

Quantifying flow-ecology relationship in the Adige River basin

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ABSTRACT

We derived flow metrics from discharge time-series at gauged river sites paired with data on benthic invertebrates. Multivariate ordinations showed that regulated and non-regulated sites formed distinct groups while several flow metrics represented limiting factors for local biodiversity.

1 INTRODUCTION

Societies are increasingly aware of the importance and benefits provided by healthy river ecosystems. However, while the generation of hydropower is among the most important source of renewable energy in the Alpine region, it also affects the natural flow regime of many rivers with negative ecological consequences. Sustainable river management requires a sound understanding of flow-ecology relationships for developing appropriate environmental flow criteria (Poff et al., 1997). Despite substantial effort by the scientific community, the identification of clear patterns in the relation between flow regime and river biodiversity is limited by the fact that flow regime is only one factor among many others influencing stream communities. Therefore, biodiversity metrics are unlikely to show a central response when correlated to specific flow variables (Konrad et al., 2008). In addition, the effect of flow alteration on river ecosystems might extend beyond the local scale (e.g. local diversity) to affect larger scale patterns of basin-scale heterogeneity (Poff et al., 2007).

In this study, we used paired eco-hydrologic information to quantify flow-ecology relationships across a range of river sites in the Adige basin (N-E Italy) with different degree of flow regulation. Considering that multiple factors influence in-stream communities (e.g. channel morphology, altitude, temperature, water quality), we specifically examined whether certain flow metrics represented limiting factors at some sites where other stream features would have

allowed the establishment of different assemblages or higher local diversity. To achieve this, we firstly used quantile regressions to quantify upper ($q=0.8$) and lower ($q=0.2$) limits in benthic macroinvertebrate metrics as a function of ecologically relevant flow metrics. Secondly, we appraised whether regulated and non-regulated river sites formed distinct groups when ordinated in the multivariate space defined by their flow characteristics and local assemblage composition.

2 RESULTS

Several biodiversity metrics displayed both central response as well as upper and lower limits as a function of flow metrics. Local taxon richness showed positive upper limits with the magnitude of minimum flow in the preceding year (Fig. 1). Richness was also linearly and negatively related to the number of low-flow pulses. Shannon diversity showed lower negative limits with both the coefficient of variation in discharge and the number of low-flow pulses in the preceding year. The index STAR_ICMi also displayed lower negative limits against the number of high-flow pulses and the mean monthly coefficient of variation in discharge (Fig. 2). Permutational Multivariate Analysis of Variance (PERMANOVA) using flow metrics and invertebrates compositional data revealed that regulated and non-regulated river sites formed distinct groups. Flow regime in regulated rivers were characterised by larger coefficient of variation, increasing rise rates, and more frequent low and high pulses as well as hydrological reversals (switches from rising to falling period and vice-versa). However, subsequent analysis of group dispersion showed that the within-group heterogeneity (defined as median distance to group centroid) did not differ between regulated and non-regulated rivers, indicating that hydrological alteration did not homogenise the overall flow-regime

patterns or benthic community composition across the catchment.

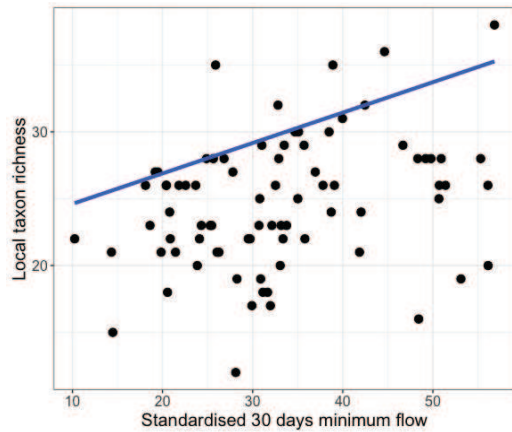


Fig.1. Relationship between taxon richness and the magnitude of minimum flow (over 30 days). Upper quantile ($q=0.8$) regression line is shown in blue.

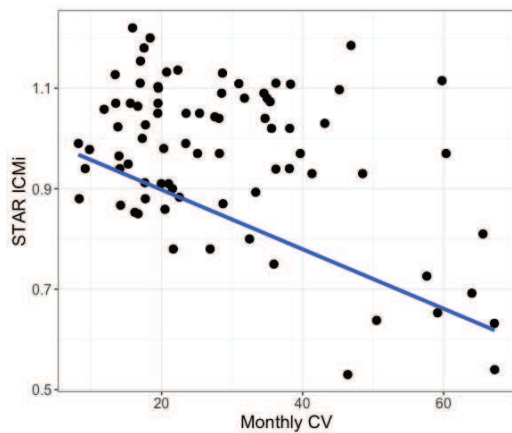


Fig.2. Relationship between the index $STAR_ICMi$ and the mean monthly coefficient of variation in flow. Lower quantile ($q=0.2$) regression line is shown in blue.

3 DISCUSSION

The use of quantile regression allowed us to identify several flow metrics that appear to set limits to macroinvertebrate assemblages across the Adige

catchment. While some biodiversity metrics did exhibit a central response to flow patterns (e.g. taxon richness declining linearly with increasing low-flows), most metrics displayed upper or lower limits against the hydrological gradient. In general, lower negative limits were associated with stronger variation in discharge. That is, increasing flow variation resulted in lower minimum values of many biodiversity metrics. Conversely, higher minimum flows allowed invertebrate assemblages to reach maximum values of local abundances and diversity.

Contrary to expectations, hydrological alteration was not associated with the homogenisation of overall flow patterns, suggesting that different water management schemes were in place across the regulated river sites. As a consequence, compositional heterogeneity of macroinvertebrate assemblages at the basin scale was also unaffected by flow regulation.

The identification of biological limits associated with specific flow metrics as the one reported here, can help conserve and restore stream ecosystems affected by flow regulation. For instance, sites can be compared against the identified flow limits to guide the management of stream flow characteristics important for maintaining specific biological conditions or target taxonomic groups.

4 REFERENCES

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