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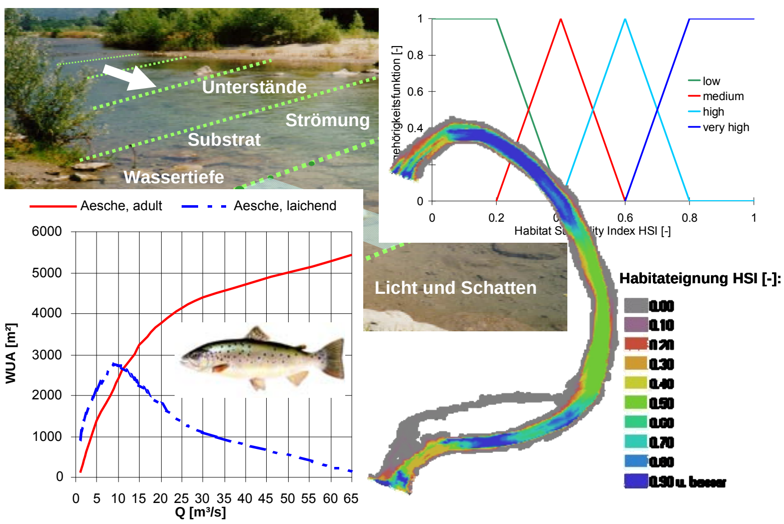
Ecological Engineering GmbH

University of Stuttgart
Institute of Hydraulic Engineering

Handbook for the Habitat Simulation Model

Module: CASiMiR-Fish

Base Version



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1 Introduction

1.1 Habitat Modeling

Ecological systems such as rivers and their habitats are complex systems showing a wide variety of relationships between biotic and abiotic components. Habitat models can be an appropriate instrument for studying the ecological functions of these systems, allowing for the qualitative assessment of habitat conditions for the indicator species. Thereby the main advantages of habitat models are justified in the following:

- *The ecological state of an aquatic ecosystem is directly coupled with the living conditions of the typical resident species.*
- *Habitat models allow for the effects of changing flow rates and structural characteristics to be accounted for, and to some extent, can be used to predict their impacts.*
- *Flow rate changes influence primarily water depth, flow velocity, and substrate conditions, all of which are the major factors when determining the habitat suitability and can be directly evaluated with numerical models.*
- *Due to the direct relationship between habitat conditions and flow rate, a quantitative basis can be established whereby an overall ecological-economical assessment can be performed.*

The European Water Framework Directive 2000 (WFD) lists fish as a key indicator species for the determination of a river's ecological status. This is due to the high level of temporal and spatial variability of fish habitat requirements, as well as their place at the top of the food chain.

1.2 Current Developments of the CASiMiR Modules

In the early 90s, the Institute of Hydraulic Engineering of Stuttgart University developed CASiMiR (**C**omputer **A**ided **Sim**ulation System for **I**nstream Flow **R**equirements), and was primarily focused on the simulation of habitat conditions for benthic organisms (JORDE, 1996). The original motivation was to promote the use of the program in some European countries in order to study problems related to hydropower operations, especially minimum flow requirements. At the same time a second program module was developed to assess the economic effects of minimum flow regulation on hydropower plants (see the handbook CASiMiR Hydropower). Meanwhile, the system has been further expanded thus that high-resolution habitat modeling including effects from structural and hydraulic changes for both fish and benthic organisms is possible.

In addition, there is a version of CASiMiR-Fish that can be used for modeling of hydraulically complex river sections and is based on the results of two-dimensional hydrodynamic models. This expanded version of the CASiMiR software can be purchased from the company sje Schneider & Jorde Ecological Engineering GmbH.

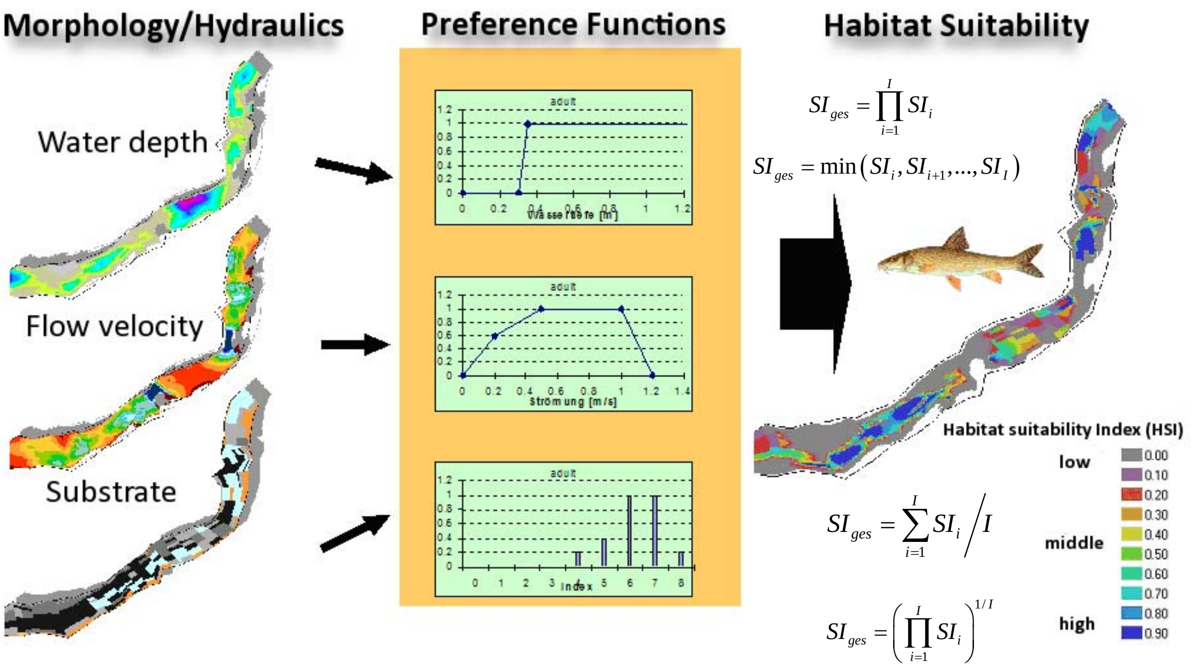
The University of Stuttgart in partnership with sje also developed a GIS-based CASiMiR module that focuses on larger, river basin scale applications. MesoCASiMiR has been designed for applications following the WFD requirements, where the smallest watershed basins to account for are defined as those having catchment areas of at least 10 km².

1.3 Modeling Principles

As shown in the previous section, the CASiMiR software suite has been designed in a modular fashion, focusing on the use of hydraulic and morphologic characteristics of riverine systems in order to determine the habitat suitability for selected indicator species. Input data for a study of fish habitat requirements primarily includes information regarding the temporal and spatial variability of water depths, flow velocities, and bed substrate types. BOVEE (1982) and HEGGENES (1988) have shown that the habitat preferences of fish species can be especially tied to these three main parameters. CASiMiR allows the calculation of a habitat suitability via either univariate preference functions with a subsequent aggregation into an integral suitability, or through the use of expert knowledge based fuzzy rules. Both methods allow for the spatial and temporal discretization of habitat conditions as well as for the provision of the composite habitat suitability for the entire investigation reach.

1.3.1 Preference Functions

Traditionally, preference functions have been the common choice when carrying out habitat modeling. A preference function describes the dependency between a relevant physical parameter (e.g. water depth, velocity, substrate index) and a biological characteristic (species' habitat preference concerning this parameter) (BOVEE et al., 1998). A habitat preference is typically defined on the scale from 0 to 1, where 0 represents a wholly unsuitable, and 1 denotes a perfect suitable conditions relating to a corresponding parameter. Generally a set of parameters determines the habitat quality and therefore the "single" suitabilities must be combined in order to obtain an overall value of habitat suitability. This can be done using a number of mathematical concatenations (single suitabilities can be multiplied together, added, averaged, etc.). The CASiMiR-Fish module utilizes the following methods when applying preference functions:

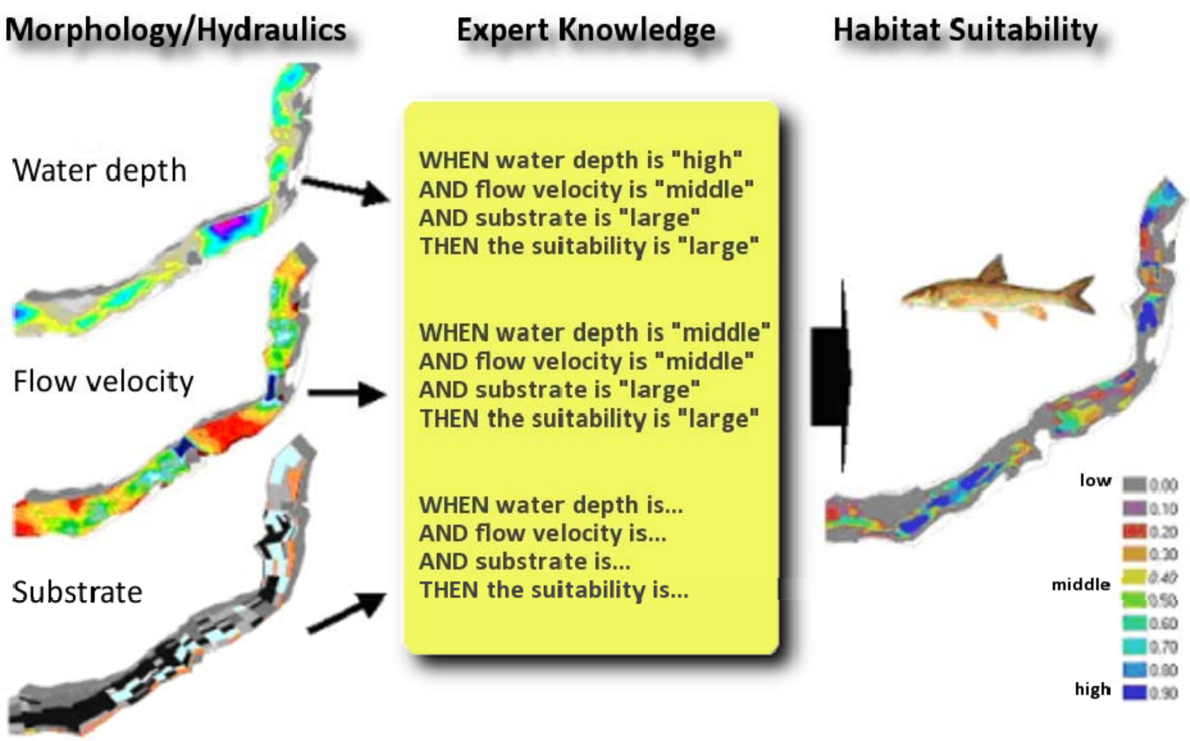


1.3.2 Fuzzy-Logic

In addition to the "classical" approach using preference functions, CASiMiR offers a fuzzy logic based approach after SCHNEIDER (2001) that shows several advantages compared to the classical habitat modeling. Fundamental to this approach is the use of fuzzy quantities based upon linguistic variables with nomenclature "high", "medium" or "low" to describe physical properties such as water depth or flow velocity. Such definitions lend themselves well to the description of environmental conditions, because fixed numerical values and exact functions are often not able to adequately capture the complexity of natural systems. Existing expert knowledge can be easily applied in fuzzy logic calculations. It can be also easily adapted for specific habitat conditions and species requirements. The main advantages of using a fuzzy system for habitat suitability simulations are:

- Existing knowledge of the specific habitat requirements of aquatic organisms, especially fish, is most commonly found in a qualitative form. This type of information can be numerically processed in CASiMiR through the use of expert knowledge based fuzzy rules.
- Fuzzy logic based calculations are able to take into account the interaction of the parameters, but do not require explicit assumptions regarding parameter independence.
- Using fuzzy logic approach, the additional, user-specified parameters can be easily included.
- Calculation approach is relatively straightforward and easy to understand; the effects of specific parameter interplay are replicable (not a "black box" approach).

The fuzzy logic based modeling principle behind CASiMiR can be illustrated as:



2 The CASiMiR-Fish Module

The CASiMiR-Fish is the main module within the CASiMiR software designed to assess the habitat conditions along the river channel and bank areas. It allows analysis and visualization of riverine structural and hydraulic properties, and was primarily designed to run fish habitat simulations using either preference functions or fuzzy rules. The newest version of CASiMiR-Fish also allows the computing of spatially referenced FST-hemisphere numbers based on a local water depth, depth averaged flow velocity and substrate characteristics (KOPECKI, 2008). Obtained FST-hemisphere distributions can be further used for assessing the habitat quantity and quality for macrozoobenthos organisms for which the FST-hemisphere based habitat preferences (in form of preference curves or fuzzy rules) are available.

This handbook provides reference to the Base version of the CASiMiR-Fish module, which involves a very simple (the so called 1.5-D) approach for calculation of flow velocities using cross-section based water surface calculations or measurements. For river reaches with complex geometry, strong lateral flows or slanted cross-sectional water surfaces the use of a 2-D hydraulic model is required. The extended version of CASiMiR-Fish can be used for processing of 2-D hydraulic data. However, the geometry and hydraulic file produced by it can also be read by the Base version. To inquire about CASiMiR-Fish with 2-D hydraulic interface capabilities, please contact sje GmbH.

2.1 Typical Applications

Based on the structural and hydraulic properties of a river reach, the following types of investigations can be made with CASiMiR-Fish:

- River characteristics (e.g. frequency distributions of depth, flow velocities etc.)
- Connectivity assessment
- Habitat quality studies
- Habitat quantity studies

The habitat quality can be further quantified using the weighted usable area (WUA) or the hydraulic habitat suitability index (HHS). The integral characteristics WUA and HHS allow for the estimation of threshold values and comparison with economic parameters such as, for example, the annual average income of a hydropower plant.

A particular advantage of modeling is the ability to create predictions. Through the variation of model parameters such as river stretch geometry, substrate and cover, and a subsequent analysis under changing flow conditions an impact on the ecological system due to the flow regulation, construction or removal of hydraulic structures, river control and renaturation measures can be assessed.

2.2 Running a Simulation Using CASiMiR-Fish

A typical application of the CASiMiR-Fish module for the determination of minimum flow requirements includes the following steps:

Investigation Reach Selection

An on-site visit is the first necessary step in determining the current ecological situation of the river reach under investigation. The entire river reach is typically not modeled for economic reasons; rather the modeler selects a limited number of representative stretches that encompass the variety of existing habitat and morphologic conditions for detailed investigation of their characteristics (geometry, hydraulics, substrate conditions, shading, etc.). Depending on the investigation goals, other requirements to the representative reach should be fulfilled, for example it should contain a part with a minimal water depth in case the connectivity of fish habitats are of interest. The proper choice of the investigation reaches is crucial thus it is highly recommended that the modeler gives a high priority to this task.

Field Survey

Cross sectional surveys of the river bed should be carried out, in order to determine the topographical conditions of each investigation reach. Additionally, a detailed mapping of the substrate conditions, refuge types (cover), shading, etc. is required. In order to calibrate the hydraulic model, water surface elevations should be measured along each investigation reach for a range of flow rates. If possible, electrofishing or other biological sampling procedures should be conducted for habitat model calibration purposes.

Digital Elevation Model

Building a digital terrain model taking into account field data for specific, pre-defined parameters such as substrate type, cover, pool types, etc. This is mainly done by arranging the field survey data into CASiMiR-Fish input files.

Hydraulic Modeling

It may be necessary to conduct hydraulic calculations using 1-D hydraulic models such as HEC-RAS or MIKE11 to obtain additional water level profiles, should there be only a few flow rates which have been measured. Hydraulic modeling is inevitable if a reach topography modification – for example in case of renaturation measures assessment – is required. As already mentioned for non-homogeneous river stretches a 2D-hydrodynamic model is required.

Biology

Creation/adjustment of preference functions and/or fuzzy rules for the characterization of habitat requirements for indicator species and their life stages should be conducted by reputable fish/benthos experts.

CASiMiR-Modeling (Fish Module)

As a first step, the Fish module determines flow velocities and water depths for the investigation reach. After importing the biological data, the habitat quality maps for each individual flow rate are computed via the coupling of structural and hydraulic characteristics with the preference curves or fuzzy rules for the target species. Calibration of the habitat model results can be conducted should biological sampling data be available.

Evaluation of Alternatives

Comparing scenarios with differing structural or morphological changes to the investigation reach with respect to their ecological impacts. Furthermore, the user is able to couple the results of the ecological investigation to the CASiMiR-Hydropower module, in order to determine the economic effects as well.

2.3 Model Results

CASiMiR-Fish allows for the following visualization types:

- Investigation reach plan views including water depths, flow velocity, substrate and cover types, FST-hemisphere numbers as well as the resulting habitat suitability,
- Cross sections (useful in assessing critical sites in terms of habitat connectivity),
- Thalweg view,
- 3-D views, as well as
- Fish (biological sampling) maps.

The module also allows for report-quality tables and graphics in order to present the following metrics:

- Wetted areas and aquatic volumes,
- Frequency distributions for water depths, velocity, FST-hemisphere numbers and substrate types,
- Frequency distributions of habitat suitability classes
- Habitat suitability distributions,
- Composite habitat suitability metrics (WUA, HHS).

3 Installation und Start

3.1 System Requirements

The following system components and settings should be considered as the minimum in order to run CASiMiR-Fish comfortably:

- MS Windows 32 bit (MS Windows 95 and newer),
- 32 MB memory (RAM),
- A minimum of 28 MB hard drive storage space for the CASiMiR-Fish program files and all example data files,
- Recommended Pentium 486 processor or better,
- VGA monitor with 800 x 600 pixel resolution.

The display and mapping functions of CASiMiR-Fish work best when the following additional requirements are met:

- Monitor resolution: 1280 x 1024 pixels,
- Color: 16 Bit,
- Font size: normal,
- Installation of the font type „Arial“ (standard for MS Windows),
- Installation of OpenGL is necessary for the 3-D visualization (may be installed, but can also be found at: www.opengl.org).

3.2 Installing CASiMiR-Fish

☞ *Uninstall, if present, the previous version of CASiMiR-Fish (see 3.5). If the link to the program is still present on the desktop, remove it manually.*

☞ *Download the current CASiMiR-Fish setup file from the www.casimir-software.de website.*

☞ *Start the installation (for example through the double clicking on the downloaded setup file) and follow the setup instructions.*

After successful installation, you will find a shortcut to **CASiMiR-Fish** on your desktop.

3.3 Starting the Program

Starting the CASiMiR-Fish module can be easily carried out by:

☞ *Double clicking on the* **CASiMiR-Fish** *desktop icon.*

or

☞ *Going to “All Programs” from the Start menu, locating the group* **CASiMiR-Base**, *and choosing the module* **CASiMiR-Fish**.

3.4 Closing the Program

☞ *From the main menu bar, go to* **File / Project** *and choose the option* **Close CASiMiR-Fish***.*

3.5 Uninstalling the Program

From the **Start** menu, go to **Control Panel**. Click the **Add or Remove Programs** icon. A list of the currently installed software is then populated. Select **CASiMiR-Fish** and click on **Remove** to remove the program.

4 Program Application

This chapter provides an explanation of how to run the CASiMiR-Fish module using an example case study on the river Neckar.

4.1 Project Description

A minimum flow study is to be carried out for a diversion channel of a hydropower plant in Rappenberghalde, Germany.

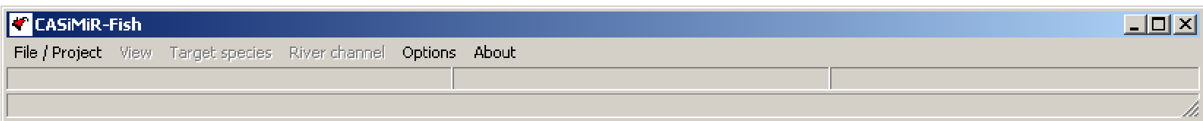
The selected investigation reach is located approximately 650 m downstream of the diversion weir. The reach contains both the river typical gravel banks and a critical section in respect to the longitudinal habitat connectivity at low flows. Hydro-morphological conditions in the investigation reach fulfill the requirements for 1-D hydraulic modeling.

The investigation reach is 154 m long and contains a total of 20 survey cross sections. Additional information regarding the dominant substrate, cover, and the interstitial pore space of the river bed is available. Water elevation profiles at 10 flow rates are calculated using the 1-D hydraulic model HEC-RAS.

4.2 The First Steps with CASiMiR-Fish

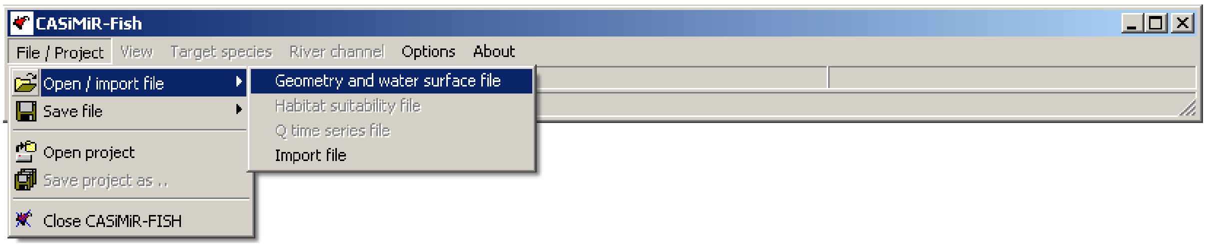
4.2.1 Opening Geometry and Water Surface Elevation Data

Upon starting the CASiMiR-Fish module, the following main menu bar should appear:



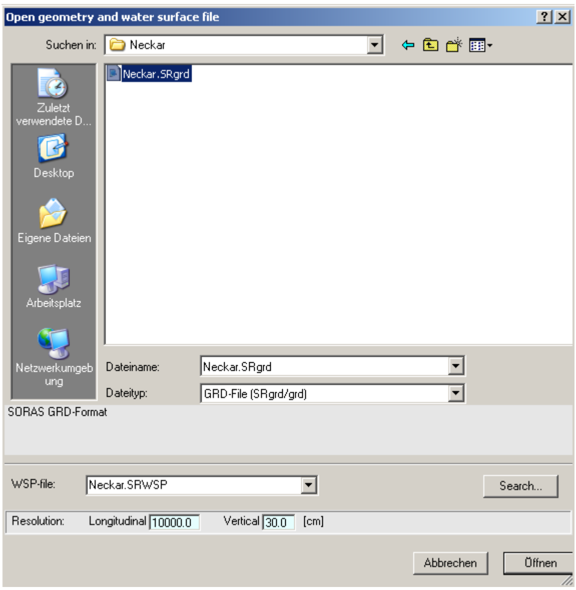
The first step in simulation with CASiMiR-Fish is to read in the geometric and structural data.

☞ *Select* ***File / Project*** *then* **Open / import File** *and then* **Geometry and water surface file.**



The Base version of CASiMiR-Fish comes with several example data sets. This data is automatically saved onto your hard drive upon installation of the software, and can be found in the CASiMiR-Base program folder. After locating the example data (for example in **C:\Programms\CASIMIR-Base\Examples\Fish**), open the folder **Neckar**. CASiMiR-Fish allows for the use of two different data types when loading geometric and structural data (*.SRstr, *.SRgrd). For more information regarding data types, please see 5.2.1. In this example, the data type *.SRgrd is used.

☞ *In the folder* **Neckar,** *select the file* **Neckar.SRgrd** *by clicking it once*.



At the bottom of the open file dialog window you can define the model output resolution, but be forewarned, the choice of resolution strongly effects the program calculation time! Standard resolution is 10000 cm by 30 cm (in the longitudinal and transverse directions, respectively). In this example, we are going to increase our model resolution in respect of the default values:

☞ *In the pop-up window, change the* **Resolution** *value in the* **Longitudinal** *to* **100.0** *and the* **Vertical** *value to* **10.0 [cm]**.

Along with the geometric data, the user can also choose to add a water surface elevation file, which can be selected in the section **WSP-File**. The program automatically checks for files with the *.SRwsp extension found in the same folder. In case you saved your data elsewhere, just click on **Search…** to navigate to the necessary file.

☞ *Make sure the program selected the* **Neckar.SRwsp** *file. In the case that the file has been saved elsewhere, locate the file manually using* **Search…**

☞ *Click* **Open** *to import the geometry and water surface data.*

During import the program checks the input data and computes the necessary parameters (for example flow velocity) for the following visualization and habitat modeling. Wait until the calculations are finished (the status of the import is shown in the progress bar). Once the program has completed the import, “OK” appears below the main menu bar.

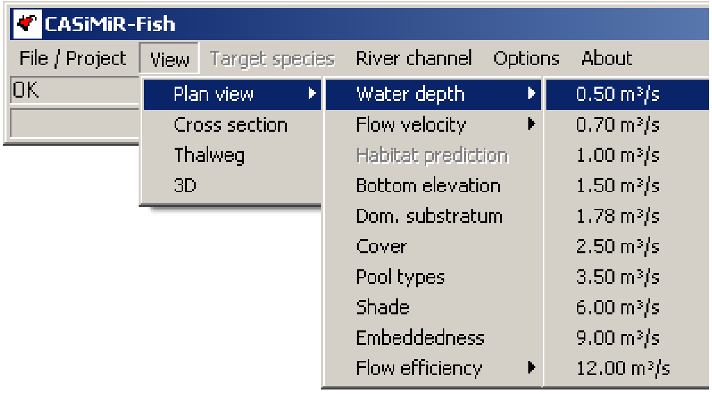
4.2.2 Visualizing Hydraulic and Structural Parameters

Once the program has finished importing the necessary geometry and structural files, you can choose from a variety of visualization options under **View** on the main menu bar. The following subsections outline the visualization capabilities of CASiMiR-Fish.

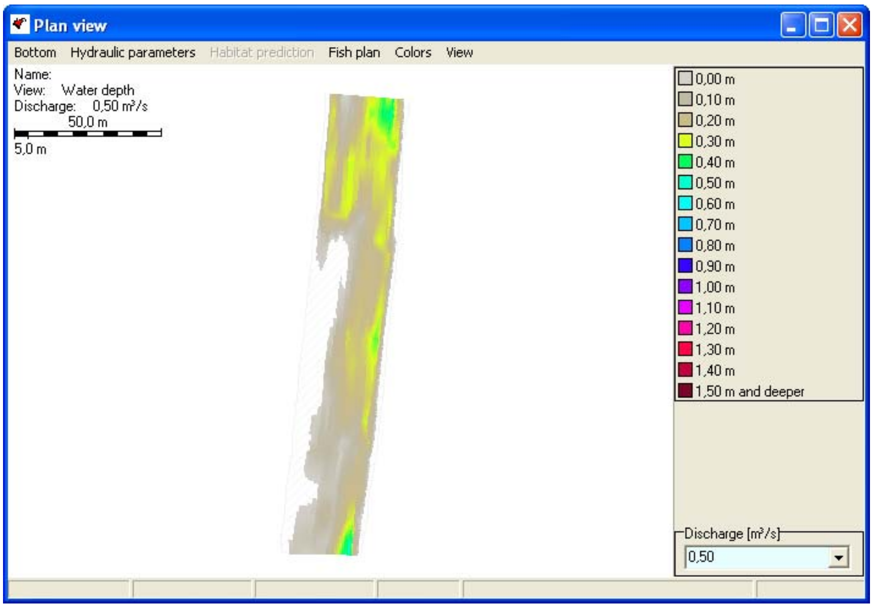
4.2.2.1 Plan View

☞ *On the main menu bar, go to* **View***, then select* **Plan view** *and then* **Water depth***. You can now choose to visualize the results for one of the flow rates included in the imported data set (see also 5.2.2).*

☞ *Select a flow rate of* **0.5 m³/s***.*



A new window opens, showing you the water depths map for the selected flow rate.

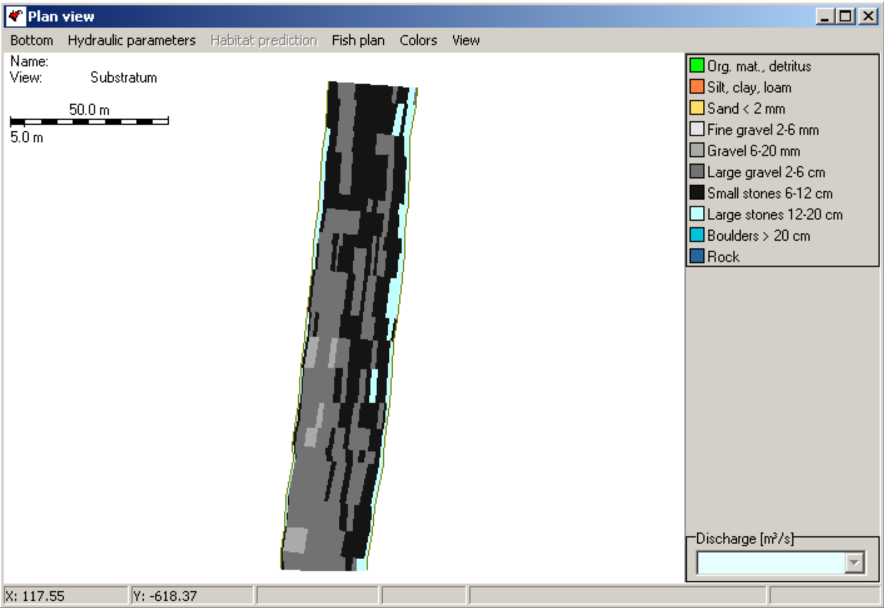


In this view, you can toggle between the imported flow rates by clicking on the values located in the **Discharge** combo-box in the lower right hand corner of the window. Using the up and down arrows on the keyboard, you can also quickly go through the full range of available flow rates. Additionally, CASiMiR-Fish can calculate a linear interpolation of results at discharges between the minimum and the maximum imported flow rate. This is done simply by typing the new value for a flow rate and pressing the “Enter” key.

The plan view also allows you to switch between structural and hydraulic parameters by selecting them from the **Bottom (River Bed)** and **Hydraulic parameters** menus.

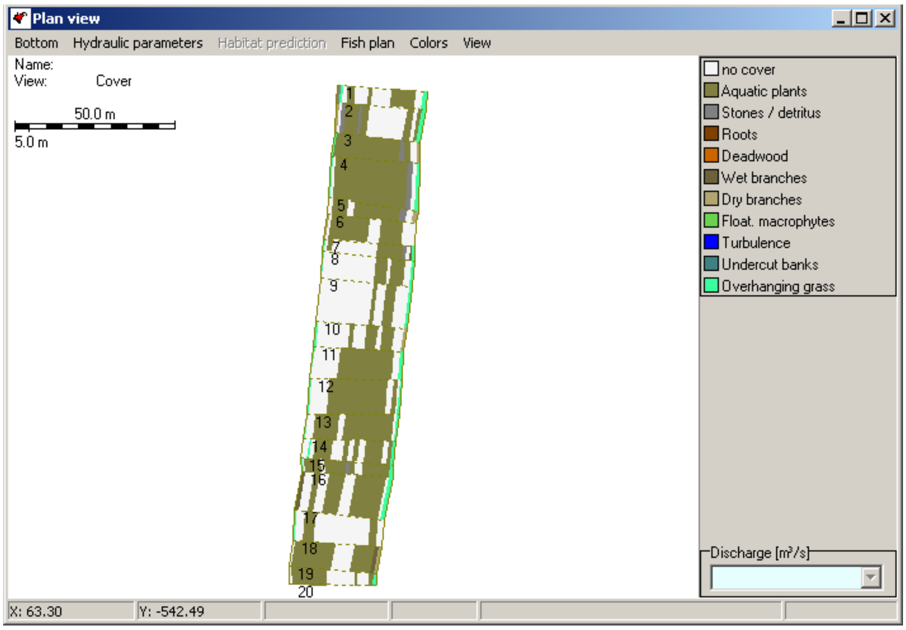
☞ *Go to the menu* **Bottom** *and choose the parameter* **Dominant Substratum***.*

The program now switches to a view showing the distribution of the dominant substrate.



☞ *Go to the menu* **Bottom** *and choose the parameter* **Cover.**

☞ *Go to the menu* **View** *to view the* **Cross Sections***.*



The plan view of the investigation reach now shows the cover type distribution, along with the locations of the cross sections and their corresponding numbering defined in the input data file. The distribution of cover is shown independent of the selected flow rate.

Under menus **Colors** and **View** you can change how the results are displayed. For instance, you can turn on and off different graphical elements, change line colors, and switch to a grayscale image view (see also 4.4.2).

☞ *Go to the menu* **Colors** *and select the option* **Dry areas color***. Choose the color* **black***.*

You can see that the cross section color has been changed from white to black and is much easier to recognize.

☞ *Under* **Hydraulic Parameters***, choose the option* **Flow velocity** *with a discharge of* **0.5 m³/s**

☞ *In the main menu bar of CASiMiR-Fish, go to* **Options**, *then to* **Spatial resolution**.

☞ *Change the value of* **Resolution** *to* **30.0** *cm in the Longitudinal and* **8.0** *cm in the Vertical directions and click on* **OK***.*

☞ *Wait until the calculations are completed with the new resolution.*

Here it can be seen that by increasing the model resolution the computation time grows considerably. It is likewise important, however, that the user does not run a simulation with a too coarse resolution, what may result in the model missing out on important locations with respect to habitat connectivity. On the other side, if the resolution is set too fine, the model results will not differ significantly from those with a reasonably lower resolution, since in the end the number and amount of survey data defines the quality of the model.

When the vertical resolution of the model grid is defined, each cross section is first separated into a series of horizontal layers using the defined interval size. For cross sections with wide, flat banks this can result in a too coarse model grid. In order to remediate this effect, CASiMiR-Fish allows for the use of a minimum horizontal separation distance (**Limit horiz. distance**) under the main menu **Options -> Spatial resolution**. Here you can also redefine the grid size for the entire reach, as well as limit the calculation area to only the wetted areas in order to save computational time.

☞ *Change the value of* **Resolution** *to* **100.0** *cm in the Longitudinal and* **10.0** *cm in the Vertical directions and click on* **OK***.*

Wait until the calculations are completed with the new resolution.

Following functions can be also used in the Plan View:

☞ *To zoom to a special area in the plan view, hold the key „Ctrl" pressed and mark the area with the left mouse button.*

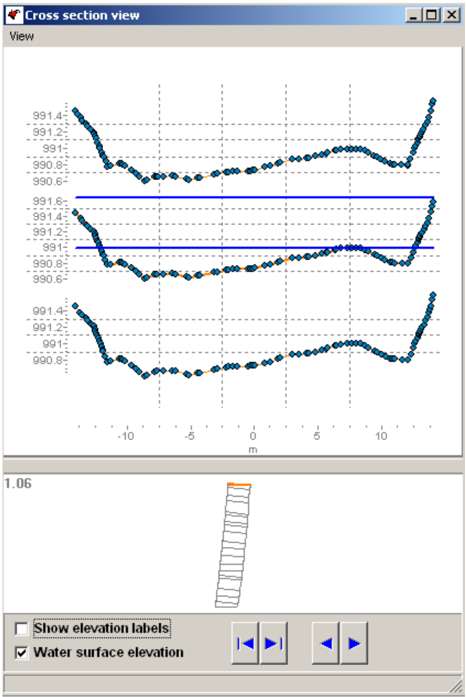
☞ *To pan the plan view, hold the key „Ctrl" pressed and move the view with a right mouse button pressed.*

☞ *To return into initial scale of a view, press a right mouse button somewhere in the plan view window.*

4.2.2.2 Viewing and Editing Cross Sections

In the **Cross Section** view the user can virtually “wander through” the river. This visualization also allows for changes to be made to the vertical position of individual points. The cross section viewer displays three sections at a time, where the middle cross section is the selected, and the above and below sections are those upstream and downstream of the selected section. Two blue lines represent the highest and lowest water surface elevations for the current cross section.

☞ *In the main menu bar of CASiMiR-Fish, select* **View** *and then the option* **Cross section***.*



☞ *The arrows with a vertical line* ▶| *allow switching between the cross sections imported from the geometric data.*

☞ *Interpolated cross sections can be viewed using the* ▶ *arrow.*

☞ *Individual point heights can be shown by checking the box* **Show elevation labels***.*

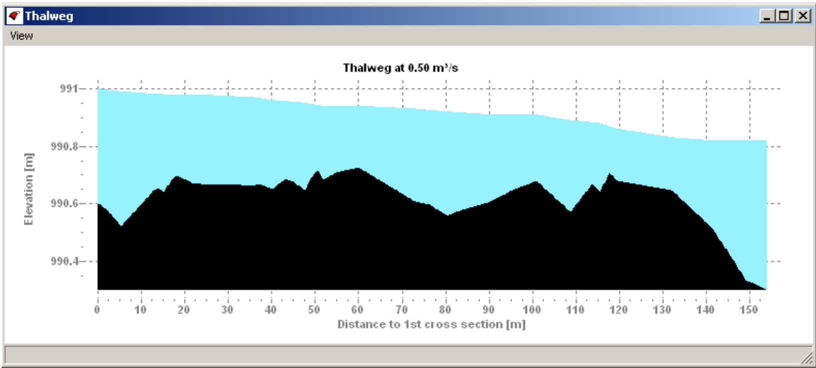
☞ *The water surface elevation lines in the middle cross section can be turned on and off by checking the box* **Water surface elevation***.*

☞ *To change the vertical position of one of the cross section points, move the cursor over the point that the hand turns into a cross pointer and press the left mouse button. Holding the mouse button, the cross section point can be brought into the desired vertical position. Note: modifying cross sections might cause a significant increase of the size of the input files since the current longitudinal resolution will be reflected in the number of cross sections in the new input files.*

4.2.2.3 Viewing the Longitudinal Profile (Thalweg)

In the longitudinal profile (Thalweg) viewer, the user can get a general idea about the longitudinal connectivity and the slope of a river bottom / water surface of the investigation reach. The river bottom line is constructed connecting the deepest points of each cross section. It is worth to notice, that this view could be misleading, as there is no guarantee that the thalweg points are indeed continuously connected to each other.

☞ *In the main menu of CASiMiR-Fish under* **View** *choose the option* **Thalweg**.



☞ *Zooming in can be done by making a bounding box using the left mouse button from the upper left to the bottom right.*

☞ *Zooming out can be done by making a bounding box with the left mouse button from the bottom right to the upper left.*

4.2.3 Evaluation of Reach Characteristics

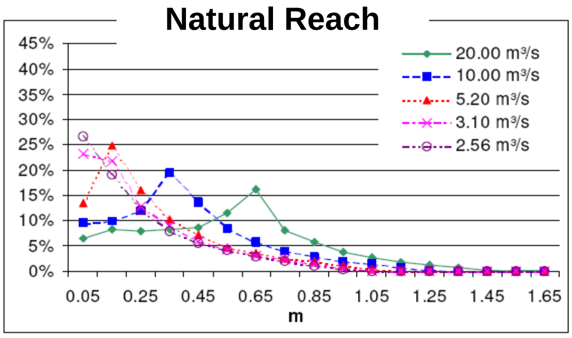
☞ *In the main menu bar, select* **River channel** *and then the option* **Properties**.

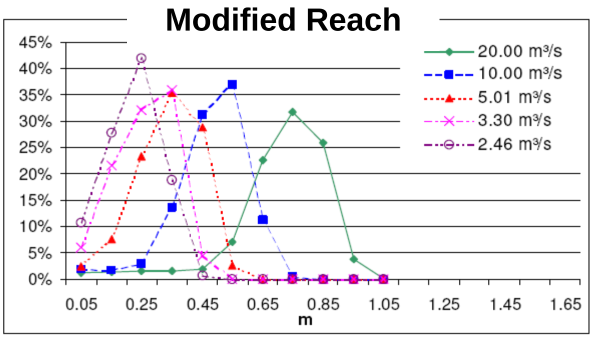
River channel properties

	A	B	C	D	E	F	G	H	I	J	K
1	River channel:										
2	Geometry file: D:\Kopecki\development\borland\casimirFrank_for_InternetDownload\work\CASIMIR_Examples\CASiMiR-Fish\Neckar\Neckar.										
3	Water surface elevation file: D:\Kopecki\development\borland\casimirFrank_for_InternetDownload\work\CASIMIR_Examples\CASiMiR-Fish\N										
4	Number of measured cross sections: 20										
5	Total length [m]: 0.0										
6	Longitudinal resolution [cm]: 30.0										
7	Vertical resolution [cm]: 8.0										
8											
9	Surface area / aq. volume:										
10	Discharge [m³/s]	0.50	0.70	1.00	1.50	1.78	2.50	3.50	6.00	9.00	12.00
11	Area [m²]	3185.88	3482.75	3677.31	3897.04	3968.39	4029.68	4085.79	4191.19	4276.06	4306.4
12	Volume [m³]	528.26	647.67	764.72	966.60	1084.25	1218.51	1490.54	2072.52	2713.76	3186.6
13											
14											
15	Classified substratum areas [m²]:										
16	Discharge [m³/s]	0.50	0.70	1.00	1.50	1.78	2.50	3.50	6.00	9.00	12.00
17											
18	Org. mat., detritus	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
19	Silt, clay, loam	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
20	Sand < 2 mm	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
21	Fine gravel 2-6 mm	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
22	Gravel 6-20 mm	61.30	85.30	105.30	113.52	124.57	133.07	136.80	136.80	136.80	136.80
23	Large gravel 2-6 cm	1361.23	1564.52	1695.58	1841.78	1876.43	1905.22	1914.44	1915.23	1917.46	1917.4
24	Small stones 6-12 cm	1647.06	1706.00	1738.70	1786.57	1799.21	1808.96	1823.00	1855.49	1868.84	1869.2
25	Large stones 12-20 cm	116.28	126.93	137.73	155.16	168.17	182.42	211.55	283.66	352.96	382.91
26	Boulders > 20 cm	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
27	Rock	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
28											

This opens a summary table of the important characteristics for the investigation reach, in particular: the values of wetted area and aquatic volume for all imported flow rates included in the *.SRwsp file. Also partial areas of substrate index, flow velocity and water depth classes as well as of FST-hemisphere numbers are listed here.

The tabular data can be marked and exported for later use in spreadsheet software (i.e. MS Excel) for visualization. Such analyses can be useful, for example, when determining the differences between natural and highly modified investigation reaches in the same river. The figure below shows the difference in flow depth distributions between two such reaches.





The next step in running CASiMiR-Fish is to import the habitat preference data.

4.2.4 Importing Habitat Preference Data

For the actual habitat modeling, the habitat preferences of indicator species should be available.

Here it is extremely important to note that the biological data included in the CASiMiR-Fish example files is related specifically to the river reaches investigated. For real-world applications, all preference functions and fuzzy rules/sets should be determined only after close consultation with a biology expert with specific knowledge on your investigation reach. The preference data transferability on other reaches with similar characteristics should also be confirmed by the experts.

For the example case Neckar, the indicator fish species is the grayling. CASiMiR can make use of two completely different types of habitat preference data: preference curves and fuzzy rules/sets (see 5.2.3).

☞ *In the main menu, go to* **File / Project → Open / import file** *and choose the option* **Habitat suitability file**.

A new dialog "Open habitat suitability file" opens.

☞ *Navigate to the folder* **habitat_demands_fuzzy** *and open the folder named* **grayling.**

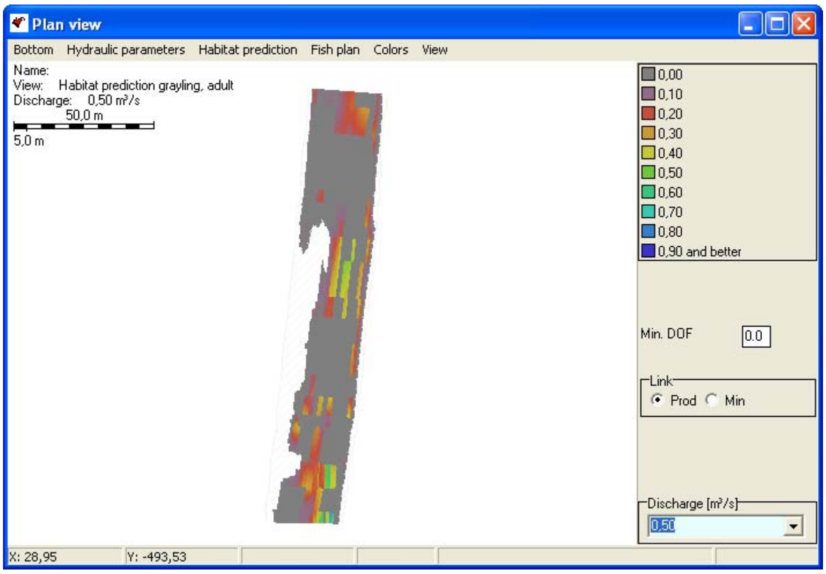
☞ *Click on the fuzzy rule file* **grayling_adult.SRfzy** *to import it.*

In order to read in the preference functions data instead, navigate to the folder **habitat_demands_pref** and select one of the files with the extension ***.SRprf**.

4.2.5 Visualizing the Habitat Suitability

☞ *In the menu of the already open plan view, choose* **Habitat prediction** *or go from the main menu bar to* **View → Plan view** *and choose* **Habitat prediction**. *You will find that you can view the results of the habitat simulation for* **grayling, adult** *for* *all flow rates included in the imported water surface elevation data.*

☞ *Next, choose the discharge* ***1.00 m³/s****.*



You can now visualize the habitat suitability for the full range of discharge rates.

The resulting visualization provides a colored map for the habitat suitability index (0-1). If you compare the results of the habitat suitability distribution to the figure showing the cover type on page 16, you will find that those areas with cover type “Aquatic plants” correlate strongly with areas having very low habitat suitability.

The standard setting for the calculation of habitat suitability in CASiMiR-Fish is the product combination method (SCHNEIDER, 2001). The parameters water depth, flow velocity and substrate type are equally weighted. The program also allows for the selection of a minimum combination method. The user can switch the method by selecting either the radio button **Prod** or **Min** in the **Link** box**.** As a rule of thumb, the best method to use when applying fuzzy logic habitat modeling is the method which gives the closest match to the observed data. However, usually both methods give nearly identical results.

An additional option when using fuzzy logic approach is to set the minimum degree of fulfillment (**DOF** see also Ch. 4.3.2.2). Only fuzzy rules that have fulfilled this value contribute to the calculation of the overall habitat suitability (SCHNEIDER, 2001). The default value for minimum DOF is set to 0.0, what means that all fuzzy rules invoked contribute to the result, irrespective of their level of fulfillment.

Analyzing the habitat suitability maps, the default **scaling** setting of CASiMiR-Fish should be taken into account (SCHNEIDER, 2001). The use of the standard CASiMiR-Fish SI fuzzy sets (consisting of four symmetrical membership functions) without such a scaling would result in calculated SI-values lying in the range from 0.16 to 0.84. That is because, according to a fuzzy logic mathematical apparatus, at most the centers of mass of a fuzzy set L (low) and of a fuzzy set VH (very high) can be achieved. The adopted standardization procedure results in the minimum possible suitability for the fuzzy system shifted from 0.16 to 0.0 and the maximum possible value shifted from 0.84 to 1.0. Such an approach is justified in case of the CASiMiR-Fish symmetrical SI fuzzy sets. Caution should be taken if redefinition of the output fuzzy sets is required. Especially in case of unsymmetrical membership functions with highly uneven widths the results can be difficult to interpret.

To cancel the default scaling of the habitat suitability:

☞ *In the main menu bar select* **Options** *and then click* **SI scaling deactivated***.*

However: for fish habitat simulations it is recommended to use the standard definition of the suitability sets and leave the SI scaling activated.

4.2.6 Evaluation of Habitat Suitability

A habitat suitability map allows for the convenient visualization of the investigation reach. However, it is often also useful to have an idea about how the reach's habitat suitability relates to a given flow rate as a whole. For this, the integral characteristic, the so called weighted usable area (WUA) can be used. The WUA value is obtained by multiplying the area of each mesh cell by its habitat suitability index value:

$$WUA = \sum_{i=1}^{n} A_i \cdot SI_i = f(Q) \qquad [m^2]$$

with SI_i *= habitat suitability index value for the* i_{th} *cell*
A_i *= area of the* i_{th} *cell*

The WUA is expressed as an area. Its theoretical maximum value is the total wetted area of a reach that could be obtained if all cells have a habitat suitability of 1.0.

Another useful summary metric to display overall habitat suitability at a given discharge is the WUA divided by the total wetted area. The resulting dimensionless metric is called the hydraulic habitat suitability index - HHS (after JORDE, 1996). The advantage of this approach is that it removes the effect of changing with discharge wetted area. The HHS is calculated as:

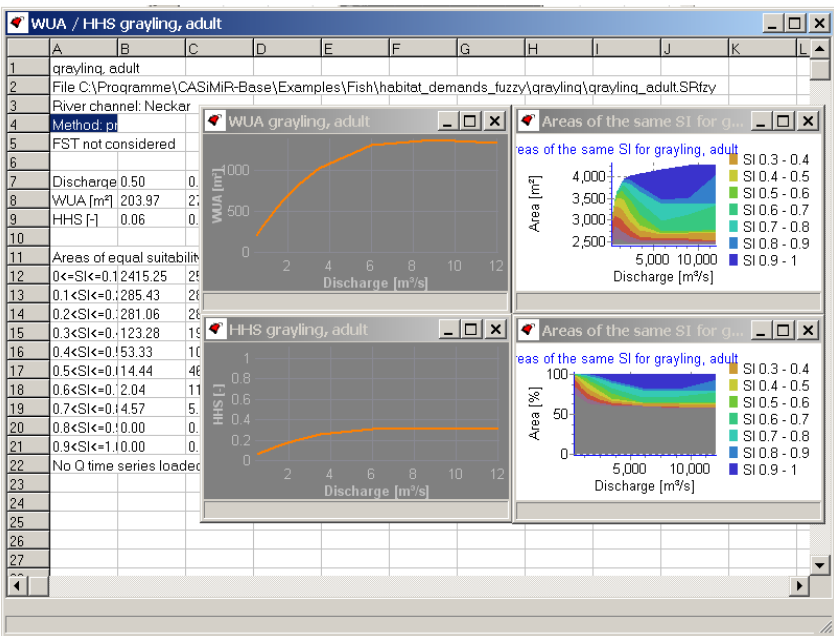
$$HHS = \frac{1}{A_{ges}} \sum_{i=1}^{n} A_i \cdot SI_i = f(Q) \qquad [-]$$

Both values are useful in describing the relation between habitat quality and discharge for a given reach. The comparison between scenario and reference cases can also be easily done.

☞ *In the main menu, go to* **Target species** *and choose* ***grayling*****, adult** *and select the option* **WUA / HHS**

The program calculates WUA and HHS values in the investigation reach for the chosen calculation approach (preference or fuzzy based). Results are shown both in tabular and graphical form. The tabular data can be exported and saved in a spreadsheet.

As can be seen in the diagram, the highest habitat suitability for the adult grayling can be found at the discharge rate of 9 m³/s.



When determining threshold values for the minimum flow requirements, it is also important to consider the life stages of the indicator species. The example data set also includes fuzzy rules for the juvenile grayling. It is clearly seen that the results of a simulation for the juvenile grayling show markedly different discharge dependencies, even for the same investigation reach. For example it can be seen that the best conditions for the juvenile fish are found at a discharge rates of about 1.5 m³/s what is in sharp contrast to the requirements for the adult grayling.

The WUA/HHS window also contains tabular data for the habitat suitability index divided into 10 ranges between 0 and 1. This information is particular useful in that the WUA and HHS, as composite values, give no information regarding the distribution of low and high habitat suitability for the investigation reach. For instance, a 20 m² area with a habitat suitability of 0.3 is in the composite metrics equally important as the combination of two smaller areas of 5 and 15 m² having suitabilities of 0.9 and 0.1 respectively as both lead to an WUA of 6 m². For the determination of minimum flow requirements the second case is more valuable for the grayling than the first one. Thus, these aspects of habitat suitability distribution should be given attention during decision making. Two additional diagrams, the absolute and relative areas of the same SI in dependency from discharge show the values of this table graphically. These diagrams are very useful to e.g. assess the portion of areas with suitabilities higher than a certain threshold value (e.g. areas with Si values higher than 0.7 could be defined as "highly suitable" habitats.)

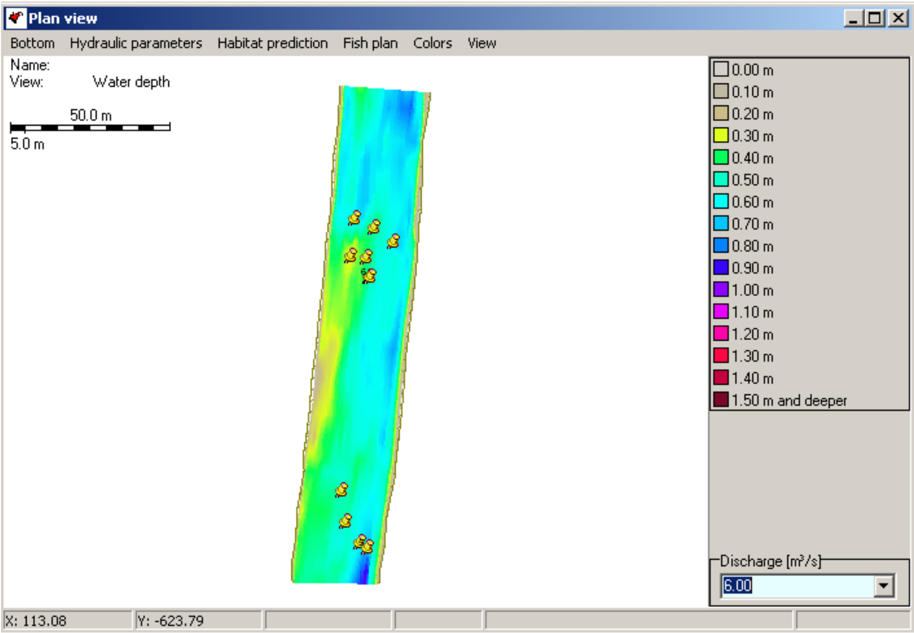
All table data can be copied into the clipboard and pasted as a text into other applications (for example into the MS Excel spreadsheet).

4.2.7 Creating "Fish Plans"

Comparing the habitat suitability results from CASiMiR-Fish with actual biological observations is the best way to calibrate the model and verify its accuracy for the investigation reach.

Assuming we have the results of electrofishing in the investigation reach for adult grayling at a discharge of 6.0 m³/s. The **Water depth** plan view suits best for creating a "fish plan", a computer documentation of the biological sampling results.

☞ *From the main menu bar, go to* **View → Plan view** *and select* **Water Depth → 6 m³/s***.*



Now you can place the locations of your "sampled" fish onto the map.

☞ *To place a fish marker onto the map, hold down the Shift key, and click the left mouse button. To remove the marker, hold the Shift key and click again on the marker.*

If more than one fish is found at a particular location, the user may add fish to that location by letting go of the Shift key and clicking the left mouse button on the marker repeatedly. The number of fish per location (if more than one) is shown next to the marker. You can reduce the number of fish by clicking with the right mouse button on the marker.

After adding the fish locations and numbers to the map, it can be saved in a fish plan file.

☞ *In the menu of the plan view window go to* **Fish plan** *and select the option* **Save in file** *and save the fish plan file (*.SRfsp) in the folder* **Neckar***.*

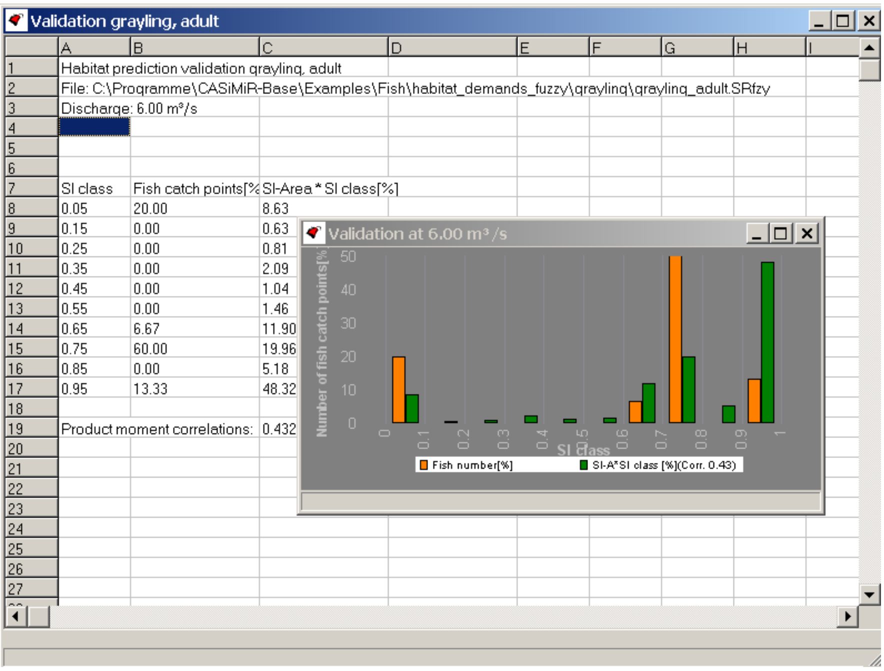
After this, the fish plan can be read in and edited again if needed (**Fish plan → Load from file**).

Using the CASiMiR-Fish capability to overlay the visualizations for habitat suitability, water depth, flow velocity, substrate types and cover with the fish plan, concrete conclusions regarding the importance of each parameter can be made. Overlapping the fish plan with a cover mapping in the plan view, you can see that the grayling adult prefers areas free from aquatic plants, therefore it is important to include the cover parameter for this investigation. Fortunately, in many cases, the three main parameters: water depth, flow velocity and substrate are sufficient to describe properly the habitat conditions for an indicator species.

☞ *In the main menu bar of CASiMiR-Fish under* **View → Plan view** *select the option* **Habitat prediction** *and look at conditions for the* **grayling, adult** *at a discharge of* **6.00 [m³/s]***.*

Calibration of the model via a visual comparison of the habitat suitability with the observed field data only is rather subjective and can lead to serious errors. To avoid this, CASiMiR-Fish offers an automated evaluation function.

☞ *In the menu of a plan view window, select* **Fish plan** *and then the option* **Evaluate fish plan with...** *for* **grayling, adult** *at the flow rate* **6.00 [m³/s]***.*



A new window appears which displays both a graphical and tabular comparison of computed habitat suitability and fish catches. The comparison is split into ten classes of habitat suitability from 0 to 1. The overall quality of the model is given by the moment correlation coefficient. The larger the correlation coefficient is, the higher the correlation between the model results and observation data. Adjustments like introduction of new parameters, increasing model resolution, revising of hydraulics and changing the fuzzy rules / sets can be made to improve the habitat model quality.

It should be stressed out that such a model evaluation is only reasonable for indicator fish species with small escape distances. Generally, a small shirk movement of a fish can result in a shift of a catch point into a less suitable habitat and thus in a corruption of the field sampling data. Thus the value of a correlation coefficient can give just an additional hint to the model quality. Considerably more weight should be given to the comparison of fish catch points with the spatial distribution of habitat classes, accounting for additional disturbances such as presence of people on the banks, predators or spatially unequal distributions of food source.

Additionally, the value of the computed correlation coefficient depends on whether the scaling of the computed suitability index is turned on or off (see 4.2.5). In the unscaled results, the two SI classes from 0 to 0.1 and from 0.9 to 1 are missing and higher correlation coefficients are usually obtained compared to the scaled SI approach.

4.3 Model Calibration

4.3.1 Conveyance (flow efficiency) factor

CASiMiR-Fish includes a simple algorithm for calculating local flow velocities. The governing parameter is the known water surface elevation at each cross section. The relation between the local velocities v_i, the energy grade line slope I_E, the local water depths h_i, the Darcy-Weisbach roughness coefficient λ and the conveyance factor f_{Aw} is given by the equation:

$$v_i = f_{Aw} \cdot \frac{1}{\sqrt{\lambda}} \cdot \sqrt{8 \cdot g \cdot h_i \cdot I_E} \quad \textbf{[m/s]}$$

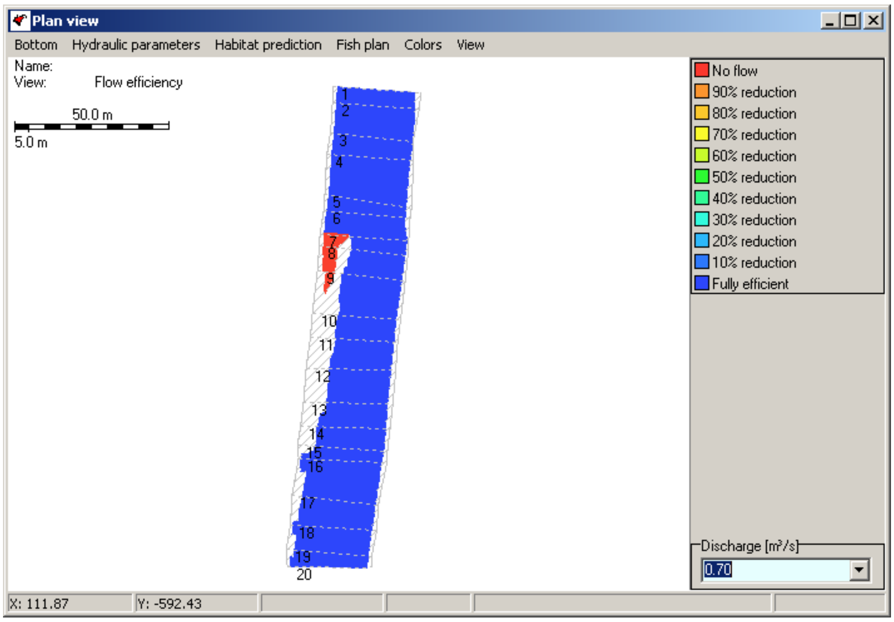
with v_i *= flow velocity in the* i_{th} *cell [m/s]*
f_{Aw} *= conveyance factor [-]*
λ *= Darcy-Weisbach roughness coefficient [-]*
g = acceleration due to gravity [m/s²]
h_i *= water depth in the* i_{th} *cell [m]*
I_E *= energy grade line slope*

The conveyance factor is included to account for the effects of back water and recirculation areas. It regulates the extent to which a particular area contributes to the main flow. For dead water zones, the user can sharply reduce the conveyance factor, allowing for a deeper, slow flowing zone to be more accurately reproduced in the hydraulic model.

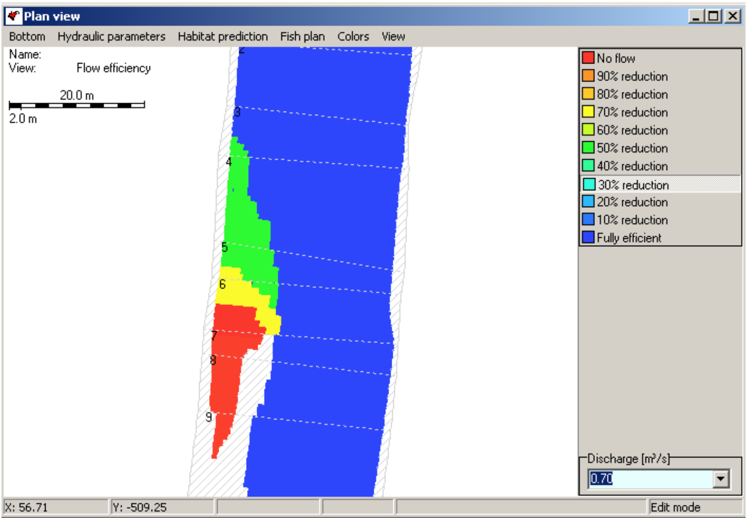
☞ *In the main menu bar go to* **View,** *select* **Plan view** *and then the option* **Flow efficiency;** *then select the flow rate* **0.70 m³/s**.

☞ *View the cross sections in the plan by selecting in the menu* **View** *the option* **Cross sections**.

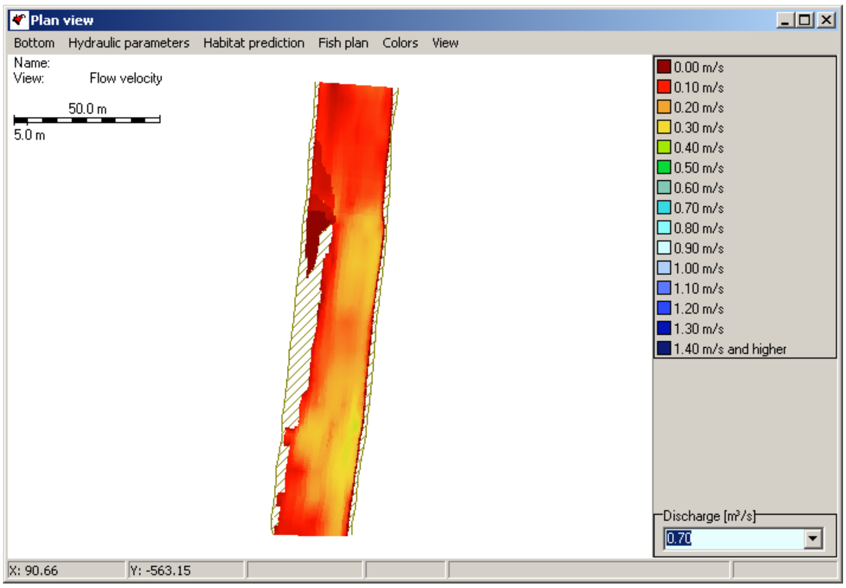
It can be clearly seen that the program has already detected some zones that are not directly related to the main channel. Unfortunately, often the predicted boundary of the zone with reduced efficiency is not realistic and has to be modified to improve the simulation results.



- *Place the mouse pointer over the investigation reach, so that the hand pointer appears.*
- *Zoom in to the area between the cross sections 3 and 10. To zoom in, hold the Ctrl-Key and mark the area with the left mouse button.*



- *In the legend, click on the level „no flow“ (dead water zone).The mouse pointer, when moving over the wetted area, changes from an arrow to a cross.*
- *Adjust the dead water zones in the model as shown in the figure with the left mouse button pressed. To change the flow efficiency class, click on the corresponding value in the legend.*
- *Deactivate the editing mode by clicking on the activated flow efficiency class in the legend and click again somewhere in the plan with the right mouse button.*
- *Under* **View →Plan view** *in the main menu bar, select the option* **Flow velocity** *for a flow rate of* **0.70 [m³/s]**

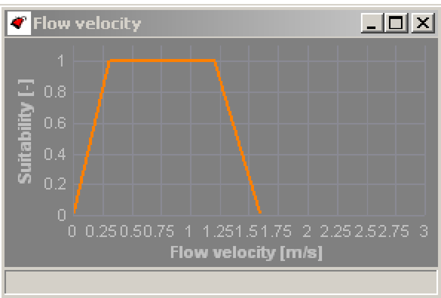


You should now have a result similar to the one above. The calculated flow velocities still deviate from the real ones, but using this simple method, areas which are grossly misrepresented can be adjusted for a better fit. For cases where1-D velocities deviate considerably from the measured values, the use of a 2-D hydraulic model together with the CASiMiR-Fish 2-D module is strongly advised. Note: instead of trying to adapt flow velocities using the described flow efficiency factor in most cases it is advisable to use a 2D hydrodynamic model in a first stage and to import the results into CASiMiR-Fish (see also Chapter 2).

4.3.2 Modifying Preference Functions and Fuzzy Sets

4.3.2.1 Preference Functions

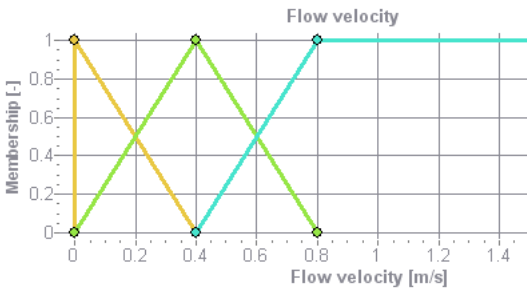
The classical habitat modeling approach requires the use of preference functions that relate the ecological responses (for example, species abundance) to the physical characteristics of a habitat. A preference function defines a degree of fulfillment of species habitat requirements in respect to each parameter value. This degree of fulfillment is called suitability index (SI). Preference functions are empirical in nature and are usually derived from experimental or observational studies. Most functions are univariate, giving the dependency of a suitability index from a single environmental variable (for example flow depth).

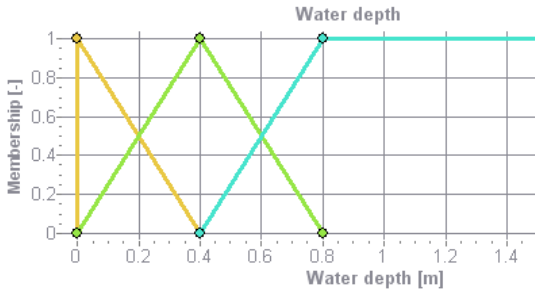


The overall habitat suitability is obtained by combination of all single habitat suitability. It is obvious, that changes to a single preference function will result in changes in the overall calculated habitat suitability. In CASiMiR-Fish, preference function data is saved in ASCII text files and can be edited with a common text editor (see 5.2.3.1).

4.3.2.2 Fuzzy Logic Based Approach

Basis for the fuzzy logic approach used in CASiMiR-Fish are the so called fuzzy sets that allow for the utilization of linguistic variables commonly used in biology. For instance, it is often stated that a river is “fast-flowing” or “very deep” rather than specifying the exact numerical values to describe hydraulic conditions.





The graphics above show the standard fuzzy sets of CASiMiR-Fish. It can be seen that the center of a fuzzy set “medium” (green line) is set to a value of 0.4 m/s for a flow velocity and to 0.4 m for a water depth respectively. There are no abrupt borders between fuzzy sets: the single parameter value belongs in the same time to more than one fuzzy set. This is expressed via the so called membership function. For instance, the velocity value of 0.2 m/s has a membership of 0.5 in the set “low” (brown line) and a membership of 0.5 in the set “medium” (green line) respectively. Respectively, the output suitability is also defined as a fuzzy parameter, in CASiMiR by default it contains four symmetrical fuzzy sets (“low”, “medium”, “high” and “very high”).

The expert knowledge on habitat requirements is either already present in form of verbal expressions or can be easily formulated this way. These formulations are called fuzzy rules; here is an example of a single rule:

> WHEN the water depth is „medium“ AND the flow velocity is „high“ AND the substrate index is „high” AND cover type is „2” THEN the habitat suitability is „very high“

Note: the input parameter cover type is not a fuzzy parameter in the given example rule.

Through the use of fuzzy sets, the fuzzy rules can be incorporated into computations. The rule base system (inference system) should contain all possible combinations of input parameter sets in respect to the overall habitat suitability. The setup of the inference system should be carried out or at least approved by a fish expert.

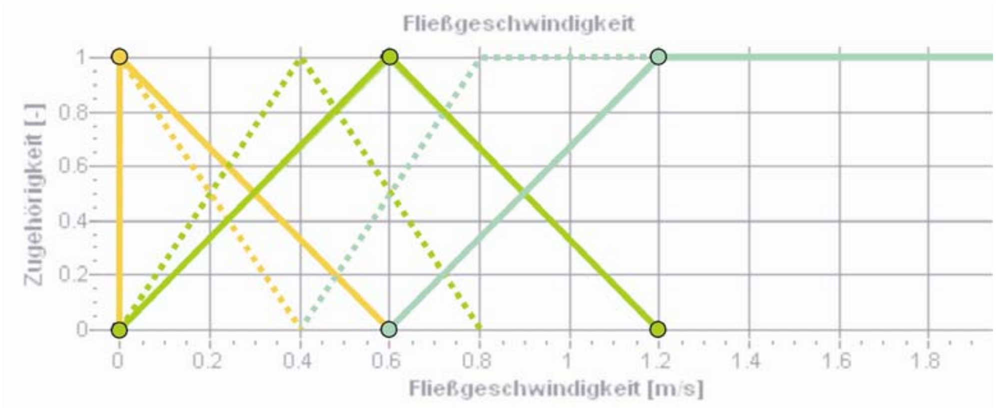
The fuzzy logic based rule formulation is so inexact, that the expert knowledge necessary for the formulation of a wide variety of possible parameter sets is available (SCHNEIDER et al. 1999, BÖHMER et al. 1999). First attempts to setup inference systems have shown that the rules formulated by different experts are in agreement on the main lines, reinforcing the analogy between fuzzy logic and human thinking (KAPPUS et al. 2000).

In some cases, existing fuzzy sets / rules can be applied for reaches having similar characteristics. However, due to the complex nature of each individual river, it is always strongly advised to get an expressed approval of a fish expert!

Calculations using the fuzzy logic approach can be explained as follows:

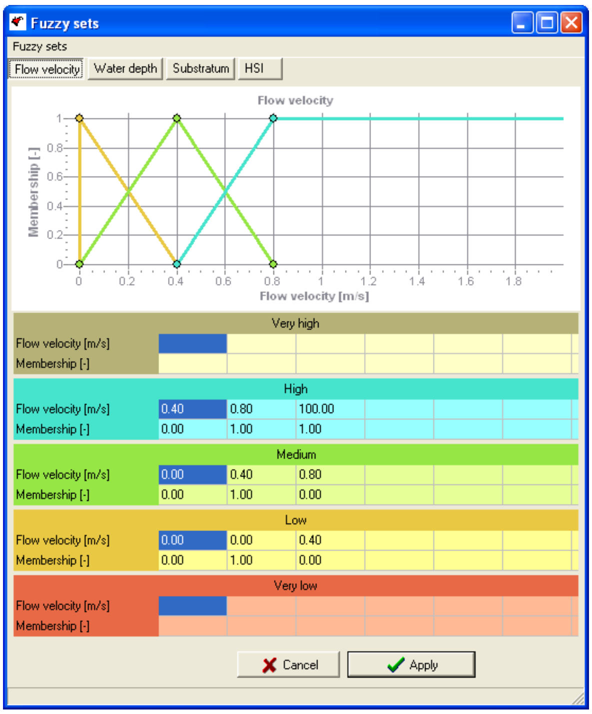
For every mesh cell, the model looks at first for the rules which are invoked for the given combination of input parameter values. For instance, at a location with a large water depth (for example 1 m), a rule containing the condition water depth is "low" does not come into play at all, as its membership in this set is zero. In return, the rules containing the condition water depth is “high” will fire and therefore contribute to an overall habitat suitability calculation (for more detail see SCHNEIDER, 2001).

It is obvious that a shift in the definition of fuzzy sets can have a large effect on the determination of the end result. However, this quality can also be used when calibrating the simulation results against observed data. For example, the user can shift the definition of the set "large" flow velocity when considering an upstream (mountain) reach of a river.



The figure above shows how the user can adjust the velocity fuzzy sets definition. (The standard fuzzy sets are shown as solid lines, sets for a mountain reach as dotted lines).

☞ *In the main menu bar, go to* **Options** *and select* **Edit fuzzy sets***. A new window appears, allowing you to modify the fuzzy sets.*



Changing the fuzzy sets in CASiMiR-Fish can be done in two ways:

☞ *Move the mouse pointer over the fuzzy sets for the parameter flow velocity, the* *mouse will change from an arrow to a hand pointer.*

☞ *Move the center point of the triangle function for* **Middle** *(green) from 0.4 to* **0.6***, both, the right lower point for the* **Low** *(brown) and the left lower point for the* **High** *from 0.4 to* **0.6;** *both the upper point of* **High** *and the right lower point of* **Middle** *from 0.8 to* **1.2***.*

☞ *Click the button* **Apply***.*

Another way to adjust the corresponding fuzzy sets' values is to edit the table below the graphics what is often faster and more precise than interactive editing.

After editing the fuzzy sets they can be saved in a new file using the option "save fuzzy sets in file".

Hint: the output SI fuzzy sets can also be adjusted although this should only be done as an exception. Here, the effect of SI scaling should be accounted for (see 4.2.5).

Now after you have edited the fuzzy sets, its effect on the calculated habitat suitability can be evaluated.

☞ *From the main menu bar, go to* **View → Plan view → Habitat prediction → grayling, adult** *and choose the flow rate* **0.70 m³/s***. Don't close the window that just appeared.*

☞ *Go back to the* **Fuzzy sets** *window and reload the original values (or you can move them back manually).*

☞ *Click the button* **Apply**

☞ *From the main menu bar, go to* **View → Plan view → Habitat prediction → grayling, adult** *and choose the flow rate* **0.70 m³/s**.

A second plan view window will appear that allows you to compare the changes you made to the fuzzy sets.

4.3.3 Modifying the Structural Parameters

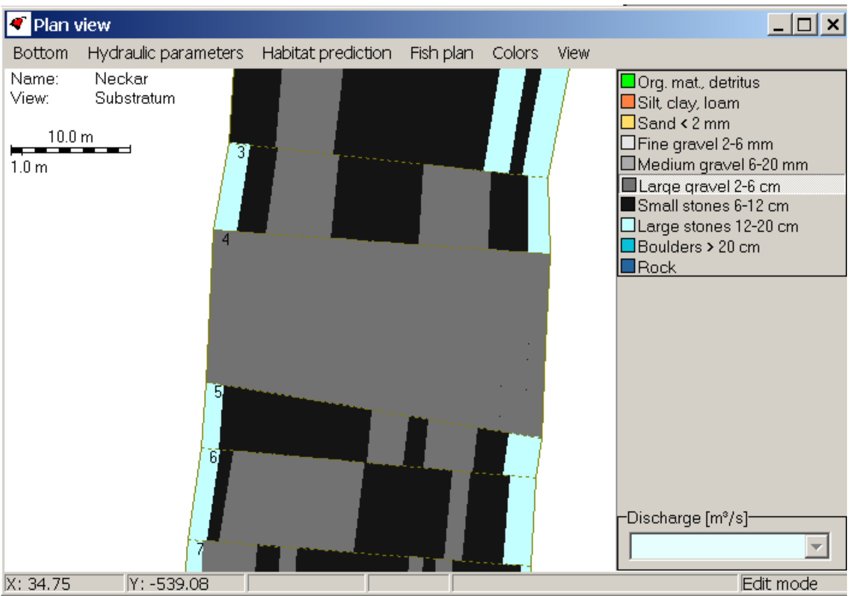
As previously noted, additional habitat model calibration and/or incorporation of changes to the investigation reach in CASiMiR-Fish can be carried out by adjusting the values of the structural parameters: dominant substrate index, cover and pool type. For example, the impact of dumping gravel and removing the aquatic plants on the adult grayling can be investigated this way. The user can change parameter values directly in the plan view window. It should be noted that the program automatically recalculates the habitat suitability, so results before and after changes should be saved for later comparison. Furthermore, making changes to the model after setting the fine spatial resolution can add significant amounts of data to the model, thus a reduced resolution is recommended in order to save computational time.

☞ *In the main menu, choose* **Options → Spatial resolution** *and change the* **Longitudinal** *resolution to* **1000.0 cm***.*

☞ *Open the plan view window and select the view* **Dom. Substratum (dominant substrate distribution)***.*

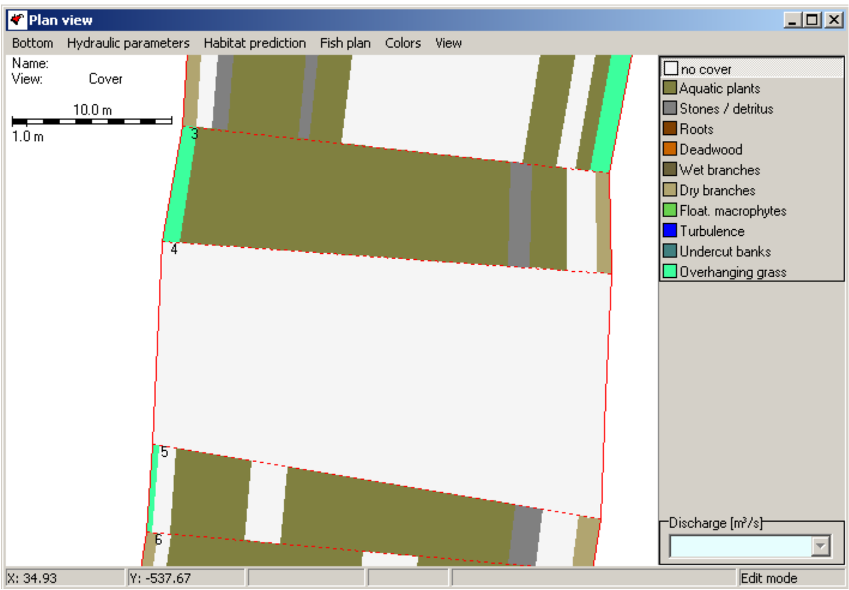
☞ *Zoom into the area between cross section 3 and 6 by holding the Ctrl-Key and* *marking the area with the left mouse button.*

☞ *Click on the substrate type* **Large gravel 2-6 cm**, *and mark the region between sections 4 and 5 with the left mouse button pressed.*



The next step is to remove the aquatic plants in the places with a new substratum.

☞ *In the plan view window, go to* **Bottom → Cover** *and assign the cover type* **No cover** *to the region between sections 4 and 5.*



☞ *From* **File / Project → Save file → Geometry and water surface file** *you can save the changes to the structural (and geometric) data file.*

In the plan view, you can now check how the changes made to the structural parameters improved the habitat suitability for the adult grayling. Additionally, the river bed elevation should be increased to account for the addition of the gravel, but this has been left out of the example for simplicity. Note: It is advisable to evaluate the effects of these morphological changes with a 2D-hydrodynamic model and import the results into CASiMiR-Fish (see also chapter 2).

4.4 Additional Options

4.4.1 Importing Discharge Hydrographs

In the main menu, you can also select to import hydrograph data. This file has the extension .SRgan and contains header data, followed by the days (column 1) and their corresponding flow rates (column 2) in m³/s (note that the water surface elevation file contains flow rates in l/s). The user can input a maximum of 366 days into one SRgan file.

```
[ABFLUSSWERTE_G]
# Neckar_demo
# Jahr:  2222
# Neckar/Rappenberghalde
#day    discharge
1       0.917
2       0.851
3       0.780
4       0.757
5       0.697
6       0.633
7       0.626
8       0.593
…
366     1.714
```

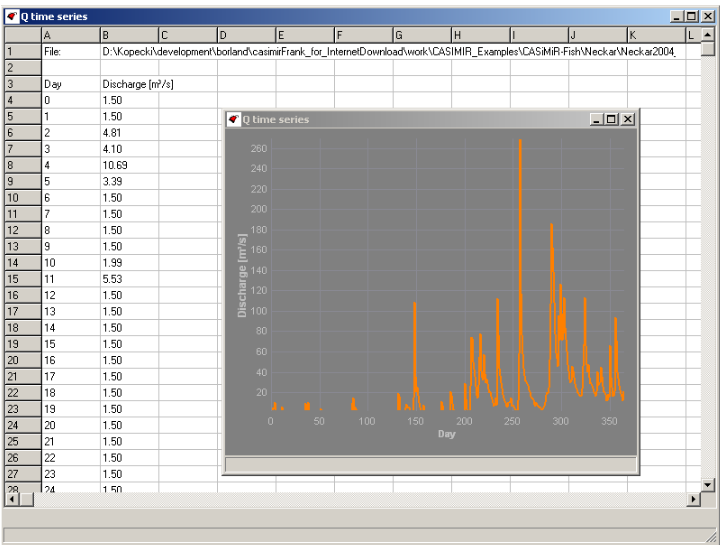
☞ *From the main menu bar go to* **File / Project → Open / import file → Q time series file**

☞ *From the file folder* **Neckar** *open the file* **Neckar2004_2005.Srgan**.

After importing the hydrograph data, you can use CASiMiR-Fish to visualize the hydrograph.

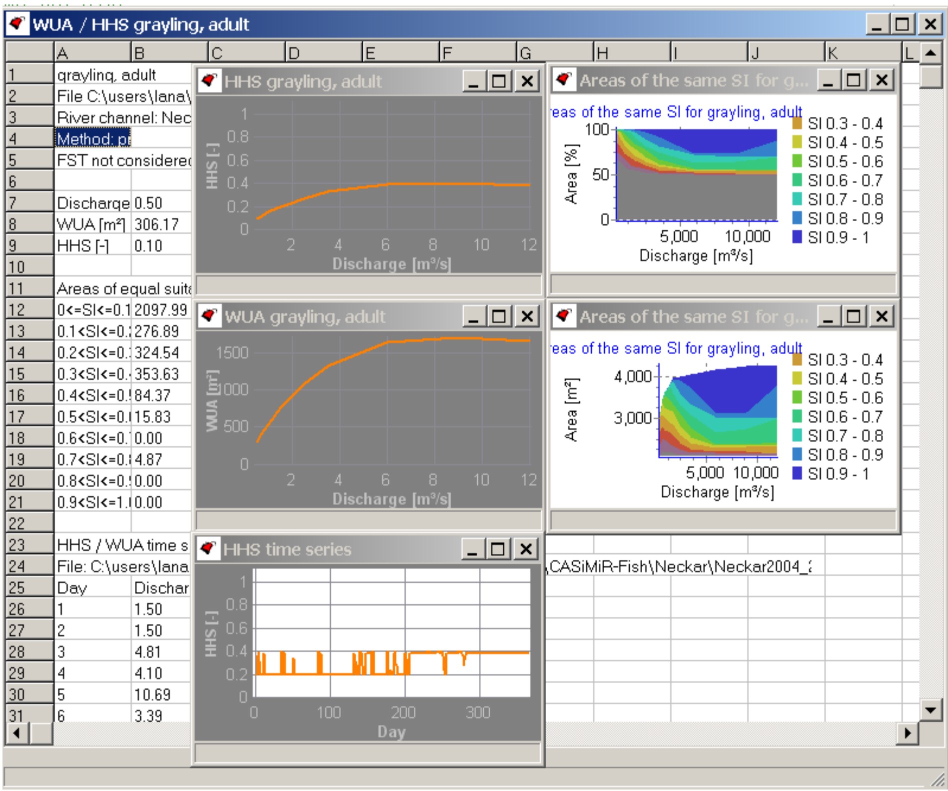
☞ *From the main menu bar select* **River channel → Q time series**.

The hydrograph view window appears as depicted below:



If the habitat preference data has already been imported, CASiMiR-Fish will additionally calculate how the composite habitat indices WUA and HHS change over time. This data will be provided in a tabular form and also as a graphical representation for the HHS values. Note: should the hydrograph discharges exceed the flow rates in the habitat model, WUA and HHS will be assigned values corresponding to the maximum discharge of a habitat model (i.e. no extrapolation for WUA and HHS values takes place).

☞ *In the main menu bar, select* **Target species → grayling, adult → WUA / HHS**.

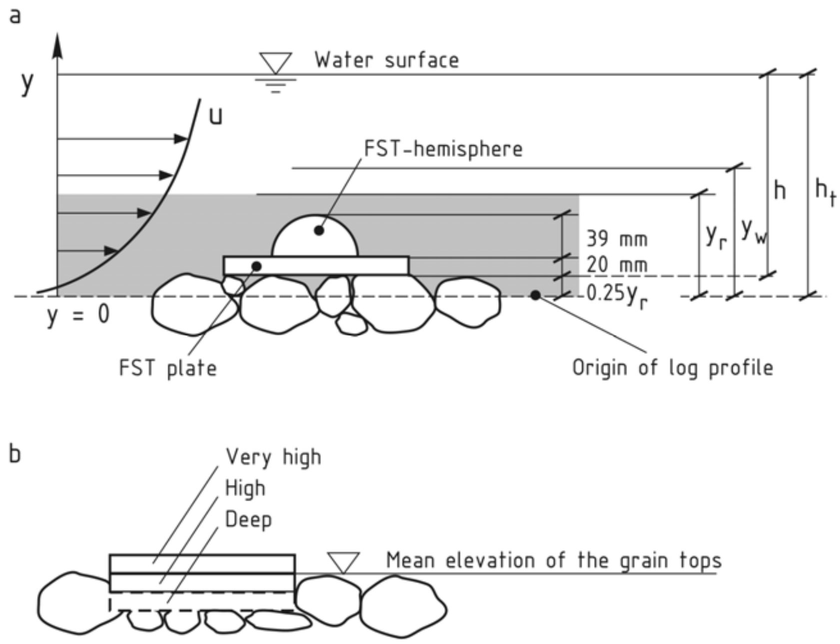


4.4.2 FST-Hemisphere Calculations

The most recent version of CASiMiR-Fish allows the calculation of spatially referenced FST-hemisphere numbers. These can be used afterwards for a classical preference based or fuzzy logic based (multiparametrical) benthos habitat modeling. The detailed description of the FST-hemisphere method and the benthos habitat modeling approach in general can be found in (KOPECKI, 2008). In following only a short description of the calculational approach to FST-hemispheres and the formats for the preference functions and fuzzy rules/sets files will be given.

4.4.2.1 Calculational approach to FST-hemispheres

The computational approach to FST-hemispheres is based on the assumption of the validity of the logarithmical velocity distribution law. To account for the very common condition of low water depths in a modeled river reaches, the modified logarithmical velocity distribution after (BEZZOLA, 2001) is used.



The basic steps of the approach are:

1. First, for every mesh cell, from the mean column velocity, water depth and substrate characteristics using the logarithmical velocity distribution formula after BEZZOLA the shear velocity u_* is calculated. In this equation the thickness of a roughness sublayer y_r (see the scheme above) is assumed to be proportional to the substrate mean diameter k ($y_r/k \cong 1.5$-2.0 for natural substrates):

2. From the known value of a shear velocity u_*, the representative velocities u_{ht} und u_{hc}, acting at the levels of a hemisphere's top y_{ht} and center of mass y_{hc}, can be calculated. The FST-hemisphere plate is assumed to be in position “very high” in CASiMiR-Fish.

3. Afterwards the FST-hemisphere density is calculated using the theoretical force equilibrium equation. The value of a friction coefficient in CASiMiR-Fish is taken equal 0.24 (as for the standard steel FST-hemisphere plate). The values of drag and lift coefficients are taken corresponding to the value of velocity u_{ht} at the level of a hemisphere's top.

4. The FST-hemisphere number obtained from the table given below is assigned to a particular mesh cell.

FST N◦ -	Density kg/m³	FST N◦ -	Density kg/m³	FST N◦ -	Density kg/m³	FST N◦ -	Density kg/m³
1	1015	7	1274	13	2637	19	5460
2	1031	8	1439	14	2987	20	6166
3	1063	9	1624	15	3361	21	6958
4	1095	10	1834	16	3795	22	7854
5	1129	11	2070	17	4284	23	8867
6	1199	12	2337	18	4836	24	10009

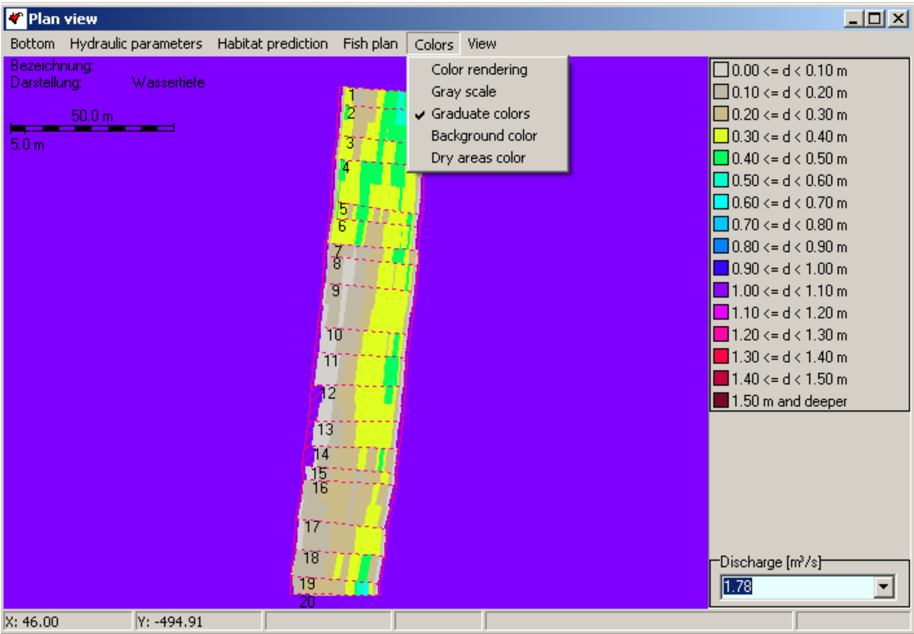
All equations for the calculation of shear velocity, flow velocities at a hemisphere top and center of mass and FST-hemisphere density as well as values for coefficients can be found in (KOPECKI, 2008).

4.4.2.2 Data Formats for FST-hemisphere Based Habitat Modeling

The data formats for preference functions, fuzzy sets and rules for FST-hemisphere based habitat calculations are principally the same of those standard CASiMiR-Fish files. These files have just to be extended to include the FST-hemisphere specific data (see 5.2.3.1, 5.2.3.2, 5.2.3.3). This can be done using a common text editor. After loading such files into the program, the algorithm of suitability index calculation will automatically switch to an FST-hemisphere based one.

4.4.3 Visualization Options

In the plan view the user can choose to change a variety of color settings such as the background color, the color of the dry areas and cross sections (the same color as the one for the dry areas).



Default settings use a blended spectrum of 16 colors for the visualization of all results, but can be fixed to their calculated values using the **graduate colors** option for a more striking presentation. **Gray scale** converts the visualization to grayscale.

A few other visualization settings are available in the menu **View**. Most important here is the possibility to turn some of the view elements on and off, such as **Grid**, the model border **Bank line** and the legend info elements (**Text box**, **Scale**). To modify font properties, select **Font**.

4.4.4 Copying and Saving Graphics in CASiMiR-Fish

In the **View** menu of a plan view window it is also possible to save the whole plan as well as its important elements (Legend, Text box, Scale Bar) in a graphic files as either .jpeg or .bmp format. Another alternative is to make a clipboard copy and paste the image into an external application (for example MS Word). It is also possible to create a series of plan view images automatically:

☞ *In the menu* **View** *select the entry* **Create image series** *and define the required parameters for the automatic image generation.*

4.5 Inspection of Datasets in CASiMiR-Fish

There are some possibilities to inspect data read into CASiMiR-Fish. This data can be also exported for use in other programs. For example, in order to export the surveying data:

☞ *From the main menu bar, select* **River channel → Channel points***.*

Here the absolute coordinates of each point are transformed into cross-section oriented co-ordinates and displayed in a tabular form. Such a data transformation is especially practical for use in 1-D hydraulic programs (for example HEC-RAS), saving much time and effort. Note that the cross section 1 is the furthest upstream section, and point 1 is the first point on the right bank when facing downstream.

For inspecting and modifying the fuzzy rules (though they cannot be saved from here):

☞ *From the main menu bar, go to* **Target species → grayling adult → Fuzzy rules***.*

To summarize and check where the data was loaded from, or exactly what is included in your current model, CASiMiR-Fish also provides a function:

☞ *From the main menu bar, go to* **Options → List open files***.*

In order to export the geometry points together with parameter values and calculated habitat suitability:

☞ *From the main menu bar select* **FILE → Save file →Geometry and habitat suitability as text**. *You will be prompted for a file name to save to. The data in the file is tab delimited (without subdivision on profiles).*

5 Creating Your Own Project

5.1 Project Requirements

In order to start using CASiMiR-Fish for your own projects, it is important to check that the investigation reach(es) fulfill the following requirements:

- the reach should be suitable to be modeled with a 1-D hydraulic model accurately;
- the reach must be considered representative for the river section as a whole both in terms of its hydraulic and morphologic properties;

and for minimum flow studies:

- the reach must include the critical region(s) where the longitudinal connectivity should be assessed for the lowest flow conditions

Due to the fact that it is often difficult and time-consuming to find a single representative investigation reach which contains all the project requirements, it is recommended that several shorter investigation reaches are chosen.

5.2 Input Data and File Formats

Before starting CASiMiR-Fish, it is important that the field data and hydraulic model results are brought into the proper formats. All input and output data of CASiMiR-Fish are in an ASCII format and can be read with any conventional text editing software.

5.2.1 River Geometry and Structure Data

The representation of the river is based on ***cross sections*** that are numbered in the ***down-stream*** direction.

Survey data is incorporated as point locations making up the individual cross sections, from the ***right bank*** to the ***left bank,*** in the downstream direction.

CASiMiR-Fish incorporates two file formats, ***.SRgrd** und ***.SRstr**. Whereas the grid-based file format .SRgrd requires absolute global coordinates (x, y, z) for all profile points, the .SRstr format uses a local coordinate system for each individual cross section, where profile data points (y_{lokal}, z) can be input directly from field measurements made with a dumpy level and a measuring tape.

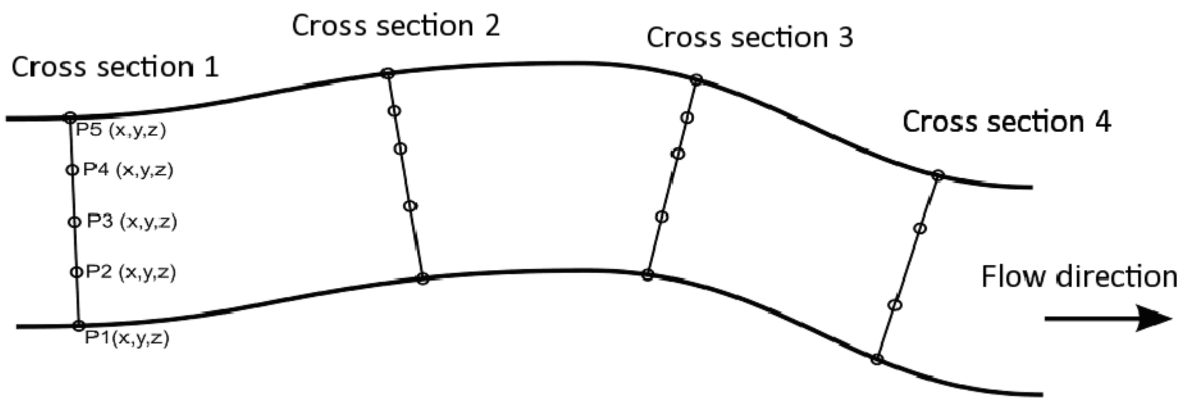
The following conventions should be observed when using either file format:

- In both file formats, cross sections are separated using the number sign (#).
- Column data in the files must be tab-delimited.
- Not available / not surveyed parameter values must be filled with the value zero (0).
- There should be no empty spaces after the last row in a data set.

CASiMiR automatically interpolates additional profiles between the measured cross sections according to the selected resolution of the model (see 4.2.1).

5.2.1.1 File Format 1: *.SRgrd

The *.SRgrd file type is based on an xyz coordinate system and consists of a header and cross sectional data. Each new cross section begins with its assigned profile number (1.21, 1.23 etc.), usually according to river stationing, but can also be user-defined.



Header data

Each row of a header *must* begin with the number sign (#), which is interpreted by the CASiMiR software modules as a comment, and is thus not used in the calculations. The first line however, is used to define the river reach name. An unlimited number of additional user-defined comment lines can follow.

Cross section data

The first line of each cross section data file for the *.SRgrd file format has to contain the profile number.

Each following line contains the points' coordinates (Columns 1-3) and structure parameter data (Columns 4-14) for each individual cross section.

The first three columns are used for the coordinates;

1.Column: x-coordinate	x
2.Column: y-coordinate	y
3.Column: z-coordinate	z

The following columns contain the numerical codes for the structural characteristics

4.Column: Dominant substrate	sub
5.Column: Smallest substrate size	sub<
6.Column: Largest substrate size	sub>
7.Column: Interstitial pore space	Lueck
8.Column: Cover type	covtype
9.Column: Cover size	covsize
10.Column: Cover percentage	covport
11.Column: Pool type	pooltype
12.Column: Boulder size	bldsize
13.Column: Number of boulders	bldnumb
14.Column: Shading	shad

Note:
Should the positions of measured cross section points not lie on one line in the plan, the program will automatically adjust the points projecting them onto the cross section line.

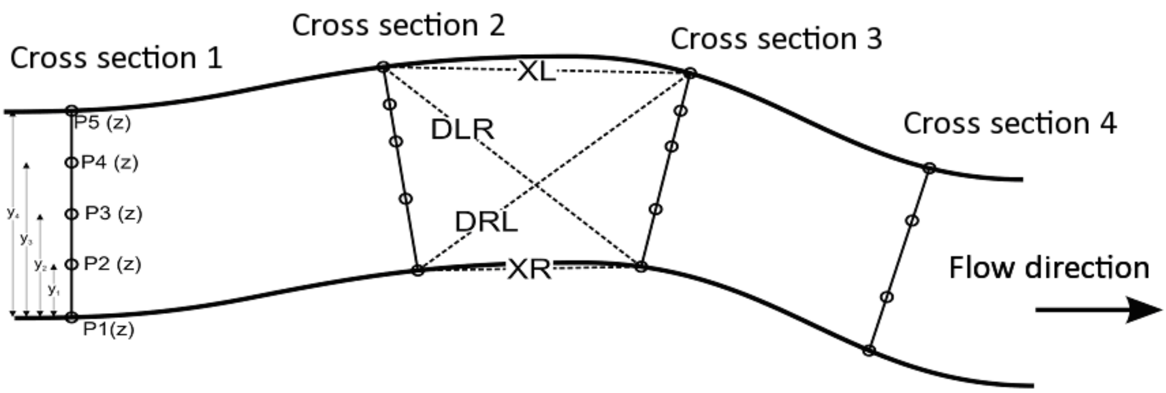
The following illustration provides an example of the *.SRgrd file format:

```
[Neckar]
# Rappenberghalde
# Comments in all following rows can be inserted when necessary...
#  x      y       z      sub  sub<  sub>  Lueck  covtype  covsize  covport  pooltype  bldsize  bldnumb  shad
#
 1.00
 6.40  -502.95  991.58   7    0     0     0      10       0        0        0         0        0        0
 6.83  -502.90  991.32   6    0     0     2      2        0        0        0         0        0        0
 7.58  -503.03  991.11   6    0     0     2      10       0        0        0         0        0        0
 8.37  -503.12  990.80   6    0     0     1      0        0        0        0         0        0        0
 9.82  -503.10  990.81   5    0     0     1      1        0        0        0         0        0        0
11.06  -503.08  990.91   5    0     0     1      1        0        0        0         0        0        0
12.14  -503.05  991.00   5    0     0     1      0        0        0        0         0        0        0
13.72  -503.13  990.99   5    0     0     1      0        0        0        0         0        0        0
15.16  -503.25  990.92   6    0     0     1      0        0        0        0         0        0        0
16.24  -503.22  990.88   6    0     0     0      1        0        0        0         0        0        0
17.57  -503.36  990.87   6    0     0     0      0        0        0        0         0        0        0
19.24  -503.62  990.78   6    0     0     0      0        0        0        0         0        0        0
20.95  -503.76  990.72   6    0     0     0      0        0        0        0         0        0        0
22.21  -503.91  990.73   6    0     0     0      0        0        0        0         0        0        0
23.37  -504.06  990.69   6    0     0     0      1        0        0        0         0        0        0
25.61  -504.37  990.62   6    0     0     0      1        0        0        0         0        0        0
26.94  -504.45  990.67   5    0     0     0      1        0        0        0         0        0        0
28.34  -504.58  990.66   6    0     0     1      1        0        0        0         0        0        0
29.12  -504.74  990.60   6    0     0     1      1        0        0        0         0        0        0
29.81  -504.62  990.70   6    0     0     0      1        0        0        0         0        0        0
30.91  -504.73  990.82   6    0     0     0      0        0        0        0         0        0        0
32.03  -504.76  990.78   7    0     0     0      0        0        0        0         0        0        0
 33.13 -504.83  991.21   7    0     0     0      10       0        0        0         0        0        0
 34.02 -504.93  991.34   5    0     0     0      10       0        0        0         0        0        0
 34.58 -505.09  991.44   0    0     0     0      10       0        0        0         0        0        0
#
  2.00
 6.17  -508.31  991.51   6    0     0     1      6        0        0        0         0        0        0
  ...
```

5.2.1.2 File Format 2: *.SRstr

The *.SRstr file format is based on y-z coordinate pairs, thus using locally referenced point stationing y_n (within cross section beginning at the **right** bank) and elevation z. In order to get a river geometry in plan, the distances between cross sections along the left and right bank and the diagonals between cross sections have to be measured. In the scheme below the following notations are used:

- XR: Distance between the right bank of the current profile to the right bank of the previous profile [m]
- XL: Distance between the left bank of the current profile to the left bank of the previous profile [m]
- DLR: Distance between the right bank of the current profile to the left bank of the previous profile [m]
- DRL: Distance between the left bank of the current profile to the right bank of the previous profile [m]



Header data

Each row of a file header *must* begin with the number sign (#), which is interpreted by the CASiMiR software modules as a comment, and thus is not used in the calculations. The first line however, is used to define the river section name. An unlimited number of additional user-defined comments can follow.

Cross section data

The **first line** of an each cross section part of *.SRstr file contains the following:

1.Column: Cross section number (actual river stationing or user-defined number)
2.Column: Distance XR
3.Column: Distance XL
4.Column: Distance DLR or 0
5.Column: Distance DRL or 0

<u>Note:</u>
Actually, only one diagonal is required for a geometry definition, the other diagonal must be set to 0. For the first profile, all distances must be zero, since there are no previous profiles.

All following lines contain the **survey data** for each cross section point.

The first two columns of the survey data contain the coordinates y and z:

1.Column: y-coordinate	y
2.Column: z-coordinate	z

The following columns contain information related to the structural properties:

3.Column: Dominant substrate	sub
4.Column: Smallest substrate size	sub<
5.Column: Largest substrate size	sub>
6.Column: Interstitial pore space	Lueck
7.Column: Cover type	covtype
8.Column: Cover size	covsize
9.Column: Cover percentage	covport
10.Column: Pool type	pooltype
11.Column: Boulder size	bldsize
12.Column: Number of boulders	bldnumb
13.Column: Shading	shad

The following illustration provides an example of the *.SRstr file format:

```
[Piano VS oben, Brenno, Schweiz]
# Comments in all following rows can be inserted when necessary...
#  y        z        sub    sub<    sub>    Lueck  covtype  covsize  covport  pooltype  bldsize  bldnumb  shad
#
  1.00      0        0      0       0
  0.00   1600.05     1      0       0       0       0        0        0        0         0        0        0
  1.00   1599.64     1      0       0       0       0        0        0        0         0        0        0
  2.00   1599.26     1      0       0       0       0        0        0        0         0        0        0
  3.20   1598.41     5      0       0       1       2        0       10        0         0        0        0
  4.40   1598.26     5      0       0       1       2        0       10        0         0        0        0
  5.10   1598.07     5      0       0       1       2        0       10        0         0        0        0
  6.10   1598.36     6      0       0       1       2        0       10        0         0        0        0
  7.30   1598.34     6      0       0       1       2        0       10        0         0        0        0
  8.30   1598.39     5      0       0       1       0        0        0        0         0        0        0
  9.40   1598.31     8      0       0       0       0        0        0        0         0        0        0
 10.60   1598.72     8      0       0       0       0        0        0        0         0        0        0
 10.80   1598.43     8      0       0       0       0        0        0        0         0        0        0
 11.30   1598.72     8      0       0       1       2        0       20        0         0        0        0
 12.10   1598.32     7      0       0       1       1        0       30        0         0        0        0
 13.50   1598.98     8      0       0       0       0        0        0        0         0        0        0
 14.90   1598.92     1      0       0       0       5        0       40        0         0        0        0
 16.10   1599.56     1      0       0       0       0        0        0        0         0        0        0
 17.40   1600.02     1      0       0       0       0        0        0        0         0        0        0
 18.80   1600.42     0      0       0       0       0        0        0        0         0        0        0
#
  2.00      1.7     1.32   18.95    0
  0.00   1599.96     1      0       0       0       0        0        0        0         0        0        0
  1.00   1599.78     1      0       0       0       5        0       20        0         0        0        0
  2.40   1598.25     5      0       0       1       0        0        0        0         0        0        0
   .        .        .      .       .       .       .        .        .        .         .        .        .
   .        .        .      .       .       .       .        .        .        .         .        .        .
   .        .        .      .       .       .       .        .        .        .         .        .        .
```

5.2.1.3 Structural Parameters and Indices Used in CASiMiR-Fish

In addition to the representation of river bathymetry, the SRgrd and SRstr files include the structural parameters needed for the calculation of habitat suitability. Every structural parameter should be assigned a numerical value according to the predefined system of indices (for example for substrate: 1= silt, 3 = fine gravel, etc.)

The number of structural parameters taken into account in every particular case study depends on the naturally occurring conditions of the investigation reach as well as the indicator species. It is worth to note, that the number of fuzzy rules required increases exponentially with the number of structural parameters used!

The following subsections describe in greater detail the structural parameters used in CASiMiR-Fish, along with their respective indices.

Substrate type

Substrate classification in CASiMiR-Fish is oriented towards the scheme developed by OTTO & REH (1999). In practice, it is rarely found that one single homogeneous substrate type exists. As bottom substrate composition has a direct correlation to a quality of interstitial pore space, a set of parameters is required for accurate mapping of river bed conditions. CASiMiR-Fish file formats allow not only for documentation of a dominant substrate size but also for largest and smallest substrate sizes observed.

Substrate Types		Index
	Organic material, detritus	0
	Silt, clay, loam	1
	Sand < 2 mm	2
	Fine gravel 2-6 mm	3
	Medium gravel 6-20 mm	4
	Large gravel 2-6 cm	5
	Small stones 6-12 cm	6
	Large stones 12-20 cm	7
	Boulders > 20 cm	8
	Rock	9

Interstitial pore space

Along with the size of the substrate material, the degree of embeddedness of an interstitial pore space plays an important role for many fish species and small aquatic organisms.

Interstitial pore space		Index
	Completely embedded	0
	Highly embedded	1
	Slightly embedded	2
	Not embedded	3

Cover types

In contrast to the substrate conditions, which are easy to categorize into the classes according to the mean grain diameter and therefore transfer into the fuzzy sets, the cover can only be described in qualitative verbal terms. In order to limit the huge range of possibilities, the number of cover types in CASiMiR-Fish has been reduced to allow for as simple and clear determination of cover conditions as possible. Thus, unlike the 17 different cover classes as described by PETER (1992), CASiMiR-Fish allows for a total of 11 classes which are meant to encompass the full range of possible cover types while allowing for an as accurate as possible determination of habitat conditions.

Cover Types		Index
	No cover	0
	Aquatic plants	1
	Stones / detritus	2
	Roots	3
	Deadwood	4
	Wet branches	5
	Dry branches	6
	Floating macrophytes	7
	Turbulence	8
	Undercut banks	9
	Overhanging grass	10

Pool types

Investigations performed on the river Körsch (see the example files) show that the indicator species **stone loach** has a strong preference for habitat conditions at the edges of pools. Other fish species also show similar preferences for regions of high structural heterogeneity appearing in connection with different kinds of pools. For this reason, CASiMiR-Fish allows for the differentiation of pool types. The main criterion used in a definition of a pool typology is its orientation to the main flow direction and the major flow conditions (fast flowing, slow flowing etc.). This is somewhat in contrast to the classification with 10 pool types defined by BISSON et al. (1981) which also includes concomitant parameters such as substrate type and dead wood.

Pool Types		Index
(white)	No pool	0
(blue)	Pool oriented in the main flow direction, fast flowing (> v_m)	1
(red)	Pool oriented in the main flow direction, slow flowing (< v_m)	2
(green)	Transverse pool, fast flowing (> v_m)	3
(yellow)	Transverse pool, slow flowing (< v_m)	4
(black)	Plunge pool	5

Degree of Shading

Although this parameter undergoes daily and seasonal changes, an assessment of “how shady“ given area is can still be reasonable. As a rule of thumb, the cardinal direction (north facing, southwest facing, etc.) can be used as a good first indication of the shading degree. Furthermore, there is *no distinction* made between the intensity and duration of shading conditions. This means that a river section which is consistently half-shaded can be assigned the index value 1, just the same as for a section which is half the time fully shaded.

Shading		Index
(white)	No shade	0
(light beige)	Shade partly/temporarily	1
(brown)	Shade complete/permanent	2

5.2.2 Water Surface Elevation Data

The combination of hydraulic model results with the structural parameters is a prerequisite for habitat modeling. This version of the CASiMiR-Fish software has been specially designed for use with 1-D hydraulic model data. For highly structured reaches with uneven water surface profiles, the user is recommended to use the CASiMiR-Fish 2D model, especially when accounting for low flow conditions when the morphology has a strong impact on hydraulic parameters. It is worthy to note that the quality of the input hydraulic model is only as good as it’s verification, and it is highly recommended that the model has been calibrated using measured water surface elevations for the full range of flow rates to be investigated.

5.2.2.1 File format *.SRwsp

Header Data

Each row of the header *must* begin with the number sign (#), which is interpreted by the CASiMiR software modules as comment, and is thus not used in the calculations. In the first line the name of the investigation reach should be specified. An unlimited number of additional user-defined comment lines can follow.

Subsequent to the comment lines the header includes a single line containing all of the flow rates (in increasing order of magnitude) for which the water surface elevation data is specified further below. It is important to ensure that this line is not a comment line, and to leave out the # when entering these values.

Water Surface Profile Data (cross section ordered)

The first line of each water surface elevation data part must include the cross section number. Each number must correspond exactly to the numbers used in the SRgrd or SRstr data files.

In the second line of the water surface part the user must input the water surface elevation for each of the above defined flow rates.

All data must be tab delimited.

After each cross section part, the user must include a line with a number sign (#) to separate data between cross sections.

```
#   Flow rate Neckar
#
#
    500         700         1000        1500
#
#Water surface elevation
    1.00
 991.000     991.020     991.070     991.120
#
    2.00
 990.990     991.020     991.070     991.110
#
    3.00
 990.980     991.020     991.060     991.100
#
    4.00
  990.98      991.01      991.05      991.1
```

Increasing flow rate →

Cross section number ↓

5.2.3 Habitat Requirements Data

5.2.3.1 Preference Functions / file format: *.SRprf

Header Data

Each row of the header *must* begin with the number sign (#), which is interpreted by the CASiMiR software modules as a comment, and is thus not used in the calculations. The first line is used for the name of the fish species and a life stage. An unlimited number of additional user-defined comment lines can follow.

Preference Data (parameter ordered)

Preference data is grouped in blocks according to the parameter type, where the beginning and the end of each block must be designated using the number sign (#). Followed by the number sign (#), a parameter name must be entered (see the example data set below). Preference functions in CASiMiR-Fish are given by two lines, where the first line contains the value of a parameter (flow velocity, water depth, substrate, etc.). The second line contains habitat suitability values (defined on the range from 0 to 1) corresponding to the parameter values in the first line.

First line: parameter values (flow velocity in m/s, water depth in m, substrate index value, etc.) from least to greatest

Second line: corresponding value of the habitat suitability index between 0 and 1

All values must be tab delimited.

```
#Adult Greyling
#
#Suitability Flow Velocity [m/s]
   0.00    0.12    0.65    0.82    100.00
   0.0     1.0     1.0     0.0     0.0
#
#Suitability Water Depth [m]
   0.00    0.30    0.51    2.99    3.00    100.00
   0.0     0.0     1.0     1.0     0.0     0.0
#
#Suitability Substrate Using the 10 Index Values
   0    1    2    3    4    5    6    7    8    9
   0    0    0.5  1    1    1    0    0    0    0
#
```

If FST-hemisphere based calculations are required the file should be extended on following block (as example):

```
#
#Suitability FST [-]
   0     1     2     3     4     5     6     7     8     9
   0.0   0.1   0.3   1.0   1.0   1.0   0.8   0.4   0.1   0.1
#
```

Note: If the FST-hemispheres is the only parameter to be accounted for, the suitabilities corresponding to all other parameters should be set to 1 in the whole range of values. E.g. if species preferences related to the water depth are not relevant for the study, the respective data block must be defined as follows:

```
#
#Suitability Water Depth [m]
   0     100
   1.0   1.0
#
```

5.2.3.2 Fuzzy Rules / File format: *.Srfzy

Header Data

Each row of the header *must* begin with the number sign (#), which is interpreted by the CASiMiR software modules as a comment, and thus is not used in the calculations. The first line is used for the name of the fish species and the life stage. An unlimited number of additional user-defined comments can follow.

Preference Data

The first line of this block (in the example file below this part is underlined contains the abbreviations of the hydraulic and structural parameters to be included in the fuzzy based habitat simulation. CASiMiR-Fish uses the following abbreviations:

vel = velocity
dep = water depth
cov = cover
sub = dominant substrate
pol = pool type
FST = FST hemisphere number
SI = habitat suitability index value

All abbreviations must be tab delimited.

The cover reassignment block follows (the lines marked in *italic*). The aim of such reassignment is to reduce the number of fuzzy rules as some cover types have (sometimes) the same functionality for a target species and can be grouped therefore together in one class. In the example file below, the user has defined a total of 5 cover classes to be used in a simulation, where the cover type 0 corresponds to the user defined cover class A, the cover types 3, 5, 4, and 2 correspond to the user defined cover class D and so on. The effect of cover reassignment is seen on the number of fuzzy rules required. For this example, at any location where cover types 3, 5, 4, 2 are found by the program, the fuzzy rules which include the user defined cover class D will involve in habitat suitability calculations.

The following lines (marked in grey) contain the fuzzy rules. In the example below, only a sample of the complete list of rules is shown. In total, there are 134 rules needed! Each one of the rules must be defined using a capital letter (tab delimited) representing the following linguistic variables:

VL = “very low”
L = „low“
M = „medium“
H = „high“
V = „very high“

The last line of the file must contain the number sign (#).

[Grayling Juvenile Fuzzy]

vel	dep	sub	cov	SI
A	*0*			
B	*1*			
C	*7*			
D	*3*	*5*	*4*	*2*
E	*6*	*10*	*9*	*8*
#				
H	**H**	**H**	**A**	**L**
H	M	H	A	L
H	L	H	A	L
H	H	H	B	L
H	M	H	B	L
H	L	H	B	L
H	H	H	C	L
H	M	H	C	L
H	L	H	C	L
H	H	H	D	L
H	M	H	D	L
H	L	H	D	L
H	H	H	E	L
H	M	H	E	L
H	L	H	E	L
H	H	M	A	L
H	M	M	A	L

For example, the first fuzzy rule (marked in **bold**) defines for the juvenile grayling the statement:

WHEN	Flow Velocity	**H** (High)
AND	Water Depth	**H** (High)
AND	Dominant Substrate	**H** (High)
AND	Cover Type	**A** (no cover)
THEN	**Habitat Suitability**	**L (Low)**

If FST-hemisphere based calculations are required, the file rules file has to be extended by a FST-hemisphere number column. This column should be placed before the column of the suitability index.

5.2.3.3 Fuzzy-Sets / File Format: *.SRFZS

Header Data

Each row of the header *must* begin with the number sign (#), which is interpreted by the CASiMiR software modules as a comment, and thus is not used in the calculations. The first line is used for the description of fuzzy sets. An unlimited number of additional user-defined comment lines can follow.

Fuzzy Sets Data (parameter ordered)

Fuzzy sets data is grouped in blocks according to the parameter type, where the beginning and the end of each block must be designated using the number sign (#). Every block starts with a line containing the parameter's name (e.g. „vel“ for flow velocity) followed by three lines for each fuzzy set defined (e.g. set L = Low for flow velocity) or one line for a not defined fuzzy set (e.g. set VL = Very Low for flow velocity). This file is generated automatically by defining the sets in the fuzzy set editor and selecting the option “save fuzzy sets in file” (see 4.3.2.2)

```
#	CASiMiR-Fish fuzzy set file
#	Standard
#
vel	5	flow velocity	flow velocity [m/s]	membership [-]
VL	very low	231	105	69	NOT_USED
L	low	233	200	67
0.00	0.40
1.00	0.00
M	medium	150	230	70
0.00	0.40	0.80
0.00	1.00	0.00
H	high	71	228	205
0.40	0.80	100.00
0.00	1.00	1.00
VH	very high	181	177	119	NOT_USED
#
dep	5	water depth	water depth [m]	membership [-]
VL	very low	231	105	69	NOT_USED
L	low	233	200	67
0.00	0.40
1.00	0.00
M	medium	150	230	70
0.00	0.40	0.80
0.00	1.00	0.00
…
```

The first line of the fuzzy set definition contains the name of the set (e.g. „L“), it's meaning (low) and the color code (RGB) for the line used in the diagram (see 4.3.2.2). The second line gives the x-values and the third line the ordinates defining the set.

If a fuzzy set is not used, in the first line after the "name", "meaning" and "RGB color code" the expression „NOT_USED“ is listed.

If FST-hemisphere based calculations are required, the sets file should be extended on the following example block (this can be done in a common text editor). This block should be placed before the suitability index block:

```
#
FST	5	FST	FST-Number [-]	membership [-]
VL	very low	231	105	69	NOT_USED
L	low	233	200	67	NOT_USED
M	medium	150	230	70
0	5	15
1.00	1.00	0.00
H	high	71	228	205
5	15	24
0.00	1.00	1.00
VH	very high	181	177	119	NOT_USED
#
```

5.2.4 Flow Velocity

In order to accurately calibrate and validate the CASiMiR-Fish hydraulic model, it is strongly recommended that flow velocity is measured for a representative number of the surveyed cross sections. This is especially critical for cross sections with highly variable geometry, and where strong lateral flows may be present. Taking field measurements for the discharge rate often requires the use of current meters, which provides velocity values which can be additionally used to validate the results of the hydraulic model. Direct comparison of the modeled to the measured results also allows the user to calibrate the CASiMiR-Fish hydraulic model using the conveyance factor (see 4.3.1).

The depth average velocity measurements should be taken at 40% of the water column depth, measured from the river bed. Practical experience has shown that such measurement data provide a reasonable estimation of actual conditions. It is also worth noting that due to the turbulent fluctuations, measurements should be taken over a period of at least 30 seconds in order to achieve average results. Since the CASiMiR-Fish hydraulic model is 1-D, it is recommended to take the velocity measurements perpendicular to cross sections so that the input closely reflects the computational approach of the program.

6 Assessing Habitat Conditions

An assessment of the overall ecological situation of riverine ecosystems is often complicated by the fact that resident species may have wildly different preferences depending on their life stage. In order to correctly assess the effectiveness of measures or impact of limiting flow rates on the ecosystem, it is often necessary to take a seemingly overwhelming number of factors into account. Mitigation of negative environmental impacts can often be achieved through the creation of a wide variety of morphological structures which are then able to aid in promoting biodiversity within a reach. Here it is also important to note that next to the environmental aspects, it is always necessary to consider the competing concerns of other water users, such as hydropower operators. The CASiMiR-Fish module is the useful instrument in determining the habitat suitability, and can be easily applied in most relevant situations.

<u>River Conditions:</u>

The various display methods allow for a simple visual inspection of the characteristic water depths and velocities for the indicator species within the range of investigated flow rates. Additionally, the program allows for the assessment of longitudinal connectivity within the investigation reach for the considered minimum flow rates.

<u>Spatial Distribution of Habitat Conditions:</u>

Through the use of habitat-morphology relations in conjunction with the individual habitat requirements of a species, it is possible to calculate the spatial distribution of habitat conditions. The habitat suitability index HSI is calculated for each individual cell of a high-resolution river geometry model. CASiMiR-Fish allows for a direct visualization of results in a plan view, and additionally for the linear interpolation of results between major flow rates.

<u>Composite Habitat Condition:</u>

A single, composite value can be calculated representing the average habitat quality characteristic of an entire investigation reach (usually WUA or HHS). Using the relation between a flow rate and a composite habitat quality value, the impact of change in flow rate on a habitat condition as a whole can be assessed (minimum flow regulations). The WUA and HHS diagrams are described in 4.2.6.

<u>Statistical Habitat Distribution:</u>

A key aspect when evaluating the habitat availability and quality is the frequency distribution of suitability classes. For instance, an investigation reach having a moderate composite habitat condition (WUA, etc.) can either have many patches of moderate habitat suitability, or it may have some small patches exhibiting excellent suitability scattered among mostly unsuitable areas. From the ecological perspective, the second case having areas with very high suitability is generally more favorable. This can be taken into consideration via the assessment of the statistical habitat distribution. The statistical distribution can be visualized by a specific diagram (areas of same SI value) described in 4.2.6.

Temporal Habitat Distribution:

Habitat variability is largely a function of the discharge rate and it's accompanying hydraulic parameters, and thus exhibits a high degree of temporal and spatial heterogeneity. By overlaying the graphs of the WUA with a hydrograph, a temporal habitat-flow rate relation can be established. Such graphs can be useful when determining the total number of days the minimum habitat suitability is established.

7 References

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