RESTORING THE NATURAL RANGE OF MISSOURI RIVER FLOW VARIABILITY TO BENEFIT DECLINING SPECIES

David L. Galat

INTRODUCTION

Flow alteration is a primary cause for the decline of native biota in rivers throughout the world (Poff et al., 1997). Re-establishing a semblance of the natural flow regime through controlled reservoir releases is becoming a successful management tool to restore ecological integrity of regulated rivers. Re-regulation of river flows first requires defining a reference condition based upon the full range of hydrologic variability present in the pre-regulation system.

Discharge of the Missouri River is highly altered by a cascade of six mainstem dams and reservoirs. The U.S. Army Corps of Engineers (COE) is revising their Current Water Control Plan (CWCP) for the reservoir system, including multipurpose regulation of storage releases for downstream needs (U.S. COE, 1998). Below the lowermost dam (Gavins Point, km 1305) two competing uses are navigation (i.e., CWCP) and fish and wildlife. Navigation operates from St. Louis, MO (km 0) to Sioux City, IA (km 1178) from April through November and nine fishes and four birds are of conservation concern in this segment.

METHODS

Three fish and wildlife alternatives (FW10, FW15 and FW20) to the CWCP were proposed by COE to more closely approximate the historical spring rise and summer low-flow periods. We evaluated these alternatives to determine how closely they simulated the magnitude, timing, and duration of pre-regulation flows. The three FW alternatives increase spring navigation service levels by 10, 15, and 20 kcfs, respectively, and reduce summer reservoir discharges by various amounts to minimum navigation service levels. These generalized alternatives were applied to 1967-1996 50th percentile (%ile) discharges at two representative sites below the reservoir: Omaha, NE, (km 991) and Boonville, MO, (km 317). The resulting flow patterns were compared with a range of percentile discharges before (1929-1948) and after (1967-1996) flow regulation.

RESULTS & DISCUSSION

Alternatives FW10 and FW15 exceed the 75th %tile and FW20 exceeds the 90th %tile, post-regulation discharge at Omaha for the entire 30 (FW10, FW15) or 75 day (FW20) period of extra releases (Fig. 1A). Similar improvements are not seen at Boonville, as FW20 never exceeds the 75th %tile post-regulation flow (Fig. 1C). Proposed reductions in reservoir releases (-6 kcfs) for FW10 and FW15 are of short duration and only briefly achieve a low-flow pulse equal to the post-regulation 10th %tile discharge at Omaha (Fig. 1A).

Assistant Unit Leader-Fisheries, U.S. Geological Survey, Cooperative Fish & Wildlife Research Unit, 302 ABNR, University of Missouri, Columbia, MO 65211-7240 (573/882-9426; galatd@missouri.edu).

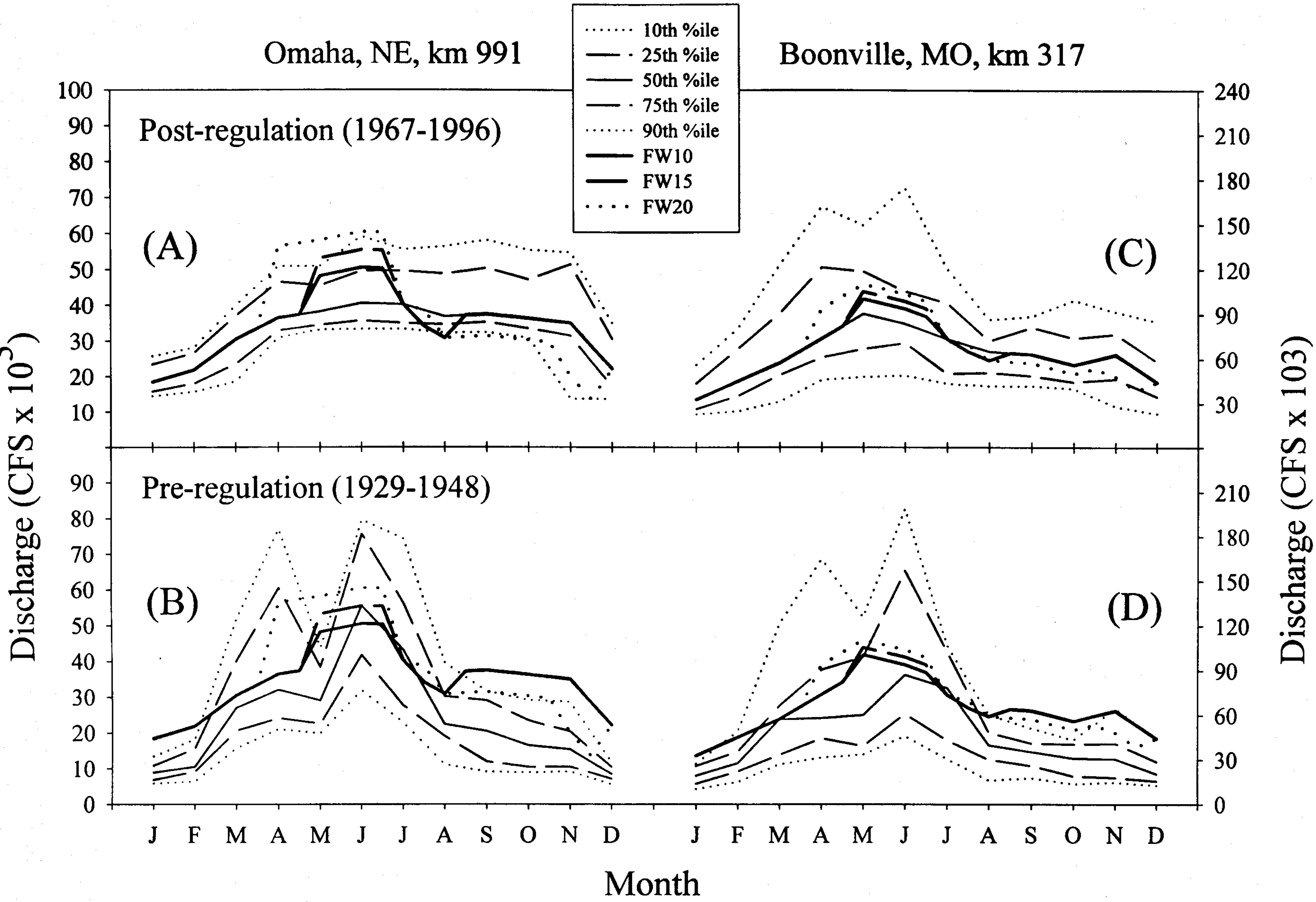

Figure 1. Three proposed fish and wildlife (FW) alternatives for the revised Current Water Control Plan in relation to pre (B, D) and post (A, C) flow regulation percentiles (%iles) of lower Missouri River monthly discharge at Omaha, NE (A, B), and Boonville, MO (C, D).

In contrast, FW20 meets or slightly exceeds the 10^{th} %ile post-regulation flow for over two months. Flow reductions to benefit fish and wildlife at Boonville never decrease post-regulation discharge to even the pre-regulation 25^{th} %tile. FW20 is clearly the most beneficial among the three alternatives at Omaha relative to CWCP, but it provides minimal variation in discharge magnitude to the lower Missouri River.

Comparing the FW alternatives to pre-regulation discharge percentiles illustrates the degree to which they approach a more natural flow regime. Timing of all alternative high-flow pulses, but particularly FW20 (April 1-June 15), partially straddles the dip between bimodal peaks in historical discharge at Omaha (Fig. 1B). Shifting the increase in flow releases to a few weeks later would correspond more closely with the historical June rise and benefit native fishes, many of which spawn in floodplain wetlands during June and early July. Magnitude of the proposed FW10 and FW15 high-flow pulses does not meet the pre-regulation 75^{th} %ile discharge for either bimodal peak at Omaha, while FW20 briefly exceeds the 75^{th} %ile discharge at Boonville during the April rise (Fig. 1D). The proposed one month (FW10, FW15) or 2.5 month (FW20) duration of high-flow releases is much less than the five month (mid-March through mid-July) total duration of the pre-regulation bimodal flood pulse at both sites.

Magnitude of low-flow pulses (i.e., reductions in low flows) at Omaha and Boonville is never less than the pre-regulation 50^{th} %ile discharge for any FW alternative and is seldom less than the 75^{th} %ile at Boonville (Fig. 1B). Annual low-flows in the Missouri River historically began in August and continued through winter, except for a brief, small November rise at Boonville and downriver due to local rains (refer to 75^{th} and 90^{th} %ile flows in Fig. 1D). The CWCP alternative keeps summer-autumn flows above the historical 75^{th} %ile until the navigation season ends in November. Timing and duration of FW10 and FW15 minimum service flows is from mid-July to mid-August during the declining limb of the historical flood pulse and for about 15 days that coincide with the beginning of pre-regulation low flows. Although the timing and duration of FW20 are more in concert with historical conditions, the proposed flow reduction is so small that it never decreases discharge below observed pre-regulation median discharge. The return to full navigation service flows after mid-August for FW10 and FW15 comes at the time of historical summer-early autumn low flows which exposed sand island and mud-flat habitats providing high-energy invertebrate forage to fuel shorebird migration. Additionally, margins of sand-bar complexes contained abundant shallow-water shoals which served as low-velocity, high production, and fish-predator free nursery habitats for riverine fishes. FW20 is the superior alternative of the three with respect to duration of low flows since discharge is reduced through October. However, the proposal to reduce reservoir discharge by an additional 10 kcfs in November by terminating the navigation season a month early occurs at an inopportune time for riverine biota. It can expose recently hibernating turtles and coincides with the historical November rise in the lower river which flooded moist-soil vegetation whose seeds are consumed by fall migrating waterfowl.

All FW alternatives, and especially FW20, are clear improvements over CWCP as they restore a more natural hydrograph to the lower Missouri River. However, declining native species can be further recovered if greater consideration is given to managing reservoir flow releases to simulate the timing, magnitude, duration and, frequency of historical high and low river flows and the natural variability inherent in pre-regulation hydrology. Specifically, river-floodplain biota will benefit if the magnitude and duration of the annual flood pulse is increased, intra-annual frequency is made bimodal, and its timing is shifted to achieve April and June peaks. Simulating a bimodal flood pulse would flood vegetation for spring migrating waterfowl and provide additional spawning cues for migratory fishes. A much greater reduction in summer-early fall reservoir releases than is proposed in any FW alternative is recommended to simulate the pre-regulation low-flow hydrograph. This would benefit sand island nesting birds and turtles, create shallow water nursery areas for at risk riverine fishes, and foraging sites for migrating shorebirds. An increase in reservoir discharge in November would mimic the pre-regulation autumn rise and benefit fall migrating waterfowl while facilitating river navigation during a period when downstream grain transport is essential. Equally important, is that FW flow alternatives be less rigid and capitalize on inter- and intra-annual climatic stochasticity to re-establish high- and low-flow disturbance events. Infrequent very high or very low flows reset the system by scouring backwaters of accumulated sediment, creating and destroying sandbars and floodplain wetlands, scouring existing sandbars of encroaching vegetation, exposing channel and floodplain sediments to oxidation, creating elevational diversity on the floodplain (ridge and swale topography), establishing a complex floodplain vegetation mosaic, exposing new habitats to colonization, shifting dominance hierarchies in species assemblages, etc. Such disturbance high- and low-flow pulses can be compatible with other system uses through acquisition of flood-prone floodplain land from willing sellers and levee removal or setbacks on these public lands.

A more detailed analysis of 32 ecologically relevant hydrological variables before and after flow regulation using Richter et al's. (1997) Indicators of Hydrologic Variation methodology at seven sites below Gavins Point Dam is reported in Galat and Lipkin (1999). They also use Richter et al's. (1997) Range of Variation Approach to provide ecologically based flow-management targets, including guidelines for establishing inter-annual ranges of flow variability. Revision of the CWCP by expanding operational flexibility within the existing system and incorporating Richter et al's. (1997) approach for setting, implementing, and refining flow management targets should help arrest the decline of native species in the Missouri River hydrosystem. Additionally, restoring a more natural range of flow variability may impede expansion of introduced species who proliferate best in stable flows and static habitats of regulated rivers.

Ecological systems function best in a stochastic environment where the full range of natural flow variability exists within the intra- and inter-annual uncertainty inherent in a natural hydrograph. In contrast, human systems achieve high, short-term efficiency and benefits in deterministic environments where there is a high degree of certainty. The analysis presented here has been overly simplistic in that it does not incorporate flow needs for the full array of Missouri River basin users. Its intent is to illustrate an ecologically defensible range of lower Missouri River flow scenarios and to urge greater flexibility in flow management. This strategy will also enhance public appreciation and use of Missouri River natural resources.

Incorporating the full range of historical flow variability into managing reservoir releases provides an ecological reference condition for decision makers to evaluate among other beneficial uses. Over the long term, integrating ecological and human values and needs into river management can yield a greater overall societal benefit than considering them independently.

ACKNOWLEDGMENT

Contributed by the Missouri Cooperative Fish & Wildlife Research Unit (U.S. Geological Survey, Missouri Department of Conservation, University of Missouri, & Wildlife Management Institute cooperating).

REFERENCES

Galat, D. L. and R. Lipkin, 1999. Characterizing the Natural Flow Regime of the Missouri River Using Historical Variability in Hydrology. Missouri Cooperative Fish & Wildlife Research Unit, University of Missouri, Columbia, MO, 67 pp. + appendices.

Poff, N. L. and 7 coauthors, 1997. The Natural Flow Regime. BioScience 47:769-784.

Richter, B. D., J. V. Baumgartner, R. Wigington and D. P. Braun, 1997. How Much Water Does a River Need? Freshwater Biology 37:231-249.

U.S. COE. 1998. Missouri River Master Water Control Manual. Preliminary Revised Draft Environmental Impact Statement. U.S. Army Corps of Engineers, Northwestern Division, Missouri River Region, Omaha, NE.