RESTORING ECOLOGICAL FLOWS TO THE LOWER SAVANNAH RIVER: A COLLABORATIVE SCIENTIFIC APPROACH TO ADAPTIVE MANAGEMENT

Amanda Wrona[1], Donna Wear[2], Jason Ward[3], Rebecca Sharitz[4], Jay Rosenzweig[5], Joseph P. Richardson[5], Douglas Peterson[6], Steven Leach[7], Linda Lee[4], C. Rhett Jackson[6], Judith Gordon[2], Mary Freeman[8], Oscar Flite[9], Gene Eidson[9], Mary Davis[10], and Darold Batzer[11]

AUTHORS: [1]The Nature Conservancy, Savannah, GA, [2]Dept. of Biology, Augusta State University, Augusta, GA, [3]United States Army Corps of Engineers, Savannah District, Savannah, GA, [4]Savannah River Ecology Laboratory, Aiken, SC, [5] Marine Sciences Program, Savannah State University, Savannah, GA, [6]University of Georgia Warnell School of Forestry and Natural Resources, [7]Normandeau Associates, Inc., [8]United States Geological Survey, Athens, GA, [9]Southeastern Natural Sciences Academy, Augusta, GA, [10]The Nature Conservancy, Atlanta, GA, [11]Dept. of Entomology, University of Georgia, Athens, GA.
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Abstract. This paper represents a special session held at the 2007 Georgia Water Resources Conference addressing an on-going collaborative research effort on the Savannah River. Savannah River flows have been intensively managed over the past decades for hydropower, flood control, and recreation. Management for ecosystem purposes has received less attention. The Nature Conservancy and The US Army Corps of Engineers have entered into a partnership to actively include ecological flow restoration into Savannah River management plans. To this end, water releases for ecosystem purposes have been conducted yearly since 2004. As part of an adaptive management plan, scientists have been monitoring the impact of flow restoration on various ecological processes and water quality, and this collaborative effort is the basis for this symposium. The paper begins with an overview of how this project developed, and then continues with a discussion of how ecological flows have been incorporated into dam management by the US Army Corps of Engineers. Subsequent sections address issues of water quality, fish passage, floodplain hydrologic conditions, response of floodplain plant communities, response of floodplain fish and invertebrate communities, the health and reproductive status of the protected rocky shoals spider lily, and effects of flood pulses on estuarine salinity.

INTRODUCTION

The Savannah River is among the most impacted of southeastern rivers. The 27,000 km^2 Savannah River watershed contains extremely high species biodiversity, including the greatest number of native fish species (108) of any river draining into the Atlantic and over 74 rare and endangered species. The watershed also contains excellent examples of rare and unique ecological communities such as longleaf pine, Carolina bays, and extensive bottomland hardwoods including some old growth examples. The Savannah River Basin is a conservation priority for both state and federal government and non government organizations. The Nature Conservancy's (TNC) staff is working with the U.S. Army Corp of Engineers and more than 7 other government, NPO, and academic partners to gain understanding of the influence of hydrologic processes (timing, duration, frequency, magnitude, and rate of change) on the river's ecology and water quality. This initiative addresses flow restoration in the Savannah and is measured in water quality, endangered species, and ecosystem function responses.

In this paper we summarize our collaborative research efforts towards implementing and assessing restoration of ecological flows to the lower Savannah River. We discuss 1) reservoir management, 2) water quality issues along the Augusta corridor, 3) the status of the endangered spider lily in the Augusta Shoals, 4) fish passage through the Savannah Bluffs Lock and Dam, 5) hydrology and ecology of floodplains along the lower Savannah River, and 6) the salinity gradient in the Savannah River estuary.

Background

The Savannah Basin supplies water for two expanding major urban areas (Savannah and Augusta, GA) and three rapidly growing coastal counties (Jasper, Hampton, and Beaufort Counties, SC). The basin supplies drinking water for over 1.5 million people, and multiple industries with 187 mgal/day of consumptive losses, 21% of which is for domestic and commercial use (Alber and Smith 2001). The Savannah River is also harnessed for hydropower within Georgia and South Carolina, and for growing industrial use including a large sea port. Thus, the Savannah River is among the most highly stressed southeastern rivers.

Pressures on the Savannah Basin are expected to grow considerably in the immediate future. Population growth in Georgia is estimated to increase by 47% over the next 25 years with a large proportion of growth located near water (rivers, lakes, and the coast). In South Carolina, statewide growth is projected at 22% over the next 25 years, with some counties projected to grow 800% with the addition of 150,000 new residents. Large land tracts in Jasper County have recently been purchased by developers with intent of providing 60,000 new residential units over the next 20 years.

To supply freshwater to municipal and industrial users, The US Army Corps of Engineers maintains three large dams on the upper Savannah River, creating Hartwell, Russell, and Thurmond reservoir lakes. The Thurmond Dam was the first built, in 1954, and is located the furthest downstream, just above Augusta. The river empties into the Atlantic through an extensive estuary surrounding the city of Savannah.

It is difficult to exaggerate the degree to which the hydrology of the Savannah River has been modified. Under the dam 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 two year flow (approximately 90,000 cfs)(Figure 1). However, subsequent development of the floodplain has effectively "bought back" the flood risk, and now localized flooding occurs when the river reaches a mere 30,000 cfs. River-floodplain interactions probably have decreased commensurately. Conversely, 7-day low flows in the lower river have increased greatly since dam operations began. In addition to these hydrologic alterations, the lower Savannah has been directly modified through dredging and channelizing to allow barge traffic to reach Augusta. Approximately 26 miles or 13% of the river's original length has been removed due to the creation of forty navigation cuts. Dredge operations in the harbor of the city of Savannah affect mixing of fresh and salt water in the estuary, and plans for harbor deepening threaten to exacerbate the problem.

Preliminary studies (Sharitz et al. 1990, Jones et al. 1994) indicate that in some sites where the hydrologic pattern has been substantially altered, floodplain forests are not regenerating. Studies in the Savannah National Wildlife Refuge demonstrated that alterations to the estuary (primarily flow alterations from channel dredging) resulted in the loss of fresh and oligohaline marsh (Latham et al. 1993; Pearlstine et al. 1993). Additional impacts of flow alteration on Savannah can be found in the document "Summary Report Supporting the Development of Ecosystem Flow Recommendations for the Savannah River below Thurmond Dam" (at http://www.rivercenter.uga.edu/publications.htm).

In 2002, TNC and the Corps began a collaborative effort resulting in a national partnership (the Sustainable Rivers Project) to restore ecological integrity to rivers across the nation. Of the 10 river projects, the Savannah River has become a national and international focus, with both agencies working towards restoring the lower river as part of the USACE Savannah Basin Comprehensive Study (a process to determine if the existing water management plan adequately addresses all stakeholder needs).

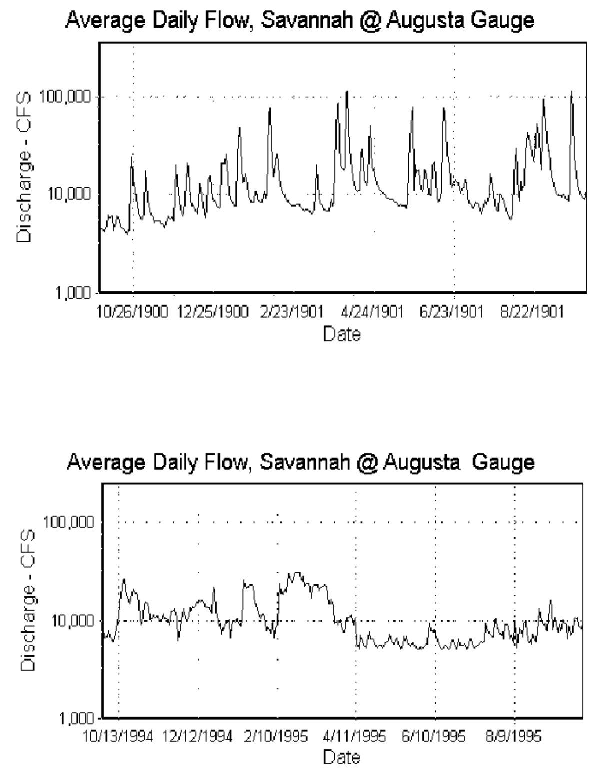

Figure 1: Two year average daily flows in the Savannah River at Augusta in pre-dam 1990 and 1901 (top graph) and post-dam 1994 and 1995 (bottom graph).

In order for the Corps to adopt ecological water management as standard practice, the flow recommendations for enacting were crafted in a scientifically credible manner. TNC convened leading scientists from across the southeastern United States to develop ecosystem flow recommendations for the Savannah River to rehabilitate channel, floodplain, and estuarine habitats. With ecosystem flow requirements in hand, the Corps has released experimental controlled flood pulses as per recommendations in spring 2004. A collaborative initiative facilitated by TNC including U.S. Fish and Wildlife Service (USFWS), GA and SC DNR, The University of Georgia, Savannah State University, The Southeastern Natural Sciences Academy, and Augusta

State University crafted and implemented monitoring approaches to determine pre- and post-release conditions. With modifications based on monitoring and modeling results another controlled flood was produced in spring and fall of 2005, and again in spring of 2006. Overall, TNC's process of developing ecosystem flow restoration recommendations has received considerable attention from scientists working on other flow restoration projects around the world. The process is iterative, where each controlled flood pulse is viewed as an experiment that is monitored and scientifically refined over time.

The resultant learning through testing, evaluation, and modifying management actions is called adaptive management (Holling 1978, Walters 1986, Gunderson et al. 1995). The application of adaptive management principles has been limited in environmental flow restoration. To date adaptive management has been defined by complicated examples (Johnson 1999). If adaptive management programs are expensive, complex, and take years to reach decisions, managers will be reluctant to invoke them (Walters 1997, Richter et al. 2006). The Savannah River provides an opportunity to give badly needed new definition to the concept of adaptive management. By advancing successful examples of ecologically sustainable water management in places like the Savannah River, the Conservancy and other scientists hope to motivate other Corps districts and water managers in other agencies to adopt similar practices around the world.

INCOPERATING ECOLOGICAL FLOW RESTORATION INTO MULTIPURPOSE RESERVOIS MANAGEMENT ON THE SAVANNAH RIVER

Reservoir Management in the Savannah Basin

Hartwell, Russell, and Thurmond Dams are three large USACE projects on the Savannah River that support multiple purposes including water supply, hydropower, flood control, fish and wildlife management, recreation, and navigation. Following is a summary table of some of the projects' characteristics:

Project	Year Built	Storage (acre-feet)	# of Turbines	# of Tainter Gates
Hartwell	1962	2549600	5	12
Russell	1984	1026244	8 (4 conv./4 pump)	10
Thurmond	1952	2510000	7	2

There are also six smaller dams owned by Georgia Power and two owned by Duke Power upstream of Hartwell Dam. Fifty eight percent of the 10,500 square mile watershed is regulated from Thurmond Dam upstream.

The USACE dams operate as a tandem system to support Congressionally authorized project purposes. For example, downstream minimum flow requirements are supported by water in storage at all three projects. Russell is a pumped storage project where water is pumped from Thurmond downstream during off peak energy hours at night and used in generation mode the next day to meet peak energy demands. Pumped storage operation helps support some of the hydropower requirements of the system and conserves water in the reservoirs during droughts. The reservoirs function interdependently to accomplish system objectives. Each pool is subdivided into conservation and flood control zones. Currently, water in conservation storage is used to meet all purposes except flood control. Changing the designated use of water in this zone can result in reduced benefits to the other project purposes, primarily hydropower.

Costs are allocated to each use in order to pay for the operation and maintenance of the dams and original capital costs. As new operational objectives are identified for the system, the effects on pre-existing projects purposes must be quantified to evaluate trade-offs. If these new objectives exceed the existing authorization, it may be necessary to perform a comprehensive basin study prior to implementation.

The Savannah River Basin Comprehensive Study was initiated in 2001 and funded by the USACE Savannah District and the states of Georgia and South Carolina. Phase I of this study recently concluded with the following products:

- An update of the District drought contingency plan
- Development of a reservoir operation model (HEC-ResSim) to evaluate alternatives
- Preliminary modeling of storage and flow changes including ecosystem flows.

Unfortunately, federal funding was lost for Phase II which would have included detailed analysis of alternatives that would likely require reallocation of storage. Until this phase is undertaken, the implementation of ecosystem flow restoration will be impeded by existing constraints.

Adaptive Management for Ecological Flows

As with all large storage reservoirs, there has been a significant effect on the timing and magnitudes of downstream hydrologic events due to operation of the dams. Over the past three years, USACE water managers and other resource agency personnel have used the ecosystem flow recommendations as guidelines to conduct flow experiments within existing operational flexibility. To provide water for these experiments, we deviated from normal operating procedures by storing additional water in the flood control pools. This continues to be an adaptive learning process in which the specific timing, magnitudes and duration of the releases are refined by collaboration with resource agencies for the basin. We have used the current percentile of calculated 90 day average natural inflow at Thurmond to categorize the year type as wet, dry, or average.

Study objectives for spring pulse flow experiments have included evaluating fish passage success at New Savannah Bluff Lock and Dam (NSBLD) and corresponding floodplain and estuary benefits associated with pulsing. In 2004, we operated with no winter time drawdown at Hartwell and Thurmond and had a 3 day pulse of 16,000 cfs in March. In March 2005, we targeted no drawdown again at Hartwell and Thurmond and provided two 3-day pulse flows of 18,000 cfs. In March 2006, we operated with a modified 2 foot drawdown at Hartwell and Thurmond due to concern about shoreline damages and provided one 3 day pulse of 23,000 cfs. The magnitude of the pulse increased each year as we learned what flow was necessary to inundate NSBLD gates while still maintaining sufficient stage for water users of the pool. Monitoring data on fish passage effectiveness and floodplain benefits will guide future targets.

Continuing the Savannah River Basin Comprehensive Basin Study is crucial to incorporate further ecological flow needs into existing management strategies. The study would help provide the supporting science and economic analyses to change reservoir operational policies. Water quality, fisheries, and ecosystem monitoring downstream can continue to be leveraged to refine flow recommendations and improve the overall management of the system as a whole.

PRELIMINARY WATER QUALITY DATA FROM THE SAVANNAH RIVER AUGUSTA CORRIDOR

EPA has required a reduction of approximately 30% of the total load of oxygen demanding substances currently being discharged into the Savannah Harbor to meet various water column dissolved oxygen concentration targets. Targeted discharges are those that directly discharge into the harbor and/or NPDES-regulated discharges originating within the upstream watershed starting at the Thurmond Dam. This requirement stems from a consent decree obligation resulting from a Sierra Club v. EPA Civil Action lawsuit. In addition, the Savannah River has other issues that require attention: fish consumption advisories pertaining to mercury bioaccumulation, wasteload allocations between Georgia and South Carolina, and water quantity issues as the Savannah becomes a significant facilitator of economic development and the potential target for further interbasin transfers, especially in Georgia.

In January 2006, the Southeastern Natural Sciences Academy initiated a two year comprehensive study within the Middle Savannah watershed, with emphasis on the Augusta urban corridor, to supply the much needed data to address current and future issues regarding water quality within the Savannah River. This study was designed to characterize the complex physical, chemical, and biological dynamics that occur within the river by using a mass balance approach. Here we present a portion of the first 6 months of data collection and analysis.

Methods

The mass balance approach was achieved by partitioning the main channel of the Savannah River, from River Mile 215 to River Mile 148, into 7 segments so we could assess fluxes within shorter river segments. We also assessed contributions from the three main tributaries to the Savannah River that were located within the study reach, Stevens Creek, Horse Creek, and Butler Creek. The study reach encompassed the length of the Augusta urban corridor which extends from River Mile 207 to River Mile 185. We employed methods which incorporate both Eulerian and Lagrangian perspectives. The Eulerian viewpoint was assessed by deploying multiparameter sondes at stationary locations in the thalweg of the mainstem channel and within the main tributaries within the study reach. The Lagrangian viewpoint was used for assessing constituent fluxes between stream reaches. Lagrangian samples were collected using a vertically integrated, flow weighted sampler when the flow allowed for such use (>1 m/s), otherwise samples were taken using a pump and end-weighted tube. Approximately 20 L of water was collected monthly from each sampling location, with approximately one-third of the total volume collected from 3 equidistant points along a transect at each location. All samples were collected and analyzed according to standard protocols.

Results

Preliminary Eulerian results showed that, on average, temperature and specific conductance increased steadily from river mile 215 to river mile 148 with the highest variability for both parameters at the downstream station. (Figure 2) The overall trend for pH showed no net change from River Mile 215 to 148 but pH increased by nearly 1 unit at River Mile 202 and was most variable at that location. The overall trend for dissolved oxygen showed a net loss of ~0.5 mg O_2/L from River Mile215 to 148 but increased by an average of 1.5mg O_2/L at River Mile 202 and remained elevated through River Mile 185 (Figure 3). Lagrangian sampling results for the May sampling event showed that increases in conductivity from River Mile 215 to 148 resulted mostly from downstream increases in sodium, alkalinity (as CO_3), sulfate, chloride, potassium, calcium, and iron. Total organic carbon, almost entirely in the dissolved phase, increased from River Mile 215 to 148. This increase was equivalent to ~700 kg C added to the river over that reach, none of which was characterized as a biologically oxygen demanding substance but may have been characterized as an oxygen demanding substance under harsher conditions (Chemical oxygen demand).

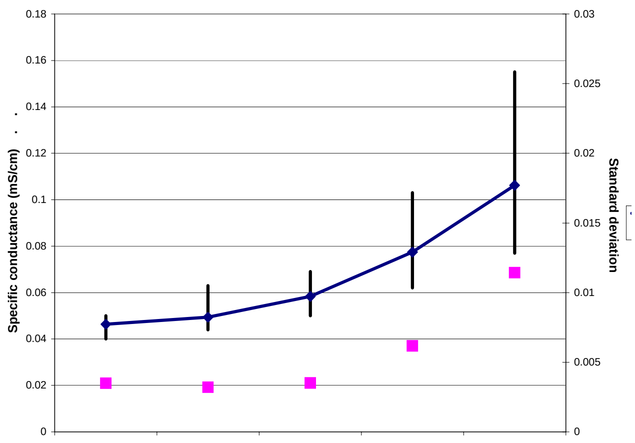

Figure 2. Specific conductance statistics from several river stations within the first 6 months of the study. Vertical bars indicate range of values.

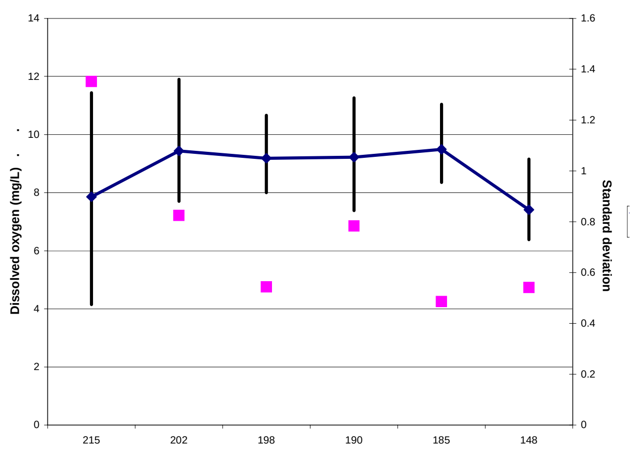

Figure 3. Dissolved oxygen statistics from several river stations within the first 6 months of the study. Vertical bars indicate range of values.

ASSESSING THE STATUS OF THE SHOALS SPIDER LILY, HYMENOCALLIS CORONARIA, IN THE AUGUSTA SHOALS

Three Southeastern states with river shoals habitat suitable for the shoals spider lily, Hymenocallis coronaria, have listed the species as being in decline due to loss of habitat. Georgia officially lists the species as endangered, South Carolina lists it as a plant of concern, and Alabama gives it no official status. There are only three small remaining populations in the Savannah River shoals, where it was first discovered in 1773 by naturalist William Bartram (1791). These populations exhibit evidence of a decline from presumed historic numbers. In this initiative, several studies have consequently been initiated to determine which parameters may account for this decline.

Methods

The parameters we examined were chosen based on results from previous studies by Aulbach-Smith (1998) and Duncan and EuDaly (2003). We examined water chemistry, flow rates, light intensity, siltation, sexual and asexual reproduction, pollinators, and herbivory as possible factors influencing population size and status. For comparative purposes we measured these factors in both the Savannah River Shoals at Augusta, GA, and in a relatively undisturbed population in Stevens Creek, east of Parksville, SC.

Results

Our results indicate that herbivory by deer, occurring in the southernmost population, is a major factor limiting reproduction. During the 2006 growing season only four flowers developed and no seedlings were found. Also absent from this population were beds of Podostemum, and aquatic perennial dicot considered an indicator of water quality, which have been shown to be critical to seedling establishment (Aulbach 1998). Abnormally fluctuating flow rates in the river after anthesis have also adversely affected the ability of all three Savannah River populations to produce flowers and/or seedlings which require sufficient time and opportunity to become established during the critical months following anthesis. The Stevens Creek population in contrast, having less fluctuation in flow rates, has higher flower numbers and more successful seedling establishment. That population has also not suffered from any type of herbivory although it is easily accessed by deer. A relatively small number of seeds from both sites show tooth damage from muskrats.

When Davenport (1996) studied Alabama populations, he suggested the possibility of apomixis in this lily. In 16 of 20 flowers buds that were bagged in the Stevens Creek population, we found no evidence of ovary development, and thus, no evidence of self-pollination. Four plants could not be scored because they were lost or broken. We captured two kinds of sphingid moths pollinating these plants at dusk: Eumorpha pandorus and Paratraea plebeja. If high water inundates flowers in May and June, as occurred in 2005 in the Savannah, then pollinators have little or no access to flowers and it is likely that pollen is dislodged from anthers and washed downstream. The same pollinators are suspected to be active for Savannah River populations, but we have been unable to determine this because of difficulties accessing these populations due to highly fluctuating flow conditions or swift moving currents. There was no difference between average flow rate on Stevens Creek and the Savannah River but maximum flow rate was greater in the Savannah River. The depth of water that was associated with the average and maximum flow rate was also greater in the Savannah River.

PRELIMINARY RESULTS OF SHORTNOSE STURGEON, ACIPENSER BREVITORUM, DAM PASSAGE ENHANCEMENT WITH ECOSYSTEM FLOW RESTORATION

The Savannah River supports more than 108 native fish species representing 36 families, the greatest number of species of any river that drains into the Atlantic. The Savannah River Basin is home to more than 75 species of rare or endangered plants and animals. Among these are 18 species of fishes tracked by the Georgia and South Carolina Heritage Programs as species of concern including the federally endangered short nose sturgeon, Acipenser brevirostrum, one of few remaining relatively robust populations left on the Atlantic coast.

Prior to mainstream impoundment by dams, shoals existed in the Savannah River from Augusta upstream to the mouth of the Tugaloo River, a distance of about 110 miles. The only existing shoal habitat in the Savannah River is a 4.5 mile reach extending downstream from the Augusta Diversion Dam. In the early 1970's the Savannah River estuary contained 21-percent of the tidal freshwater marsh in Georgia and South Carolina and these two states accounted for 28-percent of the tidal freshwater marsh along the Atlantic Seaboard. Since that time the amount of tidal freshwater marsh in the estuary has been reduced due to harbor deepening and other impacts. These two habitats are essential to adult shortnose sturgeon that spend a majority of their time in the estuarine habitat and migrate upstream to spawning habitat (Collins et al., 1999). In Georgia, spawning takes place in February-March in swiftly moving water over gravel and rocky substrates found in river shoals. Spawning may occur 1-16 years after reaching sexual maturity (age 6 in females) and individuals may skip 3-10 years between spawning events. The eggs are sticky, and adhere to the substrate until they hatch. After hatching the larval fish seek cover and hide until the yolk sack is absorbed and their sensory systems are fully developed. They begin drifting downstream in March-April to the freshwater-saltwater interface into their nursery habitat. There are approximately 3,000 shortnose sturgeon in the Savannah River. Research done in the Savannah River in 1999-2000 (Collins et al. 2002) indicate that there has been no increase in recruitment into the population over the past 8 years but that increased numbers of shortnose in the river was due to the stock enhancement program from 1990-1992. There is no current monitoring of sturgeon in the Savannah River and it is unknown if the population is able to reach critical spawning habitat (the Augusta shoals) above the New Savannah Bluff Lock and Dam (NSBLD). Since the timing of the spring controlled flood pulse is coordinated to help facilitate sturgeon passage through the NSBLD, measuring the success of sturgeon passage is a critical step in an Ecologically Sustainable Water Management framework. These preliminary results reflect the first collaborative effort to measure that success.

Methods

The design of the proposed pilot study was focused on the capture of adult shortnose sturgeon during early spring months once they have migrated to the NSBLD, just prior to their annual spring spawning. We used untrasonic telemetry, to monitor whether tagged fish passed the dam during the discrete spill events intended to mimic the river's natural flow regime. Adult shortnose sturgeon were captured by using electrofishing and gill nets during one week prior to the pulse release, March 9th -14th, 2006. Sturgeon were surgically implanted with Vemco® V-16 coded acoustic transmitters and immediately re-released within the same vicinity that they were captured. Fin clips and egg samples were taken for later genetic analysis. A total of three Vemo® underwater receivers were placed above NSBLD; on ejust above the dam, one near the base of, and one within the shoal habitat. A fourth receiver was placed just below NSBLD. No manualtracking was performed during the pulse due to dangerously high water flows in the river. The pulse lasted 3 days (March 20-22) at 23,000 cfs and was adequate to provide enough water above and below the dam for level flow through all 5 spill gates. After the pulse, data was retrieved from the receivers and manual tracking was used to locate the tagged fish.

Results

Only four fish were tagged in this 2006 pilot study. Fish size ranged from 908 to 990 mm total length. Tag 3903 was placed in a smaller fish of undetermined sex, on 3/9 and left the area on the same day. Tag 3902 was placed in a gravid female fish on 3/9 and left the area on 3/12.

Tag 3901 placed in fish of undetermined sex on 3/12 and left the area on 3/13. Tag 03904 was placed in a gravid female on 3/14 and left the area on 3/14. No data was collected from either of the receivers placed upstream of the dam indicating that none of the tagged fish passed through NSBLD. No fish were located using manual tracking of over 40 river miles downstream on March 23rd. On April 6th, 2 fish were located in the Savannah River estuary and one fish (tag 3901) was located the next day as a result of a concurrent shortnose sturgeon monitoring project in the Santee-Cooper river system in SC. This fish first appeared in the Santee Cooper river study area on 3/30, over 300 miles from where it was tagged and released.

Although flow conditions were optimal to facilitate passage of sturgeon present at NSBLD through the dam, several factors may have interfered with natural spawning movement patterns. Although water temperatures were within the reported range for short nose spawning activity in the Savannah River (9-13°C), water temperatures just prior to the pulse dropped from 16 to 13.6 °C during a cold front that passed the area, rose slightly but then dropped another 2.5 degrees during a 24 hour period because of the pulse; the release of water from Thurmond dam occurs from the bottom of the cold and stratified reservoir (see Figure 4).

Some scientists believe that surgical internal tagging through may have interrupted the spawning process in the tagged female fish. Cooke et al. 2002, looked at residence time in spawning area after tagging suggested little impact indicating that the tagging technique used in this study is minimally invasive. In the future we may consider external tag attachment since the results here may suggest aborted spawning.

It is still unclear if short nose sturgeon, primarily a benthic fish, can pass thought the NSBLD even at ideal water temperatures and flow conditions. An eight foot concrete sill is situated at the bottom of river (where the flood gates rest when closed) and shortnose sturgeon may be unlikely to swim over it (Cooke et al., 2002).

In a study of sturgeon tagged in the Santee-Copper River system, Cooke and Leach (2004) reported that one fish tagged and released in the Santee-Cooper was found 715 days later in the Savannah River. This, along with the one fish from this pilot study that migrated between the two systems, may indicate that the population in the Savannah may be an important source for genetic variability within other southeastern rivers. Preliminary results from this study indicate that ecosystem flow restoration may not be adequate alone to restore spawning success in the Savannah River. Efforts should continue to restore spawning habitat by either a fish passage facility (such as a ladder) and/or enhancing spawning habitat below the NSBLD.

FLOODPLAIN HYDROLOGY AND ECOLOGY

The Flood Pulse Concept (Junk et al. 1989) has emerged as the leading paradigm to explain the ecological functioning of large rivers, and the periodic inundation of floodplains is believed to be the major factor in sustaining the ecological functions of river-floodplain systems. Flood pulses can exert a range of influences. Large flood pulses shape the morphology of river channels and floodplains (Shannon et al. 2001). Floodplain inundation can affect soil oxygen and moisture levels, impacting biological and chemical transformations among nutrient pools (Mitsch and Gosselink 2000). Flood pulses regulate plant reproduction, with seedling establishment and development only being successful under certain hydrologic conditions (Schneider and Sharitz 1988).

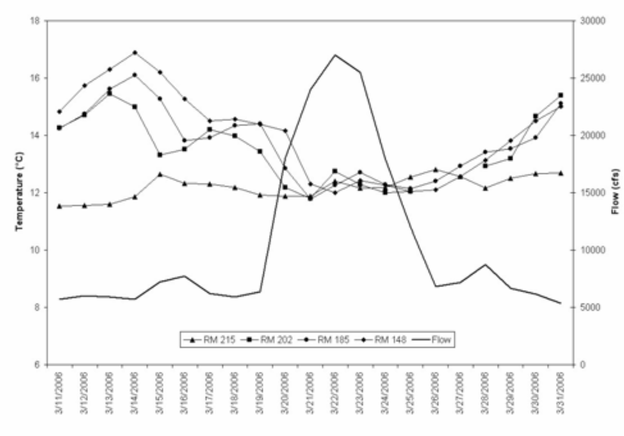

Figure 4: Water temperature in the Savannah River prior to and during flood pulse release, 2006. Betty's Branch is the water being released from Thurmond dam. “Downstream 3” gage is approximately River Mile 150.Data used with permission from G. Eidson– Southeastern Natural Sciences Academy.

The copious plant growth on floodplains, especially trees, becomes an important source of organic matter input (leaves, wood) throughout the system. Decomposition rates of this material will be influenced by changing oxygen and sulfide levels, degree of wetting and drying, and abrading force of the water (Brinson 1977, 1993).

Once decomposed, some materials move into the channel, and then downstream to influence the entire ecosystem. Many fish and invertebrates from the river channel or estuary move into inundated floodplains to feed and reproduce. In addition, the floodplains support a community of invertebrates and fish specifically adapted to live and breed in wetlands (Welcomme 1979, Junk et al 1989, Batzer and Wissinger 1996). River regulation alters 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, Jansson et al. 2000).

Because of their critical ecological functions, floodplains are habitats of key concern for the Savannah River flow restoration project. Thus, we have initiated research efforts to assess the status of hydrology and communities of trees, invertebrates, and fish on Savannah River floodplains downstream of the Thurmond Dam. We want to determine the extent to which hydrologic and biotic conditions have been degraded by past river regulation, and also to assess the ecological recovery of floodplains after flood pulses are restored. Because we lack historical data on pre-regulation biotic communities on Savannah floodplains, we are using floodplains along the Altamaha River as our reference standard. 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/estuary system in the region. TNC has named the Altamaha River as one of the 75 Last Great Places on Earth. Important 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). Thus even below these dams near-natural flood pulses occur, although sediment levels are altered.

Study Site Descriptions

Possible effects of hydrologic alteration on forest communities in the Savannah River are being examined at three sites in the Coastal Plain portion of the river. These sites are near Stave Island at the Savannah River Site (SRS), the Tuckahoe Wildlife Management Area (WMA), and the Webb WMA (Figure 5). In addition, three reference sites have been established in the Coastal Plain region of the Altamaha River, which is relatively free-flowing (Figure 3). There are only otwo dam in the headwaters of the river but are managed as a run of river facilities. These are located at the Moody Forest Natural Area, the Beards Bluff area, and the Penholloway Wildlife Management Area.

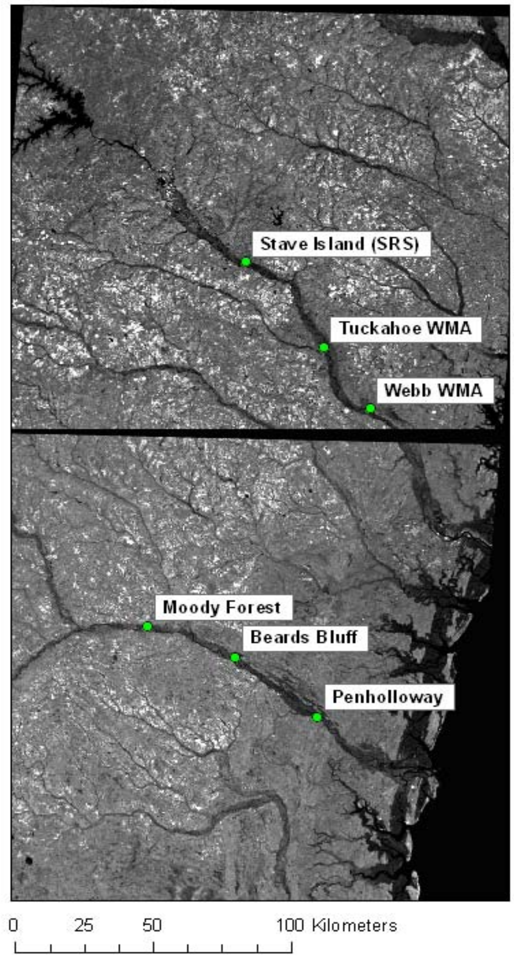

Figure 5: Floodplain sites on the Savannah (upper) and the Altamaha (lower) Rivers, GA.

These study areas were distributed along the length of each river and selected based on the presence of mature, intact floodplain forests. Features were avoided that would affect flooding of the floodplain from the river, such as bridges and large tributaries. Transect locations at each study area were selected to represent a range of species associations across a hydrologic gradient (e.g., swamps, bottomland hardwoods, and upland forests) and geomorphologic features (e.g., levees, scroll bars, and sloughs).Invertebrate and fish communities were sampled at locations roughly parallel to the sites used for plant sampling. Along the Savannah, both the Tuckahoe and Webb WMA sites were used, but instead of Stave Island, invertebrates and fish were sampled on a floodplain across the river in Georgia’s Yuchi WMA. Along the Altamaha, we had access to a large invertebrate data set (Reese and Batzer 2007) that was collected from 2002 and 2003 at sites near each of the designated plant sampling areas. From 2004-on we continued sampling invertebrates at those sites. Because we wanted to link fish with their invertebrate foods in both Savannah and Altamaha River floodplains, we started sampling fish in conjunction with invertebrates beginning in 2005.

Methods

Floodplain Ground Surface Profiles. Relative ground surface elevations were surveyed along transects to relate water levels to inundation of the floodplain. Transects generally began at randomly located points along the river bank and were oriented perpendicular to the river so as to cross the floodplain forest to the upland. A minimum of 1410 m of transect were surveyed at each study area. In all, 15 transects were laid out on the 6 sites, with a total length of just over 13.6 km.

Transect elevations were measured using a Spectra-Physics Laserplane 350 survey level, with stadia rods and receivers. Measurements at +/- 1 cm accuracy were usually taken at 10-m intervals, unless delineation of microtopographic features (e.g., stream banks, top of hummock) and/or dense vegetation shortened the distance between measurements. Generally, transect elevations were tied into either river levels, or to elevations of a nearby transect, to allow comparisons to river levels.

Floodplain Water Levels. Hydrologic regimes at each study area will be determined by relating transect elevations to water levels which will be related to nearby long-term USGS water level records. Water levels will be related to USGS water level recorders by developing a stage-stage relationship for each study area. Continuous water level recorders (Onset Computer Corporation HOBO U-series Data Loggers) were deployed in shallow PVC wells to determine stage at each study area. For most areas, a second recorder was also deployed nearby above flood level to correct for barometric pressure. Hydrologic regimes for each study area will be developed by correcting the USGS water level records with stages measured over a range of water level conditions.

Floodplain Forest Characterization and Tree Regeneration

Vegetation plots were modeled after the Carolina Vegetation Survey 20x50 m plots (10 10x10 m modules) described by Peet et al. (1998). The plots were placed at approximately 100-m intervals along each transect. However, since each plot was to sample within one general community type, plots were moved if necessary to avoid sampling across ecotones. For each plot, the distance along the transect and plot heading were recorded. Within each 20x50 m vegetation plot, all stems of canopy species ≥ 1.4 m in height were measured for diameter at breast height (1.4 m) and recorded by module.

A circular seedling plot (30 m^2) was located within each vegetation plot, centered on the 30-m point of each center line. All tree seedlings were tallied by species and height class: new germinants with cotyledons, < 30 cm tall, and 30-139 cm tall. Saplings >140 cm tall were tallied by diameter class: <1 cm and 1-2.5 cm. As an exploratory measure, ten medium to large trees were cored at breast height (or just above the buttress for tupelo and cypress) in the Savannah floodplain sites to determine whether the present canopy is likely to have established before dam construction.

Canopy openness was estimated in the center of each seedling plot using a spherical densiometer. Three 1" soil cores 30 cm in depth also will be collected from each seedling plot. Samples will be analyzed for texture (water holding capacity) and nutrients. Soils will also be analyzed for N, P, and K. Soil samples will be collected from all sites as close in time as possible.

Aerial Photographs of Floodplains. In addition to forest regeneration analyses, floodplain forest characterizations will be used to calibrate digital canopy image interpretations to estimate the extent of each forest community at each study area. Color infra-red aerial photography was taken of the study areas at 30 cm pixel (1:1000 negative scale). Images were taken in the fall to optimize differentiation of tree species by canopy color.

Floodplain Invertebrates and Fish

Fish communities before, during, and after flood events are being sampled annually at the three Savannah and three Altamaha floodplain sites using time-constrained electrofishing, coupled with some less extensive minnow trap and drift net sampling. Community composition, individual size, and diet of fish will all be useful measures for testing hypotheses. Concurrently, invertebrate community composition is being assessed at each of the six floodplains using core sampling. Because fish and aquatic invertebrate communities can develop in precipitation-filled backswamp habitats, even in the absence of flood pulses, sampling is even being conducted in dry years when over-bank floods do not develop. Gut analyses of fish will directly link the ecologies of invertebrates and fish.

Preliminary Results of Floodplain Forest, Fish and Invertebrate Sampling

Transects for hydrologic and vegetation sampling were established at each of the six sites in April and May 2006, and elevation profiles were measured. Groundwater wells with HOBO data loggers were also established. A total of 99 vegetation plots (plus 99 seedling plots) were established across the six locations: 55 on the Savannah River floodplain and 44 on the Altamaha River floodplain. Data collection began on 14 June 2006 and was completed on 15 August 2006. Entry and checking of vegetation data are underway and will continue during fall 2006. Vegetation data analysis will be coordinated with protocols developed by the Carolina Vegetation Survey (Peet et al. 1998). It is expected that soil samples will be collected in late fall 2006, and will be processed during the winter following procedures recommended by Robertson et al. (1998).

Sampling thus far indicates that mosquitofish (Gambusia spp.) and various centrarchid sunfish (Lepomis gulosus, L. macrochirus, L. punctatus, and Centrarchus macropterus) comprise much of the fish community on floodplains for both the Savannah and Altamaha Rivers. Preliminary findings indicate that pike (Esox niger, E. americanus) were very common on Altamaha, but not Savannah, floodplains, and in contrast, bullhead (Ameiurus natalis, A. nebulous) were very common on Savannah, but not Altamaha, floodplains. Additional sampling is required to verify whether this is a persistent pattern. Gut analyses indicate that these fish commonly consume microcrustaceans (Cladocera, Ostracoda), aquatic Isopoda (Asellidae), midge larvae (Chironomidae), and predaceous diving beetles (Dytiscidae). These invertebrates are also among the more common resident taxa on floodplains of both rivers.

EFFECTS OF AN UPSTREAM CONTROLLED WATER RELEASE ON THE FRESHWATER/SALTWATER INTERFACE IN THE SAVANNAH RIVER ESTUARY

In coordination with TNC and other agencies contributing toward a study of the effectiveness and environmental effects of a spring controlled release of water from the Thurmond Dam, a salinity monitoring program was developed for the freshwater/saltwater interface region of the Savannah River Estuary. This monitoring program began before the controlled release in order to refine the field methods and to gather normal salinity distribution data prior to the release event. The monitoring schedule was intensified during a two-week period following the release event, and monitoring continued after the effects of the release event on salinity distribution appeared to end (i.e., when salinity distribution was similar to pre-release distribution). Because the primary concern for this component of the overall controlled release monitoring program was salinity distribution within the estuarine region of the Savannah River, surface salinity values of 5 ppt and 10 ppt were targeted for monitoring. Typically, aquatic species richness along a salinity gradient is lowest in the 5-10 ppt range where freshwater species richness declines dramatically and marine/estuarine species richness also declines. Thus from an ecological and marine habitat perspective, this upper-estuarine salinity zone is of interest. The possible displacement or extension of this salinity zone horizontally through the estuary and the longevity of these effects within the estuary need investigation and monitoring in order to assess ecological effects of controlled releases of freshwater from upstream.

Methods

Field sampling/monitoring began February 2, 2006, and continued through April 27, 2006. Dates of sampling were: February 2, 6, 22, 28, March 8, 20, 27, 31, April 3, 5, 7, 10, 20, 27. The procedure consisted of two methods for monitoring salinity: 1) weekly determination and recording of the location of 5 ppt and 10 ppt salinity surface (1 m) haloclines; and 2) weekly salinity sampling from fixed locations.

Weekly sampling trips were made by boat to locate the positions of surface (1 m) water having salinities of 5 ppt and 10 ppt. Sampling was done at mid-channel locations, and the positions of these surface salinities were recorded using GPS. At these surface locations, bottom water was also sampled for salinity analysis to investigate the degree of vertical salinity variations. As was possible and practical, sampling was conducted during high tides. Water temperature was also recorded for all water samples. Analysis of data from this sampling program was used to determine: 1) the horizontal (up/down stream) movement of the freshwater/saltwater interface along the Savannah River channel, 2) the maintenance or degree of variation in vertical salinity distribution in this region, and 3) the temporal effect/extent of the controlled release in the upper estuary.

During the weekly sampling trips, surface (1 m) and bottom water samples were also collected and analyzed for salinity and temperature from fixed locations. Based on sampling results obtained during initial monitoring trips, the fixed locations chosen were: 1) under the Talmadge Bridge, and 2) in the vicinity of the junction of Back River and Front River near Ft. Jackson. This sampling method was employed in order to indicate the variation in salinity throughout the study period at specific sites expected to be in the upper estuarine region. Information and data gathered from these fixed locations were used in assessing the relative value of such fixed-position monitoring as a future monitoring program is proposed and developed.

Results

The controlled release of water upriver in mid to late March 2006 affected the freshwater/saltwater interface (salt wedge) in the Savannah River Estuary for approximately 10 days. The salinity alterations became apparent approximately 7 days after the maximum controlled release flows began. Peak controlled discharges from the Thurmond Dam of approximately 26,000 daily average cfs occurred March 20-22, with slightly lower discharges March 23-24, 2006. Noticeable alterations in the salinity distributions in the upper estuarine region began March 27, and continued through April 5, 2006.

The overall vertical dimensions and integrity of the freshwater/saltwater interface were maintained during the period that the interface was affected by the controlled release, as determined by surface and bottom salinity values and vertical differences. However, the horizontal (up/down stream distance) dimension of the interface was slightly compressed (approximately 0.5 mile shorter distance between the 5 ppt and 10 ppt salinity surface water locations) during the 10-day period. The greatest alteration of the freshwater/saltwater interface was a temporary displacement of the interface downriver approximately 2.5 miles during the 10 day period that the controlled release affected the upper estuarine region of the Savannah River.

Following the 10-day period during which the freshwater/saltwater interface was affected by the controlled release, the interface returned to normal (or pre-affect) positions and horizontal dimensions. It thus appears that a controlled release of this magnitude and duration caused only a temporal compression and downstream displacement of the freshwater/saltwater interface but did not disturb the integrity of the interface.

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