Using qualitative flow states for characterizing regimes of temporary streams: The 'Aquatic States'

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1. Particularities of temporary streams

Temporary streams are those water courses that suffer the recurrent cessation of flow or the complete drying of the channel. This type of streams forms a relevant part of the river networks in most regions in the World and is expected to increase due to both the climate change and increased water consumption by human activities. The interruption of the aquatic conditions in these streams plays a determinant role on the ecological communities.

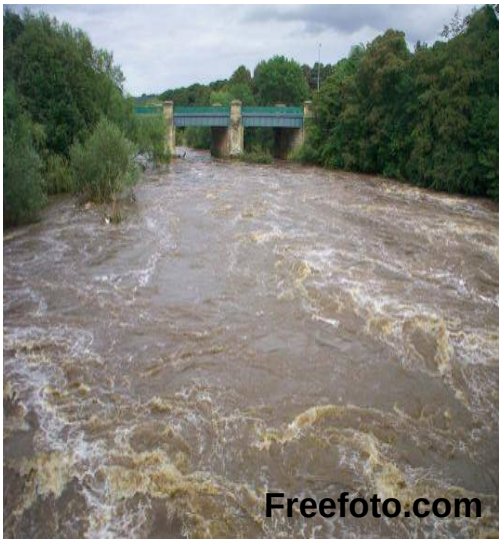
After the European Water Framework directive, the condition of the aquatic life of the streams is the main criterion for determining the ecological quality of the waters. But in temporary streams water may not be present on the sampling date or the biological communities found (even if they are pristine) may be significantly poorer than the reference ones living in permanent streams, because of the effect of dry periods.

A sound characterisation of the regime of temporary rivers is therefore necessary for scheduling the biota sampling in the more ecologically adequate moments and for the analysis of their hydrological constraints to the development of aquatic life.

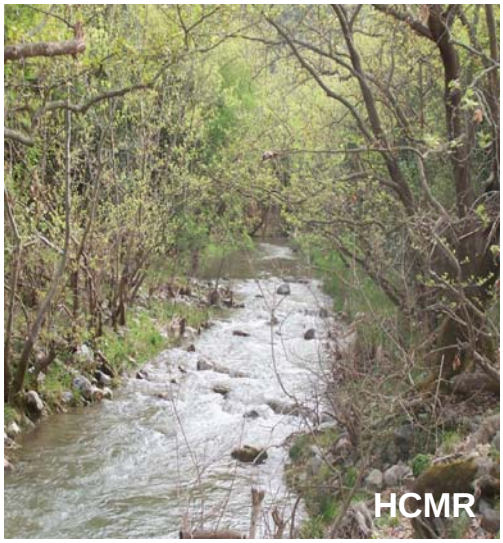
The characterisation of stream regimes is usually made in terms of discharge measurements, whereas in temporary streams the aquatic life is mainly controlled by the occurrence or absence of aquatic habitats. In temporary streams, the classical five statistics of flow measurements (magnitude, frequency, timing, duration, and rate of change) must be substituted by statistics on habitat frequency for characterising their regimes.

2. Ecologically relevant Aquatic States

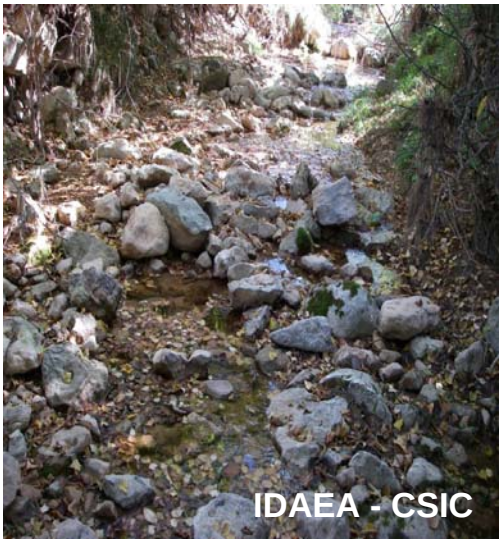
Six “aquatic states” may be defined as ranks of the assemblages of the aquatic habitats in a stream reach in a wet – dry arrangement



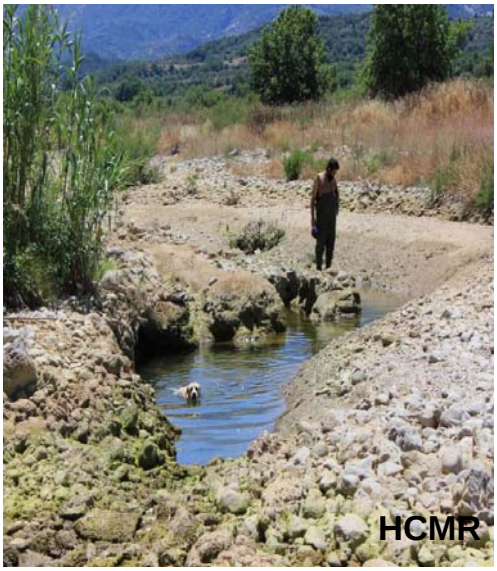
Flood: major movement of stream bed alluvium and the drift of most of the aquatic fauna in the reach.



Riffles: occurrence and connectivity of all the available habitats in the reach. Typical of permanent streams.

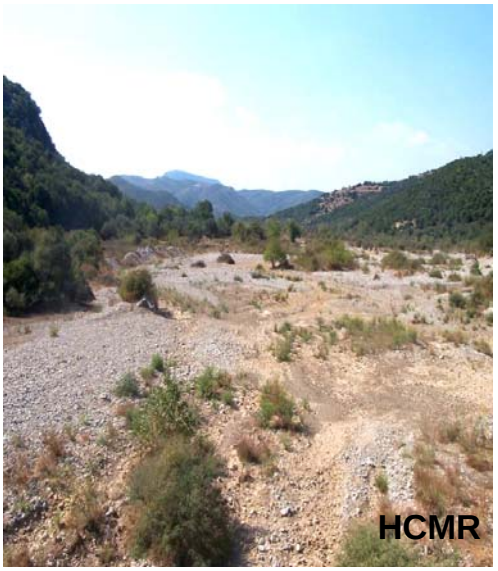


Connected: aquatic habitats are restricted to pools connected by water rivulets without riffles.



Pools: aquatic habitats are restricted to pools without surface flow connecting them.

Dry: there is no surface water but alluvium water content is higher than field capacity, allowing hyporheic life.

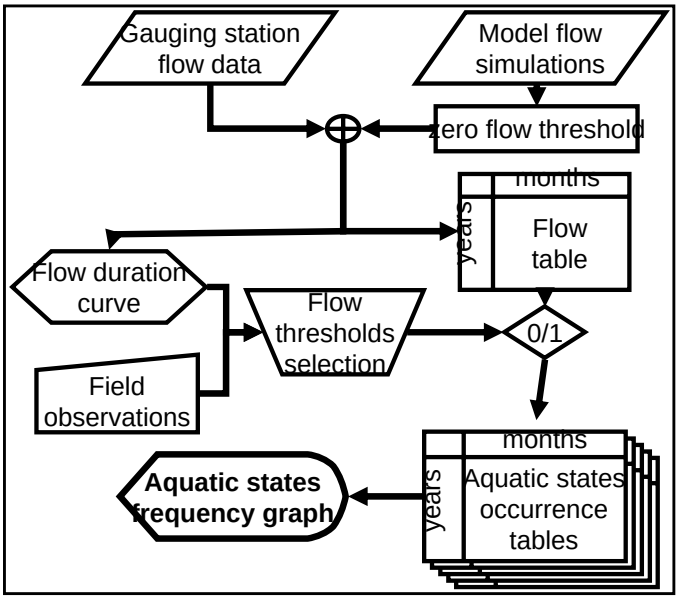


Arid: there is no surface water and alluvium water content is lower than field capacity, preventing active hyporheic life.

3. Statistics of the aquatic states

The only information currently available about the stream water regimes are flow discharge records, from either measurements at gauging stations or simulations using rainfall-runoff models.

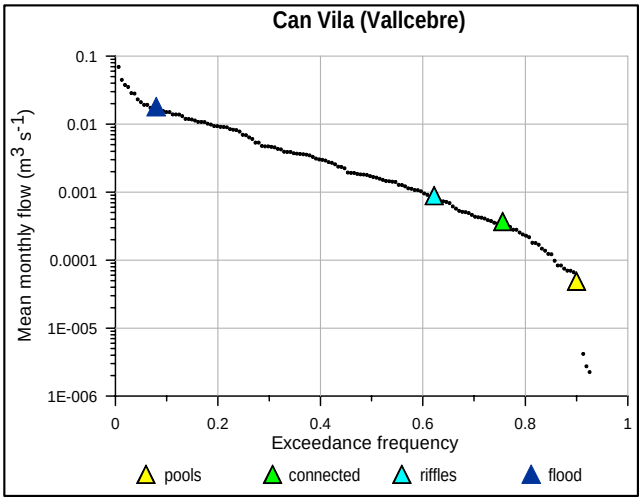
Flow data may be used to obtain the statistics of the occurrence of the wetter aquatic states (*Flood, riffles, connected*) if the flow values that represent the thresholds separating the occurrence of the diverse aquatic states are defined. A monthly temporal scale is the best compromise for this analysis.



Schematic flow chart for the procedure developed to estimate the temporal patterns of occurrence of the aquatic states from the available water flow data. The final products are the aquatic states frequency graphs (Box 4)

Field observations on the aquatic states synchronous with discharge measurements are needed for a sound identification of these thresholds. However, they can be provisionally estimated by taking into account the width and regularity of the stream bed reach near the gauging station. The form of the flow duration curve may provide some help in this task

The aquatic state meaning of the zero discharge value depends on the design of the gauging station and the characteristics of the reach. For alluvial reaches with gauging stations designed to impede subsurface flow below them, zero flow may be expected to correspond approximately to the threshold between *dry* and *pool* aquatic states. In contrast, for stream reaches over impervious bedrock or alluvial ones with gauging stations allowing the bypass of subsurface flow, zero flow may be expected to represent the threshold between *pool* and *connected* states. Consequently, discharge data can not be used to derive information on the occurrence of the *arid* aquatic state in the first case and of the *dry* and *arid* aquatic states in the second case.



Flow duration curve for the CanVila station, with the assessment of the minimum flow threshold values that separate the four wetter aquatic states

4. Aquatic States Frequency Graph

In order to make visible the seasonal occurrence of the aquatic states in a stream, the Aquatic States Frequency Graph (ASFG) was developed. This shows the observed monthly frequencies of occurrence of the diverse aquatic states in a stream reach, on the basis of the analysis of the flow duration curve with the assessment of the threshold discharges between aquatic states.

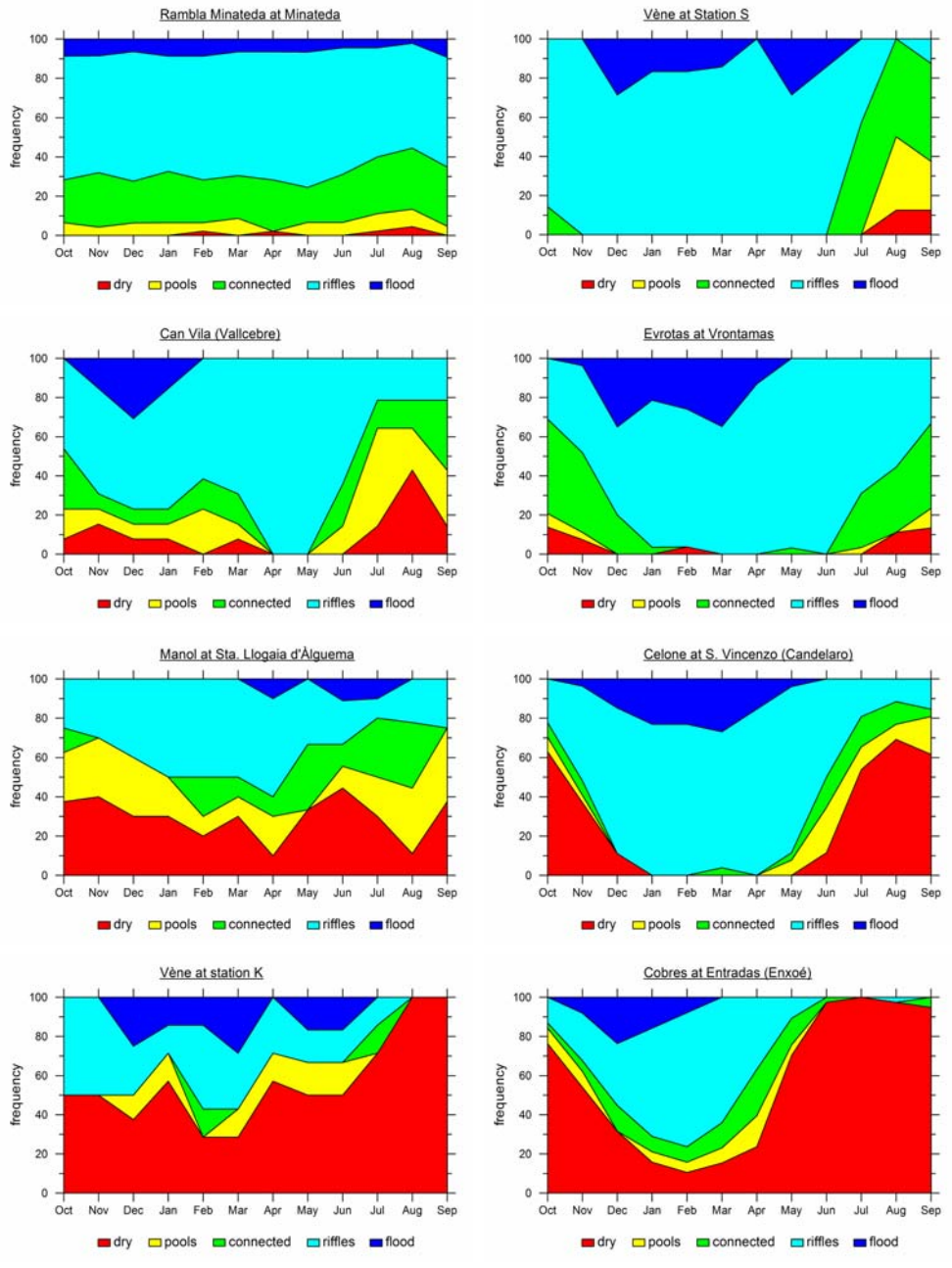
This graph tries to provide a rapid appraisal of the stream regime relevant to the development of aquatic fauna for comparisons and for making easier the design of the calendar for sampling aquatic fauna in the more relevant moments.

This analysis has been tested in eight gauging stations around the European Mediterranean basin within the EU MIRAGE project.

Location of the gauging stations on temporary streams where the water regime was analysed within the MIRAGE project

The eight ASFG in the figure on the right are arranged with the wetter streams at the top and the drier at the bottom. For similar frequencies of the states throughout the year, the right column shows the streams with a higher seasonality (predictability of the aquatic states depending on the month), whereas the left column shows the basins with a more episodic regime, with a poorer seasonal predictability.

Ecological studies made in temporary streams showed that the development of the aquatic fauna depends mainly on these two factors, as it is first controlled by the permanence of flow and pools, but the predictability of the habitat conditions favours the development of taxa specialized for living in temporary conditions.



5. Flow permanence and drying seasonality metrics

Current metrics used to analyse the regime of streams are based on quantitative measures of water flow, whereas the ecological studies in temporary streams make use of the presence or absence of aquatic habitats. This lead us to use the statistics of the zero flow values as a surrogate of the main changes in the aquatic habitats.

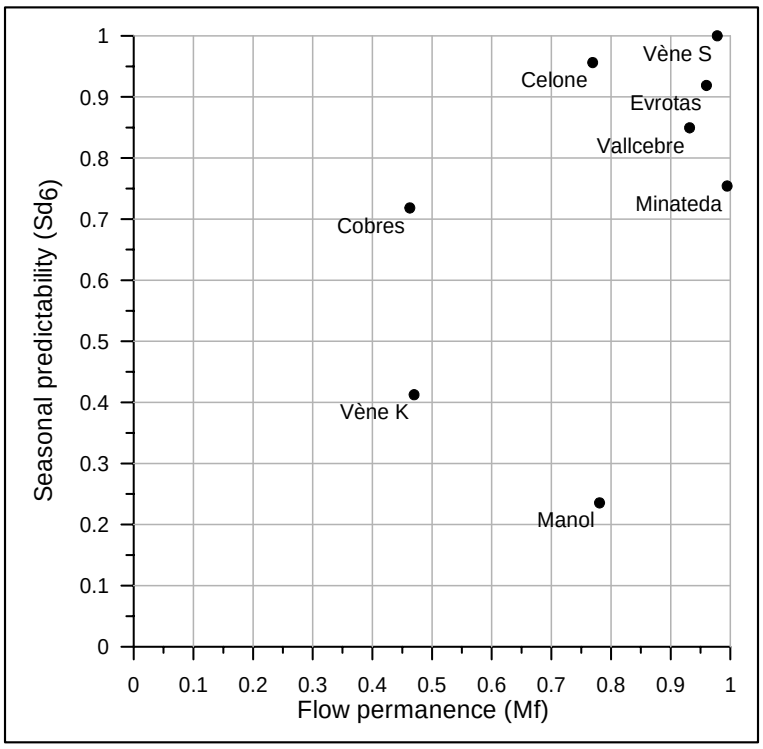
Flow permanence **Mf** is the long term mean annual relative number of months with flow, taking values between 0 and 1.

Drying seasonality is the long term predictability of the season with zero flows $\mathbf{Sd_6}$; it is measured using:

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

Where Fd_i represents the multi-annual frequencies of 0-flow months for the contiguous 6 wetter months of the year and Fd_j represents the multi-annual frequencies of 0-flow months for the remaining 6 drier months, both in terms of 0-flows occurrence.

These metrics where the more orthogonal of several metrics analysed and allowed a clear arrangement of the regimes of the studied sites, fully consistent with the results obtained with the ASFGs.



Plot of the stations studied using the two metrics tested

Reference: Gallart F., Prat N., García-Roger E.M., Latron J., Rieradevall M., Llorens P., Barberá G.G., Brito D., De Girolamo A.M., Lo Porto A., Neves R., Nikolaidis N.P., Perrin JL., Querner E.P., Quiñonero JM., Tournoud MG., Tzoraki O., Froebrich J. (in revision). A novel method to characterize temporary streams' aquatic regimes: the Aquatic States. *Aquatic Sciences.*

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