

# Using local hydro-morphology and habitat indices to evaluate e-flows

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Post-doctoral fellow at Politecnico di Torino, Italy



REFORM  
e-flows workshop  
Roma  
9th Sept. 2015

# Using local hydro-morphology and habitat indices to evaluate e-flows



RESeau Research Unit  
(FESR, PD-4619/2013, Valle d'Aosta)



HolRiverMed  
(FP7-PEOPLE-2010-IEF-275577)



CRAINat  
(LIFE08NAT/IT/000352)



Technical Report - 2015 - 086

# Ecological flows in the implementation of the Water Framework Directive

*Guidance Document No. 31*



# Ecological flows in the implementation of the Water Framework Directive

*Compilation of case studies  
referenced in CIS guidance document n°31*

Ec



Région Autonome  
**Vallée d'Aoste**  
Gouvernement régional



Regione Autonoma  
**Valle d'Aosta**  
Giunta regionale

Verbale di deliberazione adottata nell'adunanza in data 15 giugno 2012

In Aosta, il giorno quindici (15) del mese di giugno dell'anno duemiladodici con inizio alle ore otto e cinque minuti, si è riunita, nella consueta sala delle adunanze sita al secondo piano del palazzo della Regione - Piazza Deffeyes n. 1,

#### LA GIUNTA REGIONALE DELLA VALLE D'AOSTA

Partecipano alla trattazione della presente deliberazione :

**Il Presidente della Regione Augusto ROLLANDIN**

e gli Assessori

**Aurelio MARGUERETTAZ - Vice-Presidente**

**Giuseppe ISABELLON**

**Albert LANIECE**

**Ennio PASTORET**

**Laurent VIERIN**

**Marco VIERIN**

**Manuela ZUBLENA**

Si fa menzione che le funzioni di Assessore al Bilancio, Finanze e Patrimonio sono state assunte "ad interim" dal Presidente della Regione.

Svolge le funzioni rogatorie il Dirigente della Segreteria della Giunta regionale, Sig. Massimo BALESTRA

E' adottata la seguente deliberazione:

N° 1252 OGGETTO :

APPROVAZIONE DELLE MODALITÀ DI PROSECUZIONE E CONCLUSIONI DELLA SPERIMENTAZIONE CONDOTTA DALLA SOCIETÀ CVA S.P.A. A S.U., CON SEDE A CHÂTILLON, PER L'ADEGUAMENTO DELLE VENTOTTO PRINCIPALI DERIVAZIONI DEL GRUPPO A QUANTO STABILITO DAL PIANO REGIONALE DI TUTELA DELLE ACQUE IN MERITO ALLE PORTATE DI DEFLUSSO MINIMO VITALE (DMV).

Ec



Verbale di delibe

In Aosta, il gio  
alle ore otto e  
secondo piano de

Partecipano alla

Il Presiden

e gli Assessori

Si fa menzione  
assunte "ad inter

Svolge le funz  
Massimo BALE

E' adottata la seg

N° 1252

APPROVAZIONE  
SPERIMENTAZIO  
CHÂTILLON, PE  
GRUPPO A QU  
MERITO ALLE PC

December



**Agenzia Provinciale  
per la Protezione dell'Ambiente**



**Università di Trento  
Dipartimento di Ingegneria  
Civile Ambientale e Meccanica**

## **LINEE GUIDA**

**per la definizione dei piani di monitoraggio  
relativi alla valutazione degli effetti  
delle derivazioni idriche sullo stato di qualità  
dei corpi idrici superficiali**

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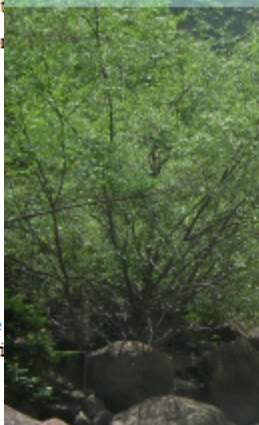
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MERITO ALLE PO

December



## SUM

# Sistema di rilevamento e classificazione delle unità morfologiche dei corsi d'acqua



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# E-flow assessment and monitoring in Italy

Minimum e-flows are required by Law (D.M. 28 Luglio 2004).  
Used methods can vary on a regional base but they mostly include:

- Hydrological regionalization approaches using Q97 as a reference;
- Hydrological indices, mean annual / low flows.

E-flows are then evaluated and monitored through a given methodology where biological and hydromorphological indicators can be used.



# E-flow assessment and monitoring in Italy

We think that hydro-morphological aspects are well suited to design, evaluate and monitor e-flows.

Biological indicators (e.g., WFD) are currently used in Italy to evaluate e-flows but they may be subject to limitations due to:

- The need of simulating a large range of e-flow scenarios
- Absence of target species
- Time lag for population recovery
- Natural population variability
- Influence of fish restocking
- Angling
- Presence of alien species

# Local hydro-morphology and habitat modelling tools

Habitat modelling tools can be used to design and monitor e-flows, as well as to evaluate the impact of both hydrological and morphological alterations on the aquatic and riparian ecosystem.



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# Habitat as a metric to evaluate e-flows

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Quantifying spatio-temporal variation of HABITAT resources for biota could be used as a metric that links

- 1 - hydrology (hydraulic conditions, flow regime);
- 2 - morphology (channel geometry, shelters, reproduction areas);
- 3 - biology (aquatic and riparian communities)

# E-flow monitoring program

## Valle d'Aosta Region

**Table 1.** List of indices used to monitor the Savara stream between 2008 and 2013

<b>Index</b>	<b>Acronym</b>	<b>Reference</b>	<b>Ecological parameter</b>
Level of Pollution from Macro-descriptors	LIM	D.L.152/99	Water physico-chemical quality
Extended Biotic Index	IBE	Ghetti (1997)	Benthic invertebrates
Fluvial Functional Index	IFF	Siligardi et al. (2007)	Hydro-morphological and biological characteristics
LIM to assess ecological status	LIMeco	D.M.260/2010	Water physico-chemical quality
Standardisation of river classifications, Intercalibration Common Metrix Index	STAR_ICMi	Buffagni and Erba (2007)	Benthic invertebrates
Intercalibration Common Metrix Index	ICMi	Mancini and Sollazzo (2009)	Diatoms
Macrophyte Biological Index for Rivers	IBMR	Haury et al. (2006)	Macrophytes
Ecological Status of Fish Communities Index	ISECI	Zerunian et al. (2009)	Fish
Morphological Quality Index	IQM	Rinaldi et al. (2013)	Geomorphology
Aggregate Index of Hydrological Alteration	IIHA	Goltara et al. (2011) Richter et al. (1997)	Hydrology
Index of Habitat Quantity	IHQ	Veza et al. (2014)	Habitat
Index of Habitat Stress Days	IHSD	Veza et al. (2014)	Habitat

# E-flows monitoring program

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2008	0	I (520)	II (8.6)	II (226)	-	-	-	-	-	-	0.59	0.18	0.05
2009	130 l/s	I (560)	II (9.0)	II (226)	-	-	-	-	-	-	0.73	0.55	0.31
2010	130 l/s	I (520)	II (8.8)	II (226)	I (0.95)	I (1+)	I (0.95)	I (0.87)	V (0.2)	-	0.72	0.51	0.24
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2012	325 l/s	I (520)	II (9.0)	II (226)	I (0.98)	II (0.83)	I (0.89)	I (0.89)	V (0.2)	-	0.75	0.75	0.35
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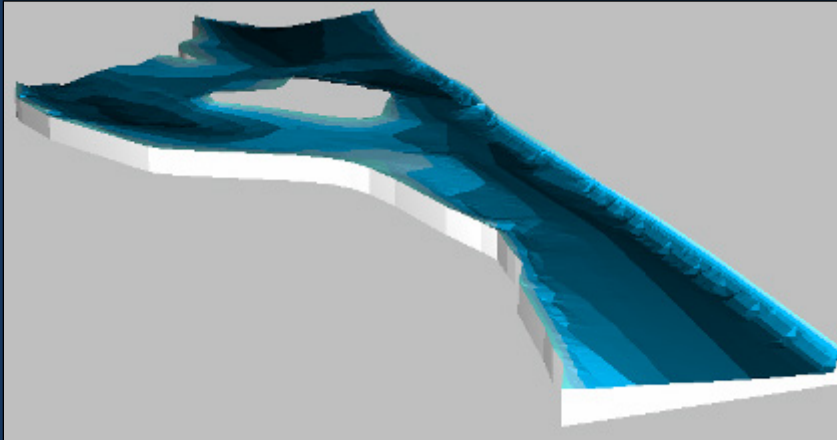
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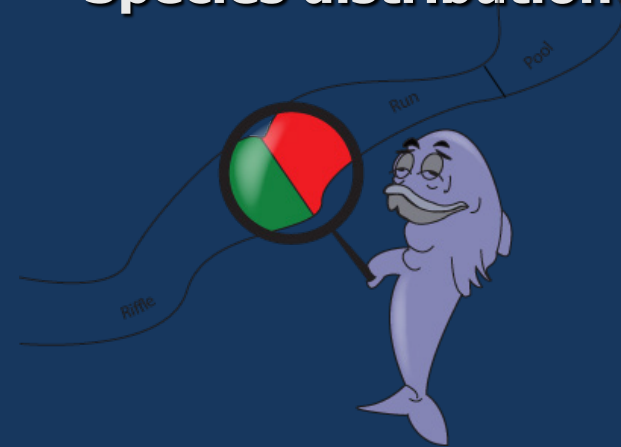
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# Habitat modelling tools

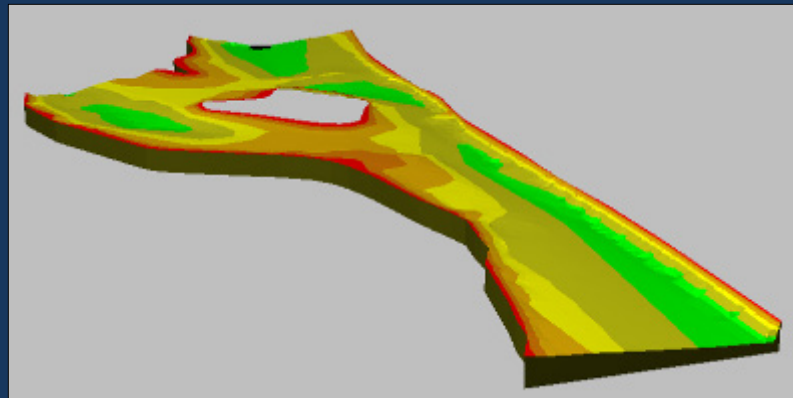
## Channel hydro-morphology



## Species distribution



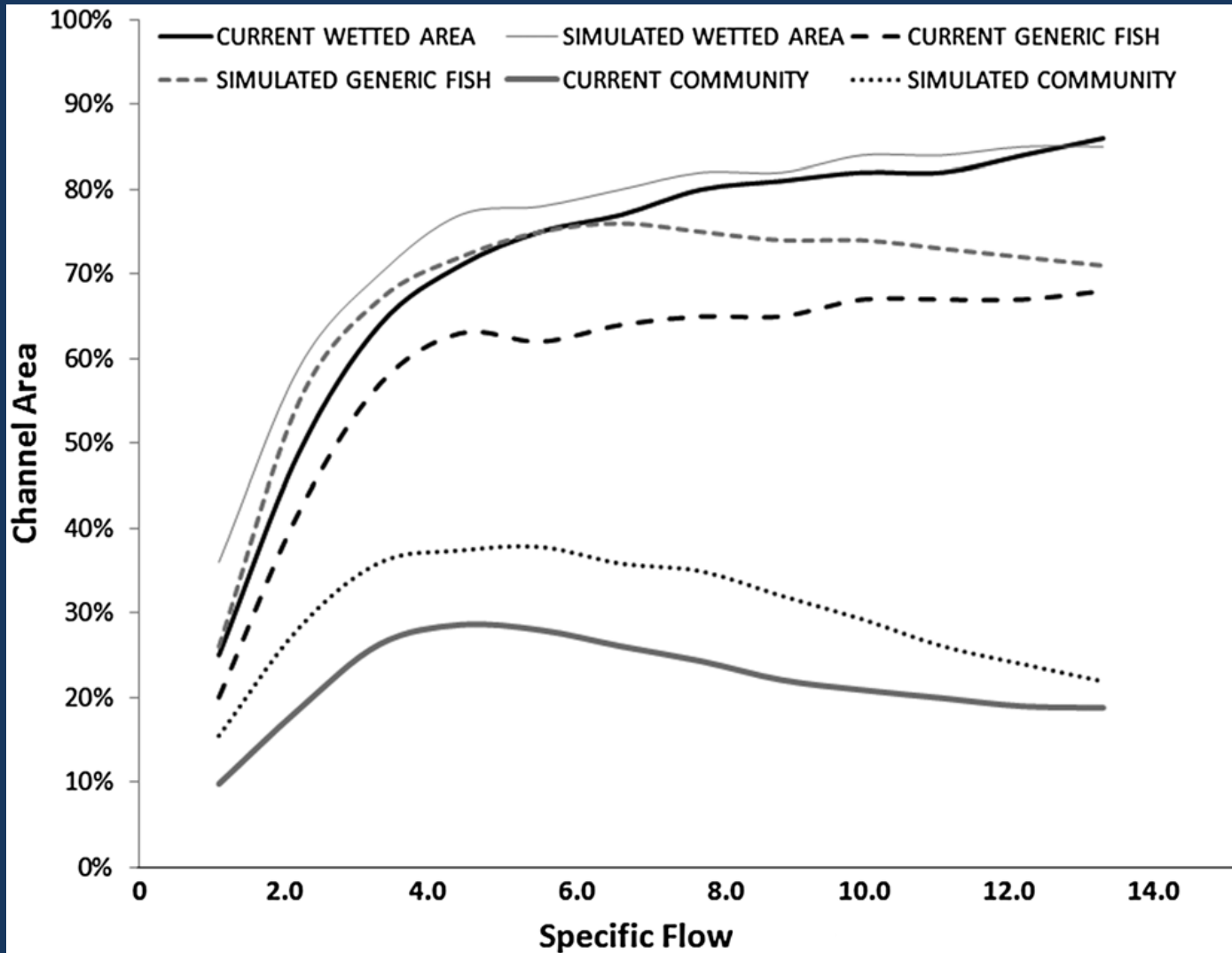
**Quantitative habitat evaluation  
over space and time**



# Meso-scale habitat models

- Include in the analysis a large range of habitat variables (hydraulic variables, cover availability, water temperature, shore characteristics, biotic interactions);
- Analyze environmental conditions around an organism, not only at the point where it is observed;
- Are more flexible to be applied where hydraulic models can not be easily calibrated (e.g., mountainous high-energy systems with exposed cobbles and boulders)
- Mesohabitats correspond in size and location to geomorphic or hydraulic units and they are integrated with the Geomorphic Units survey and classification System (GUS, D6.2 Part 4, REFORM)
- Allow a more appropriate selection of river representative sites and results can be upscaled to river sectors or entire catchments

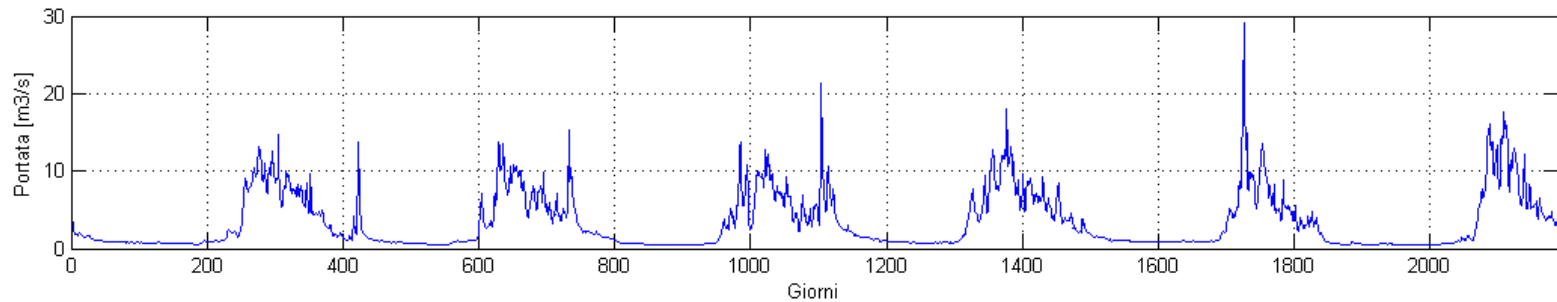
# Habitat-flow rating curve



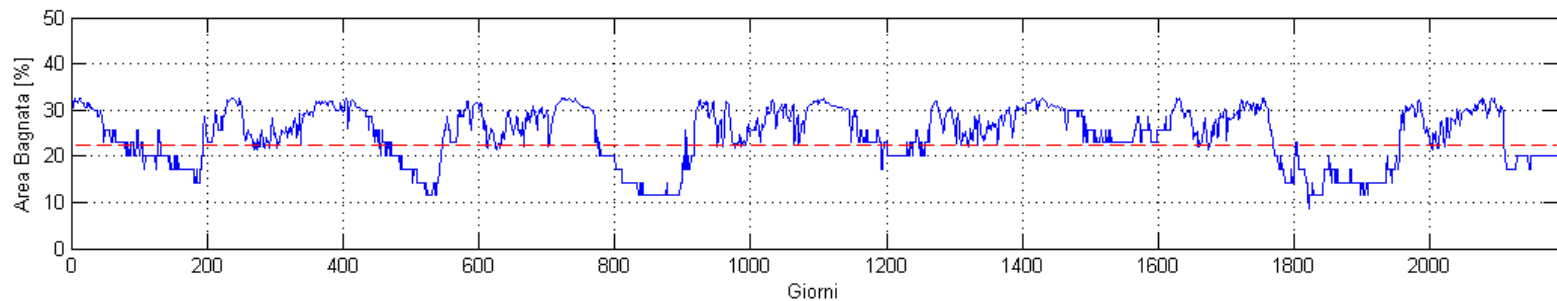


# Habitat time series

## Streamflow time series



## Habitat time series (e.g., brown trout)



# Habitat indices for e-flows evaluation

We proposed two habitat indices:

**ISH – Index of Spatial Habitat availability**

$$ISH = \min \left( \begin{cases} 1 - \frac{|A_{Hd,r} - A_{Hd}|}{A_{Hd,r}}, & \frac{|A_{Hd,r} - A_{Hd}|}{A_{Hd,r}} \leq 1 \\ 0, & \frac{|A_{Hd,r} - A_{Hd}|}{A_{Hd,r}} > 1 \end{cases} \right)_{\text{specie}}$$

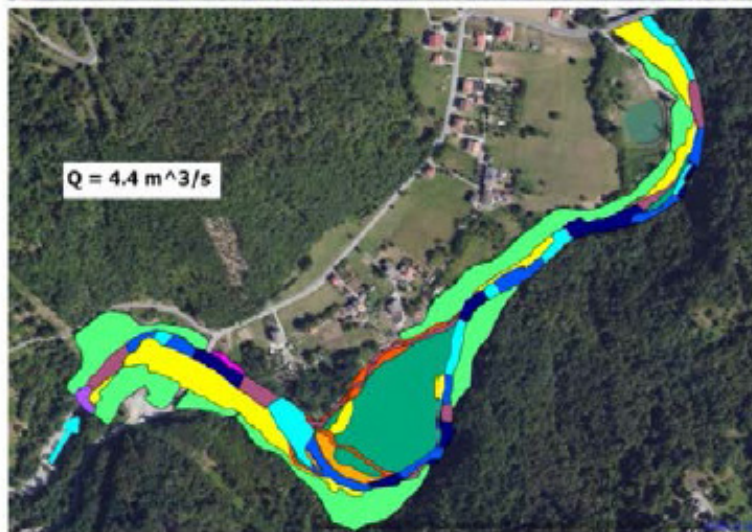
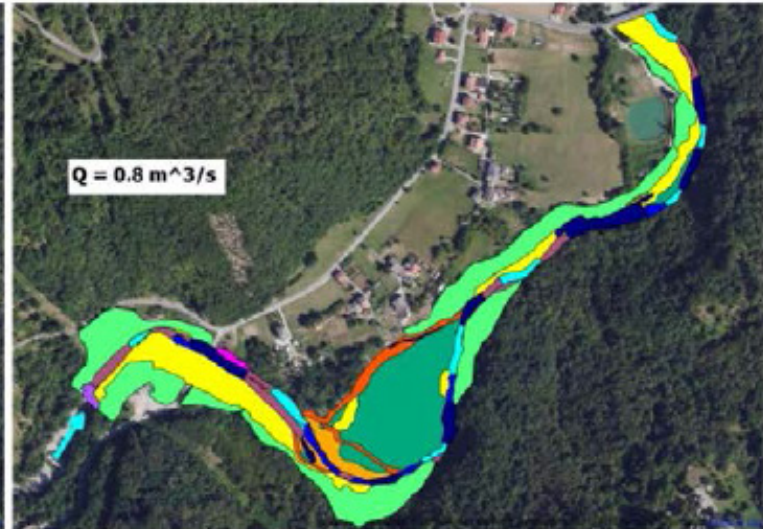
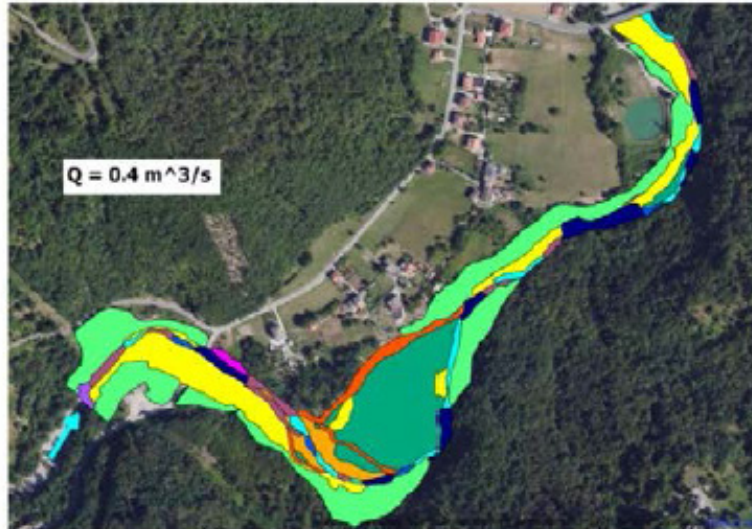
**ITH – Index of Temporal Habitat availability**

$$AGS = \frac{1}{d_{\max,r}} \cdot \sum_{k=1}^{k=d_{\max,r}} \left( \frac{|d_{c,AQ97} - d_{c,r,AQ97}|}{d_{c,r,AQ97}} \right) \quad ITH = \min(e^{-0.38 AGS})_{\text{specie}}$$

**IH – Index of Habitat integrity**

$$IH = 0.5 * (ISH + ITH)$$

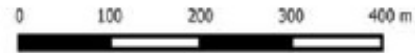
# E.g., Taro River - Piane di Carniglia (PR)



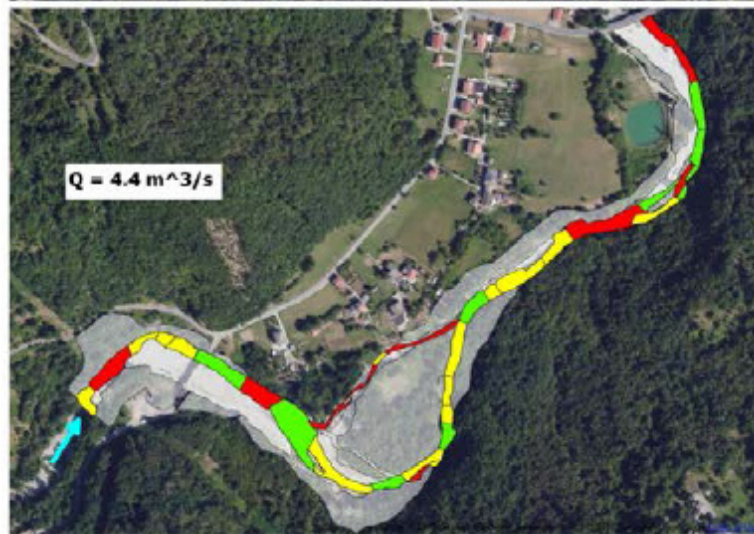
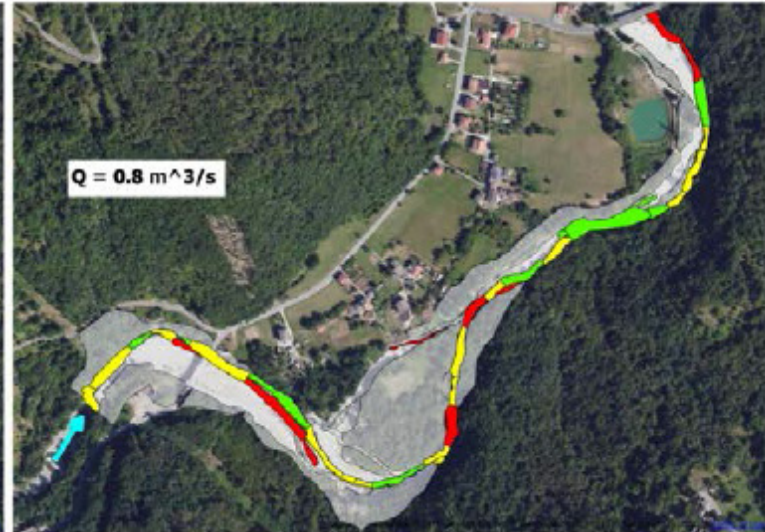
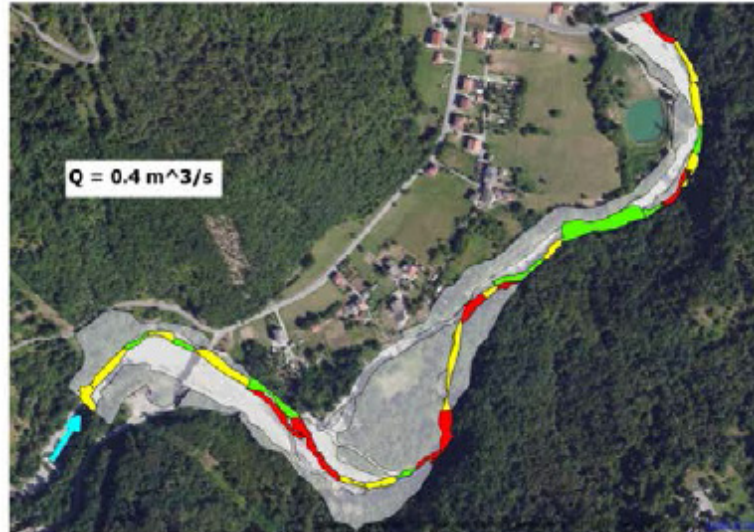
## Legend

F. Taro

- CP - plunge pool
- CP - pool
- CR - rapid
- CF - riffle
- CG - glide
- EC - barra centrale
- EA - barra laterale
- FM - bench
- ED - canale emerso
- VI - isola
- F - zona ripariale

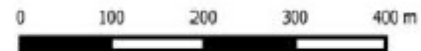


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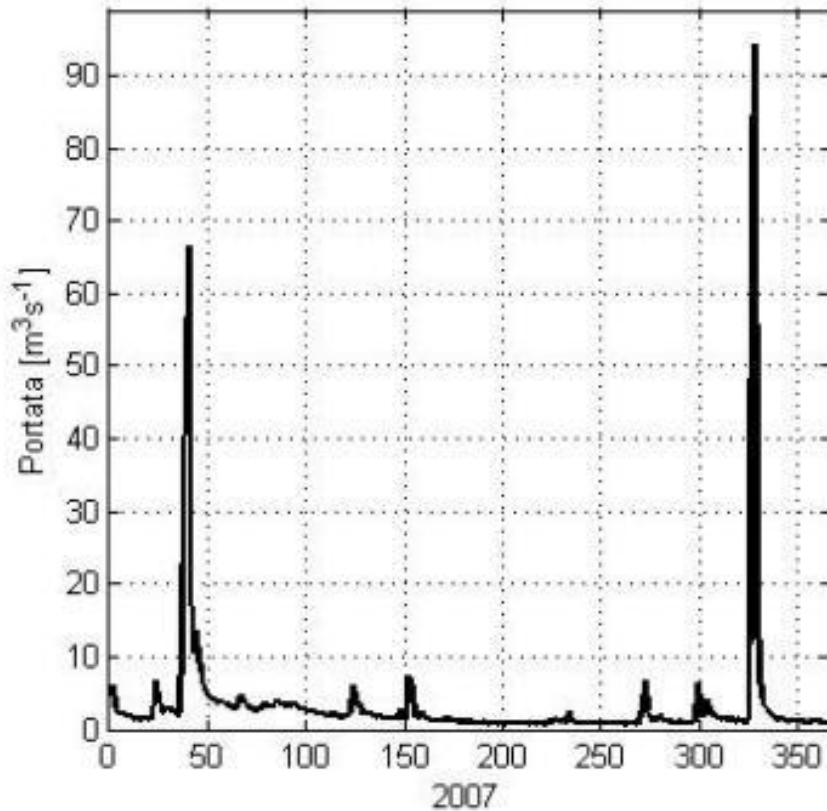
- F. Taro
- Non idoneo
  - Idoneo
  - Ottimale



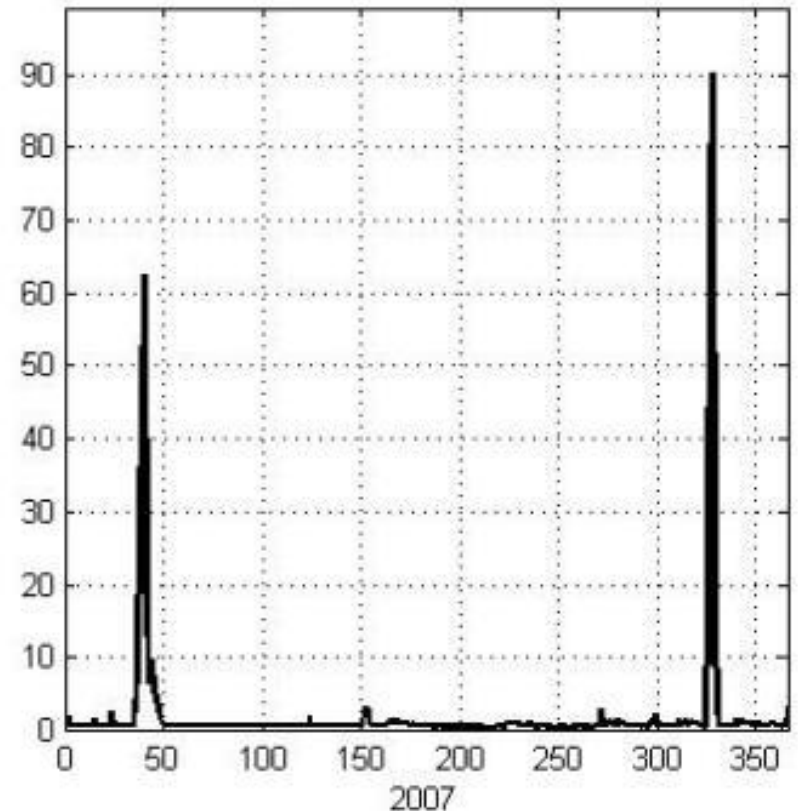


# Taro River – Piane di Carniglia (PR) Year 2007

## Reference



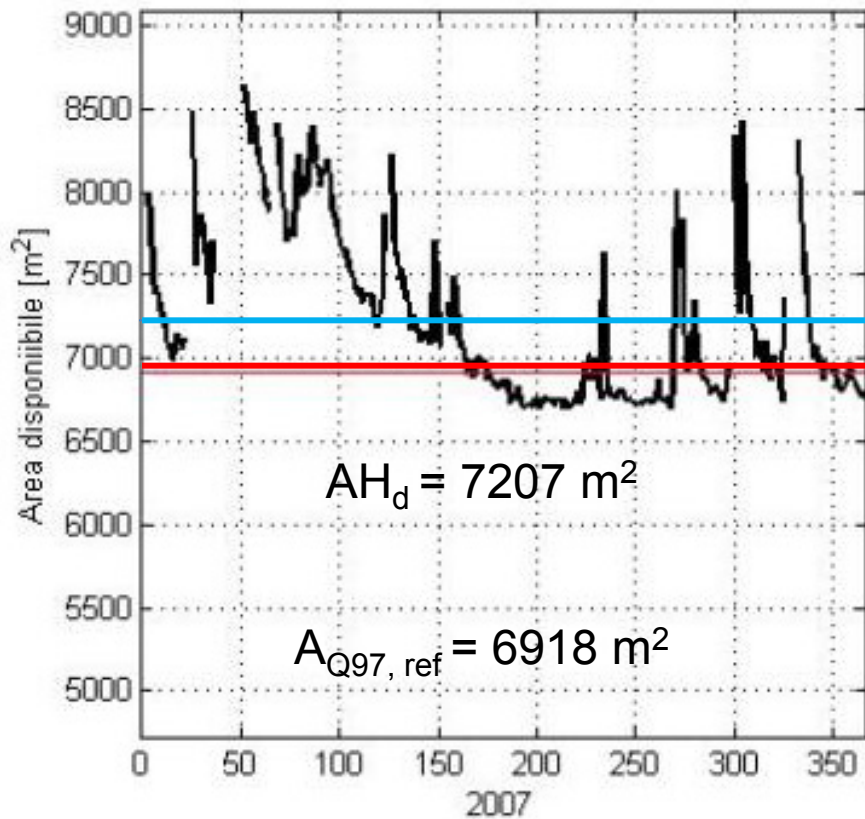
## Altered



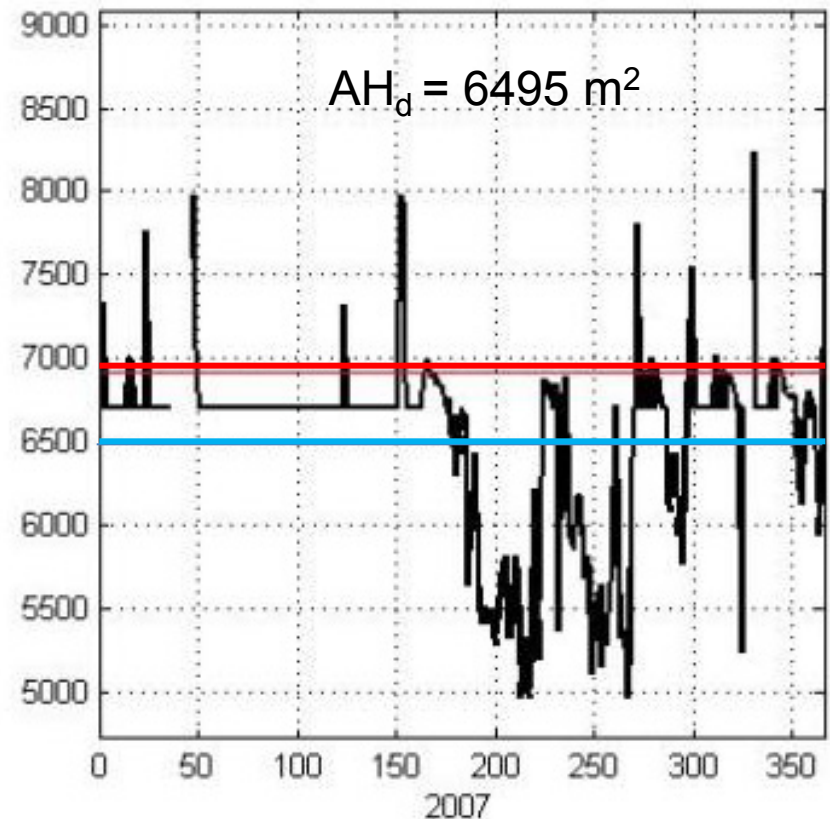
# ISH

## Index of Spatial Habitat availability

### Reference



### Altered

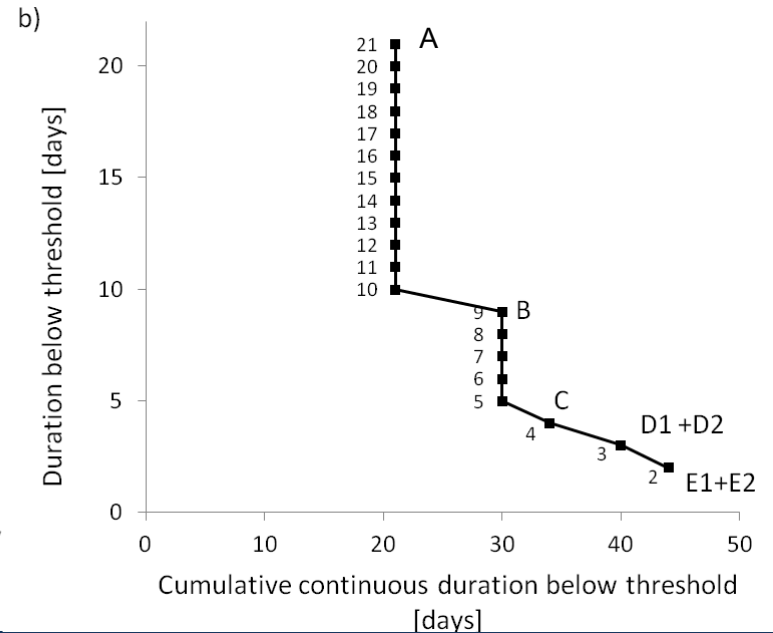
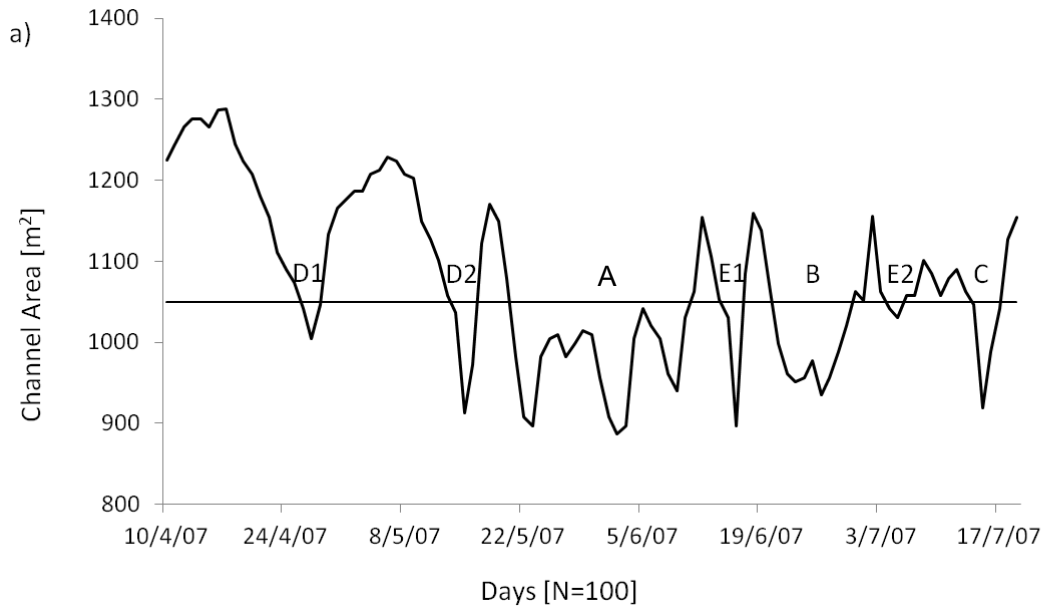


$$ISH_{\text{barbel}} = 6495 / 7207 \text{ m}^2 = 0.90$$

# Habitat time series

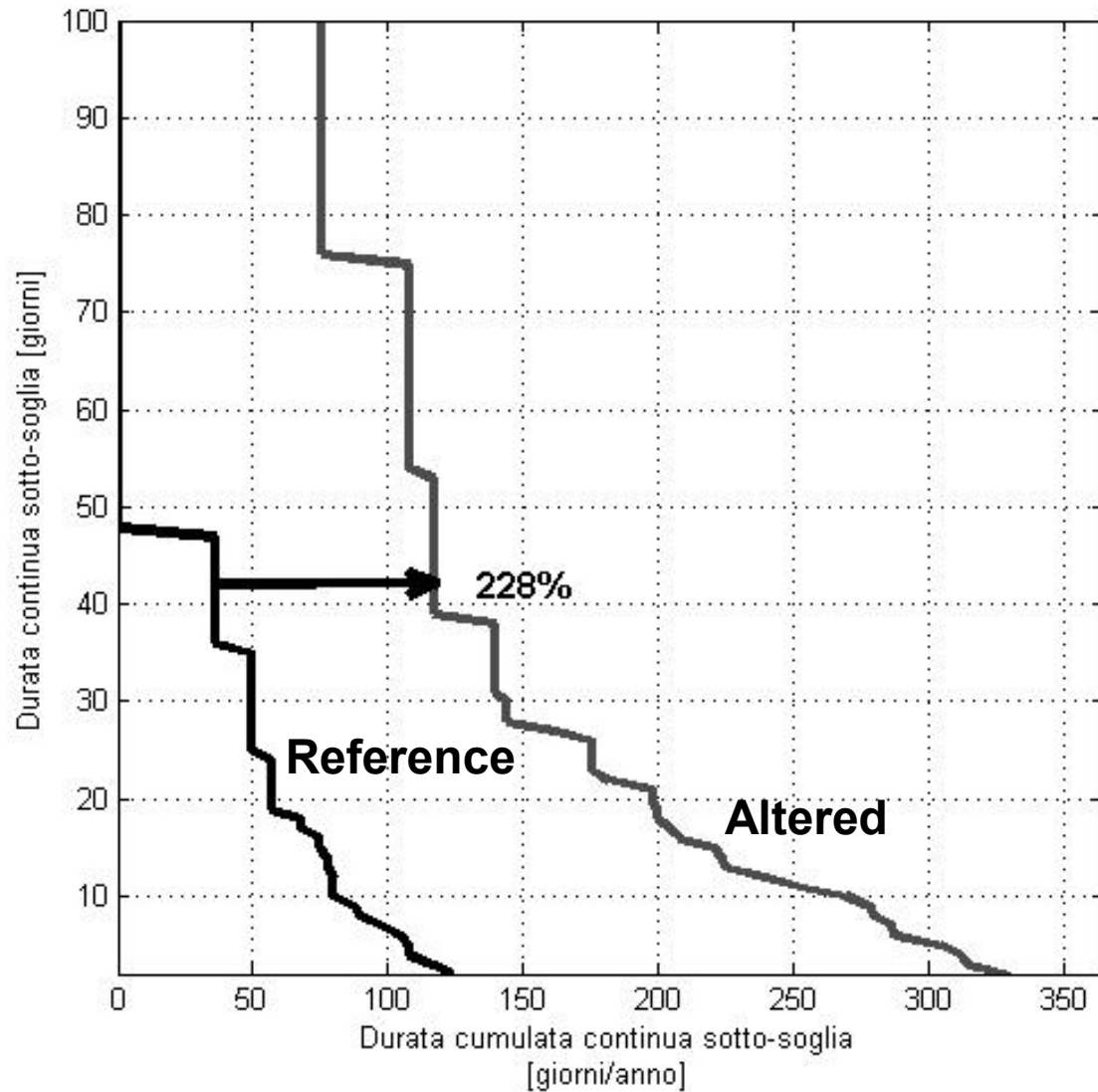
## Curve UCUT

(Uniform Continuous Duration Under Threshold)

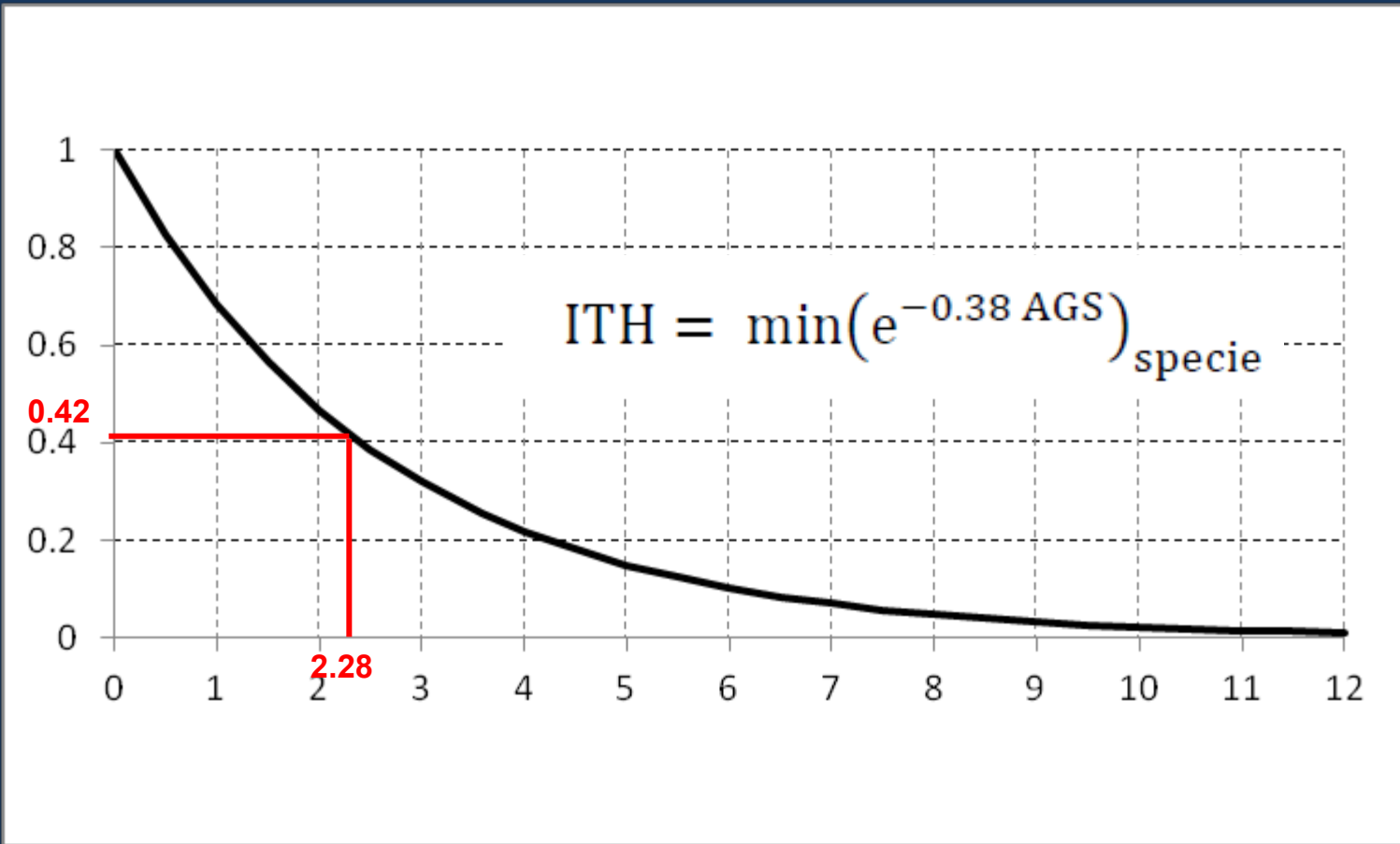




# Stress Days Alteration



# ITH – Index of Temporal Habitat availability



AGS<sub>barbel</sub> = 228%



ITH<sub>barbel</sub> = 0.42

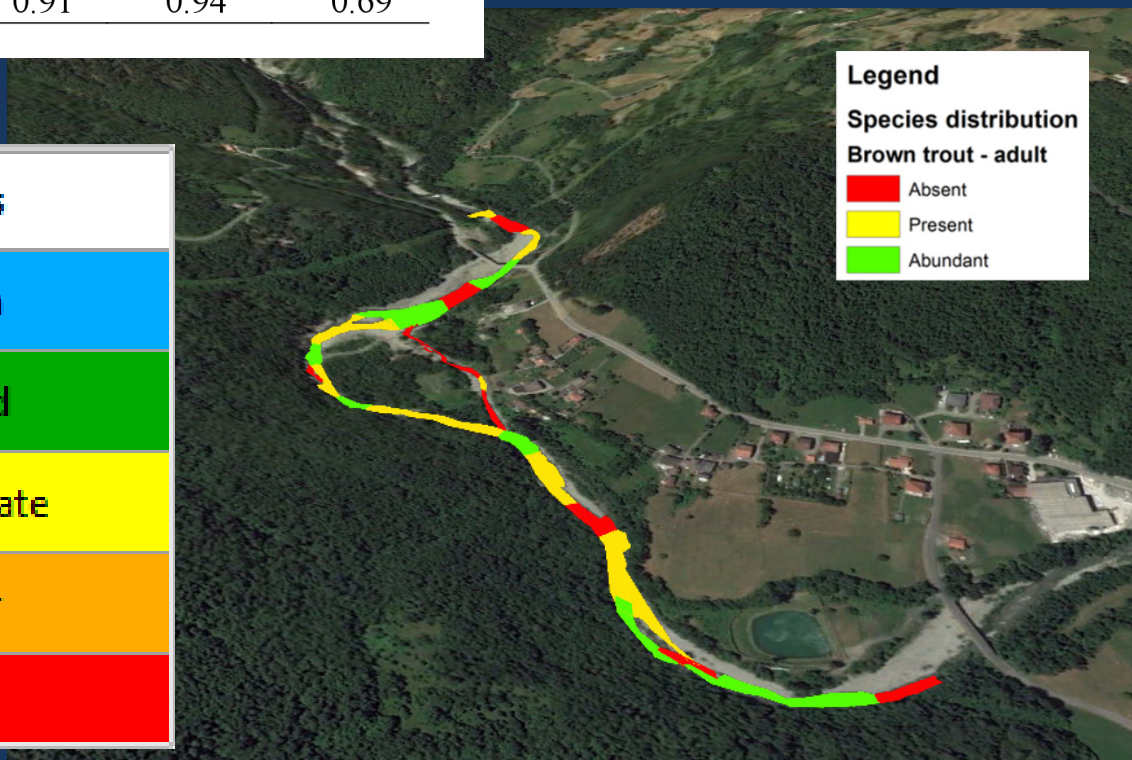
# IH – Index of Habitat Integrity

Tabella A4.2 - Valori di ISH, AGS e ITH calcolati per il caso del F. Taro a Piane di Carniglia.

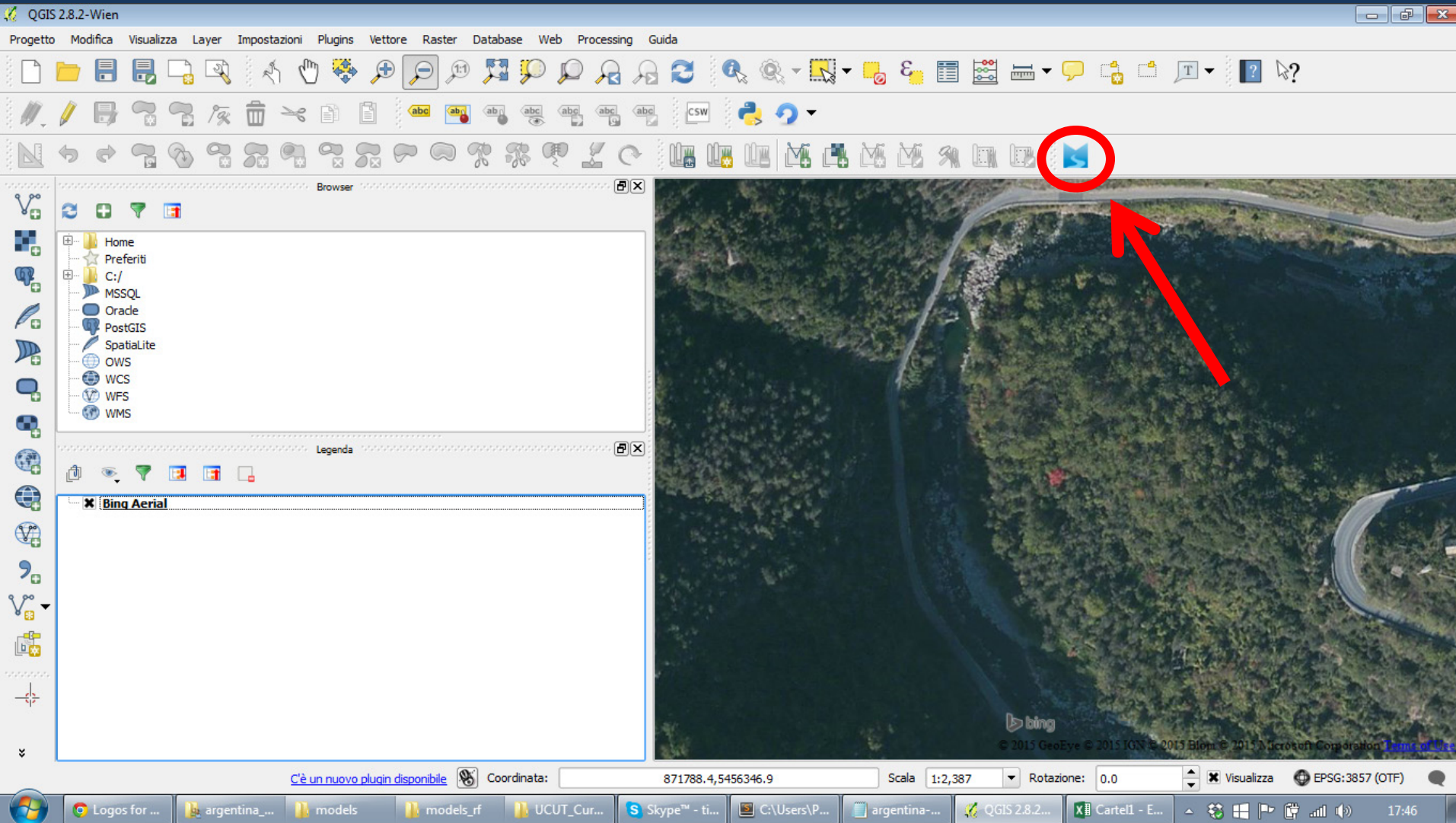
Specie/stadio vitale	ISH	AGS	ITH
Trota fario - adulta	0.92	1.60	0.54
Trota sp. - giovane	0.97	0.86	0.72
Vairone - adulto	0.95	0.13	0.95
Vairone - giovane	0.99	0.93	0.70
Barbo – Barbus sp.	<b>0.90</b>	2.28	<b>0.42</b>
Cavedano - adulto	0.97	0.83	0.72
Ghiozzo - adulto	0.91	0.94	0.69

$$IH = (0.90 + 0.42) / 2 = 0.66$$

IH	Class
$IH \geq 0.80$	High
$0.60 \leq IH < 0.80$	Good
$0.40 \leq IH < 0.60$	Moderate
$0.20 \leq IH < 0.40$	Poor
$IH < 0.20$	Bad



# QuantumGIS plug-in



# QuantumGIS plug-in

QGIS 2.8.2-Wien

Progetto Modifica Visualizza Layer

MesoHABSIM Plugin

### Site Information

Insert the the project name

Insert the river/stream name

Home  
Preferiti  
C:/  
MSSQL  
Oracle  
PostGIS  
SpatialLite  
OWS  
WCS  
WFS  
WMS

Bing Aerial

Previous Next

Logos for SL... Esplora riso... Skype™ - tim... C:\Users\Pao... argentina-m... QGIS 2.8.2-W... MesoHABSI... Cartel1 - Excel 1 - Paint

Risolvi problemi del PC: Un messaggio

17:48

# QuantumGIS plug-in

The screenshot displays the QGIS 2.8.2-Wien interface with the MesoHABSIM Plugin dialog box open. The dialog is titled "Species and life stage selection" and lists ten species with checkboxes for "PDP", "Juvenile", and "Adult". The "Juvenile" and "Adult" checkboxes are checked for Brown trout, Vairone, and Barbel. The "PDP" checkbox is checked for all species. The "Bing Aerial" layer is selected in the left sidebar. The Windows taskbar at the bottom shows the system date as martedì 8 settembre 2015 and the time as 17:49.

Species	PDP	Juvenile	Adult
Brown trout ( <i>Salmo trutta</i> )	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>
Marble trout ( <i>Salmo marmoratus</i> )	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Mediterranean trout ( <i>Salmo cetti</i> )	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Bullhead ( <i>Cottus gobio</i> )	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Vairone ( <i>Leuciscus souffia</i> )	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>
Chub ( <i>Leuciscus cephalus</i> )	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Barbel ( <i>Barbus sp.</i> )	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>
Italian freshwater goby ( <i>Padogobius martensi</i> )	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Crayfish ( <i>Austropotamobius pallipes</i> )	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

# QuantumGIS plug-in

**MesoHABSIM Plugin**

### Hydro-morphological Data

1 Date: 29/07/2015 Discharge [m3/s]: 0.250  
Habitat maps: C:/Paolo/PLUGIN/argentina\_files/argentina-hmu-29-07-2015-250ls.shp [Browse Shapefile]  
Point measurements: C:/Paolo/PLUGIN/argentina\_files/argentina-meas-29-07-2015-250ls.txt [Browse Shapefile] [Browse Text File]  
 Add

2 Date: 01/07/2015 Discharge [m3/s]: 0.420  
Habitat maps: C:/Paolo/PLUGIN/argentina\_files/argentina-hmu-01-07-2015-420ls.shp [Browse Shapefile]  
Point measurements: C:/Paolo/PLUGIN/argentina\_files/argentina-meas-01-07-2015-420ls.txt [Browse Shapefile] [Browse Text File]  
 Add

3 Date: 25/05/2015 Discharge [m3/s]: 0.650  
Habitat maps: C:/Paolo/PLUGIN/argentina\_files/argentina-hmu-25-05-2015-650ls.shp [Browse Shapefile]  
Point measurements: C:/Paolo/PLUGIN/argentina\_files/argentina-meas-25-05-2015-650ls.txt [Browse Shapefile] [Browse Text File]  
 Add

4 Date: 10/04/2015 Discharge [m3/s]: 2.200  
Habitat maps: C:/Paolo/PLUGIN/argentina\_files/argentina-hmu-10-04-2015-950ls.shp [Browse Shapefile]  
Point measurements: C:/Paolo/PLUGIN/argentina\_files/argentina-meas-10-04-2015-950ls.txt [Browse Shapefile] [Browse Text File]  
 Add

Previous Next

Visualizza EPSG:3857 (OTF)

Logos for SL... Esplora riso... Skype™ - tim... C:\Users\Pao... argentina-m... QGIS 2.8.2-W... MesoHABS... Cartel1 - Excel 3 - Paint 17:50

# QuantumGIS plug-in

The screenshot displays the QGIS 2.8.2-Wien interface with the MesoHABSIM Plugin dialog box open. The dialog box is titled "Time Series Analysis & Uniform Continuous Under Treshold (UCUT) Curves". It contains two sections for selecting time series data:

- Reference streamflow time series  
C:/Paolo/PLUGIN/argentina\_files/Argentina\_Montalto\_2008\_ref.txt [Browse Text File]
- Altered streamflow time series  
C:/Paolo/PLUGIN/argentina\_files/Argentina\_Montalto\_2008\_alt.txt [Browse Text File]

At the bottom of the dialog box, there are "Previous" and "Next" buttons. The background shows the QGIS main window with a Bing Aerial map and the Windows taskbar at the bottom.



# QuantumGIS plug-in

The screenshot displays the QGIS 2.8.2-Wien interface with the MesoHABSIM Plugin dialog box open. The dialog is titled "Output Selection" and lists several output options with checkboxes for selection:

- Hydro-morphological unit data**  GIS maps  Txt file  XYZ Txt file
- Model test**  GIS maps
- Habitat suitability**  GIS maps  Txt file
- Habitat-Flow rating curves**  Graph  Txt file
- Streamflow - Habitat time series**  Graph
- UCUT curves**  Graph  Txt file
- Habitat integrity index**  Txt file  Graph

Below the list, there is a text field for "Select an output path" containing the value "C:/Paolo/PLUGIN/prova" and a "Browse" button. A note states: "The project folder will be named as 'RiverName\_MesoHABSIM\_Project\_ProjectName' and will be created within the selected path."

At the bottom of the dialog, there are "Previous" and "Run" buttons. The background shows the QGIS main window with a Bing Aerial layer and a taskbar at the bottom with various open applications.

# QuantumGIS plug-in

The screenshot displays the QGIS 2.8.2-Wien interface. The main window shows a map of a river area in Argentina, with a multi-colored polygon overlaid on it. The polygon is composed of several distinct colored regions: yellow, green, cyan, blue, and purple. The map is sourced from Bing Aerial. The interface includes a menu bar with options like Progetto, Modifica, Visualizza, Layer, Impostazioni, Plugins, Vettore, Raster, Database, Web, Processing, and Guida. Below the menu bar are two toolbars. On the left, there is a Browser panel showing a file system tree with folders like Home, Preferiti, C:/, MSSQL, Oracle, PostGIS, SpatialLite, OWS, WCS, WFS, and WMS. Below the Browser panel is a Legend panel listing various data layers, including several 'Argentina\_1\_Jul\_2015\_Q420\_A\_BARB\_SUI' and 'Argentina\_29\_Jul\_2015\_Q250\_A\_BARB\_SUI' layers, and 'Argentina\_10\_Apr\_2015\_Q2200\_DATA'. The status bar at the bottom shows the coordinates 871542.8, 5456017.9, a scale of 1:2,387, and the date 'martedì 8 settembre 2015'. The taskbar at the bottom shows several open applications, including Barbus barb..., Esplora riso..., Skype™ - tim..., C:\Users\Pao..., argentina-m..., QGIS 2.8.2-W..., MesoHABSI..., Cartel1 - Excel, and 8 - Paint.

# QuantumGIS plug-in

The screenshot displays the QGIS 2.8.2-Wien interface. The main window shows a map of a region in Argentina, overlaid with several colored polygons (yellow, red, green) representing different data layers. The interface includes a menu bar (Progetto, Modifica, Visualizza, Layer, Impostazioni, Plugins, Vettore, Raster, Database, Web, Processing, Guida), a toolbar with various GIS tools, and a left sidebar with a Browser panel and a Legend panel. The Browser panel shows a tree view of data sources, including local files and network services. The Legend panel lists the loaded layers, with 'Argentina\_29\_Jul\_2015\_Q250\_DATA' selected. The status bar at the bottom shows the current coordinates (871554.1, 5456005.2), scale (1:2,387), rotation (0.0), and the date (martedì 8 settembre 2015). The taskbar at the bottom shows several open applications, including QGIS 2.8.2-Wien, MesoHABSI, and Excel.

QGIS 2.8.2-Wien

Progetto Modifica Visualizza Layer Impostazioni Plugins Vettore Raster Database Web Processing Guida

Browser

- Home
- Preferiti
- C:/
- MSSQL
- Orade
- PostGIS
- SpatialLite
- OWS
- WCS
- WFS
- WMS

Legenda

- Argentina\_1\_Jul\_2015\_Q420\_A\_BARB\_SUI
- Argentina\_1\_Jul\_2015\_Q420\_A\_VAIR\_SUI
- Argentina\_1\_Jul\_2015\_Q420\_J\_VAIR\_SUI
- Argentina\_1\_Jul\_2015\_Q420\_A\_BROW\_SUI
- Argentina\_1\_Jul\_2015\_Q420\_J\_BROW\_SUI
- Argentina\_29\_Jul\_2015\_Q250\_A\_BARB\_SUI
- Argentina\_29\_Jul\_2015\_Q250\_A\_VAIR\_SUI
- Argentina\_29\_Jul\_2015\_Q250\_J\_VAIR\_SUI
- Argentina\_29\_Jul\_2015\_Q250\_A\_BROW\_SUI
- Argentina\_29\_Jul\_2015\_Q250\_J\_BROW\_SUI
- Argentina\_10\_Apr\_2015\_Q2200\_DATA
- Argentina\_25\_May\_2015\_Q650\_DATA
- Argentina\_1\_Jul\_2015\_Q420\_DATA
- Argentina\_29\_Jul\_2015\_Q250\_DATA
- Bing Aerial

C'è un nuovo plugin disponibile

Coordinata: 871554.1,5456005.2 Scala 1:2,387 Rotazione: 0.0 Visualizza martedì 8 settembre 2015

Barbus barb... Esplora riso... Skype™ - tim... C:\Users\Pao... argentina-m... QGIS 2.8.2-W... MesoHABSI... Cartel1 - Excel 9 - Paint 18:07

# QuantumGIS plug-in

QGIS 2.8.2-Wien

Progetto Modifica Visualizza Layer

MesoHABSIM Plugin

## Habitat Integrity Index

Species	AHd,r	AHd	ISH
J. Brown Trout	6.71	7.83	0.83
A. Brown Trout	8.91	8.06	0.9
J. Marble Trout			
A. Marble Trout			
J. Med. Trout			
A. Med. Trout			
J. Bullhead			
A. Bullhead			
J. Vairone	23.1	23.94	0.96
A. Vairone	25.22	21.99	0.87
J. Chub			
A. Chub			
J. Barbel			
A. Barbel	19.02	17.23	0.91
J. F. I. Goby			
A. F. I. Goby			
J. Crayfish			
A. Crayfish			

Species	AQ97	AGS	ITH
J. Brown Trout	8.48	0.5	0.83
A. Brown Trout	5.19	Inf	0.0
J. Marble Trout			
A. Marble Trout			
J. Med. Trout			
A. Med. Trout			
J. Bullhead			
A. Bullhead			
J. Vairone	18.6	0.0	1.0
A. Vairone	18.77	0.0	1.0
J. Chub			
A. Chub			
J. Barbel			
A. Barbel	14.79	0.0	1.0
J. F. I. Goby			
A. F. I. Goby			
J. Crayfish			
A. Crayfish			

IH	Class
$IH \geq 0.80$	High
$0.60 \leq IH < 0.80$	Good
$0.40 \leq IH < 0.60$	Moderate
$0.20 \leq IH < 0.40$	Poor
$IH < 0.20$	Bad

Habitat Integrity Index

IH	0.41
----	------

River: Argentina

Previous

Visualizza EPSG:3857 (OTF)

Barbus barb... Esploira riso... Skype™ - tim... C:\Users\Pao... argentina-m... QGIS 2.8.2-W... MesoHABSI... CartelI - Excel 6 - Paint 17:58

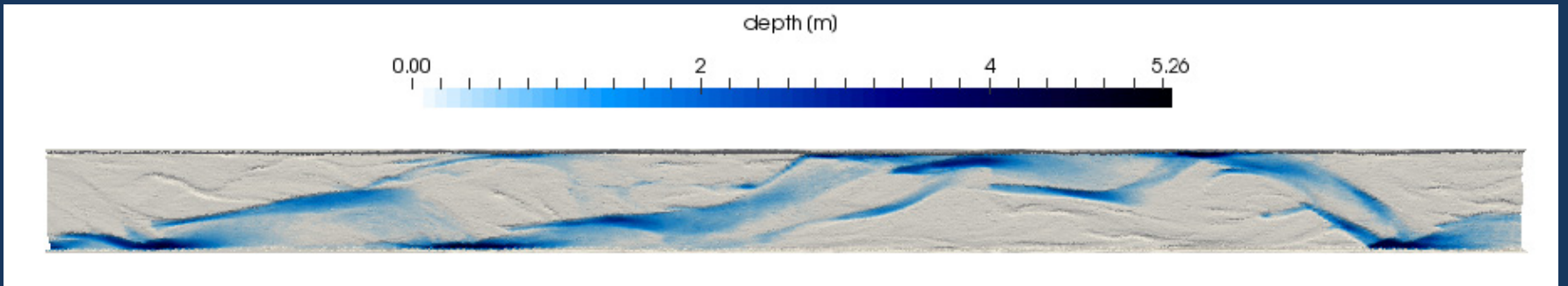
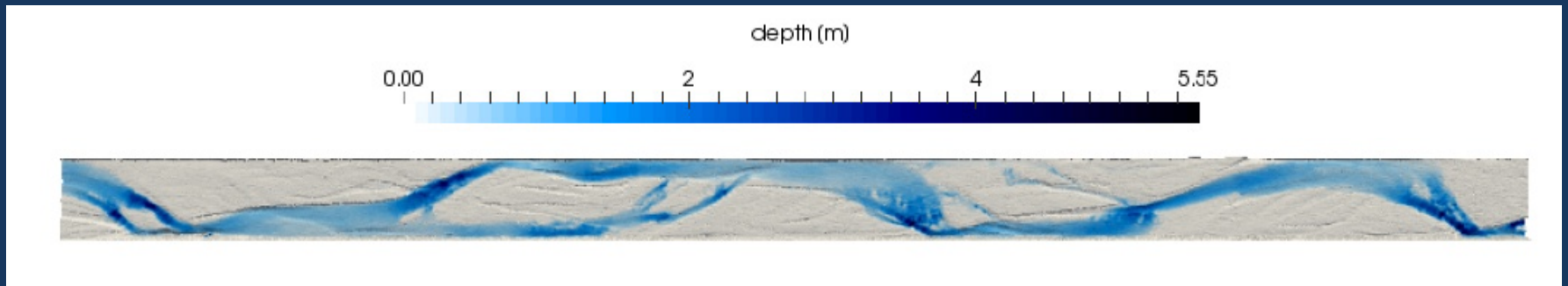
# Sediment release from dams



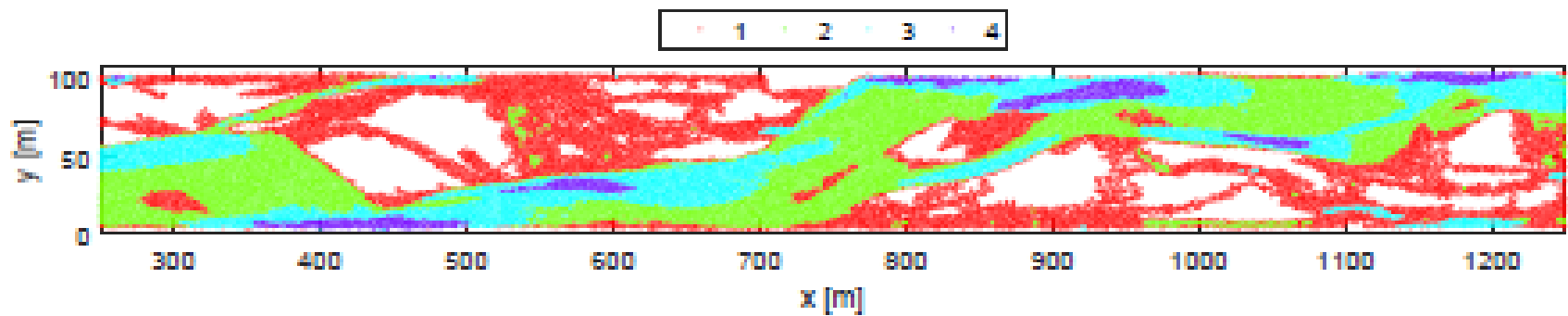
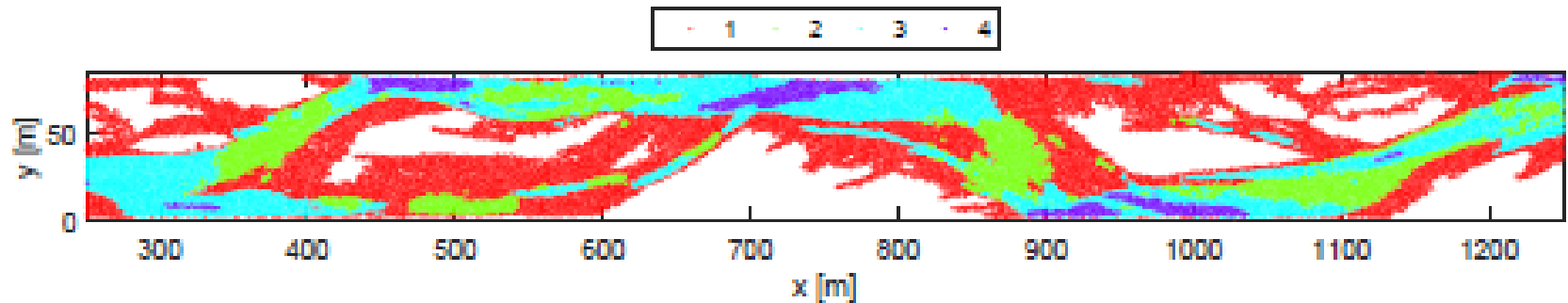
Sediment by-pass  
tunnel



# Including morphodynamics in habitat evaluation



# Unsupervised mesohabitat classification



# Conclusions

Most of the current biological assessment methods (e.g., WFD) used to evaluate e-flows are designed to assess the overall water quality impairment.

For some of the biological communities (e.g., fish) the hydro-morphological alteration may not be the only driver of community composition, which can be artificially altered by massive restocking, angling or introduction of alien species.

The proposed habitat indices can be considered flexible tools since they can capture both spatial and temporal alteration of habitat structure.

They can quantify the effect of both hydrological and morphological alteration and the analysis can be carried out for different kind of pressures.



Thanks a lot for your attention

