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Relationships between woody vegetation and geomorphological patterns in three gravel-bed rivers with different intensities of anthropogenic disturbance

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ABSTRACT

We compared three gravel-bed rivers in north-eastern Italy (Brenta, Piave, Tagliamento) having similar bioclimate, geology and fluvial morphology, but affected by different intensities of anthropogenic disturbance related particularly to hydropower dams, training works and instream gravel mining. Our aim was to test whether a corresponding difference in the interactions between vegetation and geomorphological patterns existed among the three rivers. In equally spaced and sized plots ($n = 710$) we collected descriptors of geomorphic conditions, and presence–absence of woody species. In the less disturbed river (Tagliamento), spatial succession of woody communities from the floodplain to the channel followed a profile where higher elevation floodplains featured more developed tree communities, and lower elevation islands and bars were covered by pioneer communities. In the intermediate-disturbed river (Piave), islands and floodplains lay at similar elevation and both showed species indicators of mature developed communities. In the most disturbed river (Brenta), all these patterns were simplified, all geomorphic units lay at similar elevations, were not well characterized by species composition, and presented similar persistence age. This indicates that in human-disturbed rivers, channel and vegetation adjustments are closely linked in the long term, and suggests that intermediate levels of anthropogenic disturbance, such as those encountered in the Piave River, could counteract the natural, more dynamic conditions that may periodically fragment vegetated landscapes in natural rivers.

1. Introduction

The interactions between biological drivers brought by plants and physical drivers mediated by water and sediment flows have received a lot of attention from scientists because of their complexity [8]. Fluvial dynamics influence the way riparian vegetation establishes and develops. In turn, riparian vegetation plays a crucial role in rivers, stabilizing the banks, deepening the main channel, and reducing the number of channels [22,60,61].

Unregulated large gravel-bed river systems may exhibit complex, dynamic and diverse multi-channel morphology [5]. The geomorphological processes creating the pattern of multiple channel belts and the morphology of the individual channel belts in these rivers are controlled, in many different ways, by climate and geology [11,19,64]. However, over periods of major human interference, many rivers have become dominated by incision and narrowing, resulting in relatively simpler channel forms [16,18]. The recruitment of different tree species depends on the occurrence of bank erosion on floodplains and islands, formation of new, bare alluvial surfaces, and suitable hydrological conditions. Human pressures may therefore lead to either a reduction or expansion of vegetation in rivers [44], eventually producing non-natural equilibrium states [26] that may determine centuries of channel adjustment [6]. These patterns are common in large rivers of Europe [20]. For example, in the Iberian peninsula, Lobera et al. [33] showed that hydrological regulation reduces the magnitude and frequency of floods, decreases downstream sediment supply, resulting in the loss of active bars as they become colonized by vegetation and are not subject to sediment remobilization, except during very large floods. In highly regulated rivers of the Alps, the dynamic maintenance of pioneer vegetation on gravel bars and young

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islands is hampered by the reduction in frequency of relevant flood magnitudes [29,39]. Accordingly, in the north-eastern Italian pre-Alps, Picco et al. [47] identified a missing correspondence between woody communities transversal succession and geomorphological gradients in a gravel-bed river affected by gravel mining and hydropower plants.

Although the effect of hydrological regulation on fluvial geomorphological configuration and its interaction with riparian vegetation has already been demonstrated [37], to our knowledge quantitative data are still missing on these interactions in rivers subject to different levels of disturbance, but comparable in terms of climate, geology, and biogeography.

There are many possible anthropogenic drivers of disturbance and each of them may have effects on the relationship between vegetation and geomorphology at specific spatial and temporal scales [54]. The present work applied a sampling design consisting of a set of cross-section transects established in several sub-reaches distributed along three large gravel-bed rivers located in the south-eastern pre-Alps. At this scale, the three studied rivers can be differentiated in terms of level of intensity of a set of stressors that included dam density, flow regulation and river fragmentation [63]. Landscape indicators of such stressors were the presence of instream gravel mining sites, hydroelectric power plants, channel embankments and floodplain croplands [14,30], as further explained in the study area description.

In equally spaced and sized plots we collected quantitative, semi-quantitative, and qualitative descriptors of geomorphic conditions, coupled with presence-absence of tree and shrub species. Given the uniformity of biogeographic conditions and position along the river continuum, we compare the relationships between geomorphic and sedimentary structures and woody vegetation characteristics. This makes it possible to test the validity of the intermediate disturbance hypothesis, by studying how the relationships between vegetation and geomorphological pattern change along a gradient of intensity increase in anthropogenic disturbance. The intermediate disturbance hypothesis, earlier developed by Grime [17], argues that higher numbers of species coexist at intermediate levels of disturbance. In this condition, more lively competitive interactions avoid the prevalence of few specialized species [51]. This hypothesis has been tested in several environments, including rivers [65] and extended to more complex expressions of diversity than simply species richness [34]. Here, our hypothesis is that the complexity of the relationship between vegetation and geomorphological pattern in the most disturbed river is simplified due to the adjustment of its morphological pattern to the human induced low variability of water and coarse sediment transport [7,56]. In addition, we might also expect that the complexity shown by the intermediate-disturbed river would be even higher than the less disturbed river.

2. Material and methods

2.1. Study area

The research has been conducted along three gravel-bed rivers (Brenta, Piave, and Tagliamento) located in north-eastern Italy (Fig. 1). They all fall within the Illyrian–Gardesan Dolomitic floral sector of the south-eastern pre-Alps [42], so have similar characteristics in terms of bioclimatic and geological features.

The surveyed sites are located where the rivers exit the main Alpine range and enter the Veneto plain, and have a similar morphological pattern, which is predominantly wandering-braided. However, they differ substantially in terms of anthropogenic disturbances

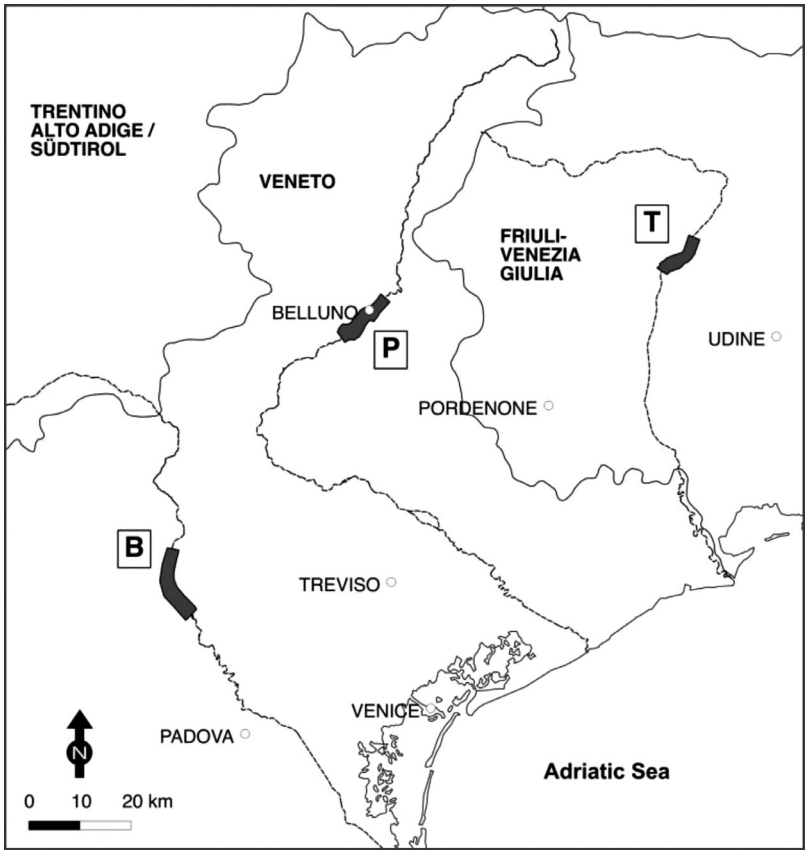

Fig. 1. Location of the three studied rivers (dotted lines) with boundaries of administrative regions (continuous line) and the sub-reaches where the sampling was done (grey polygons). B: Brenta, P: Piave, T: Tagliamento.