ECOLOGICAL CONSIDERATIONS FOR RESERVOIR PLANNING IN NORTH GEORGIA

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REFERENCE: Proceedings of the 2001 Georgia Water Resources Conference, held March 26-27, 2001 at the University of Georgia, Athens, GA. Kathryn J. Hatcher, editor, Institute of Ecology, The University of Georgia, Athens, GA.

Abstract. Plans to construct new reservoirs, primarily for municipal water supply, are multiplying as our population struggles to keep up with increasing water demands. Ecological impacts of new reservoirs in north Georgia potentially include habitat loss and population fragmentation of aquatic species already restricted within their historic ranges, and effects of hydrologic alteration on downstream habitat and water quality. These effects are most appropriately assessed at the scale of basins and landscapes. Effective basin-level planning, which should address natural resource conservation goals as well as human consumption needs, will require answers to specific questions regarding effects of alternative strategies for developing water supply through impoundments. Primary issues include: stream prioritization as an approach for conserving imperiled species and water quality in downstream systems; fragmentation effects on fauna, and relative influences of impoundments placed on high- and low-order streams; and feasibility and ecological effectiveness of ameliorating hydrologic alteration caused by impoundments. Research on stream faunal and water quality patterns in the existing landscape, in conjunction with pre- and post-construction monitoring of stream communities above and below impoundments that are already approved, would provide essential information to support effective planning.

INTRODUCTION

At least 21 water supply impoundments currently are in planning or permitting phases for construction in Georgia north of the Fall Line (Table 1). An additional 12 regional water supply reservoirs were proposed in 1989 under the Georgia Water Supply Act. New projects would augment supply from existing reservoirs, including at least 26 completed or issued 404 permits since 1985 (Table 1). Viewed as essential for protecting a rapidly growing human population from water shortages during drought (GDNR 2001), planning for new impoundments also raises concerns regarding effects on stream-supplied ecosystem services including biodiversity, fisheries and water quality maintenance. To be fully effective, water resource development strategies should meet all of society's goals, including conserving valued natural aquatic resources while providing an adequate water supply for diverse uses. In this paper, we discuss ecological issues stemming from new reservoir construction and research needed to inform effective basin-level planning.

ECOLOGICAL ISSUES

Existing stream impoundments in north Georgia currently number in the thousands (Merrill et al. 2001). The ecological effects of impoundments accumulate within basins and across the north Georgia landscape. Among the most evident landscape-level effects are the cumulative loss of stream habitat, stream system fragmentation, flow-regime alteration (including water loss from the basin), and water quality degradation.

Stream habitat loss

The great majority of Georgia's native fishes and aquatic invertebrates do not persist in impounded waters, with the result that narrowly distributed species may be threatened with extirpation or extinction by new impoundments. At least 42 imperiled species may be adversely affected by new impoundments (Table 1). Of particular conservation concern are those species that are endemic to a single basin or river system. For example, the Oconee and Ocmulgee river systems contain the entire global distribution of the Altamaha shiner (*Cyprinella xaenura*); the Etowah river system contains the entire native ranges of at least four fish species (Etowah darter *Etheostoma etowahae*, Cherokee darter

Table 1. Numbers of recent, planned and proposed water-supply impoundments in north Georgia, and of fish and mussel species protected under the Georgia Endangered Wildlife Act occurring in those river systems and potentially affected by new impoundments.

North Georgia river systems with proposed impoundments (Basin)	Completed or 404 permit issued since 1985	Proposed or in permitting process	Proposed in 1989 GA Water Supply Act	Number of Protected Fishes	Number of Protected Mussels
Etowah, Conasauga, Oostanaula (Coosa)	3	5	3	16 [1]	9 [3]
Tallapoosa (Tallapoosa)	-	1 [2]	1 [2]	7	1 [3]
Chattahoochee, Flint (Apalachicola)	8	10	3	3	4 [3]
Broad, Tugaloo (Savannah)	2	2	2	2	1
Oconee, Ocmulgee (Altamaha)	13	3	4	1	-
TOTALS	**26**	**21**	**13**	**28**	**14**

[1] Includes 5 federally-protected species
[2] The West Georgia Regional Reservoir, the only reservoir proposed in the 1989 Act currently seeking 404 approval
[3] Federally and state listed as protected

E. scotti, two holiday darter species *Etheostoma* spp.). Of the 42 species listed in Table 1, 16 fishes and one mussel species occur in only one or two river systems in a single basin. Although most of the imperiled mussel species historically occurred across several river systems, nearly all are presently restricted to subsets of their native ranges (GDNR 1999). Continued loss of stream habitat would eventually result in extinction of self-sustaining populations of narrowly distributed species.

Proliferation of impoundments may also indirectly affect imperiled stream organisms by facilitating the spread of non-native species and reservoir-tolerant fishes such as sunfishes into stream habitats, where they may compete with or prey on imperiled native species.

Stream system fragmentation

Dams and impoundments impede migration and dispersal of aquatic organisms. Dams have frequently resulted in local species extirpations; for example, the American eel (*Anguilla rostrata*), which must be able to migrate to and from the ocean, has been extirpated upstream from dams in many Georgia streams. Mussel species are depleted upstream from dams that block movements of their host fishes (Watters 1996). Less understood are the effects of fragmentation on genetic diversity and long-term viability of populations of non-migratory stream organisms that become isolated from other populations by downstream impoundments.

Hydrologic alteration

Water supply reservoirs may variously affect downstream flow regimes depending on how they are operated. Effects on low-flow levels are most often cited as a management concern. Impoundments typically release a constant and relatively low flow whenever they are not overflowing, with the result that the frequency and duration of pre-impoundment low-flow conditions are substantially increased. Reducing flows can degrade habitat quality for stream organisms by reducing habitat volume, current velocities (and thus food delivery to drift-feeding organisms) and dissolved oxygen. Extreme low flows may expose riffle habitats (and sedentary organisms such as mussels) and concentrate mobile animals in pools. In addition to lowering flows, impoundments tend to reduce natural levels of flow variability. Although natural flow variability supports a range of ecological functions (Poff et al. 1997), the effects of incremental losses in variability are not as well studied as effects of low flows.

Off-stream reservoirs pose a different concern when they are used to augment stream flow (i.e., to supply a downstream withdrawal) during low-flow periods. Managers often are not accustomed to thinking about potential adverse effects of *increasing* stream flows during low flow periods. However, shallow water habitats in riffles and along channel margins provide foraging habitat and predator refugia for many small-bodied stream organisms (Schlosser 1991); augmenting flows during summer and fall may alter habitat suitability for these species. Effects of low-flow augmentation (supplied by recently constructed reservoirs, one off-stream and one on a tributary stream) on imperiled minnow and darter species in the Conasauga and Etowah River mainstems are currently under investigation.

Impoundments may affect flow regimes at landscape scales by facilitating inter-basin transfers. Interbasin transfer occurs when water taken from a basin is eventually discharged through the wastewater treatment system to a different basin. The present magnitude of interbasin transfers in Georgia via water supply systems is not completely quantified. Potential effects of interbasin transfers on ecological function of donor and receiving basins include detriment to instream habitat and water quality.

Water quality effects

Impoundments may variously affect local, downstream water quality. Impoundments may trap sediments and contaminants transported from the watershed. Conversely, downstream water quality may suffer if water released from impoundments is low in dissolved oxygen, high in reduced metals, or different in temperature from ambient stream conditions.

Placement of new reservoirs on streams with presently high water quality may directly and indirectly degrade water quality at a larger scale. Because water-supply impoundments often are placed on the highest-quality tributary streams remaining, the effect can be to rob the downstream system of flow necessary to dilute pollutants transported by the mainstem. Growth in the watershed accompanying new reservoir development may exacerbate water quality problems, with effects including eutrophication of downstream reservoirs.

RESEARCH TO SUPPORT BASIN PLANNING

Effects of new impoundments on imperiled species and on the overall health of Georgia's stream systems will depend on reservoir number and placement. Quantifying potential effects through specific research efforts will be instrumental to developing effective planning strategies (Table 2).

Stream prioritization provides a potential mechanism for incorporating conservation goals into water resource planning. Basin-level assessments of stream habitat and water quality, biotic integrity and abundances of imperiled species would permit identification of streams that support the most intact remaining native faunal communities. One could then ask whether protecting a subset of streams within a basin could effectively conserve imperiled fauna and maintain water quality in downstream receiving water bodies. The answer to this question in part depends on how fragmented a stream system can become without losing biological integrity. Studies are needed of genetic diversity in populations of imperiled species isolated upstream of impoundments. However, analyses of stream faunal assemblages in relation to extent of up- and downstream fragmentation could also help elucidate these effects (Merrill et al. 2001), and address the question of whether fewer larger reservoirs are less biologically detrimental than a proliferation of smaller projects.

Table 2. Research needs to support basin planning.

Category	Questions
Prioritization	Would protecting particular streams as free-flowing systems: • conserve imperiled species? • enhance downstream water quality?
Fragmentation effects	• What levels of fragmentation lead to biotic degradation? • Are effects on biotic integrity greater for larger reservoirs placed low in stream systems, or for multiple smaller reservoirs spread across headwater tributaries?
Flow alteration effects	• Is it possible and feasible to protect stream biotic integrity and imperiled species through minimum-flow provision? • Is low-flow augmentation detrimental to stream biota? • What are the ecological consequences of interbasin transfers?

Determining a low flow standard to protect stream biota from detrimental flow depletion is problematic because stream communities naturally function with variable flow regimes. No single flow level can insure ecological protection. Research is thus needed to assess whether preventing depletion below a threshold minimum flow does in fact conserve stream biotic integrity downstream from impoundments. If it does, we need to assess whether it is feasible to provide protective low-flow levels, while still meeting human demands and given evaporative (and other) losses. Research on low-flow depletion effects, as well as effects of flow augmentation, on stream biota could be facilitated by well-designed before-after monitoring studies of projects that have already been permitted but not yet constructed.

Answering these questions will not solve Georgia's water supply dilemmas, but will allow decisions that

explicitly incorporate societal desires to conserve native biodiversity and other services provided by healthy stream ecosystems.

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