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

Paolo Vezza

Research Team Leader of the RESeau Research Unit, Aosta, Italy

Post-doctoral fellow at Politecnico di Torino, Italy

POLITECNICO DI TORINO 1859 1906

REFORM

REstoring rivers FOR effective catchment Management

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

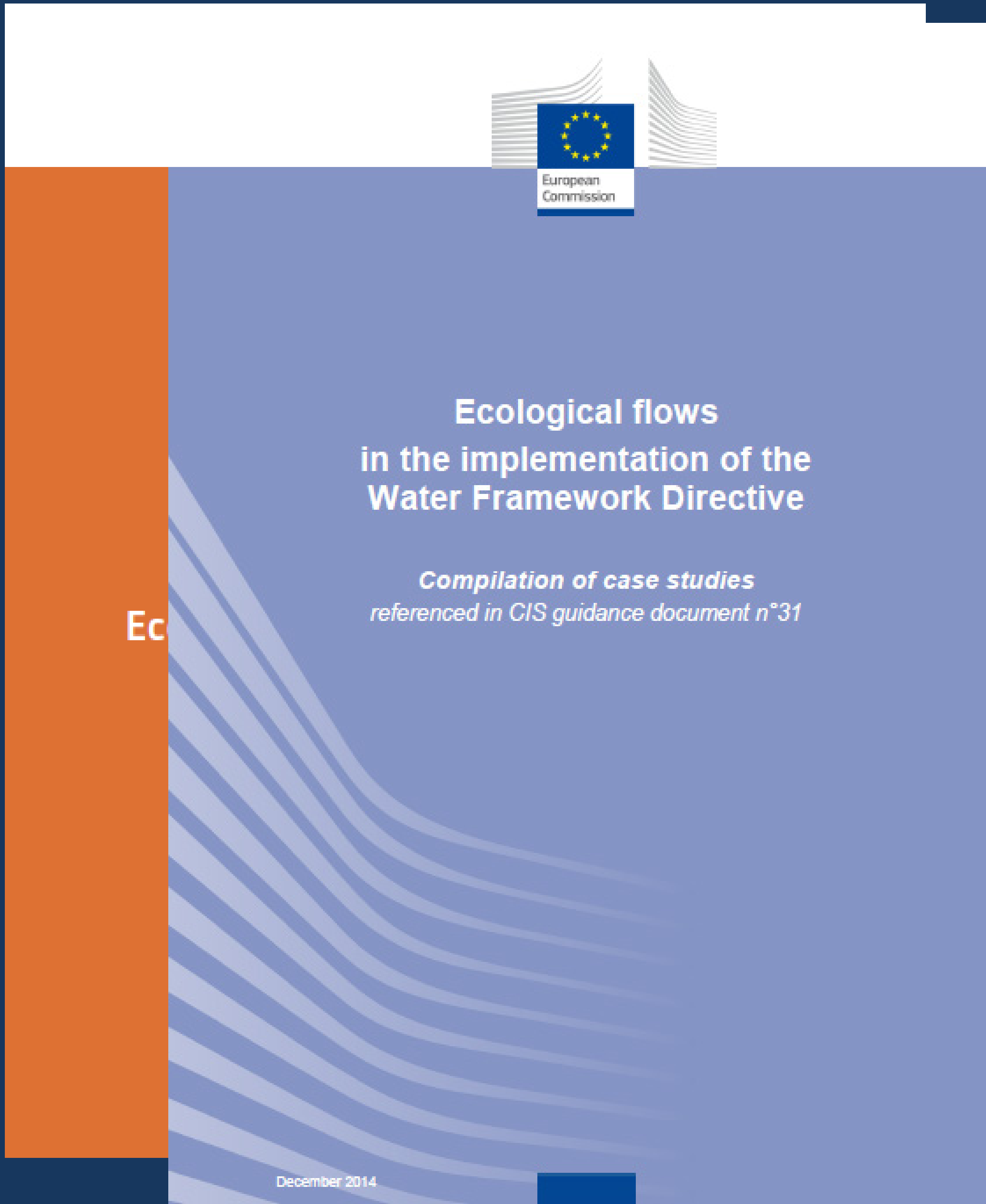
(LIFE08NAT/IT/000352)

European Commission

Technical Report - 2015 - 086

Ecological flows in the implementation of the Water Framework Directive

Guidance Document No. 31



European Commission

Ecological flows in the implementation of the Water Framework Directive

Compilation of case studies

referenced in CIS guidance document n°31

December 2014

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

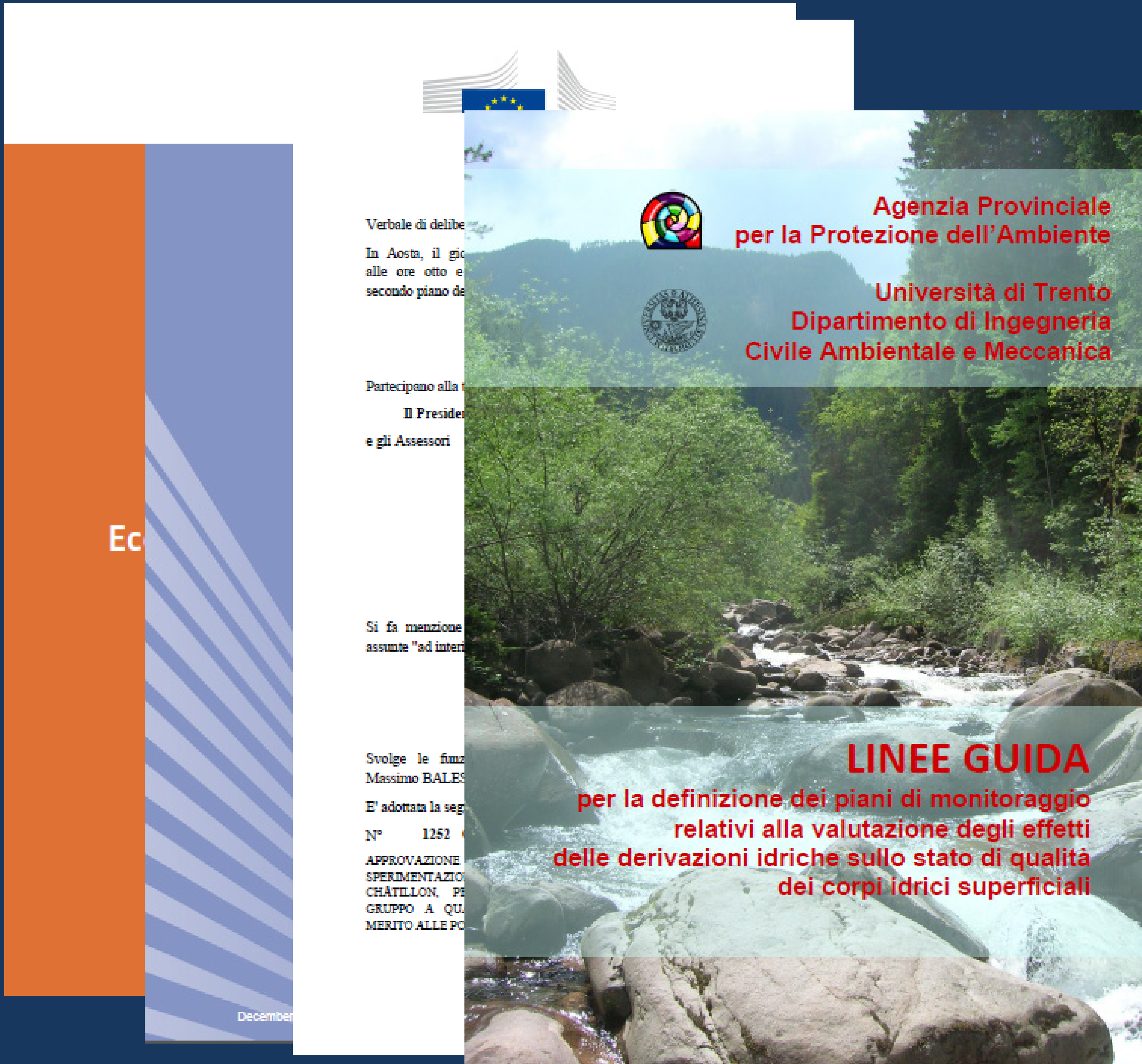
Si fa menzione che le funzioni di Assessore al Bilancio, Finanze e Patrimonio sono state assunte "ad interim" dal Presidente della Regione.

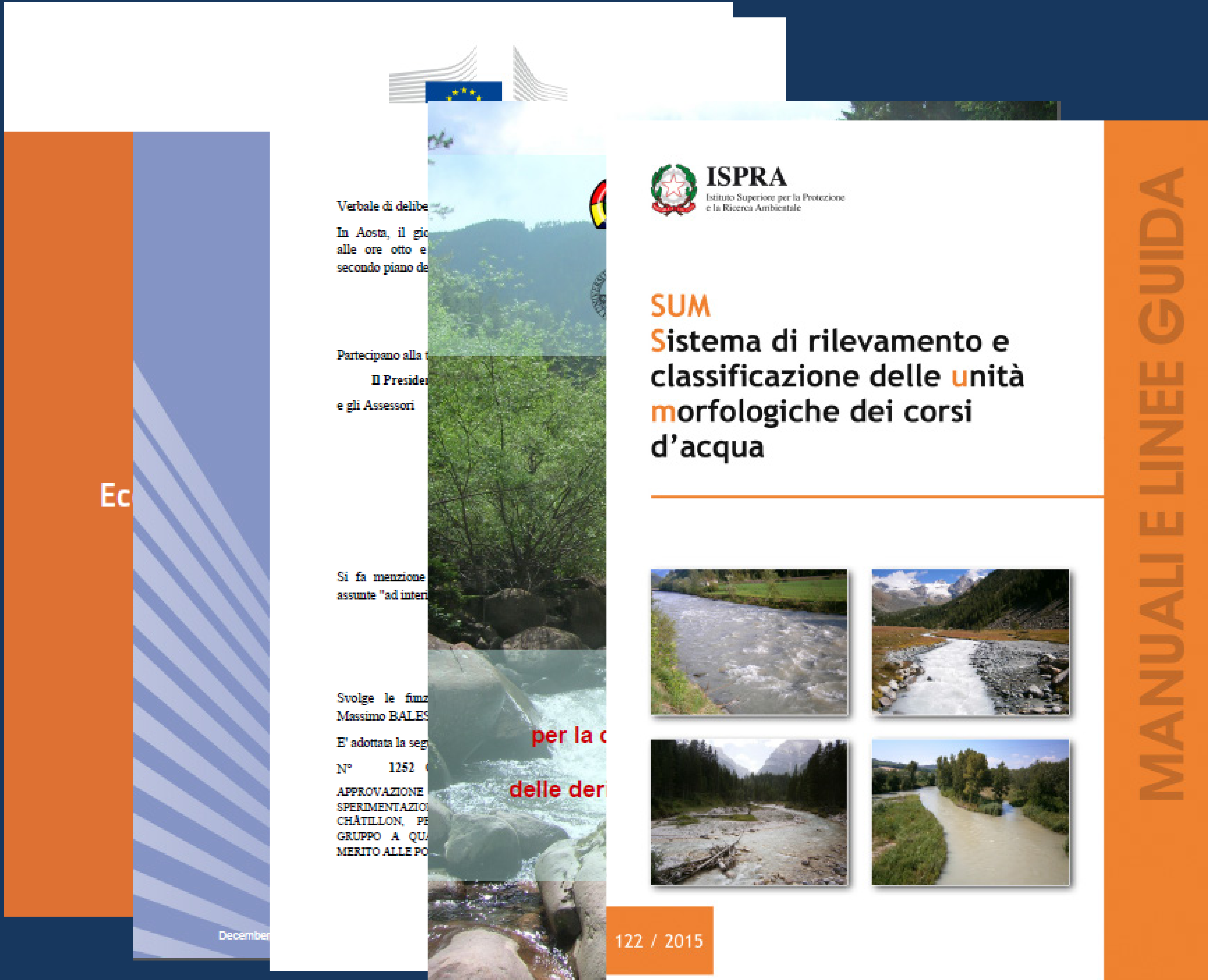
Svolge le funzioni rogatorie il Dirigente della Segreteria della Giunta regionale, Sig. Massimo BALESTRA

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).


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


Ec
December
Verbale di delibe
In Aosta, il gio
alle ore otto e
secondo piano de
Partecipano alla
Il Presider
e gli Assessori
Si fa menzione
assunte "ad interi
Svolge le funz
Massimo BALES
E' adottata la seg
N° 1252
APPROVAZIONE
SPERIMENTAZIO
CHÂTILLON, PE
GRUPPO A QUA
MERITO ALLE PO
per la c
delle deri
ISPRA
Istituto Superiore per la Protezione e la Ricerca Ambientale
SUM
Sistema di rilevamento e classificazione delle unità morfologiche dei corsi d'acqua
122 / 2015
MANUALI E LINEE GUIDA

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.

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.

Habitat as a metric to evaluate e-flows

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

Index	Acronym	Reference	Ecological parameter
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	Vezza et al. (2014)	Habitat
Index of Habitat Stress Days	IHSD	Vezza et al. (2014)	Habitat

E-flows monitoring program
Valle d'Aosta Region – Savara stream

Table 2. Monitoring data for the Savara stream during e-flows implementation (analysed period 2008 – 2013). Both ecological status and index values are reported.

Year	Min e-flow	LIM	IBE	IFF	LIMeco	STAR-ICMi	ICMi	IBMR	ISECI	IQM	IIHA	ISH	ITH
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
2011	130 l/s	I (520)	II (9.0)	II (226)	I (1.00)	I (1+)	I (0.91)	I (0.92)	V (0.2)	I (0.88)	0.70	0.49	0.23
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
2013	325 l/s	I (520)	II (9.0)	II (226)	I (0.96)	II (0.83)	I (0.89)	-	V (0.2)	I (0.88)	0.71	0.67	0.33

E-flows monitoring program
Valle d'Aosta Region – Savara stream

Table 2. Monitoring data for the Savara stream during e-flows implementation (analysed period 2008 – 2013). Both ecological status and index values are reported.

Year	Min e-flow	LIM	IBE	IFF	LIMeco	STAR -ICMi	ICMi	IBMR	ISECI	IQM	IIHA	ISH	ITH
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
2011	130 l/s	I (520)	II (9.0)	II (226)	I (1.00)	I (1+)	I (0.91)	I (0.92)	V (0.2)	I (0.88)	0.70	0.49	0.23
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
2013	325 l/s	I (520)	II (9.0)	II (226)	I (0.96)	II (0.83)	I (0.89)	-	V (0.2)	I (0.88)	0.71	0.67	0.33

E-flows monitoring program
Valle d'Aosta Region – Savara stream

Table 2. Monitoring data for the Savara stream during e-flows implementation (analysed period 2008 – 2013). Both ecological status and index values are reported.

Year	Min e-flow	LIM	IBE	IFF	LIMeco	STAR -ICMi	ICMi	IBMR	ISECI	IQM	IIHA	ISH	ITH
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
2011	130 l/s	I (520)	II (9.0)	II (226)	I (1.00)	I (1+)	I (0.91)	I (0.92)	V (0.2)	I (0.88)	0.70	0.49	0.23
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
2013	325 l/s	I (520)	II (9.0)	II (226)	I (0.96)	II (0.83)	I (0.89)	-	V (0.2)	I (0.88)	0.71	0.67	0.33

E-flows monitoring program
Valle d'Aosta Region – Savara stream

Table 2. Monitoring data for the Savara stream during e-flows implementation (analysed period 2008 – 2013). Both ecological status and index values are reported.

Year	Min e-flow	LIM	IBE	IFF	LIMeco	STAR -ICMi	ICMi	IBMR	ISECI	IQM	IIHA	ISH	ITH
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
2011	130 l/s	I (520)	II (9.0)	II (226)	I (1.00)	I (1+)	I (0.91)	I (0.92)	V (0.2)	I (0.88)	0.70	0.49	0.23
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
2013	325 l/s	I (520)	II (9.0)	II (226)	I (0.96)	II (0.83)	I (0.89)	-	V (0.2)	I (0.88)	0.71	0.67	0.33

E-flows monitoring program
Valle d'Aosta Region – Savara stream

Table 2. Monitoring data for the Savara stream during e-flows implementation (analysed period 2008 – 2013). Both ecological status and index values are reported.

Year	Min e-flow	LIM	IBE	IFF	LIMeco	STAR -ICMi	ICMi	IBMR	ISECI	IQM	IIHA	ISH	ITH
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
2011	130 l/s	I (520)	II (9.0)	II (226)	I (1.00)	I (1+)	I (0.91)	I (0.92)	V (0.2)	I (0.88)	0.70	0.49	0.23
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
2013	325 l/s	I (520)	II (9.0)	II (226)	I (0.96)	II (0.83)	I (0.89)	-	V (0.2)	I (0.88)	0.71	0.67	0.33

E-flows monitoring program
Valle d'Aosta Region – Savara stream

Table 2. Monitoring data for the Savara stream during e-flows implementation (analysed period 2008 – 2013). Both ecological status and index values are reported.

Year	Min e-flow	LIM	IBE	IFF	LIMeco	STAR -ICMi	ICMi	IBMR	ISECI	IQM	IIHA	ISH	ITH
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
2011	130 l/s	I (520)	II (9.0)	II (226)	I (1.00)	I (1+)	I (0.91)	I (0.92)	V (0.2)	I (0.88)	0.70	0.49	0.23
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
2013	325 l/s	I (520)	II (9.0)	II (226)	I (0.96)	II (0.83)	I (0.89)	-	V (0.2)	I (0.88)	0.71	0.67	0.33

E-flows monitoring program
Valle d'Aosta Region – Savara stream

Table 2. Monitoring data for the Savara stream during e-flows implementation (analysed period 2008 – 2013). Both ecological status and index values are reported.

Year	Min e-flow	LIM	IBE	IFF	LIMeco	STAR -ICMi	ICMi	IBMR	ISECI	IQM	IIHA	ISH	ITH
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
2011	130 l/s	I (520)	II (9.0)	II (226)	I (1.00)	I (1+)	I (0.91)	I (0.92)	V (0.2)	I (0.88)	0.70	0.49	0.23
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
2013	325 l/s	I (520)	II (9.0)	II (226)	I (0.96)	II (0.83)	I (0.89)	-	V (0.2)	I (0.88)	0.71	0.67	0.33

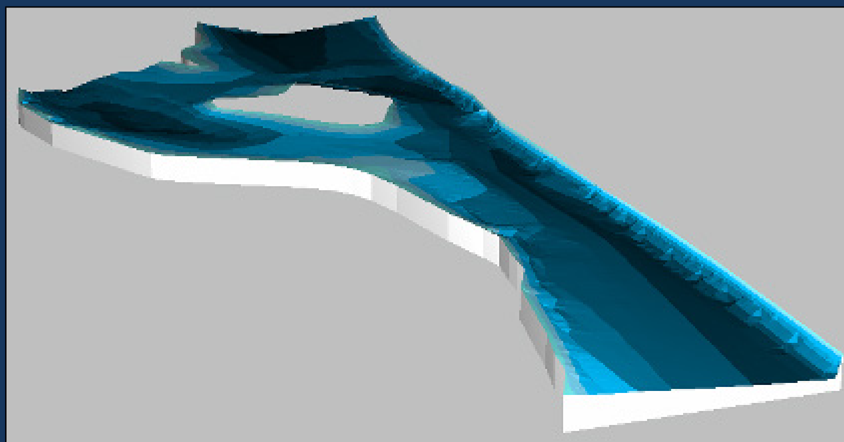
E-flows monitoring program
Valle d'Aosta Region – Savara stream

Table 2. Monitoring data for the Savara stream during e-flows implementation (analysed period 2008 – 2013). Both ecological status and index values are reported.

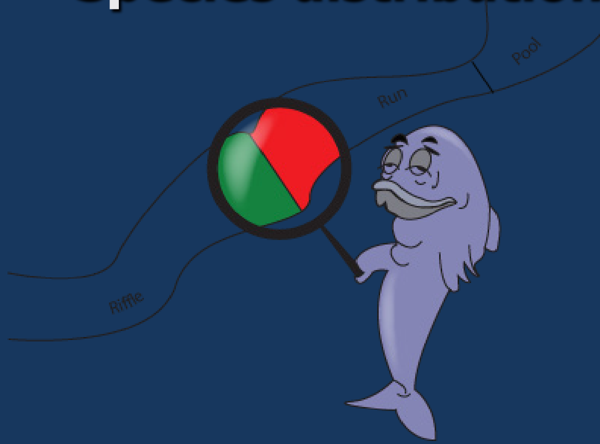
Year	Min e-flow	LIM	IBE	IFF	LIMeco	STAR -ICMi	ICMi	IBMR	ISECI	IQM	IIHA	ISH	ITH
2008	0	I (520)	II (8.6)	II (226)	-	-	-	-	-	-	0.59	0.18	0.05
2009	130 l/s	I (560)	II (9.0)	II (226)	-	-	-	-	-	-	0.73	0.55	0.31
2010	130 l/s	I (520)	II (8.8)	II (226)	I (0.95)	I (1+)	I (0.95)	I (0.87)	V (0.2)	-	0.72	0.51	0.24
2011	130 l/s	I (520)	II (9.0)	II (226)	I (1.00)	I (1+)	I (0.91)	I (0.92)	V (0.2)	I (0.88)	0.70	0.49	0.23
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
2013	325 l/s	I (520)	II (9.0)	II (226)	I (0.96)	II (0.83)	I (0.89)	-	V (0.2)	I (0.88)	0.71	0.67	0.33

Habitat modelling tools

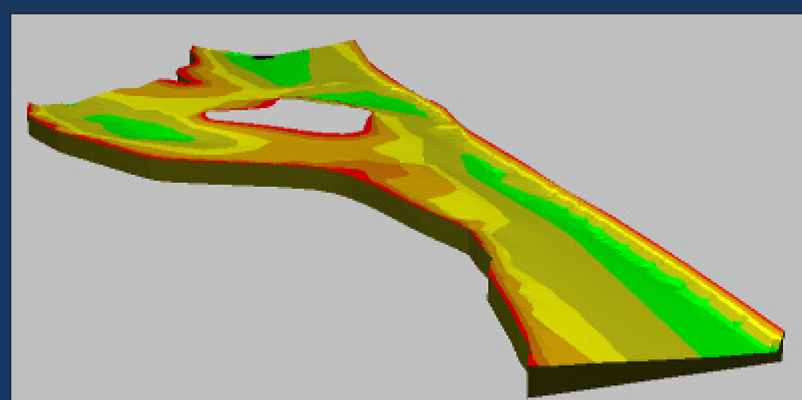
Channel hydro-morphology



Species distribution



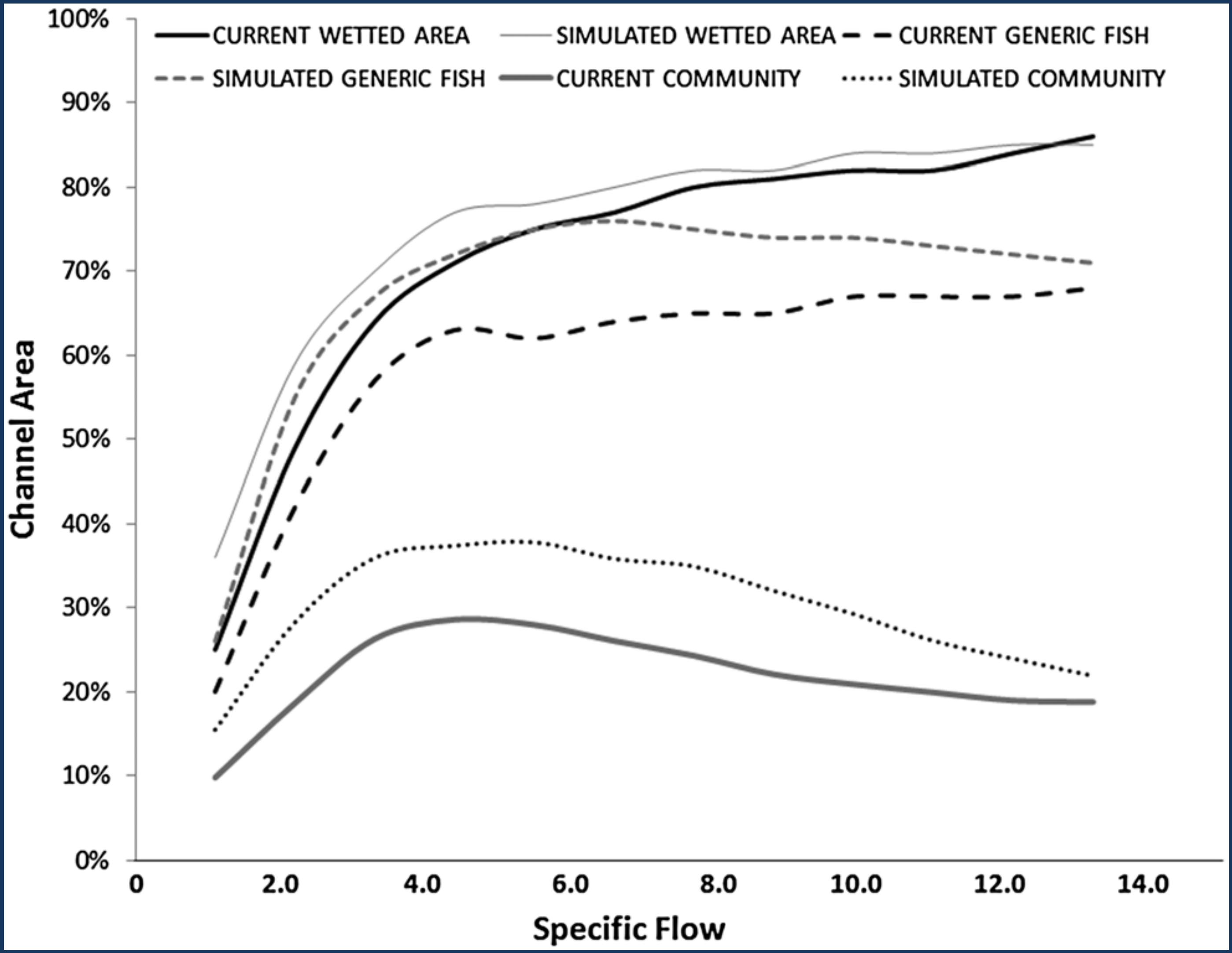
Quantitative habitat evaluation over space and time



Meso-scale habitat models

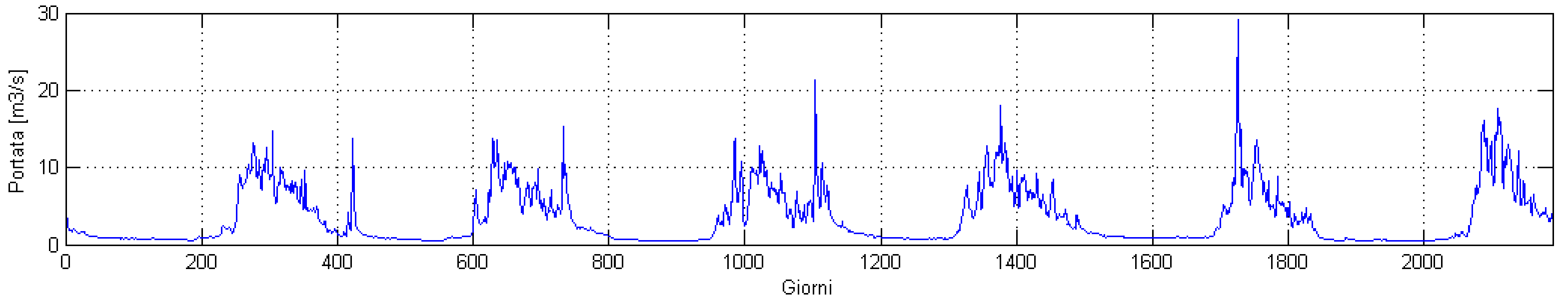
- Include in the analysis a large range of habitat variables (hydraulic variables, cover availability, water temperature, shore characteristics, biotic interactions);
- Analyze environmental conditions around an organism, not only at the point where it is observed;
- Are more flexible to be applied where 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

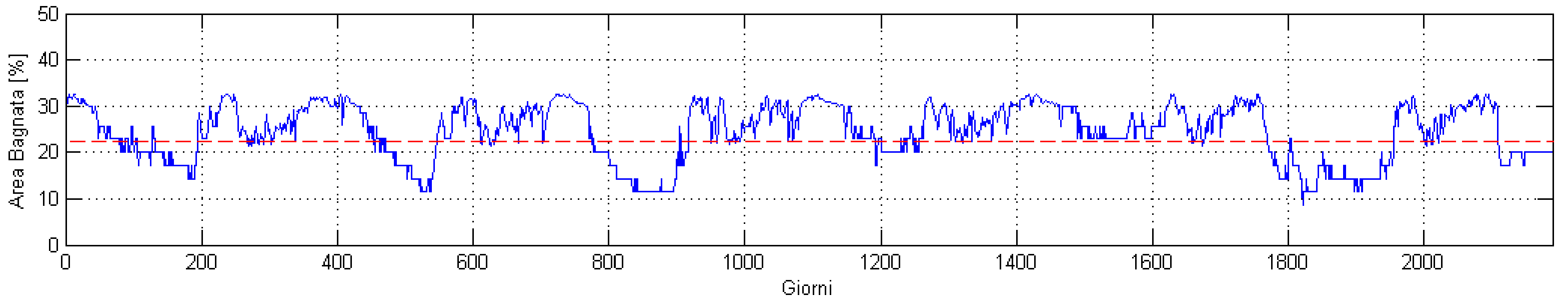


Habitat time series

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

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

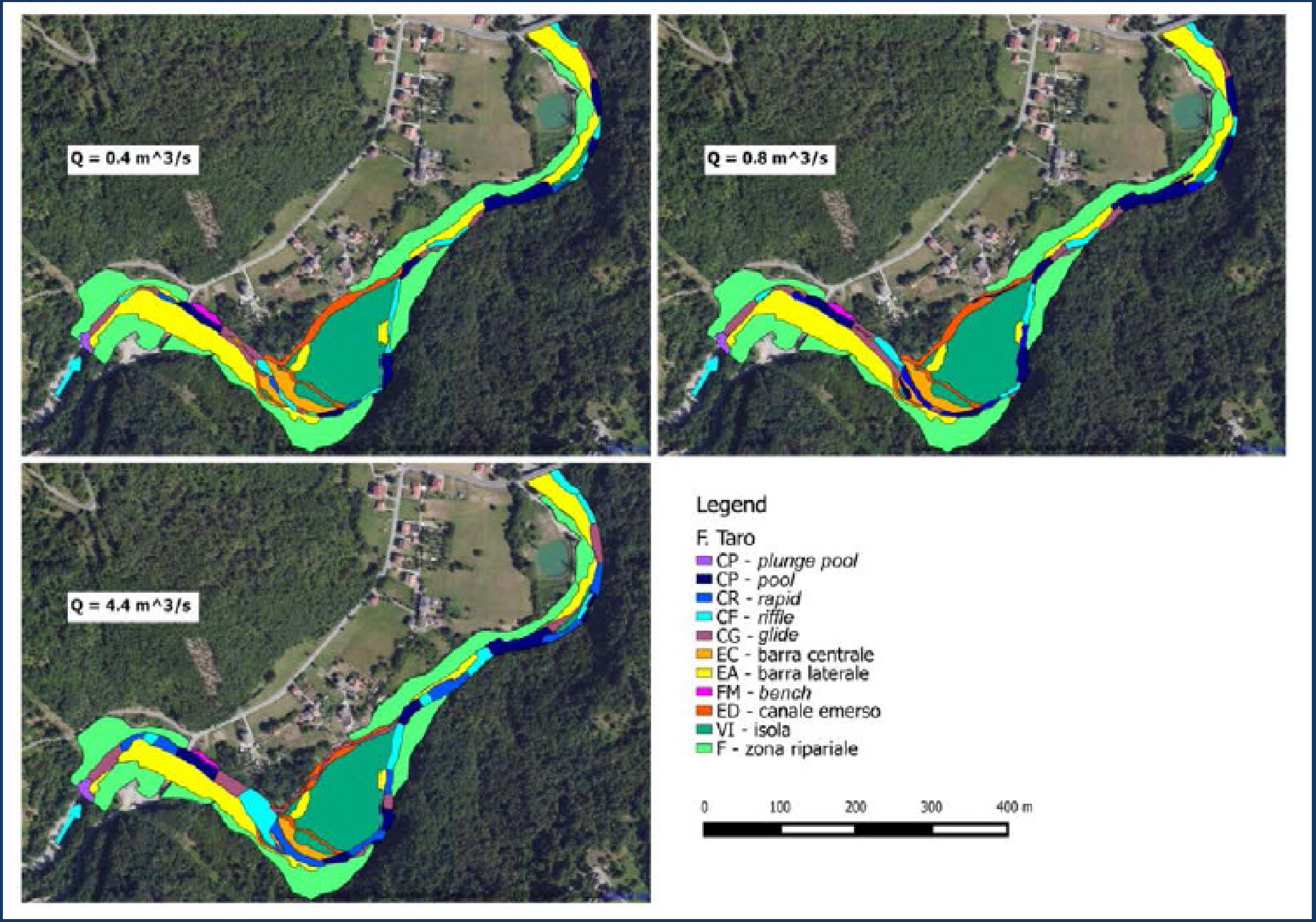
ITH – Index of Temporal Habitat availability

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

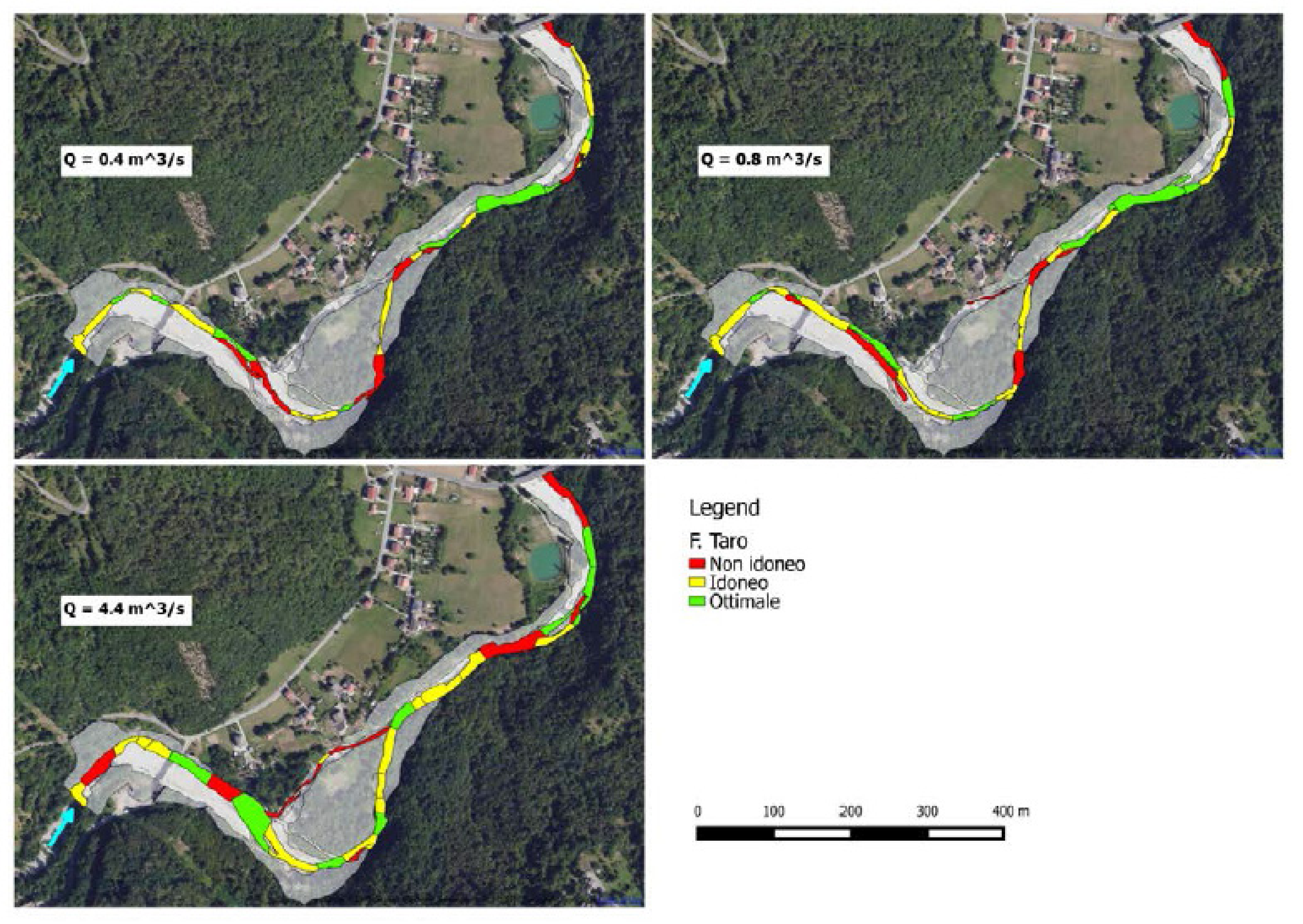
IH – Index of Habitat integrity

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

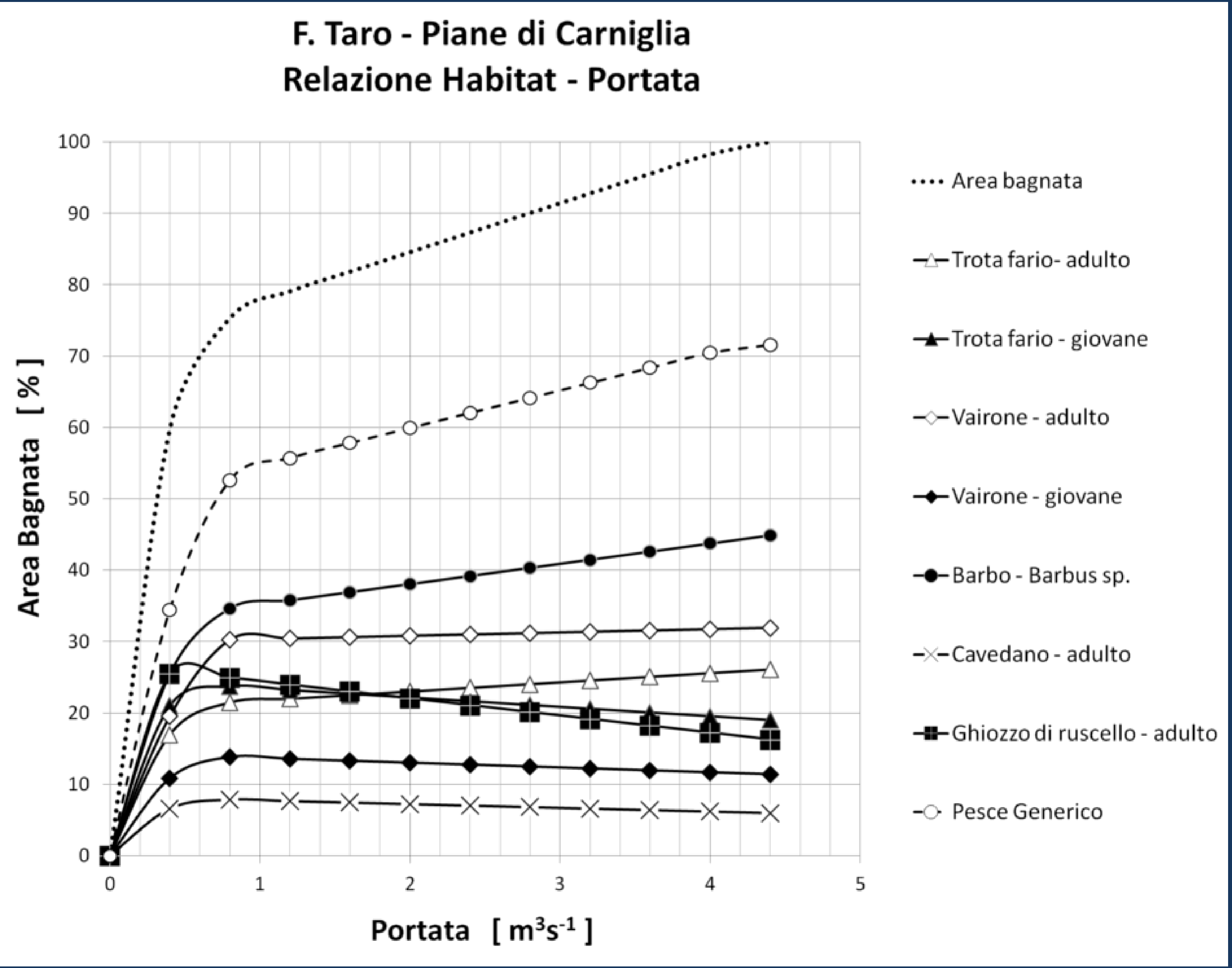
E.g., Taro River - Piane di Carniglia (PR)



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

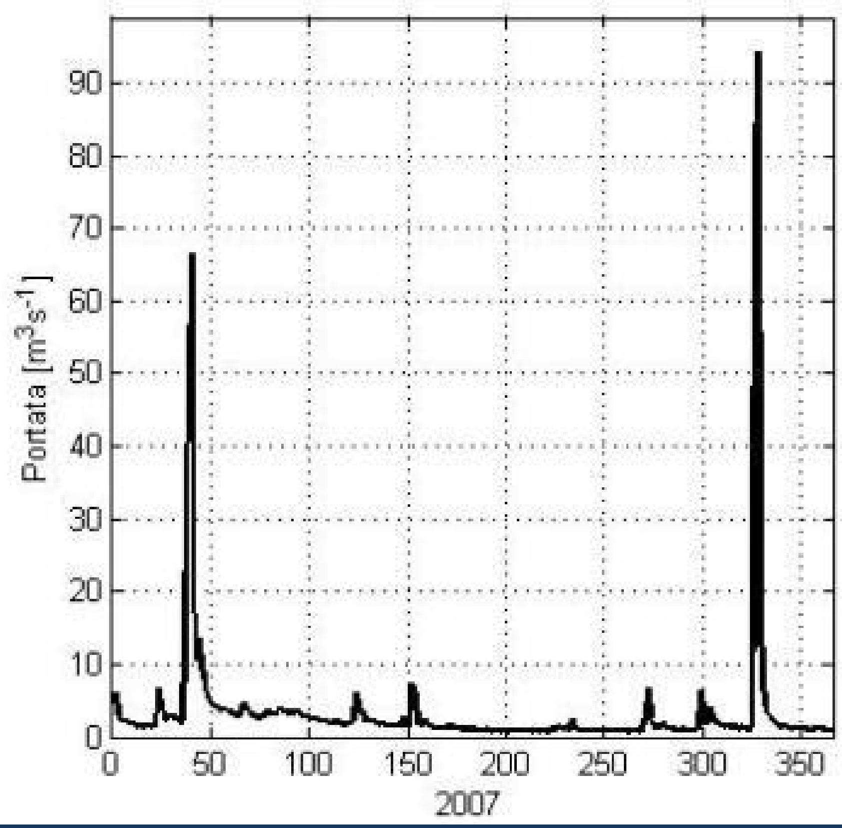


Habitat-Flow rating curve

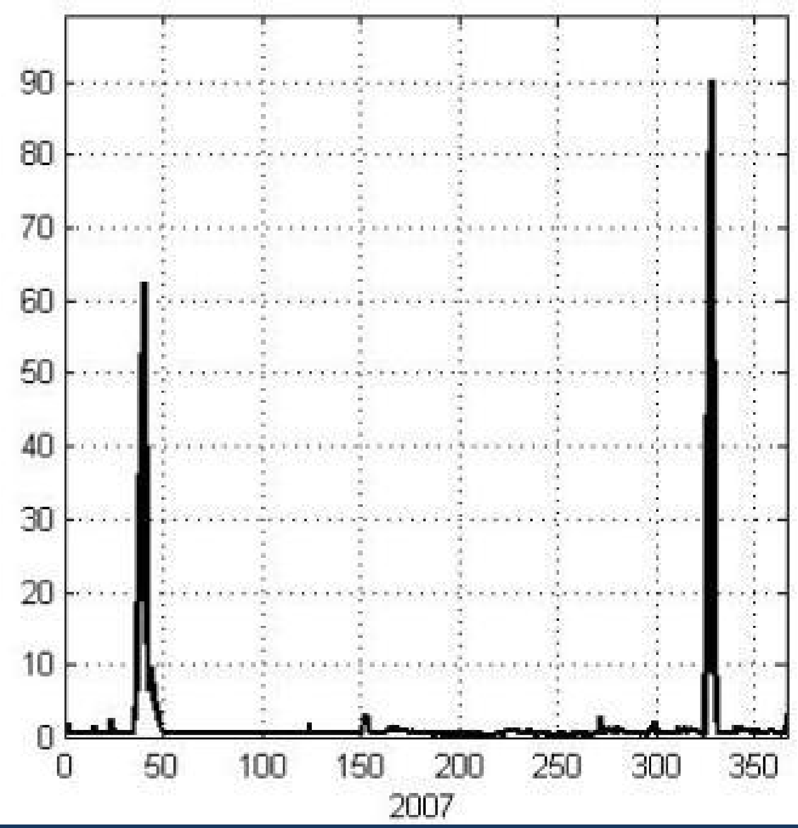


Taro River – Piane di Carniglia (PR)
Year 2007

Reference

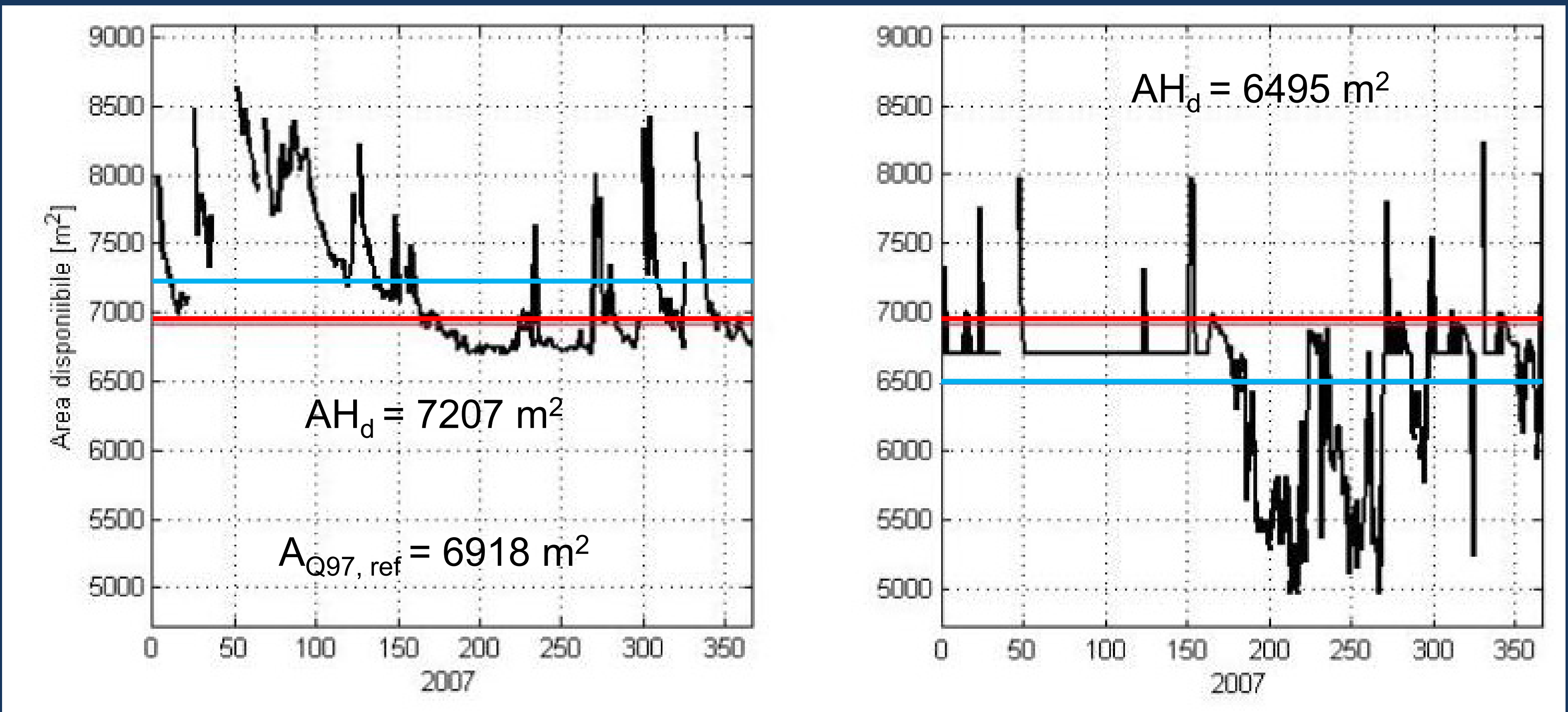


Altered



ISH
Index of Spatial Habitat availability

Reference | Altered

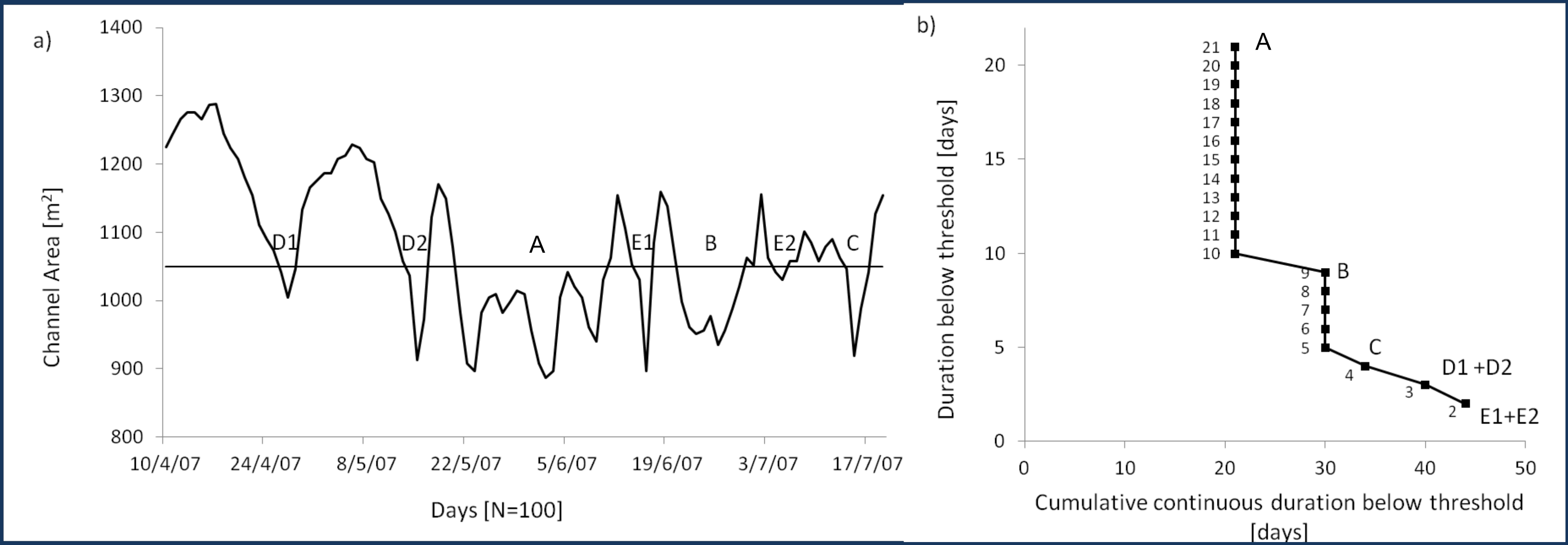


ISH$_{barbel}$= 6495 / 7207 m^2 = 0.90

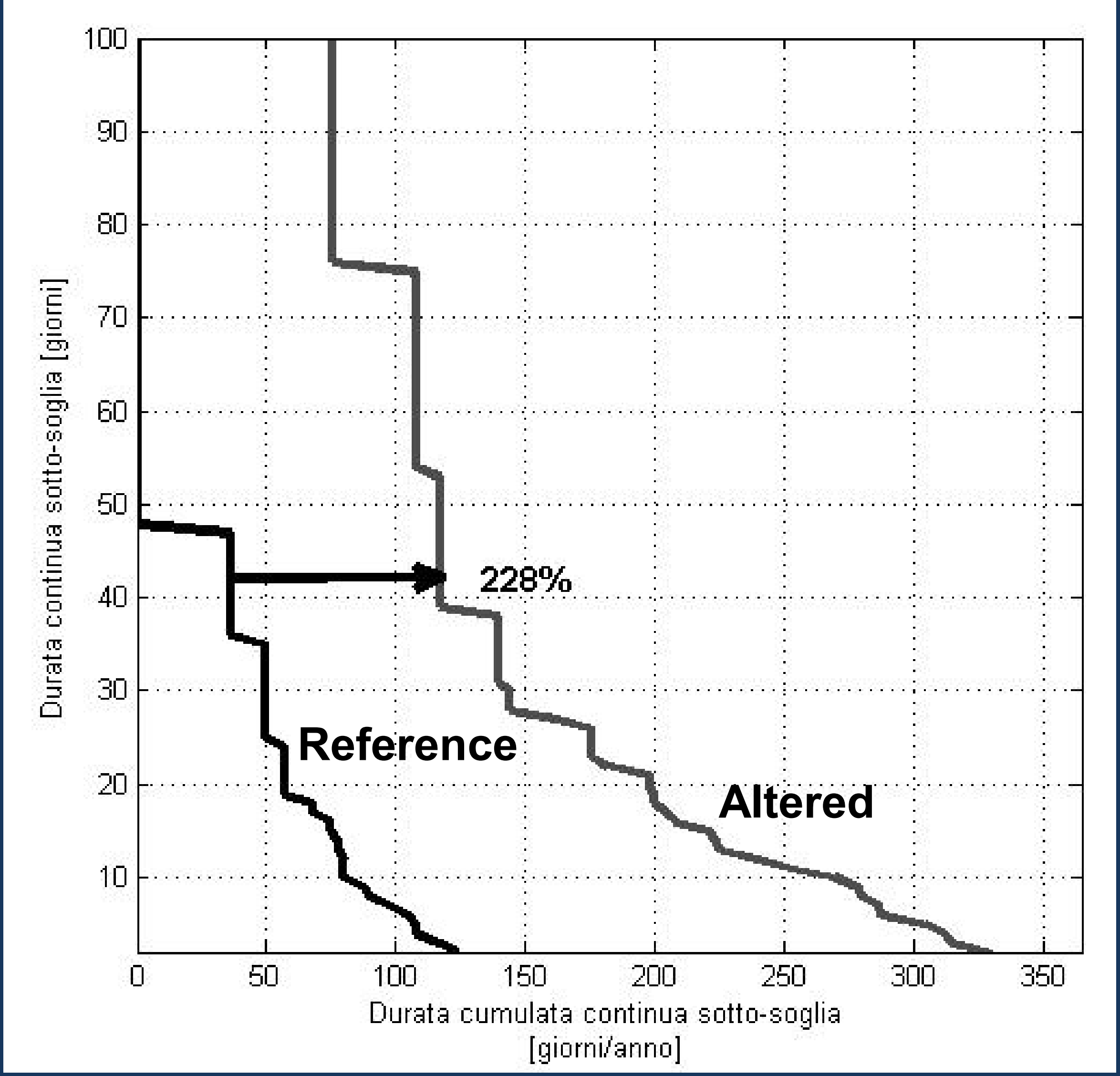
Habitat time series

Curve UCUT

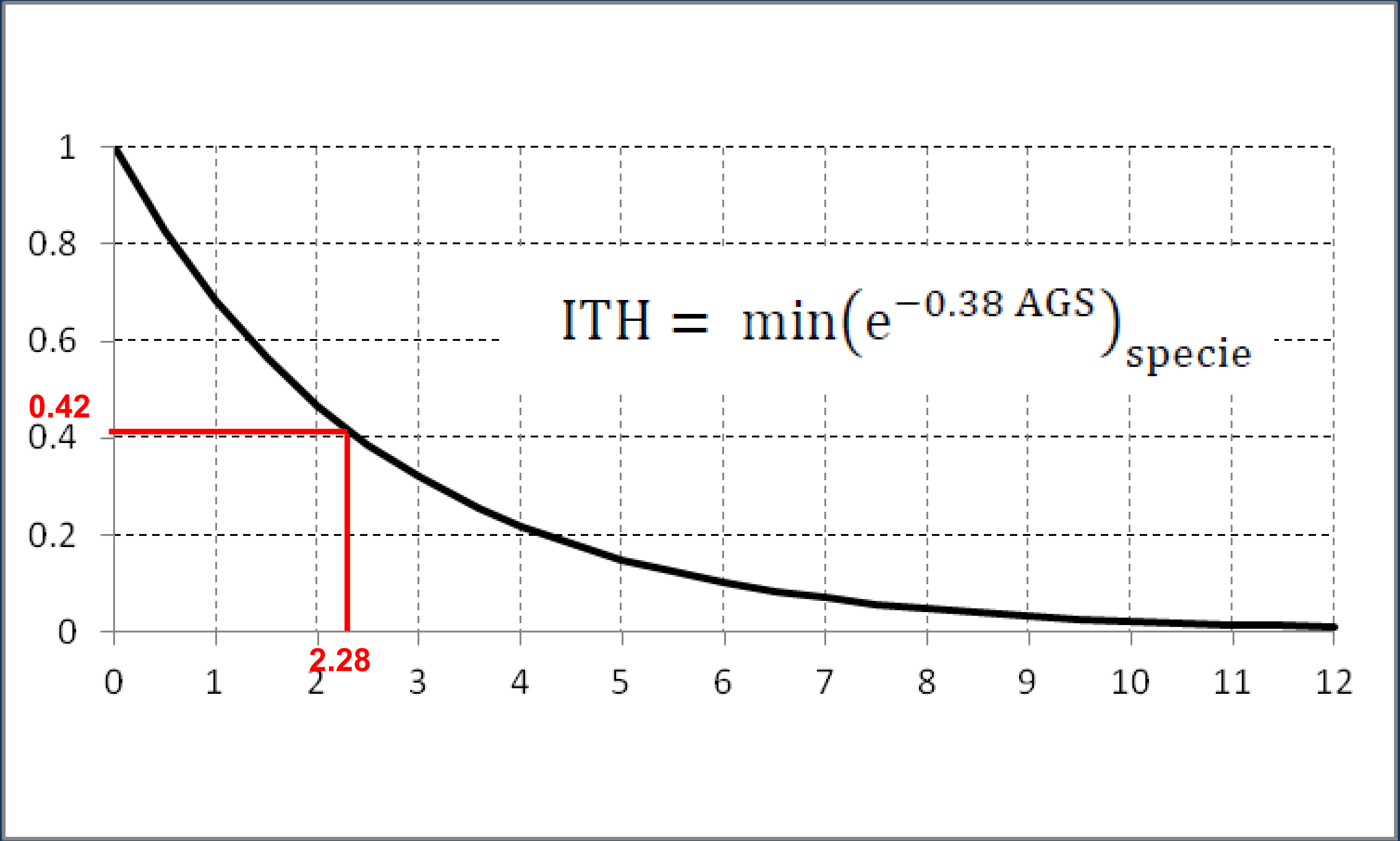
(Uniform Continuous Duration Under Threshold)



Stress Days Alteration



ITH – Index of Temporal Habitat availability



AGS_{barbel} = 228% → ITH_{barbel} = 0.42

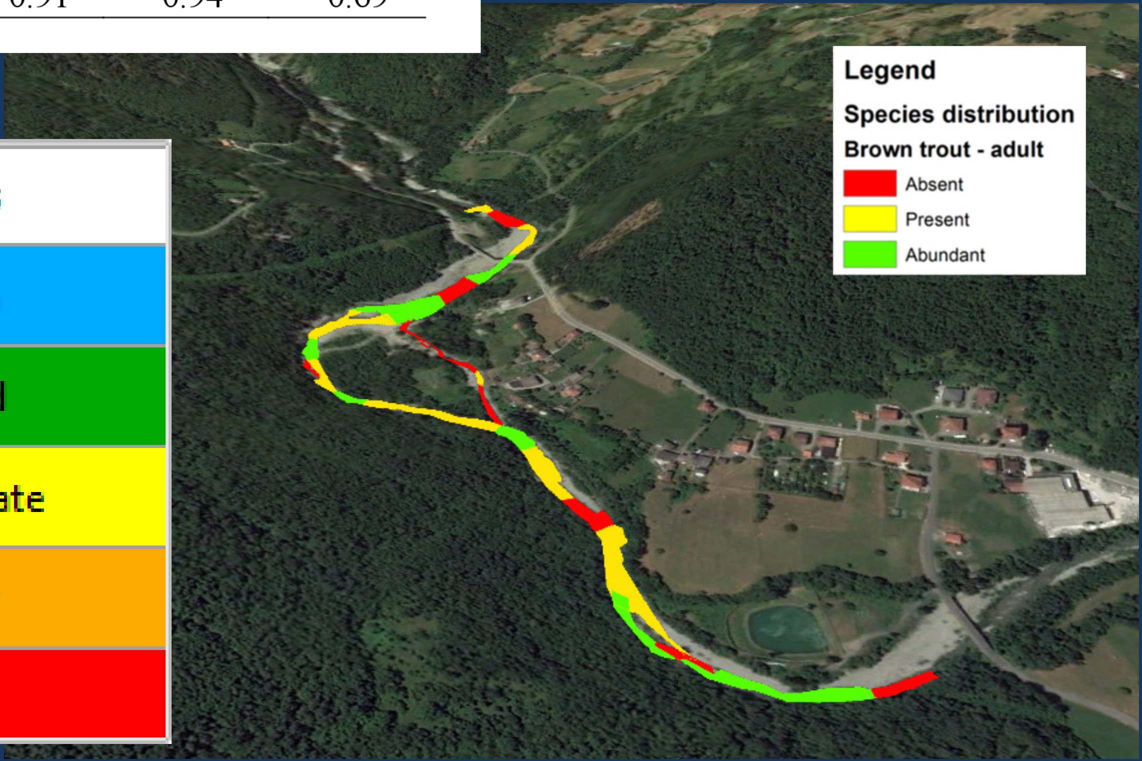
IH – Index of Habitat Integrity

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

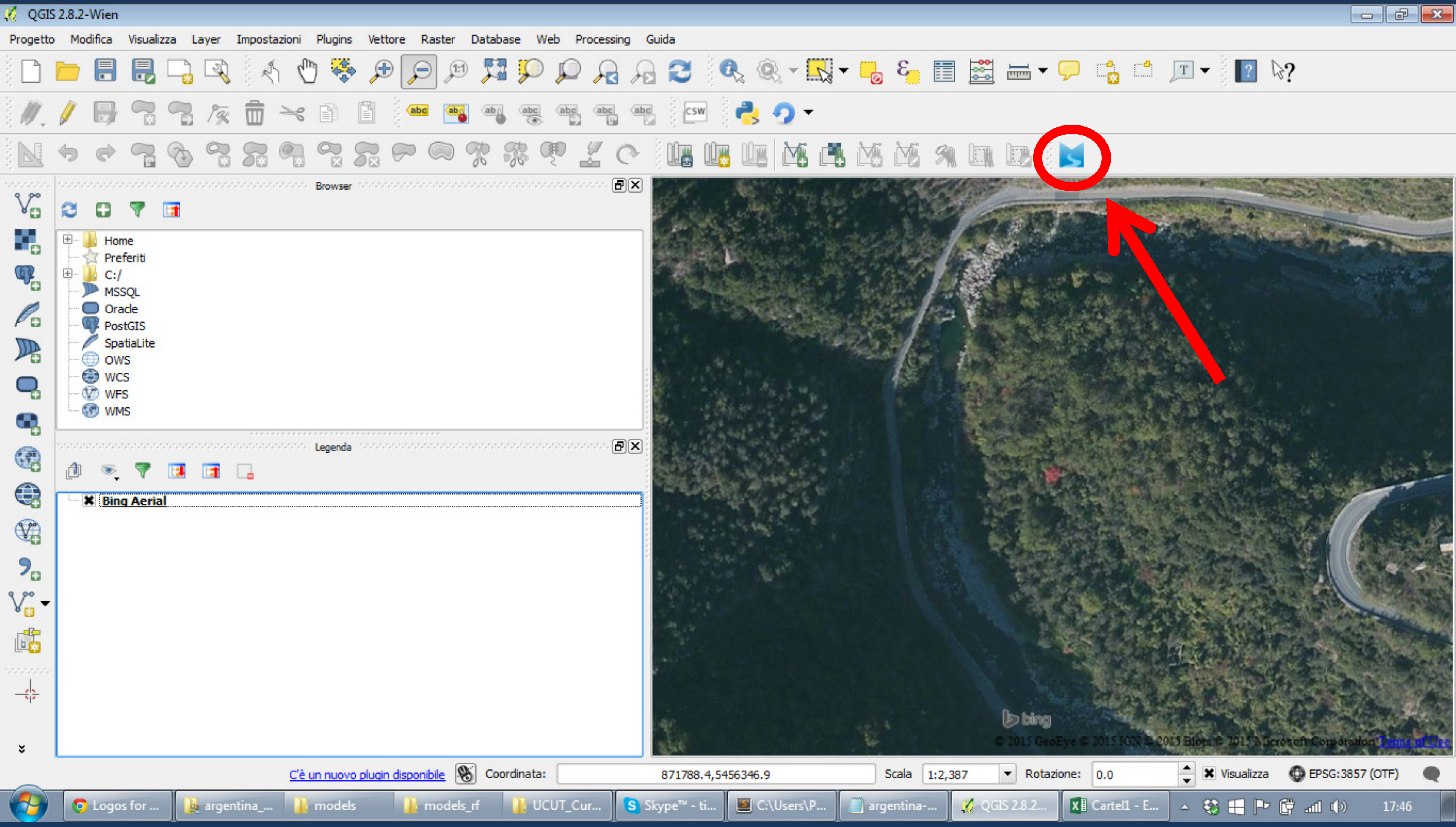
Specie/stadio vitale	ISH	AGS	ITH
Trota fario - adulta	0.92	1.60	0.54
Trota sp. - giovane	0.97	0.86	0.72
Vairone - adulto	0.95	0.13	0.95
Vairone - giovane	0.99	0.93	0.70
Barbo – Barbus sp.	**0.90**	2.28	**0.42**
Cavedano - adulto	0.97	0.83	0.72
Ghiozzo - adulto	0.91	0.94	0.69

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

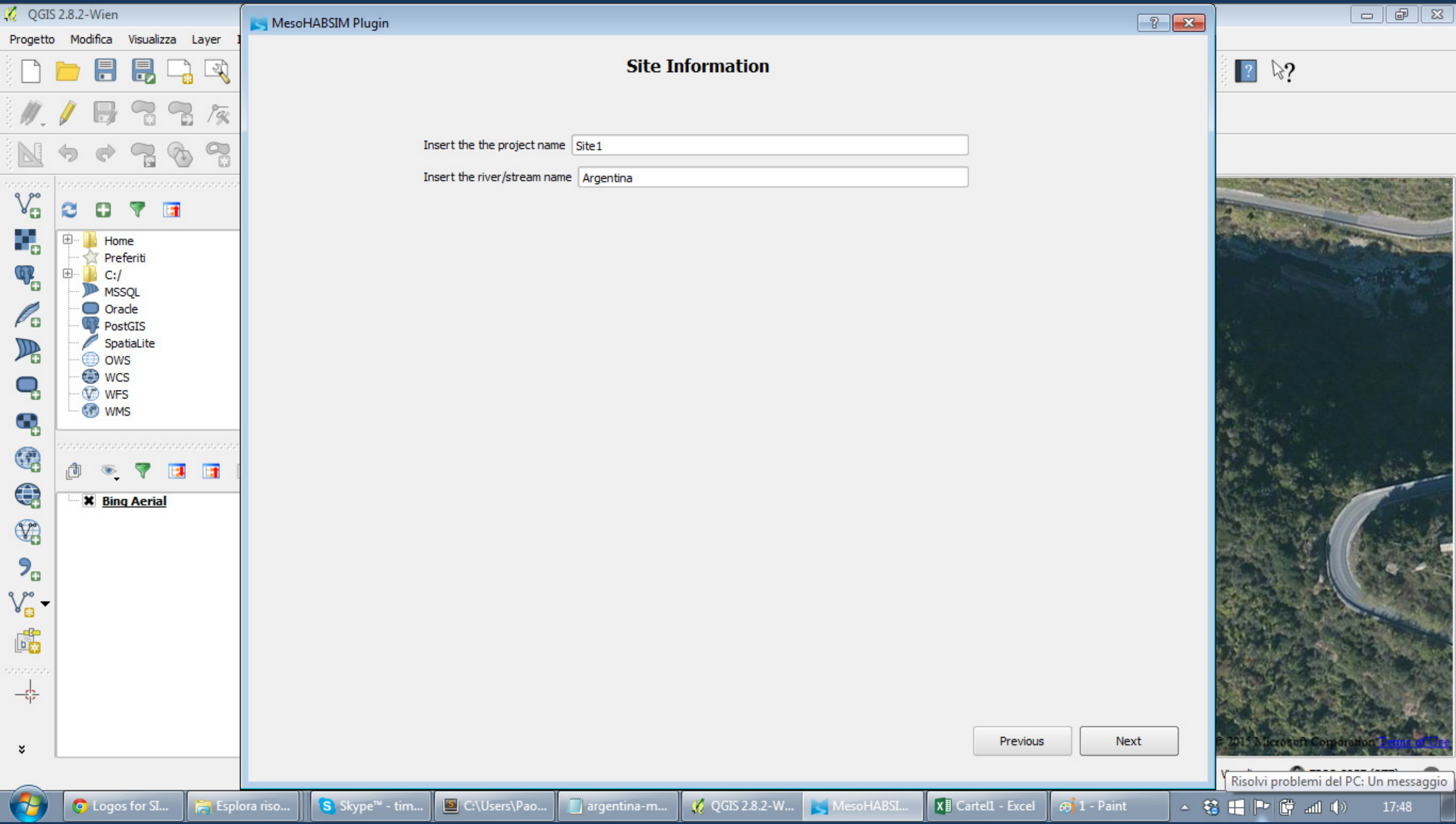
IH	Class
IH ≥ 0.80	High
0.60 ≤ IH < 0.80	Good
0.40 ≤ IH < 0.60	Moderate
0.20 ≤ IH < 0.40	Poor
IH < 0.20	Bad



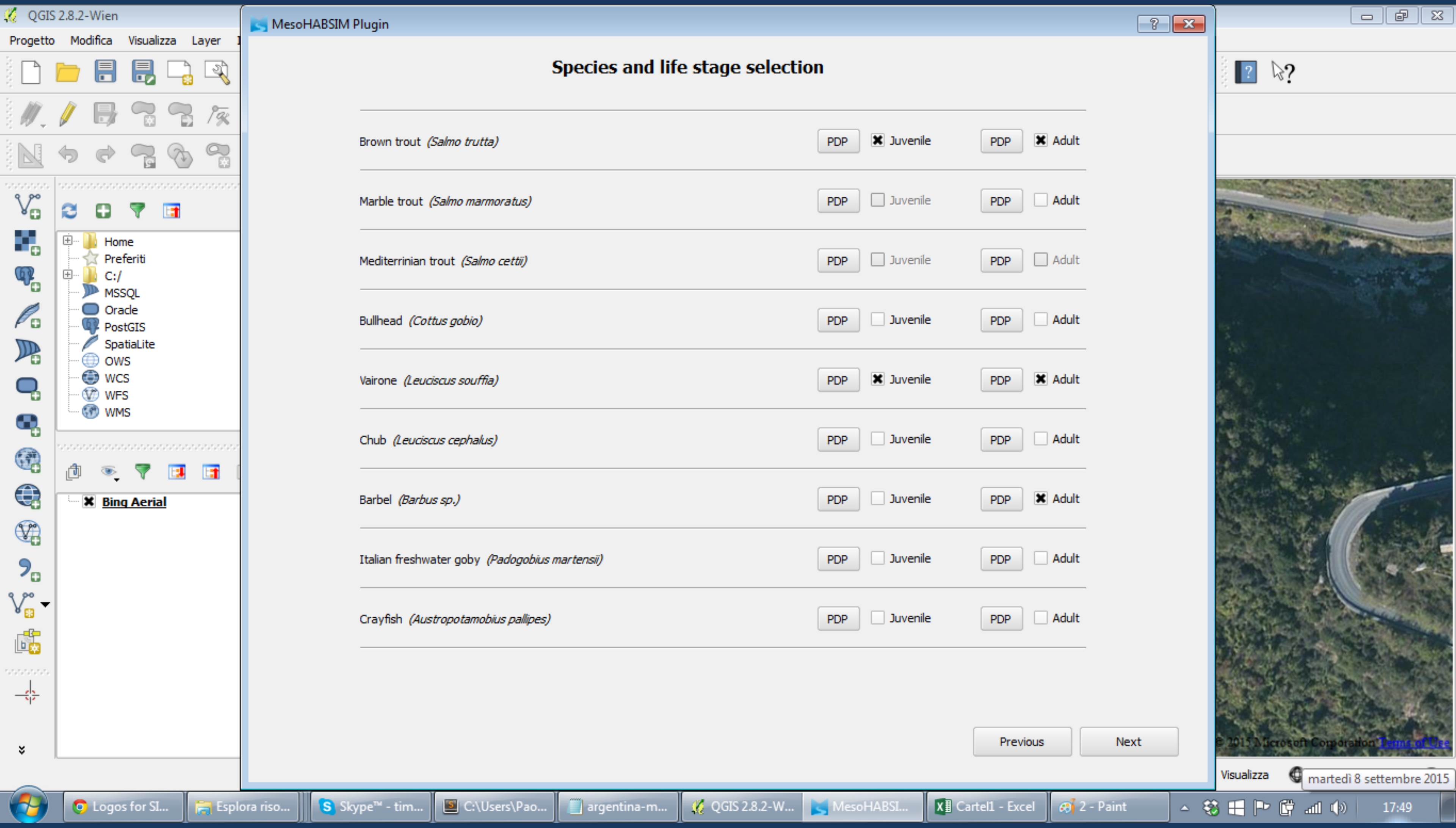
QuantumGIS plug-in



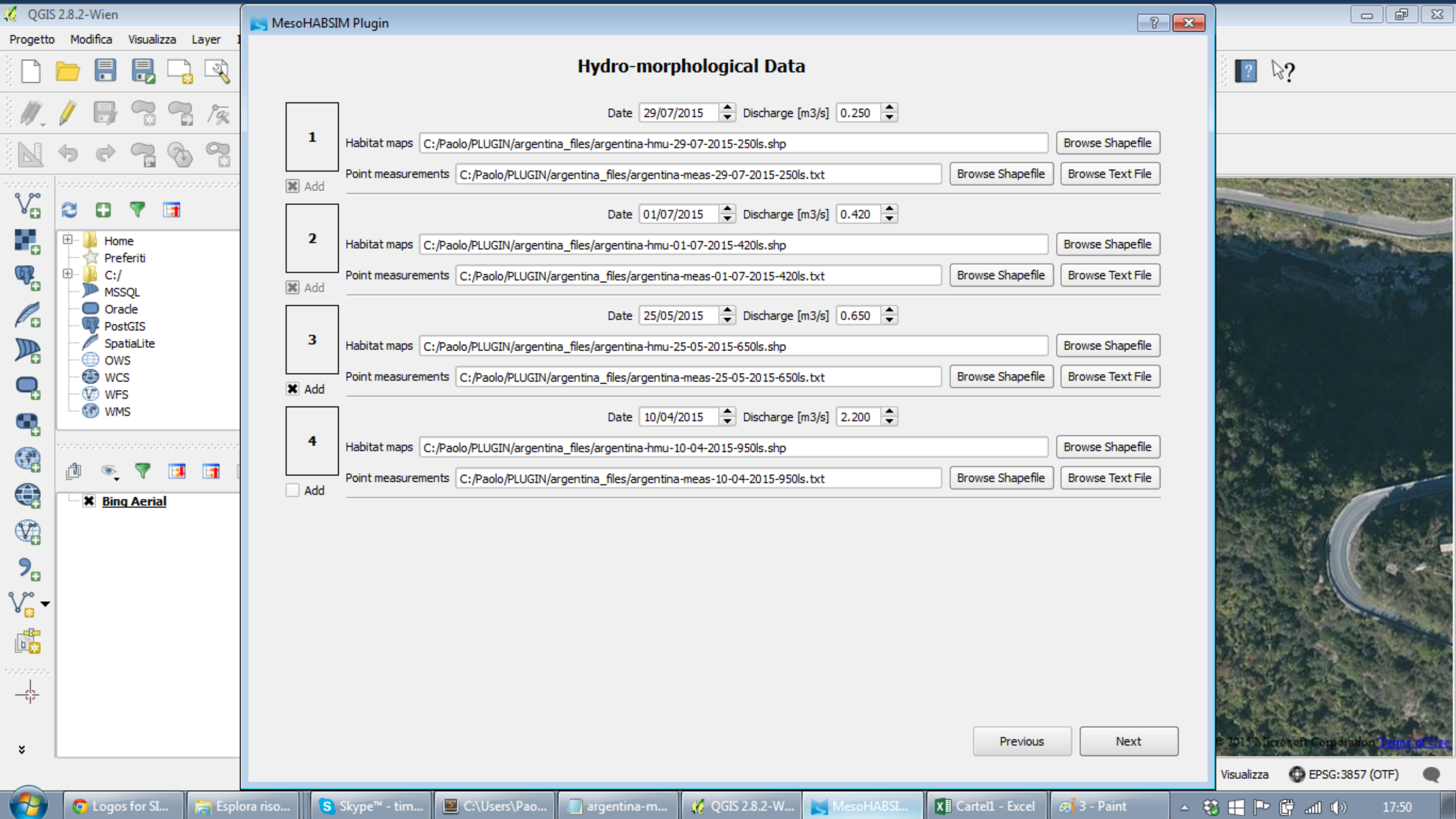
QuantumGIS plug-in



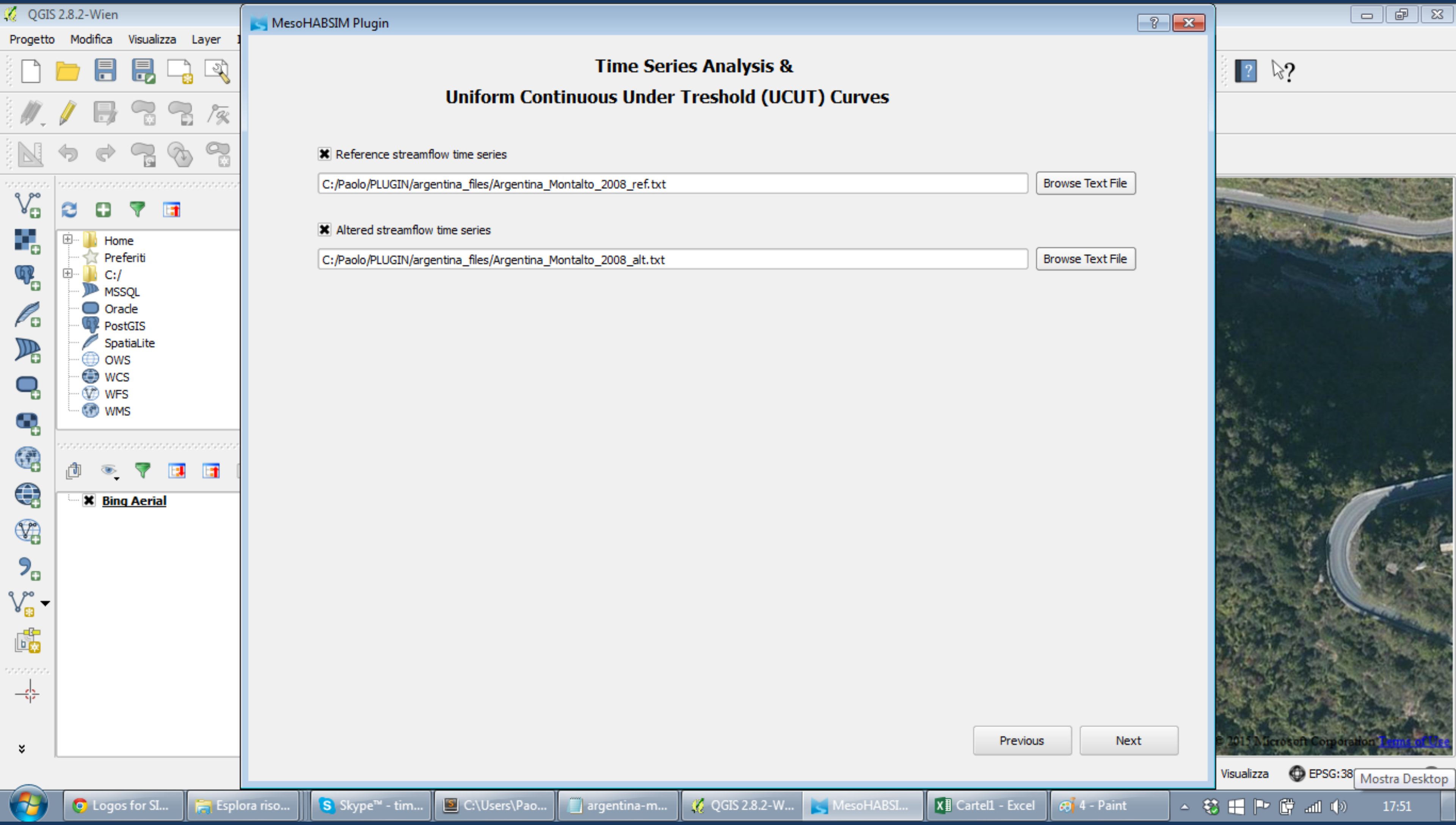
QuantumGIS plug-in



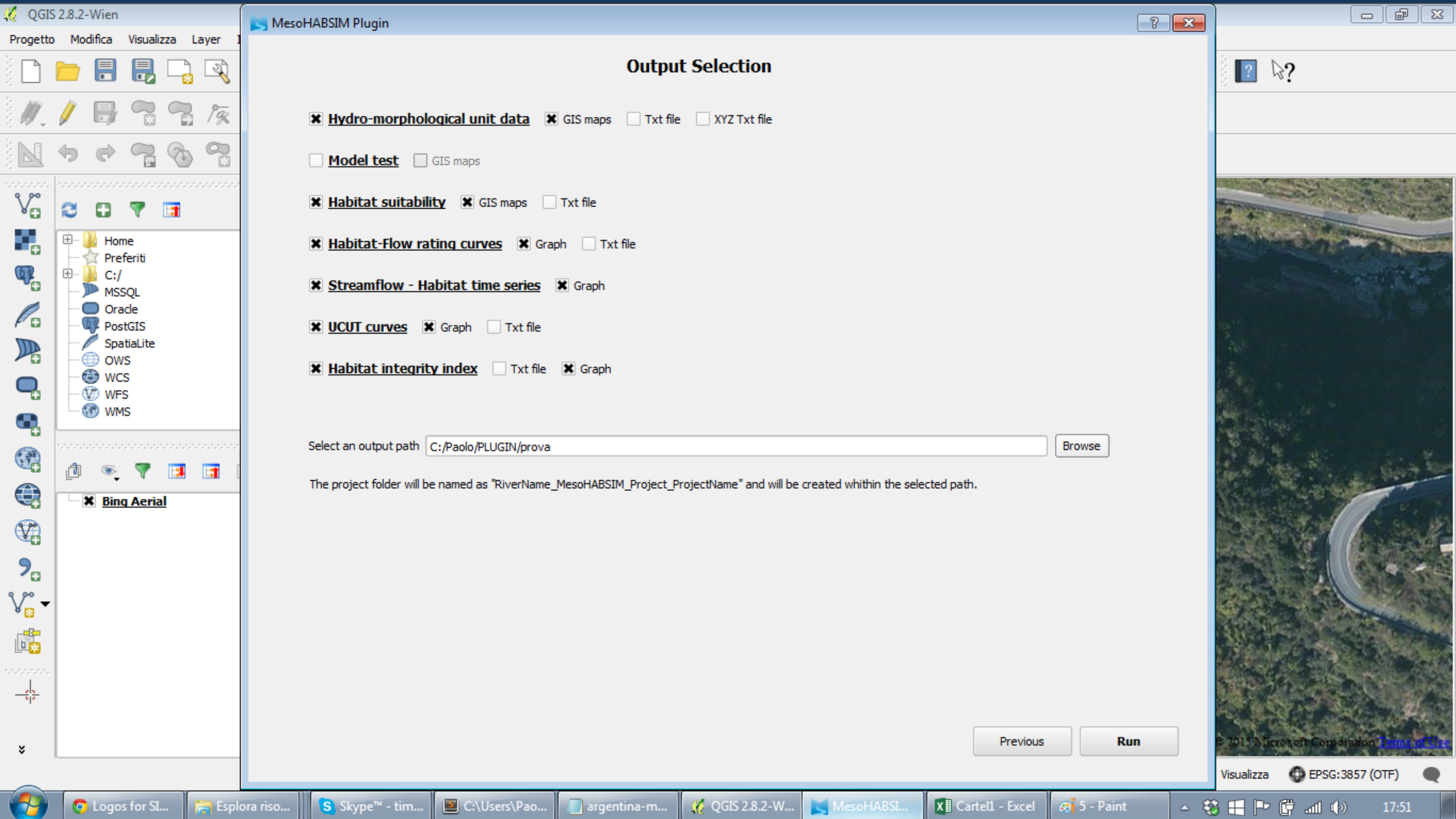
QuantumGIS plug-in



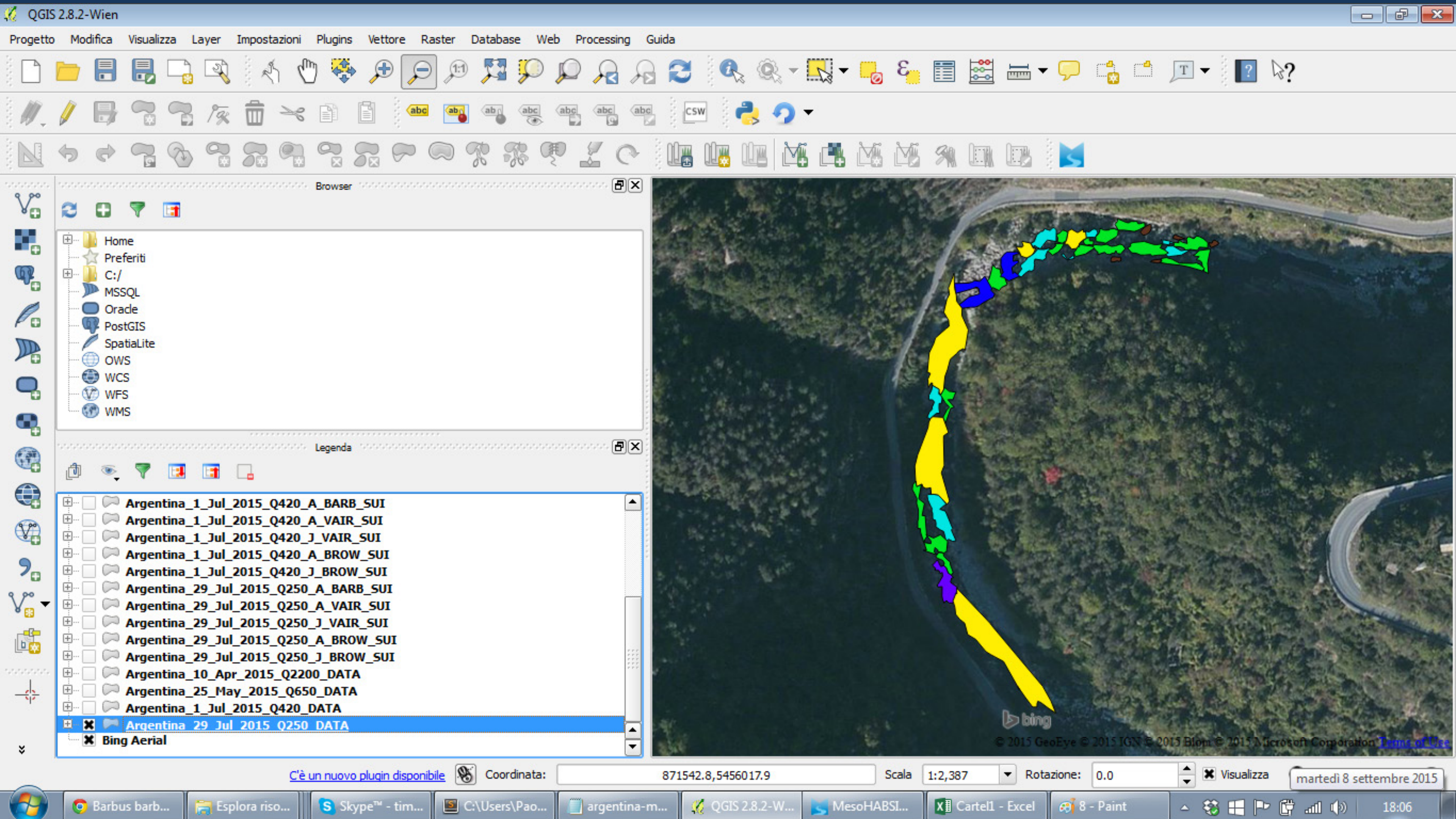
QuantumGIS plug-in



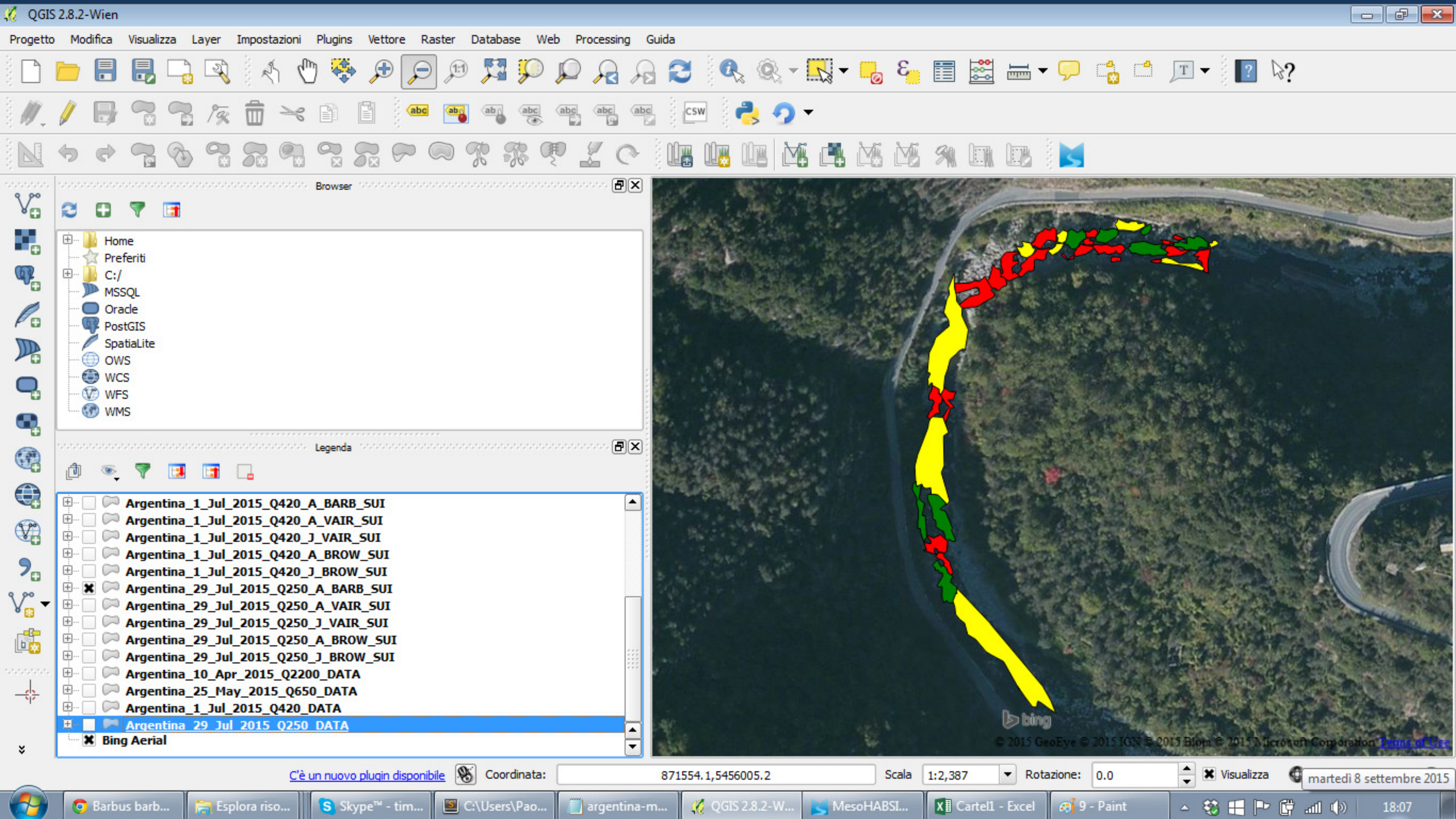
QuantumGIS plug-in



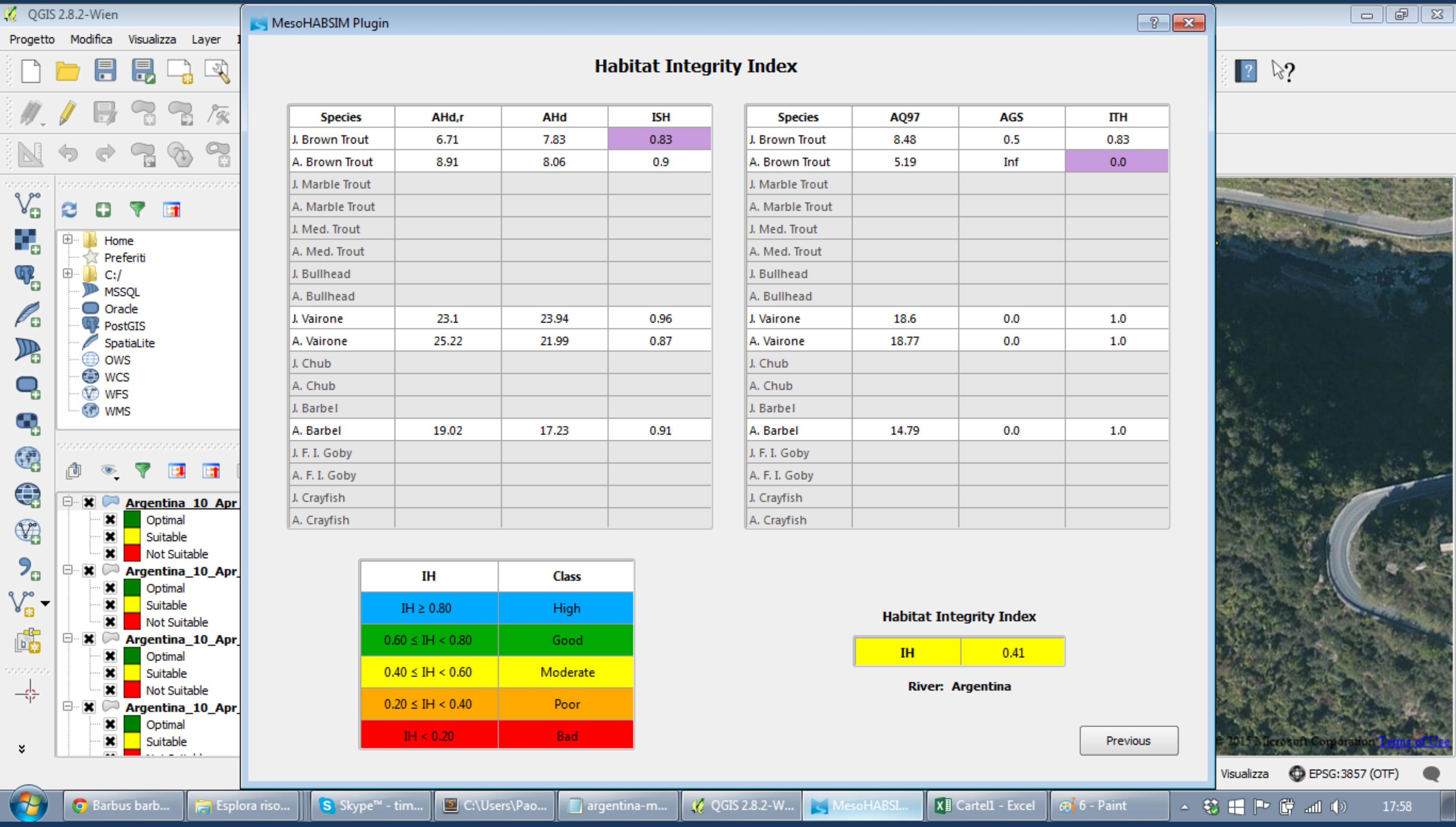
QuantumGIS plug-in



QuantumGIS plug-in



QuantumGIS plug-in



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 ≥ 0.80	High
0.60 ≤ IH < 0.80	Good
0.40 ≤ IH < 0.60	Moderate
0.20 ≤ IH < 0.40	Poor
IH < 0.20	Bad

Habitat Integrity Index

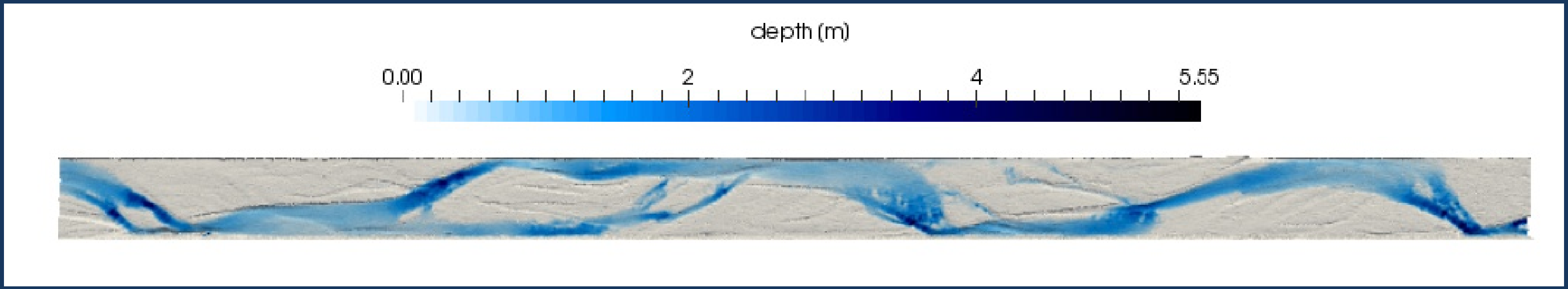
IH	0.41

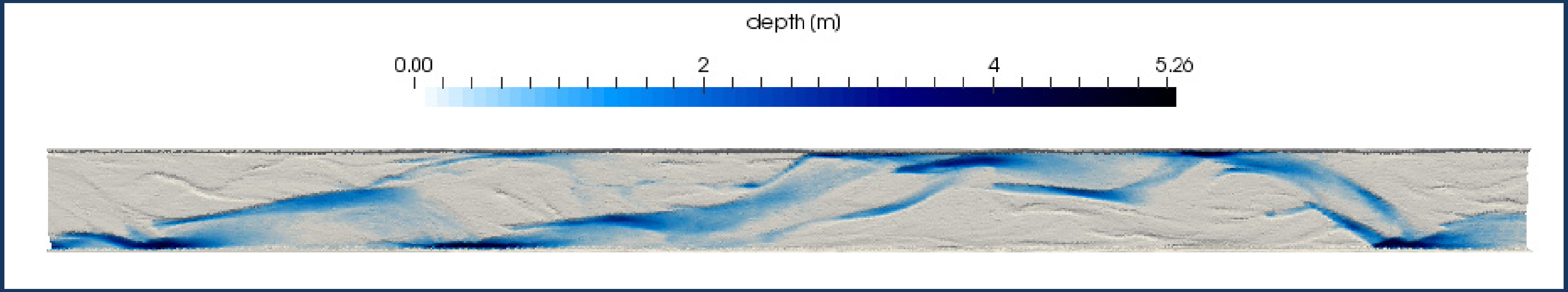
River: Argentina

Sediment release from dams

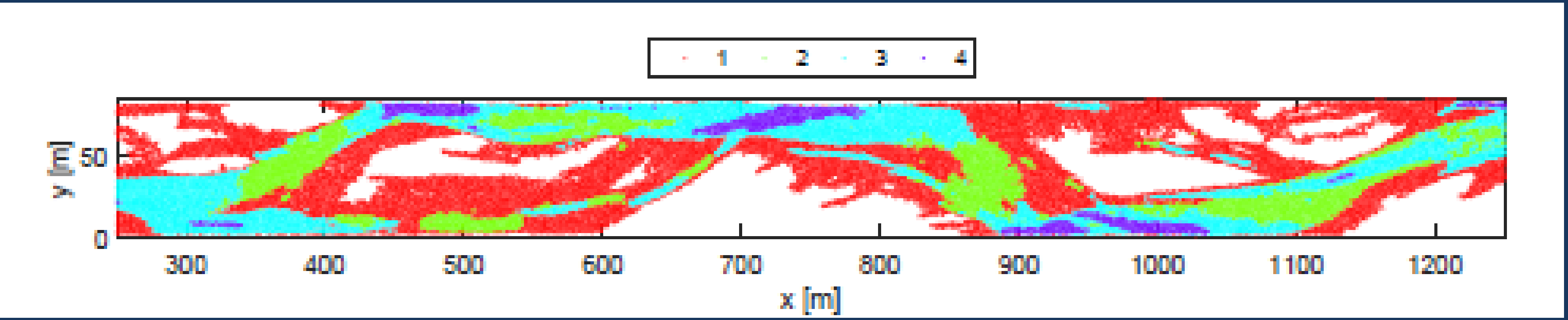
Sediment by-pass tunnel

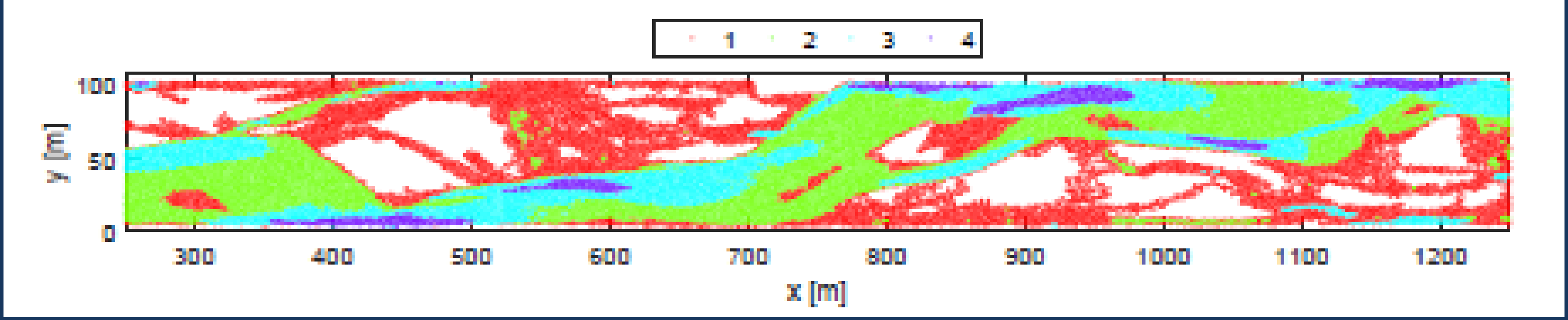
Including morphodynamics in habitat evaluation





Unsupervised mesohabitat classification





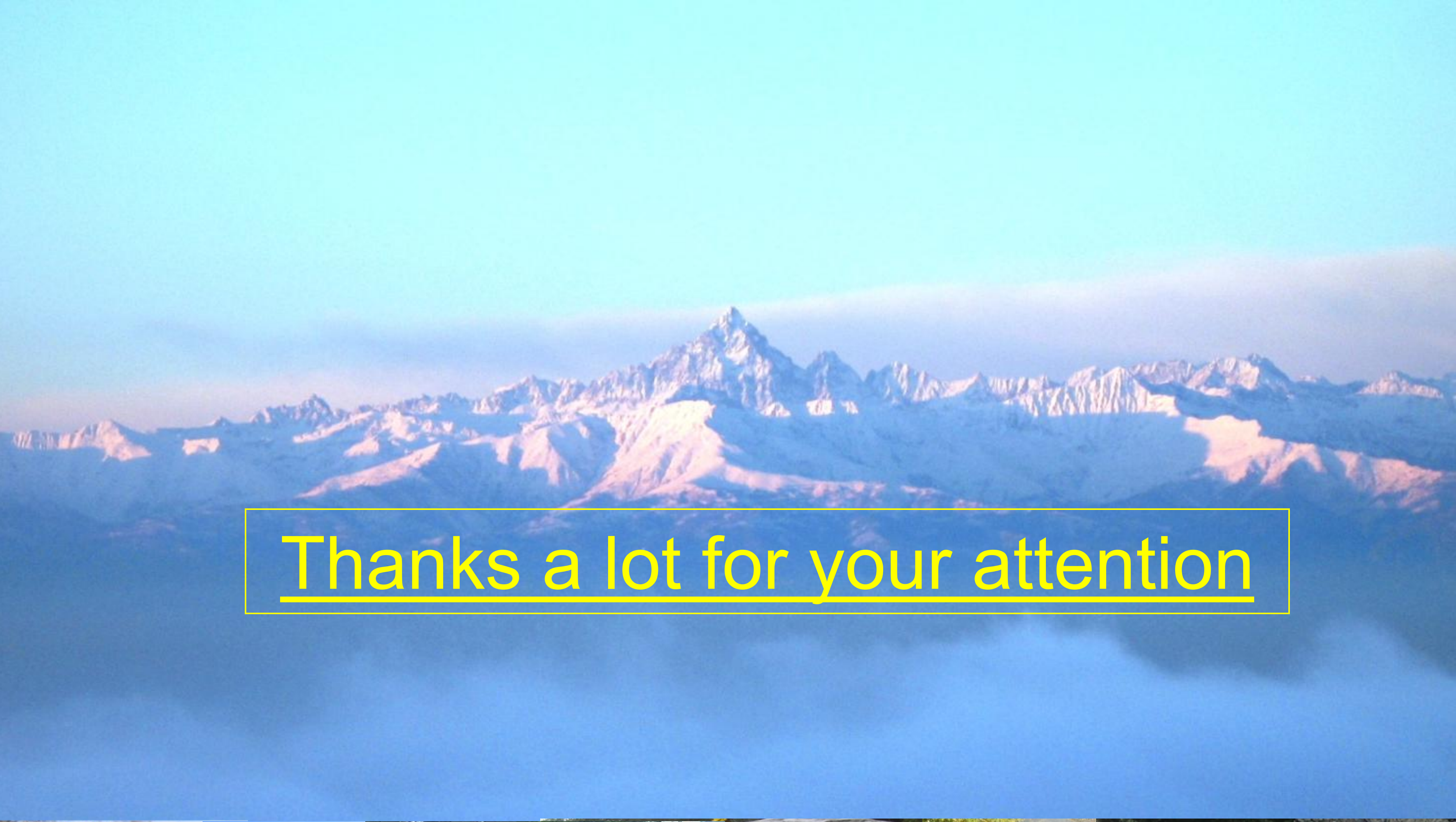
Conclusions

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