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Modeling Effects of Flow Alteration on Riparian Vegetation

One approach for predicting the effects of a proposed flow alteration in western riparian vegetation employs a relation between riparian vegetation and hydroperiod. Changes in distribution of vegetation are estimated by determining how a new flow regime would alter the hydroperiod or the time inundated. We recently developed and applied this approach to the herbaceous riparian communities in the Black Canyon of the Gunnison National Monument, Colorado.

Plant Distribution Related to Hydroperiod Gradient

Our method begins with the definition of vegetative cover types, based on the existing vegetation. We used the TWINSPAN classification program to identify cover types on 133 randomly located 1- × 2-m plots. The 83 plant species were organized into three vegetated cover types, named after a dominant species, and an open water type lacking emergent vegetation. After surveying the elevation of each plot, we used the HEC-2 step-backwater hydraulic model, in combination with linear interpolation between hydraulic cross-sections, to determine the discharge necessary to inundate each plot. The hydrologic record, as represented by a flow duration curve, allowed us to calculate the hydroperiod or the fraction of time that each plot had been inundated. The resulting positions of cover types along a hydroperiod gradient are shown in Fig. 1.

Changes From Alternative Instream Flows Simulated

A change in river management results in a new flow duration curve, which can be used to redistribute the cover types among the plots. For each hydroperiod class, we calculated the proportion of plots in each cover type (Fig. 1). We then used these proportions as probabilities to estimate the future cover type of a plot from its future hydroperiod.

Flow duration curves describing different hydrologic alternatives were used to produce plot hydroperiods for each alternative. One alternative we considered involved a general 50% reduction in flow along with an increased minimum flow (Fig. 2). Applying the cover-type probabilities to plots with new hydroperiods produced an estimate of the expected value of the new number of plots in each cover type:

$$n_{i,j} = P_{i,j} * T_j$$

where

$n_{i,j}$ = number of plots in cover type i and hydroperiod class j

$P_{i,j}$ = probability that a plot in hydroperiod class j is in cover type i

T_j = total number of plots in hydroperiod class j

Application of this model to the plots sampled for calibration produces the expected number of plots in each cover type for each alternative hydrologic regime. We interpreted change in the proportions of randomly located plots as changes in the cover-type composition of the study area (Table).

Compatible With Instream Flow Incremental Methodology

Our goal in modeling vegetation dynamics is to incorporate a consideration of effects on riparian vegetation into water management decisionmaking. Thus, the approach needs to be consistent with the conceptual, dimensional, and computational framework for making these decisions. Representing the river through a series of hydraulic cross-sections and modeling water surface elevations using Manning's equation or a step-backwater model are standard practices in water management. Likewise, summarizing hydrologic time series in flow duration curves is a common technique. The model described here employs many of the same conceptual elements, computational procedures, and field methods as the Instream Flow Incremental Methodology, which is widely used to relate instream flow to fish habitat.

Method Has Important Limitations

Limitations of the model include use of a single environmental gradient, restrictive assumptions about channel change, representation of vegetation as quasi-equilibrium cover types, and the difficulty of model validation. Although we chose to use cover types, a similar approach could be applied to the distribution and response of individual species. The assumption of a static channel geometry is probably the most serious problem limiting applicability. If channel geometry changes, the calculated plot hydroperiods are likely to be wrong. We do not believe this is a major problem in bedrock and canyon wall constrained sites like the Gunnison National Monument. In many more freely meandering and unstable bed rivers, however, the assumption may be unreasonable.

The principal advantages of the method are simplicity and reliance on relatively standard elements of plant community ecology and hydrologic engineering. It is capable of simulating some relatively complex quantitative responses. For example, the diversion and increased minimum flow alternative (Fig. 2) results in an increase in the driest cover type through the reduction in intermediate and high flows, an increase in open water from the higher minimum flow, and a decline in the wettest vegetated cover type as plots move from this cover type to open water. Thus, increasing minimum flow in this instance contributes to a decrease in the area of the wettest vegetated cover type.

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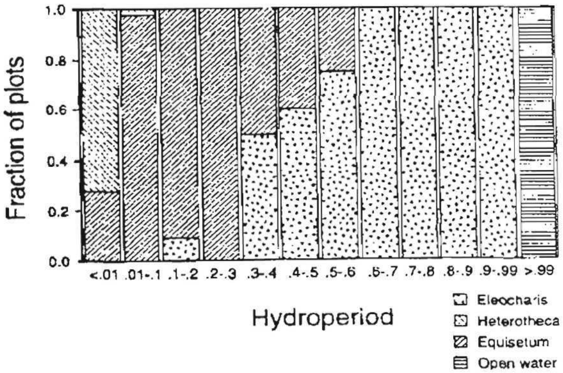

Fig. 1. Normalized distribution of cover types along hydroperiod gradient duration. Vegetated cover types are named by one of their dominant plants.

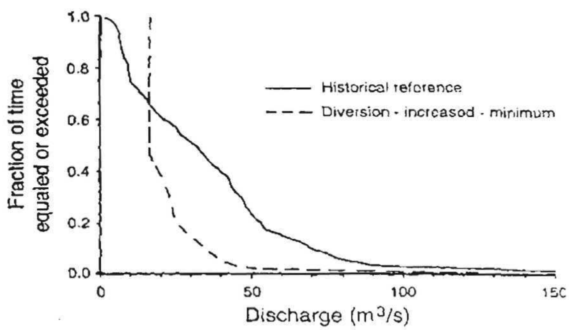

Fig. 2. Flow duration curves for the 17-year historical reference condition and a hydrologic alternative of diversion with increased minimum flow.

Table. Percent of bar area occupied by each cover type simulated under a diversion and increased minimum flow alternative compared to the reference conditions at the time of sampling.

	Cover types			
Hydrologic alternative	Open water	Eleocharis	Equisetum	Heterotheca
Reference	0	37	53	10
Diversion-increased-minimum	13	6	46	35