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The effect of flow regulation on the spatial distribution and dynamics of channel geomorphic units (CGU's) in the Soča River, Slovenia.

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INTRODUCTION

The quantity and quality of physical habitat in rivers is determined by the interaction of geomorphology and hydrology. It plays an important role in determining 'river health' and influencing the structure and function of aquatic communities (Maddock 1999). Traditional assessment of both physical habitat and biotic communities has tended to focus on sampling at individual points, cross-sections or along short (i.e. <200m) stretches of river ('micro' or small scale) with extrapolation to the sections of river inbetween ('upscaling') providing catchment assessments (at the 'macro' or large scale). More recently, Fausch et al. (2002) have argued that river habitat assessment should concentrate on assessing complete reaches at the 'meso' or 'intermediate' spatial scale in order to recognise the river landscape as a spatially continuous longitudinal and lateral mosaic of habitats. This approach underpins the use of physical habitat mapping.

A range of different river habitat mapping methods and classification systems have been developed to facilitate this approach. Habitat mapping surveys are normally completed for one of two main reasons:-
1) For survey purposes, i.e., to provide an inventory of the physical habitat present as part of a basic resource assessment in it's own right. (e.g. Halwas & Church 2002)
2) For impact assessment purposes, i.e., as part of aquatic habitat modelling studies. Habitat mapping data are used to either a) model the relationship between physical habitat availability and flow directly from the mapping results without the need for any further fieldwork (e.g. MesoHABSIM (Parasiewicz 2001)), or, b) to identify representative cross-sections and reaches for subsequent and more detailed study. This use of habitat mapping is often completed as part of PHABSIM Studies (e.g. Maddock et al. 2001).

River habitat mapping aims to identify the types and spatial configuration of geomorphic and hydraulic units. The terms used to describe these units differ between authors and include 'channel geomorphic units' (CGU's), 'mesohabitats', 'physical biotopes' and 'hydraulic biotopes'. Newson and Newson (2000) provide a review of the use of some of these terms and the differences between them.

Physical habitat units are delineated subjectively by the surveyor based on established guidelines. The subjective nature of the fieldwork raises questions about the repeatability of unit identification and issues of observer variability where different surveyors may not be consistent when applying the same technique (Poole et al. 1997). When conducting field surveys, some units are easy to classify, but others may exhibit characteristics of more than one type of habitat (e.g. some units are difficult to classify between riffles and runs). Furthermore, although surveyors are given guidelines on how to distinguish between habitat units, it is not always clear as to which are the key physical and hydraulic factors that enable the surveyor to distinguish habitats and delimit their boundaries.

The aims of this research were two fold. Firstly, we utilised a rapid habitat mapping approach in it's traditional sense to examine the impact of flow regulation on the spatial distribution and temporal dynamics of physical habitats or channel geomorphic units (CGU) in the Soča River, Slovenia. Secondly, we have applied discriminant analysis in order to carry out a quality control evaluation of the habitat mapping method. This enabled us to highlight which physical attributes were the primary distinguishing factors between CGU types, and allowed us to identify individual habitat units that subjective assessment may have mis-classified during fieldwork.

SITE DETAILS

The Soča River rises in the Slovenian Alps, flowing for 95km through Slovenia before crossing into Italy and discharging into the Adriatic Sea. It has a catchment area of 1576 km^2 and is regulated for hydro-power production at the Podsela Dam and Ajba Dam producing bypassed sections with reduced flows below each dam. The hydro-power scheme abstracts the vast majority of water for long periods of time, leaving by-passed sections of river with greatly reduced flows. Prior to 2001, the highest possible abstraction rate at Podsela Dam was 96 m^3s^{-1} and the measured flow below the Podsela Dam for most of the year was 0.2 m^3s^{-1}. The highest possible abstraction rate at the Ajba Dam is 75 m^3s^{-1} whilst flow releases until 2001 were normally 0.5 m^3s^{-1}. Since 2001, the highest possible abstraction at both dams has been increased to 180 m^3s^{-1}.

We applied habitat mapping along three reaches. Reach 1: an unregulated 5.14km stretch between Volarje and Tolmin; Reach 2: a 4.20km by-passed section affected by abstraction below the Podsela Dam surveyed at three different flows; and Reach 3: a regulated reach below Ajba Dam (4.95km).

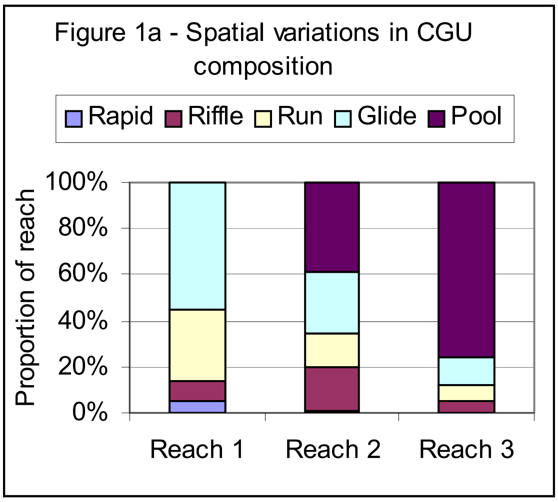
METHOD

In order to assess the impact of flow alteration on CGU type, size, hydraulics and distribution, habitat mapping surveys were completed during July 2004 along the three reaches, and at two further flows along the regulated Reach 2 during July 2005. The three flow surveys along Reach 2 were conducted at 0.940 m^3s^{-1}, 1.546 m^3s^{-1} and 3.496 m^3s^{-1}. These represent relatively small variations in discharge compared to variation associated with the natural flow regime, but in order to distinguish them for the purposes of this research have been labelled as 'low', 'medium' and 'high' respectively.

CGU's were classified using a modified version of the Hawkins et al. (1993) approach and mapped on foot and from a boat using a combination of visual assessment and physical measurements in each CGU. Channel width and water width were recorded to the nearest metre within each CGU. Maximum depth was measured to the nearest cm and the average water column velocity was recorded at a representative point in each CGU. Substrate sizes present (based on the Wentworth classification) were identified and assigned to 'dominant', 'subdominant' and 'present' categories. The proportion of the surface area of each CGU taken up with instream cover (e.g. instream macrophytes, large woody debris) and overhanging cover (e.g. from overhanging trees and boughs) were visually estimated to the nearest 10 percent. The presence of lateral-, point- and mid-channel bars, their location (e.g. left or right bank), and whether they were vegetated (>50% of surface covered) or unvegetated (<50%) were also noted. Photographs were taken of each CGU and were subsequently used to identify dominant and subdominant surface flow types (SFT). Mapping-grade GPS was used to locate CGU boundaries to sub-metre accuracy, and the application of GIS (MapInfo) enabled the description and analysis of the longitudinal distribution of CGU's along each reach.

RESULTS AND DISCUSSION

Results demonstrated significant differences in the CGU composition between the unregulated and regulated reaches (Figure 1a). The unregulated stretch (Reach 1) was dominated by glides (55%) with the rest of the reach consisting of fast-flowing and turbulent features (runs, riffles and rapids). The dominant feature of the regulated reaches were the slow flowing pool CGU's occupying 44% of Reach 2, and 76% of Reach 3, with glides, runs, riffles and rapids forming the remainder of the CGU's. This highlights the effects of reduced flows on habitat composition in the regulated reaches.



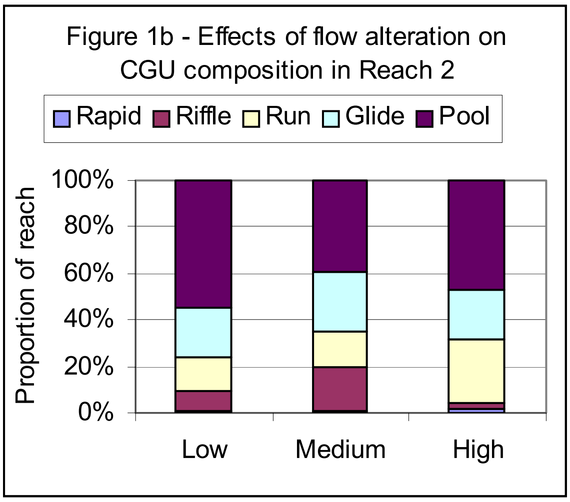


Figure 1a) Variations in CGU composition between reaches determined by flow regulation, and 1b) effects of flow alteration on CGU composition within a single reach (Reach 2).

The repeat surveys in Reach 2 (Figure 1b) highlighted differences (albeit smaller variations than the spatial changes) in habitat composition caused by changing discharges within the reach. At the relatively higher flow, the proportion of runs increased (from 14.1% to 26.9% of reach area) and the proportion of riffles decreased (from 8.6% to 2.8% of reach area). This change is created by riffles becoming submerged or 'drowned out' during the relatively higher flow and becoming run type CGU's.

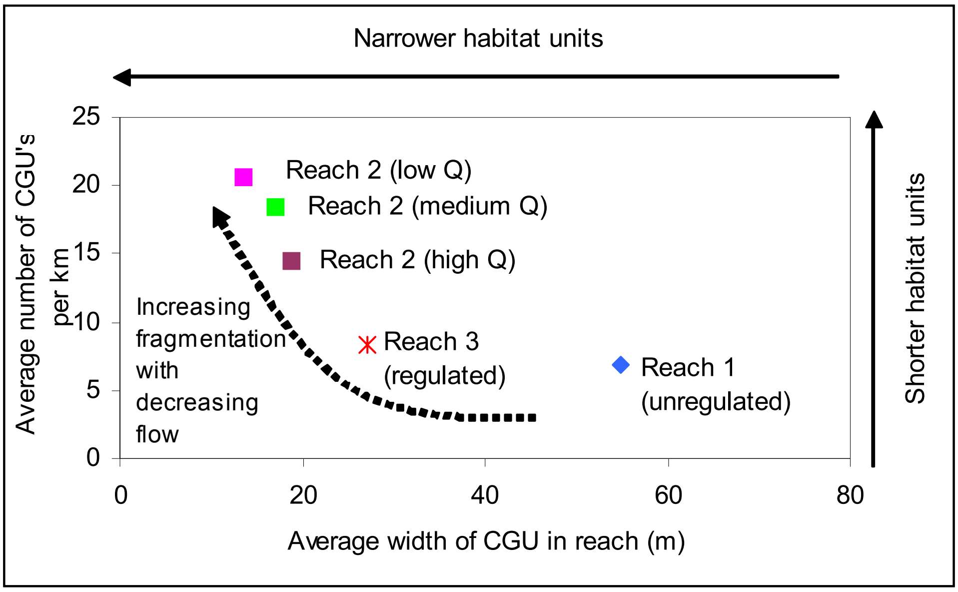


Figure 2 Comparison of average CGU width and no. of CGU's per km between reaches and within the same Reach (2) at three different flows. Points in the upper left represent reaches dominated by large numbers of short and narrow CGU's, i.e. fragmented habitats.

Habitat mapping data were analysed to evaluate the effect of flow regulation on the size of CGU's (Figure 2). The unregulated reach is dominated by larger CGU's (wider and longer units). As the flows decline, CGU's become shorter and narrower and hence fragmentation increases. This is supported by CGU's becoming progressively shorter and narrower in the three habitat mapping surveys conducted at different flows along Reach 2 (shown in Figure 2).

Discriminant analysis was applied to the three surveys recorded at different discharges in Reach 2 to identify which attributes were the most influential in distinguishing and grouping CGU's, and highlighting CGU's that were not being grouped with similar CGU's, and hence detect likely candidates that may have been 'misclassified' during fieldwork.

Firstly, discriminant analysis enabled us to test which physical and hydraulic factors distinguish between CGU's from the range of variables surveyed during fieldwork, and which were not influential and may be deemed 'redundant'. Functions 1 and 2 explained 94.9% (low flow), 98.6% (medium flow) and 95.6% (high flow) of the cumulative variance. CGU water depth was the single variable that was consistently included in Function 1 or 2 at all flows. Water velocity and dominant substrate were included for the high flow data set, and dominant and sub-dominant SFT were included for the medium and low flow results. This indicates the most influential physical and hydraulic factors that distinguish between CGU types are not the same at all discharges but they vary with flow.

Sub-dominant substrate size, CGU length, CGU width and the presence of lateral and mid-channel bars were not included in Function 1 or 2 at any discharge and therefore are not influential in distinguishing between CGU types. However, they do provide useful supplementary information to describe the fluvial geomorphology of the reach (bar presence) and the physical size of the CGU's (length and width) and therefore we believe they should continue to be recorded during field surveys.

Secondly, discriminant analysis helps quality control check the field data by detecting CGU's that may have been mis-classified. When applied to the high flow survey in Reach 2, it identified two mis-classified units. CGU no. 45 was classified as a run but would be more appropriately labelled as a riffle. CGU no. 52 was classified as a run but should have been classified as a rapid (see Figure 3).

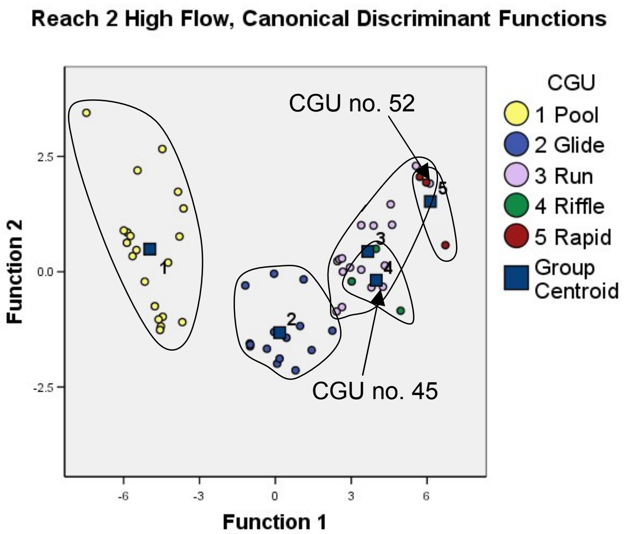


Figure 3. CGU's grouped by Discriminant Analysis using the high flow data in Reach 2.

CONCLUSION

The effect of flow regulation on the physical and hydraulic character of the river becomes apparent by using habitat mapping results to highlight differences in the dominant types of CGU's present. Flow regulation reduces discharge, and habitat mapping is an effective tool to highlight increasing proportions of slow flowing types evident under these conditions. Declining flows also reduces the size of CGU's, and affects the longitudinal distribution of types thus creating greater habitat fragmentation. The habitat mapping applied here was sufficiently sensitive to detect changes in the hydraulic and physical character of CGU's in a regulated reach with relatively small changes in flow.

Discriminant analysis suggested water depth, water velocity, dominant and sub-dominant SFT, and dominant substrate are influential in aiding field surveyors distinguish between CGUs and therefore should be recorded during habitat mapping field surveys. It also enabled us to pinpoint individual CGU's that may have been misclassified during fieldwork. This type of analysis may be a useful quality control check to reduce observer variability and increase objectivity of this approach in future.

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