Report as of FY2006 for 2006GA106B: "Restoration of flood pulses to the lower Savannah River: responses of floodplain invertebrates and fish"

Publications

Project 2006GA106B has resulted in no reported publications as of FY2006.

Report Follows

TECHNICAL REPORT: Restoration of flood pulses to the lower Savannah River: responses of invertebrates and fish

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PERFORMAMCE PERIOD: March 1, 2006 to February 28, 2007

Statement of Water Problem

River regulation is now recognized as a serious ecological problem. Dams restrict the downstream flow of water and of sediments and dissolved and suspended nutrients (Richter et al. 1997, Shannon et al. 2001). They also restrict the upstream as well as downstream movement of aquatic organisms that use the river corridors for migration (Gehrke et al. 1995). But perhaps most important to large floodplain rivers, dams alter the natural flood pulses to which organisms that occupy or use river floodplains are adapted, thus disrupting patterns of plant dispersal, establishment and growth, and of animal breeding and foraging (Junk et al. 1989, Poff et al. 1997, Ward et al. 1999, Jansson et al. 2000). These natural functions of large floodplain rivers are important to our society, not just because of their support of biodiversity but because humans derive substantial ecosystem service benefits from healthy, properly-functioning rivers (food, building material, water purification, flood mitigation, wildlife, soil maintenance, nutrient processing, coastal marsh maintenance, recreation, tourism, provision of beauty and life-fulfilling values)(Postel and Richter 2003, Dyson et al. 2003).

As such, efforts have been initiated to restore flood pulses to some regulated rivers (e.g., Shannon et al. 2001, Postel and Richter 2003, The Nature Conservancy 2004). However, projects to restore functions to river-floodplain systems by returning flood pulses are based largely on speculation because many (most) hypotheses on the ecological effects of flood pulses remain untested and responses of river ecosystems to flooding go largely unmonitored. This is highly undesirable, because being wrong about environmental flow needs has two potentially large societal consequences. Either the ecosystem will not get what it needs and degrade – with associated loss of socially valued ecosystem services – or other potential human uses of the water will be unnecessarily curtailed or limited, with attendant social and economic disruption. Water managers struggle to balance a broad spectrum of human needs or desires, and their decisions should be informed by well-documented evidence. Restoration attempts, especially the initial ones, should be based upon solid science and their success should be rigorously documented (Molles et al. 1998, Shannon et al. 2001, Middleton 2002; Poff et al. 2003). Only in this manner will water managers be able to evaluate the benefits of various water management options or scenarios.

The US Army Corps of Engineers (Corps) owns and operates three large multi-purpose dams on the Savannah River. It is difficult to exaggerate the degree to which the hydrology of the Savannah River has been modified. Under the flood management regime of the last 50 years, the 100-year flow is approximately the same size as the pre-dam 2-year flow. The current two-year flow (approximately 35,000 cfs) is one-third the size of the pre-dam 2-year flow (approximately 90,000 cfs). River-floodplain interactions probably have decreased commensurately. The altered flows and hydrographs undoubtedly have ramifications for the ecology of the Savannah River floodplain and estuary.

Nature, scope, and objectives of the project

The Nature Conservancy (TNC) and the Corps have entered into a national partnership to explore the potential for modifying Corps dam operations for ecological benefits while continuing to meet other human uses of water. This "Sustainable Rivers Project" includes 10 regulated rivers in 11 states. The Savannah River is a major project focus, with both agencies working towards returning flood pulses to the lower river, at least on an experimental basis, as part of the Savannah Basin Comprehensive Plan (which assessed authorized uses of the river to determine if existing water management adequately addresses all stakeholder needs).

In 2002, TNC and the Corps began a process to develop flow recommendations for the Savannah (Richter et al., in press). Over a series of workshops, almost 50 leading river, wetland, and estuary scientists from across the southeastern United States were convened and asked to develop expert-opinion recommendations on how to restore more natural-like river flow conditions to the Savannah River in order to rehabilitate floodplain and estuarine biotic communities. The resulting recommendations were, by intention, meant to support ecological values, with the understanding that the Corps would be assessing other interests through the comprehensive plan. Recommendations were developed for normal, wet, and dry years.

The Corps is fully supportive of working to integrate the ecosystem flow recommendations into the existing set of water management priorities. A small pulse was released in March 2004 to facilitate sturgeon migration through a small lock and dam facility below Augusta. In October 2004, a large pulse (30,000 cfs) of tropical storm induced run-off was released through Thurmond Dam to inundate floodplains as recommended for wet years, and a second pulse was released in March 2005 in conjunction with heavy regional rains. In 2006, a single pulse was released in March. In 2007, no water was released form the dam to create a flood pulse, however, a small natural pulse developed from heavy rainfall in early March. The Corps has expressed interest in making this type of adaptive, ecosystem-sustaining water management part of their standard practice. It is, however, critically important for all stakeholders that this is done in a scientifically credible manner.

Invertebrates and fish are logical organisms to use in assessing biological responses of flood restoration in Savannah floodplains. Both groups are crucial ecologically, and both groups have been successfully used in bioassessment programs elsewhere. The objective of this project is to empirically assess whether flow restoration is achieving the goal of restoring a more natural invertebrate and fish fauna on Savannah River floodplains.

Study sites

The headwaters of 27,000 km^2 Savannah River watershed are located in the Southern Appalachians. The upper Savannah flows though the Piedmont ecoregion and the lower Savannah through the Atlantic Coastal Plain, with the city of Augusta, GA located at the Fall Line that divides the two regions and Savannah, GA near the mouth of the river at the ocean terminus. On the upper Savannah River, the Corps maintains three large dams that form Hartwell, Russell, and Thurmond reservoirs. Thurmond Dam was the first built, in 1954, and is located the furthest downstream, just above Augusta. All three dams are multi-purpose, being authorized for hydropower generation, flood control, recreation, water supply, and fish and wildlife habitat.

The Corps will continue to seek to implement the flow recommendations for the Savannah River. Because weather patterns will change yearly, and the recommendations differ depending on precipitation patterns, this will result in numerous pulses of various magnitudes being released over the coming years. This variation will permit testing hypotheses addressing how biota respond to different kinds of flood pulses. A key challenge will be to gain an understanding of the necessary magnitude (size), timing, duration, frequency, and rates of rise and fall of the flood pulses that will generate a targeted ecological response. I will assess responses of invertebrates and fish to individual pulses. Over the longer term, I will assess responses on an annual or seasonal basis. Finally, over multiple years, I will measure overall community and functional recovery of the system, assessing whether invertebrate and fish communities are approaching reference standards.

To field test hypotheses, I have selected a set of habitats spaced systematically along the length of the lower Savannah River (Figure 1). My first study station is located on the reach of the Savannah just below Augusta and the Thurmond Dam, adjacent to the Savannah River Site. The second site is along the mid-reaches of the lower Savannah in Georgia's Tuckahoe Wildlife Area. The third site is along the lower portions of the river (above tidal influence) in South Carolina's Webb Wildlife Area. When hypothesis tests require contrasts with a reference standard, I am using habitats in the nearby Altamaha River that are spatially paired to those in the Savannah (Figure 1).

The Altamaha River is a useful reference because it shares many features with the Savannah in terms of size and geomorphology. Additionally, while no large river in the southeastern United States is free of human impacts, the Altamaha is perhaps the least regulated, most pristine large river system in the region. Importantly to this project is the fact that near-natural flood pulses still exist in the Altamaha. There are no dams along the 290 km length of the Altamaha. The Oconee and Ocmulgee River are the major tributaries of the Altamaha. The Ocmulgee also has no major dams along its length. Although two large dams occur on the Oconee River, they are managed using a pump-back system, where reservoirs remain near capacity. This practice reduces downstream baseflows but does not limit the magnitude of high water flood pulses through downstream habitats (what goes into these reservoirs must come out).

Figure 1. Locations of study floodplains on the Savannah and Altamaha Rivers

Hypothesis testing

The timing, duration, and magnitude of floods play an integral role in the establishment and survival of animals on river floodplains. For fish, most of the biological activity in floodplains occurs during the winter and spring flood pulses. There is a pattern of high-flows that, if provided to the river-floodplain section of the Savannah River, would increase fish production and potentially biodiversity via mechanisms associated with access to floodplain habitats and the "flood-pulse advantage". These mechanisms involve a subsidy to aquatic foodwebs by nutrients derived from the floodplain, and availability of floodplain habitats favorable to fish reproduction and growth. Floodplain habitat availability to riverine fishes depends on the physical extent and duration of floodplain inundation. Additionally, the size of the "flood-pulse advantage" - the pulse-induced increase in fish production per unit of water surface area - is hypothesized to depend on the rate of rise and fall of the flood-pulse, and pulse seasonality. Rapidly rising and falling pulses, which also tend to be short in duration, are unlikely to provide significant benefit to fishes. Pulses that occur when water temperatures are low also are less likely to benefit fishes than pulses that coincide with spawning and juvenile growth periods. Invertebrates in floodplains are influenced both by flood characteristics and fish. Wellborn et al. (1996) hypothesize that relative water permanence and fish presence or absence are the major factors structuring aquatic animal communities in lentic habitats.

I expect fish and invertebrate community changes that reflect the increase in frequency and duration of high flow events, and these changes should affect trophic dynamics of the animal community. Fish response to pulses are being assessed by sampling communities during flood events at the 3 Savannah and 3 Altamaha floodplains using electrofishing.. Community composition, individual size, and diet of fish are all useful measures for testing hypotheses. Invertebrate community composition are being assessed at each of the 6 floodplains using core sampling. Because aquatic invertebrate communities develop in precipitation-filled backswamp habitats, even in the absence of flood pulses, invertebrate sampling is being conducted in both wet and dry years, and not only during pulses. Invertebrates samples are collected soon after floodplains begin to hold water (December-February) to ensure rapid developing, aestivating forms are collected, and again in April to collect later colonizers and forms that develop slowly.

Impacts of flood pulses

Hypothesis 1. The small size and short duration of post-dam flood pulses has limited fish access to floodplains. A major question concerning the benefits of restoring pulses to the Savannah River is whether prescribed pulses will be of sufficient size and duration, and appropriately timed, to provide significant benefit to fishes. The area of floodplain inundated, as well as the rise, fall and duration of any particular pulse event likely varies geographically depending on floodplain morphology and drainage conditions. An individual flood pulse of sufficient magnitude and timed when fish are positioned to move into floodplains (spawning periods) has the potential to distribute fish across a greater portion of the floodplain.

Preliminary findings: From 2005-2007, I have collected 29 species of fish on the floodplains. Fish communities occurring on both Savannah and Altamaha floodplains comprise only a relatively small portion of the species present in the river. Collections have been dominated by various centrarchid species, mosquitofish, and assorted other typical wetland fish. I have observed minimal movements of fish onto floodplains that were not already adapted to wetlands.

Dominant fish species (of 29)

- Mosquitofish (*Gambusia* spp.)
- Warmouth (*Lepomis gulosus*)
- Chain and Grass pickerel (*Esox niger, E. americanum*)
- Pirate perch (*Aphredoderus sayanus*)
- Bullhead (*Ameiurus* spp.)
- Coastal shiner (*Notropis petersoni*)
- Flier (*Centrarchus macropterus*)
- Bluegill (*Lepomis macrochirus*)

Table. Fish collected

Fish communities have not differed markedly between the Savannah and Altamaha Rivers (Figure 2), with annual variation between the 2005 and 2006 study years exceeding the spatial difference between rivers. However, the most up-stream floodplain in the Savannah supported an aberrant fish fauna (Figure 3). In 2007, only a small early season pulse developed, and fish collections in both rivers were meager, suggesting that fish remained restricted to the rivers or deep water areas on the floodplains.

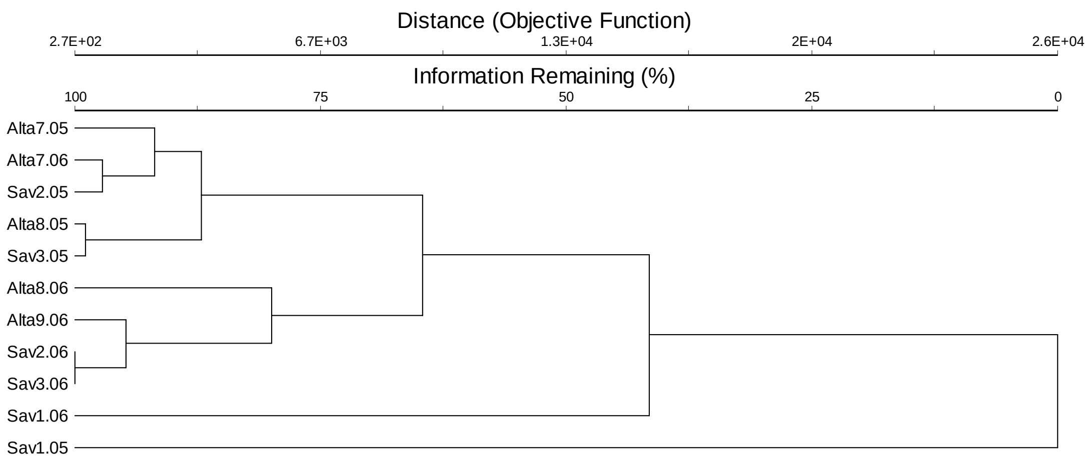

Figure 2. Fish community comparisons among 6 study floodplains over 2 years.

Hypothesis 2. An individual flood pulse of sufficient magnitude could enable predatory fish to exploit invertebrate resources on the floodplain (both aquatics and stranded terrestrials). *Preliminary findings*: Mostly aquatic invertebrates have been found in fish guts thus far, with microcrustaceans (Cladocera and Ostracoda), asselid Isopoda, Chironomidae midge larvae, and Dytiscidae beetle larvae and adults occurring most commonly and in the greatest numbers. I do not yet have sufficient information to assess whether foraging patterns on the Savannah and Altamaha differ.

Hypothesis 3. Fish reproduction will only be successful if water remains ponded on floodplains for periods sufficient for development, and that floodplain connections are maintained at least periodically to permit fish larvae to return to the river. Flood pulses must provide dual service to fish of providing access to the floodplain and an escape route, so one pulse is required when fish are ready to spawn and at least one more when fish larvae are ready to return to the river.

Preliminary findings: Because the fish fauna is dominated by wetland taxa (see above), it is unclear whether successful reproduction requires annual egress from the floodplain. I have detected most of the fish commonly caught during floods persisting in shallow backwaters long after floods have subsided (e.g., October 2006). I am developing a hypothesis that fish success in floodplains is not only dependent on the connectivity between the floodplain and the main channel, but also by connectivity with semi-permanent backwater habitats. If this is true, then the impacts of past flow regulation on the fish community on Savannah floodplains may have been buffered by the persistence of backwater habitats.

Hypothesis 4. The small size and short duration of post-dam flood pulses has probably affected invertebrate communities because species unable to complete development rapidly were inhibited. Conversely, small and short duration flood pulses have probably benefited some invertebrates because some predatory fish have been excluded. Pulse restoration should allow more invertebrates to successfully reproduce and complete development before the floodplains dry, although populations tolerant of short duration hydroperiods but susceptible to fish predation may decline.

Hypothesis 5. Low nutrient and mineral inputs from a lack of over-bank flooding may be limiting invertebrate productivity on Savannah floodplains, and water-borne chemicals associated with flood waters may affect invertebrate productivity.

Preliminary findings: Data thus far indicate that invertebrate communities in the Savannah and Altamaha River differ (Figure 2). The most aberrant invertebrate faunas on the Savannah occurred in 2 sites that were virtually fishless at the time.

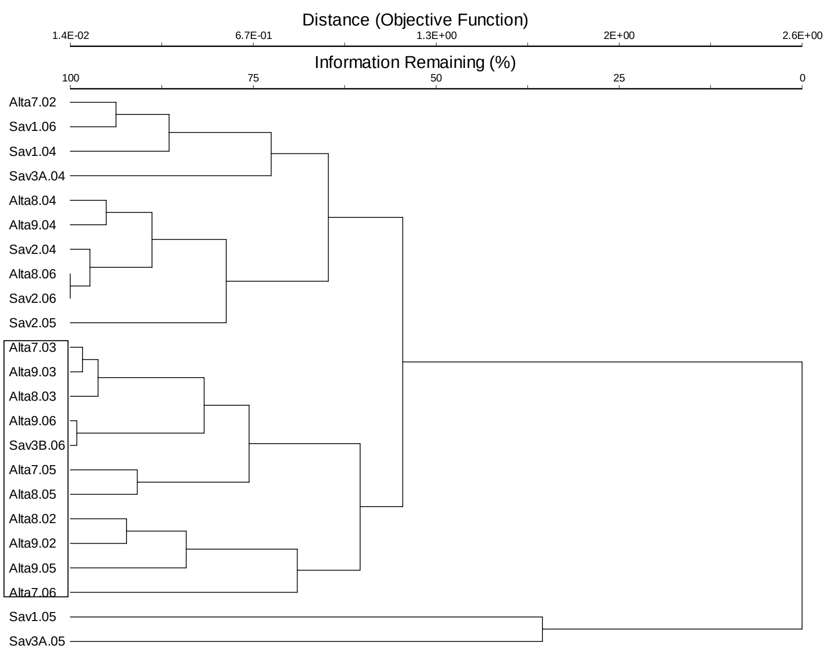

Figure 2. Invertebrate community compositions in Altmamah (Alta) and Savannah (Sav) floodplains. The first numbers indicate the floodplain number (Figure1) and the second the year.

Hypothesis 6. Fish and invertebrate communities on the Savannah should shift over the years to become more similar to those communities occurring in non-regulated systems. Animal communities will be affected by both flooding and structural and compositional changes in the vegetative community brought about by changing hydrology.

Preliminary findings: It is too early to assess responses over longer terms, but this is a goal of the project.

References

Batzer, D. P. and S. A. Wissinger. 1996. Ecology of insect communities in nontidal wetlands. Annual Review of Entomology 41:75-100.

Bayley, P. B. 1995. Understanding large river floodplain ecosystems. Bioscience 45:153:159.

Dyson, M., Berkamp, G., and Scanlon, J. (eds) 2003. Flow: The Essentials of Environmental Flows. IUCN, Gland, Switzerland.

Gehrke, P. C., P. Brown, C. B. Schiller, D. B. Moffatt, and A. M. Bruce. 1995. River regulation and fish communities in the Murray-Darling river system, Australia. Regulated Rivers: Research and Management 11:363-375.

Jansson, R. C. Nillson, M. Dynesius, and E. Andersson. 2000. Effects of river regulation on river-margin vegetation: a comparison of eight boreal rivers. Ecological Applications 10:203-224.

Junk, W.J., P.B. Bayley and R.E. Sparks. 1989. The flood pulse concept in river-floodplain systems. pp. 110-127 in: Proceedings of the International Large River Symposium, D. P. Dodge, (ed). Canadian Special Publications Fisheries Aquatic Sciences 106.

Middleton, B. A. 2002. Flood Pulsing and Wetland: an Evaluation of the National Investment in Municipal Wastewater Management: Restoring the Natural Hydrological Balance. John Wiley and Sons, New York.

Molles, M. C., C. S. Crawford, L. M. Ellis, H. M. Valett, and C. N. Dahm. 1998. Managed flooding for riparian ecosystem restoration. Bioscience 48:749-765.

Poff NL, Allan JD, Hart DD, Richter BD, Meyer JL, Palmer MA, and Stanford JA. 2003. Environmental science and water conflicts: five steps to improved scientific decision-making. Frontiers in Ecology and the Environment 1:298-306.

Postel S, and Richter B. 2003. Rivers for Life: Managing Water for People and Nature. Island Press, Washington, D.C.

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.

Richter, B.D., A.T. Warner, J.L. Meyer, and K. Lutz. A collaborative and adaptive process for developing environmental flow recommendations. River Research and Applications, in press.

Schneider, R. L. and R. R. Sharitz. 1988. Hydrochory and regeneration in a bald cypress-water tupelo swamp forest. Ecology 69:1055-1063.

Shannon, J. P., D. W. Blinn, T. McKinney, E. P. Benenati, K. P. Wilson, and C. O'Brien. 2001. Aquatic food base response to the 1996 test flood below Glen Canyon Dam, Colorado River, Arizona. Ecological Applications 11:672-685.

Welcomme, R. L. 1979. The Fisheries Ecology of Floodplain Rivers. Longman, London.

Wellborn, G. A., D. K. Skelly, and E. E. Werner. 1996. Mechanisms creating community structure across a freshwater habitat gradient. Annual Review of Ecology and Systematics 27:337-364.