Suwannee River Basin and Estuary Integrated Science Workshop: September 22-24, 2004 Cedar Key, Florida

Compiled by Brian Katz and Ellen Raabe

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SUWANNEE RIVER BASIN AND ESTUARY INITIATIVE

In response to the growing number of environmental concerns in the mostly pristine Suwannee River Basin and the Suwannee River Estuary system, the States of Florida and Georgia, the Federal government, and other local organizations have identified the Suwannee River as an ecosystem in need of protection because of its unique biota and important water resources. Organizations with vested interests in the region formed a coalition, the Suwannee Basin Interagency Alliance (SBIA), whose goals are to promote coordination in the identification, management, and scientific knowledge of the natural resources in the basin and estuary. To date, an integrated assessment of the physical, biological, and water resources has not been completed.

A holistic, multi-disciplinary approach is being pursued to address the research needs in the basin and estuary and to provide supportive data for meeting management objectives of the entire ecosystem. The USGS is well situated to focus on the larger concerns of the basin and estuary by addressing specific research questions linking water supply and quality to ecosystem function and health across county and state boundaries. A strategic plan is being prepared in cooperation with Federal, State, and local agencies to identify and implement studies to address the most compelling research issues and management questions, and to conduct fundamental environmental monitoring studies.

The USGS, Suwannee River Water Management District and the Florida Marine Research Institute are co-sponsoring this scientific workshop on the Suwannee River Basin and Estuary to:

- Discuss current and past research findings,
- Identify information gaps and research priorities, and
- Develop an action plan for coordinated and relevant research activities in the future.

This workshop builds on the highly successful basin-wide conference sponsored by the Suwannee Basin Interagency Alliance that was held three years ago in Live Oak, Florida. This year's workshop will focus on identifying information needs and priorities and developing partnerships. The USGS is seeking to define the role of the USGS Florida Integrated Science Center (FISC) in conducting integrated research in the Suwannee River Basin, and to establish a cooperative program with other agencies.

Participants interested in river, floodplain, springs, estuary, or basin-wide issues are encouraged to attend. Topics for this year's workshop include:

- Water quality and geochemistry: nutrient enrichment, reduction of nutrient loading to ground water, contaminants, and land use,
- Hydrogeology: interactions among ground water, surface water and ecosystem, modeling, and baseline mapping,
- Ecosystem dynamics: structure, process, species, and habitats (estuarine, riverine, floodplain, and wetland), and
- Information management: data sharing, database development, geographic information system (GIS), and basin-wide models.

HYDROGEOLOGY ISSUES

The Future of the Suwannee River Sill – A Review and Update

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In 1998, an Environmental Assessment of the future management of the Suwannee River Sill was completed. The Suwannee River Sill was found to not serve its intended purpose of holding water within the Okefenokee Swamp during droughts to reduce the spread of fires. Further, if it did reduce fire occurrence, it would be detrimental to the swamp under current management philosophy. The preferred action proposed to remove the two existing concrete water control structures and create four breaches within the 4.8 mile long earthen levee pending the results of hydrologic monitoring. The U.S. Fish and Wildlife Service that has responsibility for the Suwannee River Sill within the boundaries of the Okefenokee National Wildlife Refuge (NWR) contracted with the U.S. Geological Survey (USGS) to monitor potential downstream effects related to re-establishing a free-flowing river channel as it exits from the Okefenokee Swamp. USGS (Giese, 2004) found 1) no significant changes in ground-water levels at wells measured downgradient from the sill, 2) no significant change in concentrations of water-quality constituents in flows at the sill, 3) no significant changes in stream water levels downstream from the sill, 4) the sill increased the base water levels immediately upstream of the sill by about 6 ft, 5) the sill decreased the peak flows from the sill to Fargo, Georgia, and 6) the sill increased the base flows due to reduced gradients within the swamp and leakage through the sill. Based on these findings, the preferred alternative will continue to be pursued. Congressional action modifying the original sill legislation is needed along with approximately $5 million to complete this wetland restoration project. Natural hydrologic conditions will be partially restored by allowing water to pass freely through openings created by the removal of the water control structures and additional breaches. Okefenokee NWR will continue to provide bank fishing opportunities, access to the Suwannee River, and promote other recreational opportunities at this location.

Giese, G.L., 2004, Effects of alterations to the Suwannee River sill on the Suwannee River flow and water-quality regime, Florida and Georgia, U.S. Geological Survey Open File Report 2004-1237.

Surface and Ground Water Mixing along the Cody Scarp: An Example from the Santa Fe River Sink-Rise System

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The Cody Scarp represents the erosional edge of the Miocene Hawthorn Group, which confines the Floridan aquifer in north-central Florida. The scarp cuts across the Florida Peninsula from northwest to southeast, with the confined Floridan aquifer located to the northeast of the scarp. Surface water is common in the confined region but sinks underground where it flows across the Cody Scarp onto unconfined Floridan aquifer rocks. At this boundary all streams with the exception of the Suwannee River sink into the subsurface, and the Suwannee River becomes a losing stream at the boundary. A good example of a sinking stream at the Cody Scarp is the Santa Fe River. The river is captured by a sinkhole at all times except during extreme floods when a portion of the river returns to an overland flow path. The river reemerges at the surface at a first magnitude spring ~5 km to the south of where it sinks into the subsurface. Numerous karst windows intersect conduits between the River Sink and River Rise and a combination of cave diving exploration and chemical and thermal tracing have shown that conduits connect the River Sink and River Rise.

Discharge measurements at the River Sink and River Rise demonstrate that during base- and low-flow conditions, more water emerges from the River Rise than flows into the Sink, but during periods of high discharge, more water enters the Sink than reemerges at the Rise. These differences in discharge indicate that water is alternately stored and released from the aquifer during variations in flow conditions. The most likely location for the storage is in the intergranular porosity of the matrix rocks, which for the Floridan aquifer is greater than in many other well studied karst aquifers. Water emerging at the Rise at flood conditions is chemically similar to water flowing into the Sink, which would be expected if water flows from the conduits and is stored in the matrix porosity. At base-flow conditions, chemical compositions of water discharging from the River Rise differ strongly from water flowing into the Sink, which would be expected if substantial amounts of water flow into the conduits from the matrix porosity. Although gain and loss of water from the matrix porosity can be measured by differences in discharge at the Sink and Rise, as well as observed in the chemical composition of the water, it is more difficult to determine how much water exchanges with the matrix porosity, where this exchange may occur, and what conditions control the exchange. The quantity of water exchanged between matrix and conduit porosity is critical for protection of the water resources of the Floridan aquifer, but information on the quantity of the water that is exchanged might be estimated with an injected dye trace study and sampling for monitoring wells close to the conduits.

Eight monitoring wells have been drilled in the gap between the River Sink and River Rise. The wells are located at known distances from the conduits and several are instrumented with continuous water level recorders. Water levels fluctuate in the wells in response to changes in head in the conduit as estimated from water level at the River Rise and reflect pressure pulses from the conduits. Chemical compositions of some of the monitoring wells change only slightly during high discharge events suggesting that water flowing from the conduits is not sampled by these wells. Other wells show large changes in their composition and may reflect water that has flowed from the conduits into the matrix porosity. Differences in the behavior of the wells likely reflect heterogeneous permeability distribution in the Floridan aquifer. Numerous other similar locations where sinking streams are connected to springs exist along the Cody Scarp and would provide good locations to compare with results obtained from the Santa Fe Sink-Rise system.

Using Synthesized Data to Quantify Surface-Water/Ground-Water Relationships Between Madison Blue Spring and the Withlacoochee River of North Florida

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Madison Blue Spring is a first magnitude spring located on the western bank of the Withlacoochee River in Madison County, Florida. The spring has been the focus of a recent study, with the ultimate objective of setting a minimum flow and level (MFL) to protect this resource. A major obstacle in this study was the almost complete lack of any hydrologic data for the spring. Nearby gauges on the Withlacoochee River were also significantly lacking in data. To overcome this, a time-series of data for the river and spring were generated, utilizing all other available and relevant hydrologic data.

At the beginning of this study, the available data set for Madison Blue Spring consisted of 22 discharge measurements dating from 1932 to 2003. All available related hydrologic data were collected and analyzed for potential relationships to river and spring discharge. Unfortunately, most of these data coincided temporally with only a small percentage of the 22 spring discharge measurements, if at all. Ground-water level data for monitored wells in the spring basin were sporadic and therefore not useful. Daily rainfall was available, but a good relationship between this and spring or river discharge was not observed.

Madison Blue Spring contributes a significant portion of the total discharge to the Withlacoochee River, particularly during low flows. A relationship between spring discharge and river discharge was expected, however, the only gauge located downstream from the spring (the Withlacoochee River near Lee) has only been present since late 2000. The closest gauging station, located just upstream from the spring (the Withlacoochee River near Madison) has never been regularly monitored. The gauges located on the Withlacoochee River near Pinetta (10 miles upstream from the spring) and on the Suwannee River at Ellaville (just downstream from the mouth of the Withlacoochee) have been monitored since 1932. Step-wise multiple linear regressions, utilizing the stage data from the Pinetta and Ellaville gauges, were used to generate a time-series (1932-2003) of stage data for the gauges near Lee and near Madison.

The Withlacoochee River downstream from Madison Blue Spring frequently experiences backwater conditions due to the nearby confluence with the Suwannee River. Therefore, discharge is often not a simple function of stage along this reach of the river, but rather a function of stage and fall (or slope). A stage-fall-discharge rating was developed for the gauges on the Withlacoochee River near Madison and near Lee. These ratings were used to generate a time-series (1932-2003) of discharge data for these two gauges.

Another complicating factor in this study is the fact that Madison Blue Spring is an estavelle; the spring is flooded when the river rises above a certain level, and flow can even reverse during large river floods. An analysis of the synthesized data for the Madison and Lee gauges shows a complex relationship between surface-water/ground-water interactions, stage at the Withlacoochee River near Madison, and the fall on the river (representing the backwater conditions) within this reach. The range of inflows to/outflows from the river increases with increasing stage. The range of fall along this reach also increases with increasing river stage. For a given stage, the river experiences an influx from the aquifer below some level of fall, and discharges water to the aquifer above that level of fall.

The 22 Madison Blue Spring discharge measurements were compared with the synthesized discharge for the Withlacoochee River near Lee. A good relationship between the two data sets was observed; this was used to generate a partial time-series of spring discharge. This relationship was not valid at high river discharge (greater than 2500 cfs). Also, a plot of total inflows or outflows to the river versus this predicted spring discharge showed this relationship was not accounting for backwater conditions.

A better relationship was found when the 22 Madison Blue Spring discharge measurements were plotted against the inflows to the river. Towards the end of this study, some additional spring discharge data from a newly installed and calibrated acoustic flow meter became available. Comparison of the simulated spring discharge (from the relationship with total inflows to the river) with this new discharge data showed good agreement. This synthesized data set allowed for the determination of a MFL for Madison Blue Spring.

Development of Minimum Levels and Flows for Blue Spring, Madison County, Florida

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As required by Florida Statutes (§373.042 F.S.), the Suwannee River Water Management District (SRWMD) is currently developing minimum flows and levels (MFLs) for surface water bodies and springs within the District. The first spring in the SRWMD for which a MFL is being developed is Madison Blue Spring (MBS), a first-magnitude spring located in Madison County, Florida. The spring consists of a single vent on the west bank of the Withlacoochee River, which is a major tributary of the Suwannee River.

As described by Schneider (this symposium), there was little discharge or stage data from the spring, and the spring is an estevelle, so spring discharge reverses at high river stages. Consequently, stage and discharge data from gauges on the river were used to simulate spring discharge and stage data. Simulated river and spring data closely fit measurement data, indicating a high level of confidence in the simulated data. The data are also consistent with ground-water data from within the springshed.

The river exhibits hysteresis and backwater effects as it interacts with the Suwannee and the karstic limestone that makes up the river channel. Because of the estevelle behavior of the spring, river and spring discharge data were stratified to isolate low spring discharge as a result of high river stage from analysis. Flow duration analysis of the measured and synthesized spring and river data was utilized to determine the duration of occurrence of low flows and the relative contributions of spring discharge to the river during low-flow events. At low river stage, MBS appears to contribute approximately 25 percent of the base flow in the river. Therefore, it was determined that reductions in MBS discharge may create adverse consequences to river water quality or ecological conditions.

As part of the study, six representative shoals in the river downstream from MBS were surveyed to determine depths for fish passage and total area of wetted shoal, which constitutes important aquatic habitat for benthic invertebrates and algae. These data were utilized in conjunction with historic and simulated discharge and stage data to simulate low-flow conditions and identify event durations and frequencies with HEC-RAS. Since MBS contributes significant percentages of the river water downstream from the spring during low-flow conditions, the spring's ability to maintain these habitats was considered an important factor for MFL development.

Based on the 10 ecological and water-resource "values" suggested for determination of "significant harm" according to Section 62-40.473 Florida Administrative Code, five potential applicable values were identified for determination of significant harm. These values were, in order of decreasing priority: (1) fish and wildlife habitats and the passage of fish, (2) maintenance of freshwater storage and supply, (3) recreation in and on the water, (4) aesthetic and scenic attributes, and, possibly, (5) water quality. It was determined that the effects of MBS discharge on water quality in the Withlacoochee River did not result in a potential for significant harm. Since MBS is a first magnitude spring and a Florida State Park, maintenance of first magnitude status was considered important for water supply, recreational, and aesthetic reasons, but identification of significant harm criteria based on ecological needs to justify maintenance of first magnitude status could not be established at this time. A critical, low-flow MFL was identified for the spring that will prevent significant harm to fish and wildlife habitats (i.e., total wetted shoal area) and protect the passage of fish during low flow in the river.

Simulations of the number and duration of potential minimum MBS discharge events and comparisons with predicted inundation of the shoals and water depths in channels utilized for fish passage were utilized to determine the minimum MBS discharge that would support appropriate depths over shoals and in channels within the shoals while preserving the first magnitude spring status of MBS. Thus, maintenance of fish and wildlife habitats and the passage of fish in the Withlacoochee River downstream of MBS were chosen as the principal values for which significant harm could be demonstrated and an MFL could be developed.

The proposed MFL has been peer reviewed on behalf of the District, and is presently being considered by District staff.

Delineation of the Fanning and Manatee Spring Basins in the Suwannee River Water Management District

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Fanning Springs and Manatee Springs are first magnitude (flow > 100 cfs) springs that flow from the Floridan aquifer into the Suwannee River in Levy County, Florida. Increasing concentrations of nitrate in spring discharge has prompted the FDEP and the SRWMD to begin a "District Springs Initiative" project, designed to identify the areas in the spring basin that are most vulnerable in terms of recharge and contamination of ground water traveling to the springs. This information will lead to the development of a final management plan for each spring basin.

The first step in the process was to attempt to delineate the spring basin. The primary methodology was to create a dense ground-water levels network that would define the potentiometric surface on one – foot contour intervals. This task was complicated by the presence of a diurnal tidal influence that can reach a magnitude of 1.5 feet. The flow lines derived from the potentiometric contours define the spring basins. Ground-water chemistry, cave maps, and topography also enhance the understanding of ground-water flow to the springs.

Extension of Minimum Flows from the Lower Suwannee River to Upstream Tributaries and Springs using a Reach-based Method

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The purpose of this paper is to present an approach being considered by the Suwannee River Water Management District (SRWMD) to extend minimum flows and levels (MFLs) being established for the lower Suwannee River under §373.042, Florida Statutes (F.S.), to associated upstream tributaries and springs.

For a river system it is possible to establish river MFLs at a downstream location of interest (typically at a long-term gage), and then use that control and regulate all withdrawals upstream to the headwaters. In 1993, the SRWMD began a research project to obtain the data necessary for adequate determination of MFLs for the lower Suwannee River. This effort is nearing completion. However, for a large river system like the Suwannee, which crosses varying physiographic regions with multiple large and small tributaries, with a high degree of ground-water/surface-water interaction, and high ecological diversity, the possibility exists that an important upstream ecological value could be compromised without different regulatory levels than those provided by the downstream control location.

Recognizing this problem, in 2003 District staff were charged with developing a methodology for efficiently determining MFLs throughout the District, especially for the Suwannee basin. The approach was to be implemented quickly (within five years), with minimal field work beyond that currently underway as part of the District's normal data collection networks. The approach also had to include setting MFLs for the many springs in the region. For the Suwannee River and associated springs this meant finding a way to leverage the intensive data collection and study efforts that have been expended in the lower Suwannee River into a basin-wide effort, from downstream to upstream.

The methodology was initially conceived for use on the rivers like those of the SRWMD, which have two key characteristics. First, they are structurally unregulated, and will likely remain so into the foreseeable future under current District goals and management programs. Second, District rivers, and the Suwannee system in particular, exhibit a high degree of ground-water/surface-water interaction. For many reaches the only pickup is from ground-water discharge; for all practical purposes direct surface water runoff doesn't occur.

In understanding the proposed method, it should also be recognized that the District is pursuing a multiple minimum flow and level, or a minimum flow regime, as opposed to a single valued MFL. This results in an MFL-based time series that represents the historic river flow pattern at a gage as if the MFLs had been in place during the period of record and all water flow exceeding the MFL time series had been withdrawn.

Given the prior establishment of an MFL regime at a downstream location, the first step in the method is a desktop procedure; an upstream reach is identified, then the downstream MFL is projected to the upstream location at the head of the reach using a relatively simple hydraulic calculation. One method for accomplishing this follows. From the historic and MFL time series, flow duration curves (FDCs) are constructed. For each exceedance probability the ratio of MFL discharge to historic discharge is determined. These ratios are then applied to the historic FDC at the upstream location establishing an upstream MFL FDC. This FDC can then be inverted to construct the upstream MFL time series. Thus four time series result: the historic and MFL series at both the head and bottom of a river reach.

The next step in the approach is to check the proposed upstream MFL against the water requirements of any environmental values within the reach. Any local ecological values in the reach were not included in the establishment of the downstream MFL and may not be adequately protected by the initial proposed regime. If any such ecological considerations are identified, the MFL regime is modified as necessary to include adequate protection.

Once the upstream and downstream MFL regimes are final, the allocable water in a reach and the reach MFL can be computed. This is done by determining the ground-water pickup in the reach under both historic and MFL conditions. The allocable water is the difference between the historic flow pickup and the MFL pickup. The reach MFL is the ratio between the MFL pickup and the historic pickup. At this point the task for water managers becomes one of evaluating the cumulative impact of withdrawals versus the allocable water and reach MFL.

However, in any given reach points of interest (such as springs) may exist for which point-specific protection is required. Discrete spring vents may have special characteristics; magnitude, ownership, threat, etc., or supports a specific environmental value in or near their run or discharge point that needs protection. Such springs would have specific MFLs established based on the characteristics needing protection.

For other springs that have no specific characteristic needing protection the MFL would be based on the cumulative reach MFL ratio (R) defined above. For example, withdrawals in the 'springshed' of one of these springs would not be allowed to reduce the flow of the spring (as determined under non-backwater, free-flowing conditions) to less than R percent of its unimpacted (or historic) flow at any time. The rational behind this approach is the assumption that many springs serve the primary purpose of supporting the stream base flow, and thus the environment of instream locations, and have no inherent site-specific resources requiring protection above and beyond that of the reach itself.

Once the reach MFL and any specific spring MFLs are set the entire process is repeated for the next upstream location of interest. In this way interim MFLs at all contributory points of interest in the river are established.

The proposed methodology is under review for further development by the District.

Exchanges of Water Between the Upper Floridan Aquifer and the Lower Suwannee and Lower Santa Fe Rivers, Florida

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Exchanges of water between the Upper Floridan aquifer and the Lower Suwannee River were evaluated using historic and recently collected hydrologic data from the Lower Suwannee River Basin and adjacent areas which contribute ground-water flow to the lowest 76 miles of the Suwannee River and the lowest 28 miles of the Santa Fe River. These and other data were also used to develop a computer model that simulated the movement of water in the aquifer and river, and surface-water/ground-water exchanges between these systems over a range of hydrologic conditions and a set of hypothetical water-use scenarios.

Long-term data indicate that at least 15 percent of the average annual flow in the Suwannee River near Wilcox (at river mile 36) is derived from ground-water discharge to the Lower Suwannee and Lower Santa Fe Rivers. Model simulations of ground-water flow to this reach during water years 1998 and 1999 were similar to these model-independent estimates, and indicated that ground-water discharge accounted for about 12 percent of the flow in the Lower Suwannee River during this time period.

The simulated average ground-water discharge to the Lower Suwannee River downstream from the mouth of the Santa Fe River was about 2,000 cubic feet per second during water years 1998 and 1999. Simulated monthly average ground-water discharge rates to this reach ranged from about 1,500 to 3,200 cubic feet per second. These temporal variations in ground-water discharge were associated with climatic phenomena, including periods of strong influence by El Niño-associated flooding, and La Niña-associated drought. These variations showed a fairly consistent pattern in which the lowest rates of ground-water inflow occurred during periods of peak flood levels, when river levels rise faster than ground-water levels, and after periods of extended droughts, when ground-water storage was depleted. Conversely, the highest rates of ground-water inflow typically occurred during periods of receding levels that followed peak river levels.

Geologic Setting, Depositional Environments, and Geologic History of the Suwannee River Delta; Present Understanding and Proposed Work

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Research along the 300 km-long, Big Bend coast of northwest Florida in the 1980s and mid-1990's by our group has defined the overall geologic setting and primary processes active along this low-energy, sediment-starved, marsh-dominated coastline. The Big Bend coast is generally a *Juncas roemerianus* marsh supported by a thin (0-2 m thick) organic -rich mud veneer overlying an irregular karstified limestone surface. Fine-grained sediments are recycled by being eroded along the marsh front facing the open Gulf of Mexico and carried back onto the marsh top through the tidal creeks. This bedrock surface consisting of sinkholes, springs, dissolved fracture lines, and elevated rocky nubs, control coastal morphology, distribution and pattern of tidal creeks, and the distribution of plants. This incipient, epicontinental sea coastline lacks barrier islands and tidal inlets seen to the north and the south due to the regional absence of sand-sized sediments.

At the center of this coastline is the Suwannee River Delta—the only significant point source of sediment in the Big Bend area. The result is a marsh/tidal creek system dominated by sands thus reducing the influence of the underlying bedrock as compared to the rest of the Big Bend coastline. The influx of fresh water from the river insures the development of large oyster bioherms. During sea-level lowstands, the Suwannee River extended at least 20 km out across the modern shelf. Additionally, arid conditions at that time allowed parabolic dunes to form. During the ensuing sea-level rise, these sandy eolian bedforms were flooded forming today's underwater, seagrass-dominated sand shoals, sandy beaches, and elevated marsh islands covered by less salt-tolerant plants such as pines, oaks, palmettos, and other indigenous species.

This previous work provides the basis for launching new research to define the distribution of benthic environments and habitats both in the nearshore delta, into the estuary and up the Suwannee River itself. New technologies and techniques such as very shallow-water, very high- resolution seismic and side-scan sonar profiling, as well as acoustic bottom classification techniques, allow us to develop very accurate and detailed benthic habitat maps on spatial scales previously unattained. A decade ago, using uncontrolled (not georeferenced) analog side-scan sonar, we were able to demonstrate the complexity of estuarine/riverbed substrate types. Distinct and predictable patterns of active bedform-mantled sand bodies and exposed bedrock surfaces revealing fracture patterns were clearly shown on the bottom. We propose that a new map series of the delta front—inner shelf/estuarine/riverbed be generated using a package of multiple, digital geoacoustic tools tied to meter-scale navigation accuracy. Such a map would be ground-truthed using bottom sampling techniques with appropriate laboratory analysis. A data product would provide the spatial distribution of benthic environments, which could be overlain by the benthic biology providing a benchmark for comparison for future years to detect and measure temporal changes.

Ecological Characteristics and Forcing Functions of the Suwannee River Estuary

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The limited scientific information available about the Suwannee River Estuary System (SRES) indicates that its ecology is controlled by a suite of physical characteristics and ecological forcing functions that distinguish it from most rivers and estuaries in the southeast. The Suwannee River forms a large, unusual estuarine system at its confluence with the Gulf of Mexico. The greatest area of estuarine conditions is everted, lying outside the river mouth along an open coast. This main estuarine zone, Suwannee Sound, is a shallow offshore area enclosed by a semi-continuous arc of oyster reefs. Within the river, transition from high to low salinity usually occurs over very short distances. A subsystem of tidal creeks and marshes south of the river mouth comprise another component of the estuary and receives fresh water from different sources and under various conditions. At high-river stage, fresh water overflows the low-elevation marshes to the south and flows into estuarine tributaries. This major forcing function of freshwater inflow at high-river stage subjects vast areas south of the river to a relatively sudden transition from estuarine to freshwater conditions. At lower stage, estuarine tributaries receive fresh water from possibly substantial, but yet unidentified, ground-water inflow. At almost all stages, the estuarine tributaries, especially to the south, receive some fresh water on incoming tides via tidal advection of discharged Suwannee fresh water, as mixed masses or lenses of fresh water. The hydrologic forcing functions of direct flow, ground-water inflow, and freshwater advection, result in complex physical and ecological dynamics in the estuary and intertidal zone. These dynamics are further complicated by tide, which also is an important forcing function, due to its 1-m range, distinct seasonal patterns, and wind-driven characteristics. Seasonality of freshwater inflow is another unusual characteristic of the SRES. Most estuarine systems in the region experience lowest salinity levels during the meteorological "wet season," typically starting around June and peaking in September. However, peak-stage conditions in the Suwannee typically occur in March or April, resulting in low salinities during the spring, when other regional estuaries experience high salinities. The reverse is true in mid- or late summer, when SRES salinity is high due to low river stage, and salinity in other estuaries is low. The seasonal difference is undoubtedly significant to estuarine fauna and flora. Additionally, low-gradient topography and open coastline expose the SRES to episodic major storm surges of high-salinity water that also can impact flora and fauna. Low topography makes the SRES highly sensitive to surface alterations, such as roads, that interrupt local freshwater inflow, impound saline waters, and result in forest morbidity. The SRES is a unique, highly productive, and valuable ecosystem that arises from an unusual combination of physical, geological, hydrological, and biological factors. Thorough study and assessment of this large and important system is necessary if it is to be well understood, managed, and conserved.

Toward a Hydrologic Observatory in the Suwannee River Watershed

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The Consortium of Universities for the Advancement of Hydrologic Sciences (CUASHI) is a non-profit organization incorporated June 2001 in Washington DC and funded entirely by the National Science Foundation (NSF). Its purpose broadly includes coordinating hydrologic research efforts in the US through advisement to the NSF and by developing program ideas and managing infrastructure. CUASHI is organized around a concept called HydroView which is composed of four elements: Information Systems, Data Synthesis, Instrumentation infrastructure, and Hydrologic Observatories. Each of these elements is interlinked with data gathering programs organized around Hydrologic Observatories, which are to be developed within an individual watershed, focusing on the hydrologic cycle. NSF expects to fund two Hydrologic Observatories following evaluation of proposals to be submitted in spring 2004.. Three additional observatories will be funded each year between 2008 and 2010. Support for observatories is planned to consist of approximately $3 million annually for operating expenses and $10 million over five years for infrastructure development.

The overarching design concept of hydrologic observatories is that they will serve as a community resource with core data collected and made available through a common interface, equal access to the site, and support for remote investigators. The observatories will be sufficiently large to explore all interfaces including land surface and atmosphere impacts on global circulation models. Consequently, observatories are expected to be at a minimum 10,000 km^2. The five observatories will be linked in a national network, with common data collected and exchanged throughout the network. The observatories will be overseen by Observatory Design Teams that will determine the best way to characterize the site, delineate core data, and develop a work plan for data collection. The daily operation of the observatory will be conducted by a professional staff led by a director and technicians capable of field data collection, data handling, and information technology.

A group of researchers from Florida and Georgia plan to propose the Suwannee River watershed as a Hydrologic Observatory. At present, the group includes faculty from UF, FSU, USF, and UGa and staff from Suwannee River Water Management District, USDA-ARS, and USGS. The Suwannee River is ideal for an observatory, in part because it is the last major river in the United States with unrestricted flow and good water quality. This pristine nature is threatened by rapid population growth. The watershed is divided into confined and unconfined regions at the Cody Escarpment leading to variable but extensive interactions between ground and surface waters, including the world's greatest density of first magnitude springs. In selected regions across the watershed, long-term site-specific programs study and collect data to address linkages between water quality, water storage, water and nutrient fluxes, ecosystems, and environmental stressors. No centralized program links, compares, or coordinates these efforts. A Suwannee River Hydrologic Observatory could provide that centralized program and linkages to the USGS Suwannee River Basin and Estuary Initiative would strengthen both programs.

WATER QUALITY AND GEOCHEMISTRY

Hydrodynamics and Salt Transport in the Suwannee River Estuary

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Living resources in the Suwannee River estuary are highly dependent on the presence of a suitable salinity regime for habitat, growth, and reproduction. Salinity, in turn, is affected by a complex interaction among tides, weather, river flow, ground-water discharge, morphology, and perhaps vegetation. Such a dynamic system is difficult to measure in sufficient spatial and temporal detail to understand the individual roles of each of these controlling processes. Hence, determination of the effects of a change in one or more of the physical processes controlling the salinity regime requires application of a predictive model that has been accurately calibrated to current conditions and can be confidently applied to possible future scenarios.

A three-dimensional, unsteady, numerical model of hydrodynamics and salt transport in the Suwannee River estuary was developed by the U.S. Geological Survey, in cooperation with the Suwannee River Water Management District. The model includes the capability to predict time-varying water level, currents, and salinity on an orthogonal, curvilinear, finite-difference grid. Computational cell sizes range from about 60 meters by 60 meters in the river to about 1,000 meters by 1,000 meters in the western part of the model domain in the Gulf of Mexico. A total of 2,385 computational cells are contained within each of the 6 model layers. The model domain includes the downstream-most 10 kilometers of the Suwannee River, including East, West, Alligator, Wadley, and Northern Passes. From the mouth of Alligator Pass, the model domain extends northward along the Gulf of Mexico shoreline about 23 kilometers to Horseshoe Point, southward about 26 kilometers to Piney Point, and westward about 20 kilometers into the Gulf of Mexico.

The model was developed and tested using comprehensive data on water level, velocity, flow, and salinity. The primary data-collection period extended from October 1999 through September 2000. Hydrologic data included continuous (15-minute interval) measurements of water level at 5 sites in the study area, flow velocity at 3 locations, flow calculated from velocity and water level at 3 locations, wind speed and direction at 1 site, and near-surface and near-bottom salinity at 6 locations in the study area. In addition, vertical profiles of water temperature and salinity were measured at 15 sites more than 50 times under a wide range of flow and tidal conditions.

Water levels were simulated accurately (generally within 0.1 meter of measured values, with very little phase shift) at all measurement sites. The accuracy of simulated flows varied over the tidal cycle, with more accurate simulations for flood flows than ebb flows; similarly, simulated flows during neap tides were more accurate than those during spring tides. Within the river, simulated salinities were more accurate for West Pass than East Pass. Simulated top-to-bottom differences in salinity were in good agreement with measurements, but simulated salinities generally were lower than measured values. Measured and simulated salinities were within 1 – 3 parts per thousand at Red Bank Reef, located in the Gulf about 2 kilometers from the mouth of the river. The model currently is being applied by the Suwannee River Water Management District to simulate the effects of changes in low flows on salinities at key locations in the river and nearshore areas. The model could also prove useful in simulating the nutrient transport in the Suwannee, coupling delivery from terrestrial and atmospheric sources to estuarine response, with the addition of appropriate water-quality algorithms.

Ground-water discharge to the model domain is not included in the model. Although there is currently little data on ground-water discharge rates, addition of this source of freshwater could produce more realistic simulations. Likewise, addition of the many small tidal creeks and drainages located along the Gulf of Mexico shoreline within the model domain could improve model performance in those areas. Currently, the only source of freshwater in the model is the Suwannee River.

The Impact of Nutrient Loading and Hydrodynamics on Algal Biomass in the Suwannee River Estuary

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Like many estuaries subject to major riverine inputs, the ecology of the Suwannee River Estuary is closely tied to the water quality characteristics of the Suwannee River. Nutrients entering the estuary from the river support primary production, but in excess can also lead to significant environmental problems like algal blooms. In an effort to address the consequences of nutrient loading, the objective of this study was to define the relationships between changes in nutrient loading and the response in algal biomass.

Prior studies of the Suwannee River and its estuary indicate high nutrient concentrations in the Suwannee River and subsequent transport and use of these nutrients in the estuary. We hypothesized that algal biomass would be related to spatial and temporal patterns of nutrient availability. The results from the first year of our study generally supported this hypothesis. Shifts in the algal assemblages, however, suggested the role of major meteorological events, such as *El Niño* and *La Niña* in altering the basic features (e.g., color, flow rate and depth) of the river and estuary.

Hydrodynamic properties such as tidal amplitudes, riverine outflow and current patterns also influence the spatial patterns and abundance of phytoplankton biomass. Flushing rates are a major factor in the control of phytoplankton standing crop in the Suwannee River estuary. Regions of the estuary within the oyster reefs exhibited enhanced phytoplankton biomass, indicating nutrient availability and the potential for slower flushing rates. Periods of exceptionally high phytoplankton biomass (> 30 µg chl L^{-1}) were associated with on-shore wind events that may decrease flushing rates within the estuary.

The consequences of nutrient loading from natural and anthropogenic sources within the watershed are of great concern to the ecological state of the Suwannee River and estuary. From this study, it is clear that large-scale meteorological events such as drought events affect the spatial and temporal abundance and composition of primary producer communities. The results from this study could be used to help water managers in their effort to set meaningful and reasonable targets for nutrient loading, as well as for land managers in fulfilling their responsibility to guide future agricultural and urban development in the region.

Source Tracking and Microbial Water Quality in Three Florida Springs

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Microbiological sampling and viral-source tracking were conducted in tandem with geochemical studies at Hornsby, Poe, and Manatee Springs. Standard and alternate microbial water quality indicators (fecal coliforms, *E. coli, Clostridium perfringens* and enterococci) were used to screen water samples to determine if spring waters (Poe and Hornsby Springs) were being impacted by fecal sources. Source tracking assays were employed to differentiate between human and animal (agricultural) fecal contamination using human- and bovine-specific virus assays. Microbial data sets from three sample dates demonstrated good water quality (at drinking-water standard levels for Hornsby and Poe Springs) on the first two dates. On the third date, elevated indicator numbers were observed at all of the sites. In addition, human enteroviruses were detected in all of the springs on the third date via reverse transcriptase-polymerase chain reaction. These data indicate that water emanating from these springs may be susceptible to sporadic contamination by human wastewater through local ground-water-recharge dynamics.

Risk of Phosphate Movement from Soils in the Suwannee River Basin

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The karst areas within the Suwannee River Basin (SRB) are vulnerable to transport of agriculturally-applied nitrate and phosphate (P) that could potentially have ecological impacts on springs and ultimately the Suwannee River estuary. Risk of impact is heightened by karst hydrology and the sandy, permeable nature of soils that occur above the limestone. Nutrients move vertically in these areas such that runoff-based risk assessment models are not applicable. The vertical pathway means that soil retention capacity for nutrients exerts far greater control of mobility than is the case for a surface runoff pathway. Nitrate contamination risks are particularly acute in the SRB because of minimum denitrification and very low retention by soils. Therefore, nitrate is an immediate health and environmental concern. However, excessive P application could also ultimately result in environmental problems. Phosphate is reactive with soils and its "breakthrough" at springs would take longer than nitrate, but once it reached springs its influence would continue for a much longer time than in the case of nitrate. The degree to which phosphate is being retained in four SRB soils is being monitored over a 36-month period of manure (dairy wastewater and poultry solids) application. Data collected thus far suggest that the safe "lifespan" of a manure application site can be predicted with reasonable accuracy given sufficient knowledge of soil and loading variables. This lifespan is influenced by soil factors such as P retention capacity and previous loading history. Even a site with minimum previous P application may have a short safe P-application lifespan (e.g., a few years) if P retention capacity is low. Vertical P movement continues slowly even after application ceases. Therefore, applications should be discontinued before the measured P migration reaches the depth of concern, in order to minimize the risk of eventual elevated solution P concentrations at that depth. The latter requires a mindset of planning to avoid future problems.

Understanding Contaminant Sources, Ground-Water Residence Time and Flow Patterns in a Karstic Springshed

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Human health and ecological concerns have arisen due to a steady increase in nitrate-N concentrations (0.29 to 4.5 mg/L) during the past 40 years in Fannin Springs, a regional discharge point (mean flow 2.8 m^3/s) for water from the karstic Upper Floridan aquifer (UFA). Multiple chemical tracers ($^3H/^3He$, CFCs, SF_6, ^{15}N and ^{18}O of nitrate; dissolved gases; 66 pesticides and degradates; and 64 organic compounds typically found in domestic and industrial wastewater) were analyzed in samples from three ground-water flow transects and in spring water to identify contaminant sources and estimate ground-water age. A preliminary ground-water contributing area for Fannin Springs (590 km^2) was delineated from a potentiometric surface map (0.3 m contours) of the UFA based on high-resolution water level data. Nitrate-N concentrations were highly variable in the oxic UFA and ranged from <0.02 to 4.7 mg/L. Delta ^{15}N-NO_3 values (3.4 to 9.9‰) indicated that local sources of nitrate included both inorganic fertilizer and human/animal wastes. Higher nitrate concentrations in spring water relative to water from upgradient wells indicate that fertilizers or septic tank effluent inputs likely enter parts of the aquifer that contain conduits close to the spring. Other evidence for agricultural sources included the presence of atrazine at slightly above or below analytical reporting limits (0.007 µg/L) in water from Fannin Springs and three upgradient wells. An atrazine degradate, deethylatrazine, was detected at concentrations less than 0.006 µg/L in the spring water and in one well water sample. Wastewater sources of contaminants to ground water included the quantifiable presence of very low concentrations of disinfectants, fragrances, flame retardants, and insect repellants. Estimated recharge ages were younger in ground-water samples taken closer to the spring (<8 years compared to 10-50 years for water from other wells) indicating that these wells likely intersect conduits containing more recent recharge.

Impacts of Riparian Ecosystems on Water Quality in the Western Upper Suwannee River Watershed

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Riparian ecosystems strongly influence the quantity and quality of water in streams forming the western portion of the upper Suwannee River Watershed. The Withlacoochee, Alapaha, and Little Rivers begin in the Tifton-Vidalia upland in Georgia and their upper reaches are dominated by direct surface runoff and interactions with shallow surficial ground water. In many of these watersheds, naturally occurring riparian forest ecosystems typically comprise about 30 percent of the watershed area and agriculture including row-crops and pastures comprise about 70 percent of the watershed. In this watershed setting, riparian zones have been shown to retain 68 percent of the N, 30 percent of the P, 39 percent of the Ca, 23 percent of the Mg, and 6 percent of the K that is being transported from surrounding agricultural areas of the watershed. On a mass basis, denitrification and vegetation uptake were of similar importance for N removal. Very poorly drained soils had higher potential than poorly drained ones to remove nitrate by denitrification and could remove more than the present load of nitrate. Watershed scale studies of existing forest buffers showed that long-term sediment deposition rates ranged from 35 to 256 Mg/ha/yr, consistent with the low-sediment delivery ratios for Coastal Plain streams. When implemented as part of farm scale landscape management, managed and restored forest and grass buffers controlled nitrogen and phosphorus movement from conventional row crops and from areas of intensive manure management including dairy and swine lagoon effluent applications. Managed and restored forest and grass buffers also removed herbicides (atrazine and alachlor), that moved primarily in the dissolved phase of surface runoff from row crops. Because of land use patterns that have tended to preserve naturally occurring riparian forest buffers there is not a general need for riparian ecosystem restoration in the western upper Suwannee Watershed. But, understanding and modeling chemical and sediment transport from these heavily agricultural watersheds requires understanding and modeling the impacts of riparian zones.

Evidence for Rapid Transport of Recharge from Onsite Sewage Treatment and Disposal Systems to Ground Water at Manatee Springs State Park

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Given the karstic nature of much of the Suwannee watershed, recharging water should reach ground water quickly. Rapid transport, e.g., via conduit flow, also limits the potential for natural attenuation of any contamination present in the recharging water. These hypotheses, rapid transport and limited attenuation, were investigated at two onsite sewage treatment and disposal system (OSTDS) sites at Manatee Springs State Park, Levy County, in 2003/2004.

Two conventional septic systems with drainfields at the Magnolia and Hickory campgrounds were studied. Magnolia represents a river front landscape position with a shallow water table, while Hickory represents a more upland/hammock situation with a deep water table. Ground Penetrating Radar surveys at both sites indicated the presence of paleo-sinkholes. Monitoring wells with 10-ft screens were installed downstream of the drainfields in shallow ground water. One monitoring well at the Hickory site was installed into a paleo-sinkhole. Tracer tests, one at each location, consisted of injections of 50-gallon slugs of water containing two tracers, sulfur hexafluoride and fluorescein, into the drainfield. Monitoring wells were sampled for the tracers for up to a year. Sampling of the monitoring wells for nitrate, nitrite, ammonia, TKN, total phosphorous and fecal coliforms continued over a one-year period.

The results of this study clearly confirmed that there are rapid connections between the near-surface drainfields and the underlying karst aquifer at both the OSTDS sites. Tracer was observed at each site in monitoring wells within hours of the injection into the drainfields. Flow velocities, as determined by traveltimes to individual monitoring wells, were in tens of feet per day. At Magnolia campground, flow rates varied from 5 to 100 feet per day and at Hickory campground they varied from 1 to 280 ft/day. Tracer from the Hickory tracer test was detected in Manatee Spring shortly after the beginning of the test.

On the other hand, the complexity of transport in karst, likely due to multiple porosities, was indicated by more than one peak in many monitoring well concentration time series and persistently high tracer concentrations up to a year after begin of the tracer test. The more volatile sulfur hexafluoride showed both earlier and later peaks than fluorescein.

Elevated nutrients were found in wells surrounding the septic systems with nitrate concentrations in impacted wells as great as 20 to 60 mg/L at both the Magnolia and Hickory sites. In the most impacted well at Magnolia, concentrations ranged up to 55 mg/L nitrate, 0.92 mg/L total phosphorus and 930 fecal coliform colonies/100 ml. The well installed in a paleo-sinkhole was the most impacted at Hickory, with concentrations ranging up to 56 mg/L nitrate, 4.9 mg/L total phosphorus and 99 fecal coliform colonies/100 ml. The greatest concentrations observed in background wells were only 1.6 mg/L nitrate, 0.47 mg/L total phosphorus and <2 fecal colonies/100 ml. Elevated nutrient concentrations were found directly in the flow path of the effluent as indicated by the tracer experiments.

A conclusion of this study is that the good connections between surface and groundwater in the underlying karst aquifer allows rapid transport in the direction of the next surface-water body or spring.

EPA's Gulf of Mexico Program and FL DOH's Onsite Sewage Research Program provided funding for this study.

Identifying Water-Quality Domains near Ichetucknee Springs, Columbia County, Florida

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Water-quality data collected at nearly 100 wells and 6 major springs in southern Columbia and eastern Suwannee counties were investigated using factor analysis, hierarchical analysis, star diagrams and WATEQ4F. These analyses were used to identify geochemical facies within the Floridan aquifer near Ichetucknee Springs. The factor analysis suggests that six factors help explain more than 75 percent of the variability in the data. These six factors reflect flow path and recharge characteristics, as well as water-rock interactions, in the Floridan aquifer near the springs.

The variables that best represent these six factors are alkalinity, chloride, magnesium, nitrate, ammonium, and phosphorus. Hierarchal analyses of these six factors suggest that the wells and springs can be grouped into three distinct water-quality domains. These domains indicate areas where: 1) clay-rich sediments of the Hawthorn Group influence the water chemistry in the Floridan aquifer, 2) regional flow paths appear to be emerging, and 3) ground-water flow paths are short in the Floridan aquifer. This last domain can be further subdivided into two sub-domains with two distinct water quality types each.

Star diagrams representing the relative importance of each factor for each well and spring show the three major domains occupy distinct geographic areas. The first domain is located beneath the Northern Highlands, where the Hawthorn Group acts as a confining unit. The second domain is concentrated around the Santa Fe River, where upwelling of deep aquifer water is expected. The third domain occupies most of the study area, where the Floridan aquifer is poorly confined or unconfined. The subdivisions of this domain do not indicate any spatial patterns, but rather indicate areas characterized by distinct chemical fingerprints, identify areas susceptible to ground-water contamination, and locate regions where surface-water recharge is occurring.

The water-quality data collected from six major springs along the Ichetucknee River suggest that the spring water is mostly derived from areas near the springs characterized by rapid recharge and shallow flow paths. These regions supply base flow to the springs while conduit flow supplies ground water that has recently recharged the aquifer through swallets in the Cody Scarp.

Supplemental analysis of the water-quality data using WATEQ4F suggests that much of the ground water and spring water is at or near saturation with respect to calcite. However, in areas where Factor 1 is low (<1), such as in the Cody Scarp, the ground water tends to be undersaturated with respect to calcite. These areas tend to be characterized by the presence of disappearing springs, where surface water has not reached chemical equilibrium with the limestone aquifer.

Assessment of Nitrate-Nitrogen Variability in Soils of the Santa Fe River Watershed in North-East Florida

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The Santa Fe River (SFR) has been contributing to elevated loads of nitrate-nitrogen in the ground, spring and surface water of the Suwannee River Basin. Sustainable land use management in the Suwannee Basin preserving water resources requires to upscale site-specific observations of nitrate-nitrogen to watershed-scale and to understand relationships between nitrate-nitrogen and environmental factors such as land use, soils, parent material, and landscape position. Our objective was to model the space-time variability of nitrate-nitrogen across the SFR watershed using point measurements and its relationship with environmental factors. Geospatial data from the Soil Survey Geographic Database and land use derived from Landsat-TM satellite imagery was used to compute soil-land use categories (SLC). We used a stratified random sampling design for selecting sites proportional to the aerial extent of individual SLC and targeting "high-risk" SLC categories expected to contribute to high nitrogen loads. Soil sampling started in September 2003 and will continue for 2 years including 6 synoptic soil sampling events. Soil samples have been collected in composites, proportional to the support size, from four different depth increments (0 to 30, 30 to 60, 60 to120 and 120 to180 cm). Nitrate-nitrogen measured at individual sites was averaged along soil profiles. We used Classification Trees to classify nitrate-nitrogen based on environmental factor combinations. Tree models were used to upscale site-specific observations to watershed-scale. The minimum and maximum average nitrate-nitrogen values were 0 and 6.54 µg/g soil and highly skewed with a mean of 0.71 µg/g soil and standard deviation of 1.3 for the September 2003 event. Many sites showed absence of nitrate-nitrogen (values below detection limit (DL). We used various exhaustively available data layers of soil, land use and terrain attributes to develop a classification tree model predicting the presence (values > 0) or absence (values < DL) of nitrate-nitrogen. The derived classification tree model showed that land use, soil type and upslope drainage area are useful predictor variables. Land uses such as crops, feedlot, improved pasture and rangeland contributed to the tree branch predicting presence while urban, wetland and upland forests were associated with the tree branch predicting values < DL. The classification model successfully predicted 92 sites out of 100 sites in training mode, while the cross validated results showed correct classifications for 75 sites out of 100 sites. The January 2004 sampling also indicated a highly skewed nitrate-nitrogen distribution, with some higher nitrate-nitrogen values compared to the September 2003 data. The high values were associated with improved pasture, crops and rangeland. The future sampling will provide information about the seasonal variation of nitrate-nitrogen in soils across the watershed and explores the importance of environmental variables to explain nitrate-nitrogen variability. The final research output will contribute to better understand the space-time variability of nitrate-nitrogen at watershed scale and develop recommendations to improve the soil and water quality in the SFR watershed.

ECOSYSTEM DYNAMICS

Long-Term and Large-Scale Trends in Mercury Bioaccumulation in the Suwannee River Basin, Florida

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The Suwannee River exhibits strong gradients in land use and water chemistry along its 245 mile course, providing a unique opportunity for the study of mercury bioaccumulation in lotic systems. To evaluate temporal trends in mercury burden of largemouth bass (*Micropterus salmoides*), muscle tissue was analyzed for total mercury concentration in fish collected from the lower Suwannee River Basin annually from 1987 to present. As a preferred prey item crayfish (*Procambarus* sp.) were collected in 1993 and 2001, and muscle tissue was analyzed for methylmercury. Spatial trends in bioaccumulation were evaluated by analyzing mercury burden, $\delta^{13}C$, and $\delta^{15}N$ in crayfish, sunfish (*Lepomis auritis*) and largemouth bass collected in 2001 from stations 15 to170 miles upstream of the river mouth. Mercury levels in largemouth bass (age standardized, EHg_3) decreased from 0.80 (1989) to 0.25 µg/g (2001), although values peaked in 1992 and 1999. Mercury levels in crayfish also decreased by approximately 60 percent from 1989 to 2001. Mercury body burden is apparently related to river stage; regression models indicate that mercury in largemouth bass is significantly correlated to the number of days at or exceeding flood stage (days overbank, i.e., streamflow exceeding 75 percent duration flow) during the life of the fish. Mercury concentration in the muscle tissue of sunfish and largemouth bass increased with increasing river miles upstream. Preliminary analysis of stable isotope data indicates little difference in trophic position for largemouth bass among all stations ($\delta^{15}N_{lmb} - \delta^{15}N_{cray}$ = 4-6 ‰), suggesting that bioaccumulation rates are more tightly controlled by mercury source/transport, and local biogeochemical processes.

Gulf Sturgeon

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Gulf sturgeon, *Acipenser oxyrinchus desotoi*, forage extensively in the Suwannee River Estuary following emigration out of the Suwannee River. While in the estuary, juvenile sturgeon primarily feed on benthic infauna. In June-July, 2002, and February-April, 2003, random sites within the estuary were sampled for benthic macrofauna (2002, n=156; 2003, n=103). A mean abundance of 2,562 individuals/m^2 (s.e. $\pm$ 204) was found in the summer, with significantly reduced macrofaunal abundance in the winter (mean density of 1,044 individuals/m^2, s.e. $\pm$ 117). Benthic biomass was significantly higher in the summer with an average summer sample dry wt. of 5.92 (s.e. $\pm$ 0.82) g/m^2 compared to 3.91 (s.e. $\pm$ 0.67) g/m^2 in the winter. Amphipods and polychaetes were the dominant taxa collected during both sampling periods. A Principal Food estimate indicated that the potential food resource value for juvenile Gulf sturgeon is spatially heterogeneous within the Suwannee River Estuary.

Benthic Macroinvertebrate and Periphyton Monitoring in the Suwannee Basin in Florida 1: Overview and Biogeography

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This and two other papers will summarize the results of a long term program, begun in 1989, to monitor water quality, benthic macroinvertebrates and periphytic algae in the Suwannee River and its major tributaries in Florida. Invertebrates and algae were sampled quarterly as a subcomponent of a comprehensive water quality monitoring effort. Six stations on the Suwannee mainstem, four sites on the Santa Fe, two on the Withlacoochee and one sampling site on the Alapaha River have at least 12 years of continuously collected algal and/or invertebrate data, which were collected by the same firm and analyzed by the same taxonomists for the entire period. These biological data were collected concurrent with water chemistry sampling, and in many cases, at sites where continuous river stage and discharge were monitored as well. This permits examination of biological responses to changes in physical/chemical conditions. Algae were sampled with glass slide settling racks (periphytometers), and macroinvertebrates were sampled with multiple gear types; primarily Hester-Dendy multiplate samplers, but also petite ponar grabs and dip nets.

A diverse algal flora has been documented to occur in the Suwannee River and its tributaries in Florida. These plants probably account for the majority of the primary production in the riverine aquatic ecosystem. Diatoms generally dominate the taxa composition (by both relative richness and relative abundance). Dominant taxa include *Achnanthes*, *Cocconeis*, *Gomphonema* and *Melosira*, all indicative of hard, bicarbonate freshwater conditions. Green algae and blue-green bacteria make up the remainder of the periphytic algal communities in the river system, and form a greater fraction of the algal community in the upper reaches of the Suwannee and Santa Fe, where the water chemistry is more dominated by surface-water runoff (low pH and conductivity, low alkalinity).

Benthic macroinvertebrates in the Suwannee drainage fulfill several ecological roles. Primarily, they serve as the key link between autochthonous and allochthonous primary production and secondary production at higher trophic levels (e.g., fish, reptiles, and birds). Benthic invertebrates comprise a sizeable fraction of the total animal biodiversity of the Suwannee River in Florida. Chironomids dominate the taxa richness and relative abundance throughout the system.

Benthic Monitoring in the Suwannee Basin in Florida 2: Relationships Between Physical and Chemical Variables and Biology

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This paper is the second in a series of three papers that summarizes the results of a long-term monitoring program, begun in 1989, to monitor water quality, benthic macroinvertebrates, and periphytic algae in the Suwannee River and its major tributaries in Florida. This paper presents the relationships between physical and chemical variables and biology.

Physical and chemical variables influence the biological components of the Suwannee River system. Algae and benthic invertebrates serve a variety of ecological roles in river and tributaries, including primary (algae) and secondary (invertebrate) production, food for higher organisms, and transformation of energy and nutrient cycling. Both algae and invertebrates act as indicators of ecosystem health, with algal communities being more immediate indicators of environmental stress, while the benthic invertebrate community responds to environmental conditions integrated over a longer time period.

The Suwannee River Water Management District has been collecting long-term stream discharge, water-quality, and biology data (algal and invertebrate) at numerous stations throughout the District since 1989. From these data, we identified existing relationships between the physical/chemical variables and biology and assessed the relative strengths of these relationships through an extensive series of bivariate plots and Spearman correlation statistics. Logistic regression analysis was also conducted to examine relationships between water quality and physical factors and the resulting distribution (presence/absence) of taxa.

Benthic Monitoring in the Suwannee River Basin in Florida 3: Spatial and Temporal Trends

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This paper is the third in a series of three papers that summarize the results of a long-term monitoring program, begun in 1989, to monitor water quality, benthic macroinvertebrates, and periphytic algae in the Suwannee River and its major tributaries in Florida. This paper presents the spatial and temporal trends observed in the long-term monitoring data.

Algae and benthic invertebrates serve a variety of ecological roles in the Suwannee River system. Observed community responses indicate whether an ecosystem is experiencing stress or is relatively healthy. Periphytic algae and benthic macroinvertebrate data were evaluated to assess community similarity over time and between river systems (or groups of rivers) within the Suwannee River Water Management District. Trend analysis was applied to all sampling sites with 5 or more years of data to identify and quantify the significance, direction and magnitude of trends in algal and invertebrate taxa richness and abundance. Cluster analysis and other multivariate analyses were performed to identify patterns and trends at selected sampling sites and to identify the most influential physical variables with respect to the observed biological responses. These analyses represent a comprehensive review of trends in the Suwannee and its major tributaries in Florida.

Aquatic Invertebrate Communities as Tools for Establishing Minimum Flows and Levels in Suwannee River Basin Streams

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Florida's five water management districts are required by statute (373.042 F.S.) to establish minimum flows and levels (MFLs) for water bodies within their boundaries. The statute mandates that MFLs be set at levels that prevent significant harm to Florida's ecological resources. Development-related increases in consumptive water use have prompted water managers throughout the state to predict significant flow reductions in many lotic systems. In response to these predicted reductions, the Florida Fish and Wildlife Conservation Commission has implemented an instream flow program with the dual purposes of determining flow requirements of stream-dwelling communities and providing the water management districts with MFL recommendations that are protective of the biotic integrity of stream ecosystems. The Commission has identified streams within the karst area of the Suwannee River Basin of north-central Florida as particularly vulnerable to impacts from increased ground-water withdrawals related to agriculture and human population growth. Three streams within the Suwannee Basin, the Santa Fe River, the Withlacoochee River, and the Ichetucknee Springs and River complex, have been chosen as study areas for development and evaluation of MFL determination methods. A principal tool chosen for derivation of these methods is aquatic invertebrate community structure. Invertebrate communities were selected because they are flow-sensitive and are integral to the normal functioning of stream systems; invertebrate community structure is a proven sentinel of aquatic ecosystem health. Within each study stream, invertebrate communities will be sampled in areally dominant natural habitats within several stream reaches. A suite of physicochemical measurements, including current velocity, depth, and substrate type, will be recorded concurrently with the collection of each individual sample. Data compiled from the collections will provide a baseline for future flow-related evaluations. Taxa sensitive to flow will be identified using multivariate methods such as canonical correspondence analysis. Invertebrate abundance data and physicochemical data will be combined to produce habitat suitability curves for indicator species and selected community metrics. The utility of using locally derived habitat preference curves coupled with the PHABSIM model for determining usable habitat areas at different streamflows will be evaluated.

Submerged Aquatic Vegetation Mapping in the Ichetucknee Springs and River System, Florida

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In 2003, the Suwannee River Water Management District (SRWMD) began collecting ecological data within the Ichetucknee Springs and River to provide baseline information regarding the current health of this aquatic ecosystem. This presentation describes the mapping and monitoring of submerged aquatic vegetation (SAV) in this spring system. Water quality and SAV biomass were also sampled and will be presented as a separate paper for this conference. The goals of the Ichetucknee Springs mapping project were to provide a map of the spatial distribution of SAV in the Ichetucknee Springs and River, and compare existing coverages with a study performed in 1979 by Dutoit.

Approximately 78 percent of the Ichetucknee River bottom was covered by SAV in 2003, an increase of approximately 23 acres or 353 percent compared to the 1979 Dutoit survey. The most common species encountered (in order of percent cover) in the Ichetucknee Springs and River were *Sagittaria kurziana*, *Zizania aquatica*, *Vallisneria americana*, *Chara* sp., *Myriophyllum heterophyllum*, *Ludwigia repens*, and *Hydrocotyle* sp. In 2004, portions of the river which are exposed to intensive recreational use (e.g., docks used for entry and exit points by tubers, swimmers, and canoeists) were remapped and a change analysis of these areas was performed to compare SAV map data between 2003 and 2004. Maps were also created for river depth, flow, reach and tree canopy shade, and analyzed with respect to 2003 SAV maps. SAV coverage declined by approximately 454 m^2 or 0.1 acres between 2003 and 2004 in the intensive recreational use areas. This represents an approximate 2 percent loss within the remapped areas. Overall, changes in SAV coverage were minimal between the two mapping periods and the majority of loss can be explained by temporary impacts associated with the reconstruction of the take out area near U.S. 27. Other losses were the result of conversion of former SAV polygons to emergent polygons, likely due to lower river water levels observed during the drier 2004 mapping period.

Based on the spatial mapping analyses for the river, the vast majority of the river is less than 2 m deep. Just over 50 percent of the river is less than 1 m deep (75,000 m^2), with a slightly smaller area (62,000 m^2) between 1 and 2 m deep. The 2 to 3 meter interval is small (5,000 m^2, less than 5 percent) and occurs in Reach 3 (Rice Marsh) and the lower reaches. In general, flow follows the same trends as the depth, with more rapid flow in areas with greater depth. With respect to river reach, tree canopy shade decreases from reach 1 to 3, increases to reach 6, then decreases again, although more gradually, to reach 9. The decrease in shade around reach 3 is due to the greater width of the river in this area, and the presence of *Zizania* beds beyond the tree canopy. These two characteristics result in more open surface area away from the fringing tree canopy. The decrease in shade in reaches 8 and 9 appear to be due in part to the more east-west orientation of the river.

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Factors Influencing the Submersed Aquatic Vegetation of the Ichetucknee River

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Annual surveys (2003 and 2004) of the Ichetucknee River were made for a variety of parameters with the goal of measuring baseline conditions and relating the effects of stream depth, flow and terrestrial canopy cover to the abundance of submersed aquatic vegetation (SAV) and periphyton in the river. Additionally in 2004, nitrogen and phosphorus concentrations were measured in the main river and several feeder springs to explore the relations between nutrients, SAV and periphyton. SAV coverage was correlated to stream depth and terrestrial canopy. SAV biomass was correlated to stream depth, flow and terrestrial canopy. Periphyton abundance was correlated to depth and flow as well. Nutrient concentrations were not correlated to SAV or periphyton abundance in the main river; however, in the feeder springs, phosphorus availability was positively correlated to periphyton abundance. Also of interest, periphyton abundance was negatively correlated to both SAV coverage and biomass, suggesting that increases in periphyton may cause declines in the SAV community. These observations provide insight into the roles of physical and chemical parameters in shaping the SAV community as well as a framework for long-term monitoring.

Lower Suwannee River Floodplain, Florida: Hydrology, Topography, and Soils of Riverine and Tidal Floodplain Forests and Ecological Consequences of Potential Flow Reductions

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Increased water withdrawals from the Suwannee River Basin could reduce river flow, resulting in decreased floodplain inundation and an upstream movement of the saltwater interface. Impacts of hypothetical flow reductions on wetland forests were estimated in a study of hydrology, soils, and vegetation of the lower Suwannee River floodplain conducted by the U.S. Geological Survey, in cooperation with the Suwannee River Water Management District, from 1996 to 2000.

Hydrology, topography, soils, and vegetation were described from transects and plots in the floodplain of the Suwannee River from its confluence with the Santa Fe River to the tree line near the Gulf of Mexico. Flood depths and duration of inundation and saturation varied with land-surface elevations, which ranged from 13-24 ft above mean sea level at the most upstream site to 1-4 ft above mean sea level at downstream tidal sites. Surface soils were predominantly mineral in riverine forests and predominantly organic and saturated in tidal forests. Hydrologic conditions and soil characteristics were described for each of 13 wetland forest types.

Forest composition in river floodplains, which is primarily determined by flood depths, duration of inundation and saturation, and salinity, could change if flows were reduced. If forests became significantly drier or more saline due to flow reductions, upland species would invade bottomland hardwood forests, bottomland hardwood species would invade swamp forests, and tidal species would migrate upstream. Alteration of wetland hydrology could have other ecological consequences such as invasion of floodplain forests by exotic plants. Decreased soil saturation may result in oxidation of organic soils in riverine swamps, reducing water-holding capacity and pollution-filtering ability, and increasing vulnerability to fire. In riverine swamps, flow reductions at low flows could decrease aquatic habitat for floodplain fishes and aquatic invertebrates at a time when that habitat is already scarce. Flow reductions at high flows may decrease the abundance of fishes that are seasonally dependent on flooded forests for food, and may adversely affect aquatic organisms in the river and estuary that depend on nutrient and detritus exports from the floodplain.

Lower Suwannee River Floodplain, Florida: Canopy, Subcanopy, and Ground Cover Vegetation and Potential Impacts of Flow Reductions on Plant Distribution

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Plant communities in the lower Suwannee River floodplain were described in a study conducted by the U.S. Geological Survey, in cooperation with the Suwannee River Water Management District, from 1996 to 2000. The distribution of plant species in the floodplain was related to flow-dependent hydrologic characteristics such as flood depth, soil saturation, and salinity. Principal data collection sites were transects that were permanently marked for future ecological studies. Major forest types were defined from vegetative sampling and digitized aerial photography. A detailed forest map was created and an interactive version of the map was published on compact disc.

Floodplain forest types include 1 upland and 13 wetland types. A total of 77 canopy and subcanopy species were identified in floodplain wetland forests (n = 8,576). Bald cypress was the most important canopy species in the floodplain by basal area. Cabbage palm and pumpkin ash increased in importance in tidal reaches, and red cedar and sweetbay were found only in the lower tidal forests. The distributions of tree species by river mile may be due primarily to differences in flood depths and salinity. Flow reductions will lower flood depths and result in the increased importance in bottomland hardwood forests of species with less flood tolerance such as hackberry. Flow reductions will also increase the potential for higher salinities in tidal reaches, resulting in a retreat upstream of species that are less salt-tolerant such as water tupelo.

Ground cover density and species richness in wetland forests were analyzed by reach and forest type. The riverine reach had the greatest species richness (n = 203). The upper tidal reach had the lowest species richness (n = 116) and lowest density of ground cover. Density was greatest in the lower tidal reach where floods are shallow and usually of short duration. The distribution of ground cover species may also demonstrate the influences of flood depth, salinity, and soil saturation, and these distributions can be expected to change if flow reductions occur. Some species, such as poison ivy, that have a wide tolerance to hydrologic conditions, may increase in abundance in altered habitats if other species decrease.

Structural and Dynamic Habitat in the Suwannee Estuary: An Application of Remotely Sensed Imagery to Integrated Habitat Mapping

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This study characterized and mapped the shallow and nearshore benthic and intertidal habitats of the Suwannee River Estuary and identified potential relations between benthic habitat, hydrology, and ecological function. Submerged and emergent habitat characteristics were detected and evaluated from 12 bands of 4-m hyperspectral imagery flown in fall 2002. These data were combined with hydrologic, topographic, and tidal data to interpret structural and dynamic habitat and its potential as essential fish habitat. Categories and geomorphology of the intertidal zone depicted channels, submerged aquatic vegetation (SAV), oyster bars, vegetation differences, and flooding stages within the nearshore and intertidal zones. Morphologic derivatives such as tidal creek sinuosity and drainage density were also obtained from the imagery.

It was hypothesized that habitats north and south of the river are dynamically and structurally different, because the influence of the Suwannee River is greater to the south. Image analysis shows that the northern creeks support more flooded low marsh accessible to small mobile organisms, more creek edge and coarse sediment, lower runoff rates, and possibly prolonged discharge during low tide. Barnett Creek and its tributaries are straighter, fresher, and deeper than the northern creeks. Field observations suggest that the southern creeks have more exposed limestone substrate and *Vallisneria* beds, but these features were not detected with the imagery. Hydrologic monitoring confirmed fresher conditions in the southern creeks and a net influx of ground water to both northern and southern creeks, but the source and timing of freshened ground water are incompletely documented. Observed intertidal habitat differences between northern and southern creeks point to differences in underlying geology and hydrology, especially overland and ground-water flow.

Fish were collected in early April 2003 with three methods: rivulet nets, seines, and throw traps. Forty-five species were collected, 41 species from the southern creeks and 30 species from the northern creeks. Whereas the fish sampling effort in this study was insufficient to make definitive statements about species assemblages or habitat use, fish sampling does suggest that southern creeks were utilized by more freshwater species. In addition, fishery habitat value of northern and southern creeks for estuarine species may be indistinguishable, a conclusion that is supported by earlier independent FMRI fishery sampling. Additional analysis of seasonal variation and specific habitat use, and refined habitat mapping would help clarify the effects of Suwannee River discharge on habitat and species assemblages. Further assessment of the dynamic interaction between geology, tide, ground water, and river discharge in the estuary and their combined role in habitat suitability is needed. The successful detection and interpretation of detailed habitat characteristics from airborne imagery serves as an example of the application of hyperspectral imagery to aquatic and wetland mapping and monitoring.

The Florida Salt Marsh Vole on the Lower Suwannee National Wildlife Refuge

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The Florida salt marsh vole (*Microtus pennsylvanicus dukecampbelli*) was first described in 1982 from a single site on private lands in Waccasassa Bay, near Cedar Key in Levy County, Florida (Woods et al. 1982). Subsequent surveys failed to locate any other populations within Florida's Big Bend region (Bentzien 1989, Doonan and Morgan 2002, Woods 1988). Prior to our effort, only 15 Florida salt marsh voles had been captured and all were trapped at the same site in Waccasassa Bay (Doonan and Morgan 2002, Smith 1990, Woods et al. 1982). We conducted an initial survey of salt marsh habitats on the Lower Suwannee National Wildlife Refuge to determine if *Microtus* populations could be present. We surveyed several potential trapping sites and prioritized them based on plant species composition, distance to tree line, distance to open water, site protection, patch size, and proximity to the known *Microtus* population. The survey site that ranked highest was an area dominated by salt grass (*Distichlus spicata*) with a patch size of approximately 3 hectares, located near the southern boundary of the refuge. At this study site we established a grid of 40 traps. Using accepted live-trapping techniques we captured 1 adult male Florida Salt Marsh Vole, 1 sub-adult male, and 1 adult female. Our study site was approximately 12 kilometers northwest of the original Waccasassa Bay site. Future plans call for continued surveys on the refuge to determine if other areas may contain *Microtus* populations, along with an in depth population and life history study of the newly discovered population.

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The Florida Fish and Wildlife Conservation Commission's Fishery-Independent Monitoring Program, Cedar Key, Florida

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The fishery-independent monitoring (FIM) program began in the Cedar Key area during June 1996. The program was designed to monitor the relative abundance of fishery resources in Florida's major estuarine, coastal, and reef systems. Cedar Key is one of seven areas in the state where the FIM program operates.

The FIM program utilizes a multi-gear approach within a stratified random sampling design to collect data on fishes and selected invertebrates from a wide range of habitats and life history stages. A 21.3m center bag seine with 3 mm mesh is used to collect juvenile and small adult fishes in shallow water 0.3 – 1.5 m deep, a 6.1 m otter trawl with a 3 mm mesh liner is used to collect juvenile and adult fishes in water 1.8-7.6 m deep, and a 183 m haul seine with 38 mm stretch mesh is used to collect juvenile and adult fishes along shorelines in water less than 2.5 m deep.

The Cedar Key sampling universe is divided into 3 sampling zones based on geographic and logistic criteria. Each zone is subdivided into 1 nm^2 grids and each grid is further subdivided into 100 micro grids. Every month, 66 sites identified by microgrids, are randomly selected from this universe to be sampled with the suite of gears mentioned above. The Cedar Key sampling universe extends from Bumblebee Creek (north of the Suwannee River), to Porpoise Creek (south and east of the Cedar Keys). It also includes the lower Suwannee River up to the Gopher River and all tidal creeks . The western boundary is the NOAA 3-nautical -mile demarcation line.

At each sample location, all species of fish and selected invertebrates are identified (quality control procedures are in place to ensure proper identification) and all or a subsample are measured and released. Environmental data is also taken including location (latitude and longitude), water quality, habitat characteristics and other physical parameters. Depending upon research and management needs, some specimens may be brought back to the lab for otolith extraction, tissue samples, etc.

Data collected by the FIM program can be used to describe the spatial and temporal distribution of fishes, relating fish distribution and abundance to macrohabitat parameters, and tracking relative fish abundance through time, among other uses.

Gulf Sturgeon – The Central Role of an Iconic Species in the Suwannee River Initiative

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The Gulf sturgeon (*Acipenser oxyrinchus desotoi*) is an ESA-listed threatened species having known reproducing populations in seven river systems along the Gulf of Mexico. The Suwannee population is by far the largest and is critical to this anadromous species' survival and recovery. The Suwannee population seems relatively stable – reflecting the generally unaltered ecological conditions in the lower 220 km portion of the 386-km long river and its estuary, all of which provides critical habitats for various life stages. Gulf sturgeon is undoubtedly the most important protected species in the Suwannee River system, and the condition of its population is both dependent on and an indicator of the health of the Suwannee.

USGS researchers and collaborators have been studying Suwannee River Gulf sturgeon for almost two decades and have made many important scientific contributions with regard to the species' biology, ecology and protection. These include: determination of seasonal adult movement patterns within the river, identification of juvenile habitats in the river mouth and estuary, first robust estimates of population size, development of a long-term data base, identification of spawning habitats (over 200 km up river from the mouth) and conditions, determination of fall migration and movement patterns within the estuary and Suwannee Sound, first determination of winter marine migrations and habitats (during its half-year period of marine residency), contribution to critical habitat designation, acoustic analyses of jumping behavior, analyses of potential effects of flow/stage on reproductive success, testing and refutation of thermal barrier/springs holding area hypotheses, assessment of benthic prey distributions, and investigations of potential for inter-river transfers between the Suwannee population and other systems.

Despite these advances, many important questions remain, and their answers are essential to the long term conservation and protection of Suwannee River Gulf sturgeon. These include: identification of freshwater habitats of young of the year (YOY), full delineation of juvenile habitat in the river mouth and estuary, determination of prey resources of YOY and juveniles, impacts of dredging and other man-made changes on critical habitats, impacts of eutrophication (including effects of episodic benthic algal mat overgrowth on sturgeon feeding ability, prey distribution, and dissolved oxygen). Additionally, much remains to be done to protect the critically important spawning sites, including protection from direct impacts of nearby development or alteration, as well as from general ecological impacts on water quality and quantity (minimum flows) within the basin upstream of the mid-river spawning sites and nursery habitats.

The health and well being of the Suwannee River ecosystem and this magnificent fish species are intimately intertwined. Sturgeon are dependent on conservation of the ecosystem, and in turn, their protection can assist efforts to conserve the system. Gulf sturgeon should have a central role in any initiative aimed at understanding and conserving the Suwannee River.

The Florida Manatee in the Suwannee River and Estuary: Past, Present, and Future

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The Florida manatee is a federal- and state-listed endangered marine mammal, inhabiting near-shore marine areas and coastal rivers of the southeastern U.S. It is dependent on freshwater for drinking, seagrass and freshwater vegetation for forage, and warm-water refuges to survive cold winters. Early historical reports (Bartram, 1791) attest to the species long-term use of the lower Suwannee River system. In the 1980s, research by the USGS Sirenia Project (radio-telemetry, photo-identification, aerial surveys) identified the estuary and the lower Suwannee as a primary summer foraging areas for manatees in northwest Florida (Powell and Rathbun, 1984, Rathbun et al., 1990). A review of past studies and current data on summer and winter distributions identified Manatee Spring as an important area consistently used by small numbers of manatees throughout the year, but particularly during fall and spring cold spells when animals are dispersed away from the primary winter refuges near springs in the Crystal and Homosassa Rivers.

Research to monitor manatee population parameters and to assess population status indicates that presently manatees in the region are doing well. USGS estimates of survival, reproduction, and population growth rates from photo-identification data show an increasing population over the past 10 years (Runge et al., 2004). Northwest Florida, along with the Upper St. Johns River region, is the least impacted by human interactions and development. Over the years, the number of manatee deaths from watercraft strikes and cold stress has been low.

Optimism over the growing regional population, however, is tempered with concern over maintaining quality and quantity of habitat for the long-term viability of the species, particularly winter warm-water refuges and summer foraging areas. Several Working Groups under the U.S. Fish & Wildlife Service's Florida Manatee Recovery and Implementation Team (Warm-water Task Force, Habitat Working Group, and Population Status Working Group) are now coordinating to address habitat/population/management issues. USGS research to develop new models of manatee population dynamics that incorporate habitat variables show considerable promise. However, to advance our understanding of manatee population ecology, interdisciplinary research is needed to identify and quantify the ecological linkages of population dynamics to biotic and abiotic processes across the landscape. A larger ecosystem-based approach to research and management was recently identified as a high priority for all marine mammals by the U.S. Commission on Ocean Policy.

The inclusion of manatees into a larger Suwannee River Ecosystem Research Plan undoubtedly can provide important data for manatee researchers and managers, but it can also provide important data to researchers in other disciplines. Long-term monitoring of manatees in the region for over 20 years with photo-identification, aerial surveys and telemetry provides historical data for comparison to the present and future. Because of their reliance on winter warm-water refuges and summer foraging areas, the manatee could prove to be a key indicator of effects from perturbations to the Suwannee ecosystem.

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Effects of Water Level Fluctuations on Year Class Strength of Sport Fish in Four Florida Rivers

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We evaluated how annual and seasonal flows and water levels were related to year class strength of selected sportfishes across four Florida Rivers. The four rivers included the Santa Fe, Ochlockonee, Withlacoochee North, and Withlacoochee South. Residuals from catch curves were used as an index of year class strength and related to water levels/flows in each system. Species investigated included bluegill *Lepomis macrochirus*, largemouth bass *Micropterus salmoides*, redbreast sunfish *L. auritus*, and Suwannee bass *M. notius*.

Relations between flow and year class strength differed among fish species. For example, largemouth bass and Suwannee bass year class strength was negatively related to flow and stage in the Santa Fe River. Suwannee bass residuals combined from two systems indicated that year class strength was negatively correlated with annual and seasonal flow rates ($N = 8$, all $P \leq 0.10$), and models explained 38-51 percent of the variation. Conversely, redbreast sunfish year class strength was positively related to flow and stage in the Ochlockonee River. Redbreast sunfish residuals were positively correlated with flow rates in the Fall season prior to spawning in three lotic systems combined ($N = 12$, both $P \leq 0.10$), and models explained 25 and 31 percent of the variation in year class strength. Thus, high flow rates were generally beneficial for redbreast recruitment but were negatively related to black bass year class strength in rivers. Low water levels in these rivers may have improved nesting success or habitat characteristics such as aquatic macrophytes. High flows at least once every three years in the fall may allow inundation of floodplain habitat, producing favorable environmental conditions for *Lepomis* spp. reproduction. Low flows for three or more consecutive years should be prevented, and thus, MFLs should consider biological impacts to short-lived fishes.

"Where are the fish?"
An Angler Survey of the Lower Suwannee River

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This study quantitatively and qualitatively describes the sport fishery within a section of the lower Suwannee River, Florida, between the confluence of the Santa Fe River and the town of Fanning Springs (51.8 km). Data from angler surveys conducted in 1971, 1990, 1995, 1999-2004 is being used by the Florida Fish and Wildlife Conservation Commission (FWC) to broaden the understanding of trends associated with recreational fishing in this section of the river and to document the value of this resource. Since 1998, weekly river stage (mean sea level) information has been monitored, seeking to ascertain correlations between sport fishery descriptions and hydrologic regime. This multifaceted study is providing supporting data for future Minimum Flow and Level (MFL) recommendations. A roving, non-uniform, survey design based on a 12-week sample period covering the spring peak fishing season was used. Four randomly selected weekdays and one weekend day were surveyed during each 14-day period. Each sample day consisted of two six-hour periods (a.m. and p.m.), which were randomly selected by weighted probabilities based on actual fishing pressure. The data shows that the majority of the angling effort focuses on panfish species, with the redbreast sunfish (*Lepomis auritus*) being the dominant specie. Redbreast sunfish represent a five-year average of 81 percent of all harvested panfish, ranging from 70 percent to 93 percent. Other panfish species contributing to the total harvest include bluegill (*Lepomis macrochirus*), redear sunfish (*Lepomis microlophus*), spotted sunfish (*Lepomis punctatus*), and warmouth (*Lepomis gulosus*). Five-year average success rates for all panfish within the study area are 1.62 fish/hr. ranging from 1.24 fish/hr. to 2.12 fish/hour in 2003, which is considered exceptional. The 2004 survey shows a decrease in angling effort directed towards panfish; 565 hrs/km in comparison to 639 hrs/km in 2003. In addition, the 2003 survey documented the highest levels of effort, harvest, and success for panfish since survey inception, irrespective of drought conditions presiding since 1999. An identical survey was conducted concurrently (2003 and 2004), in the downstream area from Fanning Springs to East Pass (48 km). This area is considered a control zone for MFL related research because tidal influence keeps water levels from staying below bank-full even during extended low water periods, thus allowing for continued utilization of available edge and emergent vegetation by fish. The ratio of redbreast sunfish compared to spotted sunfish harvested within this section drops, indicating a gradual change within the freshwater fish community as the lower Suwannee River actually becomes the upper estuary. Total panfish success (fish/minute) within this section for 2004 was 23 percent greater than the up-stream survey zone.

Application of the Physical Habitat Simulation Model (PHABSIM) to the Santa Fe River

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The Physical Habitat Simulation Model (PHABSIM) produces an incremental analysis of a species' usable area per given river discharge. The success of this model however, has been limited to shallow (<2 m), high gradient, clear rivers, and primarily on cold-water fishes and invertebrates. Thus, the application to Florida river systems requires investigation. The objectives of this study are to (1) develop life-stage specific habitat suitability indices for the Suwannee bass *Micropterus notius* and the net-spinning caddisflies (Hydropsychidae), (2) model the relationships between hydrologic and habitat (macro and micro) variables in selected river segments, and (3) incorporate the species' suitability, hydrologic, and habitat models into the PHABSIM framework to predict the usable area of the Suwannee bass and net-spinning caddisflies under variable flows and levels. The goal of this study is to produce species-specific flows and levels recommendations for minimum flows and levels (MFL) determinations, and evaluate the use of this model for future MFL development.

INFORMATION MANAGEMENT, MODELING, NEW TOOLS

Suwannee River Partnership

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The Suwannee River Partnership was originally formed to reduce nitrogen loading from fertilizers, animal waste and human waste in the Middle Suwannee Watershed located in Suwannee and Lafayette Counties, Florida. Now its programs have expanded to other watersheds in north Florida. The Partnership, with a current membership of 50 organizations, emphasizes the use of voluntary, incentive based programs, including the implementation of agricultural Best Management Practices, to reduce nitrogen in groundwater, springs and rivers. In the Middle Suwannee 37 of 40 dairies and 136 of 140 poultry farms have conservation plans that meet Natural Resource Conservation Service requirements. The Partnership is also sponsoring research to evaluate the effectiveness of Best Management Practices. Outcomes from Partnership projects are evaluated through a Quality Assurance Program that determines if BMPs are being properly implemented and through a regional water quality monitoring program that will determine if reductions in nutrients are occurring.

Watershed Assessment Model (WAM) Evaluation of the Suwannee River Basin

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WAM was utilized to estimate the nitrogen, phosphorus, BOD, and TSS loads discharged from basins located within the Suwannee River Water Management District (SRWMD). A previous version of this model, called SR-WAM (Suwannee River Watershed Assessment Model), was developed in 1997, but was limited to average annual assessments and did not include stream routing. Though the original WAM-SR provided good general assessment information, it is not able to provide the reach specific information needed for completing TMDL assessments. Therefore, the objective of this project was to upgrade the existing WAM-SR model to a new version of WAM that includes daily stream routing and ground-water/spring flow subbasins. The simulation period was also extended through 2000 with the results comparing favorably with observed data collected throughout the District. This work was completed to assist FDEP staff in their TMDL work within the watershed by interactively simulating and assessing the environmental effects of various land-use changes and associated land-use practices.

A Suwannee River Basin Geodatabase Archetype

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Several federal and state agencies, including the Suwannee River Water Management District, USFWS, USGS, Florida Fish and Wildlife Conservation Commission and the Florida Department of Environmental Protection are involved with research and management of the Suwannee River Basin. In addition to these agencies, the Suwannee River Basin extends through 13 counties in Florida and 20 counties in Georgia, encompassing numerous metropolitan areas and local planning units. With the number of diverse agencies working on the river, we feel that there is a need to identify these groups and compile existing data into one comprehensive database, which will facilitate research and subsequent management decisions regarding the future of the basin. A basin-wide geodatabase for the Suwannee River can provide a unified and consistent system of geographic information management for both scientists and local stakeholders concerned about land use and water resources at the regional scale.

The geodatabase developed for the Greater Everglades Ecosystem project demonstrates the capability of a geodatabase to manage several types of geographic data in one database. A prototype geodatabase for the Suwannee River Basin is presented here, modeled on the Everglades geodatabase. Data used in these examples include thematic data, such as demographic information, and quantitative data, such as an elevation model, detailing the physical as well as social characteristics of the region.

Integrating Information for Watershed Management: A Suwannee River Basin Watershed Atlas

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The Suwannee River Basin covers 10,000 mi^2 in the states of Florida and Georgia. Threat of habitat alterations due to competing water needs among users has resulted in the formation of the Suwannee Basin Interagency Alliance (SBIA), a cooperative planning venture between the two states. The SBIA works with many state and local agencies, private businesses, and local land owners to promote the cooperative management of water and land resources in the basin. To assist in this effort, the U.S. Geological Survey (USGS) proposes to help the SBIA and the groups associated with it construct a watershed atlas—an online repository of maps, scientific data, and historical and cultural information about the Suwannee River Basin. The watershed atlas will provide scientific information for decision makers and at the same time serve to strengthen watershed identity.

In recent years, the watershed has become the focus of study among natural and social scientists as a holistic unit for integrating different community viewpoints and disciplinary knowledges in ecosystem and resource management. As an example, the National Watershed Forum of 2001 (http://www.epa.gov/owow/forum/finalrpt.pdf) brought together community leaders, government officials, environmental activists, and scientists to discuss cooperative action to sustain watersheds. A key recommendation of this forum was to foster the use of information technologies for better communication among citizen groups, state and local officials, and scientists. Increased access to scientific, social, cultural, and historical information about a watershed can potentially promote a cohesive watershed identity and lead to better stewardship.

In a quest for a sustainable future, many watershed groups have produced participatory watershed atlases that provide access to data and information for decision making. These atlases range in technical sophistication and scope of geographical coverage and content. Many are established by citizen groups and serve as clearinghouses for community voluntary activity and data gathering. Educational institutions and governmental organizations commonly help community groups assemble these atlases. Studies of a sampling of these atlases show that they enhance community awareness of the holistic nature of the watershed if there is sufficient community participation in the creation and ongoing maintenance of the atlas. The author's previous research on the use of the Internet for data sharing and watershed-data integration in the Pacific Northwest salmon crisis demonstrates the common dilemma of watershed management—community participation.

With its scientific background and data-management skills, the USGS is uniquely poised to provide support for the development of a participatory, interactive watershed atlas as part of its proposed Suwannee River Basin and Estuary Initiative. This atlas would build on ongoing work of such organizations as the SBIA, which is primarily driven by governmental agencies and the Upper Suwannee River Watershed Initiative, a citizen group. The atlas would strive for strong community involvement by including data and information from a wide range of stakeholders as well as scientific information organized into a geodatabase. The National Map of the USGS would supply the common base data. Such a watershed atlas would integrate knowledge about the entire watershed, helping to break down institutional and organizational boundaries, offering interpretive material for residents, and providing common information for decision makers.

Existing Geospatial Data Sets Covering the Suwannee River Basin

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A number of key geospatial data sets provide existing coverage for the Suwannee River Basin. Included are a variety of remote sensing data ranging from daily coarse resolution AVHRR and MODIS, to sixteen-day repeat moderate resolution Landsat, to infrequent high-resolution aerial photography. Elevation data is available from the National Elevation Database and from the Shuttle Radar Topography Mission. The National Land Cover Database contains land cover for 1992, and 2001 data will be available in the near future. Other data sets available include phenologic trends, fire potential index, NDVI biweekly greenness, urban areas, transportation routes, and political boundaries. Web sites for accessing these data are presented.

An Airborne High Resolution Thermal Infrared and Multi-Spectral Mapping System Trials over the Suwannee River Basin, Florida (2002)

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There is a requirement for monitoring the environment thermally, to locate natural springs and cold or warm water seeps. This is a difficult and time-consuming task by ground search methods only. By using a suite of sensors and technology on an economical aerial platform, great areas of land and wetlands is rapidly mapped. We have combined High Resolution Digital Thermal Imaging, and Digital Color IR Cameras to Map the wetlands and vegetation very accurately and rapidly, without the need of air photo ground control. This enables our custom software to generate accurate geo-tiff electronic GPS-moving-maps used to "navigate" directly to the suspect anomaly, to scientifically ground truth its dynamics. The methods used to collect and process the imagery data is done in a way that takes advantage of a custom alignment procedure of sensors to INS, (a highly accurate inertial navigation system gyro); Real-Time Differential GPS, and custom LINUX automated software processing routines. This method produces fully ortho-rectified imagery mosaics that are ready for insertion into any GIS or AM/FM system as a mosaic .geoTIFF imagery tile. The imagery is processed on-site for rapid delivery of electronic maps to hand held GPS devices and laptops with GPS to navigate to areas of interest.

The VeriMap system is an airborne, rapid delivery, Multi-Sensor, Digital Imaging System with specialized software called IMAPPS. This software processes the images rapidly into a seamless, rectified computer maps for use in any Geographic Information System; GIS. The electronic maps can be printed out to color plotter or printers in any size and resolution for use in planning and/or operations. The simplest way to describe our system is that collects, assembles and presents several imagery types, (different wavelengths) at precisely the same position/time, with the same field of view. The combined rectified imagery bands provide a more comprehensive "detailed picture" of artifacts on the ground, in different wavelengths.

The VeriMap system was developed to speed delivery time of traditional FILM ortho-photo mapping while maintaining image resolution. As well, it was developed to combine multiple sensors to increase economics of data collection while adding to the quality and amount of decisions that could be made with the data collected. The Ortho-photo is the process of correcting imagery with inherent distortions and orientation errors by rectifying known positions of accurate photo targets on the ground, shooting aerial film photography, correcting, triangulating and converting the film to a computer system later. These tasks are very time consuming and are labor intensive.

VeriMap PLUS has achieved that Survey Industry Milestone with our Solution without any ground control requirement today. The system was first flown in 1997 as a trial prototype. Today, we can collect and process imagery onboard the plane and email rectified imagery from the plane without landing to field technicians onsite with digital wireless hand held devices or laptops with wireless capabilities.

POSTERS

Stable Carbon and Nitrogen Isotope Composition of Organic Aggregates Produced by Salinity Induced Flocculation of Dissolved Organic Matter from the Suwannee River

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The Suwannee River, which originates in the Okefenokee Swamp in Georgia, is highly colored as a consequence of elevated concentrations of dissolved organic substances (predominantly humic and fulvic acids). These dissolved substances are derived largely from decaying terrestrial vegetation in the Okefenokee Swamp and are transported seaward towards the Gulf of Mexico where they are subject to further transformation by a suite of physical, chemical and biological processes. Salinity induced flocculation of dissolved organic matter likely occurs in the upper estuary and results in the formation of organic aggregates of a size suitable for filter- and suspension-feeding organisms such as clams and oysters. Flocculation of dissolved organic matter in several estuarine systems has been documented previously. Organic aggregates were produced in our laboratory by adding salts to fresh surface water collected from the Suwannee River. Based on these findings, experiments were performed to determine if the natural abundance of stable carbon and nitrogen isotopes might be used as markers to characterize organic aggregates and identify their potential role as a food source for fauna in the Suwannee River estuary.

Organic aggregates were produced by adding synthetic sea salts (Instant Ocean®) to unfiltered surface water collected from freshwater portions of the Suwannee River. The aggregates were analyzed for stable nitrogen and carbon isotope composition (^{15}N and ^{13}C, respectively) as well as elemental composition. As salinity was increased, the ^{15}N signature of the aggregates increased by approximately 4 to 6‰ in each of four experiments (two with source water from the upper Suwannee River and two with source water from the lower Suwannee River). In contrast, ^{13}C signatures of organic aggregates remained relatively uniform in any given experiment and maintained a signature typical of terrestrial derived organic matter, i.e., -26 to -29‰. The calculated C:N ratios ranged from 6 to 17, indicative of a relatively high quality food source. These findings indicate that the ^{15}N signatures might be used as a tracer of organic aggregate development as they are formed as a result of increasing salinity. More importantly, however, our results suggest that ^{13}C signatures of organic aggregates might be used to quantify their role as a food source for estuarine fauna.

Utilization of GIS Methodologies to Evaluate the Relationship Between Land Use and Aquatic Ecosystem Health

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We explored the relationship between land use and its effect on aquatic biota in the Suwannee Basin. As an initial pilot project, this approach looked at three sites on the Santa Fe River. Variables used in assessing the health and reproductive status of select species included body condition factors, glycogen content, total protein levels, sex, reproductive sex steroids and reproductive stage. The following species were evaluated based on their relative trophic level placement: freshwater mussels, Elliptio icterina and Villosa vibex (Mollusca: Bivalvia); Florida Apple snail, Pomacea paludosa (Mollusca: Gastropoda); Crayfish, Procambarus paeninsulanus (Arthropoda: Malacostraca); and largemouth bass, Micropterus salmoides (Chordata: Osteichthyes). We discuss the usefulness of this approach in evaluating the wide-variety of impacts this watershed is presently undergoing.

Florida's First Magnitude Springsheds

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At the May 2002, Workshop to Develop Blue Prints for the Management and Protection of Florida's Springs (Workshop) held in Ocala, panelist Hal Davis of the U.S. Geological Survey (USGS) stated that he felt a map of Florida's springsheds should be generated. A springshed was defined at this workshop as "those areas within ground-water and surface-water basins that contribute to the discharge of the spring." The Florida Geological Survey's (FGS) Hydrogeology Section decided to act on Mr. Davis's suggestion and took the lead in this effort. Working in conjunction with staff from the Northwest Florida, Suwannee River, St. Johns River and Southwest Florida Water Management Districts (all of which have first magnitude springs within their districts), and the USGS, the FGS has produced the "Florida's First Magnitude Springs" poster.

Quality, and possibly the quantity of water discharging from Florida's first magnitude springs are declining. The purpose of the poster is to inform citizens and decision makers (e.g., county commissioners, legislators, and local and state agency personnel) about the importance of appropriate land use within a springshed and to establish a baseline for the further refinement of the springshed boundaries. Land use within springsheds can have profound effects of the quality of the water and in some cases, the quantity of water recharging the aquifer(s) that ultimately discharge at the springs. An understanding of this is paramount to the protection and the restoration of the springs that are now impacted.

It should be noted that the springshed maps were developed with currently available information. Therefore, maps on the poster should only be used as a guide. As ongoing and future research provides additional information, more accurate springshed boundaries for these first magnitude springs can be developed. It is anticipated that maps for the individual first magnitude springsheds will be generated; however, the "Florida's First Magnitude Springs" poster probably will not be updated.

Seagrass Mapping within the Big Bend Region

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The poster will show and describe the methods currently being utilized for the mapping of seagrass habitat within the Big Bend region of Florida. Field methods, photogrammetric processes, photointerpretation, GIS and accuracy assessment methods will be presented on the poster.

Occurrence of Herbicide Degradation Compounds in Streams and Ground Water in Agricultural Areas of South Georgia, 2002

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Water samples were collected in 2002 from 2 streams and 28 wells located in agricultural areas in southern Georgia and analyzed for over 180 pesticides (including herbicides, insecticides, and their degradation compounds). The most frequently detected pesticides in stream samples were the herbicide degradation compounds metolachlor ethane sulfonic acid (ESA) (74 percent of samples), metolachlor oxanilic acid (OA) (61 percent), and alachlor ESA (61 percent). In contrast, the parent compounds, metolachlor and alachlor, were not detected in stream samples (at a reporting level of 0.05 micrograms per liter (µg/L)). Atrazine was detected in 45 percent of stream samples and the atrazine degradation compound, deethyldeisopropylatrazine, was detected in 13 percent of stream samples. In ground water, metolachlor ESA (67 percent of samples), alachlor ESA (48 percent), and metolachlor OA (33 percent) were the most frequently detected pesticides. In contrast, metolachlor was detected in only 7 percent of ground-water samples and alachlor was not detected in any ground-water samples. Concentrations of metolachlor did not exceed 0.13 µg/L in ground water; however, metolachlor ESA concentrations were as high as 19 µg/L and metolachlor OA concentrations were as high as 4.42 µg/L in ground water. The higher detection rates and higher concentrations of the metolachlor and alachlor degradation compounds relative to their parent compounds, highlight the importance of including herbicide degradation compounds in water-quality assessments to more fully evaluate the environmental fate of herbicides in hydrologic systems.

Pesticide Fate and Transport in Coastal Plain Watersheds

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The Southeast Watershed Research Laboratory is committed collecting data which can be used to more accurately assess pesticide fate and transport in agricultural watersheds in the southern portion of the Atlantic Coastal Plain. Peanuts and cotton are produced intensively in the region. The 334-km^2 Little River Watershed (LRW) which is located the upper most portion of the Suwannee River Basin is our principal experimental unit. We are intensively monitoring pesticide residue levels at the watershed outlet (beginning in 2003), developing pesticide use estimates, and assessing land cover. This is in addition to on-going precipitation and stream-flow monitoring spanning more than 35 years. The goal is to develop comprehensive data sets to calibrate watershed scale pesticide and fate models that reflect Coastal Plain conditions. Initial findings show that residue levels in surface water are extremely low (parts per trillion) even through estimated pesticide use rates exceed 1 kg $ha^{-1}yr^{-1}$ conventional active ingredient over the entire watershed. Results appear explainable in part by field and laboratory dissipation studies which show that widely used active ingredients degrade rapidly. In several studies we have shown that soil half-lives are 3 to 100 times faster than values reported in pesticide registration documents. The rapid rates of degradation rates likely result in relatively small amounts remaining available for runoff and discharge to surface waters.