The performance of the Hydromorphological Index of Diversity (HMID) in a hydropower affected meandering river

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Introduction

More than half of the Swiss electricity is produced by hydropower. Water diversion due to dams imposes downstream **residual flow regimes**. The absence of flood events and regular sediment supply disrupts sediment dynamics, favors the establishment of vegetation and disconnects floodplains, which are habitats of high value, from its main channel (Fig. 1).

Fig. 1: Sarine river in western Switzerland before (left) and after (right) the construction of the Rossens Dam (middle). ***Source:*** ***swisstopo (https://map.geo.admin.ch/)***

Objective

Pointing out the **limits** of the Hydromorpgological Index of Diversity (HMID) at a meandering river with residual flow regime.

Situation Sarine river

Characteristics of the study river (Fig. 2):

- Sarine river, Fribourg, Switzerland
- Protected floodplain
- 13 km long residual flow reach (Rossens - Hauterive)
- Lac de la Gruyère since 1948
- Besides dam, negligible human impact
- Riffle-pool sequences
- River bed ca. 50% bed-rock exposed
- River bed width 15 – 40 m
- Floodplain valley: 100 m incision
- Meandering
- No major tributaries
- Monotonous discharge Q = 2.5 m³/s
- Discharge after Hauterive Q < 75 m³/s
- Study site: Abbaye Hauterive (□)

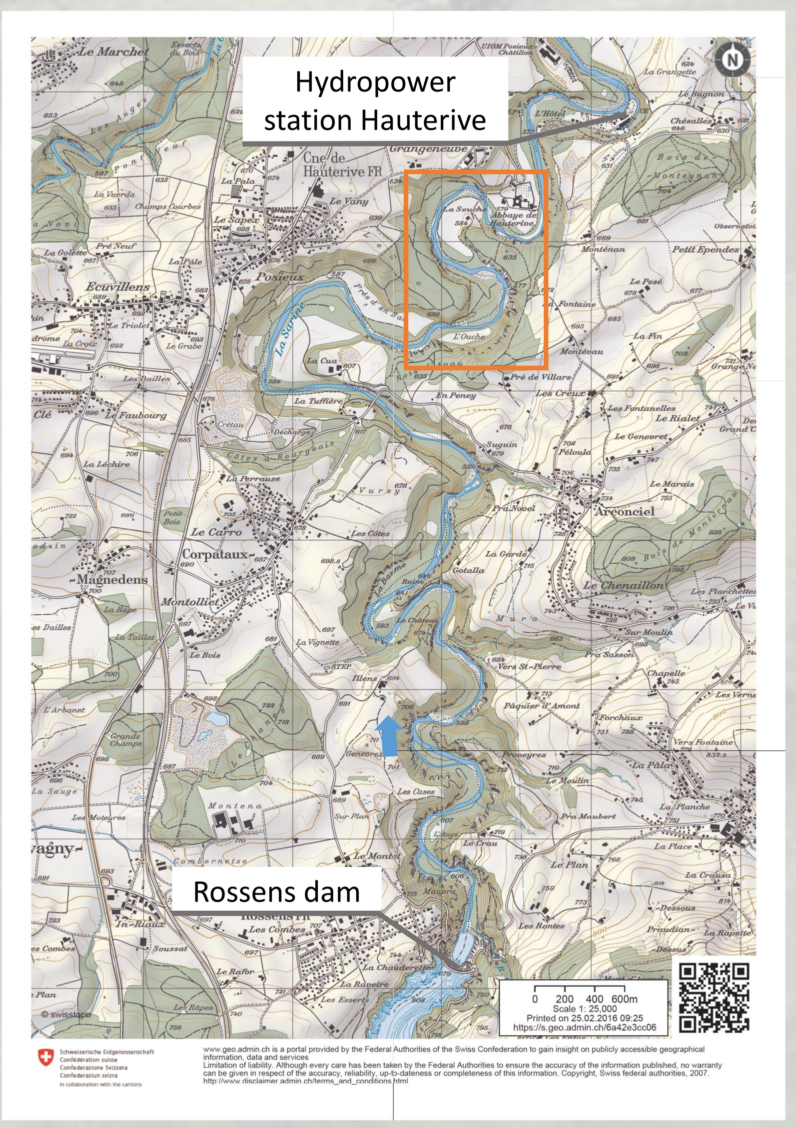

Fig. 2: Study river Sarine between Rossens and Hauterive. ***Source: swisstopo***

The Hydromorphological Index of Diversity

The Hydromorphological Index of Diversity (HMID) was defined by Gostner et al. (2013) for the objective quantification of the **diversity of mesohabitats**. It is based on the assumption that a large variability of *h* and *v* represents a large habitat diversity in a river. It's definition is given in the following equation:

$$HMID = \left(1 + \frac{\sigma_v}{\mu_v}\right)^2 \left(1 + \frac{\sigma_h}{\mu_h}\right)^2$$

σ_h Standard deviation of water depth
μ_h Mean of water depth
σ_v Standard deviation of flow velocity
μ_v Mean of flow velocity

The HMID value results in three different classes:

- HMID < 5: Channelized and morphologically heavily altered; uniform cross-sections and longitudinal slope
- 5 < HMID < 9: Less severely modified but limited variability in hydraulic units. Reaching a natural morphology at the upper level of the interval
- HMID > 9: Morphologically pristine; gravel bed streams fully develop their complete range of hydraulic mesohabitats.

Gostner, W., Alp, M., Schleiss, A. J., & Robinson, C. T. (2013). The hydro-morphological index of diversity: a tool for describing habitat heterogeneity in river engineering projects. Hydrobiologia..

Methodology

For the analysis of the HMID in this river reach, a 2 km long meander in Hauterive was chosen for the analysis (Fig. 2). Using **levelling**, **ADV** (SonTek Flowtracker®) and a floating **ADCP** (SonTek RiverSurveyor®), flow depth and velocity was measured at 15 cross-sections (Fig. 3, middle and right). Every meter (in width) a measure was taken.

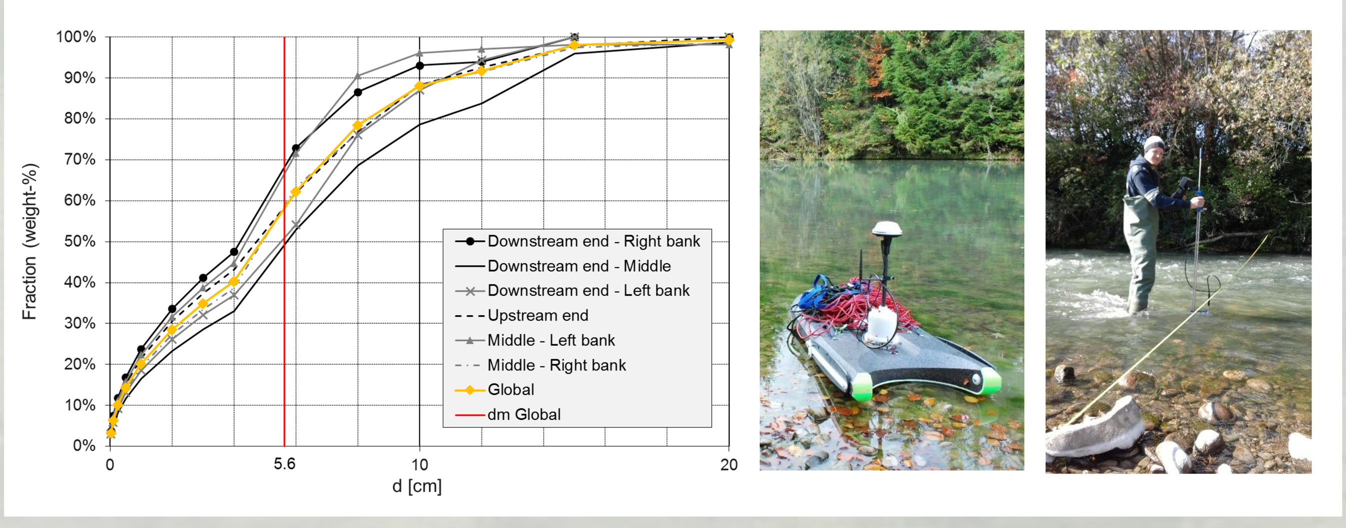

Fig. 3: Grain size distribution from an island (left), floating ADCP (middle), Handheld-ADV (right)

The flow depth in another 12 cross-sections were captured and a **2D flow model** was created in **BASEMENT**. In combination with LiDAR data and interpolation a Triangular Irregular Network (TIN) with minimal node distance of 2 m was created. 21 grain samplings were obtained using BASEGRAIN and **pebble count** in order to determine the granulometry and to calibrate the model. Fig.3 (left) shows the grain size distribution determined on an island.

Results

HMID evaluation

The HMID calculated from the **measured** flow depths and flow velocities (15 profiles) resulted in: **9.37**

This indicates a morphologically pristine site with fully developed spatial dynamics.

The HMID with the **simulated** values for the same discharge as measured (Q = 2.5 m³/s) resulted in: **8.43**

This indicates a natural morphology with a large habitat diversity.

HMID at different discharges

To evaluate the behaviour of the HMID, it was calculated at different discharges, using the 2D flow model (Tab. 1). The HMID decreases with increasing discharge.

Q		[m³/s]	2.5	3.5	10	25	50	100
h	μ_h	[m]	0.524	0.585	0.872	1.265	1.626	2.148
	σ_h		0.397	0.409	0.479	0.614	0.741	1.001
v	μ_v	[m/s]	0.209	0.244	0.381	0.542	0.668	0.821
	σ_v		0.136	0.147	0.186	0.235	0.291	0.347
HMID		[-]	**8.42**	**7.41**	**5.32**	**4.53**	**4.37**	**4.35**

Tab. 1: HMID for different discharges

Discussion

Despite the **limited sediment dynamics** in the floodplain (Fig. 1), the studied site has a natural respectively pristine morphology. Analysis result in a higher HMID for the field measurements than for the simulated HMID. This fact might be explained by the **different data volume** which have been used. The HMID from the field data was calculated with 100 times less values than using the numerical flow simulation (discharge Q = 2.5 m³/s). Both data consisted of similar maximum and minimum values. The data volume influences the mean and standard deviation due to their definition. A sensitivity analysis shows a **large influence of extreme values** on the HMID (Fig. 4).

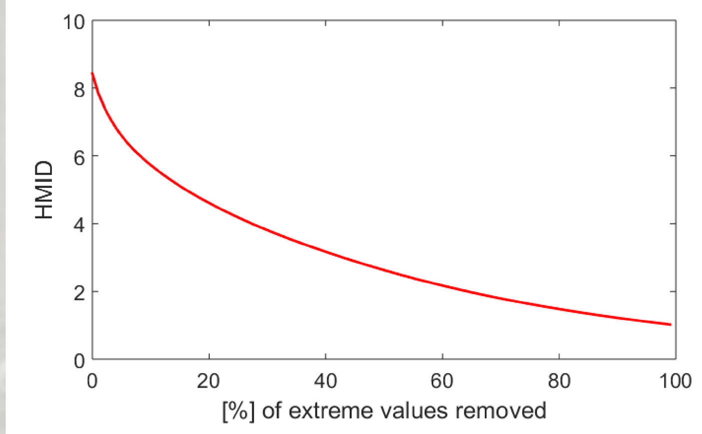

Fig. 4: Sensitivity of extreme values

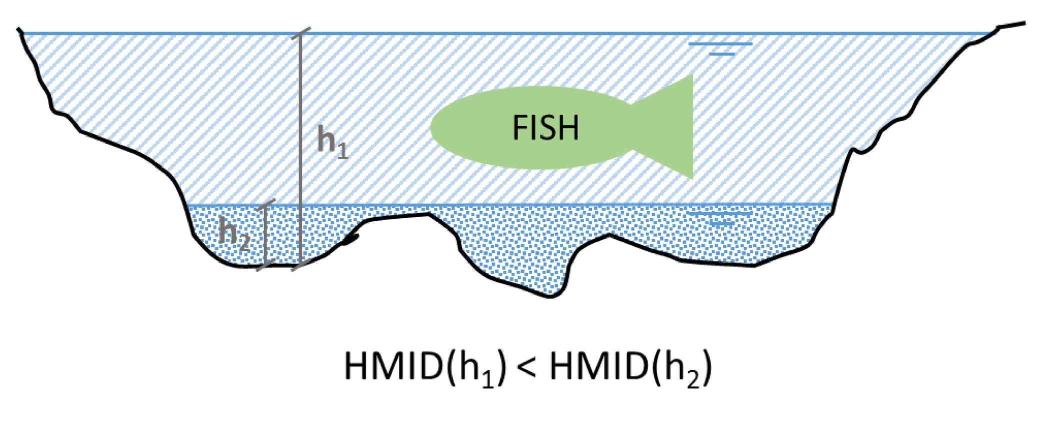

Fig. 5: HMID for low water depths

The HMID increases with decreasing discharge (Tab. 1) leading to a maximal HMID value for a flow depth *h* close to zero. However, a small flow depth causing a higher variability of hydraulic units does not necessarily lead to a more suitable habitat for in–stream species (Fig. 5).

Conclusion

The HMID captures the current condition of the river morphology. Due to the **absence of a temporal component** (e.g. hydrograph), the influence of the hydropower installation is captured in the HMID. **Extreme values** and the **data volume** have a major influence on the HMID. For low water depth, the HMID fulfils his aim to a limited extent. → ***The HMID needs enhancement for the application in residual flow regimes.***