EFFECTS OF SURFACE WATER WITHDRAWALS AND RESERVOIRS ON STREAM FISHES IN THE GEORGIA PIEDMONT

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Abstract. Altering stream flows as a consequence of withdrawing water or building impoundments for water supply has the potential to degrade aquatic habitats relative to their ability to support native biota. Research on fish assemblages downstream from water withdrawals and water supply reservoirs in the lower Piedmont region of Georgia has shown a measurable decrease in species richness associated with either large withdrawal levels or use of reservoirs. Additional research is needed in the upper Piedmont, Blue Ridge and Ridge and Valley regions to refine and test predictions from this research. Improved predictive models could support water resource planning by helping to identify water supply strategies that would minimize impacts on stream fishes.

INTRODUCTION

Avoiding or minimizing deleterious effects on aquatic animals and plants is one of the management issues involved with supplying water for human uses, such as drinking water, hydropower, and industrial or agricultural production. One of the goals of the Clean Water Act is to protect and restore the biological integrity of the Nation's waters. Biological integrity is reflected, in part, by the ecosystem's ability to support the full complement of species native to that habitat and region, in abundances similar to those that would be present naturally (Karr 1991). Managing water resources to meet human needs while avoiding detrimental effects on aquatic communities will require an understanding of biological effects of alternative management strategies. In the case of supplying water for offstream uses, data are needed to quantify relations between water withdrawal strategies (e.g., withdrawal amounts, use of instream reservoirs) and effects on aquatic biota.

Expected Effects of Flow Alteration on Stream Biota

Stream biota are expected to be affected by water withdrawals because the flow regime determines the types and amounts of habitat available to stream communities. Periodic high flows shape the stream channel, scour pools, build depositional features such as riffles, and provide aquatic animals access to habitats such as floodplains and backwaters that are not continuously connected to the main channel. Stream flows during periods between storm events determine water depths and velocities in varying portions of the stream channel, which in turn affect animals' foraging success, energetic costs, susceptibility to predation, and survival rates, with differing effects on individuals of differing species. Natural variability in stream flows creates a mosaic of habitat types that shifts though time, with various species periodically benefiting from prevailing conditions. As withdrawals become large enough to lower the availability of certain habitat types naturally present, the species or life stages dependent on those habitats are expected to decline. The extreme condition of withdrawing the total stream flow would affect all stream biota incapable of surviving in the streambed until flow returns. Because reservoirs are capable of affecting a wider range of flows (i.e., by capturing and storing water) than are withdrawals taken directly from unimpounded streams, reservoirs may have the capacity (depending on operation) to exacerbate withdrawal effects.

EVIDENCE OF EFFECTS OF FLOW ALTERATION ON STREAM BIOTA

Stream species with narrower habitat requirements should be more susceptible to changes in flow regime than species capable of living and reproducing in a wide range of habitats. Thus, an expected effect of flow alteration is decreased abundance of species whose habitats are most altered, potentially accompanied by unchanged or increased abundances of species for which the altered flows provide more habitat. There are numerous documented examples of such shifts in community structure in response to flow alteration, particularly by large dams that affect thermal and water quality regimes in addition to flow patterns. Examples from the southeastern U.S. include declines in fishes that require flowing water habitats during some portion of their life cycles (fluvial-specialists) downstream from hydropower dams (Travnichek et al. 1995, Freeman et al. 2001). Water withdrawals and water supply reservoirs are similarly expected to have relatively greater effects on fluvial-specialists species in contrast to animals capable of living and reproducing in a wide range of aquatic environments (habitat generalists). Evidence of such differential effects includes decline of fluvial-specialist fishes in the Ipswich River, which is heavily used for water supply in northeastern Massachusetts (Armstrong et al. 2001). A recently completed study in the lower Piedmont of GA shows a similar effect (Freeman and Marcinek 2004), as described below.

Withdrawal and Reservoir Effects on Piedmont Stream Fishes

A USGS State Partnership Project, conducted in collaboration with the GA Department of Natural Resources in 2000, 2001 and 2003, provided a basis for predicting effects of withdrawals and reservoirs on fluvial specialist fishes in the lower GA Piedmont. This study (Freeman and Marcinek 2004) examined fish species richness downstream from 27 municipal water withdrawals located in 21 counties. Thirteen of the withdrawals utilized a water supply reservoir that impounded a portion of the stream. For comparison among sites, withdrawal amounts were used to compute a "withdrawal index" equal to the permitted average monthly withdrawal level (in mgd) divided by the 7Q10 flow (also in mgd) at the withdrawal or impoundment site. Because only one of the 27 sites had a continuously recording flow gage, it was not feasible to express permitted withdrawal levels relative to other runoff statistics such as average annual flow. However, 7Q10 values were available from Environmental Protection Division files or could be estimated from low flow profiles (Carter et al. 1986, 1988a, 1988b, 1989). The 27 sites varied in withdrawal index from essentially 0 (at an impoundment site no longer used for water supply) to 13.3 (i.e., permitted average withdrawal rate was 13.3 times the estimated 7Q10 flow). Withdrawal permits for 14 of the sites (including six sites downstream from reservoirs) stipulated a minimum flow requirement (generally equal to the 7Q10 flow).

For each year of study, samples of the fish assemblages downstream from the withdrawal point or impoundment were used to estimate species richness for fluvial-specialist and habitat-generalist fishes. Fluvial specialists (45 species) included most minnows (Cyprinidae), darters (Percidae), suckers (Catostomidae), madtom catfishes (*Noturus* spp.), and lotic basses (spotted bass *Micropterus punctulatus*, redeye bass *M. coosae* and shoal bass *M. cataractae*). Habitat generalists (37 species) included most sunfishes and largemouth bass (*M. salmoides*; Centrarchidae) and other lake-tolerant species such as pickerels (*Esox* spp.) and most bullhead catfishes (*Ameiurus* spp.). Linear regression models relating species richness for each fish group to alternative explanatory variables were compared for relative support by the data. Explanatory variables were withdrawal index and presence of an upstream impoundment, and also drainage area (which ranged from 14 to 1010 km^2), average bed sediment size (reflecting sediment coarseness) and percent urban land use upstream from the site (based on 1998 Landsat TM imagery; Natural Resources Spatial Analysis Lab, UGA).

In each of the study years (which encompassed drought conditions in 2000 and 2001, and above-average flows in 2003), richness of fluvial-specialist fishes declined as a function of increasing withdrawal index (Figure 1) and the presence of an upstream reservoir. The best-supported linear regression models to predict fluvial-specialist richness incorporated drainage area, withdrawal index and presence of an upstream impoundment. In contrast, richness of habitat generalist fishes displayed no strong relations to any of the explanatory variables. Including a term for presence of a minimum flow requirement did not improve model fit for fluvial specialists or habitat generalists.

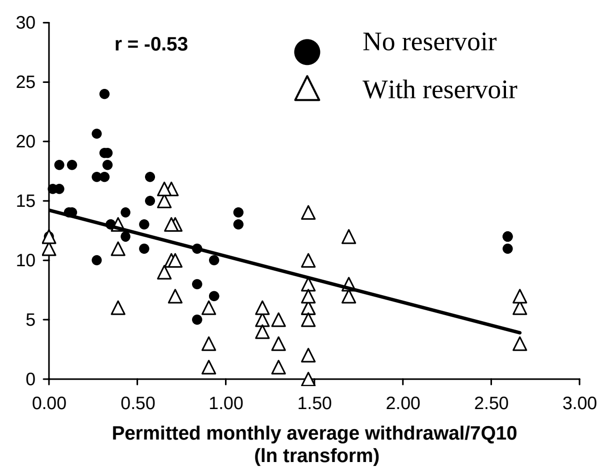

Figure 1. Number of fluvial specialist fish species at 27 withdrawals sites in relation to withdrawal index; data for 2000, 2001 and 2003.

For fluvial specialists, species loss was estimated to be about 1 to 5 species at sites downstream from reservoirs as compared to sites where withdrawals were directly from the stream, and about 1 to 8 species as permitted withdrawal amount increased from 0 to 12 times 7Q10 (M. C. Freeman, unpublished analysis using data for all years combined).

POTENTIAL APPLICATIONS TO WATER SUPPLY PLANNING

Results such as those obtained for withdrawals in the lower Piedmont of GA could be used to predict effects of proposed new or expanded withdrawals, or of proposed water supply reservoirs on components of biological integrity. For example, in the Piedmont region of Georgia, managers could use our results to hypothesize that withdrawals exceeding a given level are likely to result in species losses, and could compare biological effects of supplying water by way of multiple, smaller withdrawals to effects of concentrating supply at large withdrawals or instream reservoirs. Decision makers could identify streams that appear "over-allocated" with respect to supporting native fishes, and test and refine that hypothesis, as well as identifying areas within basins where further allocation is likely to lead to faunal decline. Decision makers could thus evaluate alternative supply scenarios with respect to predicted biological effects – preferably in the context of a model incorporating other influences such as wastewater discharge and changing land use.

Additional research is needed to broaden the geographic scope and size of the data set available for predicting effects of water supply development on stream fishes in other regions. Decisions regarding individual projects will be influenced by multiple factors, including presence of rare or imperiled stream biota (e.g., species protected under the Endangered Species Act) and economic considerations, but whatever decisions are made, one could predict effects on biological integrity in the affected stream systems. Importantly, monitoring stream biota before and after implementation of new withdrawals could then test those predictions, with the results used to improve our understanding of relations between withdrawals, water supply reservoirs, land use change and stream biota. Applied at a regional scale, water supply development could be planned to avoid detrimental depletion and fragmentation in stream systems critical for supporting unique faunal assemblages.

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