Geophysical Research Abstracts,
Vol. 10, EGU2008-A-08919, 2008
SRef-ID: 1607-7962/gra/EGU2008-A-08919
EGU General Assembly 2008
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# Habitat quality or quantity? Application of two-dimensional hydraulic and fuzzy biological modeling to the redesign of reservoir releases

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The last 10 years has seen a considerable improvement in our ability to measure and to model the complex flow fields in a range of river environments, even to the point that we have numerical schemes and data acquisition strategies that allow us to model the interaction between the detailed geometry of individual clasts and clast clusters and the associated three-dimensional flow and sediment transfer fields. At the same time, habitat modeling has developed significantly, as we have developed methods for coupling hydrodynamic models to measured habitat preferences. Here, we couple depth-averaged hydrodynamic model to habitat preferences, using a fuzzy rule-based approach. We demonstrate how this approach can be used to determine habitat suitability for Brown trout, in relation to spawning, nursery and rearing habitat, and macroinvertebrate guilds, as part of the redesign of reservoir compensation releases. The redesign involved a paired-catchment, one with a compensation release (flow per unit width) that was an order of magnitude lower (the Rivelin) than the second (the Loxley). For the first three years of the project (2001-4), we maintained these flows, and conducted intensive sampling of both invertebrates (two sites per river, 10 fixed locations per site, identification to species level, spring, summer and autumn samples) and fish (10 sites per river, annual sampling in early autumn, fully-quantitative electrofishing, skeletal sampling to determine growth rates). This sampling was then repeated for a further three years, after a reallocation of release from the wetter river to the drier river. These biological data were used to validate the fuzzy biological models that were developed for both fish and macroinvertebrates, and there was evidence both for certain macroinvertebrate characteristics and some elements of the fisheries data

that the modelled response to compensation changes was as predicted by the model. Two key findings emerged. First, the effects of the change in compensation release were sensitively dependent upon the spatial heterogeneity of the river bed surface. The Rivelin, before the compensation change, had greater spatial heterogeneity and this was reduced as a result of the increase in base compensation, notably in relation to velocity. Although the Rivelin increase necessitated a decrease on the Loxley, the lower base flow on the Loxley actually increased the spatial heterogeneity of depth and velocity, as a result of reduced relative submergence. This questions the current emphasis on minimum instream flows, as what is a sufficient minimum (or maximum) will depend upon the local bed heterogeneity. Second, the primary model signal was an increase in habitat quantity on the Rivelin, but with not much change in total habitat quality. On the Loxley, where the lower base flows were still sufficient to occupy most of the river width, there was not much change in modeled habitat quantity or quality. Interestingly, the design of the field sampling was based upon assessing changes in habitat quality at fixed locations. As the compensation flows were changed, this experimental design could have suggested changes in habitat quality that were simply the result of the spatial rearrangement of good and not so good locations, rather than the net loss or gain of good habitat. This is where the modeling is powerful. Despite the fact that it has to make critical ecological assumptions, it is able to provide a fuller picture of the entire spatial response of the habitat quality field, and hence factor changes in habitat quantity as well as quality into the design of resource allocations.