Restoration of Thermally Impacted Streams

History...

For over thirty years the bottomland hardwood forests of the Pen Branch and Fourmile Creek corridors and deltas were subjected to the discharge of coolant water from nuclear production reactors on the Savannah River Site. Coolant waters, which reached flow rates of up to 400 ft^3/sec and temperatures of 40-50^oC, killed virtually all vegetation and eliminated the seed bank and root stock from these bottomland hardwood wetlands. Release of heated effluents ended in the mid-1980's. By the early 1990's, dense black willow thickets covered the corridor of Pen Branch and, to a lesser extent, Fourmile Creek, and there was very little evidence in either of these stream systems of the pre-disturbance native bottomland hardwood vegetation. Restoration efforts in these streams began with a research study undertaken by the Savannah River Ecology Laboratory (SREL) in Fourmile Creek. This study sought to determine optimal planting methods and tree species to use when restoring native hardwood vegetation to thermally impacted SRS stream corridors. In these studies, different types and species of tree stock were transplanted to study areas in the Fourmile Creek delta to examine effects of abiotic factors such as fertilization and elevation and biotic factors such as competition and herbivory. The results of SREL's research were used in 1992 when the U.S. Forest Service (USFS), in collaboration with the Savannah River Technology Center (SRTC), SREL, and scientists from several universities, began efforts to accelerate the restoration of the Pen Branch stream system to its previous bottomland hardwood state. In this effort, which was undertaken as a result of regulatory compliance issues, approximately 85 ha over a 2.5-km section of the Pen Branch corridor were planted with trees using site preparation techniques that included no preparation, herbicides with burning, or herbicides alone, with planted areas separated by strips of non-planted control areas. Plantings included various species of oaks, hickories, persimmon, green ash, sycamore, swamp tupelo, and bald cypress. Following each planting, surveys were conducted to monitor tree survival and growth.

Steam rising around dead cypress trees, Fourmile Creek, 1960's

Aerial view of the Pen Branch corridor, 1970's.

Present Situation...

Currently, the vegetation in Pen Branch is dominated by early successional herbaceous species in planted areas and by a shrub canopy of black willow and an understory of herbaceous species in control areas; in-stream vegetation is dominated by dense beds of macrophytes. The open conditions created by disturbance and site preparation have been conducive to the establishment of early successional species. Based upon the elevated fish populations present, it is apparent that insect populations in Pen Branch are higher than in late successional stream systems. Amphibian and reptile populations are well established and the overall abundance of birds does not differ from late successional systems, although the richness and diversity of bird species are not as great in the Pen Branch corridor as in late successional stream systems.

Research...

In conjunction with the vegetation planting undertaken in Pen Branch by the USFS, a variety of research studies were begun to chart progress toward recovery of this stream system. Research studies included investigations of stream structure and function, surveys of the macroinvertebrates, fish, amphibians, reptiles, birds, and mammals

characteristic of Pen Branch and control streams on the SRS, factors related to the survival and growth of planted vegetation, characterization of soil nutrients and carbon cycling in Pen Branch, and comparisons between impacted and control streams to determine what aspects of the thermally impacted streams are impaired and what factors may be operating to cause these impairments to persist. Several studies in Pen Branch provided information on how best to perform restoration in disturbed bottomland hardwood systems. Specifically, studies determined that the highest probability for tree seedling survival existed where shrub cover or a nurse crop was present, protecting seedlings from herbivory by deer and feral hogs. Other studies focused on abiotic components of wetland function, such as soil and hydrologic conditions, nutrient turnover, light intensity, and water chemistry. For restoration of Pen Branch to be successful, these components must be restored to predisturbance conditions, or at least be on a trajectory where restoration of such components is likely.

SREL studies are comparing fish communities, riparian vegetation, physical condition of the streams, and interactions among stream biota in Pen Branch and Fourmile Creeks with control streams such as Upper Three Runs and Meyers Branch. Seasonal fish community samples and habitat information are being collected from 55 sites in these four stream systems to document the recovery of streams from thermal disturbance and to determine the factors important in successful recovery.

Results from SREL research in Fourmile Creek...

- Survival of planted vegetation was not enhanced by fertilization, elimination of existing herbaceous vegetation, or removal of low density black willow overstory.
- In areas of stream deltas where flooding by the Savannah River is influential, species with the greatest flood tolerance, such as bald cypress, water tupelo, green ash, and water hickory, are required for successful tree establishment; protection from beaver herbivory is critical.
- In areas of stream deltas where flooding is not influential, tree species with less flood tolerance, including Nuttall, overcup, water, willow, and swamp chestnut oaks, should be used to increase diversity; beaver herbivory is not a general concern, although deer and feral hogs can cause local problems.

SREL researcher sampling invertebrates in Pen Branch.

Restoration of native vegetation in thermally impacted streams on the SRS: USFS/SRI personnel performing a pre-planting burn in Pen Branch; trees grown and planted in Fourmile Creek as part of an SREL research program.

Results from SREL research in Pen Branch...

- Fish densities are 2-8 times higher in disturbed streams than in control systems.
- Fish species tolerant of conditions associated with more open canopies of willows and shrubs, such as minnows, sunfish, suckers, and mosquitofish, comprise 80-90% of the individuals in disturbed streams but only 40-50% in control streams.
- Increased aquatic macrophytes that resulted from canopy alterations have decreased the stability of the stream bottom topography by trapping sediments and diverting water flows, causing adjacent scouring. Topography of the stream bottom changes as macrophyte beds grow, die off, or change in shape.
- Differences in types and abundance of macroinvertebrates were observed between the experimentally planted thermally impacted regions of Pen Branch and upper reaches of the stream that were not subjected to discharge of thermal effluents.
- Significant differences, including hydrology, still exist between Pen Branch and unimpacted control streams such as Meyers Branch.
- Short-term effects of restoration activities included increased amounts of small woody debris, produced when herbicide-sprayed willows and shrubs died and fell into the water, further increased aquatic macrophyte growth due to the removal of the willow canopy, and additionally increased fish abundances. However, it is becoming clear that the hardwood forest will need to be reestablished if thermally impacted streams are ever to exhibit levels of ecological integrity and diversity similar to undisturbed control streams. Additional time and research will be required to assess the long-term effectiveness of current restoration efforts.