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A hydro-ecological assessment method for temporary rivers. The Candelaro river case study (SE, Italy)

A.M. De Girolamo[1]
F. Gallart[2]
G.Pappagallo[1]
G.Santese[1]
A. Lo Porto[1]

1. *Water Research Institute -National Research Council, Bari, Italy*
2. *IDAEA-CSIC, Barcelona, Spain*

Background

- The European Water Framework Directive (WFD) aims at achieving the “good chemical and ecological quality status” of water bodies.
- Aquatic systems must not significantly depart from reference “natural” conditions.
- The hydrological regime of a stream is relevant since it may influence the ecological status and then the definition of actions to be taken.
- This is particularly important for intermittent rivers since flow varies on spatial and temporal scale depending on precipitation patterns and is severely disturbed by flash floods and dry periods.
- We argue that intermittent rivers need that some specific adaptations should be introduced in the WFD implementation process.
- Some EU Member States have developed a definition for intermittent rivers based on the number of flow days per year.

WFD

⇓

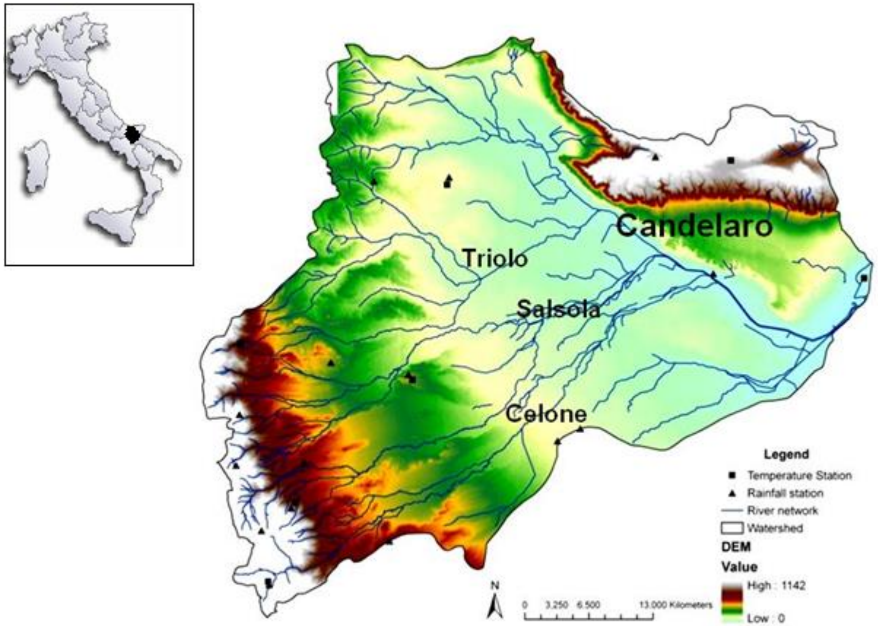
Good Ecological Status

Chemical | **Biological** | **Hydrological**

Objectives

- Defining a methodology to evaluate the **Hydrological Status** for temporary rivers
- Testing of tools to evaluate eventual departure of reach hydrological classification from the natural status.

The Candelaro River



The Candelaro river basin is one of the three important regional river basin with a well defined surface hydrography.

It is located in the second plain in Italiy in an important intensive agricultural area.

The Candelaro river flows down to an important National nature reserve wetland area

It is served by the largest Italian Irrigation Consortium.

Several EU and National research project carried out in the area.

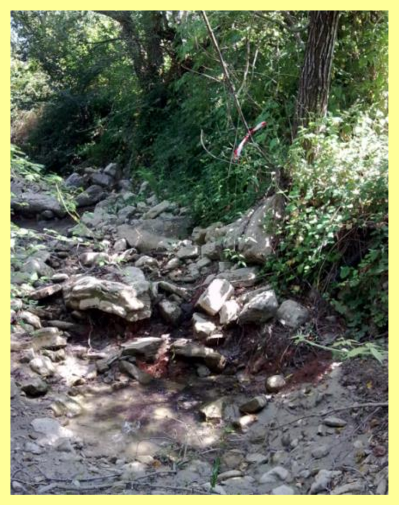
Includes some Vulnerable Zones (EU Nitrates Directive).

Member of the Pilot River Basins set up by the WFD-CIS.

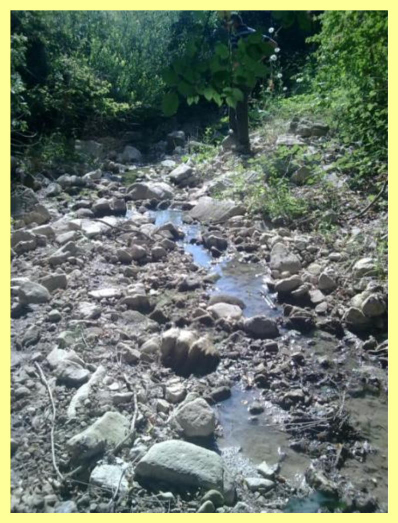
Analysing flow regime at reach scale

Gallart and Prat propose to analyse streamflow at reach scale. The method is based on the relative frequencies of the occurrence of specific flow conditions

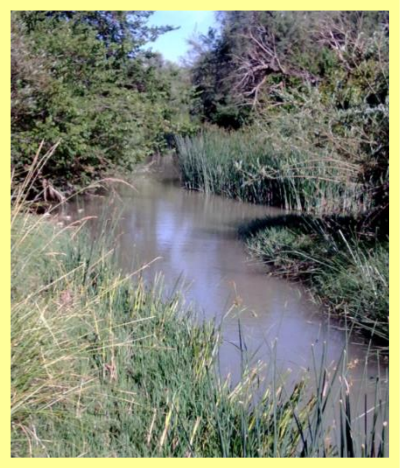
DRY



DISCONNECTED POOLS



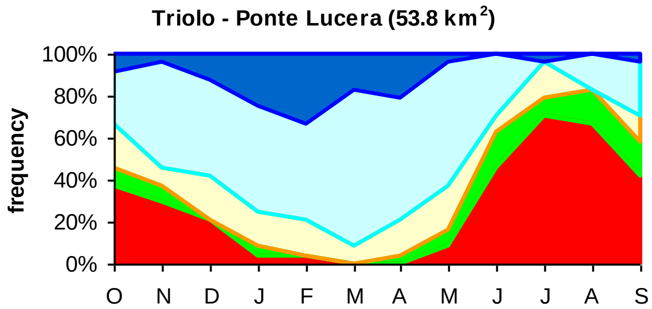
CONNECTED POOLS

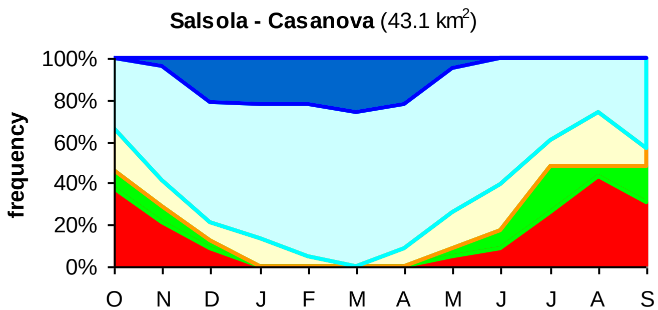


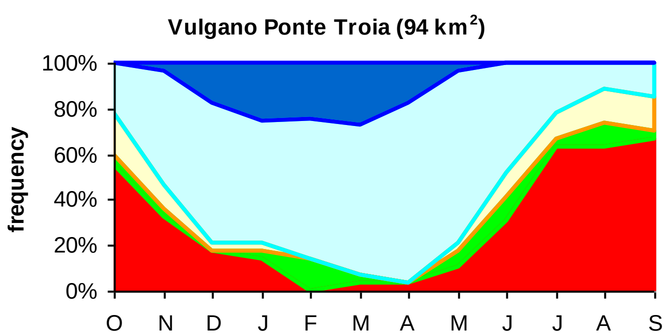
RIFFLE

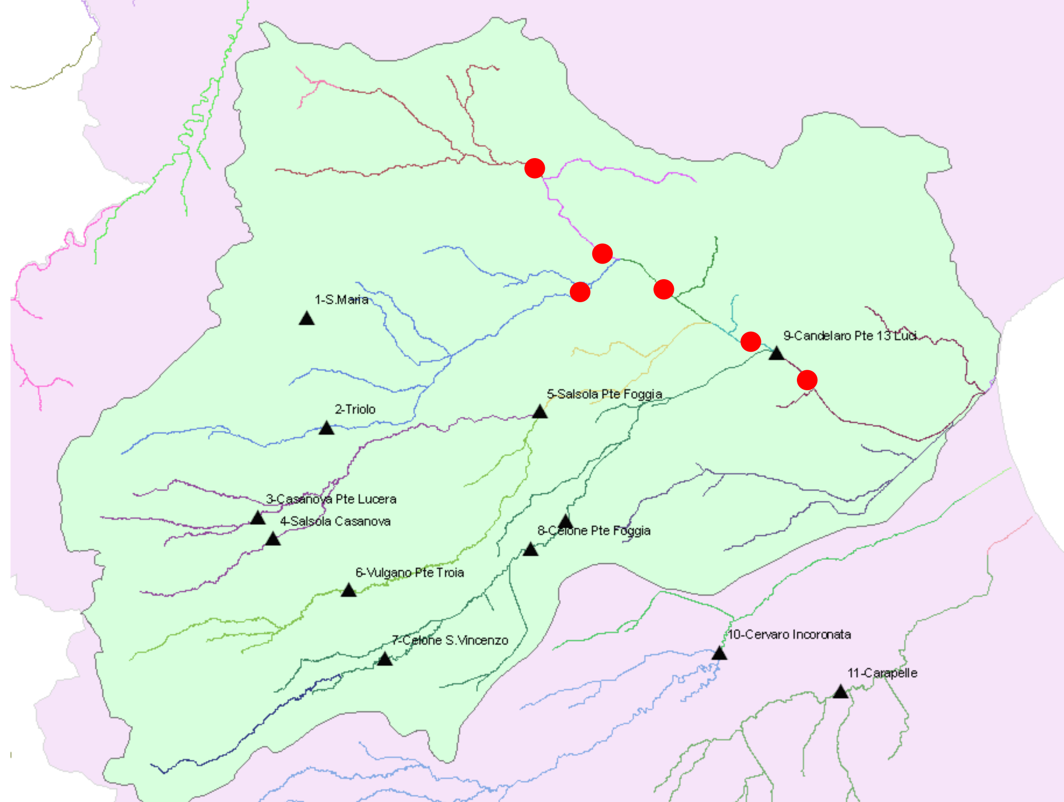
FLOOD

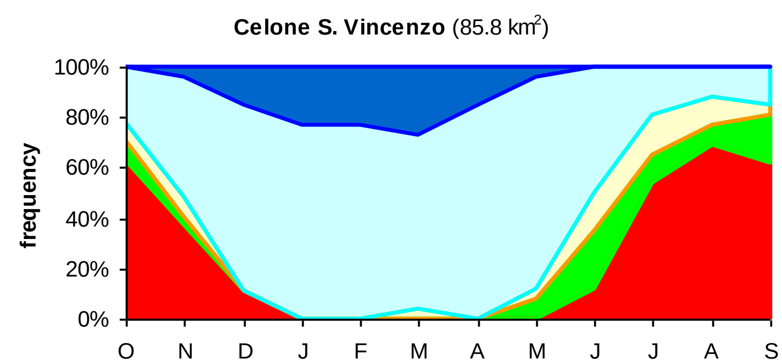
Frequency of Flow Status











dry pools connected riffles flood

Seasonal regime

Floods occur in winter and early spring

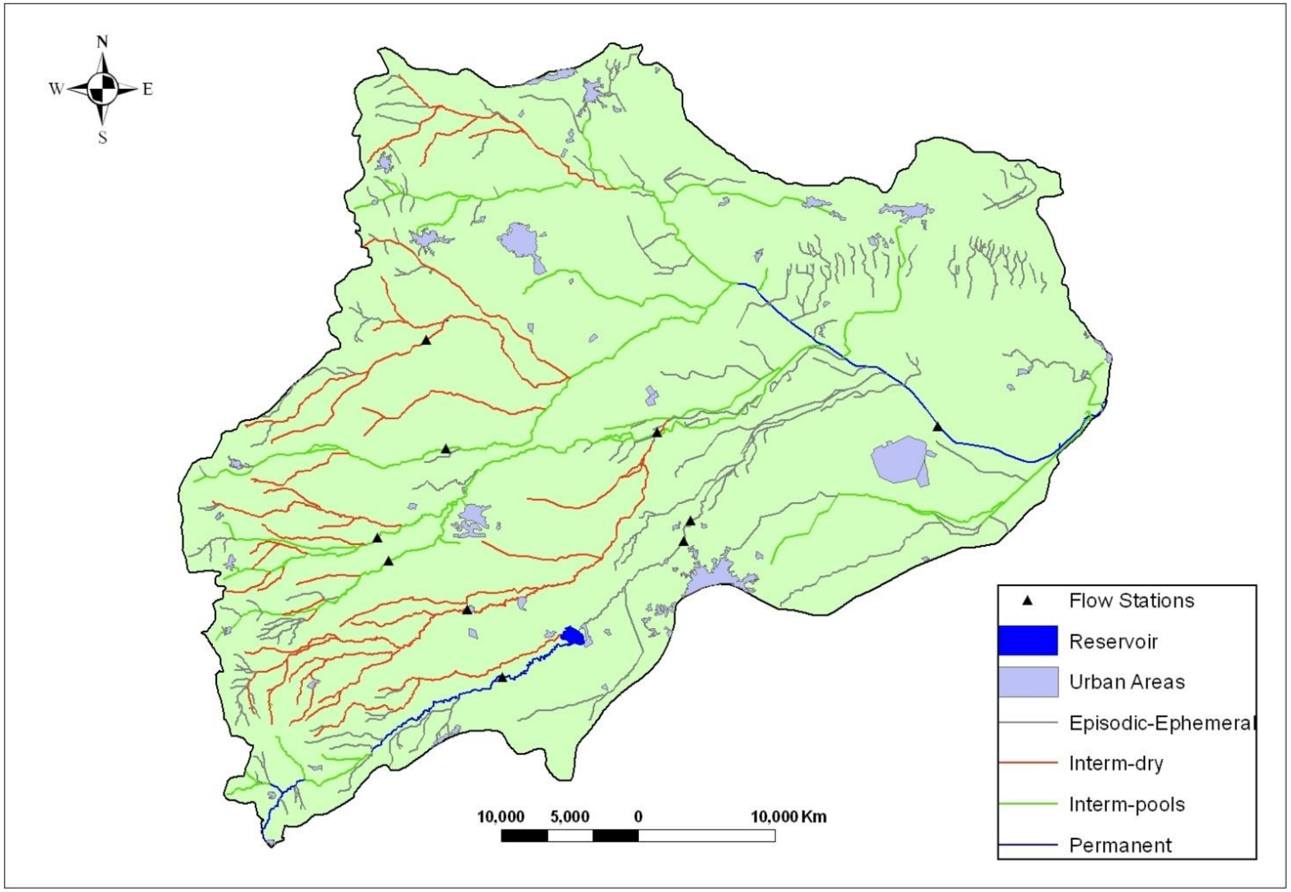
Dry conditions occur from May to December

Permanent, intermittent-pools, intermittent-dry or episodic? (MIRAGE Project suggestion)

Stream type	*Flow duration*	*Pools duration*	*Dry period*
Permanent	*≥ 10 months per year*	*≤ 2 months per year*	*No occurrence*
Intermittent-pools	*≥ 3 months per year*	*≤ 9 months per year*	*≤ 1 month*
Intermittent-dry	*≥ 3 months per year*	*≥ 1 but < 3*	*≥ 1 month*
Ephemeral-Episodic	*< 2 months per year*	*< 2 months*	*≥ 10 months*




Types of temporary streams



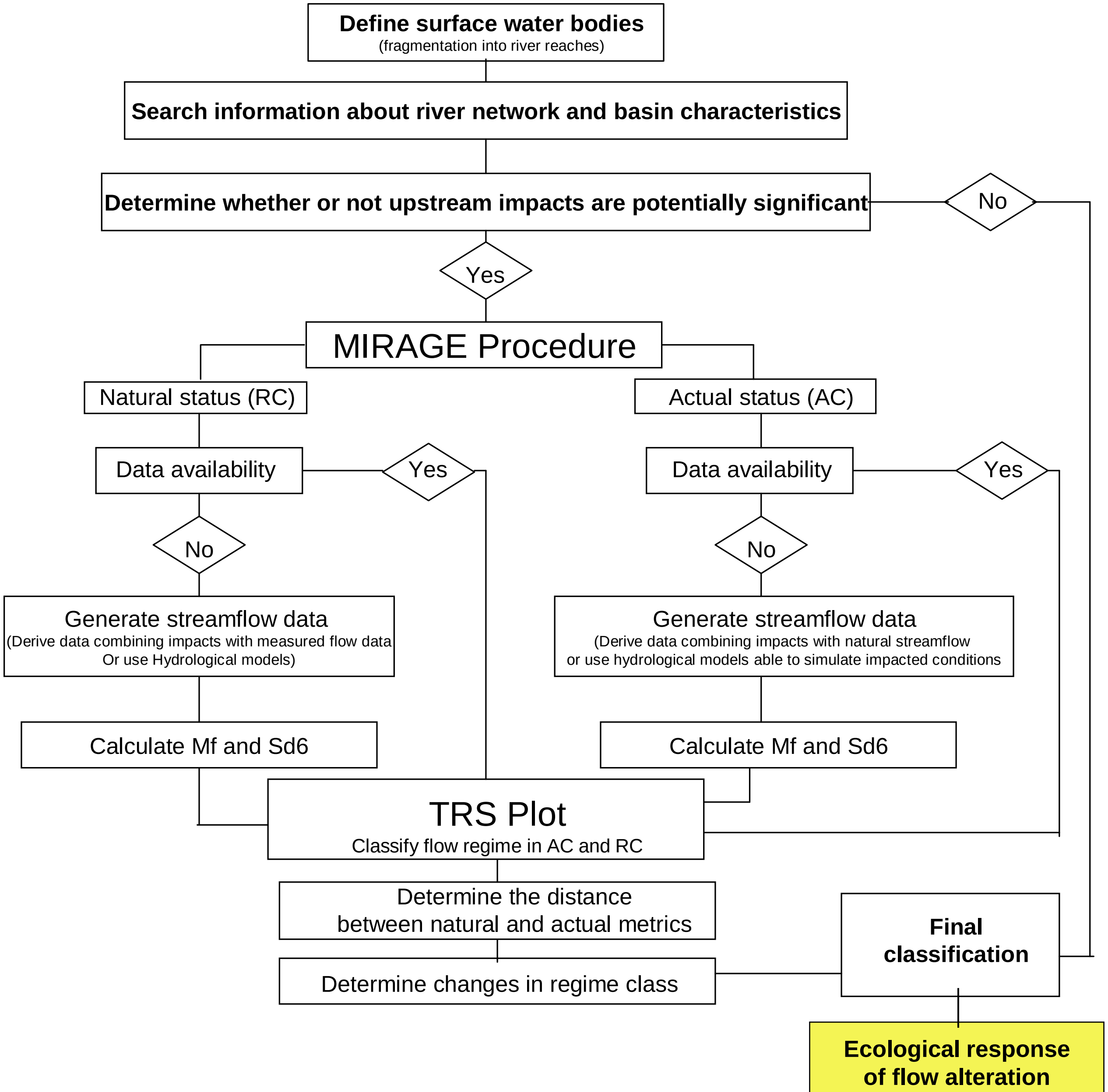
General Classification	Number of River Segments	River Length, Km	Total Length %
Episodic	123	350.01	31.57
Intermittent Dry	55	368.46	33.23
Intermittent Pools	53	316.49	28.55
Permanent	12	73.70	6.65

MIRAGE protocol to evaluate HS (Hydrological Status)

The method assumes that in temporary streams the interruption of flow is the main feature affecting the aquatic life.

Instead of using the several available statistics about flow, we decided to look for two metrics which focus on flow interruption and not on amount of flow (Gallart et al., 2012).

MIRAGE protocol to evaluate HS



A metric for efficient characterisation, ranking and comparison of stream regimes

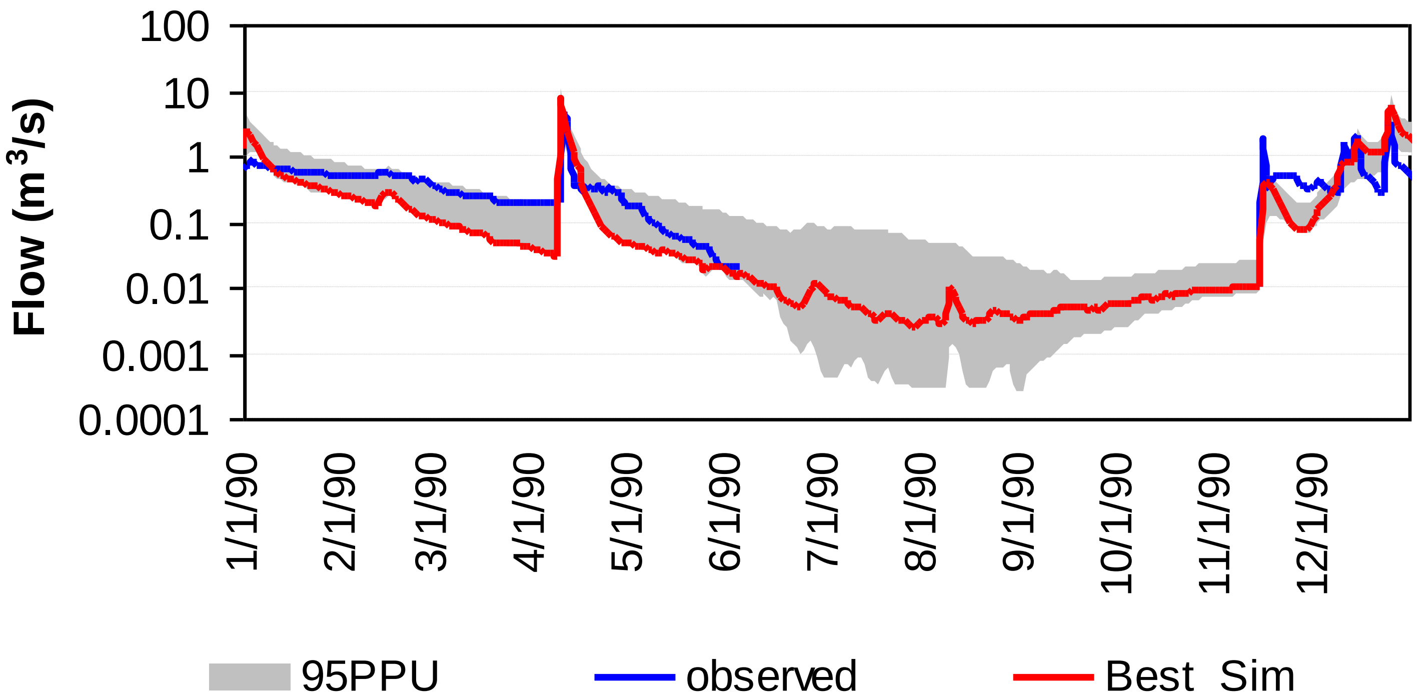
- Several indexes tested (IHA). Redundancy checked using PCA and correlation coefficients.
- Only flow permanence (Mf) and the seasonal predictability of dry periods (Sd6) were selected for the subsequent analyses.
- **Flow permanence** (Mf) = number of months with flow (rescaled 0-1)
- **Predictability** (Sd6) = the more orthogonal of the metrics tested.

$$Sd_6 = 1 - \left(\sum_{1}^{6} Fd_i \Big/ \sum_{1}^{6} Fd_j \right)$$

Fdi is the multiannual frequency of no-flow months for contiguous 6 wetter months per year

Fdj is the multiannual frequency of no-flow months for the 6 dryer months

Observed streamflow vs the “best simulation” for un-impacted conditions (reach Salsola gauge 4).



95% prediction uncertainty (95PPU) using SWAT-CUP

Model Performance for "low flow" conditions

	Gauge 4	Gauge 1	
NSE	0.56	0.61	Calibration
R^2	0.75	0.88	
NSE	0.58	0.41	Validation
R^2	0.78	0.77	

- It is well known that watershed models suffer from uncertainty in predictions from model structures, input data and parameters (Refsgaard et al., 2007).
- Uhlenbrook et al. (1999) pointed out that the effects of the model and parameter uncertainties were larger for low flow conditions than for the flood events.

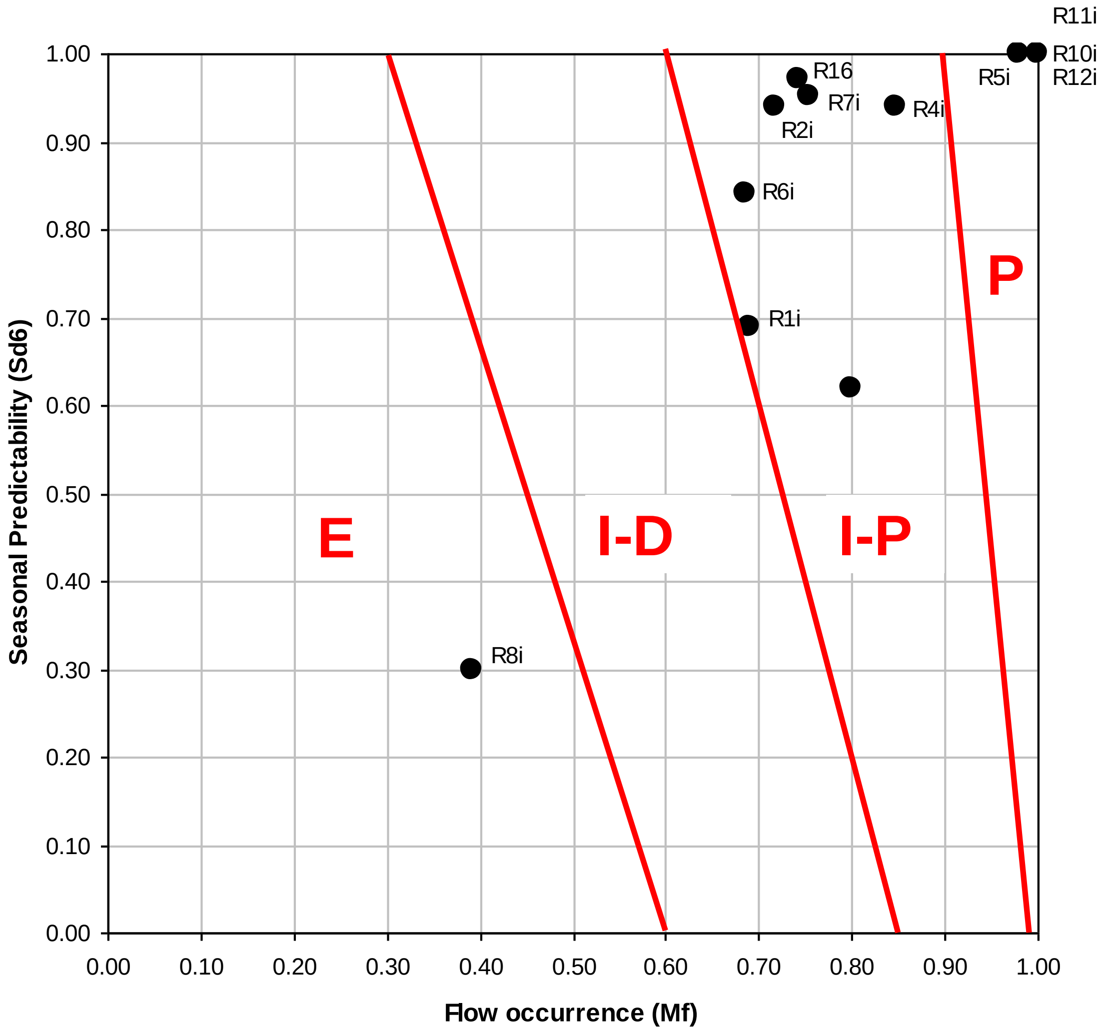
Realistic simulation of “no-flow” conditions

- The simulation of low flow may be a weak point in the use of hydrological models. Extreme low flow conditions tend to be overestimated by most hydrological models (Kirkby et al., 2011).
- The “no-flow” condition is a key point in the metric calculations, thus, it is critically important to understand if the extreme low flow conditions predicted by the model are realistic or not.
- If predicted extreme low flow in the “best simulation” is not zero in those reaches which are recognized as temporary streams, a correction of calculated flow series is needed before calculating the metrics.
- We define “Zero Flow” threshold the simulated streamflow value that corresponds to actual dry conditions (no flow) in a reach.
- This value is specific for each river section depending on the local conditions such as geology, hydraulic conductivity and river bed permeability, transmission losses, and channel width.

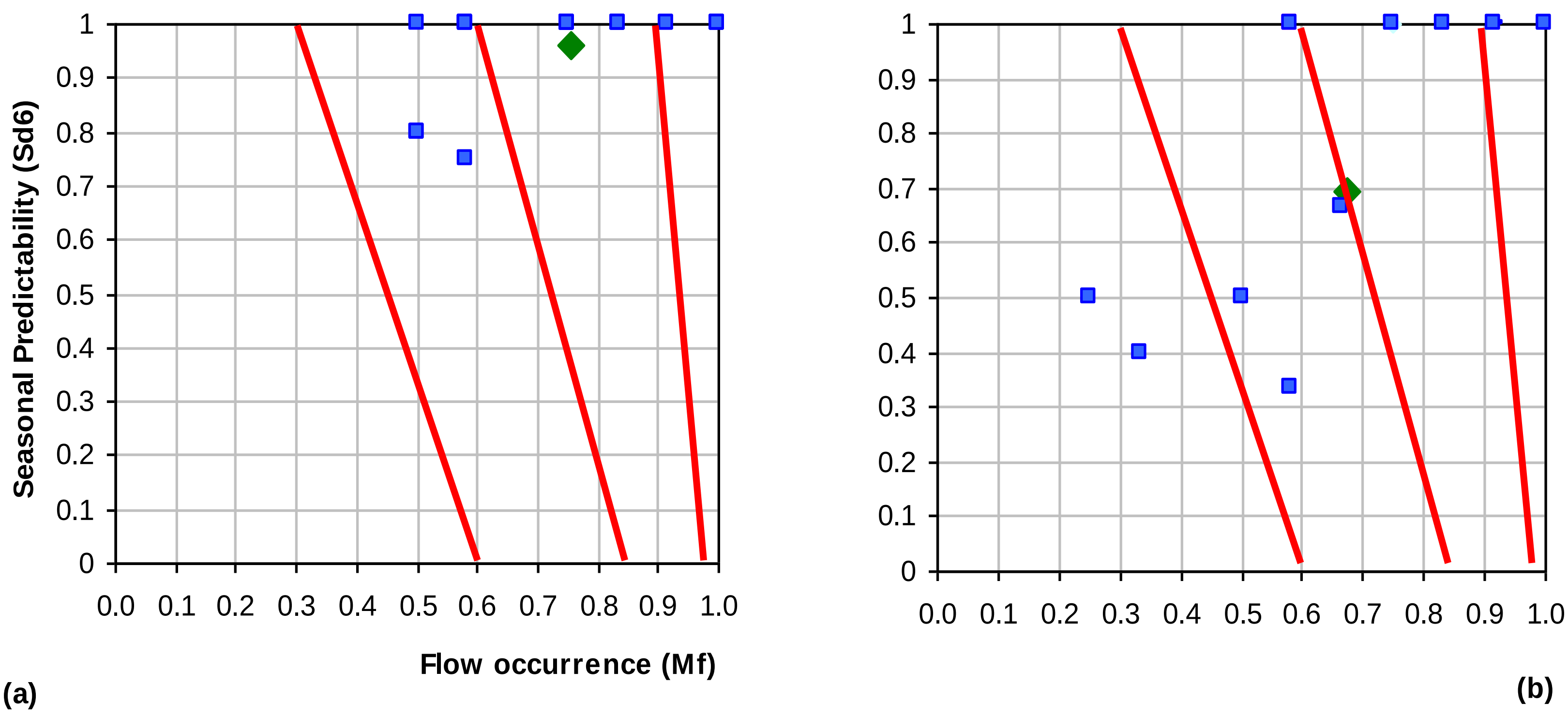
Zero Flow Thresholds: corrections

- These “zero flow” values should be determined contemporaneously comparing simulated and measured streamflow data.
- An attempt has been made to define these thresholds.
- In correspondence with the driest summers recorded in the past (1990) during which the river network was dry all over the basin, for each river section we assumed the extreme low flow value simulated by the model in that period as Zero Flow threshold.
- The values resulted to be: 0.004 m^3s^{-1} (gauge 3); 0.011 m^3s^{-1} (gauge 4); 0.055 m^3s^{-1} (gauge 1); 0.065 m^3s^{-1} (gauge 2).

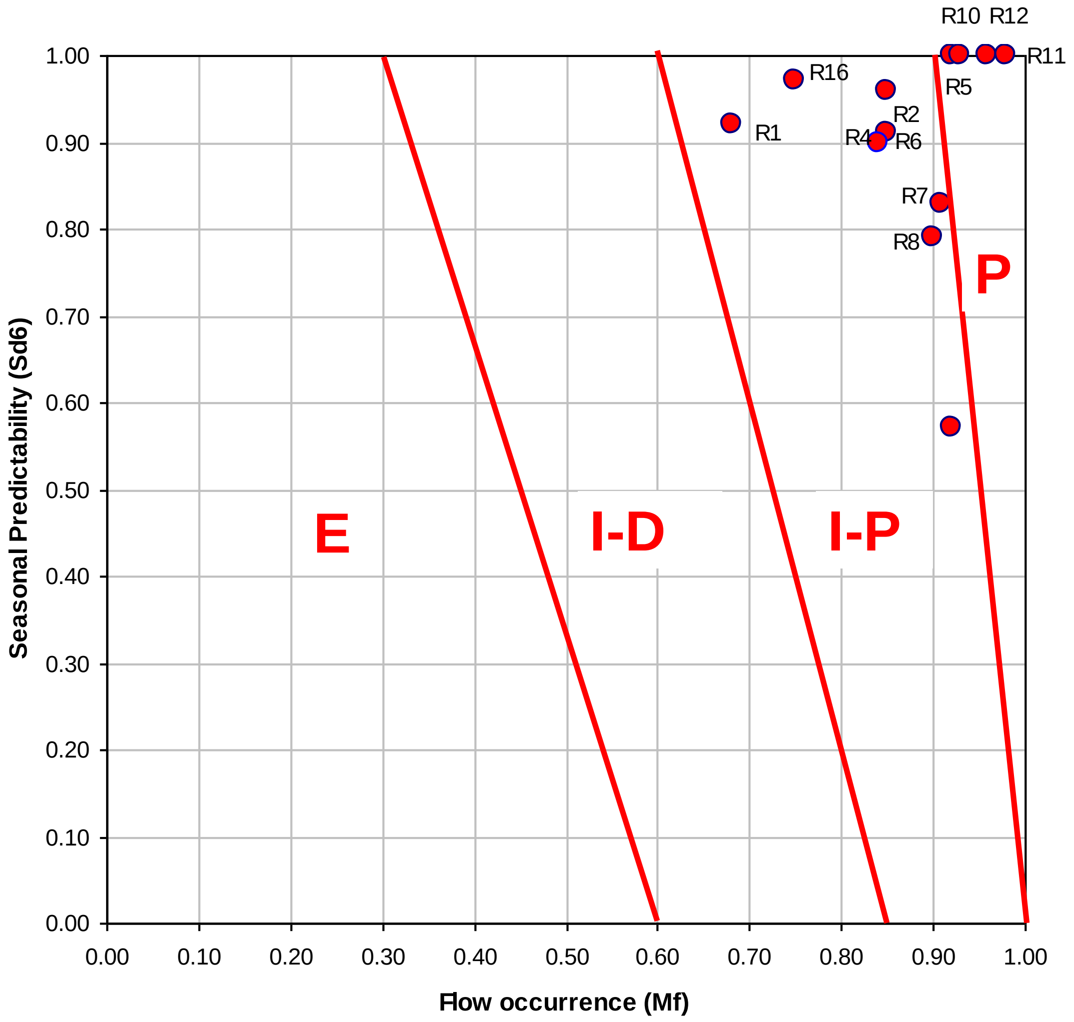
Mf-Sd6 plot for the actual streamflow data



Plot in actual conditions for the reaches R7 (a) and R1 (b) in different years

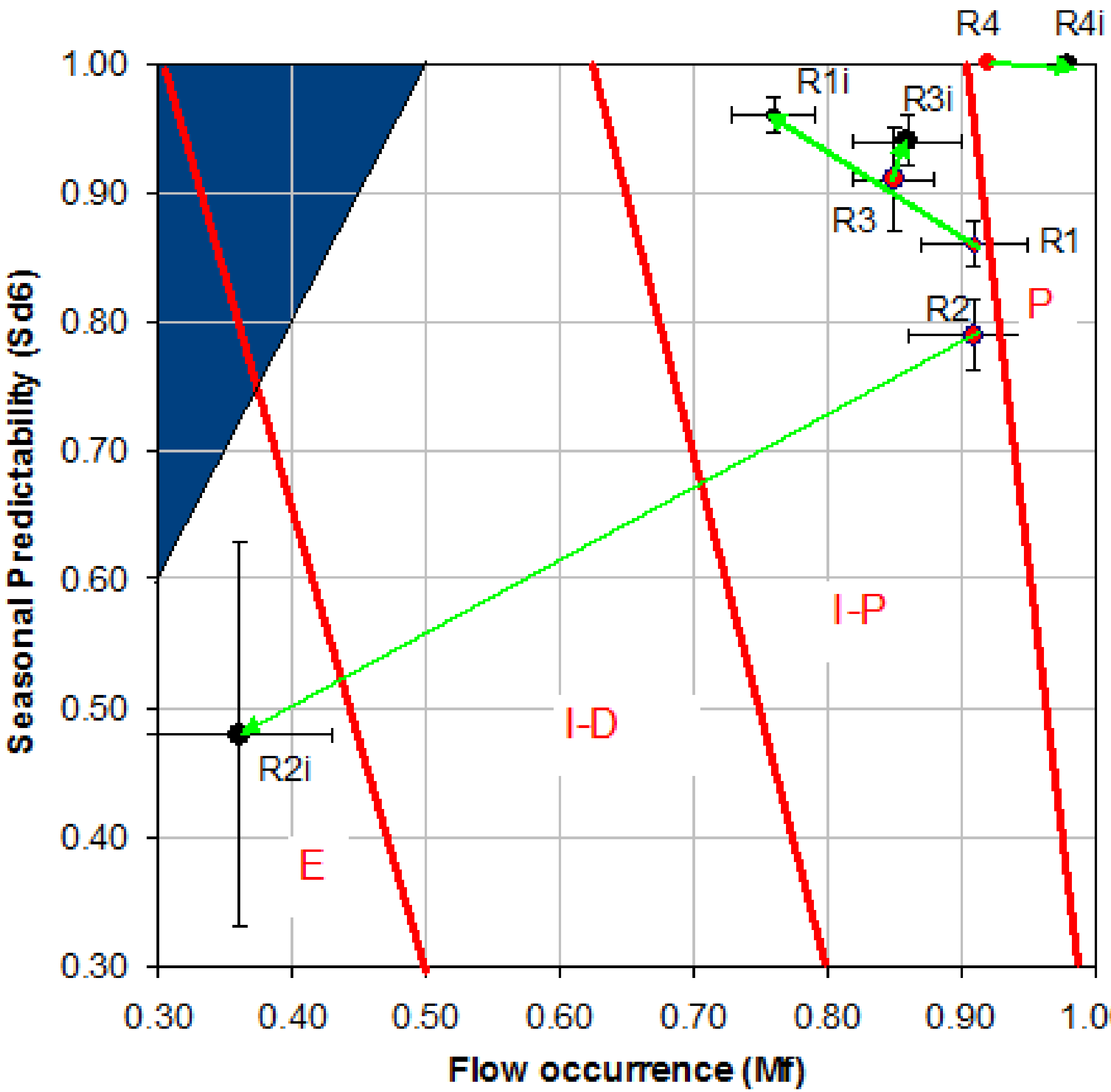


Plot in natural conditions



Natural conditions simulated using SWAT and removing WWTP inlet and irrigation withdrawals

NATURAL vs ACTUAL (impacted) situation



Mf (actual) > Mf (natural)

The presence of point source discharges increases the permanence of flow . Water quality implications

Mf (actual) < Mf (natural)

Possibly due to withdrawal or reservoirs. Changes of river type classification may happen. Distance matters

Hydrological alteration classification

2 Low risk of impact	No overlap of both x-y error bars occur and $D < 0.30^{a}$
3 Moderate risk of impact	$0.30 < D < 0.4^{b}$
4 High risk of impact	$0.4 < D < 0.5^{c}$
5 Severely impacted condition	$D > 0.5$

[a] No transition of hydrologic class (P, I-P, I-D, E) occurs after impacts.

[b] A transition of hydrological class occurs after impacts.

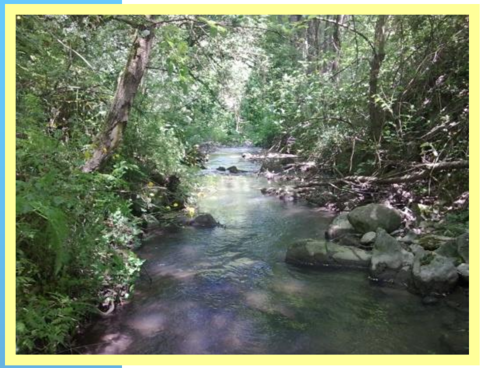
[c] A transition of more than one hydrological class occurs.

Final Hydrological alteration classification

Class	Reaches
2	R2, R7, R5, R6, R3,
3	
4	
5	R8, R10, R11, R12

The last class groups the river segments which are severely impacted (R8) and heavy modified (R10, R11, R12).

Conclusions (1)



•Flows are naturally highly variable both in space and time in this catchment.

•Low flow and dry conditions have been altered in the main course of the Candelaro river in the floodplain due to WWTPs discharges, water abstractions, river modifications.

•The flow regime is natural only in the upper part of the tributaries where dry conditions are a natural features and is related to the geomorphology of the streams.

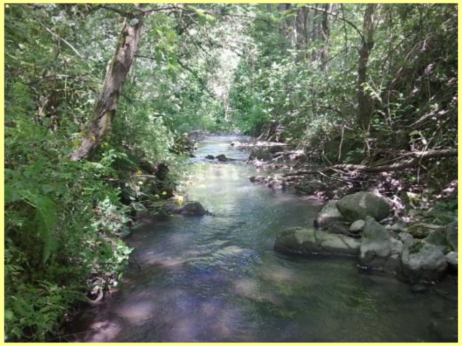
•*Dry* or *disconnected pool* statuses are frequent at the end of the summer period and their duration varies from one year to another and from reach to reach.

•Most of the streams are generally classified as Intermittent Dry and Intermittent Pools.

•The proposed Plot allows to highlight changes and to understand possible causes of flow modification.

•The proposed Plot allows to classify rivers based on flow characteristics.

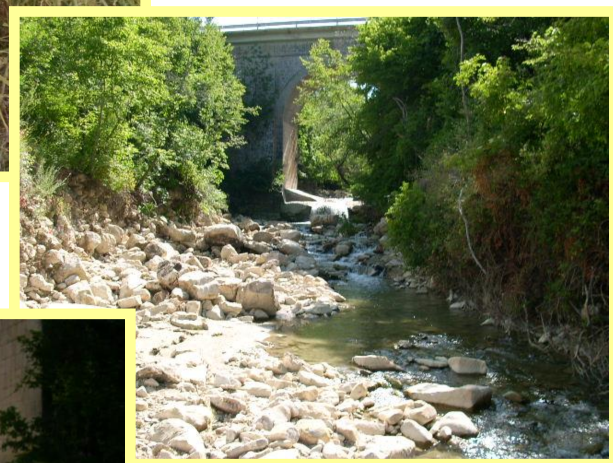
Conclusions (2)



•The classification of the river reaches regimes based on the occurrence of the different mesohabitat has proved to be a valuable operational tool to helps biologists in selecting the sampling. For reaches classified as I-P and I-D samplings have to be adapted to the hydrological regime.

•The proposed approach to evaluate hydrological status is a fast way to identify river reaches in critical hydrological conditions. The method, which analyzes only the changes occurring in two factors (flow permanence and dry seasonal predictability), compares the metrics in actual state and natural state. If critical hydrological conditions take place, further analysis must be carried out.

•Even if the SWAT model has proved to be a valuable tool in simulating streamflow in natural status, extreme low flow can be a weak point in model simulations: it is important to understand if the extreme low flows simulated by the model are realistic. In this case we identified a "Zero-Flow" threshold value through data analysis, expert judgment and field observations which corresponds to no flow conditions. A correction of the flow series was done before calculating the metrics.



Thank you for your attention