WATER RESOURCES
IMPACT

SAVANNAH RIVER, GEORGIA: SCIENCE TO SUPPORT ADAPTIVE IMPLEMENTATION OF ENVIRONMENTAL FLOWS TO A LARGE COASTAL RIVER, FLOODPLAIN, AND ESTUARY

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INTRODUCTION

Rivers of the Southeastern United States traverse a wide coastal plain where they are characterized by broad floodplains and expansive estuaries. Because of ample rainfall and the flat terrain, these rivers were historically subject to large, frequent floods, particularly in the spring or associated with tropical storms or other major rain events. Because floods can be hazardous to human settlements, extensive networks of dams have been built on many, if not most, major Southeastern rivers, and river flows have been closely regulated to minimize flooding. This has made it difficult for managers to meet competing interests for water such as property protection, hydropower, or recreational needs, along with the needs of downstream habitats and species. The services provided by healthy functioning floodplains are rarely considered in management plans. Floodplains provide flood protection, water reclamation, pollution abatement, aquifer recharge, wildlife habitat, and recreation opportunities. Estuaries and their associated tidal marshes are vital natural areas, providing habitat for fish, shellfish, and wildlife; maintenance of water quality via waste assimilation and nutrient processing; climate control via carbon sequestration; prevention of sediment erosion; and protection from storms. Riverine, floodplain, and estuarine habitats may become degraded by regulation, because many biological functions in these crucially important ecosystems rely on natural variation in flows including flooding.

FLOODPLAIN ECOLOGY

The periodic inundation of floodplains is believed to be the major factor in sustaining the ecological functions of river-floodplain systems (see review in Junk and Wantzen, 2006). The high overall productivity and biodiversity of these systems is due largely to the many-fold increase in aquatic areas occurring upon floodplain inundation. Flood pulses can exert a range of influences such as shaping the morphology of river channels and floodplains, affecting soil oxygen and moisture levels, and impacting biological and chemical transformations among nutrient pools. Flood pulses regulate plant reproduction, with seedling establishment only successful under certain hydrologic conditions (Schneider and Sharitz, 1988). Flood pulses during the plant dormant season (October-March) can increase soil moisture, disperse seeds, and inhibit germination of upland species (those species not considered wetland residents), on lower elevation sites.

When the frequency of floods is reduced in areas of intermediate (or higher) elevation, it may result in drier soil conditions that allow invasion of upland species. Thus, in rivers where pulses have become regulated, tree species that dominate juvenile size classes (saplings, seedlings) may have a different flood tolerance than canopy species that were established prior to flow regulation. In contrast, floods occurring during the growing season limit tree seedling survival during the early phases of recruitment, and summer floods of more than a few days are likely to cause mortality of newly established seedlings. The copious plant growth on floodplains, especially trees, becomes an important source of organic matter input (leaves, wood) throughout the system. Once decomposed, some organic materials move into the channel and then to downstream habitats.

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In addition, healthy floodplains support a community of invertebrates (insects and crustaceans) and fish specifically adapted to live and breed in wetlands. Most fish activity in Southeastern floodplains occurs during the winter and spring flood pulses. Floodplain habitat availability to riverine fishes depends on the physical extent and duration of floodplain inundation, 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 meaningful benefits 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 (typically spring and early summer months). Perhaps the primary reason that fish move onto floodplains is to exploit invertebrates as food, and like fish the resident invertebrate community is strongly influenced by the character of flood pulses.

Nonaquatic animals can also be affected by flood pulses. Late spring floods can destroy nests of ground-nesting birds, but prolonged late flooding provides canopy birds with protection from a variety of nest predators. Longer-term effects on bird communities will likely reflect the frequency (both within the year and annual rate) of flood pulses, as well as changes occurring in the plant community.

ESTUARY ECOLOGY

As flood pulses make their way downstream they ultimately influence estuaries and their associated intertidal marshes. Because tidal wetlands are regularly inundated to levels that are primarily influenced by sea level (Figure 1), flood pulses have a different effect in these areas as compared to upstream. Rather than increasing the period or extent of inundation, a flood pulse in a tidally-influenced area will be manifest as a slug of low salinity water. The distribution of many estuarine resources, including marsh plants, plants, animals or bacteria that live on tidal creek sediments or living within the water column can shift in response to changes in salinity. Changes in the pattern of inflow will also affect the delivery of nutrients, organic matter, and sediment, which can in turn affect estuarine productivity rates and trophic structure (Alber 2002). The effects of freshwater pulses are likely to vary depending on the length of the pulse as well as the individual life histories of estuarine organisms, but freshwater regulation can affect migration patterns, spawning habitat, and species diversity of both fish and invertebrates (Drinkwater and Frank 1994).

A short-term period of reduced salinity (i.e. days to weeks), that occurs with a flood pulse, is likely to affect the distribution of motile organisms as they move to stay in water of a preferred salinity. Wetland plants and sedentary organisms (such as oysters or benthic infauna) are generally able to tolerate a range of salinities. Over the longer term (years), however, a regular regime of flood pulses may well cause more permanent shifts in the distributions of all organisms, with effects on population dynamics and community composition.

To the extent that decreased flow tends to "squeeze" the estuary this may result in decreased areas of appropriate habitat. Upstream habitats in particular, such as tidally influenced forests and marshes, are most likely to show an immediate and measurable response to changes in freshwater inflow than habitats closer to the ocean. It is not clear how a change in the intertidal marshes, particularly a shift from tidal fresh to salt marsh, will affect the ecosystem services that marshes provide. Plant diversity is higher in tidal fresh as compared to salt marshes, but trends in overall biodiversity are less clear. Recent studies have shown that, while primary production is equivalent in fresh and saltwater marshes, rates of decomposition are much slower in fresh than salt marshes, leading to increased accumulation of soil and higher concentrations of organic carbon and nitrogen in fresh marshes (Craft 2007).

In addition to upstream management of dams and reservoirs, other types of perturbations will also affect estuarine areas. Channel dredging and sea level rise will both result in increased upstream penetration of seawater and an associated decrease in the low salinity

Figure 1. Overlooking Doboy Sound Salt Marsh, Georgia (photo by Amanda Meadows).

habitat, whereas an increase in storm activity will increase freshwater flow. Understanding the implications of changing flooding regimes and the delivery of freshwater to estuarine habitats will remain an important area of study.

THE SAVANNAH RIVER PROJECT

The Nature Conservancy (TNC) scientists are working with partners to protect downstream aquatic habitats in the Savannah River basin, Georgia, by advancing ecosystem flow restoration and adaptive management. The U.S. Army Corps of Engineers (Corps) maintains three large dam and reservoir projects within the basin. Under the water management regime of the last 50 years, there has been a removal of natural variability in the hydrograph including a reduction in peak flow volumes and frequency (Figure 2).

The Corps in partnership with TNC has released experimental controlled flood pulses per scientific recommendations developed specifically for the Savannah River. In order for the Corps to adopt ecological water management as standard practice, flow recommendations, or flow restoration hypothesis, must be tested in a scientifically credible manner. TNC and partners such as the U.S. Fish and Wildlife Service, Georgia and South Carolina Departments of Natural Resources, The University of Georgia, Savannah State University, The Southeastern Natural Sciences Academy, and Augusta State University have begun to implement monitoring approaches to determine pre-controlled and post-controlled flood release conditions (Figure 3).

Figure 3. Dr. Darold Batzer and His Students Sampling the Savannah River Floodplain During an Experimental Controlled Flood (photo by Andrew David Tucker).

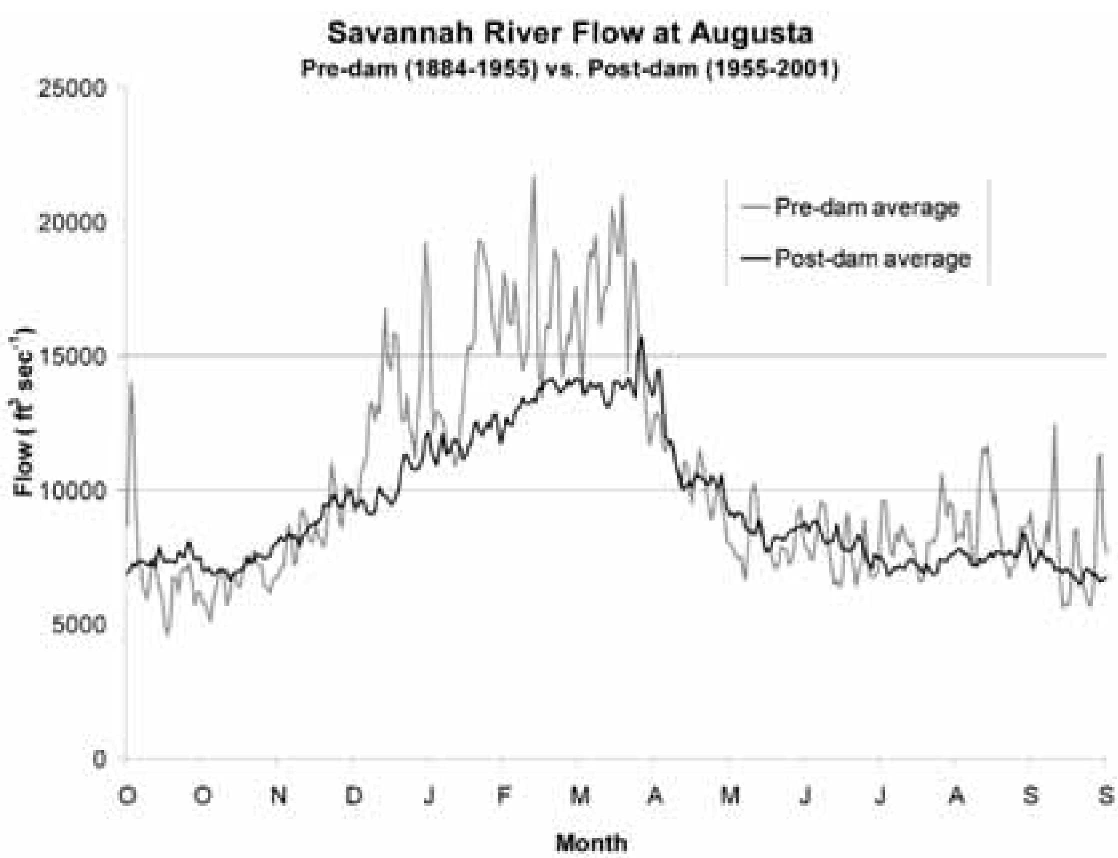

Figure 2. Comparison of Pre-Dam and Post-Dam Monthly Average Flows on the Savannah River, Measued at Augusta, Georgia, From 1884 to 2001.

This effort of supplying science to support ecosystem flow restoration has been successful because of the work of professors, students, agency biologists, Corps hydrologists, and volunteers. Initially flood pulses have been measured with dynamic response indicators such as floodplain fish use, quantity and duration of floodplain flooding, anadromous fish movements, shifts in floodplain invertebrate communities, water quality, and a temporary shift in the average location of the saltwater/freshwater interface in the estuary (Wrona *et al.,* 2007). Bench mark, or long-term indicators such as riverine freshwater mussel populations or floodplain tree recruitment and growth will need to be measured over decades. Although the adaptive management process essential to ecosystem flow restoration in the Savannah depends on rigorous scientific measures, funding sources for this type of science, especially long-term monitoring, are scarce. The cost of both short and long-term monitoring is high and is difficult to "sell" to the public as an important conservation action.

The Savannah River provides an opportunity to give much needed definitions to the concept of adaptive management as well as the opportunity to test large scale aquatic ecosystem response to flow restoration. By continuing to monitor the effects of flow restoration and feeding these results back into the adaptive management framework, we will be able to advance the Savannah River as successful example of ecologically sustainable water management.

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AUGUST 2007

5-14 / 33rd International Geological Congress (IGC). Oslo, Norway. Prof. Arne Bjorlykke, President of the 33rd International Geological Congress (arne.bjorlykke@ngu.no) or Scientific Program Committee (secretariat@33igc.org) (www.33igc.org)

13-17 / Shortcourse – Geomorphic and Ecological Fundamentals for River and Stream Restoration. Lake Tahoe, CA. **Contact** restoration.ced.berkeley.edu/shortcourse. Also restoration_shortcourse@yahoo.com

20-21 / Short Course – NGWA Geothermal Heat Pump Conf. (#5112). Columbus, OH. **Contact** NGWA, 601 Dempsey Rd., Westerville, OH 43081 (800-551-7379; 614-898-7786; w: ngwa.org/e/other/continue.cfm)

SEPTEMBER 2007

5-7 / Alabama Water Resources Conference. Orange Beach, AL. **Contact** www.auei.auburn.edu/conference or 334.844.4132

11-13 /2007 Wallingford Software International User Conference. Howbery Park, Wallingford, UK. **Contact** David Ford, Ford-Peacock Consultncy Ltd. (+44 (0) 1295 722213; w: david@ford-peacock.com)