

Completion Report: 2010

**MONITORING OF FLOODPLAIN AND RIVERINE ECOSYSTEM
RESPONSE TO FLOOD PULSES ON THE SAVANNAH RIVER,
GA/SC: Responses of floodplain invertebrates and fish**

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The US Army Corps of Engineers and The Nature Conservancy (TNC) are working collaboratively to protect downstream aquatic habitats in the Savannah River, by advancing ecosystem flow restoration and adaptive management (Wrona et al. 2007). Under the water management regime prior to 2004, natural variability in the hydrograph was intentionally muted. Since then, when sufficient water is available, the US Army Corps of Engineers has released experimental controlled flood pulses per scientific recommendations from TNC developed specifically for the Savannah River. In order to adopt ecological water management as standard practice, flow recommendations, or flow restoration hypotheses, must be tested in a scientifically credible manner.

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. Thus, developing a cost effective means of monitoring the success of flow restoration is desirable. This project describes an effort to use invertebrates and fish to assess the biotic integrity of floodplain habitats of the lower Savannah River using a cost-effective indicator organism approach.

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.

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.

PAST RESEARCH

From 2004 through 2009, I have been monitoring invertebrate and fish communities on Savannah River floodplains to assess biotic conditions and evaluate impacts of flow regimes (see Bright et al. 2010).

Methods

To sample invertebrates and fish, my laboratory selected three locations along the floodplains of each of the Savannah and Altamaha Rivers. The Savannah 1 location was in Georgia's Yuchi WMA, the Savannah 2 location was in Georgia's Tuckahoe WMA, and the Savannah 3 location was in South Carolina's Webb WMA, just above the upper extent of tidal influence. The Altamaha 1 location was just downstream of the convergence of the Ocmulgee and Oconee Rivers in Bullard Creek Wildlife Management Area (WMA). The Altamaha 2 location was further downstream in the Big Hammock WMA. The Altamaha 3 location was on privately owned floodplain just above the upper extent of tidal influence. The Altamaha River was sampled because it shared many similarities with the Savannah River, but because it is not managed for flood control it retains near natural flood pulses. Thus, the Altamaha provides a useful reference target for evaluating the condition of Savannah River floodplains.

Beginning in 2004, we began sampling invertebrates and in 2005, we began to sample fish at these six sites. Sampling continued until 2008 for invertebrates and 2009 for fish. Pulses were released down the Savannah in spring 2005 and 2006, but not thereafter because of ongoing drought conditions. At each location, sampling was stratified to be conducted in representative low lying backwater swamps of the floodplain interior; these seasonally flooded locations held water between flood events, and were where aquatic invertebrates and fish accumulated (Reese and Batzer 2007, Bright et al. 2010). All of the backwater swamps selected became hydrologically connected to the river channels during significant flood events. We sampled for invertebrates and fish two to three times over each annual flood season. Initial samples were collected in late-February/early-March soon after floodplains began to be inundated. We then resampled in April, and a third time in May, provided significant amounts of water still remained. Most sampling was conducted between major flood events after water and aquatic organisms had settled back into low lying backwater swamps. We avoided sampling during high water periods because access was difficult or dangerous, catch efficiency was low in high water because aquatic organisms (both invertebrates and fish) spread themselves across large areas, and the devices employed to sample invertebrates and fish could not be effectively used in deep water.

For invertebrates, a Hess sampler (860 cm², 500 µm mesh, Wildlife Supply Co., Buffalo, NY, U.S.A.) was used to quantitatively sample organisms in the water column and on the benthic substrate. Fish communities at each site were sampled with a backpack electroshocker (Smith-Root Inc., Model 12-B POW, Vancouver, WA) on a catch-per-unit-effort basis (numbers per 750 seconds of actual shocking time).

Results for 2005–2008

Whole community analyses were only conducted on data collected from 2005 to 2008. For invertebrates community ordination analyses (Non-metric multidimensional scaling followed by Analyses of Similarity) using all common macroinvertebrate taxa indicated only a modest difference between the floodplains of the Savannah vs. Altamaha Rivers ($R = 0.084$, $p = 0.046$). However, Indicator analyses (Dufrene and Legendre 1997) found that four invertebrate taxa (Dytiscidae, $p = 0.0058$; Planorbidae, $p = 0.0072$; Nematoda, $p = 0.0086$; Arachnida, $p = 0.0414$) were associated with the Altamaha River floodplains; no taxon was associated with the Savannah River floodplains. Although overall densities of floodplain invertebrates and densities of most individual taxa were similar between rivers, densities of all four indicator taxa were significantly greater ($p < 0.01$) in the Altamaha than Savannah River floodplains. Analysis of Similarity indicated that macroinvertebrate communities in Savannah River floodplains differed between pulsed (2005, 2006) and non-pulsed (2007, 2008) years (Global $R = 0.336$, $p = 0.006$). However the direction of change was not towards the reference condition represented by the Altamaha River, and none of the four Altamaha River indicator taxa differed in density between pulsed and non-pulsed years in Savannah River floodplains (all $p > 0.05$).

For fish, similar analyses also suggested minimal differences in overall fish community structure on floodplains of the Savannah and Altamaha Rivers ($P > 0.05$). However, chain pickerel (*Esox niger*) was one of the most commonly collected fish on Altamaha River floodplains but was relatively rare on Savannah River floodplains, and Indicator Analysis identified that fish species as an indicator taxon for the Altamaha ($P = 0.027$). The closely related grass pickerel (*Esox americanus*) had a similar overall pattern, but in this case the test result was not significant.

RESEARCH FOR 2010

Because heavier than normal rainfall occurred in 2009 and 2010, sufficient water reserves were available to restore flood pulses to the Savannah River and pulses consistent with a wet year were released. Floodplain inundation levels achieved were much greater than any over the past decades. This provides an excellent opportunity to continue and expand past efforts, and assess a pulse regime not previously encountered. Chances for substantial impacts of this pulse on biota hold greater promise than previous smaller pulses.

Based on data collected previously (see above), it appears that a select group of invertebrates, and fish in the genus *Esox* (both *E. niger* and *E. americanus*) might be useful indicator organisms to target for evaluating whether pulse restoration in the Savannah River is making floodplains biotically more natural. Since Dytiscidae predaceous water beetles and Planorbidae snails are considered valuable fish forage, targeting those two taxa seems appropriate as links potentially exist between those invertebrates and the fish. While past whole-community samplings are very valuable, the cost of continuing such labor intensive approaches, especially for invertebrates, is prohibitive. This study was designed to develop rapid assessment protocols to monitor Dytiscidae beetles, Planorbidae snails, and *Esox* pickerel in Savannah River floodplains to assess impacts of flow management.

Sampling

At the same six floodplain locations sampled from 2005-2009 (three on the Savannah, three on the Altamaha, see above), we resampled invertebrates and fish in March, April, and May of 2010. However, invertebrates were also sampled using the netting procedure outlined by USEPA (1997) for sampling macroinvertebrates in low gradient streams of the Atlantic Coastal Plain. Further laboratory processing of these samples was stream-lined from previous whole-community sampling efforts to target Dytiscidae and Planorbidae populations. However, Hess core samples were also collected in tandem with net samples to provide a quantitative measure of invertebrate densities, and provide a means to assess the accuracy of the modified EPA procedure in floodplains.

Similarly, we resampled fish communities on each of the six floodplain sites over the three months. As before, standardized collections with the back-pack electro-shocker were collected. However, these collections were modified to target *Esox*. Water depths, flow rates, and sub-habits where *Esox* occurred were recorded to develop search criteria, which are intended to be validated in future samplings.

Laboratory processing of field collected samples was conducted from June to September 2010, and data analyses were conducted in September and October.

Results for 2010

Dytiscidae beetles

In Figure 1, we present dytiscid beetle population data collected using a Hess sampler for the 2004 to 2010 period. This graph demonstrates that beetle numbers (\log_{10} -transformed) were consistently higher in Altamaha River than Savannah River floodplains over this period. However, in two years where significant pulses were released, 2006 and 2010, differences between the rivers were negligible (Fig. 1). From these data, it appears that pulses during those years were making Savannah River floodplains more similar to Altamaha river floodplains in terms of habitat quality for dytiscid beetles. We consulted with a taxonomic expert for Dytiscidae to generate a better understanding of the taxonomic composition of the fauna, and he indicated that the bulk of the beetles collected in 2010 were from the genus *Neoporus*.

Sampling beetles with sweep nets indicated a similar pattern between rivers for 2010 as did Hess sampling. Sample numbers between the floodplains of the Altamaha and Savannah Rivers were similar ($p = 0.789$, Fig. 2).

Paired sampling of sites with the Hess sampler and D-frame nets indicated that results were strongly correlated ($p = 0.0009$, Fig. 3), and thus the sweep net appears to be a suitable surrogate for the Hess sampler. In fact, results suggest that the sweep net might actually be more efficient than the Hess sampler for monitoring beetle populations. In seven samples, we failed to collect any beetles in the Hess sampler, but in six of those we successfully collected beetles using the net (including one sample where we collected >300 beetles). Field and laboratory processing time for net sampling was routinely 10% of that required to process Hess samples.

Fig. 1. Densities (\log_{10} - transformed numbers m^{-2}) of Dytiscidae beetles on the floodplain of the Altamaha River vs. the floodplain of the Savannah River from 2004 through 2008 and in 2010 (no samples were collected in 2009). Each floodplain was sampled at three sites on multiple dates per year using a Hess sampler. Overall densities were significantly higher on the Altamaha River floodplain than the Savannah River floodplain (2-way ANOVA, $P=0.002$). However, densities in 2006 ($p = 0.475$) and 2010 ($p = 0.804$) were very similar between rivers.

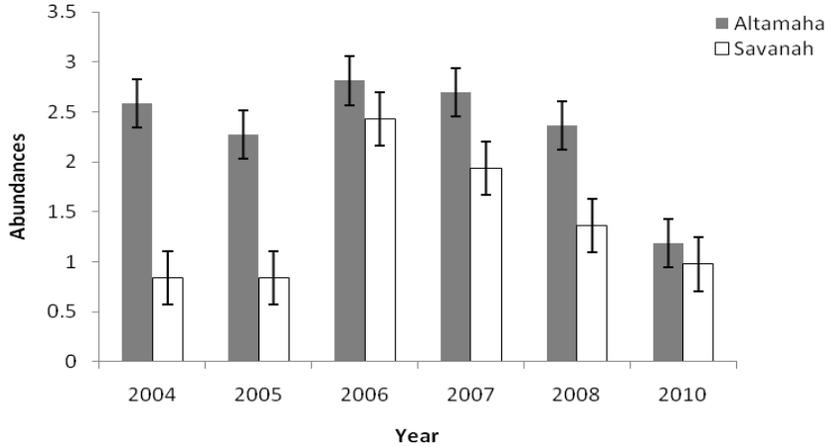


Fig. 2. Relative abundances (\log_{10} - transformed numbers per 20 sweep sample) of Dytiscidae beetles on the floodplain of the Altamaha River vs. the floodplain of the Savannah River in 2010. Each floodplain was sampled at three sites on three dates per year using a D-frame sweep net (20 sweep per collection). Numbers were similar between rivers (ANOVA, $p = 0.789$).

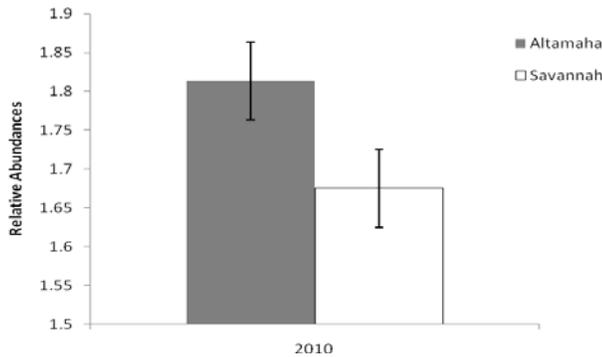
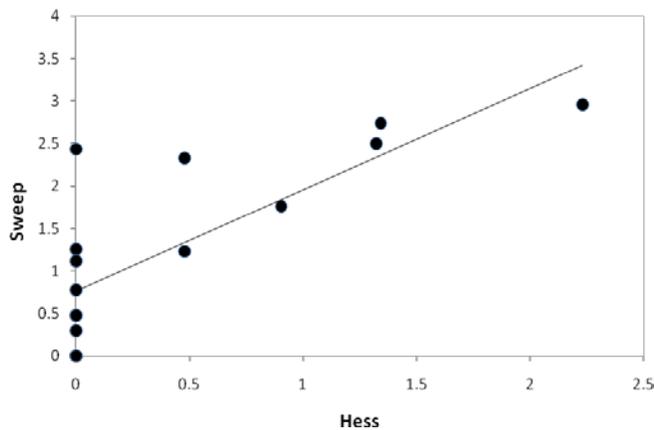


Fig. 3. Numbers of beetles collected using a Hess sampler (numbers m^{-2} ; $\log_{10}(x+1)$ transformed) vs. a D-frame sweep net (numbers per 20 1-m long sweeps; $\log_{10}(x+1)$ -transformed) were highly correlated ($r = 0.772$, $p = 0.0009$; $y = 1.1903x + 0.7635$).



Planorbidae snails

In Figure 4, we present Planorbidae snail population data collected using a Hess sampler for the 2004 to 2010 period. This graph demonstrates that beetle numbers (\log_{10} -transformed) were consistently higher in Altamaha River than Savannah River floodplains over this six year period ($p = 0.0002$). However, densities varied considerably from year to year ($p = 0.024$), and differences between rivers were not consistent from year to year (river*year interaction, $p = 0.007$). In 2006, a pulse year, snails became quite numerous on the Savannah River floodplain, but during the 2010 pulse year, snails were relatively rare along both rivers. The volatility of snail populations may make data difficult to interpret.

Paired sampling of sites for snails with the Hess sampler and D-frame nets indicated that collection results were correlated ($p = 0.003$, Fig. 5), and thus the sweep net might be a suitable surrogate for the Hess sampler. However, 5 of 13 samples were negative for snails using both devices, indicating that they were overall being sampled inefficiently, or that 2010 was simply a low year for snails in both rivers.

Fig. 4. Densities (\log_{10} - transformed numbers m^{-2}) of Planorbidae snails on the floodplain of the Altamaha River vs. the floodplain of the Savannah River from 2004 through 2008 and in 2010 (no samples were collected in 2009). Each floodplain was sampled at three sites on multiple dates per year using a Hess sampler. Overall densities were significantly higher on the Altamaha River floodplain than the Savannah River floodplain (2-way ANOVA, $P = 0.0002$).

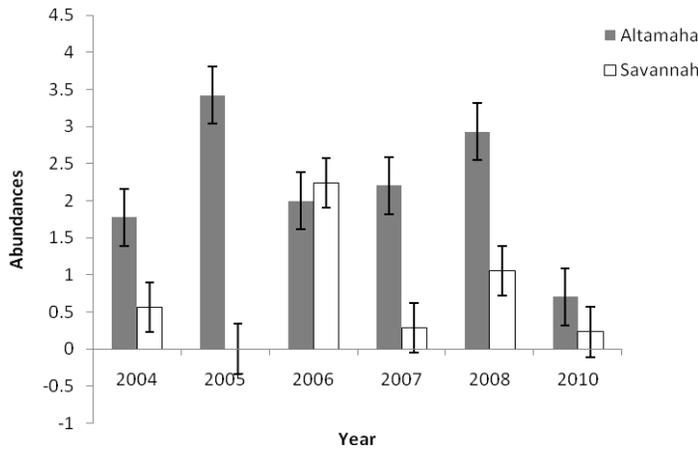
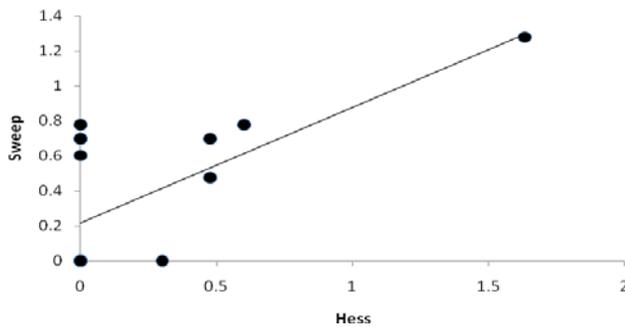


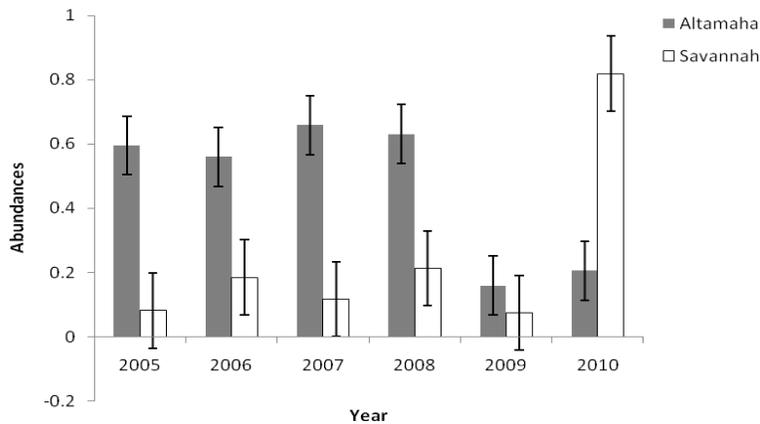
Fig. 5. Numbers of planorbidae snails collected using a Hess sampler (numbers m^{-2} ; $\log_{10}(x+1)$ transformed) vs. a D-frame sweep net (numbers per 20 1-m long sweeps; $\log_{10}(x+1)$ transformed) were highly correlated ($r = 0.669$, $p = 0.003$; $y = 0.659x + 0.218$)



Esox fish

Sampling of fish previous to 2010 had indicated that *Esox* numbers were typically lower on Savannah than the Altamaha River floodplains (Fig. 6, 2005-2009; $P = 0.002$). However, the major pulse in 2010 apparently resulted in a dramatic increase in *Esox* numbers on Savannah River floodplains, and we collected more individuals per sample that year than the previous five years combined. *Esox* numbers caught in 2010 along the Savannah actually exceeded numbers along the Altamaha ($P = 0.033$). Previous smaller pulses in 2005 and 2006 did not elicit this same result.

Fig. 6. Numbers (\log_{10} - transformed numbers of fish collected per 750 seconds of electro-shocking) of *Esox* on the floodplain of the Altamaha River vs. the floodplain of the Savannah River from 2005 through 2010. Each floodplain was sampled at three sites on multiple dates per year using a Hess sampler.



CONCLUSIONS

Research over the past six years indicates that the aquatic fauna differs between floodplains along the Savannah and Altamaha Rivers. Differences are most pronounced for Dytiscidae beetles, Planorbidae snails, and Esocidae fishes. Because these organisms appear to respond positively to winter/spring pulses induced by managed releases of water from the Strom Thurmond Dam, it suggests that past management practices contributed to the difference in floodplain communities and that current management practices might eventually restore Savannah River floodplains to a more natural state.

The goal of the research was to develop user-friendly protocols that can be employed by non-specialists, but are buttressed by validation data. Data from 2010 indicate that this is a realistic objective. Preliminary data indicate that the time consuming Hess sampler can be replaced with a more user-friendly dip-net protocol because both procedures generate similar data for key indicator invertebrates. Because of their abundance, Dytiscidae beetles (especially in the genus *Neoporus*) may be especially useful bioindicators in the Savannah River system. More validation data could cement this idea, and new research on the ecology of the beetles might suggest mechanisms of beetle response to flood pulses. Planorbidae snails, because of large natural variation (both temporally and spatially), hold less promise, but as the beetles are predators and the snails are primary consumers, more research on the snails may be merited as their responses to pulses may be unique.

The impressive response by *Esox* fish to the 2009–2010 pulse in the Savannah River was especially encouraging. Most of these fish were juveniles (20–25 mm sl),

although not newly hatched larvae. This indicates that in the first years of life, a critical period, floodplains may provide important nursery habitat for *Esox*. It will be interesting to see if this cohort of fish still utilizes Savannah River floodplains in 2010–2011.

For 2011, we recommend that:

- 1) The sampling regime conducted in 2009–2010 be repeated to buttress findings from 2010 in terms of invertebrate response and dip-net sampling efficacy.
- 2) Dip-net invertebrate sampling and fish electro-shocking (but not time-consuming Hess sampling) be expanded to include more sites along the Savannah River. This will better enable us to generalize findings.
- 3) Data be gathered on the ecology of *Neoporus* dytiscid beetles and *Esox* fish to better understand why these organisms seem to be strongly affected by flow regulation and how pulse releases may benefit them.

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