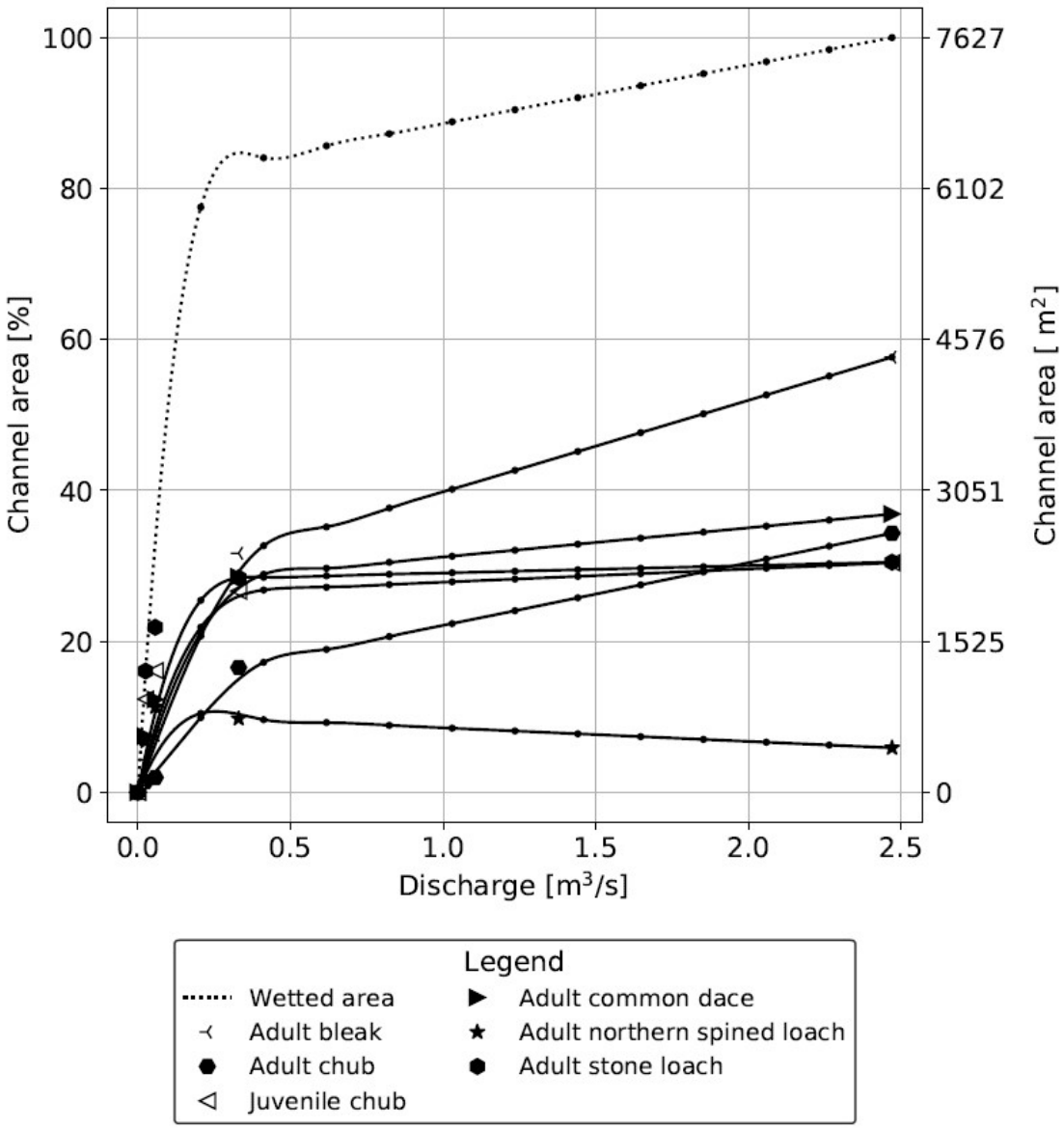
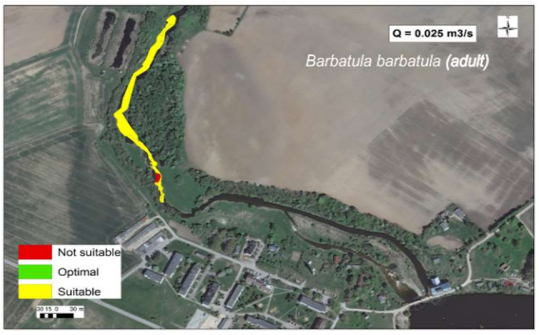
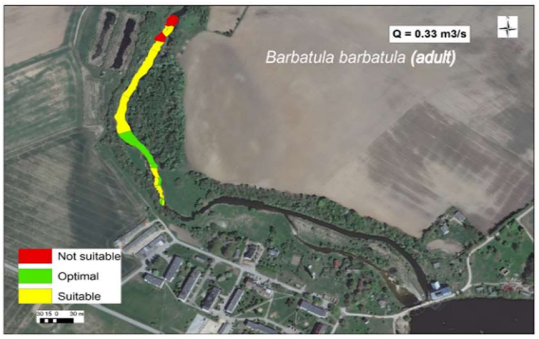
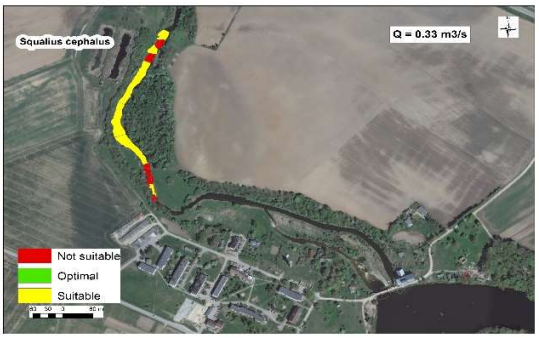


Figure 5.6.1. Habitat-Flow rating curve of Islice River downstream Rundale HPP

Islice River Habitat Suitability maps:







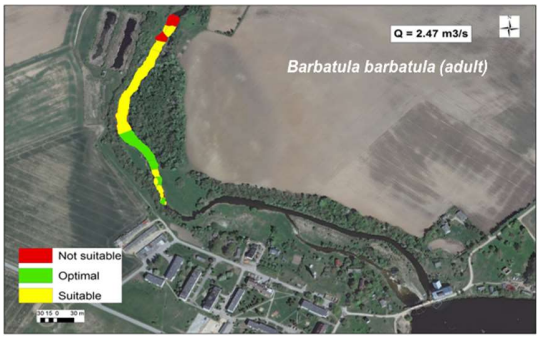


Figure 5.6.2. Habitat suitability maps for stone loach (adult) in presence of min low flow (above), max low flow (centre) and annual flow (below).

Figure 5.6.3. Habitat suitability maps for chub (adult) in presence of min low flow (above), max low flow (centre) and annual flow (below).

Habitat suitability are modelled for each *species of interest* that are showed on the Habitat-Flow rating curve. Chub and stone loach are species of high priority for Islice River. In accordance with map information the habitat suitability is increasing with increasing of water discharge. During min low flow only 8.7% of river stretch were available for adult chub. Habitat availability significantly increased during max low flow (79.3% available) and annual flow (75.5%) conditions.

Habitat availability

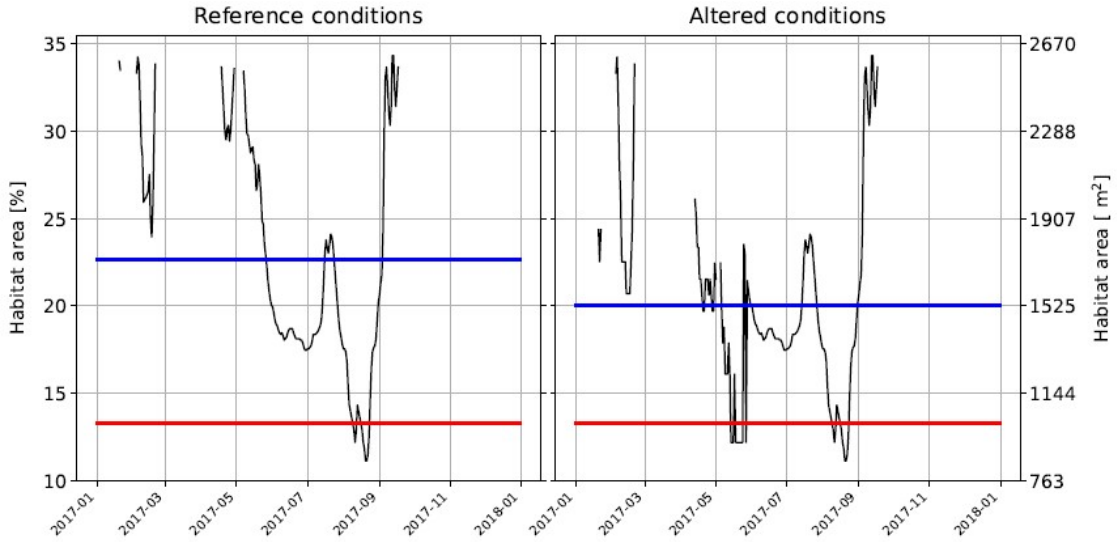
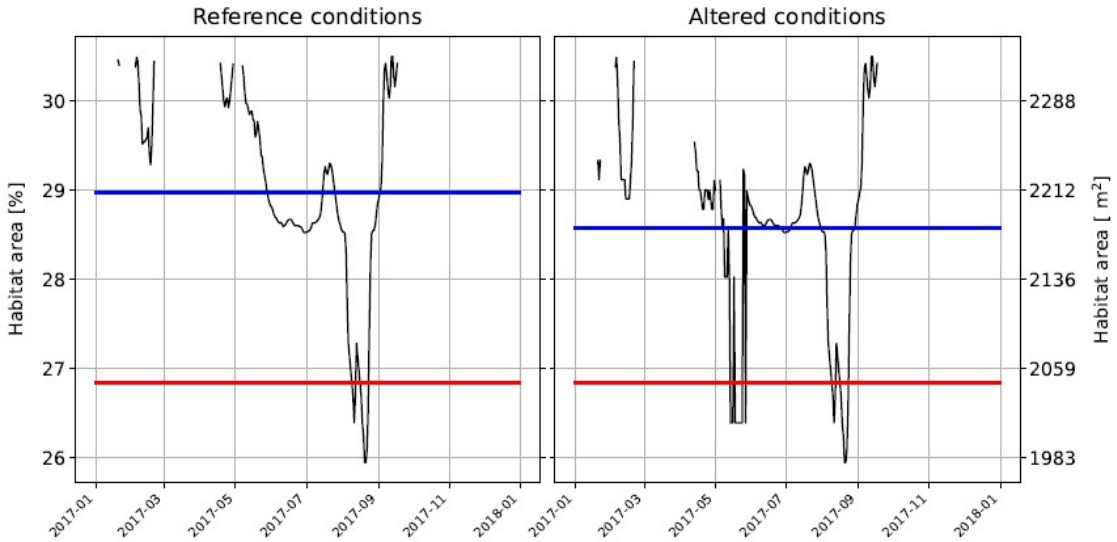


Figure 5.6.4. Habitat time series of the chub (adult) in reference and altered



conditions

Figure 5.6.5. Habitat time series of the stone loach (adult) in reference and altered conditions

Figures 5.6.4 and 5.6.5. show the habitat distribution in time particularly during 2017 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.

Habitat areas below the red line are increased in altered conditions during years with normal water runoff and correspondingly are increased the number of stress days for fish fauna. It is evident that during dry ears the habitat area below threshold will be much wider.

6. MODELLING RESULTS ANALYSIS

Comparison of the results of modelling of availability and temporal variation of the habitat area suitable for fish with the actual fish abundance and diversity in the modelled rivers has proved, that model is capable to predict presence of species quite well. The results of modelling have also revealed that during dry season the functioning of most of the studied HHPs leads to significantly reduction of the area of habitats, suitable for certain fish species (first of all, rare and protected ones), continuously for 2-4 months. This gives an explanation, why certain fish species are so rare or even absent in the studied river stretches below HPPs despite of the fact, that at natural conditions the area of habitat suitable for them is relatively large throughout the year.

In accordance with project results, regulations of the hydrological regime by hydropower plant operation influence river morphology and all aquatic fauna as well. Fish density and species composition are the proper parameters that should be used for an assessment of HPPs impact on river ecosystems (Fig. 6.1., 6.2.).

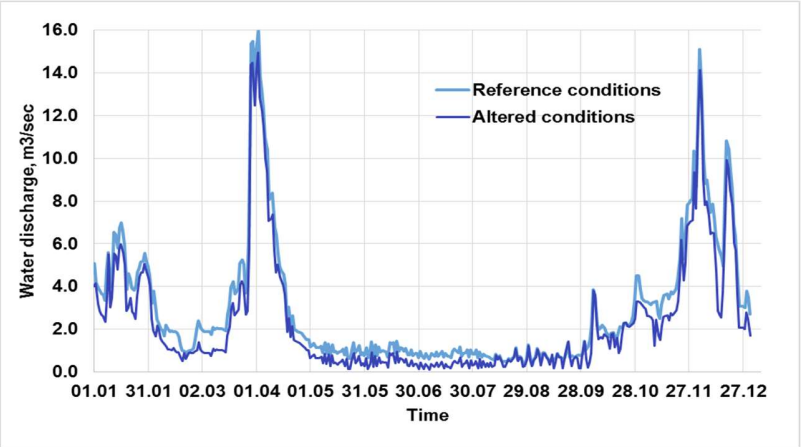


Figure 6.1. Daily water runoff of Ciecere River downstream Pakuli HPP in 2009 (reference and altered conditions)

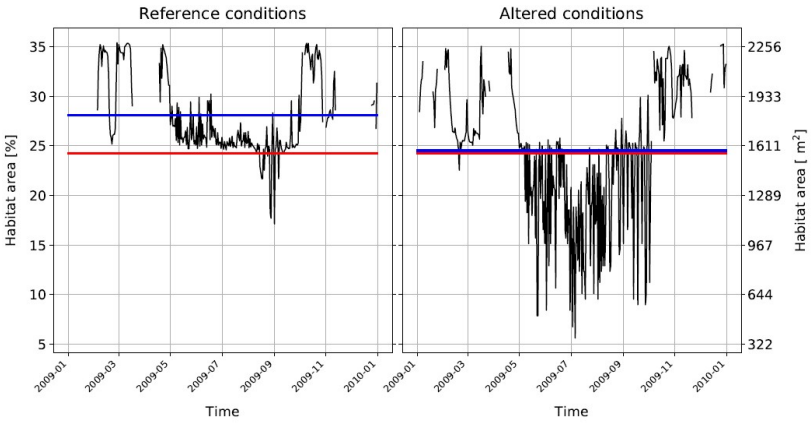


Figure 6.2. Habitat time series of juvenile trout in 2009, Ciecere River downstream Pakuli HPP

Habitat – Flow rating curves vary from 1) rapid increasing during minimum flow till almost maximum value of habitat area and slowly increasing or decreasing later on to 2) continuous increasing.

First case is common for the cyprinid fish species. Herewith the maximum value of habitat area for juveniles is smaller than for adults and corresponds with smaller water discharge (Fig. 6.3.)

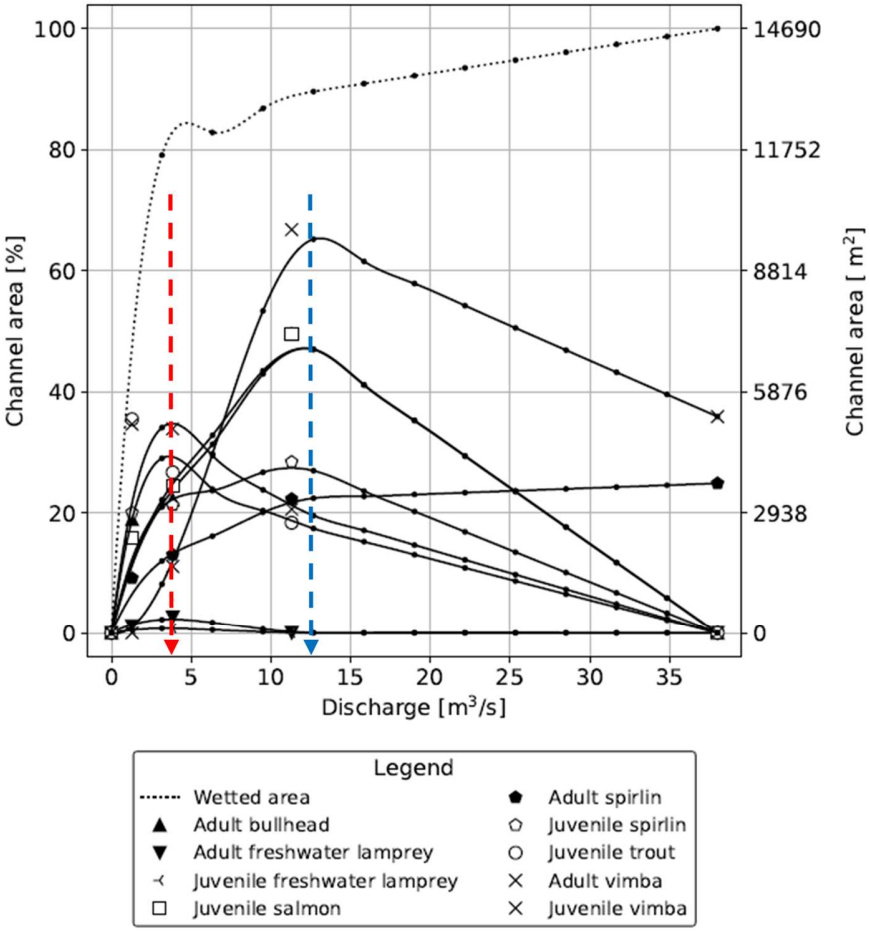


Figure 6.3. Habitat-Flow rating curve of Venta River downstream Kuodžiai HPP (red arrow shows the optimal water discharge for juveniles and blue arrow – for adults)

Second case is usual for the salmonid fish species. The conditional maximum value of habitat area might be corresponded with annual mean flow (Fig. 6.4.).

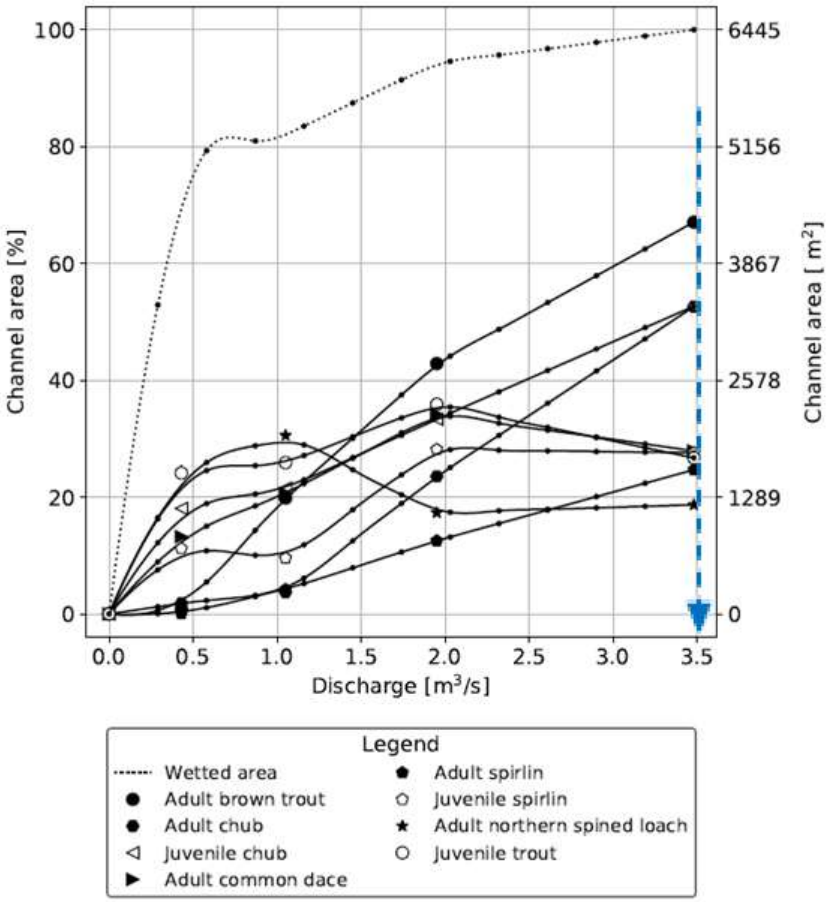


Figure 6.4. Habitat-Flow rating curve of Ciecere River downstream Pakuli HPP (blue arrow shows the optimal water discharge for adults brown trout)

The maximum habitat area and the water discharge related to this area is a critical point for evaluation of E-flow. 60% of it is the optimal value for existing and development of aquatic fauna including fish. Table 6.1. shows the Opimal water discharge value for project case studies in comparing with guaranteed and ecological water discharge of HPPs.

Table 6.1.

Optimal and existing ecological/guaranteed water flow

River	Site	Optimal water discharge		Required water discharge by Permission Act	
		Adult fish	Juvenile Fish	Ecological	Guaranteed
Venta	Papile WGS	4.41	1.80		
Venta	Leckava WGS	13.38	4.20		

River	Site	Optimal water discharge		Required water discharge by Permission Act	
		Adult fish	Juvenile Fish	Ecological	Guaranteed
Bartuva	Skuodas WGS	1.24			
Vanka	downstream Edole HPP	0.58	0.29		0.058
Eda	downstream Skede HPP	0.50	0.25	0.18	0.049
Ciecers	downstream Pakuli HPP	2.10	1.05		0.32
Musa	Ustukiai WGS	2.60			
Levuo	Bernatoniai WGS	1.74	0.56		
Berze	downstream Bikstu-Paleja HPP	0.43	0.22		0.031
Auce	downstream Bene HPP	0.19	0.09		0.007
Islice	downstream Rundale HPP	0.25	0.12		0.16

Presence of the different optimal flow for adults and juveniles implies the E-flow variations during a year depending on fish life stage and fazes of hydrological regime. Therefor not the E-flow but the *ecological flow regime* should be provided by HPPs in order to ensure the *Good ecological status* of water bodies.

7. CONCLUSIONS AND RECOMMENDATIONS

- Modelling results show the closed relations between water flow and habitat availability as well as fish species presence and abundance in altered conditions.

- Currently not only existing guaranteed water discharge but also the ecological flow set in LV-LT water use permits support the sustainability of aquatic ecosystems.

- Generally, project results show the necessity to provide the “ecological regime” in regulated rivers, and allow to estimate “winter E-flow” for fish spawning periods (from November to May) and “summer E-flow” for growing of juveniles (from June to October).

- MesoHABSIM is a biologically sound method for E-flow evaluation. However, it contents huge amount of works and is resource-consuming for applications on country scales. Therefore, on the base of modelling results some formula for E-flow calculation would be proposed.

- Taking into account the restricted number of case studies during the project (only 6 sites within 2 river basins), the main project results concerning ecological flow should be validated in different rivers in order to estimate the country-wide E-flow values.