CONSIDERATIONS FOR FLOW ALTERNATIVES THAT SUSTAIN SAVANNAH RIVER FISH POPULATIONS

William W. Duncan[1], Mary C. Freeman[2], Cecil A. Jennings[3], and J. Tavis McLean[4]

AUTHORS: [1]Institute of Ecology, The University of Georgia, Athens, Georgia, 30602, [2]U.S. Geological Survey, Patuxent Wildlife Research Center, The University of Georgia, Athens, Georgia 30602, [3]U.S. Geological Survey, Biological Resources Division, Georgia Cooperative Fish and Wildlife Research Unit, Daniel B. Warnell School of Forest Resources, The University of Georgia, Athens, Georgia 30602, [4]Warnell School of Forest Resources, The University of Georgia, Athens, Georgia 30602.
REFERENCE: Proceedings of the 2003 Georgia Water Resources Conference, held April 23-24, 2003, at the University of Georgia. Kathryn J. Hatcher, editor, Institute of Ecology, The University of Georgia, Athens, Georgia.

Abstract. Flows in the lower Savannah River have been considerably altered since the construction of Strom Thurmond Dam in 1954. The effects of this flow alteration on fish have received little attention until recent years. We are collaborating with The Nature Conservancy and the Army Corps of Engineers to develop flow alternatives below Strom Thurmond Dam by evaluating relations between flow regimes and specific life history stages of riverine and diadromous fishes within shoal, floodplain, and estuary habitats. Although restoring a natural flow regime to the Savannah River may not be a feasible objective, alternatives to current flow management could enhance the ability of the river to support native fish populations. Evaluations of flow alternatives should consider effects on habitat stability in the shoals, inter-annual and intra-annual flow variation, and provision for fish access on and off of floodplain habitats. Evaluating effects of flow alterations on estuarine habitats is complicated by the often larger effects of physical channel alteration, especially harbor deepening.

INTRODUCTION

The Savannah River extends 503.6 km from the confluence of the Tugaloo and Seneca rivers down to the Atlantic Ocean, forming the border between South Carolina and Georgia. It was once critical to the economic vitality of settlements along the river, servicing grist mills, shipping, and a prosperous fishery. Water from the Savannah River is still used for municipal and industrial purposes, hydropower production, and the Savannah harbor is now a major port. Consequently, the Savannah River has been extensively modified to service multiple demands with little regard for the river's ecological function and value as a biological resource.

The Nature Conservancy, Army Corps of Engineers, University of Georgia, and various state and federal agencies are now cooperating to develop ecosystem flow recommendations for the river below Strom Thurmond Dam, the last major hydropower dam on the Savannah River. For this effort, we divided the river into three major sections (shoals, shoals to the estuary, and estuary) because of the habitat complexity and biological significance of each. This paper emphasizes the relationship of flow to fish population dynamics and life history attributes in each section, to identify important characteristics for alternative flow regimes intended to benefit native fishes.

DESCRIPTION OF STUDY AREA

Shoals

The only extant shoal habitat in the Savannah River is a 7.2 km reach extending downstream from the Augusta Diversion Dam. The remainder from river km 333.1 to 503.6 are submerged under mainstem impoundments created by five dams. Flow regime in the Augusta Shoals is largely controlled by flow release from Strom Thurmond Dam, reregulation of flows at Stevens Creek Dam, and the diversion of water by the Augusta Diversion Dam (ADD). The ADD diverts water into the Augusta Canal at a nearly constant rate (around 2400 cfs based on USGS gauge data from gauges 02196500 and 02196485 from years 1989-1992 and 1997-2001, respectively; ENTRIX, 2002).

Low flow conditions in the shoals (measured by USGS gauge 02197000, minus flow diverted into the Canal) are lower compared to conditions prior to mainstem hydropower dam construction (1884-1954 data). Pre-dam low flows in the shoals ranged from 2840 cfs in September to 6410 cfs in April (median of lowest daily flows by month). Under current conditions (1984-2001 data) low flows average 1870 cfs to 3431 cfs (median low flows for March and October respectively) in autumn and spring, respectively. Lowest flow conditions occur on weekends when power demand and water release from Strom

Thurmond Dam are low (ENTRIX, 2002). The shoals are also subject to fluctuations in flow governed largely by the periodicity of upstream hydropower generation.

Shoals to the Estuary

The 277.8 km river section from the shoals to the estuary encompasses floodplain habitat, the most productive part of a southeastern river system. Floodplains provide essential habitat for reproduction, rearing, foraging, and refuge from predators for a wide array of fish species. The degree of floodplain inundation historically depended on natural high winter and spring flows. Prior to dam construction, peak flows near Clyo, GA exceeded 100,000 cfs every four years. Now, flows rarely exceed 35,000 cfs, the maximum outflow from Strom Thurmond Dam during power generation (pers. comm. R. Jackson and V. Hale). Flood control, along with channel straightening and dredging, has substantially altered the degree and frequency of floodplain inundation (pers. comm. R. Jackson and V. Hale).

Estuary

The Savannah River Estuary (SRE) extends from river kilometer 46 to the Atlantic Ocean. It is a complex, tidally-driven system comprising multiple deltaic channels (Front, Middle, and Back rivers) and habitats. The Front River is the largest channel, and it has been widened and deepened upstream as far as river kilometer 34 to provide shipping access to the industrial port. The Back and Middle rivers are relatively narrow and shallow (Will et al., 2002). This area contains 21% of the tidal freshwater marsh in South Carolina and Georgia and 25% of the freshwater marsh along the eastern coast of the United States (Pearlstine et al., 1993). The SRE is used for a variety of purposes, including a major industrial complex, the Savannah Harbor, and the relatively undisturbed Savannah National Wildlife Refuge (Will et al., 2002).

The SRE contains a variety of habitats that support a diverse fish community of at least 92 species of freshwater, eurohaline, and stenohaline fishes (Jennings and Weyers, 2002). Many of these fishes support substantial commercial and recreational fisheries, and are dependent on the variety of habitats that occur within the estuary for survival and growth Navigation-related, large-scale modifications (e.g., channel dredging, deepening, widening, straightening) to the riverine channels within the SRE (i.e., Front, Middle, and Back rivers) have been ongoing since the 1950s, and significant impacts on fishes have resulted, most notably, the striped bass population crash.

METHODS

A literature search was conducted to identify flow relationships to fish life history aspects (e.g. migration, reproduction, survival and growth) that are key to population success. Six species were chosen for this analysis based on their varying life histories, availability of data, federal or state status, and importance to the Savannah River fishery. All selected species (American shad *Alosa sapidissima*, shortnose sturgeon *Acipenser brevirostrum*, Atlantic sturgeon *A. oxyrinchus*, American eel *Anguilla rostrata*, striped bass *Morone saxatilis*, and robust redhorse *Moxostoma robustum*) have experienced significant abundance declines from pre-impoundment conditions. Known and unknown flow relationships were identified for each life stage.

Flow requirements in the shoals have been considered largely through studies related to the relicensing of the Augusta Diversion Dam. The Savannah River Instream Flow Study (ENTRIX, 2002) calculated weighted usable area using habitat suitability indices and habitat modeling for selected species and guilds under a range of flows. State and federal agencies are using results as a basis for developing flow recommendations for the Augusta Shoals. Savannah River oxbow collections (Schmidt and Hornesby, 1985) were compared to faunal lists from other southeastern oxbow fish collections and floodplain habitats to determine how many species would benefit from restoring the timing, duration, and extent of floodplain inundation and access (Baker et al., 1991). Additional sources were examined to determine which Savannah River fish potentially occur, reproduce, or rear young on floodplains as well as peak larval abundance seasons (Finger and Stewart, 1987; Guillory, 1979; Killgore and Baker, 1996; Light et al., 1998).

We used preliminary results from an assessment of the spatial and temporal distribution of estuarine-dependant fishes in the SRE (Jennings and Weyers, 2002) to describe the importance of flow-related conditions to fish abundance and distribution. We also compiled information from studies on the striped bass population in the SRE (e.g. Will et al., 2002) and shortnose sturgeon (e.g., Hall et al. 1991; Collins et al., 2002).

RESULTS

Known flow relationships to habitat and movement during various life stages as well as knowledge gaps were identified for each of the six selected species. For all species, flow has a large affect on spawning habitat, movement between habitats, and early developmental stages. The Atlantic Sturgeon, for example, must have access to hard substrates for spawning from February to March. Flow is necessary to maintain egg viability and larva need flow for downstream drift. Flow also affects the salinity of sturgeon rearing areas in the estuary. Thus, flow recommendations take into account the life history stages for each of the selected species.

State and federal agencies are using the Savannah River Instream Flow Study (ENTRIX, 2002), in consultation with Augusta-Richmond County, as a basis for developing baseflow recommendations in the Augusta Shoals. The purpose is to alleviate the effects of flow diversion by the ADD during low flow periods, ensuring sufficient flow and habitat in the shoals to support spawning by American shad and striped bass, and fish passage into and out of spawning habitats for larger species such as Atlantic sturgeon, striped bass and robust redhorse. Baseflow provisions for resident fishes during nonspawning periods are also under evaluation.

Savannah River oxbows provide habitat for 76 fish species (Schmidt and Hornsby, 1985), most of which are expected to occur on the seasonal floodplain, potentially in greater abundances (Baker et al. 1991). Comparisons to other southeastern floodplain studies indicate that the total number of Savannah River species that occur on floodplains ranges from 81-89 Light, 1995; Baker et al., 1991; Killgore and Baker, 1996; Paller, 1987). Of these, 22-36 reproduce on floodplains (i.e., reproduction confirmed or larvae from congeneric species occur on floodplains elsewhere). Most taxa have their peak larval abundance in the spring (43), with 19 in the summer and 2 in the winter.

Fishes in the SRE are affected by flow and channel alterations. Striped bass are most affected by changes in flow and salinity and shortnose sturgeon seem to be most affected by habitat degradation (e.g., rearing habitat and suitable water quality) related to dredging operations. The striped bass population in the SRE seems to be making a recovery based on fecundity estimates (Will et al., 2002) and the capture of larval striped bass during the spring 2002, the first such captures in over a decade (Georgia Cooperative Fish and Wildlife Research Unit; Unpublished data). This may indicate that flow-based habitat conditions are at least adequate to provide the environmental cues necessary for egg development and spawning. Sturgeon are strongly affected by salinity and temperature at specific locations (Collins et al., 2002). The abundance and distributions of at least 92 estuary fishes varies seasonally among four salinity-defined habitats (polyhaline >15ppt; mesohaline 5-15ppt; oligohaline 1-5ppt; and tidal freshwater <1ppt; Jennings and Weyers, 2002). Thus, understanding the effects of flow alterations is complicated by the large effects of harbor modification and daily movement of various salinity zones.

DISCUSSION

Habitat for fishes throughout the lower Savannah River is directly affected by river regulation, and in the case of the Augusta shoals, by water diversion. Increasing habitat stability in the shoals by reducing flow fluctuations and providing the minimum flow levels recommended by management agencies will not achieve natural conditions, but may improve the amount of habitat suitable for specific life stages of several species and guilds (Travnichek et al., 1995). Although, minimum flows will likely improve shoal productivity, management strategies that mimic the natural hydrograph produce better aquatic habitat and biotic communities than strategies aimed at providing a predetermined “minimum flow” (Jowett, 1997).

The natural hydrograph is variable, and fishes that evolved in this habitat probably depend on that variability for reproductive success (Grossman et al., 1998). Interannual variation in the shoals and estuary similar to the natural hydrograph should lessen the effects of historic modification to the system and ensure good recruitment in some or most years rather than in few.

The natural flow regime as a goal in the floodplain is inadequate to achieve historic periodicity and degree of inundation. Because of dredging activity and reduced winter and spring flows, higher flows are necessary to achieve the magnitude of inundation observed in the river’s former unaltered state. Flows that ensure access on and off of the floodplain during the winter, spring, and summer and ensure the persistence of floodplain habitats during the spawning season may increase population productivity for over 80 species.

Flow in the estuary has had a profound effect on the salinity of the system, which affects the spatial and temporal distribution of estuarine-dependant fishes. The ongoing drought in the SRE and the resultant low flows have allowed the intrusion of the salt wedge farther inland than would be seen during high flow years. As a result, there has been a gradual “inland shift” in the distribution of the fish assemblage, possibly resulting in the use of marginal or unsuitable habitat. A previous shift of this kind has had substantial adverse effects on some segments of the estuarine fish community and similar adverse effects could be expected if managed flows or alterations to the system (e.g., the Georgia Ports Authority proposed harbor expansion and deepening) cause similar shifts in the spatial and temporal distribution of estuarine-dependant fishes.

Flow alternatives that meet known flow-habitat requirements will benefit those species and others that share similar life history attributes. Unknown flow relationships (e.g. juvenile growth and survival for robust redhorse, American shad adult foraging habitat, and Atlantic sturgeon egg, larva, and juvenile development conditions) are equally important. As these unknowns become known and as our understanding of other flow relationships evolves, adjustments to recommended flows can be made.

ACKNOWLEDGMENTS

We would like to thank the Army Corps of Engineers and The Nature Conservancy for their dedication to restoring the Savannah River ecosystem. Special thanks are extended to many collaborators in the U.S. Geological Survey, U.S. Fish and Wildlife Service, National Marine Fisheries Service, South Carolina Department of Natural Resources, Georgia Department of Natural Resources, Environmental and Chemical Services, ENTRIX, Inc., and anonymous reviewers.

CITATIONS

Baker, J.A., K.J. Killgore, and R.L. Kasul. 1991. Aquatic habitats and fish communities in the lower Mississippi River. *Reviews in Aquatic Sciences*. 3: 313-356.

Collins, M. R., W. C. Post, D. C. Russ, and T. I. J. Smith. 2002. Habitat use and movement patterns of juvenile shortnose sturgeon in the Savannah River, Georgia-South Carolina. *Transactions of the American Fisheries Society*. 131:975-979.

ENTRIX, Inc. 2002. Savannah River Instream Flow Study for the Augusta Canal Hydropower Project. FERC No. 11810, September 2002.

Finger, T.R., and E.M. Stewart. 1987. Response of fishes to flooding regime in lowland hardwood wetlands. Pages 86-92. in W.J. Matthews and D.C. Heins, eds. *Community and evolutionary ecology of North American stream fishes*. University of Oklahoma Press.

Grossman, G.D., R.J. Ratajczak, Jr., M. Crawford, and M.C. Freeman. 1998. Assemblage organization in stream fishes: effects of environmental variation and interspecific interactions. *Ecological Monographs*. 68: 395-420.

Guillory, V. 1979. Utilization of an inundated floodplain by Mississippi River fishes. *Florida Scientist*. 42: 222-228.

Hall, W. J., T. I. J. Smith, and S. D. Lamprecht. 1991. Movement and habitats of shortnose sturgeon *Acipenser brevirostrum* in the Savannah River. *Copeia*. 1991:695-702.

Jennings, C. A. and R. S. Weyers. 2002. Spatial and Temporal Distribution of Estuarine-Dependant Species in the Savannah River Estuary. Annual Report prepared for Georgia Ports Authority.

Jowett, I. G. 1997. Instream Flow Methods: A comparison of approaches. *Regulated Rivers: Research and Management*. 13:115-127.

Killgore, K.J., and J.A. Baker. 1996. Patterns of larval fish abundance in a bottomland hardwood wetland. *Wetlands*. 16:288-295.

Light, H.M., M.R. Darst, and J.W. Grubbs. 1995. Hydrologic conditions, habitat characteristics, and occurrence of fishes in the Apalachicola River Floodplain, Florida: Second Annual Report of Progress, October 1993- September 1994. U.S. Geological Survey, Open-File Report 95-167.

National Marine Fisheries Service. 2002. Final Essential Fish Management Plan. www.nmfs.noaa.gov National Oceanic and Atmospheric Administration. Washington D.C.

Paller, M.H. 1987. Distribution of larval fish between macrophyte beds and open channels in a southeastern floodplain swamp. *Journal of Freshwater Ecology*. 4:191-200.

Pearlstine, L., W. Kitchens, P. Latham, and R. Bartleson. 1993. Tide gate influences on a tidal marsh. *Water Resources Bulletin*. 2:1009-1019.

Schmidt, D.N., and J.H. Hornsby. 1985. A fisheries survey of the Savannah River. Georgia Department of Natural Resources, Game and Fish Division, Atlanta, Georgia. Federal Aid in Fish Restoration Acts, Dingell- Johnson Project F-30.

Travnichek, V. H., M. B. Bain, and M. J. Maceina. 1995. Recovery of a warmwater fish assemblage after the initiation of a minimum-flow release downstream from a hydroelectric dam. *Transactions of the American Fisheries Society*. 124:836-844.

Will, T. A., T. R. Reinert, and C. A. Jennings. 2002. Maturation and fecundity of a stock-enhanced population of striped bass in the Savannah River Estuary, USA. *Journal of Fish Biology*. 60:532-544.