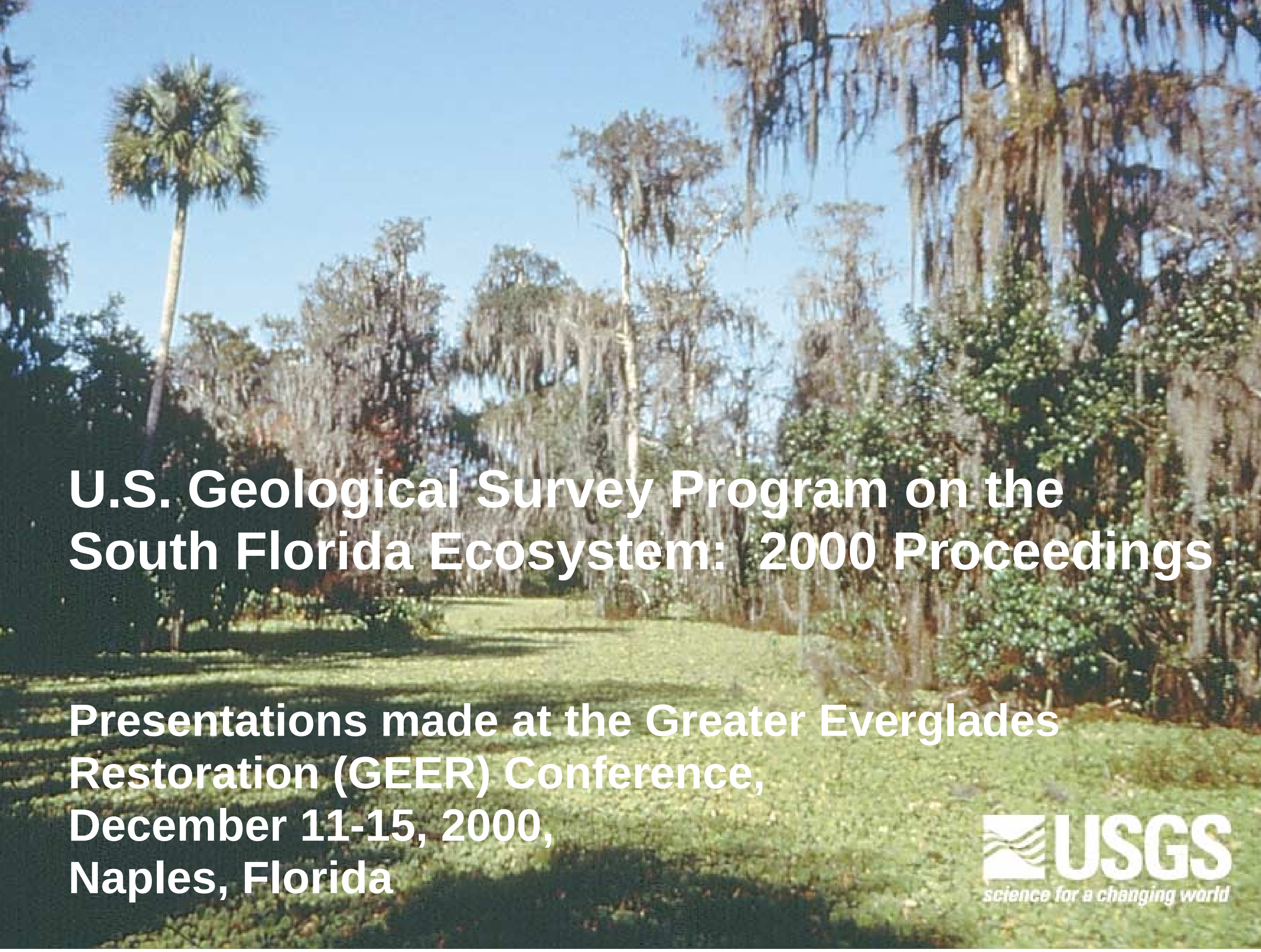

U.S. Geological Survey Program on the South Florida Ecosystem: 2000 Proceedings

Presentations made at the Greater Everglades Restoration (GEER) Conference, December 11-15, 2000, Naples, Florida

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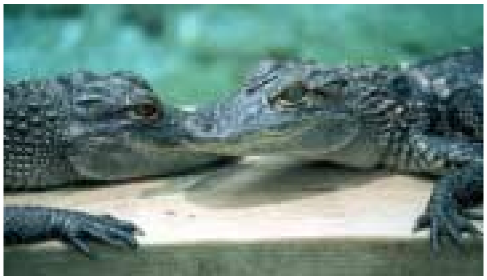

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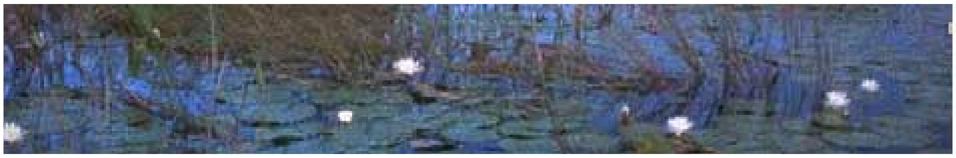

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U.S. Geological Survey Program on the South Florida Ecosystem: 2000 Proceedings

Presentations made at the Greater Everglades Ecosystem Restoration (GEER) Conference, December 11-15, 2000, Naples, Florida

Compiled by Jane R. Eggleston, Teresa L. Embry, Robert H. Mooney, Leslie Wedderburn, Carl R. Goodwin, Heather S. Henkel, Kathleen M.H. Pegram, and Tracy J. Enright

Under the direction of
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U.S. GEOLOGICAL SURVEY

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Tallahassee, Florida
2001

U.S. DEPARTMENT OF THE INTERIOR
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Greater Everglades Ecosystem Restoration (GEER) Conference

December 11-15, 2000
Naples, Florida

The Everglades ecosystem is an invaluable ecological and economic resource and is the subject of one of the most ambitious restoration efforts ever undertaken. the restoration goals stated by the South Florida Ecosytem Restoration Task Force are broad in context and short on specifics. In 1989, the Everglades Restoration Conference succeeded in synthesizing what was known concerning the ecology of the Everglades ecosystem and what was needed for restoration. In the intervening years there have been a number of advances in our understanding of the ecology and history of the Everglades.

The purpose of this conference is to provide a forum for physical, biological, and social scientists to share their knowledge and research results concerning Everglades restoration. The objectives are to define specific restoration goals, determine the best approaches to meet these goals, and provide bench-marks that can be used to measure the success of resto-ration efforts over time. The these ends, the conference will recognize the need to synthesize information gath-ered since the first Everglades conference, the interdisciplinary nature of Everglades restoration, and the need to adapt scientific understanding to management action.

This conference provided a forum for invited presentations by an outstanding array of experts as well as selected oral and poster pre-sentations of research conducted on various aspects of Everglades restoration. Plenary sessions included main themes addressed by invited speakers. Concurrent sesions included presentations grouped by topic. A panel discussion will summarize major findings during the final plenary session.

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U.S. Geological Survey Program on the South Florida Ecosystem: 2000 Proceedings

Presentations made at the Greater Everglades Ecosystem Restoration (GEER) Conference, December 11-15, 2000, Naples, Florida

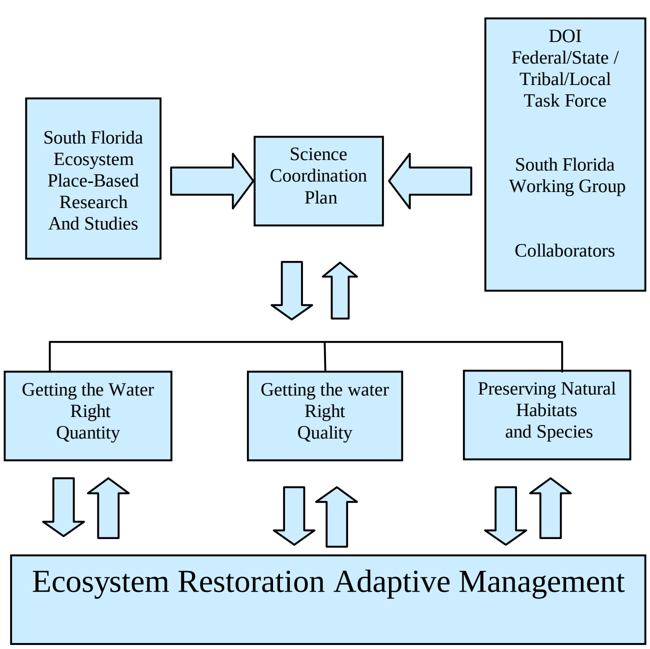
Introduction

The U.S. Geological Survey (USGS) conducts scientific investigations in south Florida to improve society's understanding of the environment and assist in the sustainable use, protection, and restoration of the Everglades and other ecosystems within the region. The investigations summarized in this document have been carried out under the South Florida Ecosystem Program, which is part of the USGS Place-Based Studies Program.

The USGS Placed-Based Studies Program is a nationwide program that concentrates on areas with severe environmental problems. Through interdisciplinary investigations the Program provides sound scientific information on which to base informed resource management decisions. Individuals from all the USGS programs (hydrology, geology, biology, mapping) work together with other scientists to cover the diverse scientific disciplines involved in this complex and challenging task. The South Florida Ecosystem Program began in 1995 as one of the initial Place-Based Studies programs and serves as a model for similar future collaborative studies. Placed-Based Studies are also being conducted in the San Francisco Bay area, Chesapeake Bay, the Platte River, Greater Yellowstone, Salton Sea, and the Mojave Desert.

The South Florida Ecosystem Program is part of a coordinated federal effort, under the South Florida Ecosystem Restoration Task Force. The Task Force was started in 1993, through interagency agreement, to coordinate the efforts of the agencies within six federal departments. In 1996, statutory authority formalized the Task Force and expanded it to include tribal, state, and local governments. The Task Force conducts its activities through the South Florida Ecosystem Working Group and teams, such as the Science Coordination Team. A Science Plan and Integrated Financial Plans are established to focus efforts and prevent duplicative efforts by the agencies.

Diagram of South Florida Ecosystem Place-Based Program Relationships



Organization and Content of the Document

This document presents the results of over 70 studies and 200 investigators that are active in the South Florida Ecosystem Program during the year 2000. The studies are categorized according to the major focuses of the South Florida Ecosystem Restoration Task Force.

- **Getting the Water Quality Right** – reducing or eliminating pollutants and other undesirable substances from the water.
- **Getting the Water Quantity Right** – establishing the volume, quantity, timing and distribution of surface and ground waters to approximate pre-development conditions.
- **Preserving Natural Habitats and Species** – providing the needs of the diverse flora and fauna of this ecologically unique area
- **Information Availability** – exchanging information regarding programs, projects, and activities to promote ecosystem restoration and maintenance - through South Florida Information Access (SOFIA)

This document also includes a bibliography of reports either published or in press, from the South Florida Ecosystem Place-Based Study Program.

South Florida Ecosystem Restoration

Restoring the Everglades is an enormous challenge, that involves returning essential functions to a large (over 11,000 square miles) and diverse ecosystem that has seen significant adverse impacts from man's activities over the past 50 years. America's Everglades is a National treasure which must be restored to ensure that south Florida's unique and irreplaceable natural environment is preserved, assure the quantity and quality of drinking water as well as agricultural and industrial water supplies, and in general improve the quality of life for all south Florida's inhabitants.

The Comprehensive Everglades Restoration Plan (CERP) was developed over a period of six years by the U.S. Army Corps of Engineers in partnership with the South Florida Water Management District and more than 30 tribes and federal, state and local agencies. It is the primary planning vehicle for achieving the goal of improving the quantity, quality, timing and distribution of water which will return health to this seriously degraded system. CERP proposes costs in excess of $7.8 billion and a time frame of about 30 years to complete this massive and unprecedented restoration effort.

Both the U.S. Government and the State of Florida have made initial funding commitments for Everglades restoration.

The complexity of this undertaking and the severity of the risks involved in an undertaking which includes some 68 interelated engineering projects mandates a science based approach to its implementation. The USGS, through its South Florida Ecosystem Place Based Program has committed to providing the highest level of scientific expertise to support decision-making and ensure a successful outcome.

USGS Role in South Florida Ecosystem Restoration

In keeping with the mission of the USGS to provide the Nation with reliable, impartial information to describe and understand the Earth, the USGS is involved in water-related, geologic, biologic, land use, and mapping studies that contribute to the safety, health, and well-being of Florida's citizens. The work conducted encompasses basic data collection, hydrologic investigations, and research. The USGS is capable of conducting multidisciplinary work because of the availability of expertise in geologic, biologic, mapping, and water resources investigations. Expertise is available nationally and can be called upon as needed for complex investigations, training of local personnel, and development of new approaches and technology to address the complex science issues involved in ecosystem restoration.

As the Department of the Interior's science agency with a multi-disciplinary, non-regulatory, and non-advocacy focus as well as an established, long-term presence in south Florida, the USGS is well positioned to pursue activities such as data collection from surface- and ground-water monitoring networks, cooperative studies with local and State agencies, and research through extensive national programs such as Place-Based Studies and National Water Quality Assessment (NAWQA) programs. In addition, about one half of the area to be restored is public land administered by the National Park Service (NPS), Fish and Wildlife Service (FWS), state agencies, and the South Florida Water Management District.
The U.S. Geological Survey science leadership in CERP and other ecosystem restoration efforts in south Florida is closely linked to its mission goal "to provide science for a changing world in response to present and anticipated needs; to expand our understanding of environmental and natural resource issues on regional, national, and global scales; and to enhance predictive/forecast modeling capabilities." The multidisciplinary approach applied by the USGS is necessary to provide a process level as well as holistic evaluation of the system responses to proposed changes.

Historically, the USGS in Florida has operated basic data collection networks and conducted investigations that provide the foundation for the wise stewardship of water and biological resources of the State. The hydrogeologic framework has been described in many reports, aquifer characteristics have been determined through geophysical logging and pumping tests, and ecological conditions have been monitored. The data that have been collected for the advancement of general knowledge of our natural resources provide the foundation for the understanding of the fate of contaminants in the environment. The data also have been used in the development of hydrologic and ecological models for predicting the effects of additional stresses on the natural resources and provide the tools for evaluation of effects of land use changes and potential contaminant releases in the environment. Real-time data networks, which include the application of satellite or cellular telephone technology to existing data-collection sites across the State, are providing needed information for advanced warning of floods and droughts.

Building Scientific Knowledge

Develop new information – Identify the pertinent issues, formulate critical scientific questions related to the issues, and address the questions through appropriate modeling, monitoring and empirical studies.

Communicate – Promote improved communication among restoration scientists and managers through scientific conferences, workshops and the mutual exchange of information.

Synthesize Scientific Knowledge Relevant to the Issues – Develop techniques for integrating and synthesizing restoration data and distribute the techniques to others involved in restoration efforts.

Manage Integrated Data – Archive inventories and other available databases in multigovernmental database management systems that are accessible through the internet and updated regularly.

Key Program Results which Contribute to Management Solutions

Several program outputs have directly contributed to management of natural resources in south Florida as follows:

- Detailed topographic information has been incorporated into computer simulation models to analyze alternatives on which the restoration plan has been based.
- Model results from the Across Trophic Level System Simulation (ATLSS) model have been used in resolving issues relating to preservation of the endangered Cape Sable Seaside Sparrow habitat.
- Geophysical studies have been used to determine the groundwater contributions to estuarine areas such as Florida Bay, and have shown that groundwater contribution to the Bay is negligible.
- Isotopic investigations have shown that some of the phosphorus that contributes to the degradation of the Everglades originates from fertilizers, indicating a possible source from the upstream Everglades Agricultural Area.
- Mercury process studies have shown that sulphur plays a major role in mercury methylation, suggesting that reduction in sulphur inputs could be an important strategy in reducing the impacts of methyl mercury on Everglades fauna.
- Improved understanding of mercury processes in the Everglades has assisted in deciding on possible impacts from nutrient removal through stormwater management systems.
- The program has shed light on the effects of nutrient enrichment, effects of altered hydrologic regimes, and suitability of physical properties of rocks and soils for restoration.
- An in-depth understanding of the history of the south Florida ecosystem has helped to shape restoration goals by enhancing appreciation of predevelopment environments and their causes.
- Predictive capability through a suite of hydrological and ecological models has been used to anticipate where water will flow under various scenarios. This will help to establish salinity yardsticks, ensure that urban and agricultural areas have sufficient water and that bird populations and natural ecological dynamics are restored in Florida Bay. The models also serve as tools for the integration of the considerable volume of information collected by numerous restoration-related studies.
- Groundwater-surface water interaction studies in the Everglades have lead to a better understanding of the factors that control these interactions, the current level of interactions and the likely effect of restoration efforts in increasing or decreasing these interactions. This information will help determine the likelihood that pollutants will be cycled through the aquifers and returned by discharge from the aquifer to the surface water system.

KEEPING ON COURSE – MODELS, MONITORING AND PERFORMANCE INDICATORS

Visions and goals are inherently conceptual. Results are concrete. Translating one into the other, especially on the scale required by south Florida ecosystem, is challenging. The restoration project is using models, monitoring, restoration, and performance indicators to translate conceptual ideas to the real world, adapt projects to changing conditions, and provide accountability.

Models – Restoration workers employ a series of computerized models to predict the responses of key variable to changing environmental, social, or economic conditions. Developing simulations that forecast responses to different scenarios permits researchers to identify management alternatives as well as target conditions that will yield desired goals. Computerized models also can be updated as new information is gained, allowing predictions to be continually refined.

Monitoring – An adaptive management strategy demands continual feedback. Developing and implementing monitoring programs are a major emphasis for many restoration projects. Some monitoring tracks variables subject to rapid change. Other monitoring programs record long term trends. Monitoring data are essential in assessing the effectiveness of restoration actions, tracking progress, and identifying problems or the need for project modification.

Performance Indicators – The restoration project also uses quantitative indicators (levels of phosphorus in runoff) and qualitative indicators (quality of life) to track and assess projects. Comparing actual conditions against predicted targets provides a yardstick for measuring the progress (were are we now, how much farther to go?) and for evaluating the results (what are the benefits/are they worth the costs).

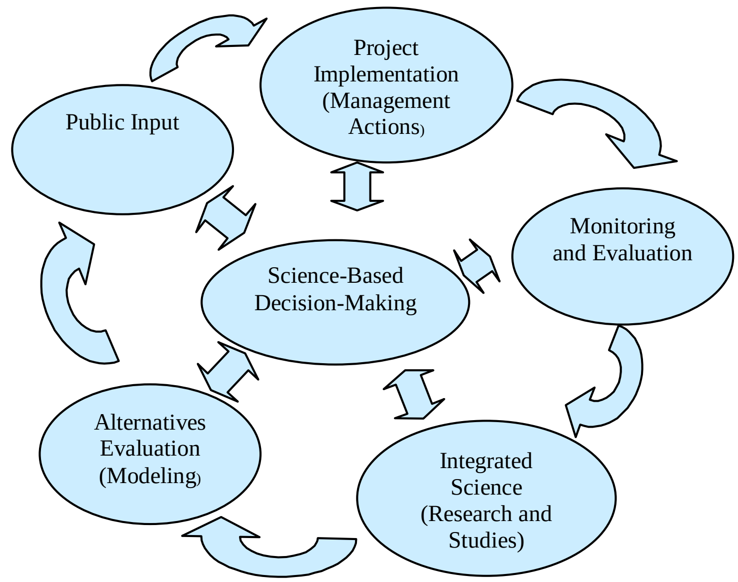
Models, monitoring, and performance indicators provide direction, feedback, and accountability for both short and long-term actions. This affords flexible, timely, and responsible management of projects and project funds.

Future Directions

Over the past five years from the inception of the USGS Place-Based Program, the focus has mainly been on program planning, data collection, process studies, and development of modeling tools. Several projects have now completed or are nearing completion of this phase and have entered into the phase of data analysis, credibility assurance (quality assurance) initial reporting, final publication of results and evaluations. An important aspect of the work will be analyzing and integrating the information to provide a synthesis of the information to maximize information content and provide management recommendations.

Full utilization of the information from these studies depends on the extent to which the information can be made available to resource managers and decision-makers in a timely manner. For this reason future efforts will include ensuring information dissemination through such means as journal publications, data reports, reports to cooperators, presentations at scientific meetings, seminars and workshops and use of the Internet. The South Florida Information Access (SOFIA) web site will be the main Internet portal for data and reports from this program.

Adaptive Management



As implementation of restoration plans proceed, a process of Adaptive Management will be used to ensure that there is flexibility to make adjustments where necessary. It will be necessary to reevaluate assumptions, measure success, and monitor the effects of restoration actions. The USGS Place-Based Program will be well placed to contribute to these efforts due to the wealth of experience gained in the initial phases of restoration. Areas of particular interest will be evaluating the regional impacts of Aquifer Storage and Recovery technology to reduce the risk of long-term detrimental effects and evaluating the effects of changed hydrologic regimes brought about by restoration on the ecology of the area. Additionally, areas such as Lake Okeechobee and the Kissimmee Basin that have not been the main focus of the program so far will be given added attention.

Collaborators:

- Bureau of Indian Affairs
- Florida Department of Environmental Protection
- Florida Geological Survey
- Florida Institute of Oceanography
- Miccosukee Tribe of Indians of Florida
- National Marine Fisheries
- National Marine Sanctuary
- National Park Service
- National Resource Conservation Service
- Office of the Governor
- Seminole Tribe of Florida
- South Florida Water Management District
- U.S. Army Corps of Engineers
- U.S. Environmental Protection Agency
- U.S. Department of Justice
- U.S. Department of Transportation
- U.S. Fish and Wildlife Service

Section I

Get the Water Quantity Right

Contents

Section I: Get the Water Quantity Right

Regional Simulation of Inundation Patterns in the South Florida Everglades

By Maria H. Ball and Raymond W. Schaffranek
U.S. Geological Survey, Reston, Virginia

The ability to quantify changes in water-surface elevations and hence water depths in the southern Everglades, throughout space and time, is fundamental to evaluating both the historical and current hydrologic behavior of the ecosystem and the success of restoration efforts. The low topographic relief yields very small water-surface gradients that produce large fluctuations in the spatial extent of inundation making the ecosystem highly sensitive to regulatory controls. A time series of daily water depths has been generated for the region of the southern Everglades encompassing the Taylor Slough and C-111 wetlands to analyze changes in seasonal inundation patterns and hydroperiods and to evaluate and correlate the response of wetland water levels to local precipitation and regulated structure flows. The time series can be used to validate the performance of flow models guiding restoration efforts and to investigate how wetland sheet flows have been affected by anthropogenic influences.

A land-surface elevation grid was interpolated from topographic data collected by the U.S. Geological Survey (USGS), National Mapping Division, using differential global positioning system technology. Water-level data, from 1995 to present, obtained from the South Florida Water Management District (SFWMD), the National Park Service (NPS) Everglades National Park, and from within the USGS are used to interpolate daily water-surface elevation grids. The water-surface elevations are then subtracted from the topographic surface to produce daily grids of computed water depths. Structure releases and precipitation data were obtained from the NPS, SFWMD, and USGS to aid in the analyses.

Water-depth accuracy is directly correlated to the spatial distribution of hydrologic monitoring stations and to the spatial resolution and accuracy of the topographic data. The spatial resolution of the topographic data is 400 meters and the stated vertical accuracy is 15 cm; however, tests against elevation values published by the National Geodetic Survey for 17 benchmark monuments resulted in an Root Mean Square Error of 4.1 cm. To estimate water-depth accuracy, computed depths were subtracted from depths measured in the wetlands adjacent to the C-111 canal and in Taylor Slough in 1997 and 1999. The standard deviation of the differences between measured and computed water depths was found to be 12 cm.

The simulated time series of regional inundation patterns is used to compare historical and current water depths and hydroperiods in order to isolate temporal changes, particularly as these may have been affected by anthropogenic influences such as the management of control structure releases and the re-engineering of canals. Further analysis is focused on quantifying the response of water-depth to precipitation and control structure releases, as illustrated in figure 1. Several time series and sample water-depth maps are available at the Tides and Inflows in the Mangroves of the Everglades (TIME) website (http://time.er.usgs.gov).

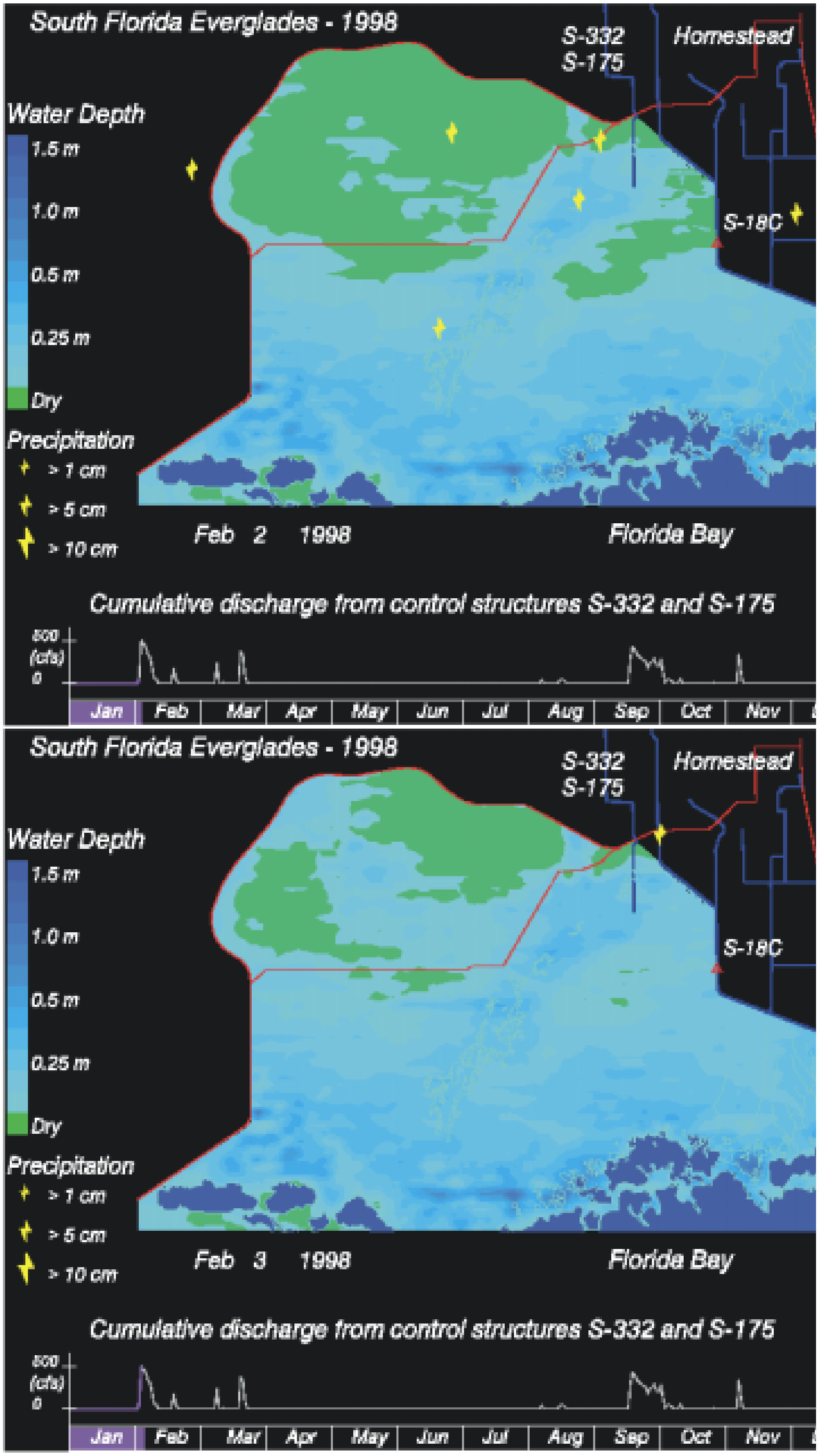


Figure 1. Computed water depths for February 2-3, 1998.

Effect of Water Management in the Everglades Nutrient Removal Area (ENR) on Hydrologic Interactions with Ground Water

By Jungyill Choi and Judson W. Harvey
U.S. Geological Survey, Reston, Virginia

Successful management of constructed wetlands for water treatment in the Everglades requires a better understanding of the interactions between surface water and ground water. These interactions affect the water budget of constructed wetlands as well as the transport and fate of environmental contaminants. In order to identify and quantify the key relations, surface-water and ground-water interactions were investigated in the Everglades Nutrient Removal project, a 1,544-hectare constructed wetland that was built as a prototype to evaluate the effectiveness of constructed wetlands in removing nutrients from agricultural drainage (fig. 1). Ground-water recharge (from the ENR to the underlying aquifer) and discharge (from the aquifer to ENR) were determined by using a combined water and solute mass-balance approach (Choi and Harvey, 2000). Over a 4-year period (1994-98), ground-water recharge averaged 0.9 cm/day, which is approximately 31 percent of the surface water pumped into the ENR for treatment (fig. 2). In contrast, ground-water discharge was much smaller (0.09 cm/day or 2.8 percent of water input to ENR for treatment) (fig. 2). Using a water-balance approach alone only allowed net ground-water exchange (discharge-recharge) to be estimated (-0.78 ± 0.16 cm/day). Discharge and recharge were individually determined by combining a chloride mass balance with the water balance.

For a variety of reasons, the ground-water discharge estimated by the combined mass balance approach was not reliable (0.09 ± 2.4 cm/day). As a result, ground-water interactions could only be reliably estimated by comparing the mass-balance results with other independent approaches, including direct seepage-meter measurements (Harvey and others, 2000) and previous estimates using ground-water modeling (Hutcheon Engineers, 1996; Guardo and Prymas, 1998). All three independent approaches provided similar estimates of average ground-water recharge, ranging from 0.84 to 0.9 cm/day (table 1). There was also relatively good agreement between ground-water discharge estimates for the mass balance and seepage meter methods, 0.09 and 0.06 cm/day, respectively. However, ground-water-flow modeling provided an average discharge estimate that was approximately a factor of four higher (0.35 cm/day) than the other two methods (table 1).

Table 1. Comparison of ground-water fluxes estimated from coupled water-solute mass balance approach, seepage-meter measurements, and ground-water-flow modeling

[Units are in centimeters per day; numbers in parenthesis indicate percent of inflow pump rate]

	Mass balance approach	Seepage-meter measurement	Ground-water-flow model
Ground-water discharge (G_i)	0.09 (3)	0.06 (2)	[2]0.35 (13)
Ground-water recharge (G_o)	[1]0.88 (31)	0.84 (30)	[3]0.90 (32)
Net ground-water flux (G_i–G_o)	-0.78	[1]-0.78	[1]-0.55

[1]Estimated by difference between other two estimates in each column.
[2]Estimated using results from Guardo and Prymas (1998).
[3]Estimated using results from Hutcheon Engineers (1996).

To determine the control that managers have over the extent of ground-water recharge, our estimate of ground-water recharge was compared with the rate of surface-water inflow to the ENR by pumping from the supply canal. Recharge was positively correlated with the pumping rate of surface water from the supply canal into ENR (fig. 3-a). This demonstrates that the relatively high surface-water inputs to this constructed wetland have the unintended effect of increasing recharge of surface water. A considerable part of the recharged ground water (73 percent)

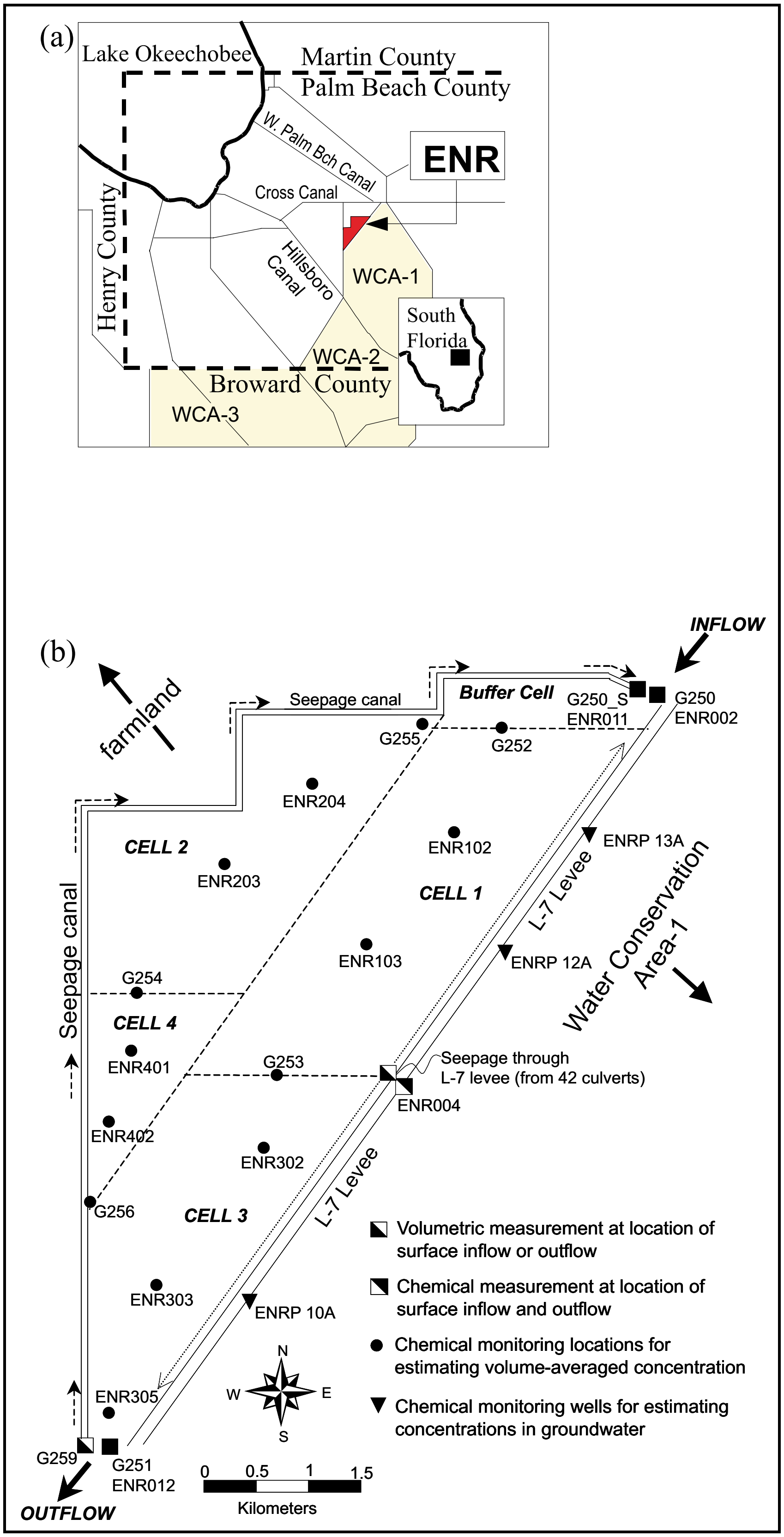


Figure 1. (1) Palm Beach and vicinity showing location of ENR relaive to Everglades Agricultural Area (EAA) and Water Conservation Area (WCA's); and (b) location map illustration hydrological and chemical monitoring sites in Everglades Nutrient Removal (ENR) project.

was collected and returned to the ENR by a seepage collection canal. Additional recharge that was not captured by the seepage canal only occurred when pumped inflow rates to ENR (and ENR water levels) were relatively high (fig. 3-b).

To determine the control that managers have over the extent of ground-water recharge, our estimate of ground-water recharge was compared with the rate of surface-water inflow to the ENR by pumping from the supply canal. Recharge was positively correlated with the pumping rate of surface water from the supply canal into ENR (fig. 3-a). This demonstrates that the relatively high surface-water inputs to this constructed wetland have the unintended effect of increasing recharge of surface water. A considerable part of the recharged ground water (73 percent) was collected and returned to the ENR by a seepage collection canal. Additional recharge that was not captured by the seepage canal only occurred when pumped inflow rates to ENR (and ENR water levels) were relatively high (fig. 3-b).

In conclusion, we have shown how management of surface water in the northern Everglades increases interactions with ground water. The increased ground-water recharge causes environmental contaminants in surface water to migrate to ground water and, possibly, discharged back to surface water outside of the treatment wetland. Consequently, a detailed understanding of wetland and ground-water interactions will be necessary to improve the operational efficiency of these treatment wetlands.

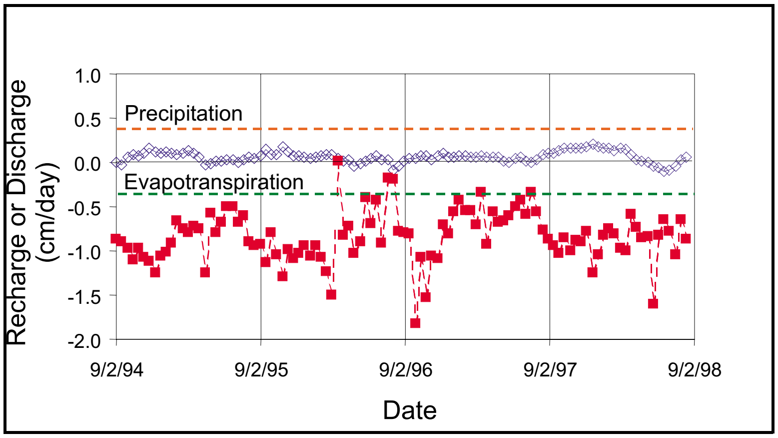


Figure 2. Comparison of estimated ground-water recharge with (a) inflow rate of surface water from supply canal into ENR (G-250); and (b) returned flow from seepage canal (G-250_S) and water level in ENR (ENR202d).

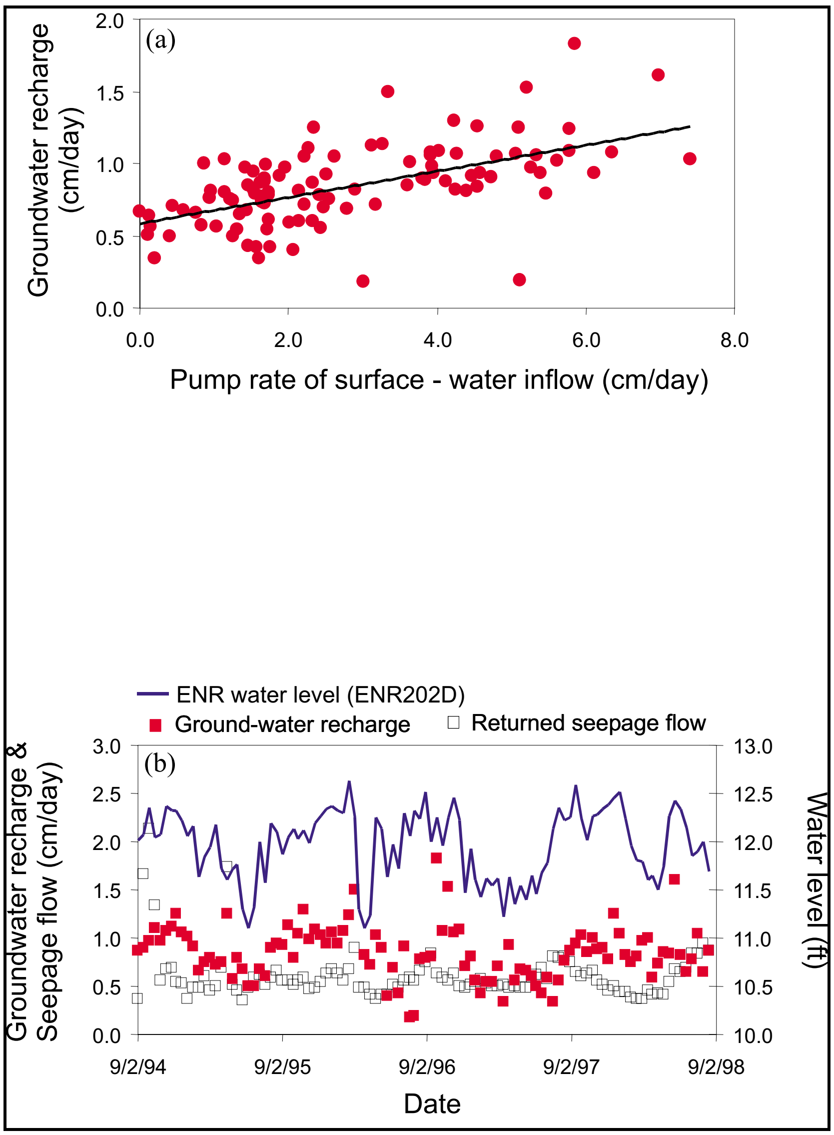


Figure 3. Comparison of estimated ground-water recharge with (a) inflow rate of surface wqter from supply canal into ENR (G-250) and (b) returned flow from seepage canal (G-250_S) and water level in ENR (ENR202D).

Topography of the Florida Everglades

By Gregory B. Desmond[1], Edward Cyran[1], Vince Caruso[1], Gordon Shupe[1], and Robert Glover[1], and Charles Henkle[2]

[1]U.S. Geological Survey, Reston, Virginia; [2]Orkand Corporation, Reston, Virginia

One of the major issues facing ecosystem restoration and management in South Florida is the availability and distribution of clean, fresh water. The South Florida ecosystem encompasses an area of approximately 28,000 square kilometers and supports a human population that exceeds 5 million and continues to grow. The natural systems of the Kissimmee-Okeechobee-Everglades watershed compete for water resources primarily with the tourism and agricultural industries and with urbanization. Therefore, surface-water flow modeling studies, as well as ecological modeling studies, are an important means of providing scientific information needed for ecosystem restoration and modeling. Hydrologic and ecological models provide much needed predictive capabilities for evaluating management options for parks and refuges, planning land acquisition, and understanding the impacts of land management practices in surrounding areas. These models require a variety of input data, however, including elevation data that define the topography of the Florida Everglades.

Sheet flow and water surface levels in South Florida are very sensitive to any changes in topography because of the region's expansive and extremely flat terrain. Therefore, hydrologic models require very accurate elevation data for input to simulate and predict water flow direction, depth, velocity, and hydroperiod. Water resources, ecosystem restoration, and other land management decisions will rely in part on the results of these models, so it is imperative to use the most accurate elevation data available to achieve meaningful simulation results. Therefore, elevation data points are being collected every 400 meters in a grid pattern to meet the requirements of hydrologic models of various cell resolutions. The vertical accuracy specification for these elevation data is 15 centimeters (6 inches), and they are referenced to the North American Vertical Datum of 1988 (NAVD88).

Because traditional methods for collecting these data for the Everglades are impractical or too costly, the U.S. Geological Survey (USGS) did a feasibility study in late 1994 and early 1995 to determine if state-of-the-art techniques using the Global Positioning System (GPS) could be used to meet the strict vertical accuracy specifications of the elevation data. The feasibility study successfully demonstrated that differential GPS techniques, using airboats to navigate transects, could meet the data accuracy requirement. The land surface being surveyed in the Everglades is typically under water and obscured by vegetation, which precludes the use of other methods for collecting elevation data, such as photogrammetry and alternative remote sensing technologies. Therefore, topographic surveys over such a large area of the Everglades with such a stringent accuracy specification can only be efficiently accomplished by using GPS. This is especially the case in an inaccessible wilderness environment.

Because the Everglades is so expansive and remote, and includes environmentally sensitive areas, impenetrable vegetation, or other areas unapproachable by airboat, access to many places is possible only by helicopter. To solve this accessibility problem the USGS developed a helicopter-based instrument, known as the Airborne Height Finder (AHF), which is able to measure the terrain surface elevation in a noninvasive, nondestructive manner. Accuracy tests have shown that the AHF system can consistently measure elevation points to within 3 to 5 cm. An accuracy test in May 2000 measured 17 National Geodetic Survey (NGS) benchmarks twice with the AHF. The average difference between the AHF measured elevations and the NGS published data sheet values was 3.3 cm. The largest difference was 8.6 cm, and the smallest difference was 0.2 cm. These accuracy test results provide confidence that the elevation dataset being produced meets the 15 cm vertical accuracy specification.

To date, thousands of elevation data points covering significant parts of the Florida Everglades have been collected and processed using differential GPS methods, from both airboats and helicopters. These data are organized by USGS 7.5-minute quadrangles and are available from the South Florida Information Access Web Site at http://sofia.usgs.gov. Data collection will continue, with emphasis on providing coverage of the Tides and Inflows in the Mangroves of the Everglades (TIME) Model Domain (http://keylime.er.usgs.gov/) and on completing coverage of Water Conservation Area 3.

Summary of Ground-Water Related Geophysical Investigations in Everglades National Park

By David V. Fitterman and Maria Deszcz-Pan

U.S. Geological Survey, Denver, Colorado

Over the past six years a series of geophysical investigations have been carried out to obtain information needed to construct ground-water models of the southern portions of Everglades National Park and adjacent areas (fig. 1). Because of the inaccessible nature of the region and the extreme difficulty of drilling except on established roads, geophysical measurements from the air, and on the ground, are the only way of obtaining information on geologic and hydrologic boundaries needed for model development. Hydrologic models are a very important tool for resource management and ecosystem restoration planning. Inadequate or insufficient data with which to construct these models reduces their reliability. Geophysical data have provided information on three factors critical to ground-water model construction: (1) the extent of saltwater intrusion in the surficial aquifer; (2) the depth to the base of the Biscayne aquifer; and (3) evidence refuting the existence of fresh ground-water flows to Florida Bay.

Helicopter electromagnetic (HEM) surveys and transient electromagnetic (TEM) soundings have been used to estimate formation resistivity throughout the study area. Formation resistivity is influenced by the resistivity of pore water in the formation and the formation porosity. If the formation porosity and geology vary gradually, then the

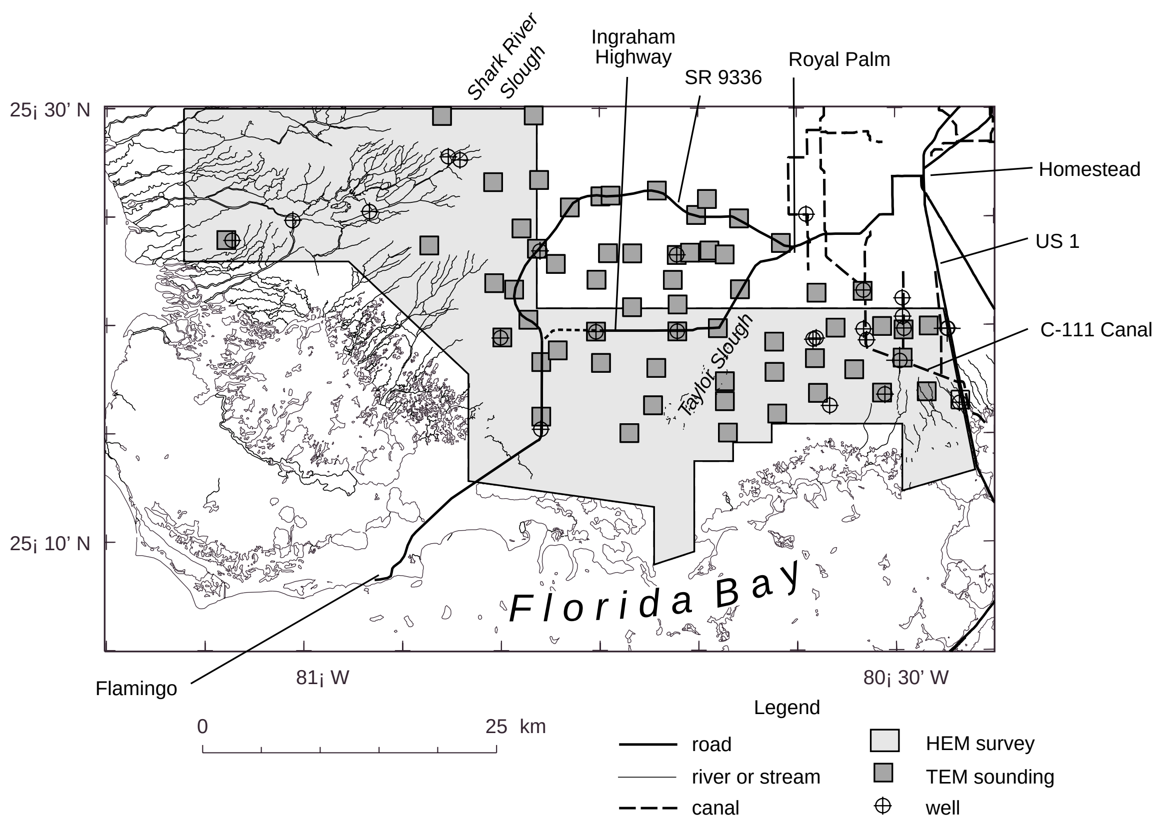


Figure 1. Location showing the HEM survey, TEM soundings, and observations wells in and near Everglades National Park used in this study.

formation resistivity is a direct measure of pore-water quality. Borehole measurements of formation resistivity and pore-water specific conductance (SC) are used to establish a relationship between these parameters, allowing SC to be estimated from the formation resistivity derived from the HEM and TEM data. Finally, an empirical relationship between SC and salinity, which has been established for the region, is used to estimate aquifer salinity. The result is a three-dimensional estimate of water quality.

The HEM surveys provide closely spaced samples (10 m along flight line with 400 m flight line spacing). The HEM data are interpreted as layered earth models at each measurement point and displayed as formation-resistivity maps at selected depths. The TEM soundings provide greater depth of exploration and better model resolution than the HEM data, however, the sampling interval is much coarser (one sounding per 25 km^2). The TEM data are also interpreted as layered earth models. Comparison of the results of these methods show good agreement.

The HEM data show a clear transition from freshwater to saltwater saturated regimes, which occurs from 8 to 20 km inland from the coast (fig. 2). The presence of tidal rivers, as found to the west of Taylor Slough, results in a jagged transition boundary whose landward extent corresponds to the terminus of the rivers. In Taylor Slough and eastward across the region draining toward Florida Bay and Barnes Sound, the interface is smooth because of the absence of tidal drainages into the area. The lack of significant drainages to the east of Taylor Slough is due to the bedrock ridge that parallels the coast and forms a barrier to large stream formation. Other features visible in the HEM data include: (1) a deep resistive zone in the middle of Taylor Slough where freshwater flow recharges the underlying aquifer: (2) variations in resistivity near raised roadways reflecting their influence on surface-water flow and aquifer recharge; (3) freshwater zones associated with infiltration from canals due to control structures and flow through cuts in the canals; and (4) historic saline water transport along a canal, formerly open to Florida Bay, adjacent to old Ingraham Highway.

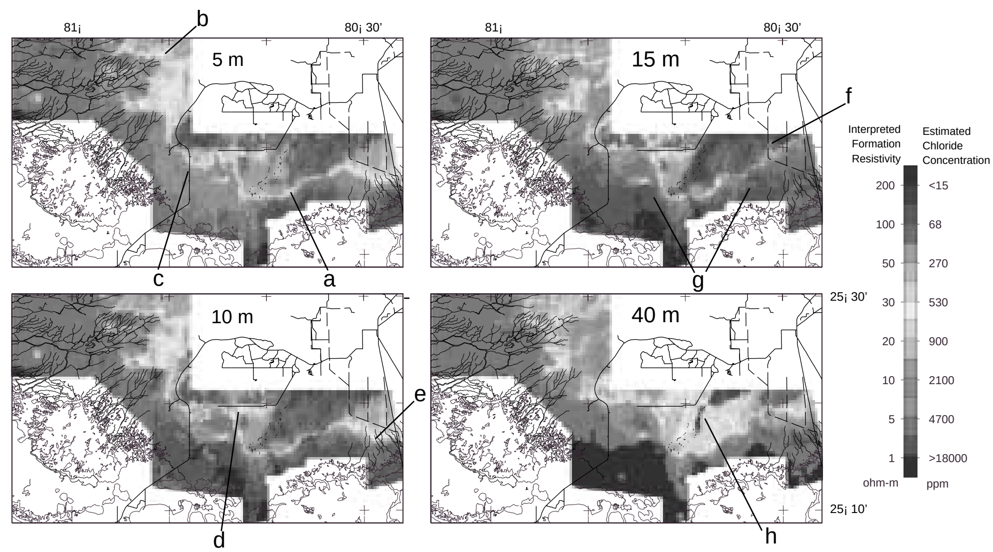


Figure 2. Interpreted HEM resistivity-depth-slice maps from Everglades National Park for depths of 5 m, 10 m, 15 m, and 40 m. The color bar gives estimated chloride concentration in the aquifer based on geophysical data. The annotated features are: (a) abrupt freshwater-saltwater interface (FWSWI) in Taylor Slough, (b) FWSWI controlled by tidal river flow, (c) change in salinity where roadway blocks surface-water flow, (d) remnant of seawater intrusion along Ingraham Highway canal, (e) effect of freshwater recharge from C-111 canal, (f) cuspin FWSWI due to water impoundment behind control structure S18C, (g) absence of freshwater flows to Florida Bay, (h) deep, high resistivity zone associated with Taylor Slough.

The TEM soundings also locate the transition from freshwater to saltwater saturated zones. TEM interpreted formation resistivities fall into two groups: (1) a freshwater saturated zone with resistivities in the range of 18-300 ohm-m, and (2) a saltwater saturated zone with resistivities of 2-7 ohm-m. On this basis the location of the fresh-water/saltwater interface is mapped (fig. 3). The result agrees well with the HEM results, but lacks the spatial detail of the HEM data because of the much coarser sampling interval.

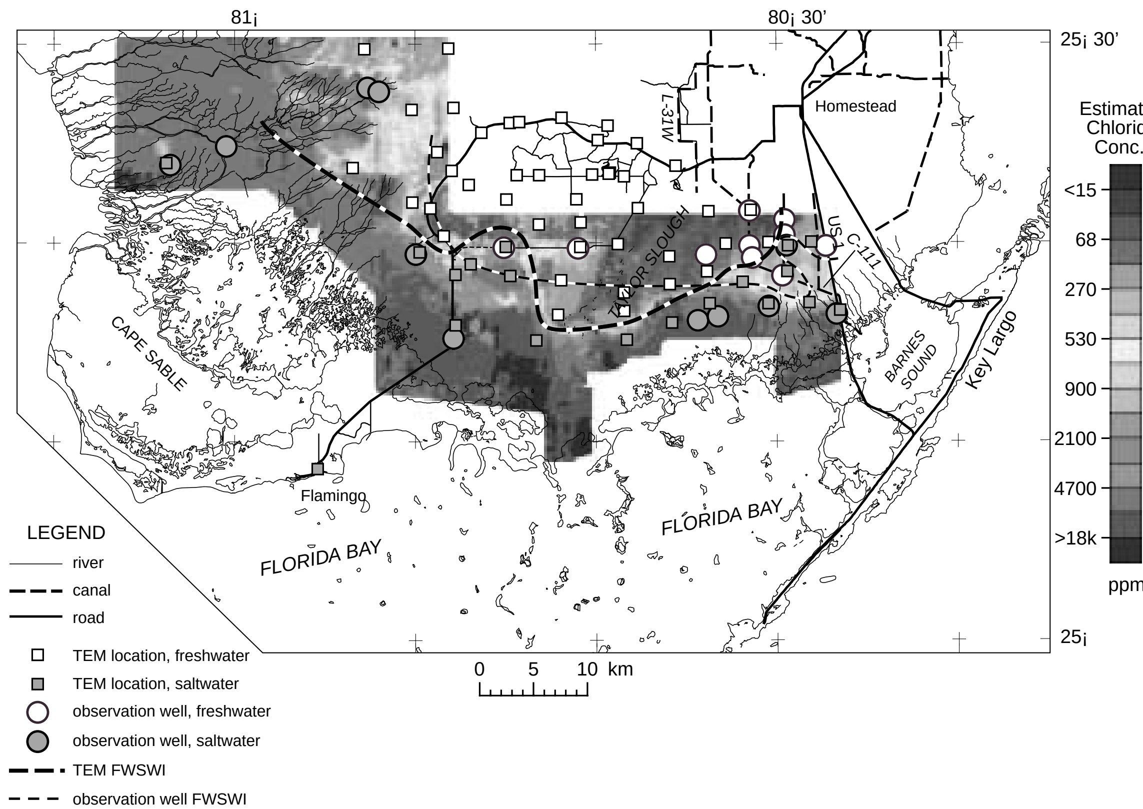


Figure 3. Location of the FWSWI in Everglades National Park based on well, TEM, and HEM data. The HEM data is from the 10-m depth slice. The color bar shows the estimated chloride concentration.

The geophysical data also provide some insight on the issue of whether fresh ground-water is flowing to Florida Bay. If flows are present, we would expect to see a high resistivity zone leading to Florida Bay. Five to ten kilometers landward of Florida Bay the HEM resistivity depth-slice maps show a uniformly low resistivity (1-2 ohm-m) zone from the surface down to a depth of at least 24 m. The base of the Biscayne aquifer, as mapped by drilling, is less than 24 m deep at locations where geophysical data are available. The low observed resistivities are indicative of saltwater saturation of the Biscayne aquifer. Similarly, the TEM results do not show the presence of a high resistivity zone in the Biscayne. While the geophysical models do not indicate the presence of a freshwater zone, thin resistive zones (1-2 m thick), that are not detectable and do not degrade the fit of the model to the data, could be embedded in the models. The likelihood of such zones existing over extended distances and being isolated hydrologically from the surrounding salt-water intruded aquifer is not considered to be of significance. Therefore, we conclude that there is no evidence of fresh, groundwater flowing to Florida Bay from the surficial aquifer.

The results of this project are of immediate value to managers who are responsible for restoration decisions because they provide information about the impact of natural and human activities on saltwater intrusion and the hydrologic regime. This work also provides a baseline for long-term monitoring of changes in the ground-water regime. Future geophysical surveys can be used to look for changes in subsurface conditions associated with planned modification of water deliveries to Everglades National Park.

Regional Evaluation of Evapotranspiration in the Everglades

By Edward R. German
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Nine sites in the Florida Everglades were selected and instrumented for collection of data necessary for evapotranspiration (ET) determination using the Bowen-ratio energy-budget method. The sites were selected to represent sawgrass or cattail marshes, wet prairie, and open-water areas that comprise most of the natural Everglades system. The study area and site locations are shown in figure 1. Site characteristics are given in the following table.

Site number	Community	Latitude-Longitude	Comments
1	Cattails	263910 0802432	Never dry
2	Open water	263740 0802612	Never dry
3	Open water	263120 0802013	Never dry
4	Dense sawgrass	261900 0802307	Dry part of most years
5	Medium sawgrass	261541 0804356	Dry part of some years
6	Medium sawgrass	254450 0803007	Never dry
7	Sparse sawgrass	253655 0804211	Never dry
8	Sparse rushes	252112 0803807	Dry part of every year
9	Sparse sawgrass	252135 0804600	Dry part of every year

At each site, measurements necessary for ET calculation and modeling were automatically made and stored on-site at 15- or 30-minute intervals. Data collected included air temperature, humidity, wind speed and direction, incoming solar radiation, net solar radiation, water level and temperature, soil moisture content, soil temperature, soil heat flux, and rainfall. Data are available for eight of the nine sites for January 1996 through December 1997, and for one site January-December 1997. Four sites were continued through September 1999 and two sites were still being operated in September 2000. Four additional sites were installed in November 2000 in Shark Valley Slough to provide ET and meteorological data for development of hydrologic models, and to confirm regional models of ET developed using data from the original network of 9 ET sites.

Modified Priestley-Taylor models of latent heat (ET) as a function of selected independent variables were developed at each of the nine sites, using data for January 1996 through December 1997, when all nine sites were operated. The Priestley-Taylor model was selected because it provided a good fit at all sites, and requires less information than other ET models. The site models were used to fill in periods of missing latent-heat measurement. The individual site models were combined and used to formulate regional models of ET that may be used to estimate ET in wet prairie, sawgrass or cattail marsh, and open-water portions of the natural Everglades system. The models are not applicable to forested areas or to the brackish areas adjacent to Florida Bay.

Two types of regional models were developed. One type of model uses measurements of the energy budget at a site, together with incoming solar energy and water depth, to estimate ET for 30-minute intervals. This energy-based model requires site data for net radiation, water heat storage, and soil heat flux, as well as data for incoming solar radiation and water depth. A second type of model was developed that does not require site energy-budget data and uses only incoming solar energy, air temperature, and water depth data to provide estimates of ET at 30-minute intervals. The second model thus uses data that are more readily available than the data required for the available-energy model, but does not give as precise an estimate of ET as the model using energy-budget measurements.

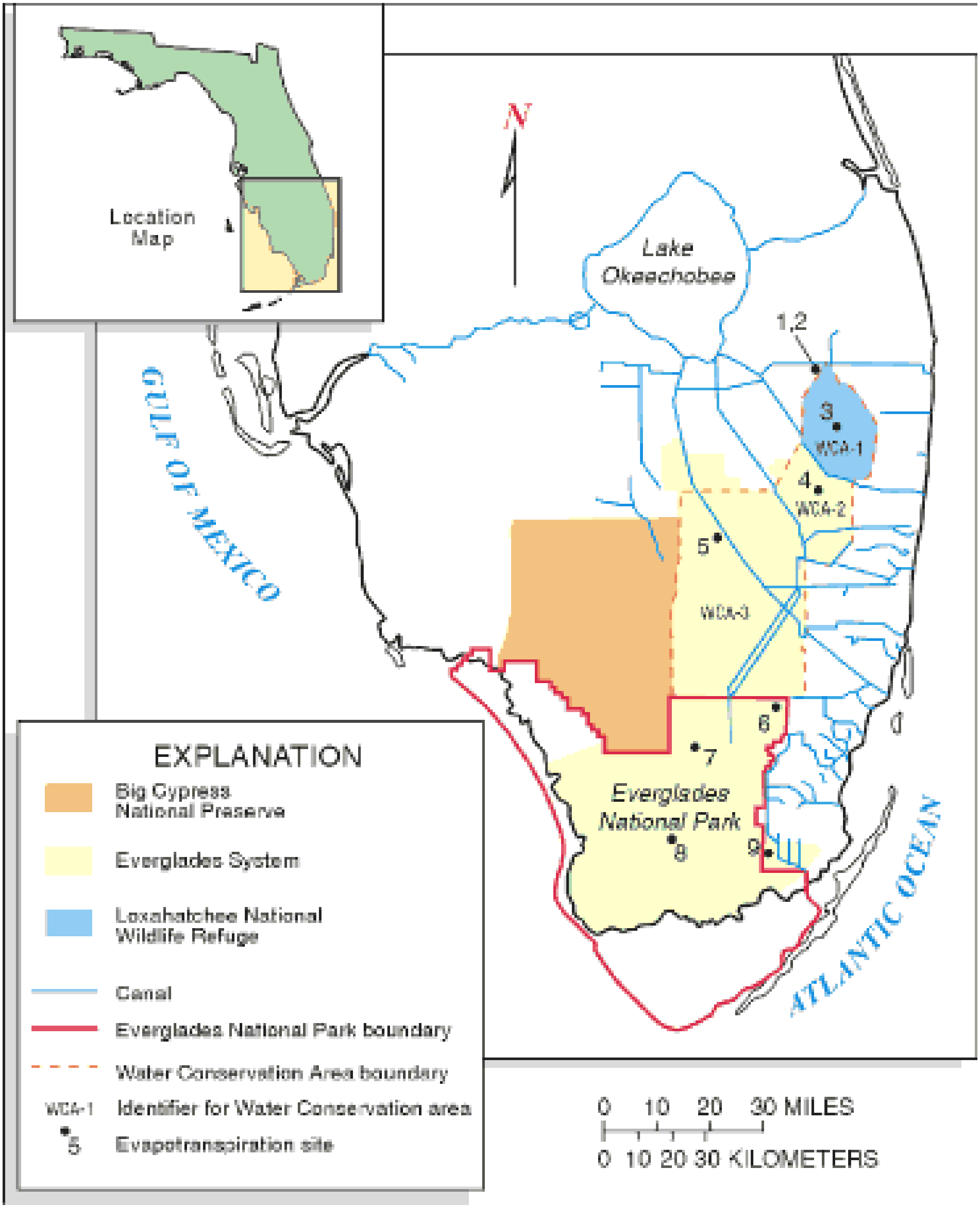

Figure 1. The Everglades and locations of evapotranspiration (ET) stations.

Precision of the site models and the regional models was evaluated for each site, and median model standard errors for the nine sites are shown in figure 2. Precision of the individual site models is only slightly better than the regional model based on energy-budget measurement. The difference in precision of the two types of regional models is most noticeable for 30-minute ET totals. For 30-minute ET totals, the energy-based model has a standard error of about 32 percent and the non-energy-based model has a standard error of about 58 percent. For monthly ET totals, both types of models are much more precise, and have standard errors of about 7 percent for the energy-based model and about 9 percent for the non-energy-based model.

Computed ET mean annual totals for all nine sites for the 1996-97 period (fig. 3) range from 42.4 inches per year at site 9, where the water level is below land surface for several months each year to 57.4 inches per year at site 2, an open-water site with no emergent vegetation. The variation in ET follows a seasonal pattern, with lowest monthly ET totals occurring in December through February, and highest ET occurring in May through August. The monthly total ET among all nine sites for the 2-year period ranged from 1.81 inches in December 1997 to 6.84 inches in July 1996.

There is an inverse relation between ET and water level. This inverse relation applies whether the water level is above land surface or below land surface.

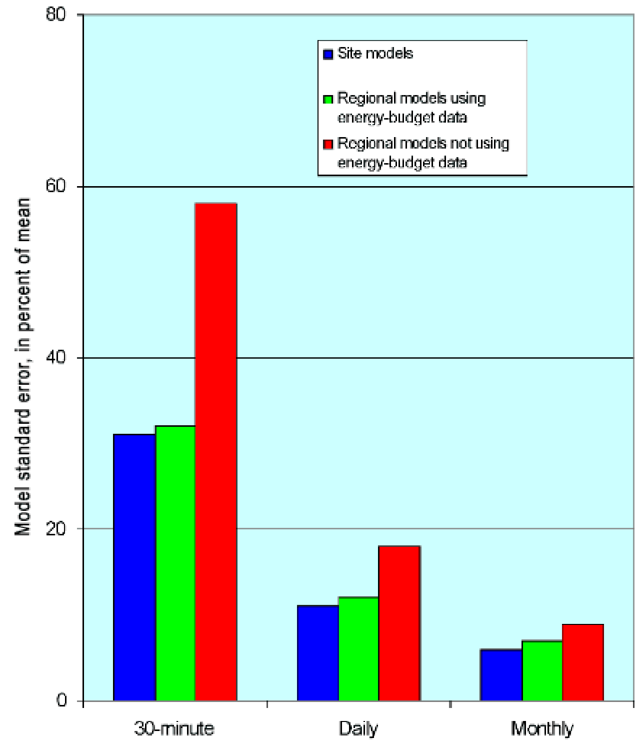

Figure 2. Median standard error for site and regional ET models.

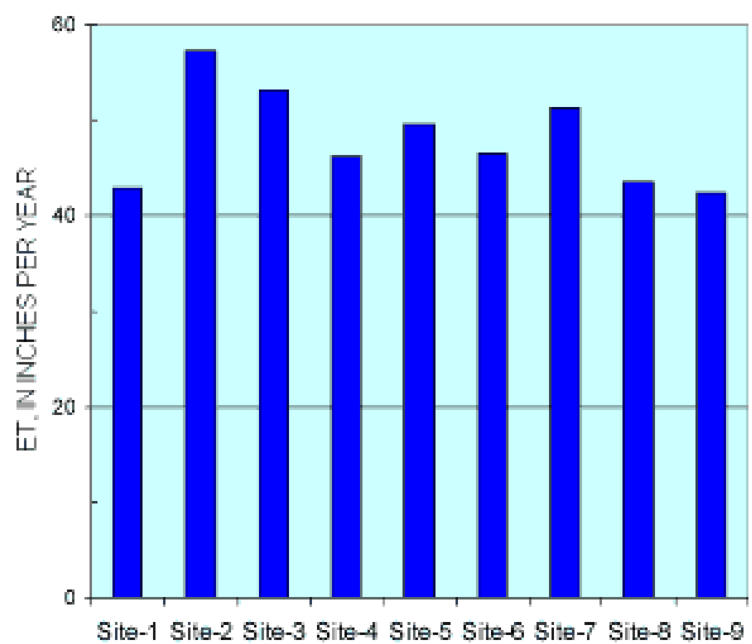

Figure 3. Mean annual ET for 1996-97.

Hydrologic Interactions Between Surface Water and Ground Water in Taylor Slough, Everglades National Park

By Judson W. Harvey[1], Jungyill Choi[1], and Robert H. Mooney[2]
[1]U.S. Geological Survey, Reston, Virginia; [2]U.S. Geological Survey, Miami, Florida

Determining the extent of hydrologic interactions between wetland surface water and ground water in Taylor Slough is important because the balance of freshwater flow in the lower part of the Slough is uncertain. Although freshwater flows through Taylor Slough are quite small in comparison to Shark Slough (the larger of the two major sloughs in Everglades National Park), flows through Taylor Slough are especially important to the ecology of estuarine mangrove embayments of northeastern Florida Bay. The extent of wetland and ground-water interactions must also be known before their role in affecting water quality can be determined. Taylor Slough is separated from Shark Slough by a series of low-lying coastal ridges referred to as Long Pine Key, and by an area of relatively high-elevation wetlands called the Rocky Glades. Historically, Taylor Slough received water from precipitation, surface overflow from Shark Slough, and possibly as ground-water discharge from the coastal ridge systems. Presently, Taylor Slough receives much of its water from the L31-W canal at the S332 pumping structure (at what is effectively the northern terminus of Taylor Slough), and from outflow at the southern end of the L31-W canal (fig. 1).

Taylor Slough is underlain by organic wetland peat that varies in depth (0.2 – 2 m) and in the content of calcitic mud. Under the peat is a highly permeable sand and limestone aquifer (Biscayne aquifer). Two approaches were used to investigate wetland and ground-water interactions in Taylor Slough. One approach involved computing ground-water discharge using chloride as a tracer. Measured flows at pumping or release structures and estimates of precipitation, evapotranspiration, and surface-flow velocity were needed in addition to chloride measurements in surface water and in ground water. The second approach estimating ground-water discharge by combining estimates of hydraulic conductivity in the peat (determined by the piezometer slug test method) with measurements of vertical hydraulic gradient. Vertical discharge from the peat was computed from those data using Darcy's law.

The research was conducted during seven primary measurement periods between September 1997 and September 1999. Results are discussed with reference to four segments (referred to as reaches) that comprise Taylor Slough (fig. 1). The first reach is between structure S332 and Taylor Slough Bridge. A net loss of surface flow by recharge from Taylor Slough to ground water was evident in this reach. Evidence for recharge is based on the substantially lower surface flow measured at Taylor Slough Bridge compared to that measured at S332 structure. During some periods recharge accounted for as much as 80 percent of the pumped input from the S332 structure. In reach 2 (directly south of Taylor Slough Bridge) there was only minor dilution of chloride in surface water, suggesting that discharge of ground water with lower chloride concentration was minor in Taylor Slough. The slight decrease in chloride concentration with distance in reach 2 could usually be explained by accounting for precipitation and evapotranspiration. In reach 3 there was a significant decrease in chloride concentration that could not be explained by precipitation and evapotranspiration, suggesting a substantial discharge of ground water into Taylor Slough during all data collection periods in both wet and dry seasons (fig. 2). For example, a calculation for November 1997 indicated that ground-water discharge might have been as large as 3 cm/day in reach 3, or approximately an order of magnitude higher than evapotranspiration (fig. 3). The average observed chloride concentrations increased in reach 4 cannot be explained by the simulations, because both the observed precipitation and evapotranspiration, and ground-water inflow would cause dilution of chloride. Chloride concentrations therefore appeared to be affected by tidal inputs of chloride from Florida Bay or by discharge of saline ground water in reach 4, and cannot be estimated by the chloride balance method.

The source of discharging ground water detected by the chloride balance is chemically dilute ground water and surface water that enters the Slough from the western side. The ultimate source of that water is probably precipitation that recharges the aquifer on Long Pine Key and the Rocky Glades. Surface-water inputs to Taylor Slough cannot be separated definitively from ground-water inflow on the western side of the Slough because both are relatively low in chloride concentration. It is assumed that much of that surface flow also had its origin as recharge on Long Pine Key and the Rocky Glades, flowing to the southeast in the shallow ground-water system, discharging prior to reaching the measurement point at Ingraham Highway. Because of those complex interactions, all of the water entering from the western side of Taylor Slough that was delineated using chloride as a tracer identified as "shallow ground-water discharge."

In contrast, vertical discharge of ground water from directly beneath Taylor Slough cannot be detected by using chloride as a tracer. This is because of the similarity in chloride concentration between Taylor Slough surface water and ground water directly beneath the channel. The best estimate of ground-water discharge from directly beneath Taylor Slough was 0.06 cm/day, which represents a relatively minor component of inflow in comparison with shallow ground-water discharge from the west.

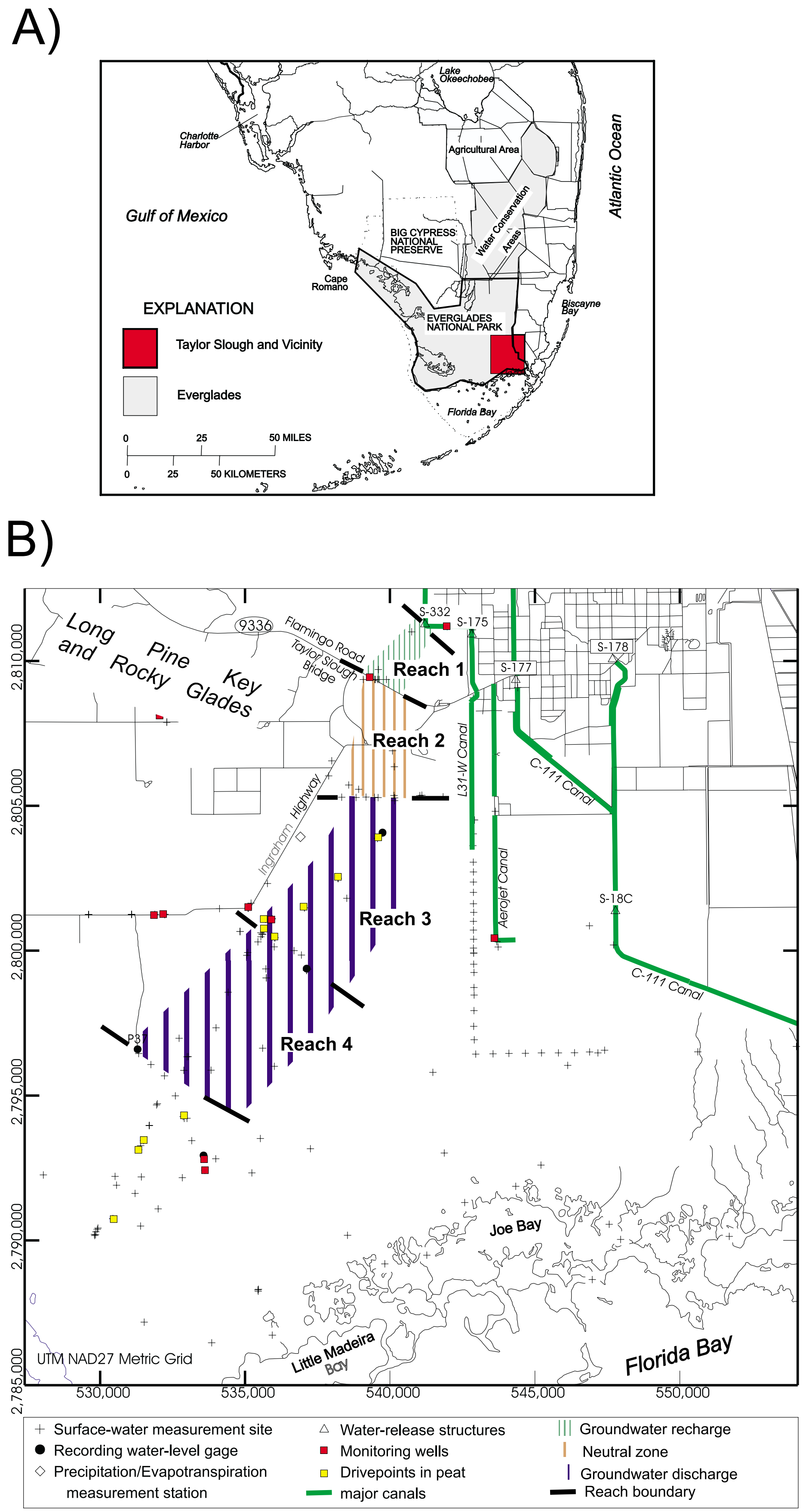

Figure 1. General location map (a) and (b) locations of measurements of recharge and discharge in Taylor Slough, Everglades National Park.

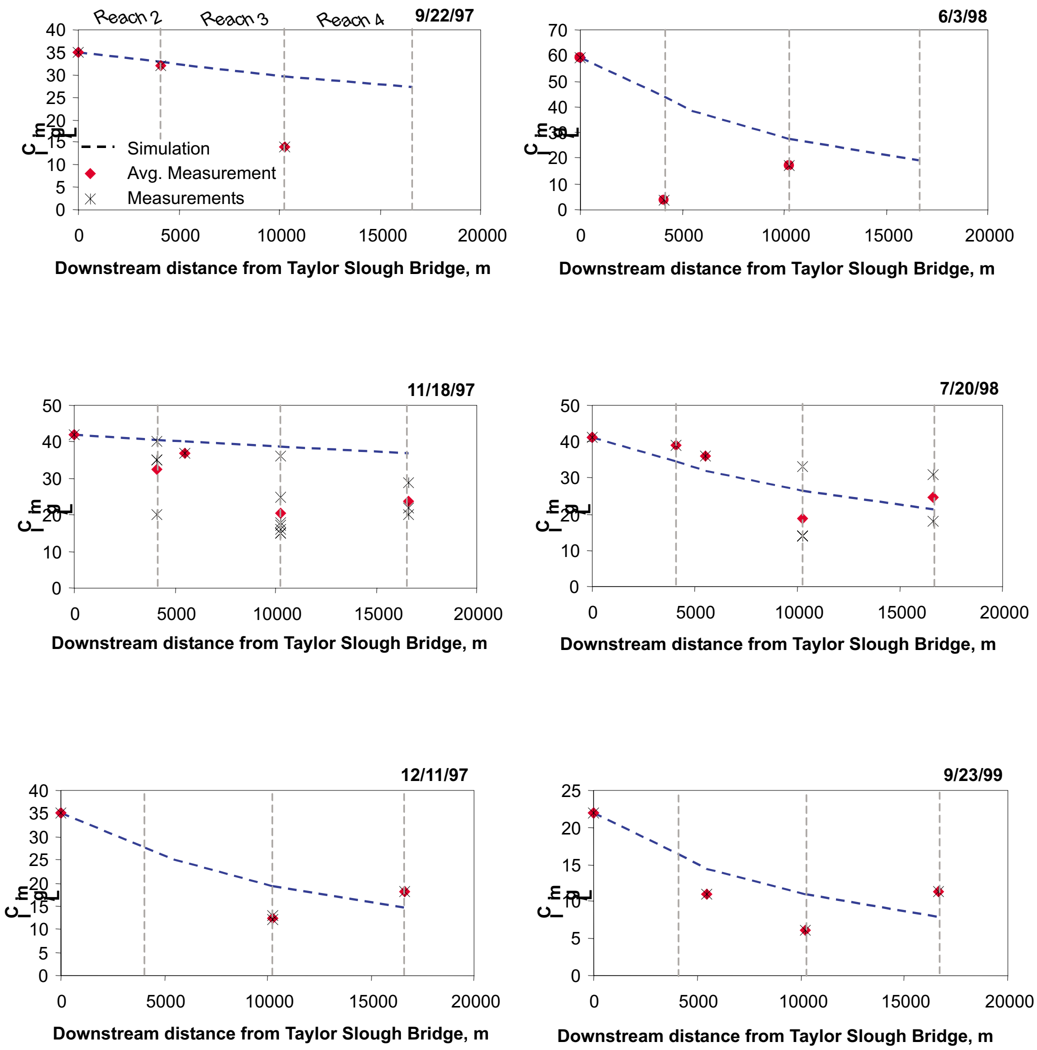

Figure 2. Comparison between observed and simulated chloride measurements in Taylor Slough surface water. The simulations considered only precipitation and evapotransportation without ground-water discharge or recharge.

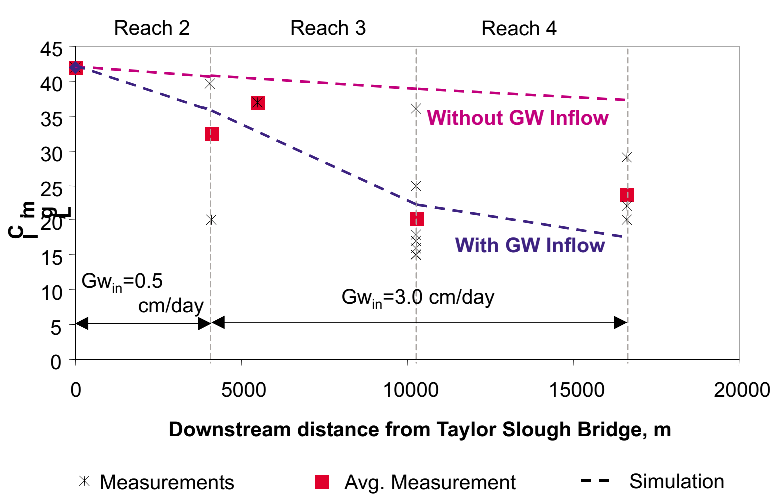

Figure 3. Calculated ground-water discharge for November 18, 1997 using flow velocity of 1.0 cm/sec.

Quantity, Timing, and Distribution of Freshwater Flows into Northeastern Florida Bay

By Clinton Hittle
U.S. Geological Survey

A major Everglades restoration goal is to provide the wetland and Florida Bay with the right amount of water at the right time. The need for accurate information on the quantity, timing, and distribution of water flows through the Everglades into Florida Bay is essential for successful water management as it relates to restoration efforts. Accurate flow information is needed to help understand and simulate circulation, mixing, and salinity dynamics in Florida Bay as well as to help verify terrestrial simulations of south Florida marsh-flow dynamics. Such simulations are, in turn, used to drive projections of ecosystem changes in response to restoration alternatives. Also, with this flow information, water management practices can be monitored and informed decisions can be made to help restore the Everglades.

In October 1994, the U.S. Geological Survey (USGS), as part of the South Florida Place Based Studies Program, began a study to measure freshwater discharge into northeastern Florida Bay. Water flow, stage, and salinity data were collected at five instrumented sites, and water flow only at four noninstrumented sites. The five instrumented sites from east to west are West Highway Creek, Trout Creek, Mud Creek, Taylor River, and McCormick Creek. The four

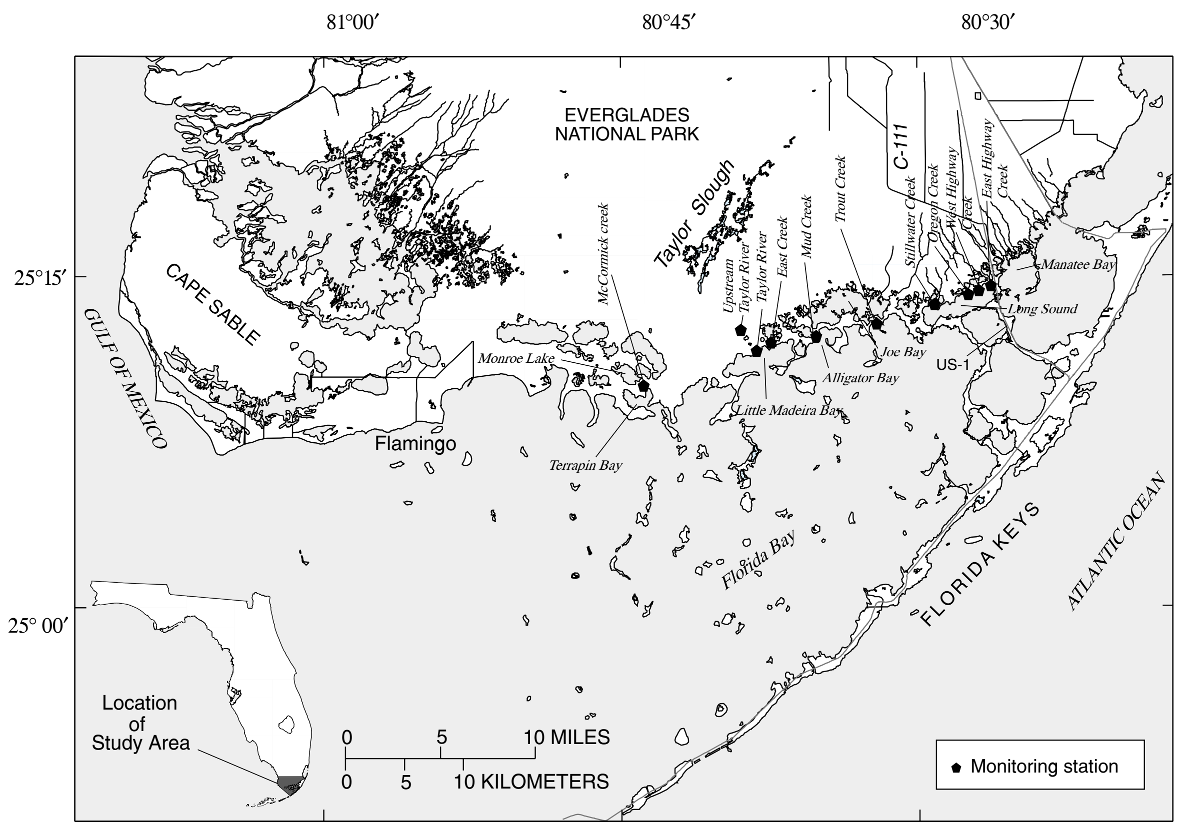

Figure 1. Location of Florida Bay monitoring stations.

noninstrumented sites from east to west are East Highway Creek, Oregon Creek, Stillwater Creek and East Creek (fig. 1). Data at the instrumented sites are collected every 15 minutes and transmitted via satellite every 4 hours to the USGS Miami office. Data from the noninstrumented sites are collected on a monthly and storm event basis. The study was expanded in 1999 to determine flow distribution into Joe Bay and upstream flow characteristics for Taylor River. Four salinity probes were installed at creeks along the northern coast of Joe Bay, and additional instrumented sites were installed along upstream Taylor River and Stillwater Creek (fig. 1).

The quantity of water flowing through Taylor Slough and the C-111 Basin, including rainfall and evaporative losses, can be defined as total cumulative outflow volume in acre-feet from the creeks. The USGS water year (October through September) annual summaries for 1996-99 of outflow volume for the five instrumented and four noninstrumented sites are presented in table 1. Sheetflow into northeastern Florida Bay is considered negligible because flow is channeled through a low lying ridge along the northeastern shore of the bay.

Table 1. Annual outflow volumes for creeks in northeastern Florida Bay in acre-ft.
[* noninstrumented creek outflows that are estimated using correlation with instrumented creeks.]

Water Year	West Highway	East Highway *	Oregon *	Stillwater *	Trout	Mud	East *	Taylor	McCormick
1996	33,764	12,933	12,307	13,713	143,696	18,017	22,307	16,674	12,028
1997	43,657	17,906	15,811	17,225	190,088	18,577	23,040	23,809	24,484
1998	27,909	9,694	10,258	11,761	138,853	18,748	19,308	27,959	-14,997
1999	28,699	10,107	10,537	14,532	110,361	19,298	23,584	28,361	22,418

The timing of flows is directly related to the wet/dry season variations with more than 80 percent of annual freshwater flow entering northeastern Florida Bay between June and November. Negative flows predominate the dry season and lower water levels in the wetland along with southerly winds cause saltwater to intrude upstream and into the coastal sub-embayments, such as Joe Bay and upstream Taylor River.

Due to the complex drainage basin of the southeastern Everglades and the flat topography, small changes in water level can cause changes in flow distribution that would not be observed without directly computing discharge at the creeks. Discharge computation and salinity observations at the creeks and sub-embayments have led to the following flow distrtibution interpretations: (1) Trout Creek carries approximately 50 percent of the freshwater outflow to northeastern Florida Bay including the gaged and ungaged creeks; (2) West Highway Creek rarely has net negative flow on a monthly basis; (3) McCormick Creek had net negative flow for water year 1998 following the El Nino event; (4) flow exchange between Joe Bay and Long Sound does occur, and direction of flow is dependent upon water levels in the Taylor Slough and C-111 Basins; and (5) northeastern Joe Bay shows a direct connection with outflows from S-18C.

Ground-Water Discharge to Biscayne Bay

By Christian Langevin
U.S. Geological Survey, Miami, Florida

One of the main goals of Everglades restoration is to “get the water right” by modifying the existing canal network and management operations. There is concern that the modifications could adversely affect salinities in Biscayne Bay, which hosts a wide range of estuarine organisms. To evaluate the effects of the modifications on Biscayne Bay, the U.S. Army Corps of Engineers is constructing a hydrodynamic circulation model. To achieve a reasonable calibration, the model requires the accurate specification of freshwater discharges to the bay. The two most important mechanisms for freshwater discharge to Biscayne Bay are thought to be canal discharges and submarine ground-water discharge from the Biscayne aquifer. Canal discharges are routinely measured and recorded, but few studies have attempted to quantify the rates and patterns of submarine ground-water discharge. In 1996, the U.S. Geological Survey initiated a project, in cooperation with the U.S. Army Corps of Engineers, to quantify the rates and patterns of submarine ground-water discharge to Biscayne Bay. These rates have been incorporated into the circulation model, which is currently under development by the Corps.

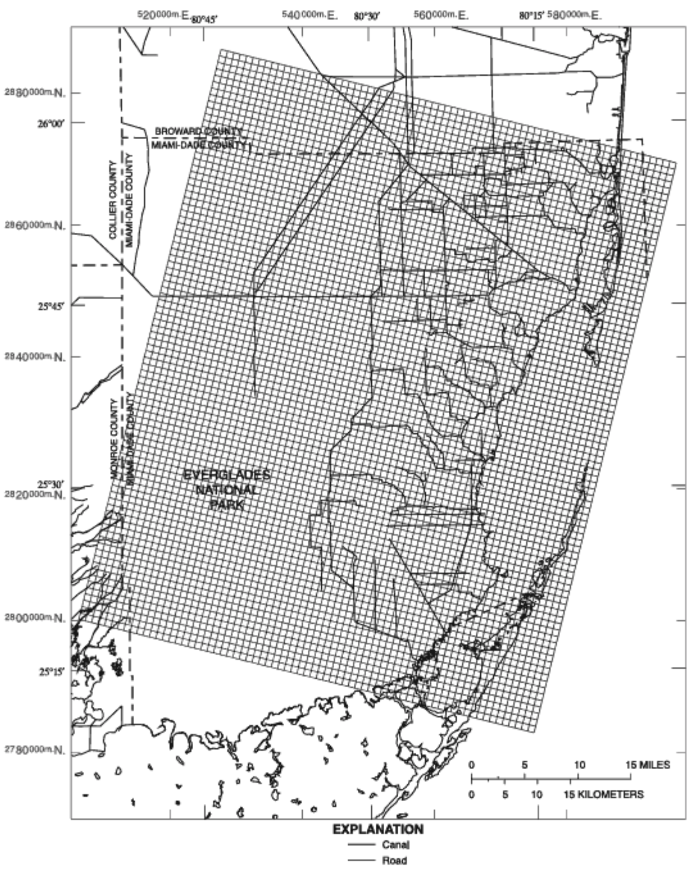

Figure 1. Finite-difference model grid for the regional-scale model used to simulate variable-density ground-water flow to Biscayne Bay from 1989 to 1998.

To quantify rates and patterns of submarine ground-water discharge, field studies were combined with numerical modeling techniques. The field studies were performed at three transects: Coconut Grove, Cutler Ridge, and Mowry Canal. At each transect, monitoring wells were installed inland and offshore to characterize the interface between fresh and saline ground water. Data from the offshore monitoring wells indicate that ground water beneath Biscayne Bay has relatively low salinity values along the coast. At distances of about 300 to 500 meters from shore, however, ground-water salinities are nearly equal to seawater salinities. This suggests that most of the ground-water discharge is confined to a narrow band along the coast. The salinity data also support the conceptual model of cyclic ground-water flow within the freshwater/saltwater interface being driven by density variations.Ground-water discharge rates to Biscayne Bay were quantified by constructing variable-density ground-water flow models that use the assumption of an equivalent porous medium. The models were developed with a code called SEAWAT, which is a combination of MODFLOW and MT3D. The numerical models were constructed at the local and regional scales. Local-scale models were developed and calibrated using the field data collected at the Coconut Grove and Cutler Ridge transects. Results from the local-scale models were used to guide the development and calibration of the larger, regional-scale model (fig. 1). The regional-scale model covers most of Miami-Dade County and represents the period from January 1989 to October 1998. The model includes the following hydrologic stresses: recharge, evapotranspiration, canal interaction, interaction with surface water in the Everglades, municipal well fields, and ground-water discharge to Biscayne Bay.

Results from the regional-scale model provide important information about the rates and patterns of ground-water discharge to Biscayne Bay. The model results suggest that ground-water discharge rates are probably 3 to 10 percent of the total discharge from the coastal canals (fig. 2). The results also suggest that most of the ground-water discharge to Biscayne Bay occurs along the northern half of the coast, where the Atlantic Coastal Ridge is directly adjacent to the bay. Ground-water discharge rates for southern Biscayne Bay are nearly zero because the low-lying areas prevent the water table from rising more than a few tenths of a meter above sea level. The importance of tidal canals also was highlighted by the model. Simulated ground-water discharges to the tidal portions of the Miami, Coral Gables, and Snapper Creek Canals are similar in magnitude to submarine ground-water discharge directly to Biscayne Bay.

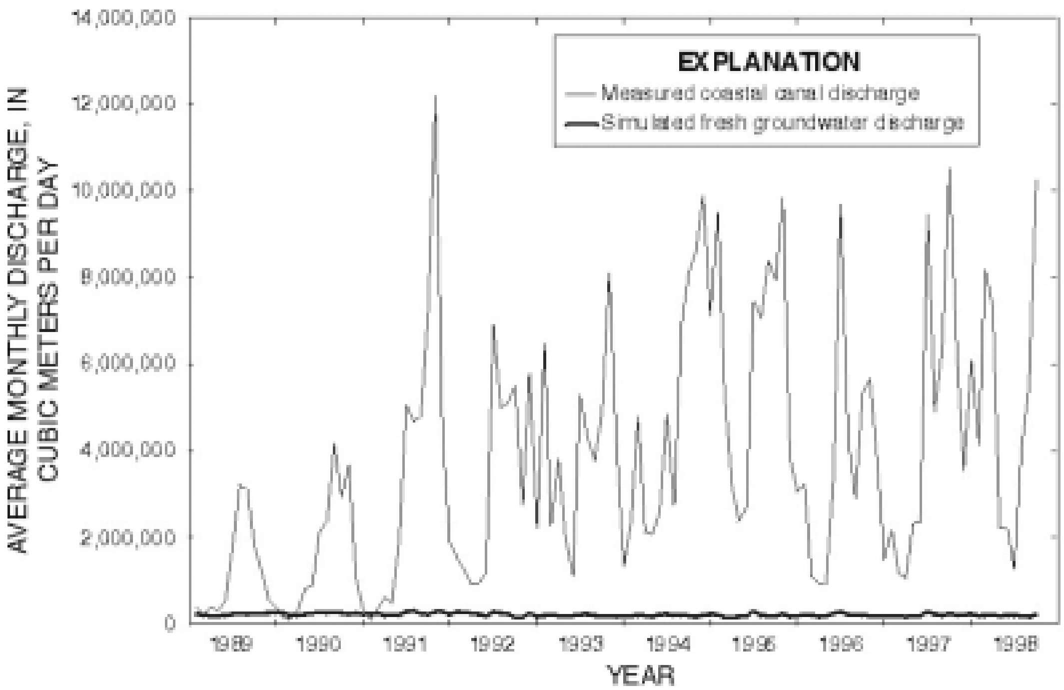

Figure 2. Submarine ground-water discharge as simulated by the regional-scale model compared with discharge at the coastal canals. Data for the coastal canal discharges were retrieved from the DBHYDRO database maintained by the South Florida Water Management District.

A Pipe Manometer for the Determination of Very Small Water-Surface Slopes in the Florida Everglades

By Jonathan K. Lee[1], Harry L. Jenter[2], Vincent C. Lai, Hannah M. Visser[3] and Michael P. Duff[3]

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[3]U.S. Geological Survey, Reston, Virginia;

Restoration and management decisions regarding the south Florida ecosystem are based in part on the results of numerical surface-water flow models. These model results are sensitive, in turn, to the expressions used to account for the resistance effects of vegetation on flow and to the values of the coefficients that appear in those expressions. U.S. Geological Survey (USGS) hydrologists and ecologists are conducting studies to quantify vegetative flow resistance in order to improve the models.

Expressions for vegetative flow resistance include coefficients that must be evaluated in terms of measurable parameters that describe the flow conditions and the vegetation characteristics. These parameters include the flow velocity through the vegetation, water depth, slope of the water surface, and the type, physical characteristics, and density of the vegetation. Water-surface slope is perhaps the most difficult of the flow-resistance parameters to measure in the Everglades due to the very low-gradient characteristics of the topography and flow. Conventional surveying methods do not provide the level of precision needed to accurately determine water-surface slopes in such wetland environments. A unique pipe manometer (fig. 1) has been developed by the authors to evaluate these very small water-surface slopes that are typically on the order of 1 cm per 1 km $^{(10\text{-}5)}$.

The pipe manometer is a 2.4-m-long, 7.6-cm-diameter PVC pipe with a short elbow of the same internal diameter at one end. In application, the pipe is positioned fully submerged near the water surface with its long axis parallel to the direction of flow. It is oriented with the elbow opening downward at the upstream end of the pipe. For low Reynolds number flow, water velocity in the pipe is theoretically a function of only the pipe geometry, water viscosity and the head difference between the ends of the pipe (that is, Streeter and Wylie, 1979). The relationship, either theoretical or empirical, between the flow velocity in the pipe and the head difference can be used as a surrogate for measurement of the water-surface slope. It is under this assumption that the pipe manometer is developed to determine water-surface slope.

A series of steady-state controlled flows, conducted in the tilting flume at the USGS Hydrologic Instrumentation Facility at Stennis Space Center in Bay St. Louis, Mississippi during February and March of 1999, were used to establish the relationship between the pipe-centerline velocity and water-surface slope. During this time period, eleven separate flow conditions were replicated, representing a variety of water depths and slopes. Each controlled condition consisted of two water-surface slope measurements and approximately twenty pipe-centerline velocity measurements.

A single water-surface slope was calculated from six independent stage measurements collected using hook gages equipped with digital calipers at each of five locations along a side of the 60-m-long, 2-m-wide flume (fig. 2). Pipe-centerline velocity was measured by inserting the side-looking probe of an acoustic Doppler velocity meter into the downstream end of the pipe manometer at five locations along each side of the flume using the configuration shown in figure 1.

Analyses of the observations collected under the controlled flow conditions show a strong empirical relationship between pipe-centerline velocity and water-surface slope. The relationship between pipe-centerline velocity and the square root of water-surface slope is nearly linear within the range of flow conditions observed in the Everglades. Efforts are currently underway to reconcile the observations with pipe flow theory in order to establish design criteria for pipe manometers with geometries different than the pipe manometer used in this study.

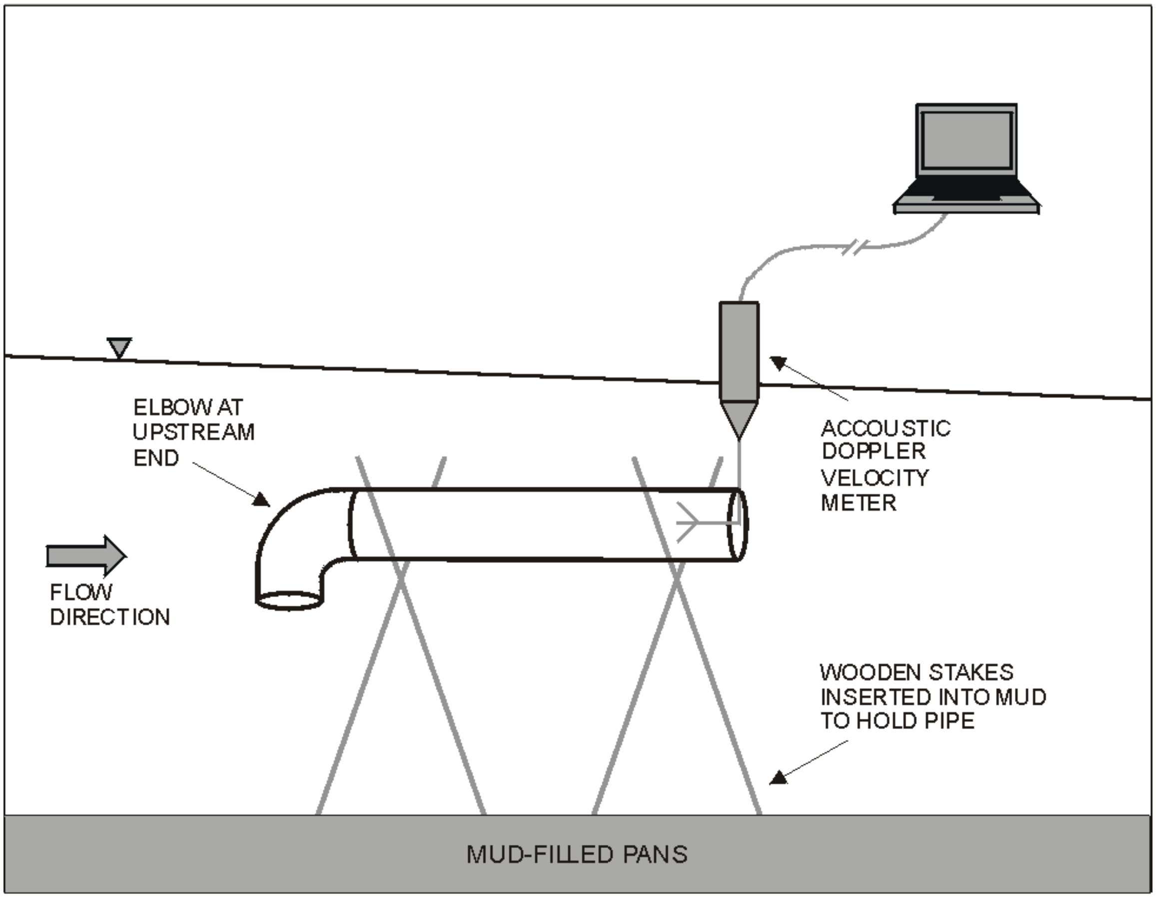

Figure 1. Pipe manometer, laboratory configuration. Not drawn to scale.

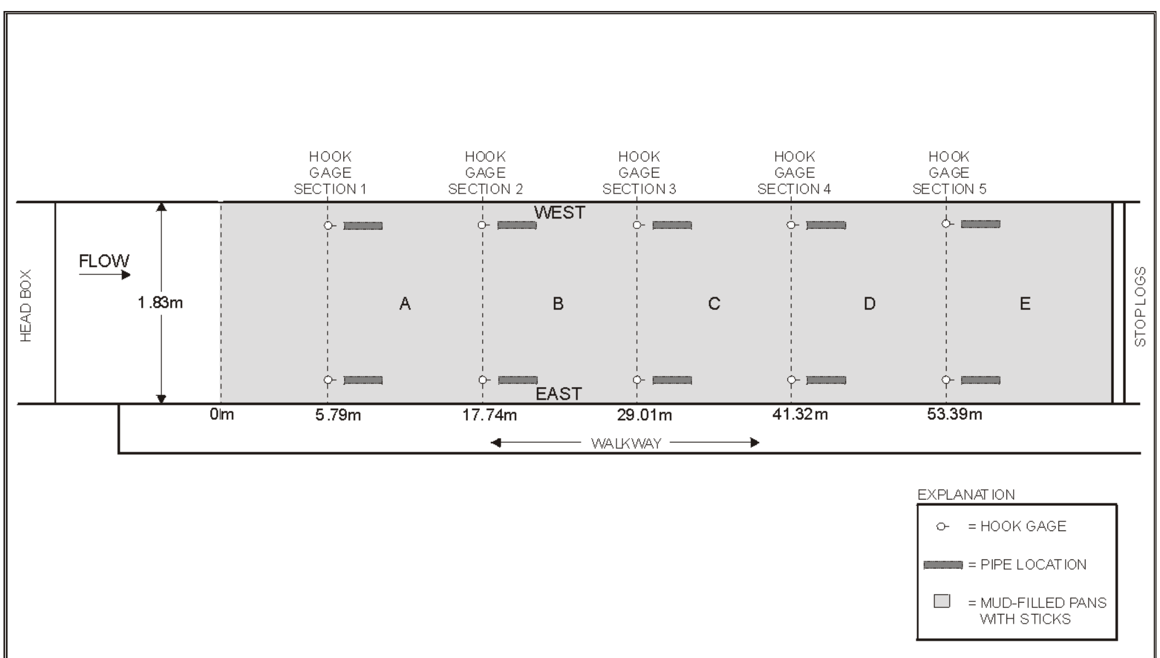

Figure 2. Flume layout, plan view. Not drawn to scale.

Determination of Resistance Coefficients for Flow through Submersed and Emergent Vegetation in the Florida Everglades

By Jonathan K. Lee[1], Lisa C. Roig[2], Harry L. Jenter[3], Hannah M. Visser[3]

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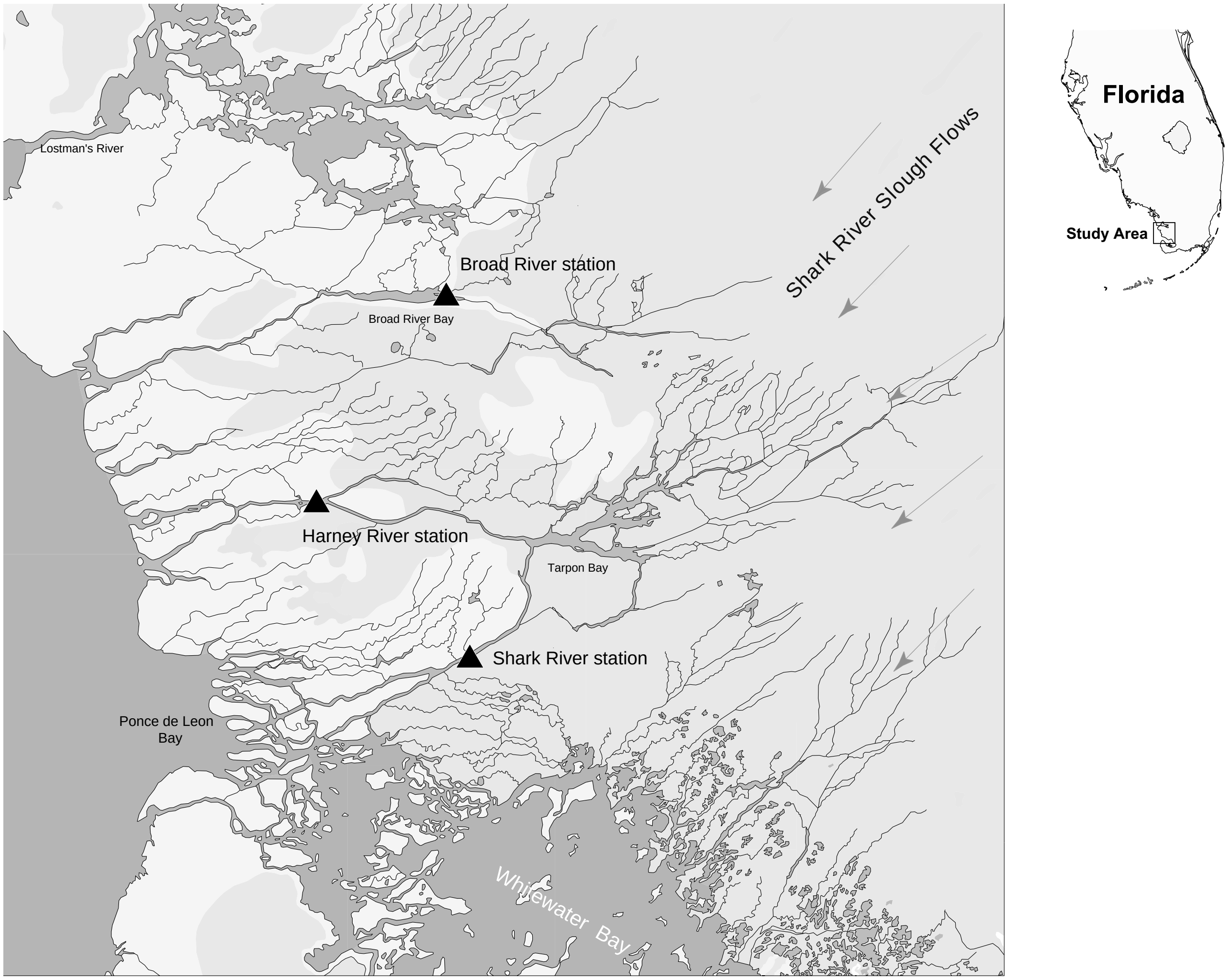
Indoor flume experiments and field surveys have been conducted to yield unique data sets describing flow through submersed and emergent vegetation at low Reynolds numbers (Lee and Carter, 1999; Lee and Carter, 1997). Hydraulic measurements were conducted concurrently with vegetation sampling surveys to provide the data needed to determine the correlation between frictional resistance and vegetative characteristics (Carter and others, 1999; Rybicki and others, 1999). In addition, an innovative method for measuring the extremely small water-surface slope has been developed (Lee and others, 2000). The objectives of the present effort are as follows: (1) to determine the flow resistance due to vegetation for each of the plant communities sampled in the laboratory and field surveys; (2) to derive equivalent Manning's n functions to quantify frictional resistance for the specific vegetation types surveyed; and (3) to examine the role of upscaling on the derived Manning's n values. Future USGS research will correlate the flow resistance to specific physical characteristics of the plants. This future work will permit flow resistance to be predicted from generalized functions, rather than requiring physical surveys in each plant community.

Fluid moving through an array of erect objects is commonly characterized by the "stem" Reynolds number, $Re_D = DV/\nu$, where D is the average spacing of the objects, V is the discharge velocity, and ν is the kinematic viscosity. Preliminary analyses indicate that the laboratory and field data have stem Reynolds numbers in the range 10 to 400. Let us consider what is known about the flow regime in this range (Churchill, 1982). For an isolated erect cylinder in a horizontal flow field, flow is laminar for $Re_D < 150$. For $6 < Re_D < 44$, separation occurs behind the cylinder creating a recirculation zone in the lee of the object. For $44 < Re_D < 150$, organized vortex shedding is observed. For $150 < Re_D < 30000$, a turbulent wake forms. In a multi-cylinder array, the limits of these different regimes are different because of wake interference, sheltering, and tortuosity. Nonetheless, the range of Re_D experienced in the Everglades data suggests that the flow regime varies from laminar to transitional, but does not become fully developed turbulent flow, as is commonly assumed for open channel flow. Other researchers suggest that laminar flow in a multi-cylinder array occurs for $Re_D < 200$ (Nepf, 1999).

The conceptual model of a multi-cylinder array is useful for advancing the analysis of flow through submersed and emergent vegetation to a certain point. Yet the vegetation array is much more complex. The vertical variation of the plant form and the vertical variation of the plant population density affect the flow field. The velocity profiles observed in the laboratory and field studies are very different than what is typical for open channel flows, and than what has been suggested for uniform multi-cylinder arrays. These observations indicate that the historical use of Manning's n to describe the flow resistance of heavily vegetated environments is inappropriate. One goal of this work is to identify a simple and useful function for specifying the resistance factor for each plant community sampled in the field survey. Resistance coefficients such as the Darcy-Weisbach friction factor or the average stem drag coefficient may be more suitable than Manning's n for this purpose. An approximation of Manning's n for use in Everglades hydraulic routing models can be derived for either of these.



gure 1. Location of southwest estuarine river stations.

Southwest Coast of Everglades National Park—Broad, Harney, and Shark River Hydrodynamics and Discharges During 1999

By Victor A. Levesque
U.S. Geological Survey, Tampa, Florida

The analysis of 1999 discharge data provides information on annual discharge characteristics and the effects of weather systems on discharges for the Broad, Harney, and Shark Rivers. As a part of the U.S. Geological Survey South Florida Placed Based Studies Program, these three estuarine-river sites were selected using the criterion that a large amount of the water that flows through Shark River Slough, sometimes referred to as the “Heart of the Everglades,” must pass by these sites. This study’s data will be used, in conjunction with data from other ongoing studies, to determine the effects changes in water deliveries to Everglades National Park (ENP) have on the southwest estuaries and Florida Bay ecosystems. Each station was equipped with a vertically oriented acoustic-velocity sensor, water-level pressure transducer, bottom water-temperature thermistor, and specific conductance four-electrode sensor.

Discharges from the Broad, Harney, and Shark Rivers are influenced by semi-diurnal tides, wind events, and freshwater inflow. All three rivers are well mixed, with a difference in specific conductance from top to bottom usually no greater than 500 microsiemens per centimeter during flood and ebb tides. Discharge is one-dimensional except for brief (less than 20 minutes) periods during slack water (between flood and ebb tide) when flow is vertically bi-directional (moving upstream and downstream). The flood discharges (water moving upstream, denoted as negative values) are usually of greater magnitude and shorter duration than the ebb discharges (water moving downstream, denoted as positive values).

Instantaneous and residual daily discharges for the three stations were calculated for the 1999 calendar year. During 1999, the Broad River instantaneous discharges ranged from –2,400 to +3,500 cubic feet per second (ft^3/s), while the Harney and Shark River instantaneous discharges ranged from –15,600 to +12,900 ft^3/s and –10,100 to +10,500 ft^3/s, respectively. The instantaneous discharge values were processed using a ninth-order Butterworth low-pass filter to remove semidiurnal tidal frequencies that eliminates bias associated with lunar cycles when computing daily, weekly, monthly, or yearly mean or median residual (filtered) discharge values. The residual daily discharges for the Broad, Harney, and Shark River stations ranged from –900 to +2,500 ft^3/s, -3600 to +5,700 ft^3/s, and –2300 to +4,400 ft^3/s, respectively. The Broad River station is the furthest upstream from the Gulf of Mexico (9.3 river miles) and exhibits lesser magnitudes of instantaneous and residual discharges than the other two stations and longer duration positive discharges than the Harney (4.4 river miles upstream) or Shark (6.2 river miles upstream) River stations.

Mean annual residual daily discharges were computed for the Broad and Shark River stations and estimated for the Harney River station. Discharge data were missing for the Harney River from April 4 to June 11, 1999, due to erroneous index-velocity data. This period coincided with prolonged minimum residual discharges recorded at the Broad and Shark River stations. The mean annual residual discharge for the Broad and Shark River stations, using the complete 1999 record were computed as +400 and +440 ft^3/s respectively. Excluding the period of missing discharge data for the Harney River station, the mean annual residual discharges for the Broad, Harney, and Shark River stations were +520 ft^3/s, +580 ft^3/s, and +550 ft^3/s, respectively. Applying the same difference of approximately 100 ft^3/s between mean annual residual discharges for the Broad and Shark River stations, the Harney River station mean annual residual discharge for 1999 was estimated to be approximately +470 ft^3/s. The mean annual residual discharges reflect the net downstream flows with minimal errors associated with water storage.

Wind events such as cold fronts, tropical storms, and hurricanes can amplify, attenuate, or completely overwhelm the tidal forces that normally dominate flow patterns in the estuaries along the southwest coast of the ENP. Four strong cold fronts occurred between January and March 1999 that significantly affected short-term discharges (less than a few days) for the Broad, Harney, and Shark Rivers. The lowest water levels for the Broad, Harney, and Shark Rivers occurred during the passage of strong cold fronts in February and March 1999, when mean water levels were lower than in the late summer and early fall. The most significant effects on maximum water level and discharge occurred during the passages of Tropical Storm Harvey and Hurricane Irene in September and October 1999. The two storms had different effects on the water levels and discharges during their movement towards and away from the southwest coast.

Tropical Storm Harvey approached the Broad, Harney, and Shark Rivers from the northwest and moved to the east with maximum sustained winds of 60 miles per hour (mph). The winds associated with Harvey forced water into the mangrove forests of the southwest coast to water levels of approximately 1.81 feet above mean water levels at the Broad River station, 3.30 feet above mean water level at the Harney River station, and 2.96 feet above mean water level at the Shark River station. Some pulsations in water level and discharge not attributable to semi-diurnal tidal forcing preceded the storm by 2 to 3 days. The center storm surge caused a prolonged flood (upstream) flow that lasted almost 24 hours; then as the winds shifted and abated, the stored water flowed back out to the Gulf of Mexico for approximately 24 hours with no tidal flow reversal. The maximum positive and negative instantaneous and residual discharges for the Harney and Shark River stations were recorded on September 21, 1999, as Tropical Storm Harvey made landfall. The Broad River discharges exhibited similar patterns but to a lesser magnitude than the Harney and Shark River stations due to the location of the station and the storm track.

Hurricane Irene caused a different response at the three river stations because of the storm path and wind strength. Hurricane Irene approached from the southwest and moved to the northeast on October 15, 1999, with maximum sustained winds of 85 mph. The winds associated with Irene forced water out of the mangrove forests and the return seiche was of lesser magnitude than during Tropical Storm Harvey. Water levels during Irene decreased and caused a rapid increase in ebb flow (toward the Gulf of Mexico) that lasted approximately 24 hours with no flow reversals during the 24-hour period. The Broad River instantaneous and residual daily discharges reached maximum values of +3,500 and +2,500 ft^3/s respectively during the passage of Hurricane Irene.

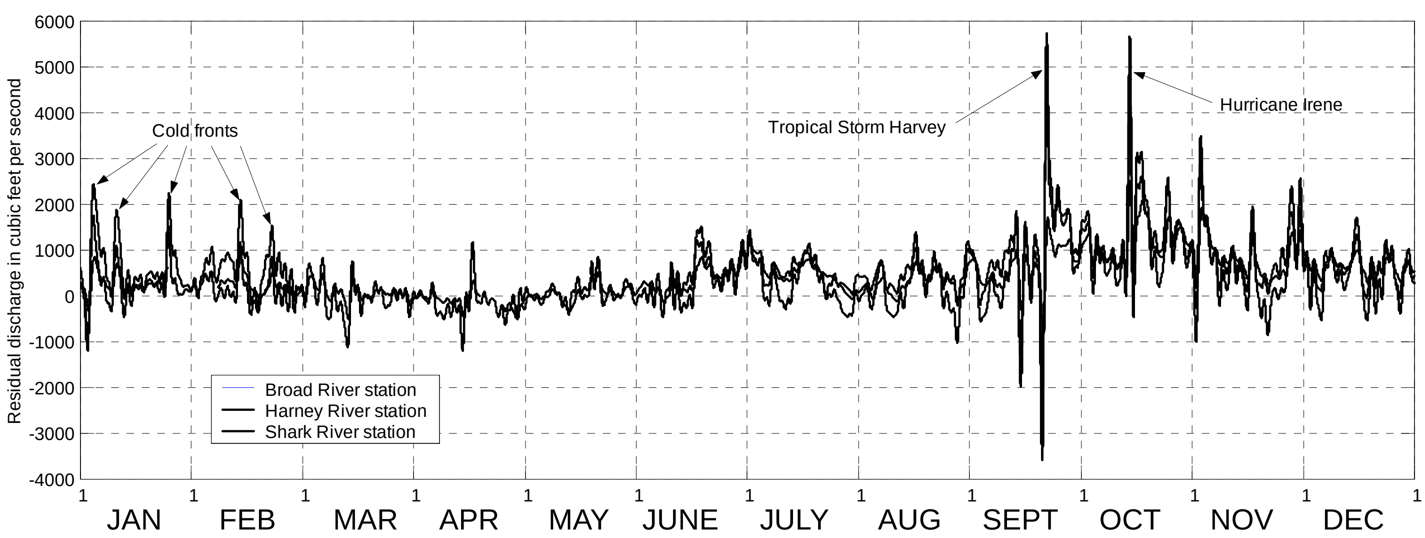


Figure 2. Residual discharges in 1999 for the Broad, Harney, and Shark River stations.

Quantifying Internal Canal Flows in South Florida

By Mitchell H. Murray
U.S. Geological Survey, Miami, Florida

Historical changes in water-management practices to accommodate a large and rapidly growing urban population along the Atlantic Coast of south Florida as well as intensive agricultural activities have resulted in a highly managed hydrologic system with canals, levees, and pumping stations. These structures have altered the hydrology of the Everglades ecosystem on coastal and interior lands. Surface-water flows south of Lake Okeechobee have been regulated by an extensive canal network, begun in the 1940's, to provide for drainage, flood control, saltwater intrusion control, agricultural requirements, and various environmental needs. Much of the development and subsequent monitoring of canal and river discharge south of Lake Okeechobee have traditionally focused on the eastern coastal areas of Florida. Recently, increased emphasis has been placed on providing a more accurate accounting of canal flows in interior regions of south Florida.

As part of its Place-Based Studies Program, the U.S. Geological Survey (USGS) is presently conducting a study to: (1) evaluate approaches for quantifying freshwater flows to and from Native American Lands, and (2) provide hydrologic data to support various other federal, state, and tribal hydrologic investigations. The implementation and development of strategically placed streamflow and water-quality gaging sites in the interior have provided vital information for determining future surface-water flow requirements in the internal canal system. Subsequent studies, based on accurate flow determinations at these sites, have been used for computation of nutrient loadings in the canal system. Providing continuous-flow data from selected impact points for internal basins complements the data from the eastern flow canal discharge network. This has resulted in increased accuracy for timed water deliveries to specific locations.

During 1996-97, the USGS constructed, instrumented, and calibrated three streamflow monitoring sites south of Lake Okeechobee (fig. 1) in an effort to accurately gage flows in canals entering and exiting Tribal Lands, Big Cypress National Preserve, and Water Conservation Area 3A in south Florida. The L-28U site is used to monitor freshwater flows to and from Seminole and Miccosukee Indian Tribal Lands. The L-28IN site is used to monitor freshwater flows from Seminole Indian Tribal lands to Big Cypress National Preserve and ultimately to Miccosukee Tribal Lands. The L-28IS site, discontinued in September 1999, was used to monitor flows from Seminole Indian Tribal Lands and Big Cypress National Preserve to Miccosukee Indian Tribal Lands. This site also was instrumental in bracketing and quality assuring the flow calibration conditions for the upstream L-28IN site.

Acoustic instrumentation, in lieu of standard methods for field data collection and flow computations, is used to gage flows in the canals. With the acoustic velocity meter (AVM) and the acoustic doppler current profiler (ADCP), it is possible to more accurately gage flows in this type of environment because they can quickly measure low or rapidly changing water velocities. The ADCP calibration of the *in situ* AVM index velocities is ongoing. A sum of least squares regression has been developed for data processing at all sites and continues to be refined.

Velocity data collected during the dry season have displayed a phenomenon known as acoustic refraction or ray bending. This is produced by thermal stratification in the water column during extended periods of very slow flow. At one site, a point velocity electromagnetic velocity meter and associated velocity index were established in conjunction with the AVM to verify periods when these episodes occur.

Average annual runoff of 70,100 acre-feet was recorded during 1997-99 at L-28U (fig. 2). This represents about twice the inflow amount determined by the South Florida Water Management District (SFWMD) at their upstream U.S. Sugar Outflow (USSO) site located on the northwestern border of the Seminole Indian Tribal Lands. An average annual runoff of 53,770 acre-feet has been recorded at L-28IN since its inception in 1997, and an average annual runoff of 49,070 acre-feet was recorded during 1997-99 at L-28IS (fig. 3). The lesser discharge recorded at the more southerly site of the two on the Interceptor canal was likely due to the heavy influence of the S-140 pump station where losses could be attributed to heavy operational pumping periods.

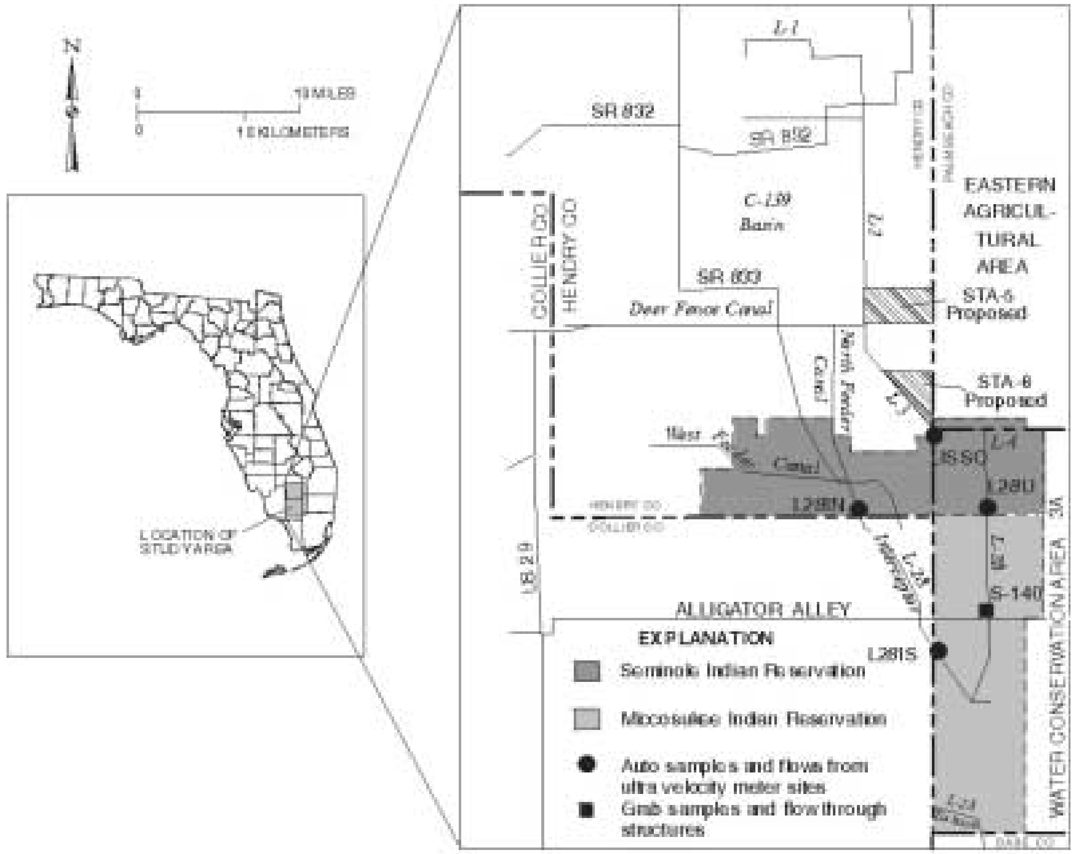


Figure 1. South Florida Water Management District/Seminole Agreement water-quality and flow sampling sites.

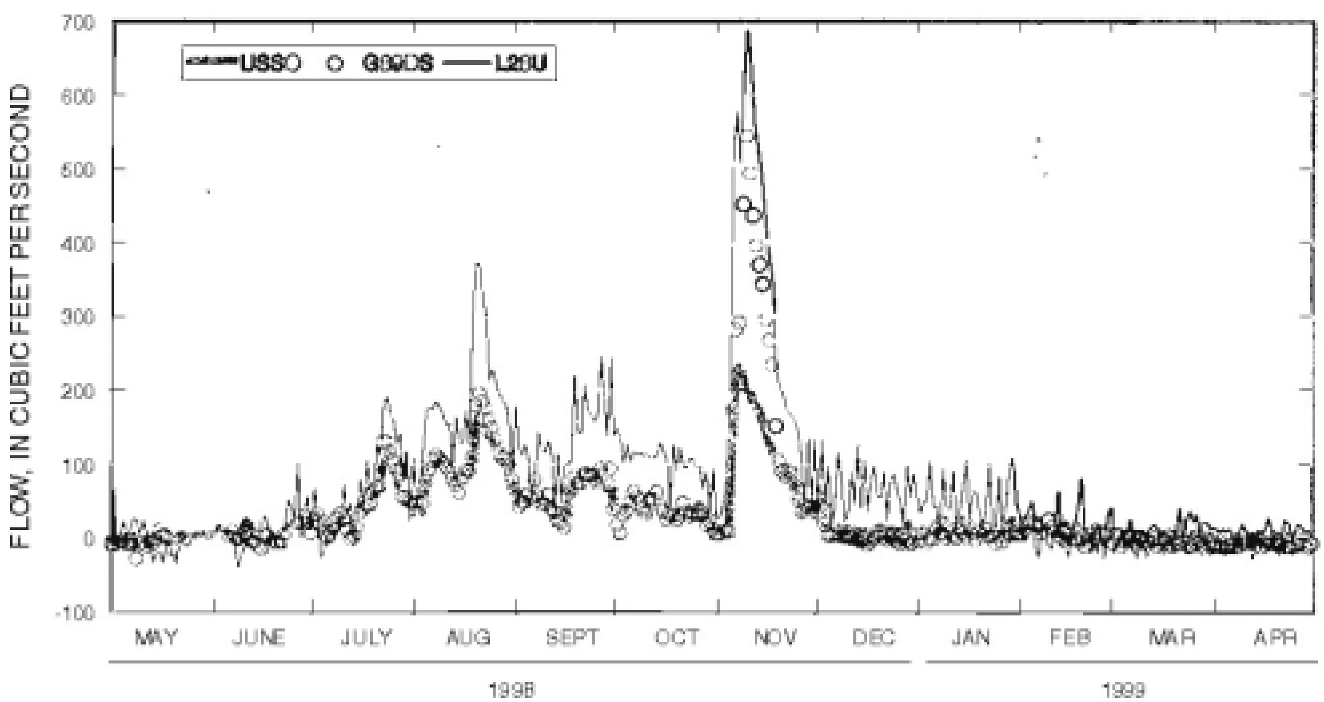


Figure 2. Comparison of L28U flow with G89DS and USSO flows, May 1998 to April 1999. USSO is U.S. Sugar Outflow site.

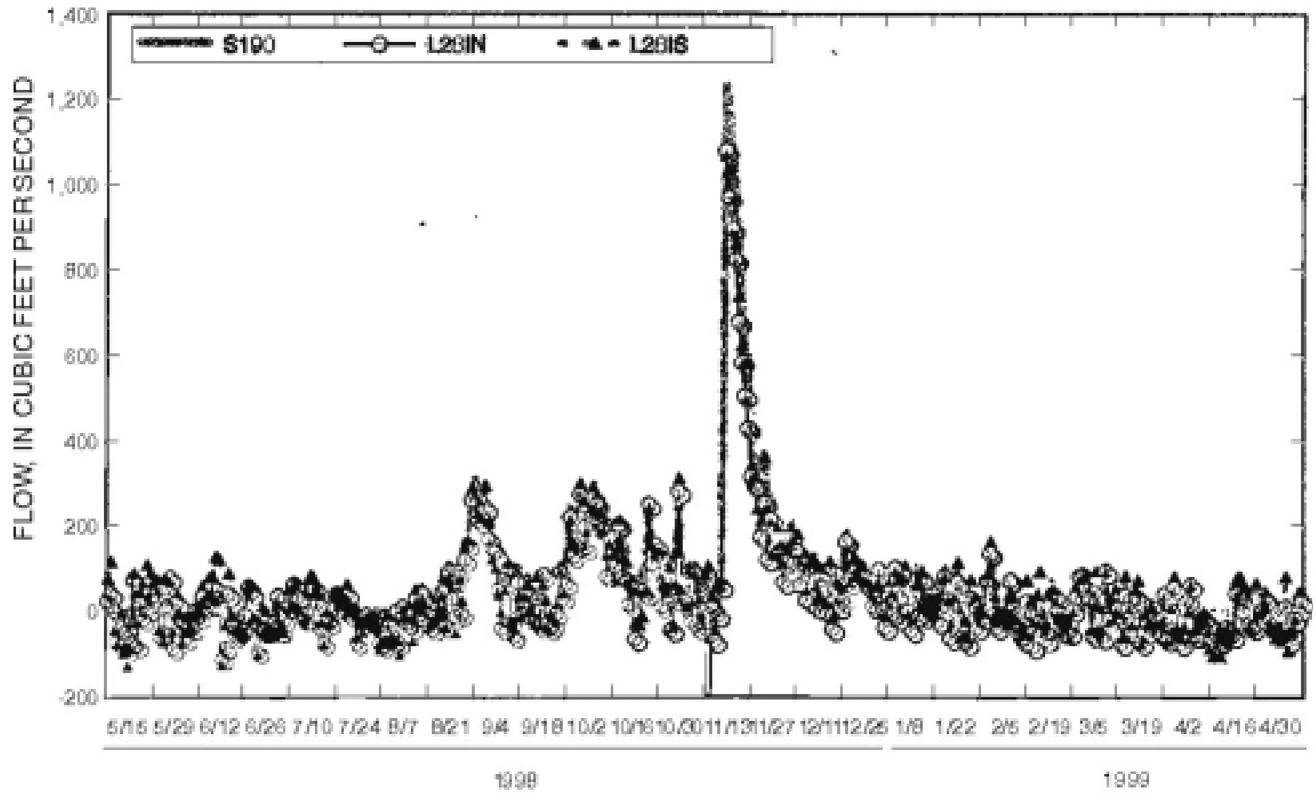


Figure 3. Comparison of L28IN and L2BIS flows with S190 flow, May 1998 to April 1999.

These flows also are being monitored as part of a multiagency effort to calculate nutrient loads in the canals that cross or border Tribal Lands. The SFWMD installed flow-weighted samplers at the gaging sites for nutrient analysis in conjunction with the streamflow monitoring; the flow-weighted samplers have been serviced by the Seminole and Miccosukee Indian Tribes, respectively. Real-time telemetry programming assistance and phosphorus and nitrogen load calculations have been provided by the SFWMD. The nutrient load data from all three sites is used by water managers for resource planning and management.

The implementation of strategically placed streamflow and water-quality gaging sites in the interior of south Florida – in conjunction with four entities to collect, analyze, and distribute useful information to help water managers determine future surface-water flow requirements in the interior canal system – has been a success. Ongoing flow-weighted nutrient loads require accurate flow data collection combined with a highly coordinated nutrient collection and analysis SFWMD/Seminole Working Group. The SFWMD is in the process of documenting the protocol used for collection, computation, and processing of "flow-weighted" nutrient loads in the interior canal system and a future quality assurance/quality control document will be forthcoming. Another future effort is being considered to co-locate an *in situ* side-looking, acoustic Doppler, continuous recording flowmeter with the existing AVM at the L-28IN site to more accurately monitor flows along with the potential ability to provide auxiliary nutrient information at little cost.

A Retrospective and Critical Review of Aquifer Storage and Recovery Sites and Conceptual Frameworks of the Upper Floridan Aquifer in South Florida

By Ronald S. Reese
U.S. Geological Survey, Miami, Florida

Regional aquifer storage and recovery (ASR) in south Florida is proposed as a cost-effective water-supply alternative that can help meet needs of agricultural, municipal, and recreational users and help provide for Everglades ecosystem restoration. In the Comprehensive Everglades Restoration Plan (CERP), about 300 ASR wells are planned in south Florida, and the estimated capacity for each well is 5 million gallons per day during injection and withdrawal, a planned ASR applcation much larger than any yet attempted. ASR technology has been tested and implemented in some areas of south Florida; ASR wells have been constructed at 24 sites in an area that extends southward from Charlotte, DeSoto, Glades, Okeechobee, and St. Lucie Counties, and wells are planned (or are in the permitting process) at five additional sites. A pilot ASR facility currently is under construction by the South Florida Water Management District on the Hillsboro Canal in southeastern Palm Beach County. Three ASR facilities are operational.

Existing and historical ASR sites in south Florida (fig. 1) have mostly been located along the east and west coast. At most of these sites, the recovered water is being used, or is planned to be used, as additional water supply for local municipalities. In the CERP wells, however, will be located in more inland area such as around Lake Okeechobee, in central Palm Beach County, and along the Caloosahatchee River in Lee, Glades, and Hendry Counties. The recovered water will be used for additional purposes, including maintaining water levels in wetland areas. Historical, current, and planned ASR sites are listed in table 1 along with aquifers being used, their status, type of source injection water, and number of wells drilled. The source water planned for the CERP ASR program is untreated or minimally treated ground water or surface water. The injection interval being used at most sites is the Upper Floridan aquifer, which is in the Floridan aquifer system, and is underlain by the middle confining unit and Lower Floridan aquifer.

Few regional investigations of the Floridan aquifer system hydrogeology in south Florida have been conducted, and these studies did not address many of the scientific issues relating to ASR. Lacking a regional ASR framework to aid the decision-making process, ASR well sites in south Florida have been primarily located based on factors such as land availability, source-water quality, and source-water proximity (pre-existing surface-water canal systems or surficial aquifer system well fields). Little effort has been made to link information collected from each existing ASR site and from other historical non-ASR wells into a regional hydrogeologic analysis. Additional tools and data are needed to make informed decisions that incorporate constraining hydrogeologic factors in the placement and construction of ASR facilities in south Florida.

Important hydrogeologic and construction related attributes are being determined for each ASR site, and these attributes are being plotted on maps for the purpose of a comparative analysis of differences between the ASR sites. Hydrogeologic attributes include aquifer transmissivity and degree of confinement, native ground-water salinity, and the structural setting of the site. Construction related attributes include placement of the injection zone relative to the top of the aquifer and the diameter and thickness of the injection zone, which in most cases, is an open hole interval below the final casing. Published hydrogeologic frameworks of the Floridan aquifer system in south Florida are being reviewed and refined in order to relate ASR well sites to a regional scale.

Historical and current data on ASR cycle testing at each site are being assembled, and the recovery efficiency, if not clearly defined or substantiated in a report, will be evaluated. The recovery efficiency will be related to the hydrogeologic and construction related attributes listed above to identify common threads, technical issues, or potential problems that have been encountered and that influence the level of success of ASR. Data collected so far indicate that some important problems are injection zones with a transmissivity that is too high due to fractured dolomite, transmissivity that is too low, ambient ground-water salinity that is too high, and casings that have been set too deep within the aquifer resulting in the loss of injected water. Sites that are located in structural depressions could also be problematic because of loss of injected water due to buoyancy effects.

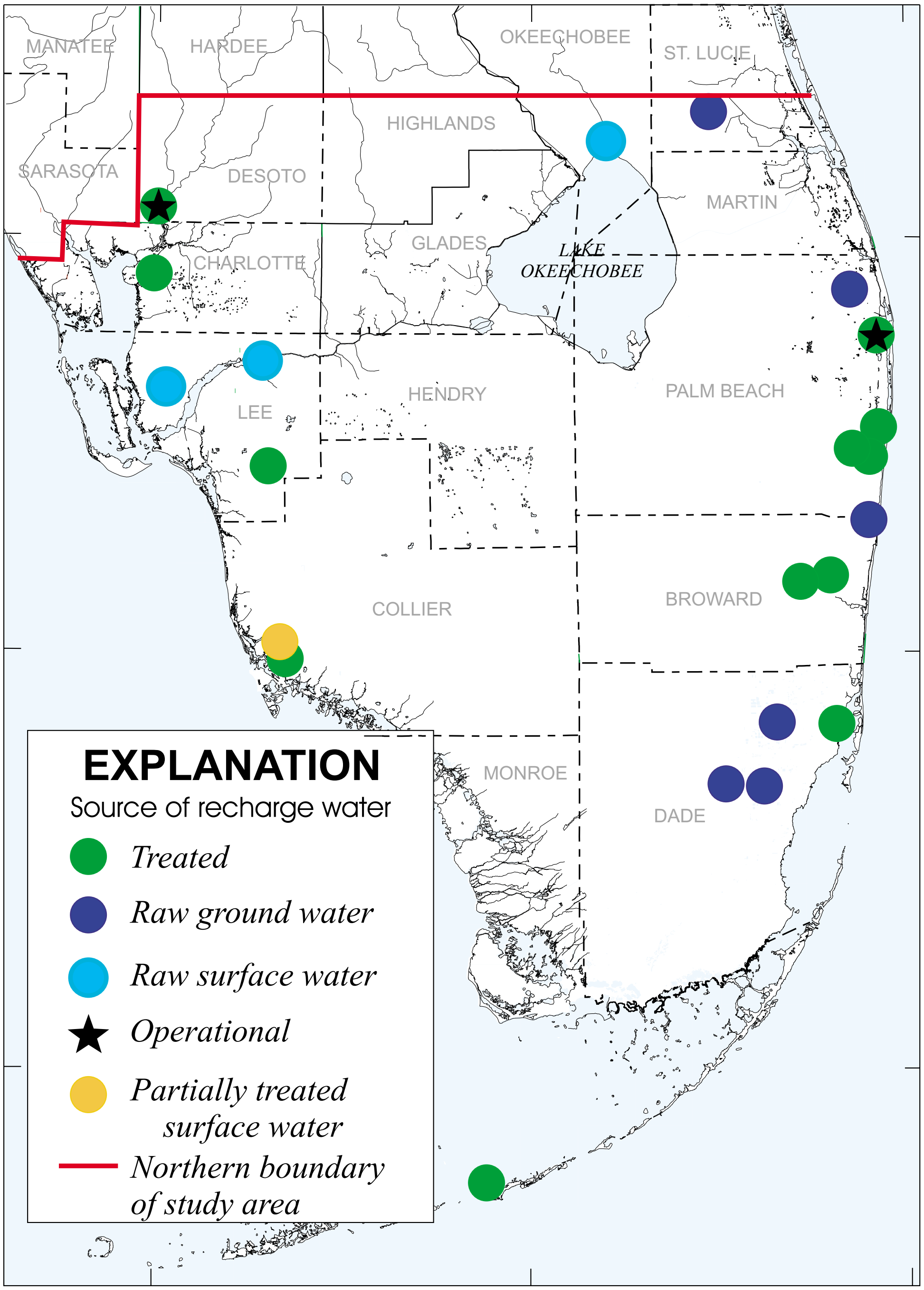


Figure 1. Existing and historical aquifer storage and recovery sites and study areas.

Table 1. Aquifer, storage, and recovery sites in south Florida—historical, current, and planned

[Source water: RGW, raw ground water; RSW, raw surface water; PTSW, partially treated surface water; TDW, treated drinking water (through water plant); RCW, reclaimed water;. ASR, aquifer storage and recovery]

Site name and target zone	County	Status	Source water	No. of injection wells (active and proposed)	No. of monitor wells in the ASR zone
WTP 2A (BCOES) Upper Floridan aquifer	Broward	Operational testing, Request to resume cycle testing 12/99	RGW	1	1
Deerfield Beach Upper Floridan aquifer	Broward	Wells Constructed	TDW	1	1
Fiveash-Ft. Lauderdale Upper Floridan aquifer	Broward	Operational testing to begin 1/99	TDW (future RGW)	1	1
Sunrise-Springtree Upper Floridan aquifer	Broward	Operational testing-request to resume cycle testing 11/99	TDW	1	0
Englewood	Charlotte	Wells constructed	RCW	1	1
Punta Gorda	Charlotte	Wells constructed	TDW	1	2
Collier County Mid-Hawthorn aquifer	Collier	Operating	TDW	1	3
Marco Lakes Upper Floridan aquifer	Collier	Operational testing	PTSW	9	2
Peace River/Manasota (RWSA) Upper Floridan aquifer	DeSoto	Operating	TDW	1	Unknown
Lee County WTP (USGS) Mid-Hawthorn and Upper Floridan aquifer	Lee	Experimental Inactive	Raw and treated SW	1	2
Bonita Springs, Kehl Canal Upper Floridan aquifer	Lee	Construction Permit Issued	TDW	1	
Bonita Springs, San Carlos Estates Upper Floridan aquifer	Lee	Operational testing, cycle 1,1/00	TDW	1	1
Corkscrew WTP Mid-Hawthorn aquifer	Lee	Operational testing	TDW	6	5
Ft. Myers-Winkler Ave.	Lee	Well Contructed	TDW	1	
North Reservoir Upper Floridan aquifer	Lee	Operational testing	TDW	1	1
Olga Upper Floridan aquifer	Lee	Construction complete	TDW	1	2
Hialeah (USGS) Upper Floridan aquifer	Miami-Dade	Experimental Inactive	RGW	1	1
Miami Beach Biscayne aquifer	Miami-Dade	Operational testing	TDW	1	Unknown
Southwest Well Field Upper Floridan aquifer	Miami-Dade	Drilling	RGW	2	
West Well Field Upper Floridan aquifer	Miami-Dade	Operational testing	RGW	3	1
FKAA Marathon Pliocene	Monroe	Operational testing Now inactive	TDW	1	1
FKAA Stock Island Pliocene	Monroe	Inactive. ASR never tested	TDW	1	Unknown
Taylor Creek-Lake Okeechobee (SFWMD) Lower Floridan aquifer	Okee-chobee	Experimental Inactive	RSW	1	1
Boynton Beach Upper Floridan aquifer	Palm Beach	Operating	TDW	1	0
Delray Beach Upper Floridan aquifer	Palm Beach	Operational testing plan, 1/00	TDW	1	0
W. Hillsboro Site 1 (SFWMD) Upper Floridan aquifer	Palm Beach	Experimental Under construction	RGW	1	1
System 3 Upper Floridan aquifer	Palm Beach	Waiting on Permit (LAE) 1/00	TDW (future RGW)	1	1
West Palm Beach Upper Floridan aquifer	Palm Beach	Operational testing	TDW (Interim PTSW, future RSW)_	1	1
St. Lucie (SFWMD) Upper Floridan aquifer	St Lucie	Experimental Inactive	RGW	1	2

Synthesis on the Impact of 20th Century Water-Management and Land-Use Practices on the Coastal Hydrology of Southeastern Florida

By Robert A. Renken
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The urban and agricultural corridor of south Florida lies between the Everglades and water-conservation areas to the west and the Atlantic Ocean to the east.

This area includes eastern Dade, Broward, and Palm Beach Counties and is subject to widely conflicting stresses on the environment. The Shark River Slough, which historically channeled water from the eastern Everglades and moved water to the southwest, is located immediately west of this corridor. A highly controlled water-management system has evolved during this century largely to provide drained land for a rapidly expanding population. Draining of Everglades wetland areas during the last 75 years has provided the opportunity for westward expansion of agricultural, mining, and urban activities. In water-conservation areas that lie to the west of the protective levee system, surface water is impounded partly to sustain an Everglades ecosystem, partly to keep overland sheetflow from moving eastward and flooding urban and agricultural areas, and partly for water supply. In coastal areas of the urban-agricultural corridor, parallel environmental conflicts exist. Coastal residential and urban areas must be drained for flood control; the underlying aquifer system must simultaneously serve as the principal source for water supply and aquifer water levels must be maintained to prevent saltwater intrusion. Changes in pre-development ground-water flow patterns and the associated reduction in ground-water discharge to coastal bays have altered salinity and affected the local ecology.

Saltwater intrusion in the surficial aquifer system is a direct consequence of water-management practices, concurrent agricultural and urban development, and natural drought conditions. The objectives of this synthesis are to: (1) provide a temporal and spatial overview of coastal saltwater intrusion in southeastern Florida; (2) identify the principal factors that control the extent of saltwater intrusion; (3) evaluate long-term trends in ground-water withdrawal rates, ground-water-level change, rainfall, and increases in chloride concentration; and (4) illustrate causal relations between the position of the saltwater interface, water-management practices, and the expansion of agricultural and urban areas. Hydrologic maps and interpretive analyses, land-use and population density maps, and geologic information are being used in combination to illustrate the effect of anthropogenic change during the 20th century on the coastal ground-water hydrology of southeastern Florida. This synthesis provides an overview of long-term water-management practices in southeastern Florida and examines its canal discharge, consumptive water use, water levels within the surficial aquifer system, chloride concentrations, ground-water discharge, and Holocene paleohistory of Florida Bay and Biscayne Bay.

Urban and agricultural growth and land-use change has greatly impacted the ecological health and stability of the Everglades and Biscayne Bay area. A review of 100 years of land use and population changes is being conducted, to illustrate impacts of key historical events such as the development of the Florida East Coast Railroad, the 1920's land boom and bust, Cuban immigration, and post-war development and redevelopment. The population growth has been explosive; in 1900, southeastern Florida included a few small towns that has grown to a modern-day megapolis with almost 4 million inhabitants. Canal construction, designed to drain lands west of the Atlantic Coastal Ridge, has helped to provide the impetus for the westward expansion of agricultural and urban development. Urban areas are encroaching and replacing agricultural areas in Miami-Dade and Palm Beach Counties.

Potentiometric maps indicate that average ground-water levels rose in coastal areas, but have declined in western developed areas between the 1940's and 1990's. Some declines in water levels can be directly attributed to municipal ground-water withdrawals; however, water-level declines over wider areas are a direct result of canal drainage. During that same period of time, canal discharge to the ocean has declined, but coastal canal stage has been increasing, largely as a hedge to impede saltwater intrusion into the major canals and the aquifer. Conversely, canals near the western margin of the urban areas do not exhibit increasing or declining flows. A potential factor in this process is that municipal ground-water withdrawals from the surficial aquifer system in the Miami-Dade, Broward, and Palm Beach tri-County area increased from 85 million gallons per day in 1940 to 756 million gallons per day in 1995. Possible factors that contribute to a decrease in canal discharge to the ocean include: Flow in major canals recharge the surficial aquifer system along the urban reach, and surface-water flow is being rerouted to secondary canals to elevate coastal ground-water levels.

Landward movement of the saltwater interface has been an issue of local and regional concern since the 1940's. Miami-Dade, Broward and southeastern Palm Beach Counties are the areas most affected by saltwater intrusion. In decreasing importance, canal over-drainage, over-pumpage from wells located near the coast, and upconing of relict water are the primary sources of saltwater in the surficial aquifer system.

The marine ecosystem of Biscayne Bay has been profoundly affected over the past 150 years. Significant changes in land and water uses and within the bay, in addition to natural phenomena, have contributed to the deteriorating conditions of its marine ecosystem. Since the early 1900's, freshwater delivery (both ground water and surface water) to Biscayne Bay has been significantly altered both in style (sheetflow to point source) and volume. Water quality has greatly deteriorated with increased nutrient loads, heavy metals, and other pollutants. Dredging and channelization within the bay decreased the water quality by removing natural seagrass beds and increasing turbidity. Recent studies of sediment cores from Biscayne Bay show distinct changes in the marine ecosystem over the past 150 years. Shallow-water marine organisms (foraminifera, ostracodes, and mollusks) are very sensitive to environmental changes such as salinity, temperature, nutrient input, and dissolved oxygen, among others. Changes in the occurrence and abundance of these marine organisms in the sediment cores provide a record of ecosystem change in Biscayne Bay.

The Biscayne Bay ecosystem was different in the early to mid-1850's than it is today. The salinity of the bay was much lower than the normal marine salinities found today. The southern extreme of Biscayne Bay was nearly of fresh-water salinity. The central bay also was lower in salinity, possibly with lowered oxygen or higher organic concentrations in the surficial sediments, which may have had a profound effect on the limited seagrass abundance or density present during that time. The early 1900's recorded the first profound salinity change, reaching close to normal marine salinity, reflected by a significant increase in the abundance of typical Atlantic Continental shelf fauna components. Seagrass indicators became increasingly more abundant from the early 1900's to present time in the central bay. A similar record of ecosystem change is recorded in the coastal region, Manatee Bay, with a significant change in salinity to mesohaline conditions occurring in the early 1900's. Coastal vegetation changes at that time are consistent with marine records, indicating increased salinity conditions by the initial presence of red mangrove in this region. Bay salinity remained relatively stable until the early 1940's when it increased to euhaline and polyhaline conditions, but was subject to broad salinity fluctuations. The occurrence and increasing abundance of epiphytal and macro-algal habitat dwelling organisms indicate a change in substrate conditions and increased seagrass abundance during this time. From the late 1980's to present, a slight salinity decrease in Manatee Bay has been noted, and field observations in this region suggest deteriorating conditions in the health of the seagrasses.

Observations of salinity and seagrass changes in Biscayne Bay over the past 150 years have been consistent with records obtained for Florida Bay. The timing and magnitude of the change are correlative, indicating that the south Florida marine ecosystem has been affected on a broad geographic scale and that the impact of Everglades restoration measures will be as great on Biscayne Bay as it will be on Florida Bay.

Flow Velocities in Wetlands Adjacent to C-111 Canal in South Florida

By Raymond W. Schaffranek and Maria H. Ball
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Wetlands between C-111 canal and the eastern panhandle area of Everglades National Park (ENP) are of particular concern to south Florida ecosystem restoration efforts in that they constitute a major pathway for fresh water to reach nearshore embayments of Florida Bay. Past construction features of the Central and Southern Florida Project are suspected of contributing to the reduction of marsh hydroperiods in the C-111 canal basin and to the development of hypersaline conditions in the subtidal embayments of central and northeast Florida Bay as a consequence of channeled and diminished freshwater flows. Changes in the hydraulic infrastructure and water management operations are being implemented to restore more natural temporal and spatial flow patterns through the wetlands. In 1996 and 1997, spoil mounds along the southwest bank of the C-111 canal between hydraulic-control structures S-18C and S-197 were removed to enable overbank flow from the canal to enhance sheet flow in the wetlands. In September 1997 and 1999, extensive sets of flow-velocity data, basic water-quality parameters, and information on vegetation characteristics were collected in the wetlands adjacent to the canal to determine flow patterns in the wetlands, to analyze canal/wetland flow exchanges, and to support the development of a model for this canal and wetlands ecosystem (Schaffranek, 1996).

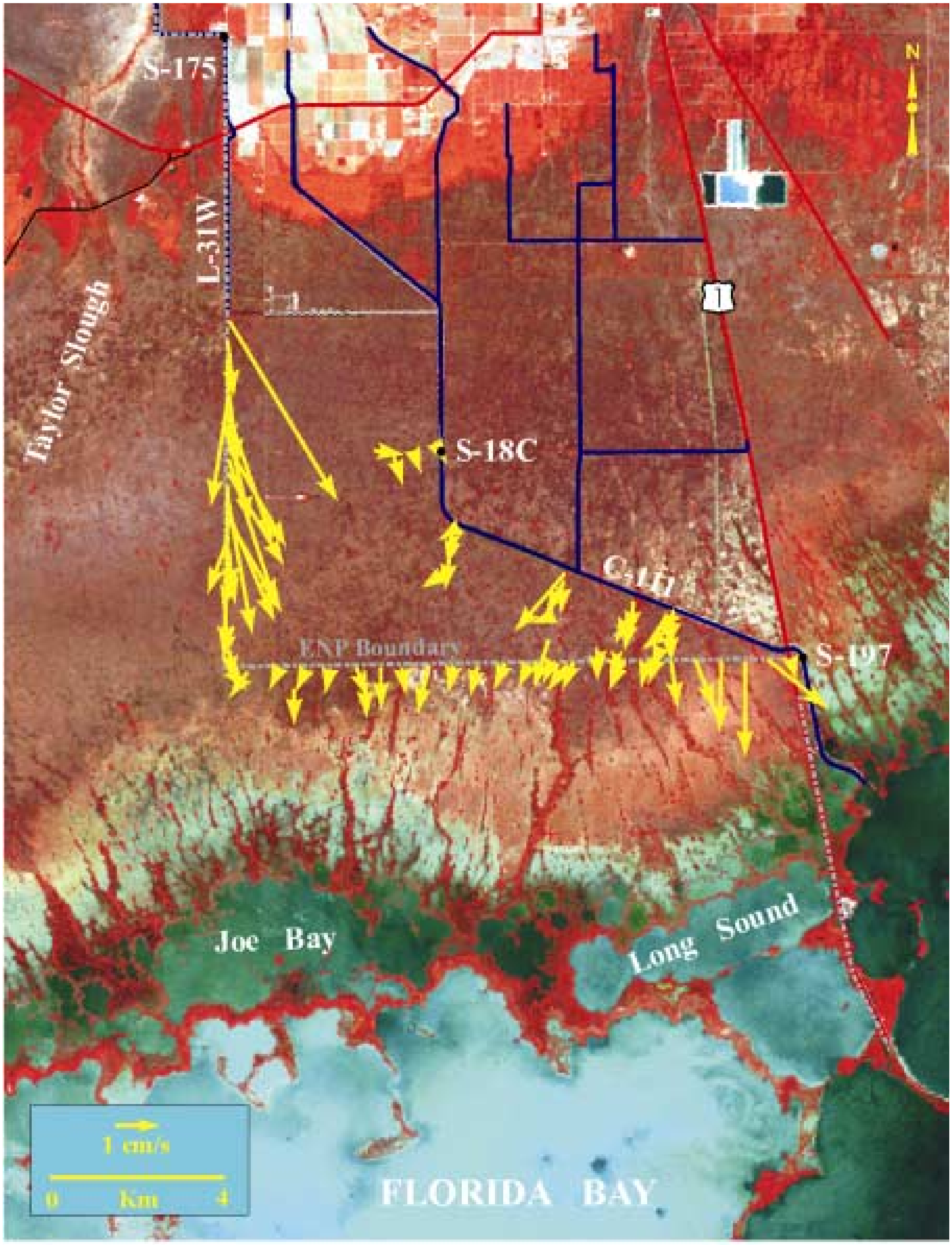
In September 1997, near the conclusion of the spoil removal efforts, flow measurements were made at nine transects spaced at variable intervals along the 8-km overbank segment of the canal. Transects were spaced at variable intervals perpendicular to the canal and extended approximately 2 km into the adjacent wetlands. Measurements were repeated along similar transects in September 1999 and the spatial extent of wetland coverage was expanded to include two new transects—one oriented north-south and the other east-west—along the ENP boundary. These new transects were added to evaluate interbasin exchanges between Taylor Slough and the C-111 canal wetlands and to quantify other potential inflow sources. The north-south transect extended southward from L-31W canal along and parallel to the ENP boundary to the point where the boundary makes a 90° turn eastward. The east-west transect extended eastward from the southern end of the north-south transect along and parallel to the ENP boundary and terminated at the C-111 canal.

Flow velocities were measured using portable SonTek 10-MHz acoustic Doppler velocity (ADV) meters suspended from tripods. The meters were retrofitted with electronic compasses to geodetically reference flow directions to East, North, and Up (ENU) coordinates. The SonTek ADV meter measures flow in a 0.25 cm^3 remote sampling volume to a resolution of 0.1 mm/s (SonTek, 1997). Velocity data were typically collected at 0.2, 0.5, and 0.8 depth fractions, measured from the water surface to the top of the litter layer. At each depth, 2-minute burst samples were taken at a frequency of 10 Hz. Measured ENU velocity components were processed through a series of automated filters and plotted for visual inspection to identify anomalous data (Ball and Schaffranek, 2000). Examination of the component-velocity standard deviation and visual inspection of the plots generally identified suspect data not detected by the automated filters. Anomalous data were eliminated and depth-averaged velocity magnitudes and flow directions were computed and plotted (fig. 1) for subsequent analyses.

Flows in the wetlands adjacent to the C-111 canal overbank area were fairly consistently in south-southwest and south by west directions within and between measurement years averaging 205 and 191 degrees clockwise from magnetic north in 1997 and 1999, respectively. Flow velocities were slightly more variable within years but consistent between years averaging 0.8 and 0.5 cm/s in 1997 and 1999, respectively. In the wetlands adjacent to the canal, velocities were greatest in the immediate vicinity of the regraded spoil mounds, but decreased rapidly and variably away from the canal. The spatial variability of the wetland flow velocities is likely due to the variable influence of overbank flows combined with local effects of the irregular topographic relief, wind effects on the flow, and frictional resistance of the heterogeneous vegetation. Several mangrove-lined channels extend southward from the canal and likely act to convey sheet flow away from the wetlands—additional monitoring is needed to identify sheet versus channel flow differences.

Flow directions measured along the north-south and east-west ENP boundary transects in 1999 averaged 170 and 186 degrees clockwise from magnetic north, respectively, with average magnitudes of 1.9 and 0.7 cm/s. Along the north-south transect, velocities were greatest at the northern end near the L-31W canal outlet, where discharges were high due to the S-332D Pump Test (**http://www.sfwmd.gov/org/erd/webboard/s332dtest.html**) and to releases from the S-175 control structure related to tropical storm Harvey. Higher flow velocities along the north-south boundary indicate a significant inflow into the C-111 canal basin from a north by west direction likely originating from the L-31W canal or eastern Taylor Slough. Along the east-west transect, velocities were greatest near the U.S. Highway 1 end with significant flow toward the eastern part of Long Sound. Flows along the east-west transect from its western end to approximately the midpoint of the C-111 canal overbank area were consistently in the direction of Joe Bay, indicating that Joe Bay is the primary recipient of flows from the upstream part of the overbank segment of the C-111 canal. This indicates that a significant amount of fresh water from C-111 canal and potentially eastern Taylor Slough flows into Joe Bay which supports findings that discharges from Joe Bay are a major source of fresh water for northeastern Florida Bay (Patino, 1999).

Graphical representation of measured flow vectors from September 1999, overlaid on a satellite image for visual inspection, can be found in the What's New page of the Tides and Inflows in the Mangroves of the Everglades (TIME) website (http://time.er.usgs.gov). Unedited velocity data collected during 1997 and 1999 along with associated correlation statistics, signal strength values, water-quality parameters, and vegetation characteristics are available at the South Florida Information Access (SOFIA) website (**http://sofia.usgs.gov/**). Site averaged data summaries, data-quality indicators, and velocity filtering results are available at the SOFIA website and presented in Ball and Schaffranek (2000).



Satellite image courtesy Land Characteristics from Remote Sensing Project, J.W. Jones.

Figure 1. Flow velocities measured in C-111 canal wetlands on September 22-23, 1999.

Quantification of Ground-Water Seepage Beneath Levee 31N, Miami-Dade County, Florida

By Helena Solo-Gabriele and Mark Nemeth
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A method to quantify the exchange of water between surface-water channels and the ground-water aquifer based on the concept of reach transmissivity was evaluated for use in numerical models. Linking ground-water and surface-water models to each other is frequently problematic because the two models use different sets of governing equations; additionally, the time-scale of interest is often significantly longer for ground-water modeling than for surface-water modeling.

Currently, the formulation of the most common method used for leakage calculations assumes vertical flow of water through a low permeability layer at the bottom of the surface-water channel (fig. 1A). The mathematical formulation of this relation is based on Darcy's law and may be expressed as follows:

$$q = \frac{k'}{b'} B(Z - h) \qquad (1)$$

where

- q is leakage to the aquifer from the channel (volume of water per unit channel length per unit time),
- k' is hydraulic conductivity of the low permeability layer of the channel bottom,
- b' is thickness of the low permeability layer of the channel bottom,
- B is top width of the channel,
- Z is surface-water elevation in the channel,
- h is piezometric head directly beneath the channel bed.

In the reach transmissivity leakage relation, the flow resistance is based on the transmissivity of the aquifer, and the reference ground-water head is measured at points located a distance L from the center of the channel (fig. 1B). The mathematical formulation of the reach transmissivity relation is

$$q = \frac{T_R\left(Z - h_R\right)}{L_R - \frac{B}{2}} + \frac{T_L\left(Z - h_L\right)}{L_L - \frac{B}{2}} \qquad (2)$$

where T is the transmissivity of the aquifer and the subscripts L and R designate the left and right sides of the channel, respectively.

Differences between the vertical flow and reach transmissivity relations were examined. The input parameters required for the reach transmissivity relation are easier to obtain from published sources than those required for the vertical flow relation, which must be established through model calibration or site-specific sampling. The reach transmissivity relation also calculates leakage to each side of the channel separately, and its parameters are less dependent on model grid spacing.

The derivation of a form of the reach transmissivity relation that is suitable for use in numerical modeling relies on the following assumptions: steady state conditions, full penetration of the aquifer by the channel, and the Dupuit-Forcheimer assumption. These assumptions may preclude use of the reach transmissivity relation in certain conditions, such as when very short time steps are used in a numerical model. Furthermore, the validity of the Dupuit-Forcheimer assumption requires that ground-water heads used as input to leakage calculations be obtained from locations a significant distance from the edge of the surface-water channel. Despite these restrictions, the reach transmissivity leakage relation is applicable to a wide range of conditions.

Methods were developed to quantify the error associated with use of the reach transmissivity relation to simulate both periodic and aperiodic transient conditions; these methods can be used to evaluate the suitability of the reach transmissivity relation for a particular application. The differences in leakage between fully and partially penetrating channels were examined using a simple MODFLOW model; the results suggest that the assumption of full penetration does not usually introduce significant error. Leakage calculations based on the reach transmissivity relation were compared to measured leakage on the L-31N Canal; differences between the calculated and measured data had approximately the same magnitude as measurement errors in the gaging data. In addition, leakage calculated using the reach transmissivity relation matched the measured data better than leakage calculated using the vertical flow relation.

The equations associated with the reach transmissivity relation were developed in finite-difference form and incorporated into a modified version of MODBRANCH, a numerical flow model that couples a ground-water model (MODFLOW) and surface-water model (BRANCH). The modified program was then tested for three problems with analytical solutions and one problem that had previously been solved with the original version of MODBRANCH. The reach transmissivity relation was judged to have functioned satisfactorily in these tests. Additionally, the modified model required only about 60 percent as many iterations as the original model.

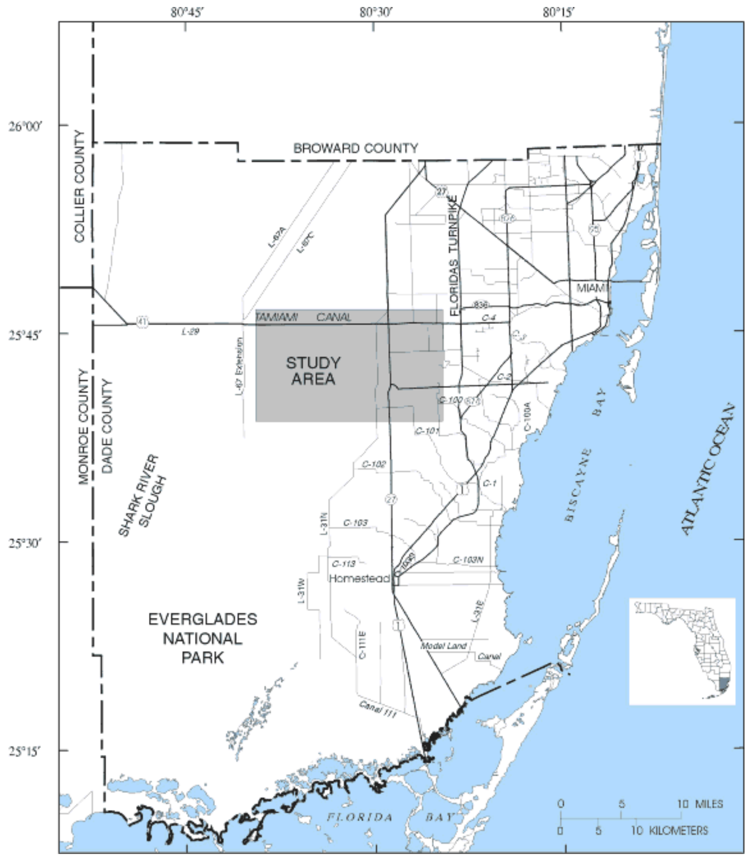


Figure 2. Location of Levee 31N study area.

A model using both the vertical flow and reach transmissivity versions of MODBRANCH was developed for a region centered on Levee 31N that includes wetland areas of the Everglades and nonwetland areas of western Miami (fig. 2). The model grid consisted of 49 rows, 58 columns, and 6 layers. Row and column spacing was 500 ft near the center of the study area and 1,000 ft elsewhere. The top layer was assigned a hydraulic conductivity of 3,000,000 ft/d to simulate the wetlands environment; the hydraulic conductivities of the other layers were based on hydrogeologic properties of the surficial aquifer, which is exceptionally transmissive. Each MODFLOW stress period was 1 day, and each BRANCH stress period was 1 hour. The model was run to simulate transient conditions throughout a calendar year. Ground-water boundary conditions consisted of interpolated heads obtained from monitoring wells and canal gaging stations around the perimeter of the study area; initial conditions were obtained by interpolation, using an inverse distance method, of measured heads at the beginning of the simulation. Evapotranspiration and recharge were obtained from measured data. Potential evapotranspiration was constant throughout the model area, and the extinction depth was specified as 20 ft, based on previous research. Recharge was obtained from three rain gages within the study site and was spatially variable. A 6-mi reach of the L-31N Canal was simulated by BRANCH; boundary conditions consisted of specified head and discharge at the upstream and downstream ends of the channel, respectively.

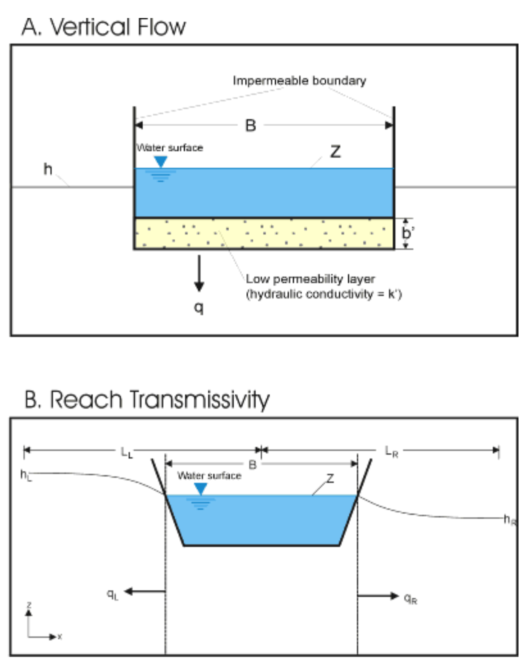


Figure 1. (A) Vertical flow leakage relations, (B) reach transmissivity leakage relations.

The computer model of the Levee 31N area was first run using the existing version of MODBRANCH (with the vertical flow relation) and calibrated by varying aquifer hydraulic conductivity and the vertical flow leakage coefficient. Calibration was based on data from the 1996 calendar year. The model was found to be more sensitive to changes in the aquifer hydraulic conductivity than in the leakage coefficient. The overall transmissivity of the surficial aquifer was calibrated to 1.4 x 10^6 ft/d, and the vertical flow leakage coefficient was established as 0.0009 s^{-1}; both results were similar to those of previous studies.

The version of MODBRANCH modified to use the reach transmissivity relation was then calibrated with the aquifer hydraulic conductivities previously obtained using the vertical flow relation. When aquifer transmissivity is fixed, the reach transmissivity leakage coefficients are only a function of the distance from the channel at which the reference ground-water head is obtained. The best results were obtained when this distance was such that the ground-water head was obtained from the model cells immediately adjacent to the channel, but results were similar for varying distances. Comparisons of modeled and measured ground-water head are presented in figure 3. There were no large differences between results modeled using the vertical flow and reach transmissivity leakage relations. The mean annual modeled ground-water heads differed by only 0.02 ft, and the mean yearly modeled canal discharges varied less than 1.0 ft^3/s. The vertical flow and reach transmissivity models' output provided coefficients of determination (R^2) values within 0.03 of one another for mean ground-water head, canal stage, and canal discharge within the study area. The reach transmissivity version of MODBRANCH, however, reached a solution in about 40 percent fewer iterations.

An estimation of seepage beneath Levee 31N was obtained by summing the MODFLOW cell-by-cell flow terms for all layers of model cells directly west of the levee. These values were converted to a seepage rate per foot of distance along the levee, yielding mean values of 198.9 ft^3/s and 179.1 ft^3/s per foot of levee for 1996 and 1997, respectively.

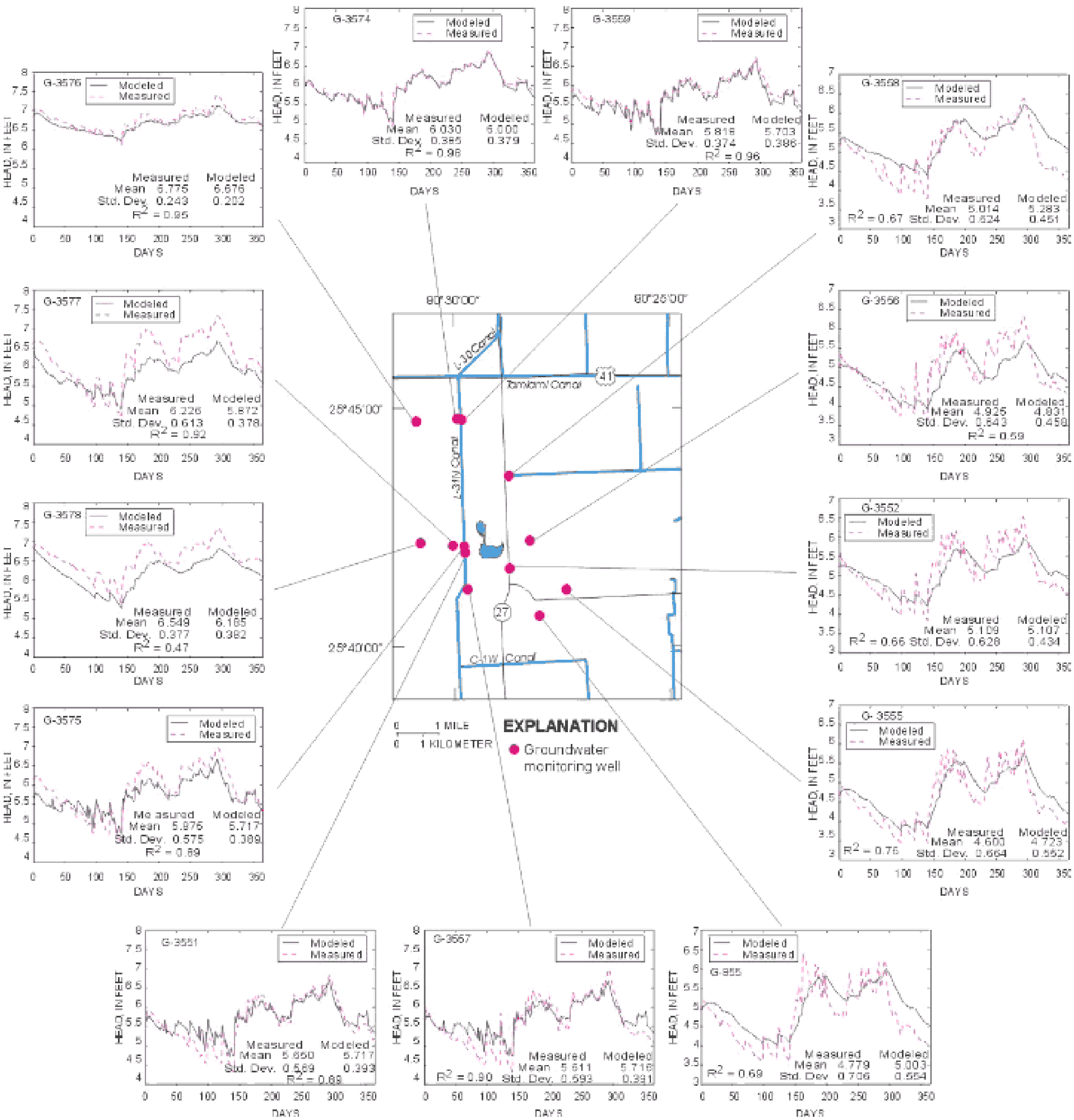


Figure 3. Comparison of measured ground-water heads and ground-water heads modeled using the reach transmissivity version of MODFLOW, 1996 data.

Seepage Beneath Levee 30, Miami-Dade County, Florida

By Roy S. Sonenshein
U.S. Geological Survey, Miami, Florida

In 1948, the United States Congress authorized the Central and Southern Florida Flood Control Project (currently managed by the South Florida Water Management District) in response to catastrophic floods that had occurred in south Florida. This enormous undertaking resulted in the construction of levees, canal networks, pumping stations, and water-conservation areas (fig. 1) to provide adequate control of water levels and surface-water routing. The initial effort established an interconnected network of levees and adjacent canals from central Palm Beach County to southern Miami-Dade County. This 80-mile long network of levees and borrow canals constitutes the eastern limit of the water-conservation areas and prevents Everglades overland sheetflow from reaching the developed areas to the east. This network includes the 14-mile long Levee 30 and adjacent canal in central Miami-Dade County. Completed in 1954, Levee 30 is part of the eastern boundary of Water Conservation Area 3B.

Determining the volume of water seeping from the water-conservation areas to the underlying aquifers is important in managing water levels in the conservation areas and freshwater deliveries to Everglades National Park. From Water Conservation Area 3B, water seeps into the Biscayne aquifer and flows relatively fast (due to high permeability of the aquifer) toward the urban and agricultural areas to the east. Ground water is also discharged to the canal along the eastern part of Levee 30. The stage in the canal, which affects the rate of discharge, is controlled by structures at the northern and southern ends of the canal. This seepage to the aquifer and canal discharge of water are critical for water-supply wells to the east and for preventing saltwater intrusion. However, lowered ground-water levels to the east have resulted in higher ground-water seepage and canal discharge, reducing surface-water flows to the south in the water-conservation area. The altering of historical flow directions and water-level durations has adversely affected parts of the Everglades ecosystem. Water managers want to restore predevelopment flow conditions and keep this ecosystem viable, while also providing for urban and agricultural needs.

A two-dimensional, cross-sectional, finite-difference, ground-water flow model and a simple application of Darcy's law were used to quantify ground-water flow from the wetland beneath Levee 30. Geologic and geophysical data, vertical seepage data from the wetland, canal discharge data, ground-water-level data, and surface-water stage data collected during 1995 and 1996 were used to develop boundary conditions and to calibrate the ground-water flow model. These data were also used as input for the application of Darcy's law.

Vertical seepage data (fig. 2) indicated that water from the wetland infiltrated the subsurface near Levee 30 at rates ranging from approximately 0.03 to 0.25 foot per day, with the gates at the structures in Levee 30 canal closed. During the same period, stage differences between the wetland (Water Conservation Area 3B) and Levee 30 canal ranged from approximately 0.10 to 1.25 feet (fig. 3). A layer of low-permeability limestone, located 7 to 10 feet below land surface, restricts vertical flow between the surface water in the wetland and the ground water. Based on measured water-level data, ground-water flow appears to be generally horizontal, except in the immediate vicinity of the canal. The increase in canal flow rate along a 2-mile reach of the Levee 30 canal ranged from approximately 9 to 23 cubic feet per second per mile (fig. 2) and can be primarily attributed to ground-water inflow. Flow rates in Levee 30 canal were greatest when the gates at the control structures were open.

The ground-water flow model data were compared with the measured ground-water heads and vertical seepage from the wetland. Estimating the horizontal ground-water flow rate beneath Levee 30 was difficult, owing to the uncertainty in the horizontal hydraulic conductivity of the main flow zone of the Biscayne aquifer. Measurements of ground-water flows into Levee 30 canal, a significant component of the water budget, were also uncertain, which lessened the ability to validate the model results. Because of vertical ground-water flows near Levee 30 canal and a very low hydraulic gradient east of the canal, a simplified Darcian approach does not accurately estimate the horizontal ground-water flow rate. Horizontal ground-water flow rates simulated with the ground-water flow model (for a 60-foot deep by 1-foot wide section of the Biscayne aquifer) ranged from approximately 150 to 450 cubic feet per day west of Levee 30 and from approximately 15 to 170 cubic feet per day east of Levee 30 canal. Vertical seepage from the wetlands within 500 feet of Levee 30 generally accounted for 10 to 15 percent of the total horizontal flow beneath the levee. Horizontal ground-water flow was highest during the wet-season simulations and when the gates at the control structures were open.

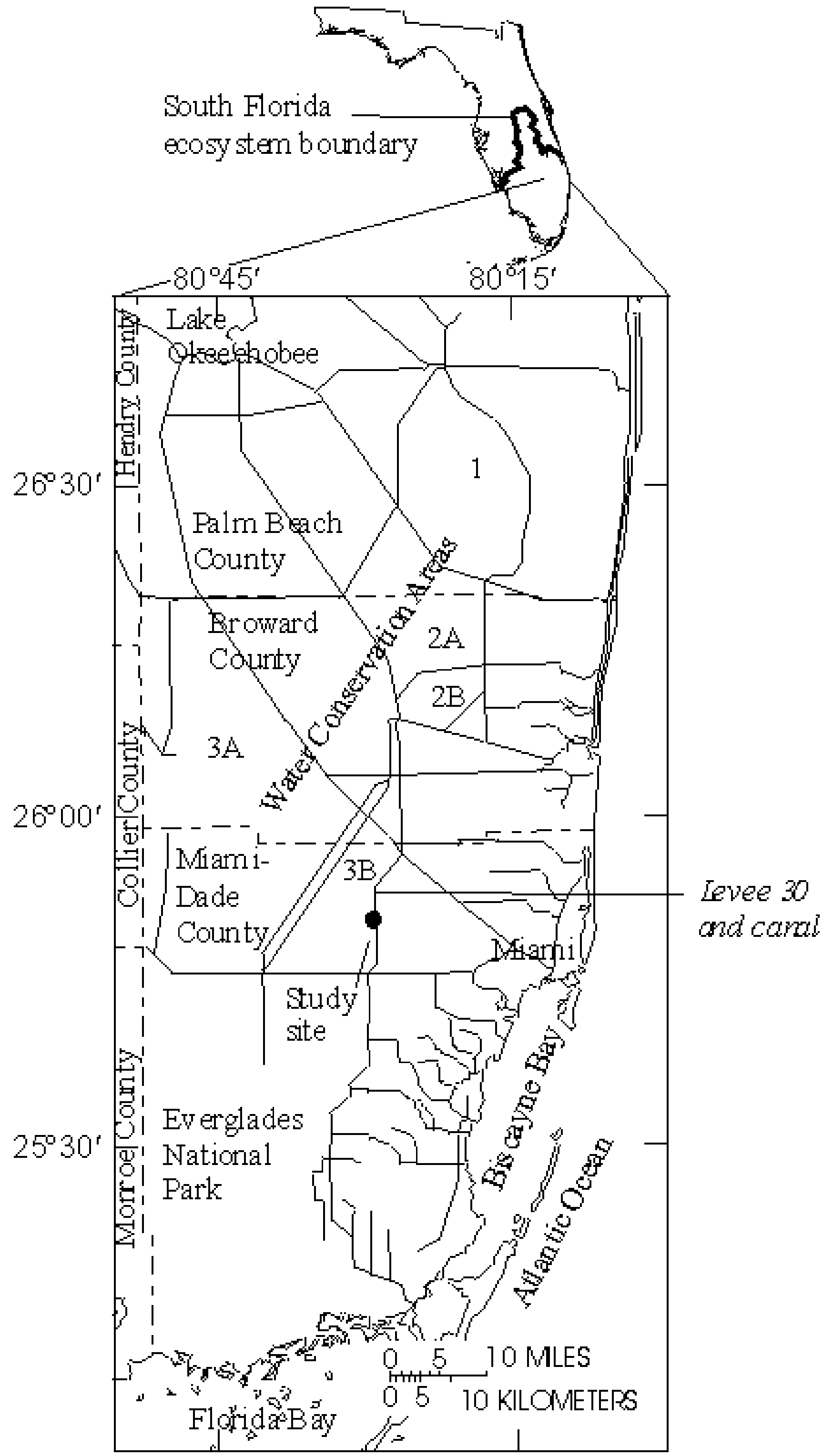


Figure 1. Southeastern Florida showing water-conservation areas, primary canals, and location of study site.

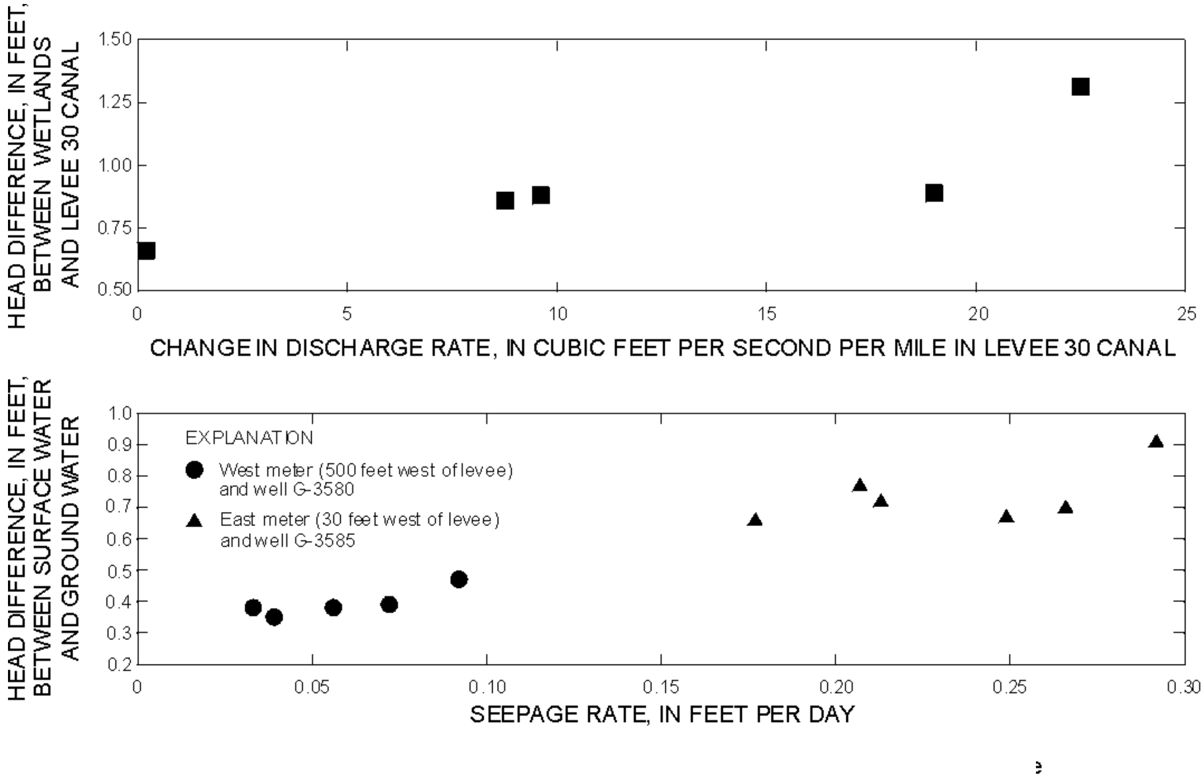


Figure 2. Relations between head difference and change in discharge rate and between head difference and seepage rate.

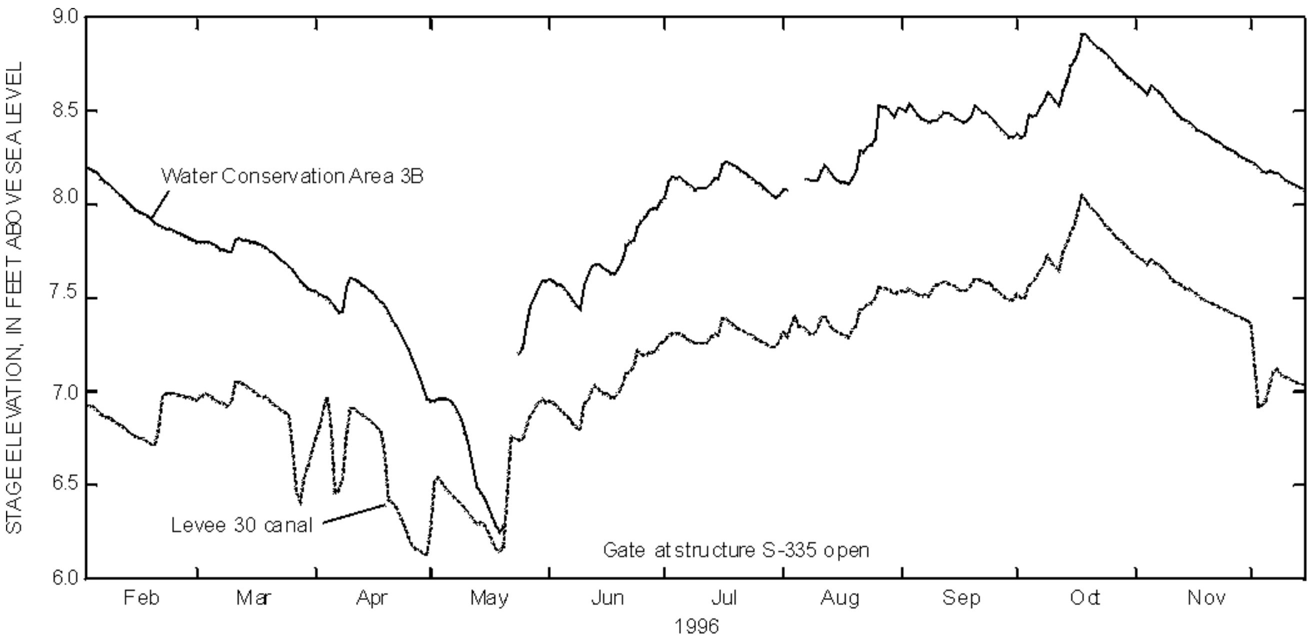


Figure 3. Stage elevation and gate openings from February to December 1996.

Development of Numerical Tools for Integrating Wetland Hydrologic Processes: SICS and TIME

By Eric D. Swain

U.S. Geological Survey, Miami, Florida

An objective of the U. S. Geological Survey (USGS) Place-Based Studies (PBS) Program in south Florida is to develop accurate and reliable tools for simulating the hydrology of wetlands. Such tools are necessary to expand the capabilities of regional flow simulations, which are used for developing the Comprehensive Everglades Restoration Plan (CERP). Reliable detailed information is required to design public works needed to implement CERP concepts and to assure that these public works all function harmoniously to achieve the overall restoration goal, to "get the water right."

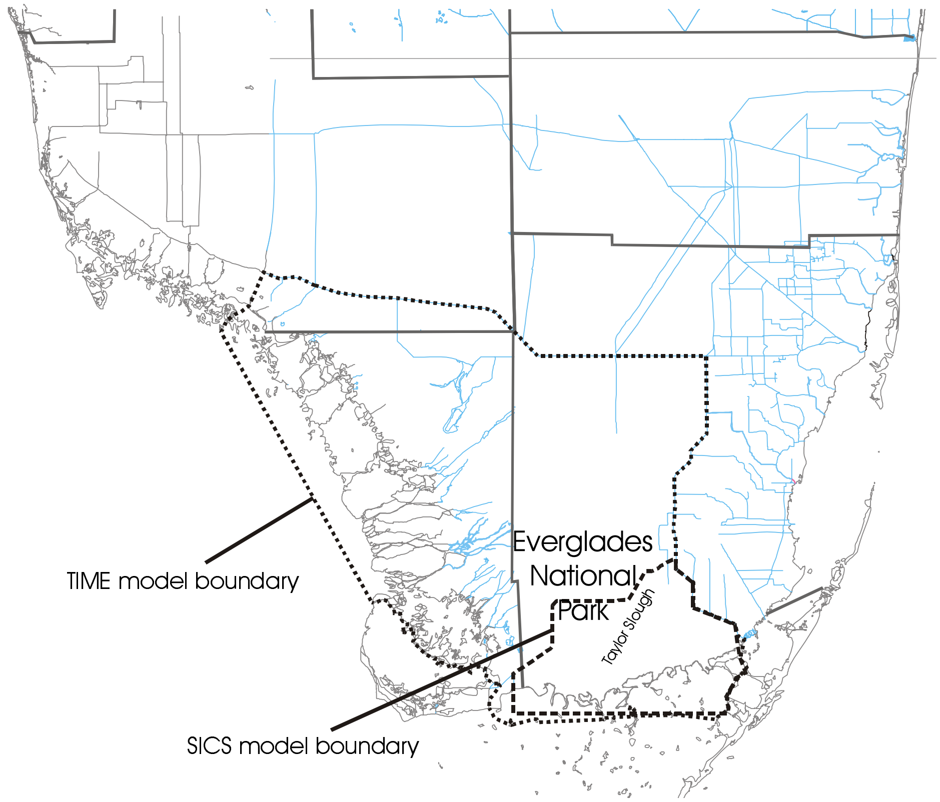


Figure 1. Boundaries for the Southern Inland and Coastal Systems (SICS) and Tides and Inflows in the Mangroves of the Everglades (TIME) models.

To achieve this objective, the USGS has initially focused on development of a dynamic wetland flow model that incorporates accurate land-surface elevations, all principal water-budget components (including precipitation and evapotranspiration) as well as all forces that significantly effect water flow (including vegetative flow resistance and wind drag on the water surface). Wide-ranging process-study and data-collection activities have also been undertaken on these and other parameters with the objective of eliminating as much subjectivity and empiricism as possible in the model-development process. The result of this intensive effort is the Southern Inland and Coastal Systems (SICS) model of the Taylor Slough region of Everglades National Park (fig 1). This area was chosen for initial model application because it is very representative of south Florida wetland settings; has a limited spatial extent; reasonably well-defined boundaries; and for its accessibility. Data-collection for model verification, research activities, and field parameter measurements could all be undertaken within reasonable time and cost constraints.

To minimize subjectivity in the SICS model calibration process, and thereby raise the level of confidence in model reliability, numerous process studies were undertaken to supply model input data sets and nearly eliminate the need for adjustment of empirical coefficients to obtain calibration. Additional studies included an investigation of evapotranspiration in various wetland environments, which indicated that it is possible to regionally define the Priestly-Taylor α coefficient as a function of solar radiation and water depth. Using this formulation of α and a least squares fit of α, water depth, and solar radiation to field measured evapotranspiration, the SICS model computes cell-by-cell evapotranspiration rates using only regional solar radiation data as input. Although approximated by the least squares fit, this computation of evapotranspiration provides a robust and practical method for defining an important parameter that can be difficult to quantify.

The frictional resistance coefficient is a crucial surface-water parameter that usually is estimated and adjusted in the calibration process. This is because little real data usually exists to determine friction effects. However, in the SICS model area, where frictional resistance in wetland flow is a function of vegetation type, airborne and ground methods were used to delineate vegetation types and density in the study area. Another study used a laboratory flume and field measurements to relate vegetation type to frictional resistance. Thus, frictional resistance terms are directly defined spatially in the model without need for adjustment. Through the variety of vegetation types, the average Manning's *n* values range from 0.38 to 0.46 for typical flow depths.

Because the large-scale topography is flat, small variations in land-surface elevation can substantially affect the wetlands flow regime. An extensive data set of land- surface elevations was collected in the SICS area by the U.S. Geological Survey. Because land based surveying is difficult in wetland terrain, helicopter-borne methods were used. Reproducibility within several centimeters was shown for this application.

Additional research projects have yielded data for wind-friction effects on flow, distributions of ground-water inflows, salinity boundaries, coastal creek outflows, and wetland flow velocities. Using this information, the model performed well in the initial simulation, successfully matching measured coastal creek flows and unit discharges measured by mobile velocity meters in the wetlands. This success indicates that the input parameters developed from the process studies were probably accurate and correctly defined their hydrodynamic effects.

A more extensive simulation indicated the ability to match measured water levels at stations in the wetlands; matching within 0.3 foot most of the time. An uncertainty analysis was performed, and the coastal creek frictional resistances were identified as having the least certainty, followed by wind friction terms and ground-water inflows. These findings have motivated further efforts that include; multiple stage and flow stations on Taylor River to compute the creek frictional coefficient, laboratory research on wind friction in wetlands with emergent vegetation, and coupling of the vertically averaged, dynamic, two-dimensional surface-water code SWIFT2D with the ground-water flow and variable-density transport model SEAWAT.

The SICS model is useful for testing management scenarios for restoration. Figure 2 shows the model-produced effects of increasing flow at Taylor Slough Bridge by 50 percent. The model results indicate that the volumes from local rainfall have a greater effect on water levels than do flows at Taylor Slough Bridge. For this particular scenario, the effects of Taylor Slough Bridge flows on water levels are only significant in the northern areas, where there is a noticeable shift in the location of the 1.0-foot water-level contour (fig. 2). To develop a model for observing long-term phenomena, a simulation with a 2-year duration was created. This time span allows: (1) adequate output data to supply water-level data for the Across Trophic Levels System Simulation (ATLSS) model of biological processes in the Everglades; and (2) improved tracking of waters entering the study area to their destinations.

Although results of the initial SICS modeling efforts are very encouraging, an important limitation exists in that interactions between ground-water and surface-water were approximated. These interactions are important even in areas remote from drainage features and canals. Therefore, these processes were incorporated into SICS via the explicit coupling of SWIFT2D with SEAWAT, which allows for density-dependent transport of constituents. This coupled model is referred to as Flow and Transport Linked Overland-Aquifer Density-Dependent Simulator (FTLOADDS); it simulates flow and salinity exchange between the surface water and ground water.

FTLOADDS will also be used for the Tides and Inflows to the Mangroves of the Everglades (TIME) model, which covers essentially all the non-urban area south of Tamiami Trail extending to the western coast (fig. 1). The western areas have received far less field study and hydrologic data collection than the SICS study area. New data collection for the western area includes: Continuous acoustic measurements of coastal flows and wetland flow velocity, airborne mapping of topography, and collection of ground-water levels and salinity. The reliable hydrodynamic simulation of surface-water and ground-water flow and transport in the major part of Everglades National Park and part of Big Cypress National Park, using the TIME model, is important to evaluate potential impacts of restoration alternatives. This larger simulation area also is more useful as a source of input to the ATLSS model. The ground-water/surface-water coupling created for the SICS model and the expanded model area and data collection effort for the TIME model will result in an important numerical tool for answering restoration questions. It will allow resource managers and planners to examine the effect of restoration alternatives with greater confidence prior to expensive physical and operational changes to the water management system.

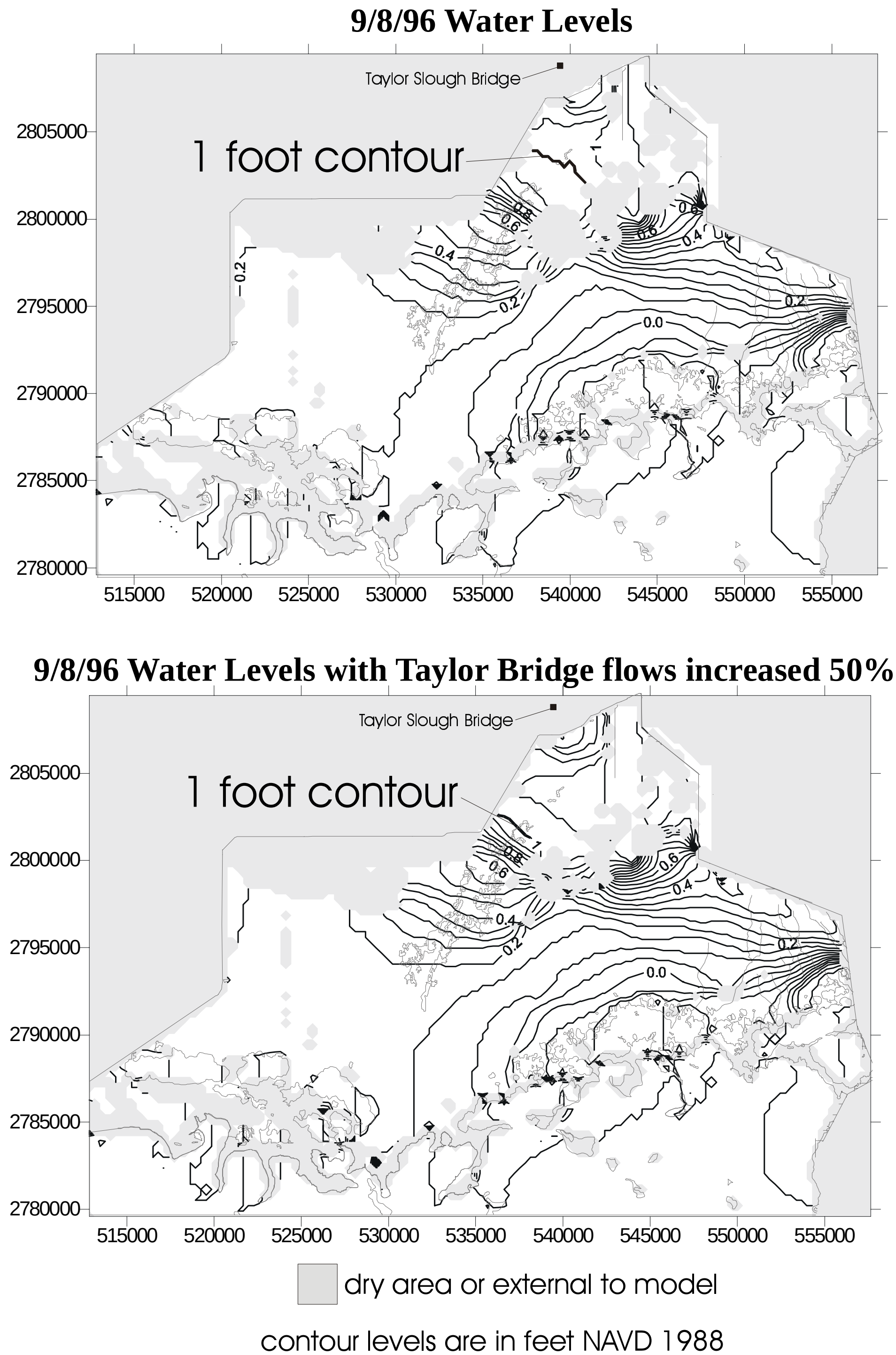
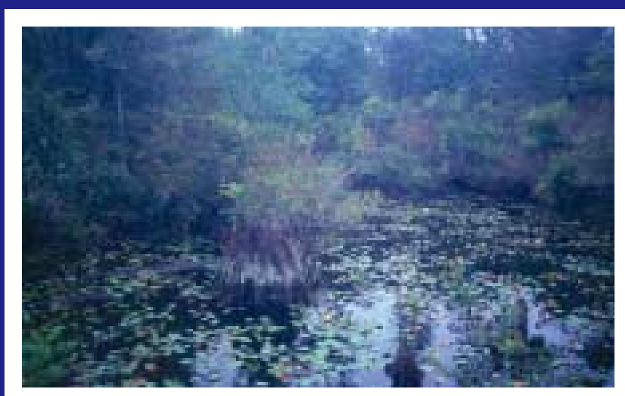


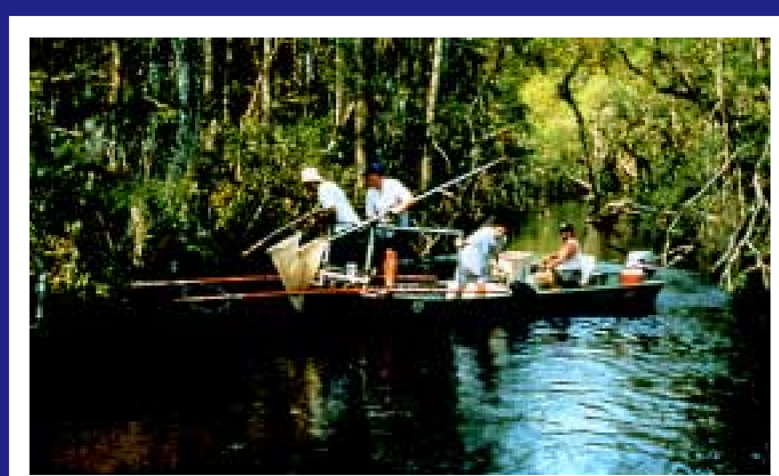
Figure 2. Effects on water levels of increasing inflows at Taylor Slough Bridge.





Section II

Get the Water Quality Right

Contents

Section II: Get the Water Quality Right

Interactions Between Dissolved Organic Matter and Mercury

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Effective management strategies for mitigating mercury (Hg) contamination of game fish in South Florida require understanding of the factors and processes resulting in the transport and controlling the reactivity and bioaccumulation of Hg in the Everglades. Our project focuses on the effect of dissolved organic matter (DOM) on the reactivity of Hg in the Everglades. DOM reactivity with Hg is especially important in South Florida because the high production of organic matter in peat soils and wetlands results in large DOM concentrations in surface water and shallow ground water systems in the region. The findings of our project are important to consider in designing remediation strategies. Factors such as
vegetation and hydrology, for instance, may be very important in controlling both DOM and Hg reactivity. In addition, our research efforts to study distribution of Hg between DOM and particulate organic matter, and the determination of Hg-DOM binding constants are critical for adequate modeling of Hg in the Everglades.

Our research is driven by the hypothesis that the chemistry and structural characteristics of the DOM in the Everglades strongly influence the processes that control Hg cycling and bioavailability in the environment. Specific ultraviolet absorbance (SUVA) measurements, in combination with DOC and DOC fractionation analyses using XAD resins, were used to determine both the amount and nature of DOC along a north-south transect (approximately 40 miles). Samples collected in the northern part of the transect had higher DOC concentrations, were more aromatic, and had a greater amount of hydrophobic acids and hydrophobic neutrals than samples collected further south. In addition, porewaters were found to contain greater DOC concentrations than overlying surface waters. The porewaters in the eutrophic areas to the north were found to contain the highest DOC concentrations. DOC concentrations and SUVA were lower in those areas with higher concentrations of methylmercury. Our field studies have shown that the amount and nature of DOM in the Everglades is dependent on the dominant vegetation types, hydroperiod, and interactions of surface water with peat porewaters. For instance, in areas were water migrates to the surface through the peat, the DOM was found to be more aromatic and contain greater sulfur content compared to samples were surface water was lost to the subsurface.

The speciation of Hg(II) in aquatic systems depends, in large part, on pH, DOM concentration, the concentrations of inorganic ligands, especially sulfide, and the distribution of Hg(II) between dissolved and particulate phases. The hydrophobic acid fraction (HPOA), hydrophilic acid fraction (HPIA), fulvic acid and humic acid were isolated from surface waters along the transect using XAD resins. These isolates and whole water samples were used to study interactions of DOM with Hg in cinnabar (HgS) dissolution and precipitation experiments under a range of pH and concentration conditions. In addition, interactions of Hg with DOM were studied using an ion-exchange technique designed to yield information on Hg-DOM binding constants. In each of these studies, organic matter from the northern, eutrophic field sites interacted more strongly than did samples from the southern part of the transect. These isolates were more aromatic and contained greater amounts of reduced sulfur than other samples studied.

Cinnabar is a relatively insoluble solid (log K_{sp} = -52.4) under most environmental conditions. In the presence of DOM, particularly the humic fractions (HPOA, humic acid, and fulvic acid), a significant amount of Hg (up to 1.7 μM/mg C) was released from cinnabar suggesting strong interactions. The amount of Hg dissolved by various fractions of organic matter followed the order: humic acid > HPOA ≅ fulvic acid >> HPIA. The hydrophobic and hydrophilic neutral fractions dissolved insignificant quantities of Hg from cinnabar. In model compound studies, cysteine and thioglycolic acid dissolved small amounts of Hg from the cinnabar surface, while acetate, citrate, and EDTA dissolved no detectable Hg. There was a positive correlation (R^2 = 0.84) between the amount of Hg released and the aromatic carbon content (determined by ^{13}C-NMR) of the DOM.

Conversely, precipitation and aggregation of metacinnabar (black HgS) was inhibited in the presence of low concentrations (≤3 mg C/L) of DOM isolated from the Florida Everglades. At low Hg concentrations ($\leq 5x10^{-8}$ M), DOM completely prevented the precipitation of metacinnabar. Organic matter rich in aromatic moieties was more reactive with colloidal and particulate HgS. HPOA, humic and fulvic acids inhibited aggregation better than HPIA. Chloride, acetate, salicylate, EDTA, and cysteine did not inhibit the precipitation or aggregation of metacinnabar. The interactions of DOM with HgS in these experiments appear to be the result of strong DOM-Hg binding and colloidal stabilization.

The strength of DOM – Hg binding interactions was investigated using competitive binding on ion-exchange resins. We compared the distribution ratios for mercury between the resin and water ($[Hg_{resin}]/[Hg_{soln}]$) in the presence of organic matter isolates and several inorganic (chloride, bromide) and organic (citric, EDTA, thioglycolic acid) ligands with known Hg-ligand stability constants. The distribution ratio is inversely related to the binding strength between the ligand and Hg. The distribution ratios determined in the presence of the HPOA isolates were comparable to those obtained for the most strongly binding ligand, thioglycolic acid ($\beta=10^{30}$) suggesting similar reduced sulfur binding sites in both. The HPOA isolates bound mercury more strongly than the HPIA fraction with the samples from the northern sites binding most strongly.

Finally, DOM also was found to influence the binding of Hg(II) to two Everglades peat samples. This is significant because it is hypothesized that dissolved Hg is more bioavailable than particulate bound Hg. Again, the HPOA isolate from the northern, eutrophic site was more effective at competing with the peat for Hg(II). Our studies have demonstrated that the chemical composition of the DOM, especially aromatic carbon and reduced sulfur functional group content, is
important in controlling DOM interactions with Hg(II). These interactions are important factors controlling both bioavailability and photochemical reactivity of Hg in the Everglades.

Spatial Changes in Redox Conditions and Food Web Relations at Low and High Nutrient Sites in the Everglades

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A clear understanding of the aquatic food web is essential for determining the entry points and subsequent biomagnification pathways of contaminants such as methylmercury (MeHg) up the food chain. The isotopic compositions of sediment, plant, insect, and fish samples collected at several hundred sites in the Everglades show strong spatial patterns on a landscape scale. Study findings suggest that biogeochemical processes (such as denitrification, sulfate reduction, photosynthesis, respiration, and methane production/oxidation) control the isotopic compositions of dissolved nutrients, and that the local isotopic compositions of biota then reflect those of the nutrients utilized, as modified by trophic fractionations and other factors. In particular, areas dominated by sulfate reduction, which often correlate with high methyl mercury contents, appear to be “labeled” by the carbon (C), nitrate (N), and especially the sulfer (S) isotopic compositions of organisms. The temporal and spatial isotopic patterns caused by environmental conditions must be “subtracted” from the biota isotopic compositions before spatial and temporal changes in trophic relations can be determined.

The traditional method of food web investigation focused on the determination of gut contents (literally, "who ate what"), and is still used today. More recently, stable C, N, and S isotope analyses of plants and animals have been used to establish relative trophic levels among various organisms. At each ascending trophic level (from prey to predator), there is an increase in the ^{13}C content ($\delta^{13}C$ value) and ^{15}N content ($\delta^{15}N$ value) of the organism due to selective metabolic loss of ^{12}C and ^{14}N during food assimilation and growth (fig. 1). Thus, an organism is typically enriched in ^{13}C and ^{15}N relative to its diet by 1 to 3 parts-per-thousand. There appears to be little or no enrichment in ^{34}S with increasing trophic level.

The average $\delta^{15}N$ and $\delta^{13}C$ values of selected fish have been normalized to the compositions of mosquitofish, an important indicator species, to allow direct comparisons of samples collected at different sites and times (fig. 2). Normalization is accomplished by subtracting the average isotopic composition of mosquitofish from the average isotopic composition of the organism of interest, collected at the same site and date. The $\delta^{15}N$ values are in good agreement with suspected trophic positions; primary producers have lower values than herbivores, while omnivores and carnivores have successively higher values. In contrast, the $\delta^{13}C$ values of algae, invertebrates, and fish show considerable variability with little or no consistent increase in $\delta^{13}C$ with increasing trophic level. Hence, bulk carbon isotopes are not very useful for determining trophic position. The generally high $\delta^{13}C$ values of the macrophytes (for example, lily pads, sawgrass) are inconsistent with their being a major food source in most locations.

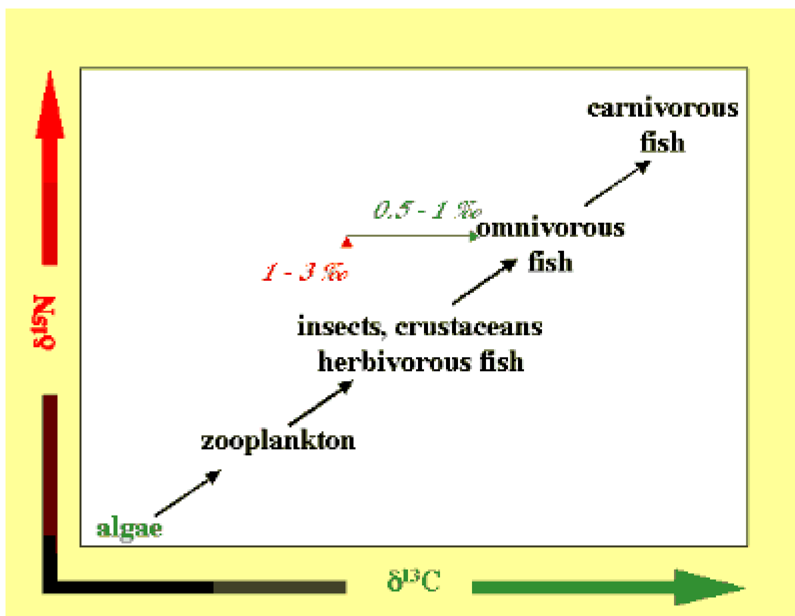

Figure 1. The $\delta^{13}C$ and $\delta^{15}N$ of organisms increase with increasing trophic level.

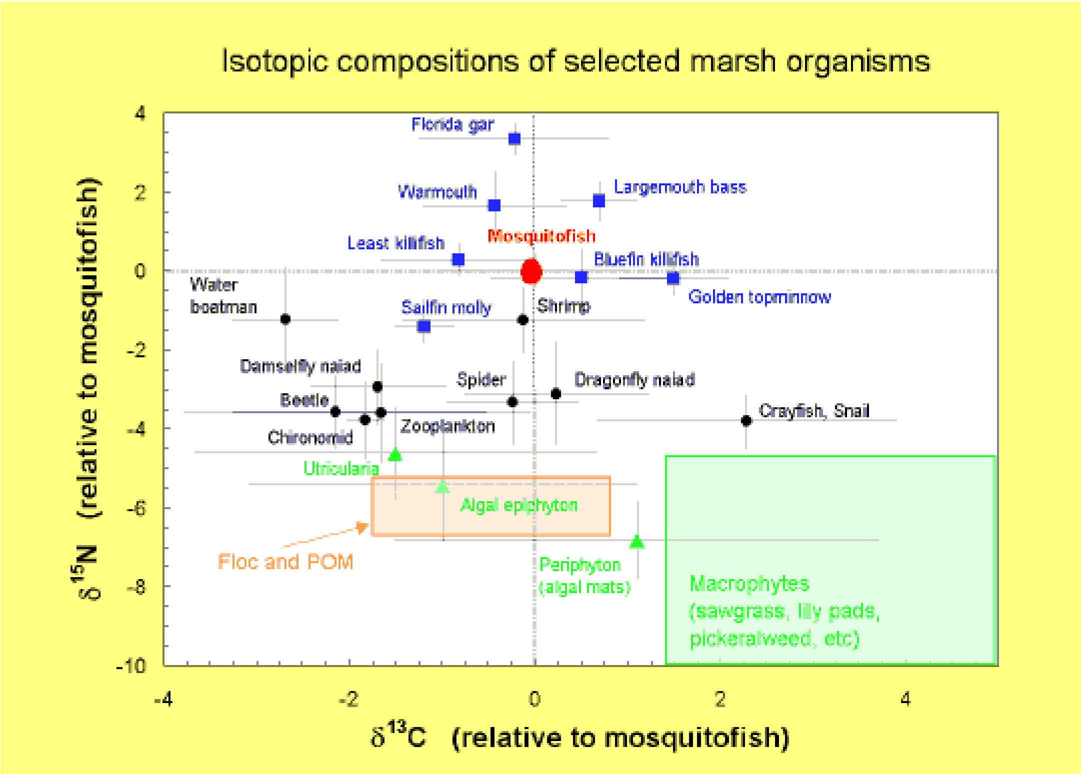

Figure 2: The average isotopic compositions of selected marsh organisms (with ranges shown as error bars), normalized to the composition of mosquitofish. The shaded zones show the range of large numbers of samples that can be grouped together.

Isotopes can be used to distinguish between what a fish eats and what it assimilates. For example, the $\delta^{15}N$ values of organisms can be used to test the diet estimates determined by gut contents analysis. Using this approach, we find that although algae (periphyton) often is a major component of the stomach contents of mosquitofish, it appears to be only a minor component of what is actually digested (fig. 3). This is an important observation, since the MeHg content of algae can be high in some environments; however, it is not known whether MeHg within the algal mats can be absorbed by the fish even if the algae is not assimilated.

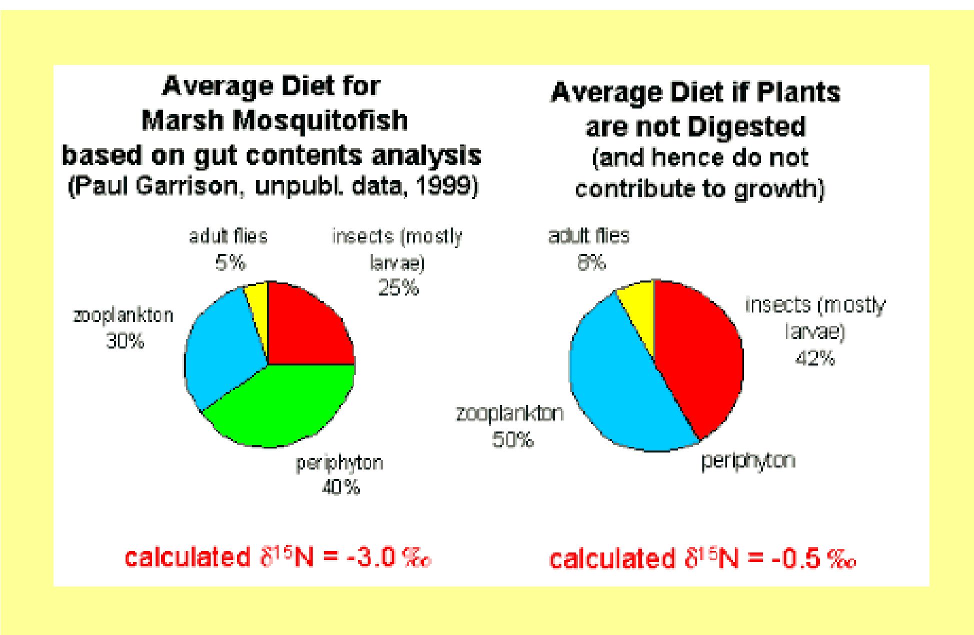

Figure 3. The isotopic values in figure 2 were used to calcualate the average 15N values of mosquitofish based on gut contents data.

In general, organisms collected in high-nutrient sites near the Everglades Agricultural Area have higher $\delta^{15}N$ values than ones collected in more pristine areas to the south. Near the agricultural areas, organisms in the canals generally have higher $\delta^{15}N$ values than samples from adjacent marshes, and the $\delta^{15}N$ values decrease with distance from the canals. This difference probably reflects denitrification and ammonium uptake in anoxic waters and sediments in stagnant parts of the canals.

The isotopic compositions of organisms from areas of high and low nutrient concentrations are very different. We observed the expected increases in $\delta^{13}C$ and $\delta^{15}N$ with increasing trophic level at low-nutrient marsh sites. However, at high-nutrient marsh and canal sites, the $\delta^{13}C$ values consistently decrease with increasing trophic level, producing food web structures that are not consistent with the trophic enrichment theory. While is not yet clear what causes the striking isotopic difference between nutrient-impacted sites and more pristine sites, isotopes appear to provide a quick and easy method for determining if high-nutrient areas might be causing significant changes in food web relations.

Spatial variability of $\delta^{15}N$, $\delta^{13}C$, and $\delta^{34}S$ values in the Everglades reflects spatial variability of reducing conditions in the marshes that promote methane production, sulfate reduction and denitrification. The isotopic compositions of aquatic plants integrate the variability in water column isotopic compositions and these same patterns are incorporated throughout the food web. Therefore, organisms that live in sites where geochemical conditions are dominated by particular redox reactions have distinctive isotopic compositions. The **"isotopic labeling"** of different environments suggests that isotopic techniques could be useful for determining whether fish migrate in and out of the marshes in response to hydrologic or nutrient-level conditions. Furthermore, because MeHg concentrations are a function of local environmental conditions, these isotopic data should prove useful for determining where some populations of game fish are acquiring elevated levels of MeHg. Stable isotope analyses distinguish fish populations and offer a more **cost-effective** alternative to tag-and-release programs for the determination of migration habits. Furthermore, stable isotope analyses complement gut-content-based food web studies, provide an independent check on diet estimates, and provide insight into the difference between what an organism eats and what it actually assimilates. Such an assessment should prove useful for the better regulation of hydrologic, geochemical, and biological conditions most favorable to the restoration of the Everglades.

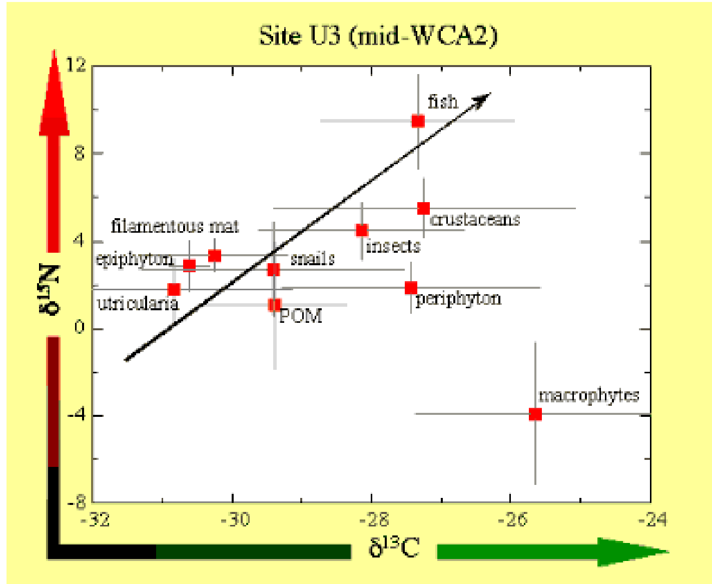

Figure 4. The isotopic compositions of organisms collected January 1998 at site U3.

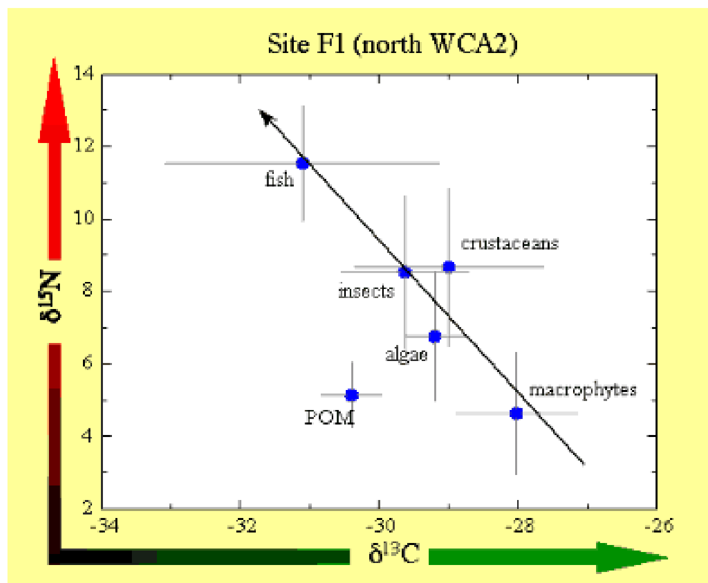

Figure 5. The isotopic compositions of organisms collected January 1998 at site F1.

Aquatic Cycling of Mercury in the Everglades (ACME) Project: Synopsis of Phase I Studies and Plans for Phase II Studies

By David P. Krabbenhoft[1], Cynthia C. Gilmour[2], William H. Orem[3], George R. Aiken[4], Carol Kendall[5], Mark L. Olson[1], and John DeWild[1]

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In 1994, a consortium of agencies lead by the U.S. Geological Survey began a multi-investigator study of the factors contributing to the high levels of mercury (Hg) in Everglade's biota, the Aquatic Cycling of Mercury in the Everglades (ACME) project. The overall objective has been to understand Hg cycling well enough to create management strategies that will minimize methylmercury (MeHg) bioaccumulation in the Everglades, while fulfilling other management objectives such as nutrient reduction and natural hydroperiod restoration.

Mercury contamination of the Everglades ecosystem is one of the most severe cases in the published literature. Currently, no human consumption of any Everglades' sport fish is recommended due to high Hg levels in fish tissues. Because virtually all Hg contained in edible fish is MeHg, a complete understanding of the processes controlling the environmental fate of MeHg is requisite to making responsible ecosystem management decisions. Information necessary to meet the project objectives includes, the precise locations and rates of MeHg production and destruction, environmental factors (such as water chemistry) that either exacerbate or mitigate MeHg production, and food-web bioaccumulation pathways.

Results of Phase I Studies (1995-1998)

The precise underpinnings of why wetlands, such as the Everglades, are susceptible to methylmercury production and bioaccumulation are not completely understood. High rates of microbial MeHg production in anaerobic, organic-rich sediments and advective flows of nutrient bearing water are probable causes. Previous work by the ACME project has revealed that Hg and MeHg distributions in water, sediment and biota show complex seasonal and spatial trends, and that the cycling rates of Hg and MeHg are so rapid that many measurements need to be conducted on a diel basis. In addition, *in situ* microbial processes and photochemical processes control MeHg levels at the ecosystem level. Mercury loads to the Everglades are dominantly derived from atmospheric sources, but toxicity is largely controlled by the relative rates of conversion to methylmercury, which in turn appears to be intimately associated with other complex biogeochemical cycles, such as the sulfate/sulfide cycle.

Specific key findings of Phase I of the ACME project are the following:

(1) MeHg bioaccumulation is driven by internal MeHg production, mainly in surface sediments;
(2) MeHg concentrations in all matrices (sediment, surface water, pore water, and biota) are maximal in the central Everglades (southern WCA2A, WCA2B and north-central WCA3);
(3) MeHg is somewhat lower in more pristine areas like Everglades National Park and WCA1, and much lower in the most eutrophic areas of WCA2A and the constructed nutrient-retention wetlands;
(4) The spatial MeHg pattern is not driven primarily by inorganic Hg concentration, although there is weak but significant relationship between Hg and MeHg concentrations in surface sediments;
(5) Photochemical reduction and photo-demethylation are important mechanisms for removal of mercury and destruction of MeHg, respectively, over much of the Everglades;
(6) Sulfur inputs from areas north of the Everglades have a large impact on MeHg production, but the magnitude and even direction of the impact varies with the sulfate and sulfide concentration;

(7) Phosphate and nitrate generally have no direct effect on MeHg production rates in sediment cores;

(8) Anaerobic microbial processes, including sulfate reduction, are key components of microbial organic carbon decomposition in Everglades sediment;

(9) Microbial dissimilatory sulfate reduction (rather than assimilation by plants) appears to be the most important mechanism for reduced sulfur storage in Everglades peat;

(10) Natural fires and extended periods of peat exposure can greatly exacerbate MeHg production (for example 10x increases in sediment MeHg levels), and this phenomenon appears to be driven by sediment oxidation and release of sulfate after re-inundation;

(11) Bioaccumulation of MeHg in Gambusia appears to be facilitated by the movement of benthic invertebrates (insects and zooplankton) into the water column, and less importantly by direct grazing on surface sediments and periphyton;

(12) Methylation occurs only in periphyton "mats" where microbial sulfur cycling occurs, and is most common in the less-calcareous periphyton found in eutrophic areas.

Plans for Phase II Studies (1999-2003)

To provide predictive capabilities of the potential effects of restoration efforts on Hg cycling in the Everglades, the complex relationships between loadings of Hg, sulfur, and nutrients on MeHg production and bioaccumulation need to be better understood. In the next phase of this research, we will better quantify these individual relationships, and the interactions among these three key parameters, through amendments to *in situ* mesocosms. Short-term addition experiments are useful in examining processes, but may not predict long-term responses, for a number of reasons. Response of plant growth to nutrients is the obvious example, but other changes, like changes in Hg speciation and bioavailability over time, or development of microbial communities, are also important. An understanding of the relationship between Hg, S or nutrient loading and MeHg production and bioaccumulation requires a long-term, large-scale approach because there are many steps between the entry of "new" Hg to the ecosystem, its conversion to MeHg, and bioaccumulation in the food web.

We will use stable Hg isotope amendments to examine the relationship between Hg loading and MeHg production and bioaccumulation. This new approach will allow us to track the fate of newly deposited Hg separately from the larger existing pools, and to track the bioavailability of new Hg over time. The use of individual stable Hg isotopes will allow us to follow the cycle of new Hg added to the system, from initial partitioning, accumulation in vegetation, MeHg production and accumulation in sediments, fluxes and accumulation in the food web. We will also be able to trace burial, post-depositional reworking of Hg through sediments and plants, and Hg^0 formation.

Important unknowns that stable isotopes will allow us to address are the availability of Hg in decaying plant material relative to newly deposited Hg adsorbed to sediments for methylation; and the recycling of buried Hg to the sediment surface through plant growth and decay. We also plan to make sulfur amendments as either a stable or radioisotope for the same reason. Sulfur isotope additions will allow us to find out how fast sulfide is turned over in sediments and made available again for sulfate reduction (through photosynthetic re-oxidation of sulfide), a key variable in modeling the relationship between sulfate load, sulfate reduction rate and sulfide accumulation in the oligotrophic Everglades. Isotopes will also allow us to track what fraction of newly added sulfate is retained in sediments.

Nutrient Transport to Biscayne Bay and Water-Quality Trends at Selected Sites in South Florida

By A. Clint Lietz
U.S. Geological Survey, Miami, Florida

Since the 1940's a highly managed water distribution system has been developed in south Florida consisting of levees, pump stations, gated control structures, and water-conservation areas. This complex system was created for the purposes of flood control, water storage, replenishment of ground-water supplies, and retardation of saltwater intrusion. As an unintended consequence, this manmade system has also altered natural hydropatterns and contributed to degraded water quality in south Florida.

Plans for restoring the remaining south Florida ecosystem include development of large surface and subsurface water-storage facilities, filling of canals, removal of levees, and redistribution of water to meet current and future needs of natural and developed areas. Expected results include changes in quantity, timing, and quality of waters delivered to many areas of south Florida. The U.S. Geological Survey, as part of its Place-Based Studies Program, has documented nutrient transport to Biscayne Bay, a shallow subtropical estuary along Florida's southeastern coast, and has analyzed water-quality trends at two long-term sites, one near Biscayne Bay and one within the Big Cypress National Preserve. This information will help provide a baseline and historical perspective against which to evaluate future changes.

Biscayne Bay provides an aquatic environment that is habitat to a diverse population of plant and animal species. As a result of agricultural and urban activities, increased nutrient loads in discharges from the east coast canals are a potential threat to the health of Biscayne Bay (fig. 1). An understanding of past and present nutrient transport to Biscayne Bay is needed to help assess the ecological health of the bay, to help evaluate the water-quality effects if this water is diverted to other areas, and to provide a basis for comparison of future nutrient flow.

Water samples were collected from east coast canals in 1996-97 (primarily during the wet season) to determine concentrations of major organic and inorganic nitrogen and phosphorus species. Study results indicate that within the Biscayne Bay watershed, median concentrations of some nitrogen and phosphorus species were highest in selected land-use categories: (1) nitrite plus nitrate in the agricultural land-use category; (2) ammonia, total phosphorus, and orthophosphate in the urban land-use category; and (3) total organic nitrogen in the wetlands category.

Depth-integrated samples were significantly different in total phosphorus concentration than 25 percent of grab samples at 1.0 meter depth and 33 percent of grab samples collected at 0.5 meter depth. No statistically significant differences were found for total nitrogen between grab and depth-integrated samples. Grab samples also were found to be biased low when compared to depth-integrated samples. A simple linear regression analysis was used to develop models for estimating total nitrogen and total phosphorus loads from the east coast canals to Biscayne Bay. Because of the large number of water samples collected over the years (1987-96) and the availability of continuous discharge record, a log-linear model (ESTIMATOR) employing a minimum variance unbiased estimator, was used to compute total nitrogen and total phosphorus loads for site S-26 in Miami (fig. 1 and table 1).

Restoring and enhancing the natural ecosystem requires an understanding of how water quality has been affected over time by anthropogenic influences in south Florida. Two U.S. Geological Survey daily discharge stations, one located within the wetlands of the Big Cypress National Preserve (Tamiami Canal station) and the other located in an urban area near Biscayne Bay (Miami Canal station), were analyzed for long- term (1966-94) trends in water quality to characterize pre-restoration water quality in different land-use categories and to document changes in water quality over time.

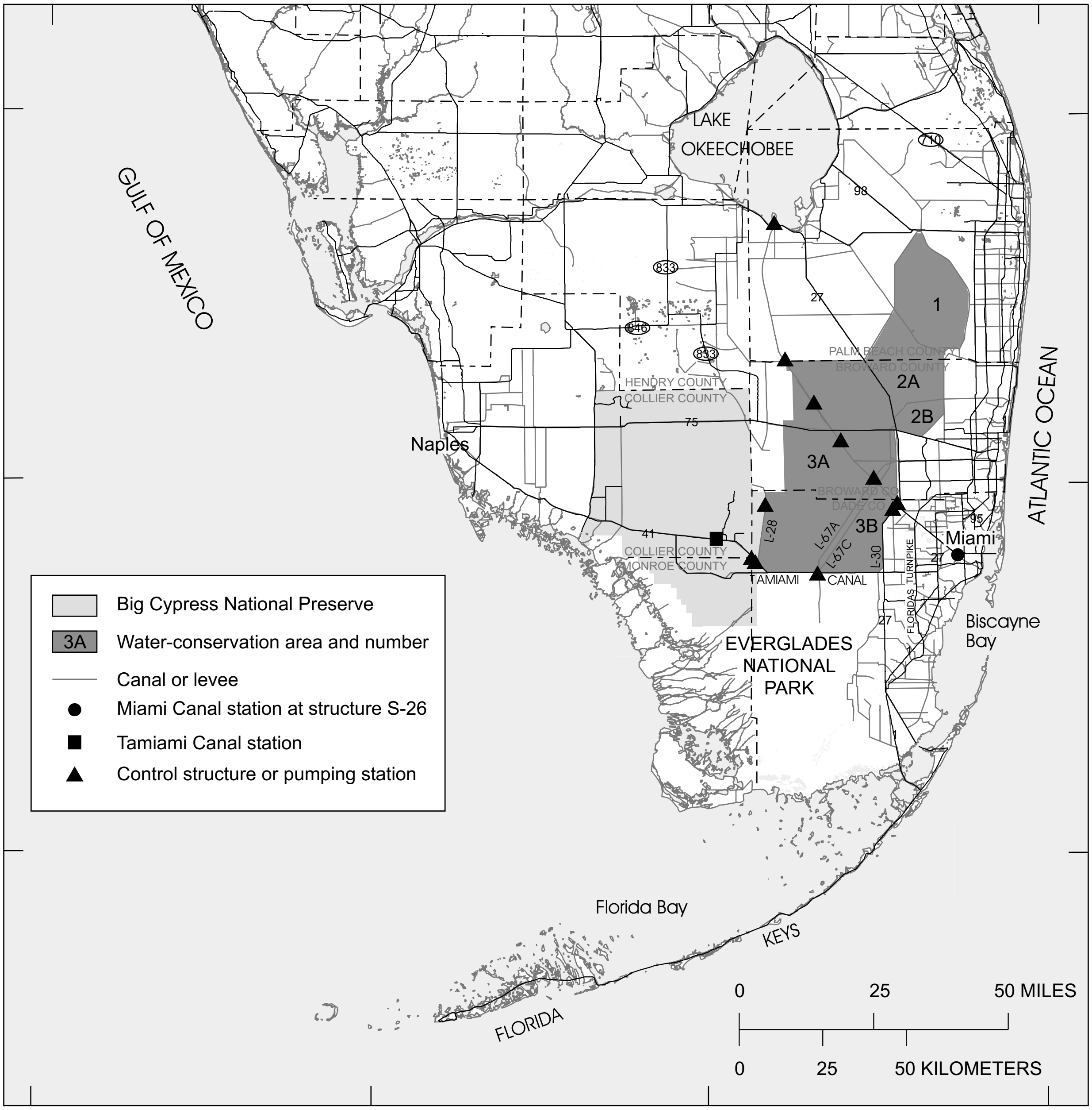

Figure 1. South Florida showing location of study sites, major canals, control structures, pumping stations, and land-use areas.

The principal tool used for the water-quality analysis was the Seasonal Kendall Trend (SKT) test, a nonparametric test that compares relative ranks of data values from the same seasons to negate variation caused by seasonality. To discern the anthropogenic influences that have affected water quality over the years, variation caused by discharge also should be negated. This was accomplished by performing the SKT test on flow-adjusted concentrations (residuals) from statistically significant concentration/discharge relations developed using linear regression models. Long-term trends were determined at both sites for selected major inorganic constituents and physical characteristics; pH and dissolved oxygen; suspended sediment; nitrogen, phosphorus, and carbon species; trace metals; and bacteriological and biological characteristics.

Statistically significant (p-value less than 0.01) temporal trends for water-quality constituents at the Miami and Tamiami Canal stations were classified as indicators of either improvement or deterioration in water quality over time (table 2). Most downward trends indicate improvement in water quality over time; however, downward trends in pH and dissolved oxygen indicate deterioration over time and the potential for harmful effects on aquatic life. At the Miami Canal station, improvement in water quality was documented by 7 trends and deterioration in water quality was documented by 14 trends. At the Tamiami Canal station, improvement and deterioration in water quality were indicated by 4 and 9 trends, respectively. Median and maximum concentrations at both sites were compared to the State of Florida freshwater standards; most concentrations were within these standards. However, the median concentrations of dissolved oxygen at the Miami and Tamiami Canal stations were 3.3 and 2.7 milligrams per liter, respectively, and did not meet the State freshwater standard of at least 5.0 milligrams per liter. Additionally, the median and maximum concentrations of total ammonia at both sites exceeded the State freshwater standard of 0.02 milligram per liter.

Table 1. Summary statistics for the estimation of total nitrogen and total phosphorus loads at site S-26 computed by the ESTIMATOR program for water years 1987-96

Water year	Constituent	Maximum monthly mean daily load (tons per day)	Minimum monthly mean daily load (tons per day)	Annual daily load (tons per year)
1987	Total nitrogen	0.72	0.011	78.2
	Total phosphorus	.008	1.85×10^{-4}	.70
1988	Total nitrogen	1.68	.004	190
	Total phosphorus	.021	6.32×10^{-4}	2.47
1989	Total nitrogen	.54	.00	46.5
	Total phosphorus	.007	.00	.61
1990	Total nitrogen	1.01	.00	85.5
	Total phosphorus	.012	.00	1.11
1991	Total nitrogen	1.60	.013	144
	Total phosphorus	.018	2.21×10^{-4}	1.81
1992	Total nitrogen	2.63	.040	261
	Total phosphorus	.028	6.55×10^{-4}	2.98
1993	Total nitrogen	1.04	.008	188
	Total phosphorus	.012	1.38×10^{-4}	2.18
1994	Total nitrogen	.77	.018	127
	Total phosphorus	.008	2.48×10^{-4}	1.45
1995	Total nitrogen	2.00	.00	268
	Total phosphorus	.019	.00	2.71
1996	Total nitrogen	1.72	.00	199
	Total phosphorus	.016	.00	2.19

Table 2. Summary of water-quality indicators showing improvement or deterioration at the Miami and Tamiami Canal stations over time

[Based on trends determined at a p-value of 0.10]

Water-quality constituent	Time period	Trend	Effect on water quality
Miami Canal Station			
Chloride	1966-94	Upward	Deterioration
Magnesium	1966-94	Upward	Deterioration
Potassium	1966-94	Upward	Deterioration
Silica	1966-94	Upward	Deterioration
Sodium	1966-94	Upward	Deterioration
Sulfate	1966-94	Upward	Deterioration
Turbidity	1970-78	Downward	Improvement
Specific conductance	1966-94	Upward	Deterioration
	1966-94	Upward	Deterioration
Dissolved Solids	1976-94	Upward	Deterioration
	1987-94	Upward	Deterioration
pH	1966-94	Downward	Deterioration
Suspended sediment	1974-94	Upward	Deterioration
	1987-94	Downward	Improvement
Total ammonia	1971-94	Downward	Improvement
Total organic carbon	1970-81	Upward	Deterioration
Total phosphorus	1987-94	Downward	Improvement
Barium	1978-94	Downward	Improvement
Iron	1969-94	Downward	Improvement
Fecal coliform	1976-94	Downward	Improvement
Fecal streptococcus	1987-94	Upward	Deterioration
Tamiami Canal Station			
Chloride	1967-93	Upward	Deterioration
Fluoride	1967-93	Downward	Improvement
Magnesium	1967-93	Upward	Deterioration
Potassium	1967-93	Upward	Deterioration
Sodium	1967-93	Upward	Deterioration
Specific conductance	1967-93	Upward	Deterioration
Dissolved solids	1967-93	Upward	Deterioration
Dissolved oxygen	1967-93	Downward	Deterioration
Suspended sediment	1976-93	Upward	Deterioration
Total ammonia	1970-92	Downward	Improvement
Total nitrite plus nitrate	1975-85	Downward	Improvement
Barium	1978-93	Downward	Improvement
Strontium	1967-93	Upward	Deterioration

Nutrient and Sulfur Contamination in the South Florida Ecosystem: Synopsis of Phase I Studies and Plans for Phase II Studies

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The south Florida ecosystem, including the Everglades, has been greatly impacted by anthropogenic activities. More than 35 percent of the original natural ecosystem has been converted to agricultural or urban use, and most of the remaining wetland areas are threatened by altered (unnatural) hydroperiods, over 1,400 miles of canals that dissect a once continuum of wetlands, chemical pollutants, fires, and a steady loss of wildlife habitat. The studies described here focus on several of the major water quality issues facing this ecosystem (*phosphorus* (P), *nitrogen* (N), and *sulfur* (S)), and the biological impacts of water quality issues. Specifically, this study is examining: (1) the major sources of excess nutrients (nitrogen and phosphorus) and sulfur to the ecosystem, (2) the important role of chemical and biological processes in sediments (biogeochemical processes) in sequestering and recycling these substances, and (3) the ultimate fate (that is, sinks) of these elements in the ecosystem.

The focus on nutrients reflects the problem of eutrophication in the ecosystem, whereby excess P and to a lesser degree N from canal discharge has dramatically altered the biology of the ecosystem. Studies of S contamination are important for understanding the processes involved in methylmercury production in the Everglades. Methylmercury (a potent neurotoxin) poses a health risk to biota in the ecosystem and potentially to humans, and S is a key control on the methylation of mercury by sulfate-reducing bacteria in wetland soils. Excess sulfide produced by bacterial sulfate reduction in wetland sediments may have toxic effects on macrophytes and tree islands in the ecosystem by limiting oxygen transport to root systems.

In addition to a focus on water quality issues, sediment studies conducted for this project are being used to construct a geochemical history of the ecosystem. An understanding of past changes in the geochemical environment of south Florida will provide land and water managers with baseline information defining water quality parameters of the pre-drainage Everglades. Historical geochemistry in combination with paleoecological studies will also help deliniate ecosystem response to natural environmental change (climate, sealevel rise), and allow prediction of likely ecosystem response to changes that will accompany restoration.

Results of Phase I Studies (1994-1999)

Phase 1 studies have shown that excess P, N, and S enter the Everglades from canal discharge originating in Lake Okeechobee and the Everglades Agricultural Area (EAA). Uranium concentrations and isotopic activity ratios ($^{234}U/^{238}U$) were used as tracers to show that P contamination in the northern Everglades is derived from phosphate fertilizer used in the EAA; the first definitive evidence that the phosphate contamination in the Everglades originates from phosphate fertilizer. Concentrations of P at pristine sites in the freshwater Everglades range from 1-20 ppb in surface water, 10-100 ppb in sediment porewater, and 300-500 μg/g dry wt. in sediments. At contaminated marsh sites, however, P concentrations often exceed 100 ppb in surface water, 3,000 ppb in porewater, and 2,000 μg/g dry wt. in sediment. Accumulation rates of P in peat at contaminated sites are typically 10x to 100x higher compared to pristine areas (fig. 1). The increased P load has altered biotic assemblages within parts of the ecosystem, especially in marsh areas near canal discharge where eutrophic-adapted cattail (*Typha domingensis*) has replaced native, oligotrophic-adapted sawgrass (*Cladium jamaicense*). Sites of excess P accumulation (contaminated sites) also recycle P rapidly, due to the high biodegradability of cattails compared to sawgrass. Because of the high rate of P recycling in cattail peat, constructed wetlands (STA's) that consist primarily of cattail vegetation may not serve as effective long-term sinks for P. Further study of this will be a focus of Phase II work.

The extent of S contamination in the Everglades was first documented by results from Phase I studies. Unnaturally high levels of sulfate enter the Everglades from canal discharge, and S isotope ($\delta^{34}S$) studies suggest that the S contamination may originate largely from the use of agricultural S in the EAA (fig. 2). Accumulation rates of S in surface sediments of the Everglades are about 5x higher near canals compared to areas remote from canal discharge.

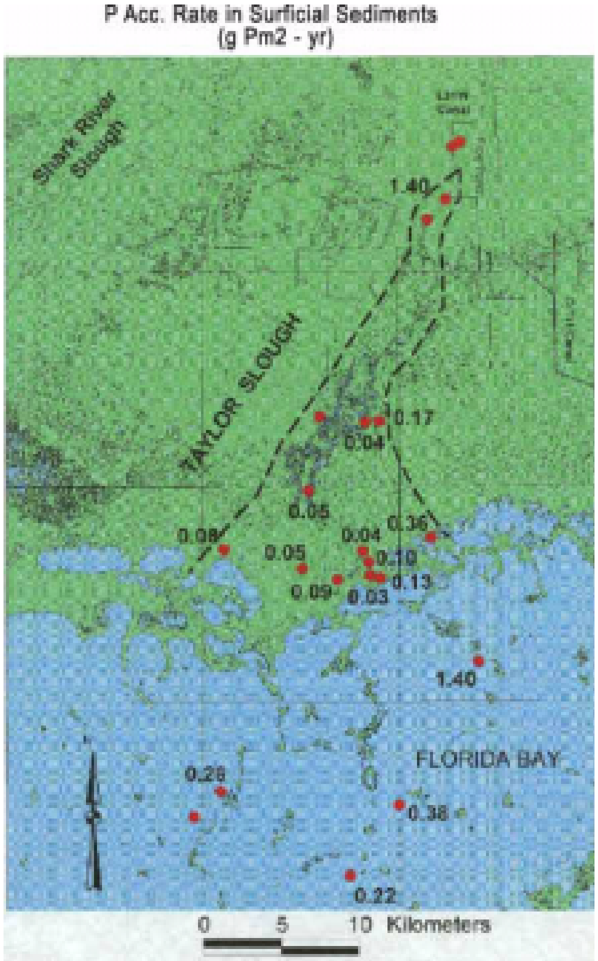

Figure 1. Accumulation rates for total P in surface sediments from Taylor Slough, Everglades National Park. Note the much higher accumulation rates for P at the northern top of the slough, reflecting input from agriculture south of Homestead. Note also the high P accumulation rates in northeastern Florida Bay.

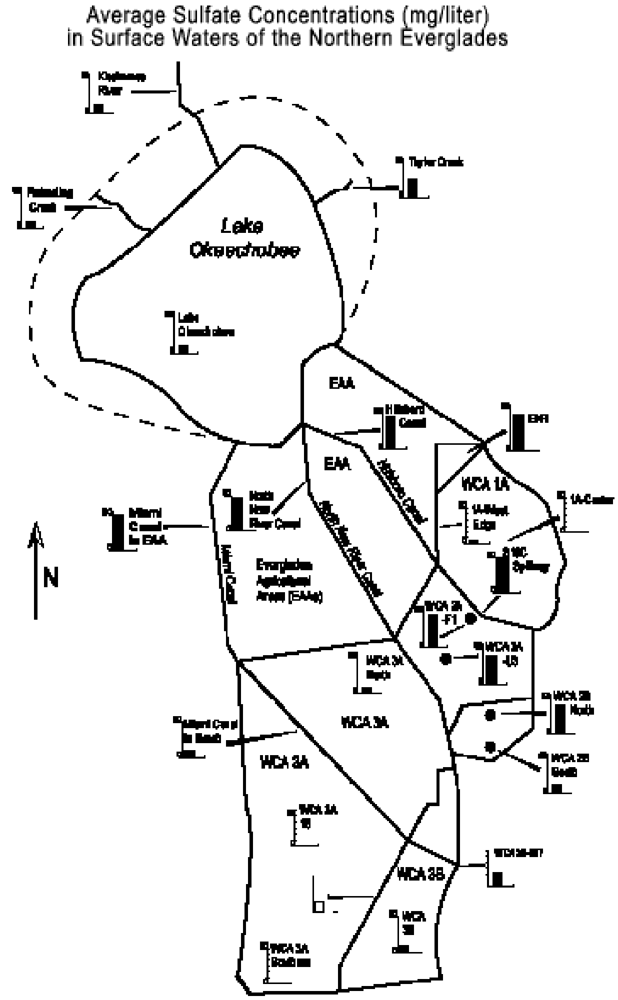

Figure 2. Average surface water sulfate concentrations from sites in the northern Everglades, canals draining the EAA, and Lake Okeechobee and tributaries. Note that sulfate concentrations are highest in canals draining the EAA. Concentrations of sulfate in marsh waters generally diminish from north to south.

The principal form of S in sediments at all marsh sites is organic sulfur, reflecting the reaction of sulfide with organic matter in the sediments. S contamination has altered the nature of microbial processes in the freshwater marshes of the Everglades by stimulating sulfate reduction. Collaborative work with the Aquatic Cycling of Mercury in the Everglades (ACME) group showed that S contamination in the marsh sediments is a major control on mercury methylation in the Everglades. The relationship between the microbial methylation of mercury and the biogeochemistry of S is complex, but the distribution of S in the ecosystem is a major control on the location of methylmercury "hot spots" in the Everglades.

Plans for Phase II Studies (1999-2003)

Phase II will extend Phase I studies using similar field approaches, but with the addition of field and laboratory experimental work to further refine and quantify previous observations and conclusions. This will include the use of environmental chambers (field mesocosms and laboratory microcosms), and isotopic tracers to provide a more definitive means addressing specific management questions, such as: "Over what time scales could we expect to see improvements to the ecosystem if nutrient and sulfur loading were reduced by implementation of agricultural best management practices (BMP's) and the storm water treatment (STA) program?" Results will provide critical elements for building ecosystem models and screening-level risk assessment for contaminants in the ecosystem.

Phase II work will expand our existing database on sources of nutrients and S contamination to the ecosystem, including the initiation of work on sources of contamination from grazing areas (cattle) north of Lake Okeechobee. The use of Lake Okeechobee water in proposed aquifer storage and recovery (ASR) approaches to water management in south Florida will require information on the quality of water entering the lake. Sources of organic contaminants (for example, polycyclic aromatic hydrocarbons) to the ecosystem will also be initiated during Phase II.

The effectiveness of STA's in retaining contaminants (nutrients and S) in long-term storage will be a major goal of Phase II studies. Resilts from Phase I studies suggest that peat derived from cattail vegetation (cattails are likely to dominate the emergent macrophyte vegetation in STA's) is far less effective at long-term retention of P than sawgrass peat.

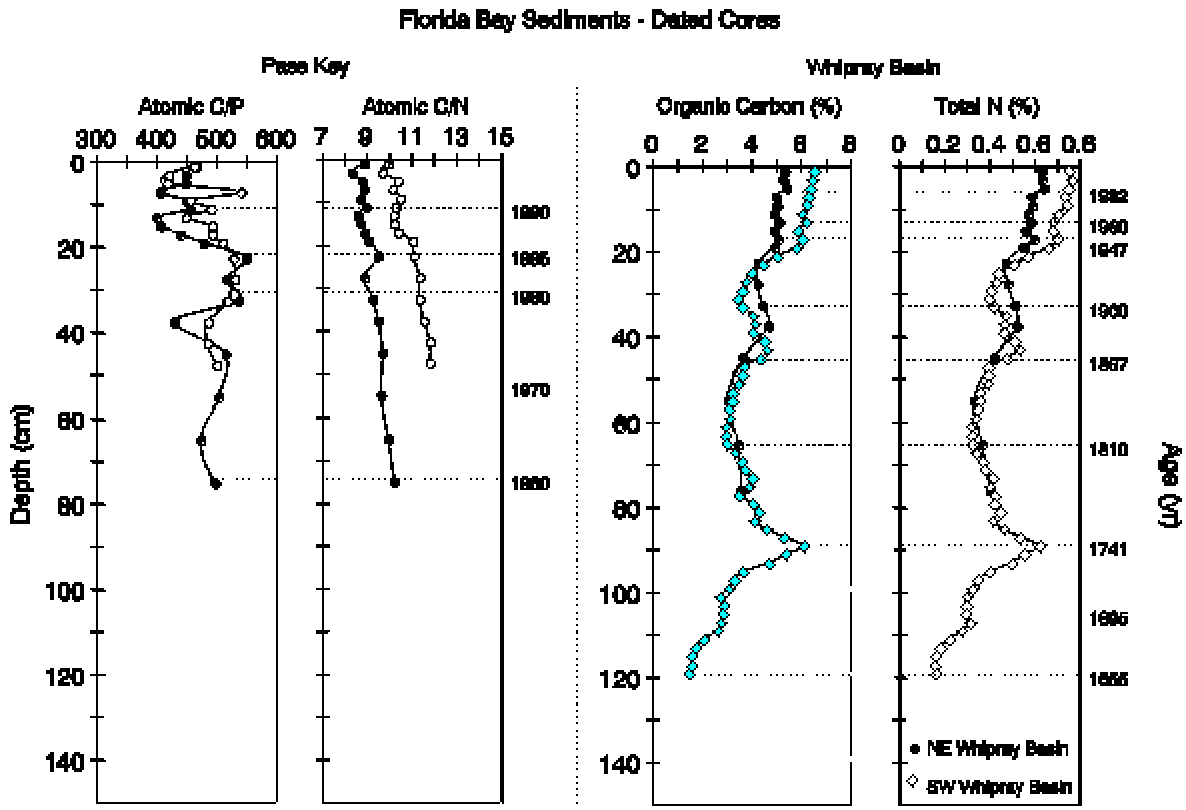

Figure 3. The two figures on the left illustrate changes in atomic C/P and C/N ratios with depth at sites near Pass Key in northeastern Florida Bay. Note the sharp changes in C/P and C/N in the near surface sediments, since about 1980, indicating increased nutrient input since then. The two figures at right show changes in organi C and total N in sediments from Whipray Basin in central Florida Bay. Note the recent and historical changes in both organic C and total N over time.

Salinity Pattern in Florida Bay: A Synthesis

By Michael Robblee[1], Gail Clement[2], DeWitt Smith[3], and Robert Halley[4]

[1]U.S. Geological Survey, South Florida Ecosystem Restoration Committee, Miami, Florida; [2]Southeast Environmental Research Center, Florida International University, Miami, Florida; [3] Everglades National Park, Homestead, Florida; [4]Center for Coastal Geology, St. Petersburg, Florida

Understanding the salinity dynamics of Florida Bay is central to its restoration. Salinity is an intermediate link in the cause and effect that connects upstream water-management activities to the structure and function of the Florida Bay ecosystem. Long-term regional water-management practices are widely thought to have reduced the quantity and shifted the distribution and timing of freshwater inflow leading to a marinification of Florida Bay. The perception of ecological decline in Florida Bay as evidenced by seagrass die-off, the onset of extensive turbidity/algal blooms, and corresponding declines in dependent fisheries, is often linked, at least in part, to salinity stress and long-term changes in salinity within the bay (Robblee and others, 1991; Boyer, and others; 1999; Browder and others, 1999; Fourqurean and Robblee, 1999). Prominent elements within the Florida Bay Restoration Program involve restoring historic freshwater flows; enabling predictions of salinity in Florida Bay based on upstream hydrology and water-management; and developing, as a possible restoration target, a model of the salinity regime in Florida Bay prior to water management (Armentano, 1994; Florida Bay Program Management Committee, 1997). The success of these restoration efforts requires an understanding of the historical salinity pattern in Florida Bay.

This project has several objectives: (1) to complete the existing salinity record for Florida Bay by conducting a comprehensive search for salinity data, published or unpublished literature referencing salinity, and anecdotal information interpretable in terms of salinity conditions within the bay; (2) to compile these data in a relational database searchable via the internet; and (3) to provide a synthesis characterizing salinity conditions in Florida Bay over the last century.

The geographical scope of this study (fig. 1) has been defined as the region south of mainland Florida but including the semi-enclosed bays and sounds of the mangrove estuary, north and west of U.S. Route 1 from its junction with the mainland southwest through the Florida Keys to the southern tip of Long Key and east of a line between Long Key (80^{o} 56.0', 24^{o} 48.1') and East Cape Sable (81^{o} 05.3', 25^{o} 07.0'). Generally this region includes the portion of Florida Bay as contained within Everglades National Park. However, salinity patterns in Florida Bay are dependent on processes occurring along its periphery. As such, data and reference material were included for Manatee Bay and Barnes Sound to the east, Largo Sound and the major passes through the Florida Keys south to Long Key, near vicinity Gulf of Mexico waters, and Whitewater Bay and the rivers and bays from Lostmans River south. Future efforts will extend this west coast search area north as far as Cape Romano.

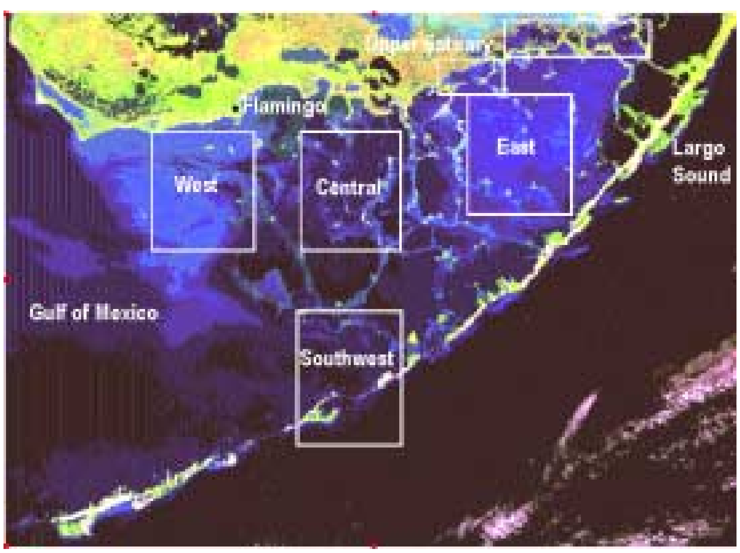

Figure 1. Map of Florida Bay showing five salinity reference areas used to capture east-west gradient in salinity patterns.

To compile a comprehensive salinity database for Florida Bay, extensive searches for salinity data were conducted across a diverse body of literature and collections spanning more than 150 years. The primary aim of the search was to identify and locate salinity observations that met the following criteria:

- the observation was made within Florida Bay waters or in waters adjacent to the Bay;
- the measurement was a discrete observation (not an average value); the date and time that the observation was made is known;
- the location at which the salinity observation had been made was available or could be estimated; and
- the depth at which the observation was made could be determined.

A second aim of the search was to identify and retrieve reference and anecdotal materials containing information interpretable in terms of salinity conditions within the bay. Sources include both quantitative salinity values as well as anecdotal observations about salinity and related conditions (for example, direct observations of freshwater occurrences, fish kills, and other phenomena reflecting changes in water quality). A partial listing of resources searched is included as table 1.

Table 1. Selected sources searched for references to salinity in Florida Bay. 1A. On-line Databases Searched; 1B. Personal Interviews

1a. On-line Databases Searched

Name	Web Site
FirstSearch/WorldCat	//firstsearch.altip.oclc.org/
JSTOR	//www.jstor.org/cgi-bin/jstor
Everglades On-Line	//everglades.fiu.edu/
Cambridge Scientific	//www.csa2.com
Eureka/RLG	//eureka.rlg.org/
NARA-NAIL search	//www.nara.gov/nara/nail.html
Caloosahatchee On-Line	//library.fgcu.edu/cgibin/caloosa.taf?function=form
US Army COE	//lepac1.brodart.com/search/um/ex_br.html
NOAA “CEDAR”	//www.aoml.noaa.gov/general/lib/CEDAR.html
GeoRef	//georef.cos.com
ASFA	//www.silverplatter.com/catalog/asfa.htm
Dissertation Abstracts	//www.asog.co.at/spcatalog/umda.htm
NOAA library	//www.aoml.noaa.gov/general/lib/

1b. Personal Interviews

Title	Place of Work
Historian	DEP, Tallahassee, Florida
Archivist	Henry M. Flagler Museum, Palm Beach, Florida
Archivist	Historical Museum of South Florida, Miami, Florida
Scientist	National Audubon Society, Tavernier, Florida
Librarian	South Florida Water Management District, Palm Beach, Florida
Librarian	Miami-Dade Public Library, Miami, Florida
Librarian/Historian	Monroe County Public Library, Key West, Florida
Librarian/Historian	Monroe County Public Library, Islamorada, Florida
Scientist/Historian	National Marine Fishery Statistics, Key West, Florida
Librarian	US Army Corps of Engineers Library, Jacksonville, Florida
Historian	Upper Keys Historical Society, Key Largo, Florida
Private Collections	Papers of Durbin C. Tabb, acquired by Florida International University Green library, Miami, Florida

This effort to compile a salinity record for Florida Bay began in 1987 and has continued intermittently since then (Robblee, 1989; Nuttle and others, 2000). With this study the effort has produced a database containing 232 references, including 70 sources of salinity data extending from 1936 (Davis, 1940) to the present. Spatially extensive data are available from the mid-1950's. Comprehensive salinity monitoring begins in the late 1980's. Less quantitative or anecdotal references to salinity conditions date back to the turn-of-the-century in the scientific literature, and to the mid-19th Century in the historical record.

A principal goal of this study is to integrate these diverse studies and observations into a relational database within which the data can be explored, data sets can be developed, and data files can be exported for further analysis. The database interface supports multiple types of queries, including geospatial, temporal, and reference. From the results of any query, searchers may retrieve both salinity data and annotated reference materials. Latitude/Longitude or UTM coordinates, basin, or place name, define location. Within the database, basins are defined according to the polygon structure employed in FATHOM (Cosby, Nuttle and Fourqurean, 1999). Place names are defined according to the U.S. Board on Geographic Names (Orth and Payne, 1997). The primary data for each study are available in the database. A data set of daily average salinity calculated for each station within each study forms the basis for integrated data searches. Integration of data sets differing widely in spatial and temporal scale has been achieved within the database using a series of decision rules. To expedite data searches, predefined data summaries will be available for monthly, seasonal (wet/dry), and annual time steps. Metadata records providing summaries of the study; geospatial and temporal coverage of the study; descriptive keywords and place names; and related references where applicable will accompany data retrieved in each search.

An initial analysis of the data in the database indicates that, over the period-of-record, Florida Bay has varied between being a positive (salinity decreasing west to east) and a negative estuary (salinity increasing west to east) (fig. 2). These patterns of salinity appear to be linked to the wet/dry cycle characteristic of south Florida. During periods of drought the Bay behaves as a hypersaline lagoon. The highest recorded salinity for open bay waters (70 psu) occurred in April of 1956 at Buoy Key east of Flamingo (Finucane and Dragovitch, 1959). Twice normal seawater, 70 psu, was observed again in May 1991 in Rankin Lake near Buoy Key at the end of the 1989-1991 drought. Hypersaline conditions appear first and have been most severe and persistent in central Florida Bay where salinities have reached or exceeded 40 psu for over 50 percent of the period-of-record. In contrast, Florida Bay behaves as a positive estuary less often. Episodic events associated with high rainfall such as tropical waves or depressions, hurricanes or periods of above average rainfall like the 1993-1995 high water period are needed for Florida Bay to be a positive estuary. Upstream water management may have achieved this effect as well. Increased flows through the C-111 Canal cutouts into Florida Bay due to operational changes upstream had the effect of maintaining Florida Bay as a positive estuary during the period 1983-1985, a period of significant below average rainfall in south Florida.

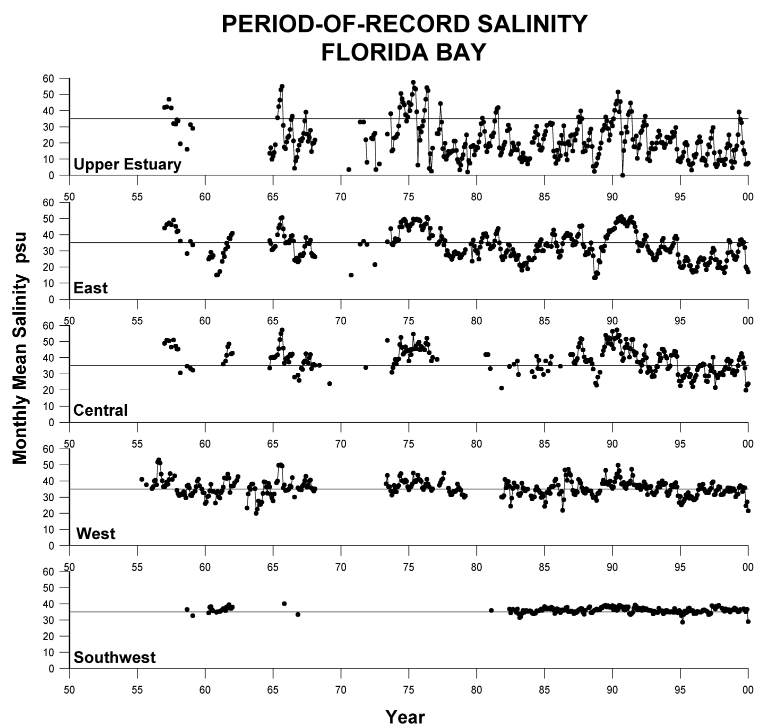

Figure 2. Monthly mean salinity for period-of-record, 1950-1999, for 5 reference areas in Florida Bay.

Geochemical Monitoring of Productivity in Florida Bay

By Kimberly Yates and Robert Halley

U.S. Geological Survey, Center for Coastal Geology, St. Petersburg, Florida

Monitoring changes in biogeochemical processes provides a mechanism for measuring early response of the Florida Bay ecosystem to environmental perturbations. Seasonal measurements of productivity associated with representative benthic substrate types in Florida Bay were performed. Monitoring changes in productivity during implementation of restoration plans will allow resource managers to evaluate the progress and success of south Florida restoration efforts. Carbonate environments such as Florida Bay are characterized by three primary biogeochemical processes: (1) carbonate sediment production by calcifying organisms and dissolution; (2) photosynthesis; and (3) respiration (collectively referred to as productivity). These processes are sensitive to changes in water quality including salinity and nutrients, and show distinct rate changes before visual evidence of environmental disturbances such as seagrass die-off, algal blooms, and shifts in ecosystem success indicator species. Water management practices in south Florida have already been altered in an effort to restore the Everglades and Florida Bay. Resulting changes in water chemistry will first affect biogeochemical processes, and may, subsequently, result in changes in species distributions (such as seagrass and algae).

Carbonate sedimentation and organic productivity (calcification, photosynthesis, and respiration) are most effectively determined from precise, *in situ* measurements of alkalinity, pH, temperature, conductivity, and air:sea CO_2 and O_2 gas fluxes. Net productivity was determined on seagrass beds in basins located in the western bay near Buchanon Keys and in the central bay near Manatee Key during March 1999 and 2000 and during September 1999, and on mud-bottom and hard-bottom (soft corals and small hard corals, sponges, calcareous algae) communities during March 2000.

A large incubation chamber called the Submersible Habitat for Analyzing Reef Quality, or SHARQ, was used to isolate water over the substrate and to measure temporal changes in key geochemical parameters over 24 hour time periods. Productivity in the water column was determined in March 2000 by isolating a mass of water inside of the SHARQ from the substrate by placing a floor in the incubation chamber. Geochemical parameters including pH, dissolved oxygen and temperature were measured continuously using a flow-through analytical system throughout the duration of incubation periods. Water samples were removed every 4 hours from sample ports for total alkalinity measurements. Dissolved oxygen, pH and alkalinity data were used to calculate average rates of net calcification, photosynthesis, and respiration for light and dark hours.

Productivity on mudbanks located at Russell Bank was measured during March and September 1999 and March 2000 using an upstream/downstream sampling strategy. Changes in key geochemical parameters were determined by identifying unidirectional currents across Russell Bank and establishing upstream and downstream sampling sites along 200-400 meter bank transects. Average rates of net calcification, photosynthesis and respiration were calculated from total alkalinity, pH, dissolved oxygen, air:sea CO_2 and O_2 gas fluxes, salinity, temperature, and wind measurements taken every 4 hours during 24-hour time periods at each sampling site.

Average rates of calcification for Buchanon Keys Basin and Manatee Key Basin seagrass beds indicate net precipitation of carbonate sediments during daylight hours of 0.012 g $CaCO_3$ m^{-2} hr^{-1} and 0.009 g $CaCO_3$ m^{-2} hr^{-1}, respectively, and net dissolution during the night of 0.019 and 0.017 g $CaCO_3$ m^{-2} hr^{-1}, respectively, in March 1999 and 2000 and September 1999. The average rate of net photosynthesis during daylight hours for Buchanon Keys Basin seagrass beds is 0.071 g carbon m^{-2} hr^{-1} with values ranging from 0.04 to 0.08 g carbon m^{-2} hr^{-1}. Net photosynthesis values for Manatee Key Basin seagrass beds ranged from 0.005 to 0.13 g carbon m^{-2} hr^{-1} with an average of 0.069 g carbon m^{-2} hr^{-1} (fig. 1). Average rates of respiration during night hours were 0.09 g carbon m^{-2} hr^{-1} for Buchanon Keys Basin and 0.06 g carbon m^{-2} hr^{-1} for Manatee Key Basin seagrass beds (fig. 1).

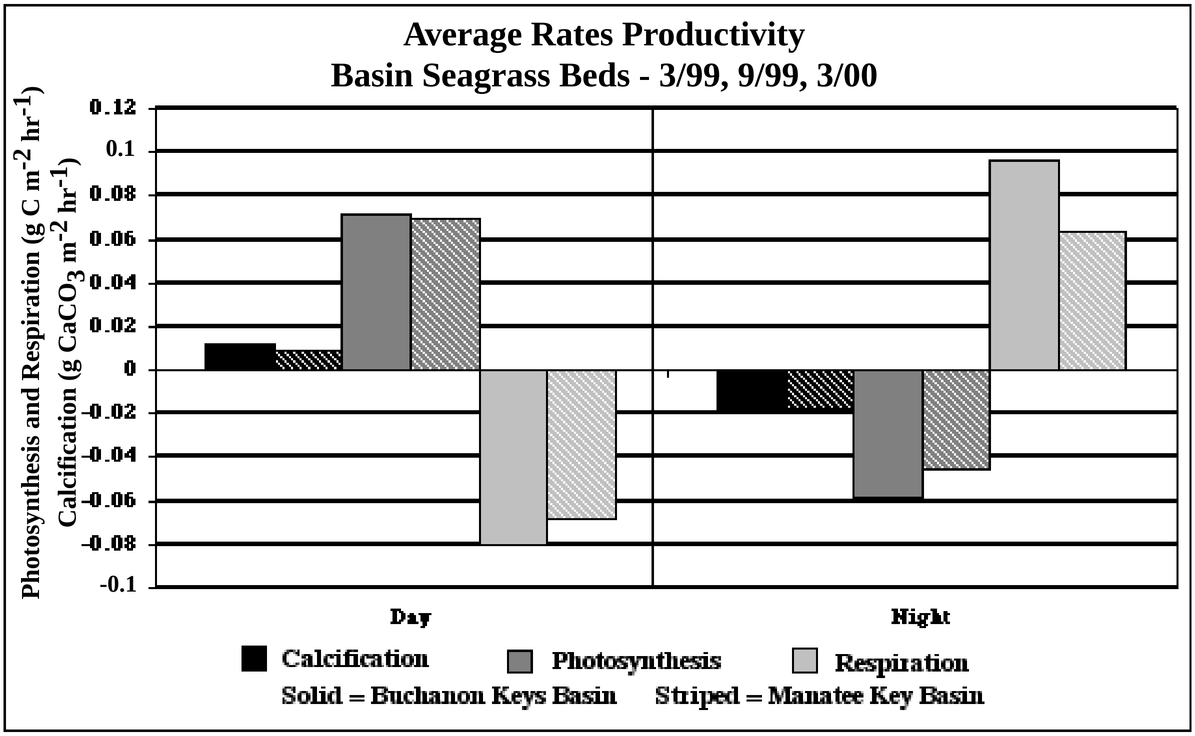

Figure 1. Average rates of net calcification, photosynthesis, and respiration during day and night hours for seagrass beds located in basins near Manatee Keys and Buchanon Keys. Averages were calculated from values for March 1999 and 2000 and September 1999.

Preliminary results of productivity measurements on representative substrate types during March 2000 are shown in figure 2. Highest rates of net photosynthesis occurred on seagrass beds in Manatee Key Basin followed by seagrass and hard-bottom communities in Buchanon Keys Basin. Highest net calcification rates (day calcification—night dissolution) were associated with the hard-bottom community. Rates of calcification and photosynthesis for mud-bottom communities and water column in Manatee Key Basin were up to an order of magnitude less than rates for seagrass and hard-bottom communities. Generally, for all substrate types, net precipitation of carbonate sediments was observed during daylight hours, whereas net dissolution occurred at night.

Results of Russell Bank productivity measurements indicate net carbonate sediment production during March 1999 of 0.69 g $CaCO_3$ m^{-2} 24 hrs^{-1} and net sediment dissolution during September 1999 of 0.09 g $CaCO_3$ m^{-2} 24 hrs^{-1}. Dissolved oxygen measurements indicate net oxygen consumption during daylight and dark hours for March and September. However, total CO_2 (TCO_2) calculations indicate carbon consumption rates (net photosynthesis) of 0.117 and 0.038 g carbon m^{-2} day^{-1} for March and September. This suggests that oxygen may be consumed through inorganic oxidative processes (for example, sulfide oxidation) and that additional nutrient measurements will be required to quantify these processes.

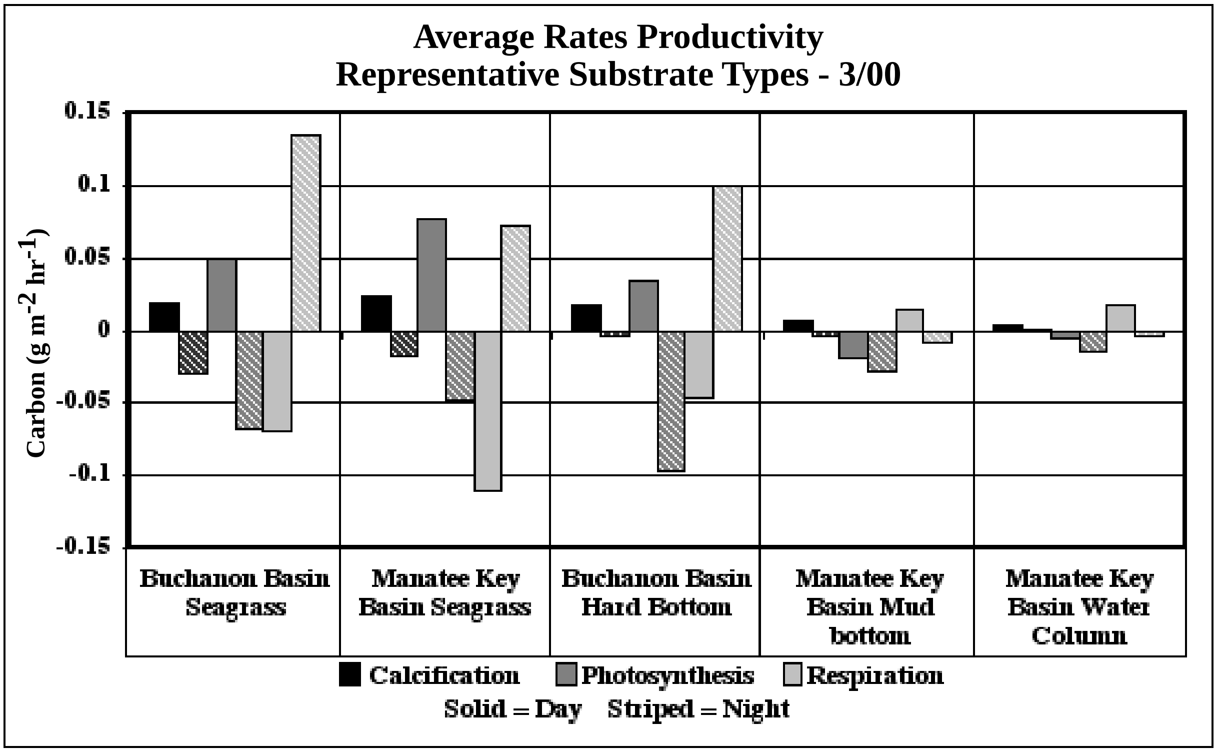

Figure 2. Average rates of net calcification, photosynthesis, and respiration during day and night hours for representative substrate types including seagrass, hard-bottom and mud-bottom communities, and water column. Averages were calculated from 24-hour incubation periods performed during March 2000.

Section III

Preserving Natural Habitats and Species

Contents

Section III: Preserving Natural Habitats and Species

Molluscan Faunal Distribution in Florida Bay, Past and Present: An Integration of Down-Core and Modern Data

By G. Lynn Brewster-Wingard[1], Jeffery R. Stone[1], and Charles. W. Holmes[2]

[1] U.S. Geological Survey, Reston, Virginia; [2] U.S. Geological Survey, St. Petersburg, Florida

Statistical comparison of modern molluscan fauna to down-core molluscan assemblages in four cores elucidates changes in the Florida Bay ecosystem during the past 100 to 200 years. Fluctuations within molluscan faunal dominance and diversity patterns suggest a response to changing environmental conditions. Faunal dominance patterns indicate an increase in salinity in the northern transitional zone, and possibly the eastern portion of Florida Bay. Distinctive faunal shifts recorded at Russell Bank occur approximately between 1910 and 1930 and at Bob Allen mudbank between approximately 1900 and 1910. The period from approximately 1930 to 1980 within these cores shows rapid and dramatic fluctuations in species dominance and faunal richness. Beginning around 1980, the mussel Brachidontes exustus, which can tolerate diminished water quality and a wide range of salinities, increases in percent abundance in the upper portion of all four cores and becomes the dominant species at Russell Bank and Bob Allen Mudbank.

While these fluctuations within assemblages are distinctive, they are not so profound that they represent a major shift in estuarine zonations within northern, eastern, and central Florida Bay during the past 100 to 200 years. The majority of the molluscan fauna that are present at the core sites today are generally present throughout the period of deposition. Fluctuations in the molluscan faunal record down-core primarily express changes in dominance and diversity within assemblages and do not reflect substantial changes in overall assemblages. It is these fluctuations in dominance and the appearance or disappearance of critical indicator species that are indicative of salinity changes.

Understanding the dynamics of an ecosystem and the natural range of variation in the system over an extended period of time is a critical component of effective restoration. Analysis of the modern environment provides a means to interpret biological data preserved in cores, and to determine the physical and chemical variations in the environment indicated by the biota. Knowledge of the past provides the best insight to predicting the impact of future change on the environment.

Historical Reconstruction of Seagrass Distribution, Water Quality and Salinity, Using Molluscan Indicator Species

By G. Lynn Brewster-Wingard and Jeffery R. Stone
U.S. Geological Survey, Reston, Virginia

Molluscan fauna have been used successfully to reconstruct 200 years of historical information on seagrass distribution, water quality, salinity, biodiversity, and faunal abundance in Florida Bay. Molluscan assemblages identify significant perturbations of an environment and filter out "noise" caused by day-to-day or short-term fluctuations, such as those caused by tropical storms. Estuarine molluscs tolerate a wide range of fluctuating environmental conditions, yet on a scale of seasons, their populations will migrate to more ideal conditions as Lyons (1996, 1998) has demonstrated. Individual molluscs, however, are relatively limited in their movement in post larval stages, and typically provide information about a specific site for the duration of their lifetime. In addition, molluscs occupy a number of trophic levels and represent a diverse, significant component of the biomass of the Florida Bay ecosystem, allowing this single group to serve as a proxy for the trophic structure and ecologic health of the system.

Evidence for significant changes in abundance and distribution of seagrass and aquatic vegetation (SAV) in Florida Bay can be seen by examining the distribution of epiphytic species (fig 1). Molluscs that live on macro-benthic algae or seagrass have increased during the 20th century in the Bob Allen, Russell Bank, and Taylor cores. Species that live on seagrass exclusively have declined relative to the general SAV dwellers since about 1970 at Bob Allen and Russell Bank, and in the upper portions of Pass and Taylor. While substrate data are site specific, repetition of this trend in these four cores (as well as other cores not reported on here) indicates this may reflect a genuine increase in SAV during the 20th century throughout eastern and central Florida Bay. If, through examination of additional cores, this trend can be substantiated, it could have a significant impact on restoration efforts. These data imply that the abundance of seagrass in Florida Bay in the latter half of the 20th century may represent an anomaly.

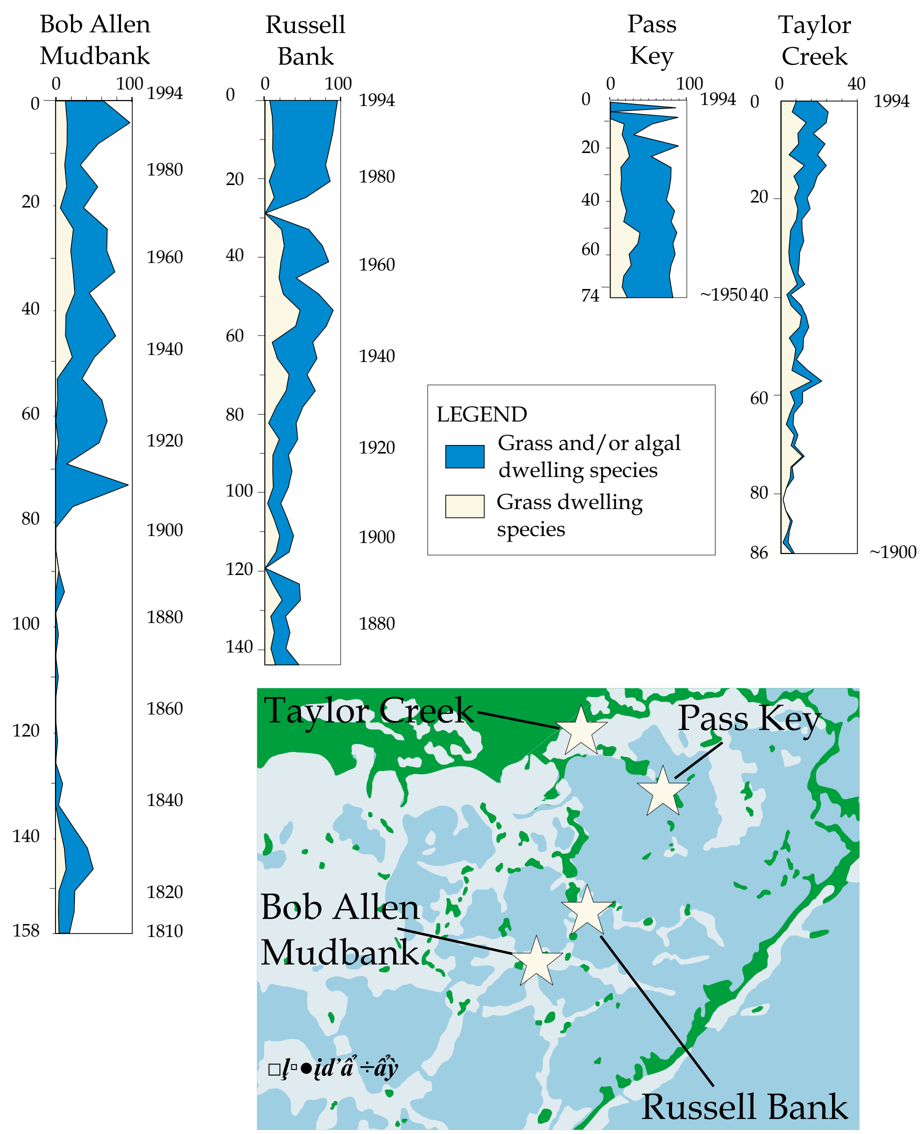

Figure 1. Aquatic vegetation indicators (in percentage abundance) in four cores from Florida Bay. Cores are scaled to years on the right-hand side and depth (cm) on the left.

Brachidontes exustus is a euryhaline species that can tolerate diminished water quality, and it is nearly ubiquitous at sites in central and eastern Florida Bay today. Beginning about 1980, *Brachidontes exustus* became the most dominant species at Russell Bank and Bob Allen, and it increased in dominance in the upper portion of the cores from Pass Key and Taylor (fig. 2). The concentration of this euryhaline opportunist species in the upper portion of all the cores implies that the system has been under increasing stress in the last 20 years, either due to increased salinity fluctuations and/or diminished water quality.

Molluscan faunal data illustrates important changes in the distribution of fresh and low salinity water in northern transitional, eastern, and central Florida Bay (Fig. 2). Since about 1900, there has been a steady decline in fresh water and mesohaline (<12 ppt) molluscs at the mouth of Taylor Creek. Changes in salinity at Taylor Creek and Pass Key (southeast of Little Madeira Bay) may be due to water management practices, fluctuations in average annual precipitation, sea level, or a combination of all of these. Russell Bank core, in eastern Florida Bay, shows distinctive changes in the molluscan assemblage between 1910 and 1930, indicating conditions that are more saline. Changes that occur between 1910 and 1920 at Bob Allen and between 1910 and 1930 at Russell indicate a shift toward less stable conditions. During this time period, average rainfall did not fluctuate significantly in southern Florida, but substantial human alteration of the environment occurred with the construction of Flagler Railroad in the Keys.

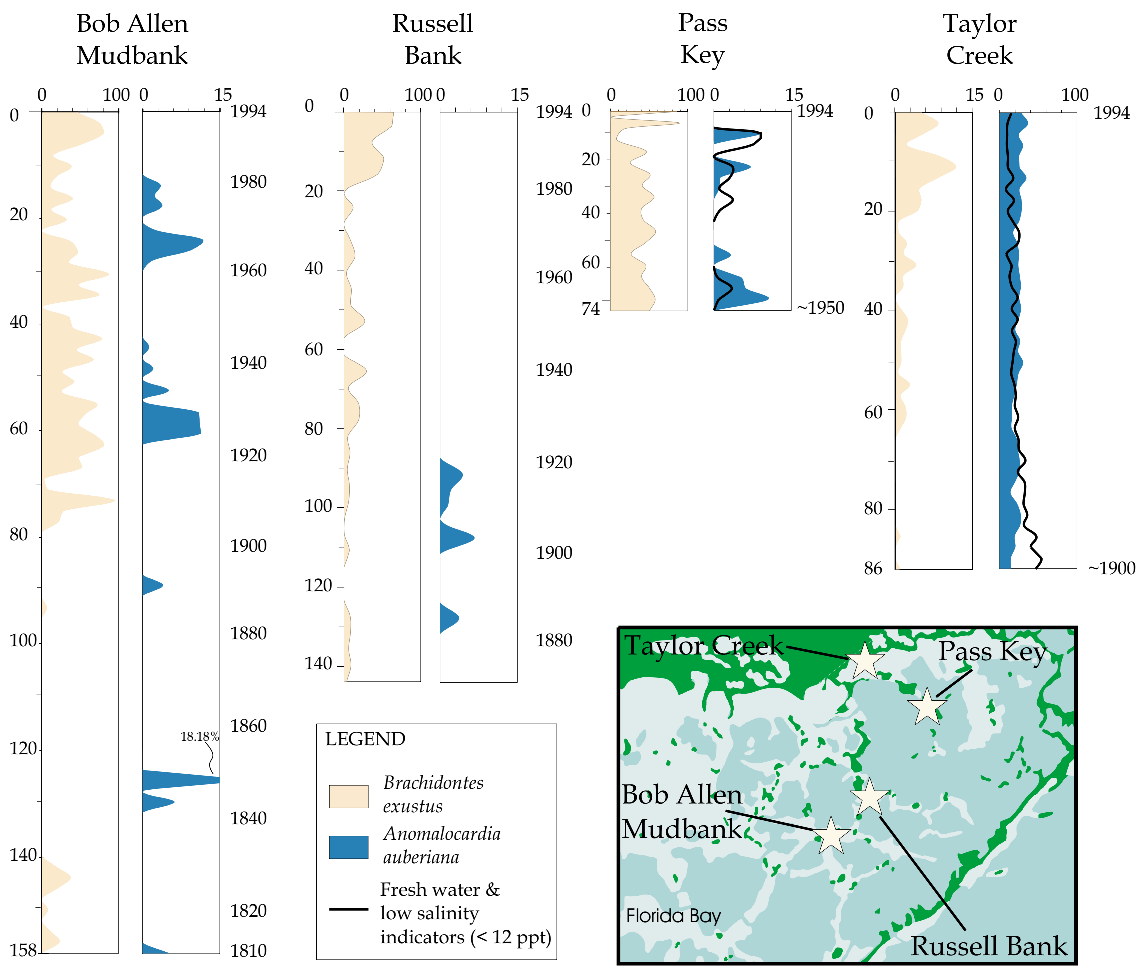

Figure 2. Key mollusc indicator species (in percentage abundance) in Florida Bay. Cores are scaled to years on the right-hand side and depth (cm) on the left.

Several measures of diversity were calculated for the cores: (1) total number of individual molluscan specimens; (2) faunal richness; (3) evenness; and (4) Shannon's diversity index (fig. 3). In general, these measures of diversity all fluctuate over time, which is to be expected in an estuarine environment. However, at Bob Allen and Russell Bank, evenness shows an inverse relationship to the percent abundance of *Brachidontes* in the upper part of the core. This is consistent with our hypothesis that the increase in *Brachidontes* in the last two decades indicates a stressed system.

Molluscan data help to clearly define restoration goals on a number of components critical to successful resource management. Information on seagrass distribution, salinity, water quality, and biodiversity, interpreted from molluscan data, can be used in models by water and land managers. By establishing what the system was like prior to significant human influence, and examining how the system has changed during the 20th century, mangers can establish realistic success criteria for restoration efforts. By answering the question "What was the system like 100 years ago?" we can then answer the question "What should the system look like after restoration?" We can also can answer the question "How will the system respond to the changes induced by restoration?"

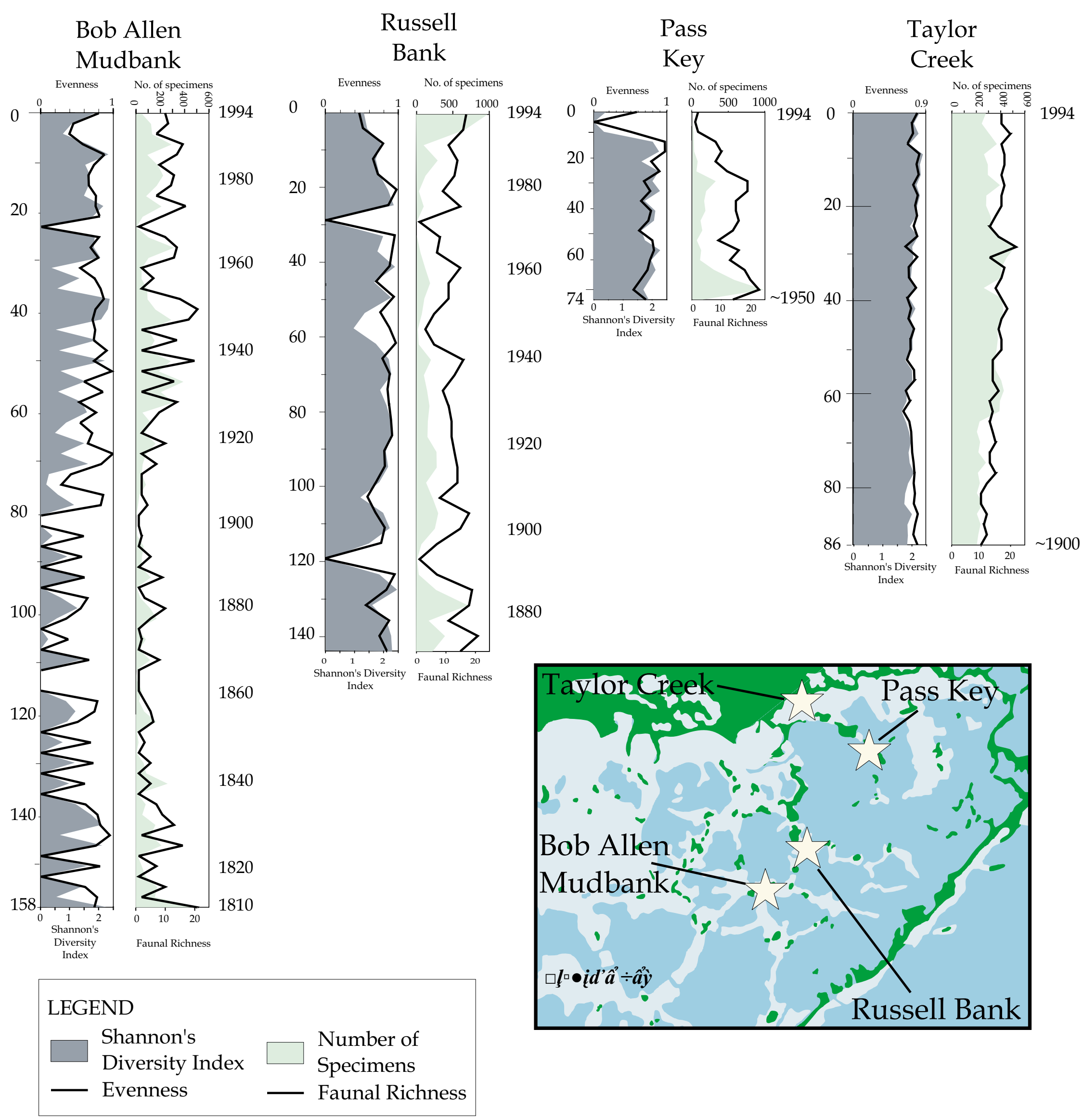

Figure 3. Diversity measures in four cores from Florida Bay. Cores are scaled to years on the right-hand side and depth (cm) on the left.

Historical Trends in Epiphytal Ostracodes from Florida Bay: Implications for Seagrass and Macrobenthic Algal Variability

By T.M. Cronin[1], Charles W. Holmes[2], G. Lynn Brewster-Wingard[1], S.E. Ishman[1], H.J. Dowsett[1], and N.M. Waibel[1]

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Living and fossil epiphytal ostracodes were investigated from central and eastern Florida Bay to determine historical trends in seagrass and macro-benthic algal habitats during the past century. Living assemblages collected in February and July, 1998 from 15 sites throughout Florida Bay revealed that *Loxoconcha matagordensis* and *Malzella floridana* are the dominant species living on *Thalassia* and that *Xestoleberis* spp. is the most abundant ostracode group living on *Syringodium* and marine algae such as *Chondria*. *Peratocytheridea setipunctata* is a species that is common on muddy substrates and on *Halodule*.

Temporal trends in epiphytal ostracodes were reconstructed from radiometrically-dated sediment cores from Whipray mudbank, Russell Banks, Bob Allen mudbank, Pass and Park Keys, Taylor Creek (near Little Madiera Bay) and Manatee Bay. The results show that there have been frequent changes in the relative frequencies of *L. matagordensis, M. floridana,* and *Xestoleberis* over the past century. Prior to the mid-20th century, seagrass- and algal-dwelling ostracode species were relatively rare at our sites in central and eastern Florida Bay. Ostracode assemblages living between about 1900 and 1940 were characterized by moderate to large proportions (10 to >60 percent) of *Peratocytheridea setipunctata* when *Thalassia* and macrobenthic algal species were significantly less common than during the later half of the 20th century.

Beginning about 1930, and continuing until 1950, *P. setipunctata* populations experienced significant declines while *L matagordensis* and *Xestoleberis* increased progressively from 0-10 percent to >25-40 percent, depending on the site. This long-term faunal shift in central Florida Bay suggests that there has been a much greater abundance and/or density of subaquatic vegetation over the past 50 years compared to the prior half century. Since 1950, our sites in central and eastern Florida Bay have experienced high amplitude swings in the proportion of seagrass and macro-benthic algal-dwelling species suggesting subaquatic vegetation has been extremely dynamic both spatially and temporally over decadal timescales. Some of these oscillations, such as the decline in *L. matagordensis, Xestoleberis*, and *M. floridana* during the 1970's and early 1980's, appear to be synchronous across the study area and may represent large-scale dieoffs.

Across Trophic Level Systems Simulation (ATLSS) Program

By Donald L. DeAngelis
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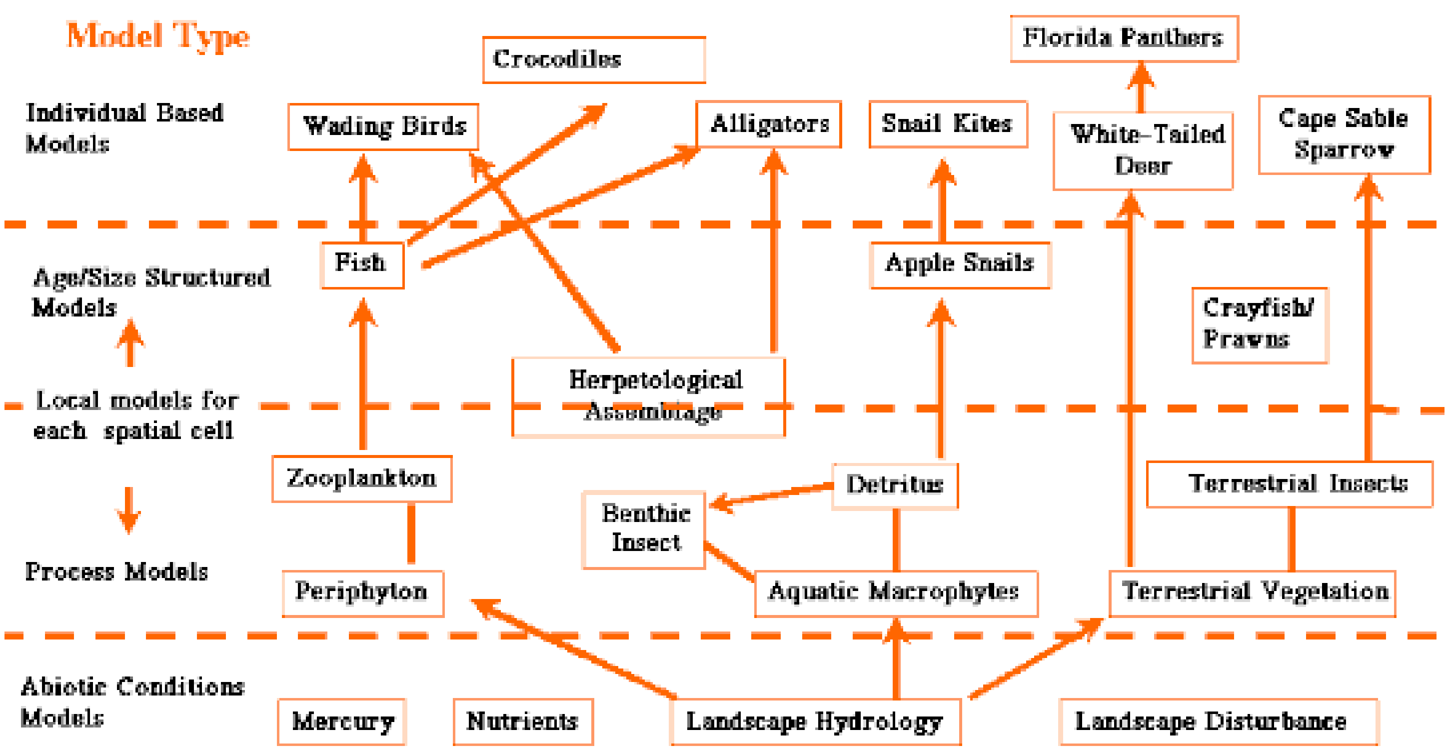
The major objective of the USGS's ATLSS (Across Trophic Level Systems Simulation) Project is to compare the relative differences between alternative hydrologic scenarios on the biotic components of the greater Everglades ecosystem. The goal is to provide a rational, scientific basis for ranking the hydrologic scenarios as input to the planning process, and through this to aid development of appropriate monitoring and adaptive management schemes.

ATLSS is constructed as a multimodel, meaning that it includes a collection of linked models for various physical and biotic systems components of the greater Everglades (fig. 1). This landscape modeling approach is the work of USGS scientists and collaborators from several universities. The ATLSS models are all linked through a common framework that allows for the necessary interaction between spatially-explicit information on physical processes and the dynamics of organism response across the landscape.

The ATLSS hierarchy starts with models which translate coarse resolution hydrologic information to a finer resolution appropriate for biotic components that operate at a spatial extent much smaller than the 2-mile resolution of the South Florida Water Management Model, which provides hydrologic input to ATLSS. The development of such a high resolution hydrology uses GIS vegetation maps and the hydroperiods associated with vegetation types, to characterize a 28.5 meter resolution topography (pseudotopography) of water derived from the 2-mile resolution hydrology model.



igure 1. Schematic representation of models used in the Across Trophic Level System Simulation Program.

The ATLSS hierarchy next includes Spatially-Explicit Species Index (SESI) models that make use of the spatially-explicit, within-year dynamics of hydrology to compare the relative potential for breeding and/or foraging across the landscape. SESI models have been constructed and applied during the Central and Southern Florida Comprehensive Review Study (Restudy) to the Cape Sable Seaside Sparrow, the Snail Kite, Short- and Long-Legged Wading Birds, and White-tailed Deer, with an additional model for Alligators now near completion.

Considerably more detailed models have been developed for the distribution of functional groups of fish across the freshwater landscape. This model considers the size distribution of large and small fish as important to the basic food chain which supports wading birds. It has been applied to assess the spatial and temporal distribution of availability of fish prey for wading birds. Individual-based models, which track the behavior, growth and reproduction of individual organisms across the landscape, have been constructed for the Cape Sable seaside sparrow, the snail kite, the white-tailed deer, the Florida panther, and various wading bird species. The models include great mechanistic detail, and their outputs may be compared to the wide variety of organism distribution data available, including that from radio collared individuals. An advantage of these more detailed models is that they link each individual animal to specific environmental conditions on the landscape. These conditions (e.g., water depth, food availability) can change dramatically through time and from one location to another, and determine when and where particular species will be able to survive and reproduce. ATLSS models have been developed and tested in close collaboration with field scientists who have years of experience and data from working with the major animal species of South Florida.

The most important need in greater Everglades restoration is the ability to predict the relative effects of different alternative restoration plans, compared with the base case of no restoration. The ATLSS integrated suite of models has been used extensively for that purpose in Everglades restoration planning. In particular, it has been used in the evaluation of the effects of Restudy, ModWaters, and C-111 hydrology scenarios on key biota. The role of USGS's ATLSS Program is to predict the effects of changes in water management on greater Everglades species and biological communities, as an aid to identifying and selecting those changes most needed and most effective for the restoration effort. The suite of ATLSS models can be used in parallel with monitoring and adaptive management during and after implementation of a restoration plan.

Developing an ATLSS/ELM Lower Trophic Level Model

By Quan Dong

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This project focuses on the lower trophic levels of the food web in freshwater marshes of the Everglades. The lower trophic levels of the Everglades that we focus on here are some of the key primary producers and primary consumers. The Everglades freshwater wetland is a mosaic of open water sloughs and grey-green marshes sprinkled with tree islands. In the open water slough habitats, the periphyton assemblage is a conspicuous feature. It is the major primary producer, providing both food and habitats for an array of small aquatic microfauna and mesofauna: grazers, detritivores, and omnivores. These small animals comprise the primary consumers. They channel energy and material to support large animals in the upper trophic levels, such as alligators and wading birds. The marshes are covered by emergent macrophytes. Sawgrass is a dominant species in a majority of marsh areas and often forms large dense monospecific stands. Few animals appear to consume live emergent macrophytes directly. Nevertheless, emergent macrophytes may provide habitats for terrestrial predators and produce a large amount of detritus, supporting detrital food chains in aquatic habitats. Thus, most primary consumers are algal grazers, detritivores, or omnivores that can practice both grazing and detritivory. The Everglades food web typically displays: (1) high primary productivity and high standing crops of periphyton and macrophytes; (2) low standing crops of the lower trophic levels; and (3) relatively abundant predators at higher trophic levels.

Environmental conditions have been significantly changed in the Everglades wetland. These changes affect the dynamics of communities and food webs. Two major changes, altered hydrology and phosphorus enrichment, have interacted to bring about many undesirable changes in biological communities and the landscape. Thus, restoration of natural hydrology and reduction of phosphorus inputs are two essential measures in the ecological restoration of the Everglades.

Hydrology and phosphorus enrichment drive the dynamics of primary producers. The response of the primary producers in turn can also affect phosphorus supply and hydrology. For example, in slough areas, calcareous periphyton takes up phosphorus very quickly and deposits the phosphorus into sediment after death, thus removing it from the water column. These mechanisms maintain phosphorus at low levels in the natural system. However, phosphorus enrichment leads to break-down of calcareous periphyton mats, increases in microbial biomass, and faster rates of decomposition and nutrient cycling. As a result, the rate of removal of phosphorus from the water column has been reduced and phosphorus levels have become high. The changes in primary producers, which are driven by hydrology and nutrient supply, can propagate to higher trophic levels through processes beginning with the primary producers (bottom-up processes). On the other hand, consumers might control the dynamics of their food through classic trophic cascades, as they reach a high level of abundance. Such top-down control may reach down further to the interaction between primary producers and the nutrient supply. Thus, the lower trophic levels serve as two-way links between hydrology, phosphorus enrichment, and the dynamics of higher trophic levels. They are important components of the integrity and health of ecosystems. The trophic structure of the lower trophic levels changes with the interplay between bottom-up and top-down controls. It can serve as an important performance measure for Everglades restoration.

The lower trophic model is designed to provide a tool for a mechanistic understanding of the links among the lower trophic levels, their predators, and the two main abiotic driving forces, hydrology and phosphorus input. This understanding is critical for ecological restoration because it links some important restoration measures, such as water management and nutrient removal methods, to some of the restoration targets, such as wading birds and other predator populations. The quantitative understanding can shed light on the design of scientific experiments, field monitoring, and restoration projects.

The model is designed to perform two functions: (1) generate scientific hypotheses, and (2) evaluate management scenarios. The model contains three trophic levels and simulates trophic interactions among seven trophic groups: periphyton, macrophytes, detritus, grazers (herbivores), detritivores, omnivores, and predators (fig 1). Hydrology and nutrient supply are two major environmental forces driving the lower trophic levels. Mathematical analyses are used to describe the general features of the system and to identify critical processes and parameters. Simulations will be run to examine hydrological scenarios. The model system contains a suite of modules, which can be used individually as independent models to address some issues. For example, a periphyton model was built to examine the interactive relationship between periphyton and phosphorus. Then, in the lower-trophic-level model, periphyton was incorporated as a component.

Analysis of the model has led to some new hypotheses. First, model simulations suggest that phosphorus loading has significant effects on lower trophic level system behavior. More than one equilibrium point may exist, with different steady state levels of periphyton. The number and positions of steady states depend upon the rate of sloughing; that is, deposition of refractory phosphorus into sediment by periphyton. Due to nonlinear interactions between periphyton and phosphorus in this model, periphyton may change dramatically with small changes in phosphorus supply. Changes to the periphyton community due to the increase in phosphorus loading cannot be reversed without lowering the input

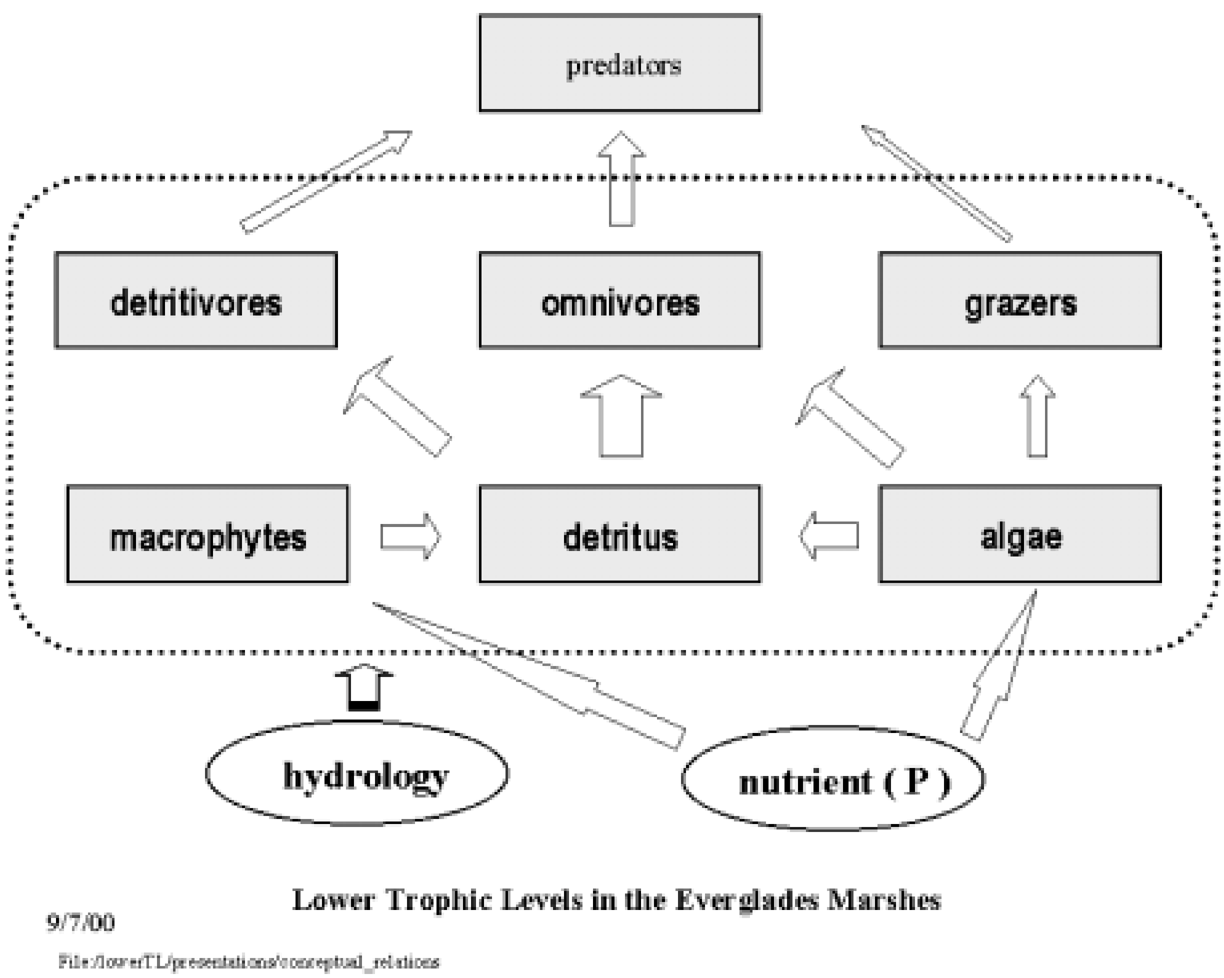

Figure 1. Schematic of the lower trophic level model, showing the seven functional groups included in the model. There are two driving forces, hydrology and nutrient input.

below the threshold level that caused the changes (hysteresis). Second, the Everglades ecosystem appears to be detritally dominated. The detrital dominance hypothesis asserts that much of the primary productivity is uneaten by herbivores and goes into detritus in the Everglades marshes. The detritivorous channel is very important in supporting upper trophic levels. Preliminary simulations showed that phosphorus enrichment may further reduce herbivory and enhance the detrital link to predators. Thus, phosphorus enrichment can lead to changes in the trophic structure of the lower trophic levels. Third, because there is a great deal of energy flow through the detrital food chain, the consumers supported by this chain may be responsible for the top-down control on herbivorous grazers. Finally, omnivory appears to be common in the Everglades ecosystem.

Research methods include construction and application of a suite of process-oriented models with different levels of complexity. First, models with only the simplest biological processes were built. Model complexity was then increased to look at more detailed and complex problems. This additional complexity included increases in the number of ecological functional groups and the inclusion of non-linearities and discontinuities in the functional relationships of the model. The model is designed to be incorporated into a spatially explicit design. Simulations will be performed to link ecological processes at different temporal and spatial scales, and to examine management scenarios. This modeling design provides answers to various questions progressively along a spectrum of temporal and spatial scales and degree of detail. The model can be used to perform multiple functions, such as scientific hypothesis test and decision-making support in restoration projects.

Ostracode Shell Chemistry as a Paleosalinity Proxy in Florida Bay

By Gary S. Dwyer[1] and Thomas M. Cronin[2]

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The use of ostracode metal/calcium ratios (Mg/Ca, Sr/Ca, and Na/Ca) was investigated to reconstruct the salinity history of central Florida Bay from its sedimentary record. First, provisional partition coefficients ($K_{D\text{-}Mg}$ and $K_{D\text{-}Sr}$) were developed from the average me/Ca ratio for modern Florida Bay water and 171 modern shells of *Loxoconcha matagordensis* at a mean Florida Bay water temperature of 26.5 °C. Trends in Mg/Ca ratios for *L. matagordensis* and *Peratocytheridea setipunctata* from radiometrically dated sediment cores from Russell Bank, Park Key, and Bob Allen Keys appear to provide a reasonable estimate of Florida Bay salinity history for the past 130 years. The most complete Mg/Ca record from Russell Bank extends back to 1875 and shows a good correspondence between estimated paleosalinity and measured annual rainfall in south Florida. Paleosalinity estimates for the Russell Bank area range from ~13 to ~55 ppt. Estimates for the post-1950’s period are comparable to instrumental measurements of salinity near the Russell Bank site.

The overall record indicates a decadal-scale variability in salinity in which large amplitude shifts in ostracode Mg/Ca ratios with high Mg/Ca (higher salinity) values corresponding to periods of low rainfall from ~1895 to ~1920 and from 1940 to present. The intervening 20 years (~1920-40) are characterized by relatively low amplitude shifts in Mg/Ca and rainfall. Since 1950, periods of high salinity (~45 to ~55 ppt) occur during each decade. Prior to 1940, salinity never exceeded ~45 ppt and generally remained below 40 ppt, despite evidence in the rainfall record of dry intervals in the early 1900’s equivalent to those of the last 50 years. Salinity minima associated with the decadal-scale oscillations range from ~15 to ~25 ppt. Four of the five extreme low values (~1915, ~1940, ~1983, ~1998) appear to correspond with times of strongly negative values of the Southern Oscillation Index, that is, El Nino Conditions that bring anomalously high winter rainfall in the southeastern U.S.

These results support the hypothesis that seasonal and decadal-scale salinity fluctuations are a natural part of the Florida Bay Ecosystem, and that these fluctuations are largely a function of natural variability of regional climate (rainfall). The relatively low peak salinity values associated with apparent dry periods in the early 1900’s suggests that, since ~1950, anthropogenic factors played a role in the magnitude of the salinity fluctuations in more recent times.

Computer Simulation Modeling of Intermediate Trophic Levels for Across Trophic Level Systems Simulation of the Everglades/ Big Cypress Region

By Michael S. Gaines

Department of Biology, University of Miami

The project has three primary components: (1) modeling of the snail kite population in Florida; (2) modeling of wading bird populations in the Everglades; and (3) modeling of the reptile and amphibian food web in the Everglades.

Snail kite modeling: The snail kite is a raptor whose distribution in the United States is limited to the freshwater marshes of southern and central Florida, including the Everglades. The snail kite is listed as an endangered species in the United States. Although its numbers have appeared to increase in recent years, total population size is probably still below 2000. Because of its endangered status, the snail kite is among the species being given specific attention in the ongoing Everglades restoration project (Bennetts and others, 1994, Davis and Ogden 1994). It is the objective of this work to develop an individual-based, spatially-explicit model of the snail kite population that includes the response of the snail kite population, both in its spatial patterns and its survival to drought conditions. The model is being applied to both historical data on the spatial pattern of water levels throughout the snail kite's range as well as the pattern of water levels projected from models for changed water regulation conditions.

The spatial structure of the model consists of several disjunct habitat areas, which we will refer to as wetland habitat sites. Following Bennetts and Kitchens (1996), fourteen major wetlands in southern and central Florida were identified as suitable snail kite habitat: Everglades National Park, Big Cypress National Preserve, Water Conservation Areas 3A, 3B, 2A, 2B, and 1 (Loxahatchee National Wildlife Refuge Preserve), Loxahatchee Slough, Holey Land Wildlife Management Area, Lake Okeechobee, Upper Saint John's Marsh, Lake Kissimmee, Kissimmee Chain of Lakes, Lake Tohopekaliga, and East Lake Tohopekaliga. A fifteenth habitat area was added to the model, representing the scattered pieces of peripheral habitat in the agricultural areas, as a refugium for the kites during a system-wide drought.

The hydrology of individual wetland habitat sites in particular years is critically important to whether that site can be used for nesting by snail kites. Their sole food supply, apple snails, die or become unavailable when a site becomes dry. After drydown, a particular site may not be good habitat for a few years, until the apple snail population recovers. For purposes of modeling, the water levels in each wetland habitat site can be defined by a historical record estimated from a single water gauge near the core habitat of the snail kites on the wetland site, or these water levels can be produced from hydrologic models applied to forecast future water levels under different water regulation conditions. Each modeled kite goes through a fixed set of life stages. These life stages affect the probabilities with which the demographic processes of breeding, movement, and mortality occur. Each individual kite is simulated in the model on a weekly basis. Figure 1 shows sample model predictions of the relative effects of different hydrologic scenarios on the growth rates of the snail kite in a particular wetland over the 31-year period.

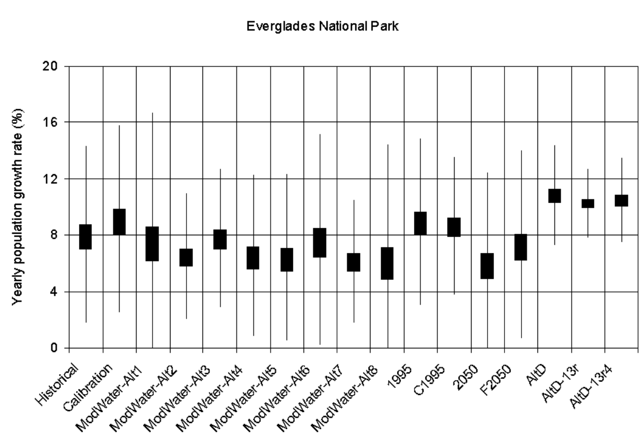

Figure 1. Output of the ATLSS snail kite model. The output compares the mean annual growth rate of the snail kite population in one particular breeding site, Everglades National Park, under a number of different water regulation scenarios.

Wading bird modeling: The purpose of the wading bird model is to investigate the dynamics of colonies and nesting success in relation to different hydrologic scenarios and the resulting spatial and temporal distribution of their prey. The model uses an individual-based approach and simulates the activities of potential nesting adults for a period of time immediately preceding the formation of a nesting colony and then through the entire nesting season. The model will enable wading bird ecologists to assess the effects of changes in the volume, timing, and spatial distribution of water flows on wading bird colonies sited at various locations in the Everglades.

Each individual wading bird in the model is described by a set of species-specific rules that govern their behavioral activities. A model wading bird does not operate on a fixed time scale, because its behavioral activities are of different duration. Instead, the wading bird model uses an event-driven approach, in which each bird sets its own time scales depending on its current activities. In its current version, the wading bird model operates on spatial grid of 500 m x 500 m grid cells.

Decisions made by the birds are guided by various constraints. Each bird must meet its energy demand during each day. If it can not meet this requirement, the bird is assumed to have died or left the system and is removed from the simulation. Colony formation, courtship, nesting, and egg laying are also determined by energetic constraints. The model assumes that nesting will only start if females have acquired sufficient energy reserves to produce eggs. Unless female birds can meet these demands, nesting will not start. Colony formation and nesting is therefore directly tied to the availability of prey and the ability of the birds to obtain enough food in close proximity to their potential colony site.

The model keeps track of colony sizes and the number of nesting adults as well as the number of successfully fledged nestlings after the breeding season is over. Because energetic constraints drive most of their activities, in particular the onset and timing of nesting, different environmental conditions will lead to varying reproductive behavior and recruitment of young wading birds into the population.

Reptilian and amphibian modeling: The herpetological assemblage may play a vital role in sustaining a number of trophic groups and species in the Everglades. The American alligator, an important top predator in the region and a major concern of the Everglades restoration effort, is a good example. A recent study in the central Everglades indicated that reptiles and amphibians make up to 65 percent, on average, of adult alligator diets. In addition, wading birds, raptors, arthropods, mammals, and fish also prey on members of the assemblage. Given the importance of reptiles and amphibians to the freshwater aquatic ecosystems in the Everglades, an estimate was developed of the amount of biomass the assemblage produces that could be available to higher predators, given the internal feeding dynamics between assemblage members, and energetic constraints.

Food web structures were constructed consisting of nine functional groups for each of three general habitat types based on stomach content analyses. Estimates were made of energy gains and losses (fluxes) for each functional group. The model was parameterized using estimates derived from field data and the literature. Linear Programming was used to solve for a better set of estimates of the fluxes, given conditions of mass balance and constraints set by the initially estimated values. Critical to the model were choices of: (1) the relevant natural history of the assemblage and modeling considerations; (2) the choice of three habitat types; (3) decisions for lumping species into functional groups; (4) the mathematical relationships describing energy flow; (5) the linear programming models; and (6) parameter estimation.

Crocodile modeling and empirical work: The American crocodile individual-based model has been developed within the a modeling platform developed at the Netherlands Institute of Ecology (OSIRIS) framework. The purpose of the model is to predict how the American crocodile population will respond to alterations in freshwater flow into the estuary habitat. In the working version of the model individuals grow, interact, breed and suffer mortality dependent upon a static hypothetical landscape, salinity, and interactions with other crocodiles. The most recent work has focused on creating a dynamic landscape dependent upon freshwater input. In support of this modeling effort, the American crocodile radio-tracking project seeks to test for salinity effects upon hatchlings. Based on the literature, it is expected that hatchlings would prefer freshwater and would lose weight in hypersaline habitats.

The population of American crocodiles is being modeled using a spatially-explicit individual-based approach from the estuary areas of south Florida. The model imports an initial estuary landscape and then runs hypothetical water delivery scenarios which can alter the dominate vegetation types and salinity levels. Figure 2 shows the body condition of a model crocodile hatchling under different salinity conditions due to differences in rainfall for different years. Other work involves model parameterization, which is currently focused on fitting growth data to available models and acquisition of hatchling movement and survivorship data via radio-tracking. During the summer of 1999 11 radio-transmitters were placed on hatchling American crocodiles at the Florida Power and Light Company's Turkey Point Power Plant. Of these, 5 individuals were successfully tracked for up to 82 days in both the hypersaline cooling canal system and in surrounding freshwater and low saline habitats.

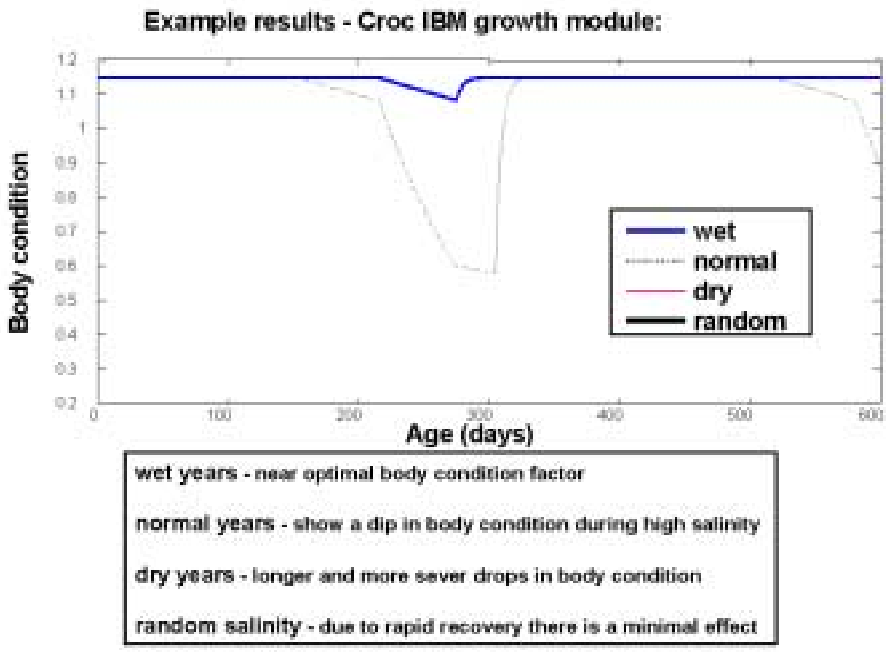

Figure 2. Output from individual-based model of American crocodile. Body condition of a particular crocodile is shown as a function of age under different environmental conditions.

Effects of Hydrology on Wading Bird Foraging Parameters

By Dale E. Gawlik and Fred H. Sklar

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The recovery of wading bird populations has been identified as a key component of successful Everglades restoration. Proposed causes for the decline in wading bird numbers (Frederick and Collopy, 1989; Bancroft and others, 1990; Walters and others, 1992) have in common the notion that current hydropatterns have altered the availability of prey. Indeed, food availability may be the single most important factor limiting populations of wading birds in the Everglades (Frederick and Spalding, 1994). Food availability is determined by the abundance of prey and the vulnerability of prey to capture. Prey abundance is affected by factors such as nutrient levels and hydroperiod whereas vulnerability to capture is affected by such things as water depth, vegetation density, and body size. Each component of prey availability is affected differently under various water management scenarios. For example, long periods without severe drydowns are thought to increase the abundance of fish (Loftus and Eklund, 1994). In direct contrast, these fish become most vulnerable to capture by birds when water depth is shallow. Thus, the subtle, and as of yet undefined, interaction between water depth and hydroperiod may be critical for supporting healthy populations of both fish and birds.

In the face of such conflicting management scenarios, knowing the relative importance of each component of food availability is a precursor to understanding the effects of specific water management regimes on wading birds. Ongoing modeling efforts in south Florida such as the Across Trophic Level Systems Simulations (ATLSS) program integrate such information and provide predictive power for future management decisions. Currently, the biggest information gap limiting the wading bird model of ATLSS is foraging success as a function of prey availability (United States Geological Survey, 1997). The South Florida Water Management District (SFWMD) is currently conducting a series of experiments aimed at determining the effects of water management on the use of foraging sites by wading birds. Site-use data are available immediately after each experiment and thus allow for quick analyses and write-up. However, also as part of those experiments, foraging behavior of wading birds at feeding sites with known prey availabilities was recorded on film. Current funding levels at SFWMD dictate that the foraging data, which will require thousands of hours to extract from the films, will require increased funding to meet the time schedule proposed for ATLSS (U.S. Geological Survey, 1997). This foraging data will greatly aid the development of a successful wading bird component of ATLSS.

The conceptual model for this study is based on the idea that hydroperiod is a long-term process that primarily influences the abundance, body size, and species composition of the prey community, whereas water depth has immediate effects on individual birds by influencing their ability to capture prey. This study seeks to determine through field experiments, the proximate effects of water depth, prey density, prey size, and prey species on wading bird foraging parameters. The species of wading birds examined in this study are those in the ATLSS wading bird model: the Wood Stork, White Ibis, Great Egret, and Great Blue Heron.

Field experiments were conducted in a set of 15 0.2-ha ponds directly adjacent to, and NW of, Arthur R. Marshall Loxahatchee National Wildlife Refuge in Palm Beach County, Florida. Three experiments (water depth and fish density, water depth and fish size, water depth and fish species) were conducted between March 1996 and March 1997. Each experiment began when ponds were stocked with fish and ended when bird-use nearly ceased (a period of approximately two weeks). The maximum number of birds present in a day (all ponds pooled) was approximately 280. For the fish density experiment, two treatments were assigned randomly among 12 ponds using a 3x2x2 factorial arrangement (water depth: 10 cm, 19 cm, 28 cm; fish density: 3 fish/m^2, 10 fish/m^2; replicates: 2). For the fish size experiment, 2 treatments were assigned randomly among 12 ponds using a 3x2x2 factorial arrangement (water depth: 19 cm, 28 cm, 37 cm; fish size: 3 cm, 8 cm; replicates: 2). All ponds were stocked at a density of 8 fish/m^2. For the fish species experiment, three treatments (water depth: 10 cm, 28 cm; fish density: 4 fish/m^2, 16 fish/m^2; fish species: bluegill, golden shiner; replicates: 2) were assigned randomly among 12 ponds. This 2x2x2x2 arrangement was more complex because the treatment of high fish density and low water was eliminated from the design.

To measure wading bird foraging responses, we filmed feeding flocks for 5-45 minutes from a vehicle with a Hi-8 mm video camera and 8-120 mm zoom lens. A pilot study indicated that filming from a parked vehicle with cloth-covered windows disturbed birds less than a portable blind. Following the field portion of the study, time-activity budgets of focal birds (Altmann, 1974) were constructed from videotapes. From each time-activity budget, we calculated mean prey-intake rate as the response variable.

Thus far, only the water depth and fish density experiment has been analyzed. Key results include the development and refinement of a conceptual model of wading bird foraging behavior. This model provided the rules for quantifying time-activity budgets for all species, including tactile and visual foragers, under the circumstance encountered during the experiments. We calculated prey-intake rates and their associated variability for two prey densities and three water depths (table 1). These numbers can be used to refine parameter estimates currently in the ATLSS wading bird model. We reported foraging costs (giving-up densities of fish) and their associated variability for each species at three depths.

Foraging costs for all species generally increased as a function of water depth. Prey intake rates were higher for the Wood Stork and White Ibis than for the Great Egret and Great Blue Heron, however; so were their foraging costs. The higher foraging costs for White Ibises and Wood Storks relative to the other two species suggests that Wood Storks and White Ibises need to be in habitat that provides higher prey intake rates, and therefore may be affected more by a degradation in habitat quality. Because the giving-up density at individual ponds is a measure of habitat quality relative to the surrounding ponds, the results indicate that birds perceived deeper water ponds to be equal in quality to shallow water ponds only when they contained more fish. In other words, all species perceived foraging costs to be higher in the two deeper treatments but those costs were offset by fish density. In addition, the higher giving-up density for Wood Storks and White Ibises suggest that these species would be more negatively affected by deep water than would Great Egrets and Great Blue Herons. Great Blue Herons did not appear to perceive greater foraging costs in the deepest treatment as compared to the medium depth treatment, but giving-up densities in both of those depths were greater than in the shallow treatment. Finally, we found that the rate of fish depletion in ponds increased with decreased water depth, confirming that fish were more vulnerable in shallow water.

Table 1. Prey intake rates (fish/min) for the Wood Stork, White Ibis, Great Blue Heron, and Great Egret during foraging experiments, 1996. Fish density quantile 1 was 0 – 0.79 fish m^2 and fish density quantile 2 was 0.8 – 1.59 fish m^2. Fish densities are numbers of fish captured in throw traps uncorrected for sampling bias.

Water Depth	Fish density Quantile	Parameter	Wood Stork	White Ibis	Great Blue Heron	Great Egret
10 cm	1	Ö fish/min		0.42	0.13	0.25
		SD		0.25	0.04	0.23
		N		15	2	22
		Range		0.13 – 0.97	0.11 – 0.16	0.03 – 0.88
	2	Ö fish/min		0.56		0.15
		SD		0.39		
		N		2		1
		Range		0.29 – 0.84		
	All densities	Ö fish/min		0.43	0.13	0.25
		SD		0.26	0.04	0.23
		N		17	2	23
		Range		0.13 – 0.97	0.11 – 0.16	0.03 – 0.88

19 cm	1	Ö fish/min	0.51	0.68	0.15	0.19
		SD	0.17	0.48	0.05	0.13
		N	8	12	2	78
		Range	0.26 – 0.78	0.05 – 1.45	0.12 – 0.18	0.05 – 0.96
	2	Ö fish/min		0.85		0.25
		SD		0.48		0.11
		N		8		13
		Range		0.31 – 1.57		0.05 – 0.40
	All densities	Ö fish/min	0.51	0.75	0.15	0.20
		SD	0.17	0.48	0.05	0.13
		N	8	20	2	91
		Range	0.26 – 0.78	0.05 – 1.57	0.12 – 0.18	0.05 – 0.96
28 cm	1	Ö fish/min	0.32		0.23	0.34
		SD	0.12			0.38
		N	9		1	35
		Range	0.13 – 0.50			0.07 – 2.14
	2	Ö fish/min	0.77	0.58		0.22
		SD	0.33	0.52		0.12
		N	12	4		15
		Range	0.14 – 1.18	0.20 – 1.34		0.10 – 0.52
	All densities	Ö fish/min	0.57	0.58	0.23	0.30
		SD	0.34	0.52		0.33
		N	21	4	1	50
		Range	0.13 – 1.18	0.20 – 1.34		0.07 – 2.14
All depths	1	Ö fish/min	0.41	0.54	0.16	0.24
		SD	0.17	0.39	0.05	0.24
		N	17	27	5	135
		Range	0.13 – 0.78	0.05 – 1.45	0.11 – 0.23	0.03 – 2.14
	2	Ö fish/min	0.77	0.73		0.23
		SD	0.33	0.47		0.11
		N	12	14		29
		Range	0.14 – 1.18	0.20 – 1.57		0.05 – 0.52
	All densities	Ö fish/min	0.56	0.60	0.16	0.24
		SD	0.30	0.42	0.05	0.22
		N	29	41	5	164
		Range	0.13 – 1.18	0.05 – 1.57	0.11 – 0.23	0.03 – 2.14

Development of Selected Model Components of an Across-Tropic Level Systems Simulation (ATLSS) for Wetland Ecosystems of South Florida

By Louis J. Gross
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The Across Trophic Level System Simulation (ATLSS) Project components at the University of Tennessee (UT) have been ongoing since 1991 and much of the models, code and results produced by the ATLSS project to date have been based at The Institute for Environmental Modeling (TIEM) at UT. The project began with very limited financial support from the National Park Service to develop an individual-based wading bird model (Fleming, Wolff, and DeAngelis, 1994; Wolff, 1994) and an individual-based model for white-tailed deer and Florida panther (Comiskey and others, 1997). Under the leadership of the then ATLSS project manager D. M. Fleming, a major long-term plan was developed for ATLSS as a linked set of models capable of analyzing the effects of alternative hydrologic plans on key components of the Everglades landscape (Fleming and others, 1994). The emphasis throughout has been on developing scientifically defensible models that, in addition to their utility to the planning process, are capable of generating hypotheses and analyzing basic scientific issues arising in the Everglades. Major components of the ATLSS project applied during the Restudy are described below. Interested readers are encouraged to peruse the ATLSS Home Page (http://atlss.org) for further information.

The ATLSS Project is playing a key role in the ongoing hydrologic planning process in south Florida. ATLSS uses the various alternative water plans to drive computer models that contrast the relative impacts of these plans on the biotic components of south Florida. These computer models analyze the relative impact of plans on endangered species such as the Cape Sable seaside sparrow as well as wading birds, deer, and fish. ATLSS is one of the most complex and sophisticated ecological modeling approaches ever attempted. It simulates the interactions of the various elements of wetlands within the framework of a single, encompassing computational scheme. The planning products produced as well as information about the models are available at http://atlss.org/. ATLSS will continue to be used to aid monitoring planning and is expected to be used in ongoing adaptive management of the system. It will also be extended to include estuarine and marine components.

An essential component of restoration planning in South Florida has been the development and use of computer simulation models for the major physical processes driving the system, notably models for freshwater hydrologic dynamics as it is affected by alternative human control systems and non-controlled inputs such as rainfall. The major objective of the ATLSS Project has been to utilize the outputs of such physical systems models to drive a variety of biotic models that attempt to compare and contrast the relative impacts of alternative hydrologic scenarios on the biotic components of south Florida. The biotic models are constructed at varying levels of spatial, temporal, and organismal resolution, and have focused to date on intermediate and upper trophic level biotic components. The essential goal is to provide a rational, scientific basis for developing relative rankings of hydrologic scenarios as input to the planning process, and through this to aid development of appropriate monitoring and adaptive management schemes.

Two primary components of the ATLSS project have been development of methodologies for linking dynamic ecological models to spatially explicit information, which can itself be dynamic, and development of a high resolution hydrology. The first of these, called the ATLSS Landscape Structure Model, provides the primary interface between all ATLSS component models and landscape data, as well as providing a framework for communication of spatially explicit information between ATLSS components. The High Resolution Hydrology model translates coarse resolution hydrologic information to a finer resolution appropriate for the biotic components in ATLSS.

Several ATLSS models makes use of information on breeding and foraging requirements for species and how these relate to habitat and hydrologic conditions, but do not attempt to track in detail the population dynamics or behavior of individuals for these species. These Spatially Explicit Species Index (SESI) models make use of the spatially explicit, within-year dynamics of hydrology to compare the relative potential for breeding and/or foraging across the landscape. SESI models are viewed as approximations which are useful in coarse evaluations of scenarios and are an

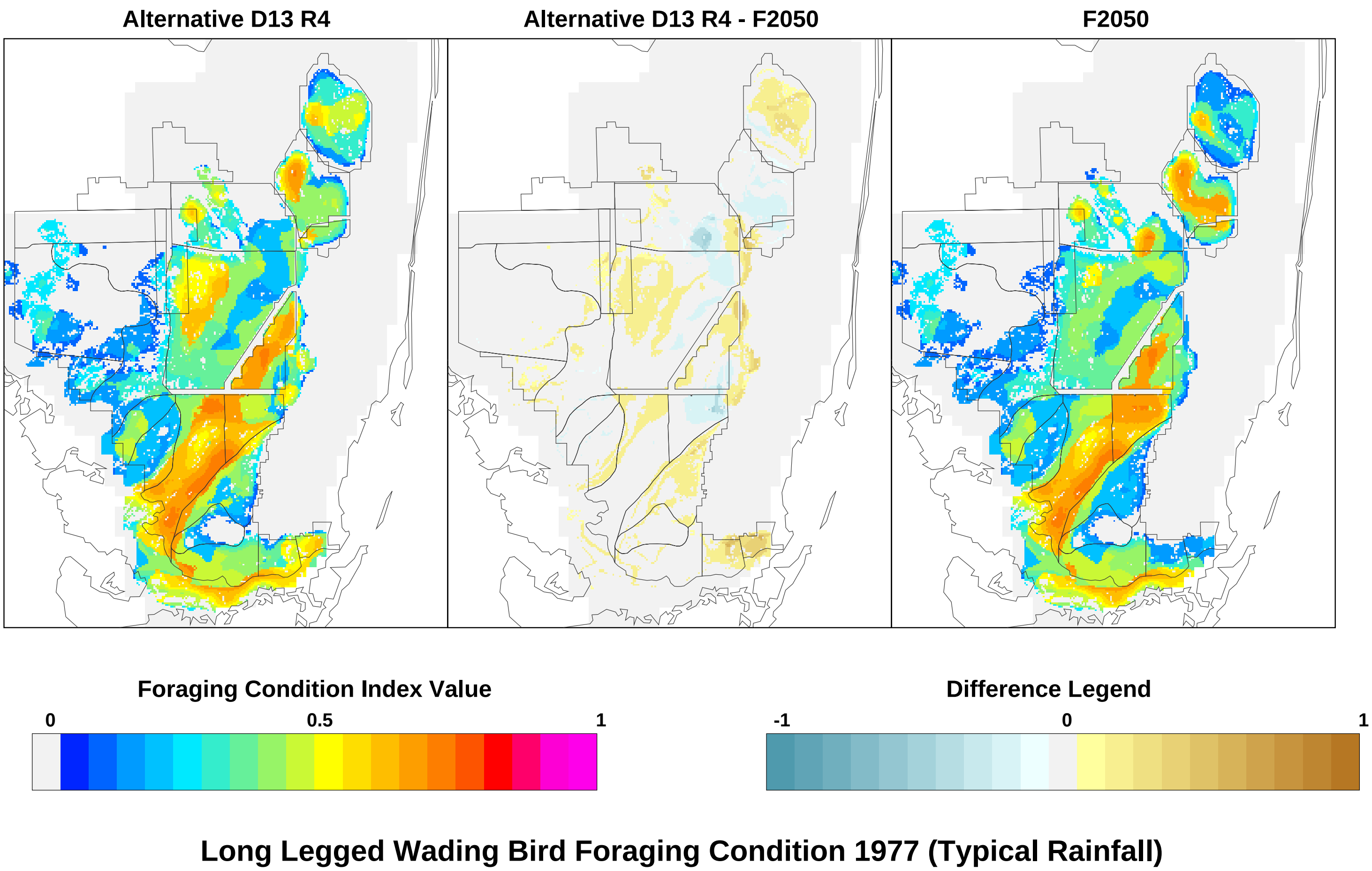

Figure 1. Comparison of two different scenarios for long-legged wading birds using a SESI model. The left and right panels show the foraging indices under, respectively, a proposed water-regulation plan and the base case. The middle panel shows the differences between these alternatives.

aid in interpreting more detailed models. SESI models have been constructed and applied during the Central and Southern Florida Comprehensive Review Study (Restudy) to the Cape Sable seaside sparrow, snail kite, short- and long-legged wading birds, and white-tailed deer, with an alligator model now completed as well. The application of a SESI model to comparison of two hydrologic scenarious is shown in figure 1.

The ATLSS Landscape Fish model (ALFISH) has as its main objective the capability to compare in a spatially explicit manner the relative effects of alternative hydrologic scenarios on freshwater fish densities across South Florida. Another objective is to provide a measure of the dynamic, spatially explicit food resources available to wading birds. By providing a model for the key resource base for wading birds, ALFISH allows the linkage of the hydrologic effects on fish densities with models for wading bird foraging. ALFISH has been developed in regular consultation with several field biologists and has made use of a variety of data sources on fish distributions to estimate parameters.

The PANTRACK tool is designed to analyze radio-telemetry monitoring data, such as that collected for Florida panthers, and display observations over a variety of background maps. Subsetting of monitoring data by time periods and/or by individuals allows movement patterns to be analyzed and interpreted in terms of factors such as habitat variability, seasonality, age, gender, reproductive status, and causes of mortality. PANTRACK can help wildlife biologists and modelers translate raw location data into information about key animal behaviors, such as territoriality and movement patterns, breeding, predation, social interactions, dispersal patterns, aggressive encounters, and habitat use. This information can be used to expand what is known about the animal being tracked, suggest topics for research, guide management decisions, and develop behavior rules for predictive models to evaluate the effects of various management options.

PANTRACK was developed to help define panther behavior rules for the spatially explicit, individual-based ATLSS Deer/Panther model. The effectiveness of individual-based models depends on the availability of detailed observations about individuals on the landscape, and on the ability to find patterns in these observations that provide insight into key animal behaviors.

Synopsis of Research Methods

ATLSS is constructed as a multimodel, meaning that it includes a collection of linked models for various physical and biotic systems components. The component models utilize a variety of different approaches and operate at different spatial and temporal resolutions, depending upon the level of detail appropriate for the organisms being addressed as well as limitations imposed by inadequate data to realistically model the system. The ATLSS models all are linked through a common framework which allows for the necessary interaction between spatially explicit information on physical processes and the dynamics of organism response across the landscape. ATLSS models all include some mechanistic components, though some are considerably more detailed in the level of description of the organisms involved. ATLSS outputs all are interpreted in a relative assessment framework, in which an alternative is compared to a base scenario.

The ATLSS hierarchy starts with models which translate coarse resolution hydrologic information to a finer resolution appropriate for biotic components that operate at spatial extents much smaller than the 2-mile resolution of the main hydrologic model. The development of such a high resolution hydrology relies upon vegetation maps and the associated limitations on hydroperiod associated with these, to characterize a 28.5-meter resolution topography chosen to preserve the volumes of water derived from the 2-mile resolution hydrology model.

The ATLSS hierarchy next includes SESI models which make use of the spatially explicit, within-year dynamics of hydrology to compare the relative potential for breeding and(or) foraging across the landscape. SESI models differ from traditional index models in that they: (1) have a temporal component and, thus, incorporate both static and dynamic “landscape features;” (2) are based on a “landscape structure” which, once established, can be used to model the responses of any species in the system; and (3) can provide a relatively easy means of comparing species responses to more complex ATLSS models, including process models, size-structured population models, and individual-based models.

Individual-based models, which track the behavior, growth and reproduction of individual organisms across the landscape, have been constructed for the Cape Sable seaside sparrow, snail kite, white-tailed deer, Florida panther, and various wading bird species. The models include great mechanistic detail, and their outputs may be compared to the wide variety of organism distribution data available, including that from radio-collared individuals. An advantage of these more detailed models is that they link each individual animal to specific environmental conditions on the landscape. These conditions (for example, water depth, food availability) can change dramatically through time and from one location to another, and determine when and where particular species will be able to survive and reproduce.

Ecological Risk Assessment of Toxic Substances in the South Florida Ecosystem: Wildlife Effects and Exposure Assessment

By Timothy S. Gross
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Few studies have assessed contaminants and their potential adverse effects on wildlife in the south Florida ecosystems. Available data indicates a wide array of organic contaminants, including pesticides, PCB's and PAH's, as well as mercury and nutrients (phosphorous) are present and of primary concern in south Florida (Kolipinski and Higer, 1969; Waller, 1982; Haag and McPherson, 1997; Miles and Pfeuffer, 1997). The potential adverse effects on wildlife are not known, although a wide variety of fish, reptiles, invertebrates, amphibians, birds and mammals utilize this critical ecosystem. Recent results have linked previous water management efforts to altered contaminant distributions and potential wildlife exposures. The South Florida Restoration Task Force has initiated a hydrologic restoration as a primary goal of ecosystem restoration and resource management. These efforts are designed to restore original habitat conditions to support viable wildlife populations while providing available water resources. However, these restoration efforts have not considered nor evaluated the potential adverse effects on contaminant distributions and subsequent wildlife exposures. The project assesses current wildlife contaminant exposures and predicts and monitors future restoration-driven exposures. Results can be used to prevent adverse effects on wildlife within the south Florida ecosystems.

To determine whether chemical stressors/contaminants in south Florida harm wildlife, it is important to study animals that are potentially exposed and appear sensitive to contaminants. Utilization of several receptors/species at multiple trophic levels have been utilized for the current study to detect potential exposures and adverse effects within the south Florida ecosystems. The American alligator (*Alligator mississippiensis*), largemouth bass (*Micropterus salmoides*), and brown-bullhead catfish have been utilized as receptors for study. These species are important in south Florida ecosystems and of high priority due to our extensive previous data which indicates their utility as bioindicators of chemical stressor/contaminant effects in other Florida ecosystems.

Also, species from two other taxonomic groups and trophic levels were selected for study: freshwater mollusks and wading birds. Wading bird populations have been the subject of frequent monitoring efforts for the south Florida ecosystems. White ibises (*Eudocimus albus*) and great egrets (*Casmerodius albus*) are being utilized for the current assessment of potential contaminant exposures and effects in south Florida. White ibises have shown the greatest declines in reproductive success and population size, and are also of special interest in the Everglades. The white ibis is a key species because it remains the most numerous breeding wading bird in the Everglades, and restoration of breeding populations of ibises would have a huge numerical effect on the total population of breeding birds in the ecosystem.

Little is known about the effects of environmental contaminants on invertebrates. However, invertebrate species have been recognized as important environmental sentinels, and serve as models for a wide variety of toxicity tests that utilize mortality and lethality as the endpoints of significance. Indeed, invertebrates are an important, trophic level within ecosystems and a group with high exposure potentials to a wide variety of environmental contaminants/chemicals. Freshwater mollusks, mussels (*Elliptio buckleyi* and *Utterbackia imbecillis*) and the Florida apple snail *(Pomacea paludosa*), are being used as models for general toxicity and as important environmental sentinels, early signals, of environmental effects for contaminants such as endocrine-disruptors.

Efforts have involved the collection of alligators at six sites throughout the south Florida/Everglades ecosystem. Contaminant analyses and preliminary assessments of potential effects are currently underway. These efforts have also included a full survey/assessment of freshwater mussels in historic locations throughout south Florida. These analyses indicated a severe decline in freshwater mussels populations in coastal areas, Miami-Dade County, Water Conservations Areas, and canals within the Everglades. Most importantly, these analyses suggested that altered population status may be partly due to altered reproductive function and potential contaminant causation. Additional assessments of fish throughout the south Florida ecosystems is currently underway. Additional assessments of wading birds and other species will be conducted in Spring 2001 and preliminary risk assessments will be completed.

A complete ecological risk assessment requires hazard identification, documentation of adverse effects, demonstration of exposure, and knowledge of dose-response relationships. Currently available information concerning potential contaminant effects for wildlife within south Florida consists primarily of the identification of exposure to potential hazards. Indeed the south Florida ecosystem is contaminated with a wide array of chemical stressors/contaminants, including chlorinated hydrocarbon pesticides, heavy metals, water soluble pesticides, and nutrients. However, evidence of adverse effects, cause and effect relationships, or dose-response relationships have not yet been documented for specific contaminants or mixtures. It is critical that potential exposures and subsequent adverse effects be assessed for wildlife in south Florida to enable a complete ecological risk assessment as well as an assessment and evaluation of proposed restoration strategies.

The initial exposure assessment is utilizing sampling regimes at selected critical areas to provide an evaluation of soil, water and sediments. These evaluations include pH, percent water, grain size, cation exchange capacity, and total volatile solids as well as quantitation of organochlorine pesticides and polychlorinated biphenyls (PCB's, polynuclear aromatic hydrocarbons (PAHs), organophosphate pesticides (Ops), nitrogen based herbicides, phenoxy-acid herbicides, and heavy metals. Tissue samples from the ecological receptors , outlined above will be analyzed for lipid content, as well as quantitation of organochlorine pesticides and polychlorinated biphenyls (PCB's, polynuclear aromatic hydrocarbons (PAHs), organophosphate pesticides (Ops), nitrogen based herbicides, phenoxy-acid herbicides, and heavy metals.

These studies are expected to show significant wildlife exposures to chemical stressors/contaminants in south Florida, and adverse effects as a result of these exposures. Effects characterization will focus on non-lethal effects such as decreased health status, altered reproductive success, and endocrine disruption. In addition, it is likely that we will be able to demonstrate population and community level effects may show a decrease in sensitive species in sites with significant contaminant of exposure. Study results are expected to demonstrate convincing evidence as to the causal role of specific chemicals and/or mixtures. Finally, studies comparing responses of these selected species will likely provide major insights into the basis of interspecies differences in sensitivity to contaminants.

Sea-Level Rise and the Future of Florida Bay in the Next Century

By Robert B. Halley[1], Kimberly K. Yates[1], and Charles H. Holmes[1]

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During the next century the physiography of Florida Bay will change due to a complex interplay between sediment production, transport, and accumulation and the local, relative rate of sea-level rise. Some estimates have predicted that the Bay will eventually fill with sediments and become part of the Everglades (Enos and Perkins, 1979). Others have suggested erosion and removal of sediment will result in the expansion of the open Gulf of Mexico throughout the Bay (Wanless and Tagett, 1989; Parkinson and Meeder, 1991). These predictions, while geologically correct, incorporate time-scales of centuries to millennia, beyond those applicable to ecosystem restoration planning. Recent process studies, including estimates of sediment production (Bosence, 1989; Halley and others, 1999; Yates and Halley, 1999), transport (Prager and Halley, 1999; Stumpf and others., 1999), and accumulation (Robbins and others., in press), indicate neither of these scenarios is correct for the next hundred years. Rather, subtle and complex changes that have characterized the physiographic evolution of the Bay during the 1900s will continue. Process studies provide more accurate forecasting for this century because they may be inferred on time-scales of decades to centuries.

About 60 percent of Florida Bay sediment has accumulated in mud banks during that last 4,000 years (Scholl, 1964). The remaining sediment (38 percent) is in flanking deposits and spread over lake floors in the central and western parts of the Bay. Islands, tidal channel deltas, and filled solution holes account for only a few percent of the sediment in the Bay. Geochemical and constituent sediment analyses demonstrate that the sediment has formed from the biota living in the bay. About 90-95 percent of the sediment is mineral carbonate skeletal debris and 5-10 percent is organic debris, mostly mangrove and seagrass. There is a small detrital fraction, generally less than a few percent, consisting of quartz, clays and dolomite (Prager and Halley, 1997). Surface sediments are about three-fifths sand and two-fifths mud by weight, but analyses of cores indicate subsurface sediments contain more mud with a sand/mud ratio of about 1:5. The sand-enriched surface sediments result from winnowing processes that preferentially transport fine sediment to mud banks leaving a sand veneer over large areas of the Bay floor.

Sediment is continuously produced by living organisms and is remobilized by erosion. Erosion occurs along unprotected shorelines, exposed mud banks, and areas recently denuded by seagrass mortality. Eroding islands show the most rapid erosion rates, with extreme shoreline retreat rates that approach 1 m yr^{-1}. The presence or absence of seagrass is a first-order control of subtidal erosion and deposition. Some mud banks that erode on exposed margins are accreting on protected margins, causing a net migration on the order of a few decimeters yr^{-1}. Areas of seagrass mortality may expose extremely fluid mud to transport, resulting in redeposition of several centimeters of sediment per year.

Wave modeling and direct measurement help to understand the complexities of erosion and deposition and the importance of seagrass. Waves form in the basins and propagate most effectively across basins with long axes parallel to the wind. Refraction effectively turns waves parallel to the banks. Seagrass diminishes wave energy along bank margins (Prager and Halley, 1999). If seagrass is absent, significant erosion may occur on bank margins. Although summer thunderstorms account for some erosion and turbidity, remote sensing studies indicate that winter cold fronts account for most of the turbidity and sediment transport in the Bay. Turbidity patterns also reveal a seasonally consistent west-central clear zone, indicating that little sediment from the central and eastern Bay escapes the estuary (Stumpf and others, 1999). Only hurricanes are energetic enough to redeposit sediment on islands and along shorelines.

Sedimentation rates between 0.5 and 2 cm yr^{-1} have been measured on the accreting margins of mud banks (Holmes and others., in press). These rates are almost an order of magnitude greater than sea-level rise and indicate that mud banks can outpace sea-level rise. However, coring reveals that mud banks are just keeping up to sea level, not catching up or becoming islands. It is hypothesized that seagrass dynamics prevent the banks from growing above sea level. Periodic episodes of seagrass mortality, probably caused by excessive aerial exposure, limit the ability of the banks to accrete above the annual low tide.

Newly formed sediment is a minor contribution to the banks. Radiocarbon can be used as a tracer of carbonate produced since thermonuclear atmospheric testing of the late 1950s and early 1960s. It can be shown that only a fraction of a percent of new carbonate sediment has been produced in the past 40 years (Halley at al., in preparation). Although carbonate production rates are estimated in the range of 100s gms m^{-2} yr^{-1} (Bosence, 1989), much of this production is redissolved (Walter and Burton, 1990). Net accumulation over the past 3500 yrs has been approximately 0.2 mm yr^{-1} (2.2 gms m^{-2} yr^{-1}). These production rates are similar to carbonate productivity estimates calculated from alkalinity and pH measurements made during 1998 and 1999.

Production rates of a fraction of a mm yr^{-1}, by themselves, are insufficient to keep up with sea-level rise. But the continuous redistribution of sediment, preferentially accumulating in seagrass on mud banks, will maintain the banks close to the annual low tide (fig. 1). The basins, on the other hand, will slowly deepen because sediment produced in the basins is removed and transported to the mudbanks. Basin deepening will result directly from sea-level rise and can be approximated using the methods of Titus and Narayanan (1995). The long-term evolution of Florida Bay, forced by sedimentation and sea-level change, defines the context within which long-term restoration activities will occur.

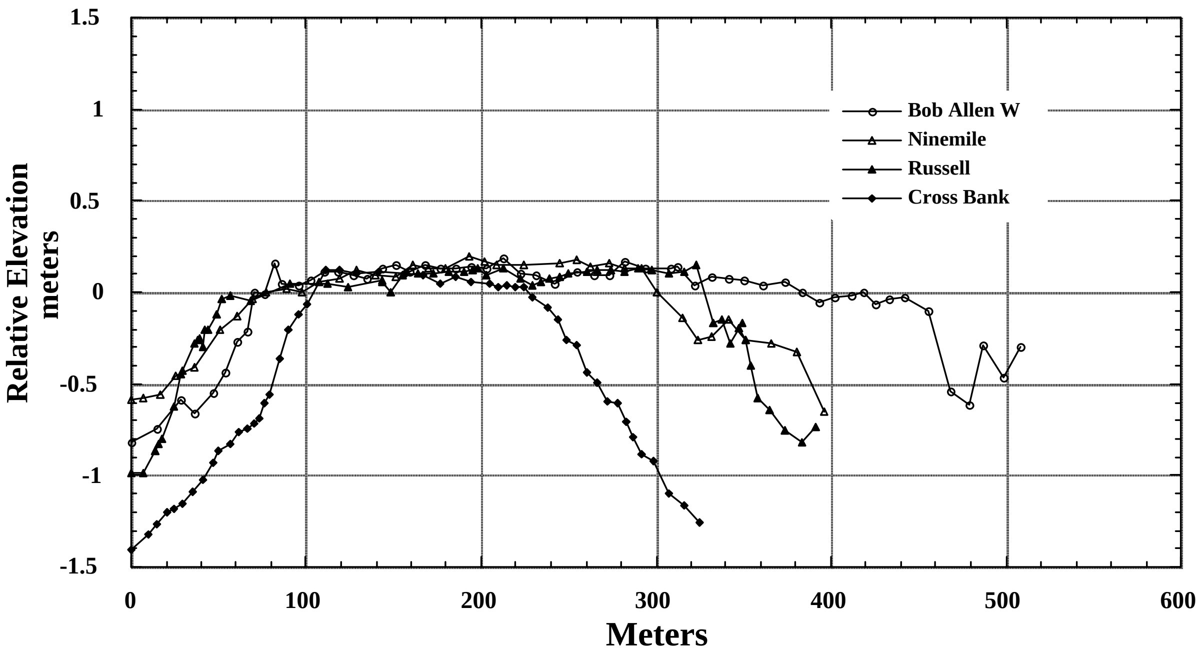

Figure 1. Profiles of Florida Bay mudbanks. Mudbanks have extremely level and uniform tops resulting from the interplay of sediment deposition and erosion influenced by seagrass presence and absence. The slopes of the banks, together with vertical accretion and erosion rates, may be used to estimate lateral migration rates. These profiles were surveyed with an electronic level and stadia rod, accurate to +/-3cm.

Life History, Ecology, and Interactions of Everglades Crayfishes in Response to Hydrological Restoration

By Noble Hendrix[1] and David Armstrong[1], and William F. Loftus[2]
[1]University of Washington; [2]U.S. Geological Survey, Homestead, Florida

Crayfish species composition and abundance are indicators of hydroperiod and are predictably influenced by hydromanagement. Two species of crayfish inhabit south Florida marshes. The Everglades crayfish, *Procambarus alleni*, is found in locations that dry seasonally (typically with a hydroperiod of less than 10 months), and it burrows when water recedes from the surface. The slough crayfish, *P. fallax*, is found in perennially flooded habitats and, although capable of burrowing, has not been observed in burrows in the field. Sympatric populations were found in locations that were flooded from 9 to 11 months (intermediate hydroperiod), or at sites that remained flooded in the dry season. This distribution pattern is useful in back-casting and in predicting the relative occurrence of species.

Life-history characteristics of each species are tied to different hydrologic requirements. For example, reproduction in the Everglades crayfish occurs synchronously and coincides with loss of water from the surface, whereas the slough crayfish breeds almost continuously. The species-specific responses to hydropattern are predictable and can be modeled. Spatially explicit models that incorporate the dynamics of crayfish response to variation in hydrology are being constructed. The results of this project will address how the loss of spatial extent, fragmentation of habitat, and compartmentilization of the watershed, have combined to affect crayfish distributions and abundance. These topics are important when considering that white ibis (Eudocimus albus) consume crayfish almost exclusively during nesting, and that foraging flight distance is markedly reduced when crayfish are locally available. Using Across Trophic Level Systems Simulation (ATLSS) wading bird models, the role of crayfish as an intermediate through which hydrology may affect nesting success can be addressed.

Sediment Dynamics of Florida Bay Mud Banks on a Decadal Time Scale

By Charles W. Holmes[1], John Robbins[2], Robert B. Halley[1], Michael Bothner[3], Marilyn Ten Brink[3], and Marci Marot[1]

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Ecosystem management requires knowledge of environmental dynamics. If historical environmental records do not exist, other methods must be employed to obtain this information. A well-known geochemical procedure that supplies this type of data is the use of natural radioactive nuclides to “date” the timing of events. Of the many naturally occurring nuclides, ^{210}Pb is the best suited for gauging the timing of episodes in Florida Bay. The age-depth relationships were calculated using the ^{210}Pb method for thirty-five sites within Florida Bay. The ages were independently confirmed by comparing the distribution of known concentrations of atmospherically anthropogenic lead recorded in dated cores to similar data in an annually banded coral. Sediments in the western and northern fringe of Florida Bay are accumulating at 0.3 cm/yr, a rate similar to that of sea level rise. In the north-central part of the bay, sediments are accumulating at a faster rate of ~1.0 cm/yr. The highest rate, ~2.0 cm/yr was measured in the northeastern part of the bay on the bank between Pass and Lake Keys. The rapid rate of accumulation in the northeastern part of the bay permits the deciphering of biological and geochemical changes with an accuracy of about two years. In contrast, the intermediate sediment rate in the central part of the bay provides adequate age-depth relationships for deciphering the environmental record of the past 100 years.

Diatoms as Indicators of Environmental Change in Sediment Cores from Northeastern Florida Bay

By J.K. Huvane and S.R. Cooper
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Diatom assemblages found in two sediment cores from northeastern Florida Bay indicated fluctuations in both salinity and subaquatic vegetation cover during the past 100 years. Diatoms from Russell Bank core 19A indicate that salinity was high prior to the 20th century. Between 1890 and 1920, assemblages dominated by *Mastogloia* species prevailed. After 1920, there was a dramatic shift to assemblages dominated by an epipelic (bottom-dwelling) taxon, *Nitzschia granulata*. About 1950, this taxon declined and the epiphytic species increased. Epiphytic species remained common until about 1972. After 1972, epiphytic diatoms decreased and diatoms indicative of higher salinity increased. Similar trends were seen in the Pass Key core 37 (which only spanned about 35 years, between 1960-96). Epiphytic diatoms were common between about 1967-77, and there was a general trend toward increasing salinity upcore. These findings are in general agreement with other studies of fossil indicators related to salinity and seagrass cover found in Florida Bay sediment cores.

Ecological Controls on Benthic Foraminifer Distributions in Biscayne Bay, Florida

By Scott E. Ishman

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Four benthic foraminiferal assemblages are recognized from surficial sediment samples collected in Biscayne Bay. The assemblages include: (1) a productivity assemblage; (2) a restricted environment assemblage; (3) an open-bay grass assemblage, and (4) an open-bay coarse sediment assemblage. The distribution patterns of these assemblages appear to be controlled by salinity, substrate, and organic input. The restricted environment assemblage is controlled by salinity and occurs in oligohaline to polyhaline conditions where point source fresh water input is a major factor. The productivity assemblage is associated with a region of Biscayne Bay with high surface water productivity and organic input. The open-bay seagrass assemblage occupies part of the open portion of Biscayne Bay with free circulation and exchange with the Atlantic Ocean. The open-bay coarse sediment assemblage overlaps the previous open-bay assemblage but is distinct in its faunal composition and higher species dominance associated with coarse sandy substrates.

The Derivation of Land Cover Characteristics for Hydrologic Research in the Everglades

By John W. Jones
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Research into the measurement and modeling of water movement and other hydrologic processes has been identified as a primary scientific need in support of Everglades restoration. To accurately simulate surface water hydrology in south Florida, scientists must understand the variation in vegetation cover and the role vegetation plays in surface water flow, surface water removal, and water quality.

Numerous efforts to map vegetation type and/or associations have been completed recently in the south Florida region (Welch and others, 1999). However, we need to account for the effect vegetation has on surface water flows, so additional vegetation characterization has been necessary to meet the needs of hydrodynamic models being developed for the Everglades. Field and flume experiments are measuring the importance of vegetation structure and amount on resistance to flow (Lee and others, this volume). Therefore, two objectives of this remote sensing effort are the creation of land cover maps to which resistance coefficients can be assigned (Carter and others, 1999) and the derivation of biomass or density maps for dominant vegetation types, such as sawgrass (Jones, 2000). By combining information extracted from the literature and field experience with a unique combination of satellite image data, we have generated a nine-class map of vegetation types to which preliminary vegetation flow resistance values have been assigned (fig. 1). The resultant flow resistance information has been used successfully in the hydrodynamic modeling of the Southern Inland Coastal System (Swain, 1999).

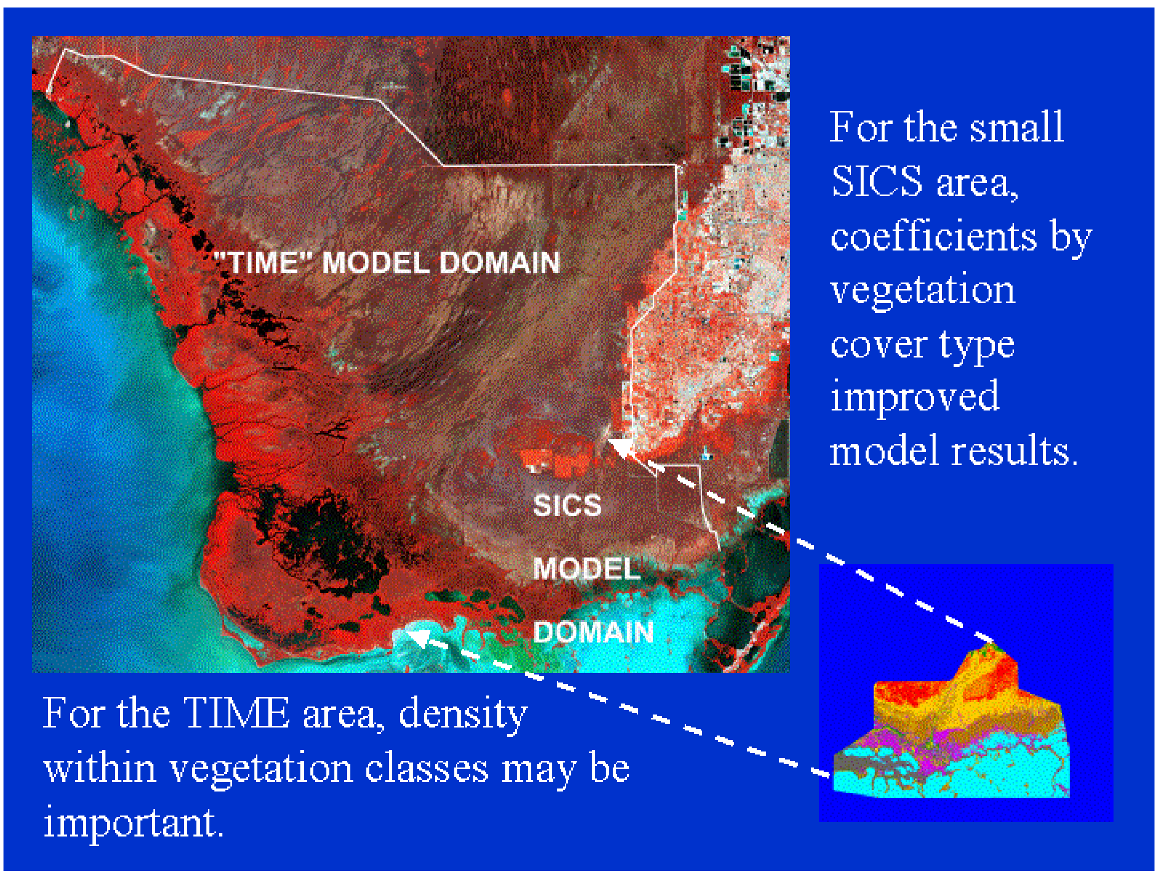


Figure 1. A land cover map to which flow resistance values could be assigned was generated for the Southern Inland Coastal System (SICS) model domain. Other methods of land cover characterization are being developed for the larger Tides and Inflows in the Mangroves of the Everglades (TIME) model area.

Although logistical constraints, variable water levels, and changing vegetation conditions present great challenges, a set of ground truth data points are being continually augmented for use in accuracy assessment. In this heterogeneous environment, however, comparison of point characterizations of land cover with variables derived from satellite imagery is problematic. Spatial analysis of high-resolution airborne imagery collected for this project indicates that the scale lengths over which sawgrass densities are strongly related are extremely short–with statistically significant relationships ending at lengths of approximately 30 meters (fig. 2). Thematic mapper (TM) resolution is therefore at the limit required to capture inter-patch dynamics and represent the average distribution of sawgrass over large areas. Intra-patch dynamics are not resolved through conventional classification of TM pixels into nominal density classes. The importance of variation at these short scale lengths remains in question, given a planned hydrodynamic model resolution of 500 m. None the less, subpixel classification of satellite data presents one possible means of characterizing sub-30 m heterogeneity. Spectral un-mixing is being investigated for the estimation of fractions of cover type within TM pixels or the generation of continuous fields of vegetation density for use in model parameterization. These results will be compared with neural network based classification techniques also being developed through this project and detailed elsewhere in this volume (Lemeshewsky, this volume).

The characterization of other surface features is important for process modeling in the Everglades. The important role that periphyton composition plays in mercury cycling has been recently discovered (Cleckner and others, 1999). Its composition and placement in the water column vary in time and space – making it both an attractive target for and a complicating factor in remote sensing activities. For example, on an event timescale, periphyton can separate from the soil substrate and form mats that float on the water surface. The result can be a drastically different canopy substrate as imaged by the remote sensing instrument. Although limited in temporal and spatial extent, hyperspectral imagery collected from airplane platforms may provide data of sufficient spatial and spectral resolution to develop

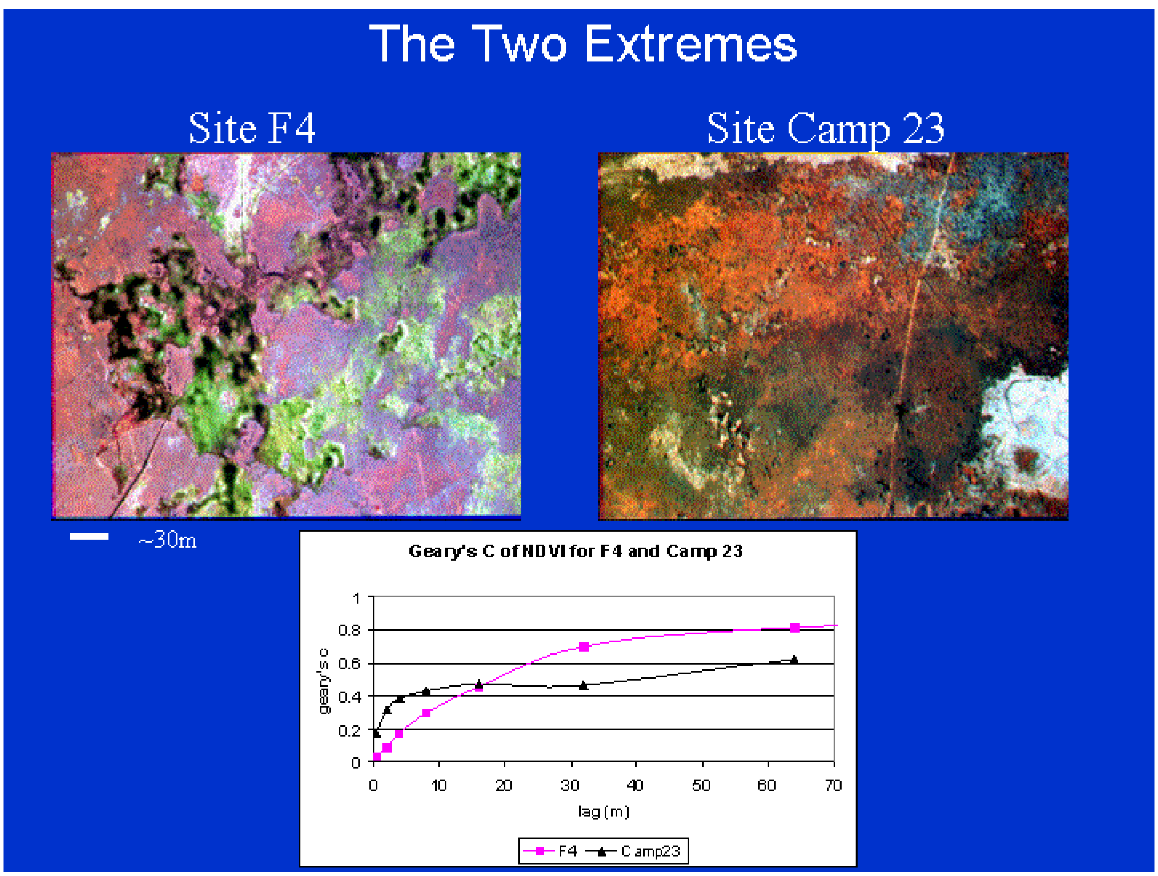


Figure 2. An isotropic measure of spatial autocorrelation (Geary's C) was calculated for vegetation index values generated from high resolution imagery for seven of nine evapotranspiration monitoring sites. The two sites shown exhibit the extremes of decay rates for autocorrelation. On average, significant correlation ends at lengths of about 30 m.

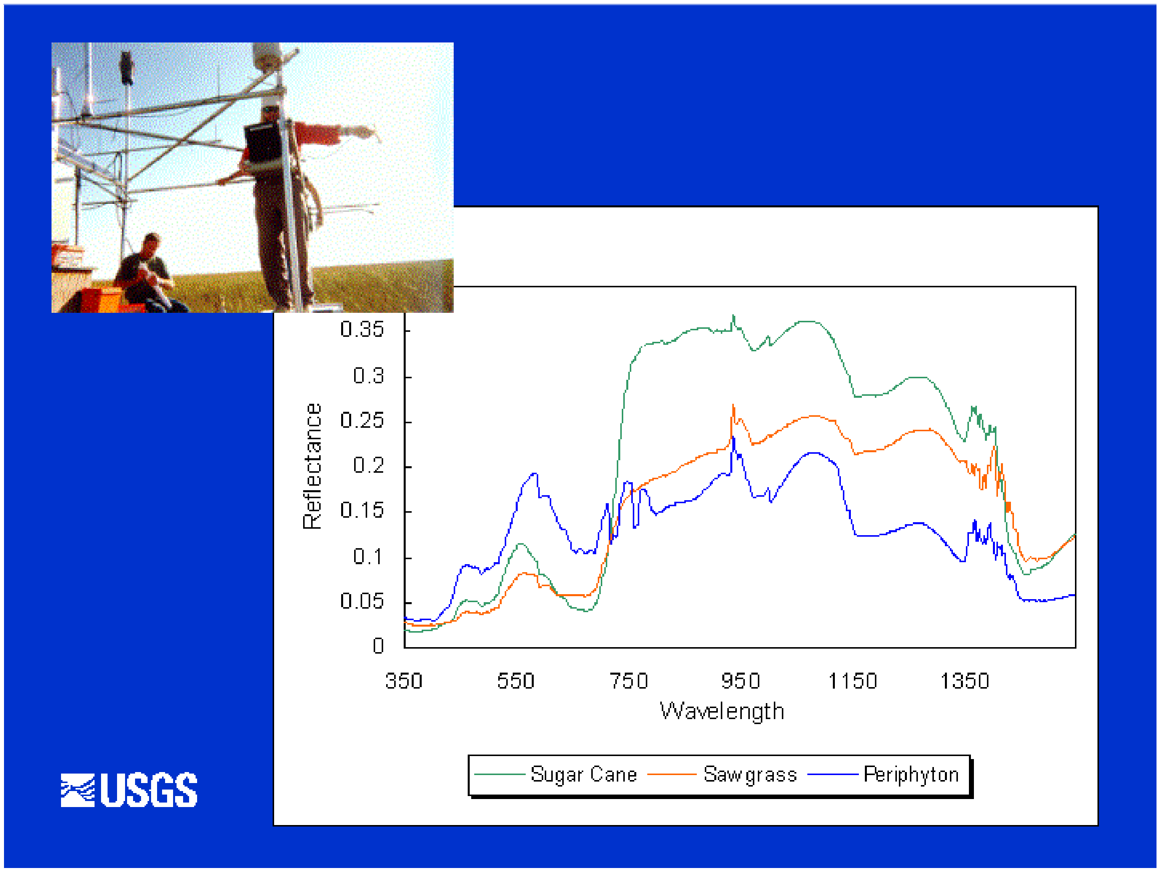


Figure 3. A spectral library is being assembled using field and laboratory spectra collected from various land surfaces. These spectra are used in the analysis of airborne hyperspectral imagery.

effective techniques for mapping periphyton characteristics. A spectral library is being assembled using reflectance spectra collected in the field over various vegetation canopies, water, bedrock, and other surfaces (fig. 3). In May of 2000, reflectance spectra were collected in the field using a hand-held spectroradiometer within 24 hours of the collection of airborne hyperspectral remote sensing data. Periphyton field spectra collected at this time compare well with spectra drawn from calibrated imagery. These and other hyperspectral data are being used to develop periphyton mapping methods.

Measurement of evapotranspiration (ET), a dominant component of the Everglades water balance, has been under way at nine locations for several years (German, 1996). While the importance of the role of vegetation in wetland evaporation remains a source of controversy (Allen and others, 1997), results from these sites suggest that, as in many environments, available energy and water levels are the first-order variables (German, this volume). Therefore, remotely sensed data have been used to empirically derive spatially distributed fields of ET for selected image dates. Although this technique provides a glimpse of spatially distributed ET, its application is limited to the clear-sky dates for which both imagery and sufficient ET point estimates are available. Therefore, a simple, more widely applicable technique has been developed, in which the spectral characteristics of the regions immediately surrounding each ET monitoring site are used to generate ET regions under various water level conditions. ET values from ET site measurements or from the models developed from them are then used to provide spatially distributed values of ET.

The overall objective of this research is to develop and apply innovative remote sensing and geographic information system techniques to map and characterize vegetation and related hydrologic variables, such as evapotranspiration, through space and over time. The effective use of in situ measurements and the use of remotely sensed data from multiple systems allows us to derive regional fields of information about the land surface that are not possible through any other means. Continued hydrodynamic model development and water quality research will assess the value of biophysical fields generated through these techniques.

Vegetation Density Mapping From Multispectral and SAR Imagery Using Artificial Neural Network Techniques

By George P. Lemeshewsky

U.S. Geological Survey, Reston, Virginia

Vegetation cover information was determined for the South Florida Everglades using unsupervised and artificial neural network (NN)-based supervised classification techniques applied to multisensor, multispectral, and RADAR imagery. The main objective was to develop and demonstrate an automated, supervised classification process for mapping vegetation type and density from moderate spatial resolution (30-m) Landsat thematic mapper (TM) multispectral imagery, integrated with higher spatial resolution synthetic aperature RADAR (SAR) data of the European Space Agency satellite.

Unique to this mapping requirement, the defined land cover classes can be mixtures of homogeneous cover types. For example, within the 30- by 30-m ground-projected instantaneous field of view (GIFOV) of the TM multispectral sensor, the cover for the low-density sawgrass class includes open water and sparse sawgrass. Consequently, the spectral signal corresponds to a mixture of ground covers instead of to a homogeneous area on the ground. Mixed pixels also occur when boundaries between homogeneous cover types are within the GIFOV; for example, the boundary between dense, homogeneous sawgrass and open water. The accurate classification of mixed pixels is difficult to obtain from multispectral imagery with the often used parametric maximum likelihood classification techniques applied on a per-pixel basis. Spectral unmixing techniques offer an alternative to the classification of mixed pixels, but there are other problems, such as the requirement for reference, or end-member spectra, for each class (Foody and others, 1997).

The application of multilayer NN techniques for the supervised classification of mixed pixels has been reported (for example, by Foody and others, 1997). The vegetation density mapping described here used a hybrid classification process that combined unsupervised, fuzzy clustering with supervised NN classification techniques. The overall process is thus NN-based classification and fusion of fuzzy-clustered, preprocessed, multisensor data. For this vegetation density mapping requirement, the individual NN outputs represent class (for example, vegetation type), while their output levels represent the fuzzy categories of low-, medium-, and high-density vegetation. With training, the NN learns to produce the three output levels that denote the respective density classes. This learned classification is optimal in the sense that the training process attempts to minimize the square error between the NN learned output level for class and the true level. It provides an automated method for mapping the image feature data into class; in this case, into the fuzzy (low, medium and high) -density classes. A class cover map results from hard thresholding the output values.

Input data for training were obtained by a two-step process. First, clusters were found by an iterative fuzzy clustering process (Fuzzy Learning Vector Quantization) (Bezdek, 1993) applied to the feature data derived from preprocessed multispectral (XS) and SAR imagery. The XS and SAR data were each clustered separately, using 10 and 8 clusters, respectively; simply more clusters than classes were used.

NN input values for each class-labeled feature vector used for training were the respective fuzzy memberships (a continuous value, proportional to the distance to the cluster) between the feature vector and all clusters. This may be contrasted to hard clustering, where the input feature data are associated only in a binary sense and with only one cluster. Information related to the other clusters is lost.

Preprocessing and feature extraction techniques were developed and applied to the TM and SAR data before clustering. For example, new techniques were developed for the resolution enhancement of TM 120-m thermal infrared data to improve classification results (Lemeshewsky, 1998, 2000). Also, a discrete wavelet transform (DWT)-based technique for the fusion of TM and higher spatial resolution panchromatic imagery (Lemeshewsky, 1999) was developed to produce several false-color 1:24000-scale photoimage maps. The SAR speckle noise was reduced using the reported (DWT)-based soft-thresholding technique of Donohoe and was implemented with shift-invariant DWT (Lemeshewsky, 1999). To improve the classification accuracy of TM mixed pixels, especially where the GIFOV contains boundaries between cover types, a reported (Wu and Schowengerdt, 1993) 'partial restoration' preprocessing technique was applied to the TM spectral band data, excluding the thermal band. The TM pixel feature data vector used in clustering included TM bands 2, 4, 5, and 7 after 'partial restoration' preprocessing, resolution-enhanced band 6 thermal data, and normalized difference vegetation index (NDVI) computed from partial restoration processed bands 3 and 4. Local mean and variance features were derived from the denoised SAR imagery.

A vegetation-type density image map was produced for the SICS area, and several 1:24,000-scale image photomap examples were printed. Classification results are promising, and further study of this technique applied to higher spatial resolution hyperspectral imagery is suggested.

Mercury Transfer Through an Everglades Aquatic Food Web

By William F. Loftus[1], Joel C. Trexler[2], and Ronald Jones[2]
[1]U.S. Geological Survey, Homestead, Florida; [2] Florida International University, Miami, Florida

Aquatic animal and plant species accumulate mercury in body tissues, from which it is passed by consumption to higher trophic levels in the food web. Top-level carnivores may accumulate burdens at which toxic effects, such as nerve damage, convulsions, or death, become evident. Of the various forms of mercury, methylmercury is the most toxic and accumulatory mercury compound. It is produced mainly by the microbial methylation of inorganic Hg in aquatic systems. Although the mercury contamination problem in the Everglades is now well-publicized, the processes by which mercury is made available to the biota, the extent of contamination in species at various trophic levels, and the pathways by which mercury is passed through the Everglades biota are poorly understood. Those questions are being addressed in this project, which began in March 1995, with field and laboratory data collections completed in the summer of 1998. A final report has been produced and manuscripts of the study segments are being prepared for publication.

Past studies of mercury in the biota have focused on the top-level predators in the Everglades, with little analytical emphasis being placed on the smaller fishes and invertebrates upon which the predatory fishes, wading birds, and small alligators feed. To understand the extent of the contamination problem, and to identify the most important routes by which mercury is being passed to the top levels in the system, mercury concentrations must be measured at lower trophic levels in the Everglades aquatic food web. It is not possible to obtain information on food web pathways and marsh hydropattern relationships from the extensive literature on mercury because few studies have taken the approach of examining an entire aquatic assemblage. In addition, most studies of mercury bioaccumulation and food web transfer have been done either in the laboratory, in temperate lakes and reservoirs, or in riverine or marine systems. Those results are not very transferable to a subtropical wetland like the Everglades. The need for research in non-temperate systems, particularly wetlands, is increasingly important to understand and deal with the mercury problem in the Everglades.

This study examined the pathways of mercury (Hg) bioaccumulation and its relation to trophic position and hydroperiod in the Everglades by performing three related studies. The project was divided into three segments formulated to support and extend other State and Federal study plans intended to address the mercury contamination problem in Florida. Element I described the food habits and trophic positions of Everglades freshwater fishes at high-water and low-water periods from three habitats; Element II addressed total mercury concentrations in Everglades freshwater biota, as related to trophic position, at one study location; and Element III examined the effects of time-of-year and site hydroperiod on mercury levels of wild and caged mosquitofish at three pairs of Everglades locations. This study was conducted entirely within Everglades National Park (ENP), Florida, in spikerush marshes and alligator holes, where past sampling for mercury had demonstrated some of the highest Hg levels in Everglades aquatic biota. Detailed site descriptions are provided within the Element sections. The sampling for Elements I and II was done in northern Shark Slough, centering on a long-hydroperiod, central Everglades marsh complex designated as 1-L. The caged and wild mosquitofish studies in Element III were run at three pairs of long- and short-hydroperiod sites in northern Shark Slough, middle Shark Slough, and in Taylor Slough.

To describe dietary differences in fishes across habitat and season for Element I, 4,000 stomachs of 32 native and introduced species were analyzed. Major foods included periphyton, detritus/algal conglomerate, small invertebrates, aquatic insects, decapods, and fishes. Florida gar, largemouth bass, pike killifish, and bowfin were at the top of the piscine food web. Using gut contents, the fishes were classified into trophic groups of herbivores, omnivores, and carnivores. Stable-isotope analysis of fishes and invertebrates gave an independent assessment of trophic placement. Element II tested for correlations of total mercury to trophic position. Over 1,000 fish, 620 invertebrate, and 46 plant samples were analyzed with an atomic fluorescence spectrometer. Mercury varied within and among taxa. Most invertebrates were in the range of 25 to 200 $ng \cdot g^{-1}$. Small-bodied fishes varied from 78 to >400 $ng \cdot g^{-1}$. Large predatory fish had the highest concentrations, up to 1515 $ng \cdot g^{-1}$. Hg concentrations among the fishes and the invertebrates were positively correlated with trophic position. Element III examined the effects of season and site hydroperiod on mercury in wild and caged mosquitofish at three pairs of marshes. Twelve monthly collections of wild mosquitofish were analyzed. Hydroperiod significantly affected concentrations, but there were interactions among marsh hydroperiod, fish size, site, and time-of year. A complimentary experiment to control for wild-fish dispersal, and to measure *in situ* uptake and growth, used captive-reared, low-mercury fish stocked into field cages in those marshes. Neonate fish with mercury levels from 7 - 14 $ng \cdot g^{-1}$ were introduced in six trials. Uptake rates ranged from 0.25-3.61 $ng \cdot g^{-1} d^{-1}$, and there were interactions among time-of-year, site and hydroperiod. Survival normally exceeded 80 percent. Growth varied with time of year, site and hydroperiod, but greatest growth occurred in the short-hydroperiod marshes. The results suggest that bioaccumulation through the diet strongly determines mercury in Everglades fishes and invertebrates, and that, although hydroperiod plays a role in mercury uptake, its effect varies with season and specific location.

Figure 1. Field cages in Shark Slough into which captive mosquitofish were stocked to measure mercury uptake in Element III.

The diet data have been used to describe the structure of the aquatic food web and its changes with water-level fluctuations. Statistical analyses indicate a strong positive correlation between the trophic position of both fishes and invertebrates and their mercury levels, demonstrating bioaccumulation with diet. The mosquitofish seems to be a good candidate for measuring *in situ* uptake of mercury in field cages. Patterns of mercury concentrations in wild and caged fishes at the same locations were similar across hydroperiod and season, but site hydroperiod did not explain much of the variation in mercury in the fishes. These data, combined with landscape-level studies of mercury geochemistry and patterns of concentrations in biota, will be useful as Performance Measures in the Restudy. The results were used in Phase 1 of the South Florida Mercury Program, in the development of the EPA BASS model of bioaccumulation, and in comparison with other studies in the Everglades.

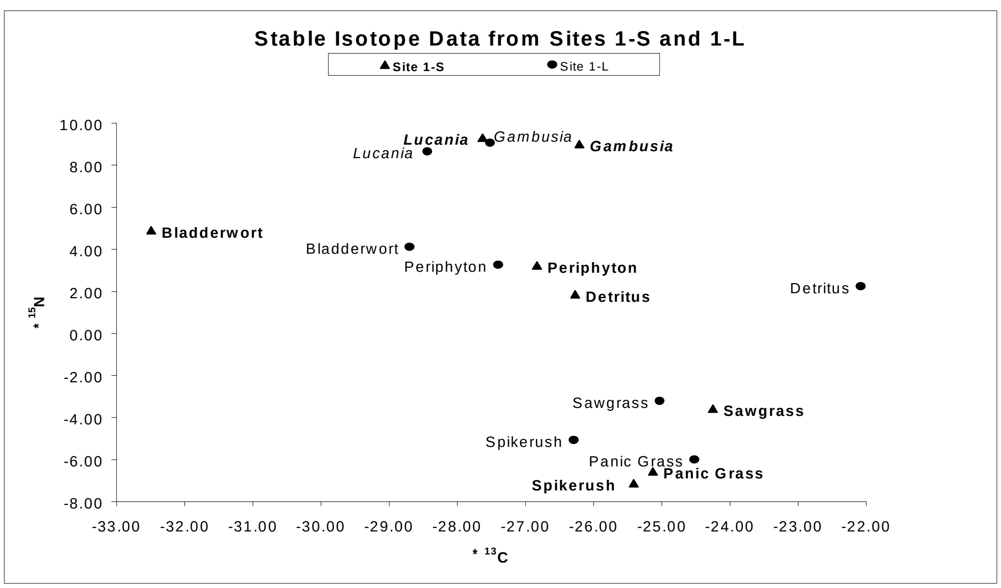


Figure 2. Stable-isotope data for mosquitofish *(Gambusia holbrooki)* and bluefin killifish *(Lucania goodei)*, and associated primary producers from long- and short hydroperiod marshes in northern Shark Slough, ENP in February, 1996.

The Role of Aquatic Refuges in the Rockland Wetland Complex of South Florida in Relation to System Restoration

By William F. Loftus[1], Sue Perry[2], *and* Joel C. Trexler[3]

[1]U.S. Geological Survey, Homestead, Florida; [2]National Park Service, Homestead, Florida; [3]Florida International University, Miami, Florida

To assess the role of rockland aquatic refuges and subterranean habitats in relation to system restoration, multi-disciplinary baseline data is being collected on constituent aquatic communities and their ecology. The Rocky Glades region has been adversely affected by water diversions, agriculture, and urban development. The highly eroded landscape of the Rocky Glades offers dry-season refuge to aquatic animals by permitting them access to ground water by way of deep solution holes, as well as in shallower solution holes. The Atlantic Coastal Ridge contains deeper cavities known to house truly subterranean aquatic species but the community composition, distribution, and abundance of hypogean species is still unknown. In this first project year, data are being collected that meet the project's objectives and also complement a related National Park Service (NPS)–Critical Ecosystem Studies Initiative project that examines fish and invertebrate dynamics in shallow solution holes. Objectives include:

- Develop effective traps to capture macro-invertebrates and fish from subterranean habitats in south Florida and describe those poorly known communities.
- Collect environmental parameters in wells to correlate seasonal changes in the groundwater aquatic environment with species distributions.
- Topographicly survey the habitat around the NPS solution-hole sampling sites to provide depth-distribution data for the Across Trophic Level Systems Simulation (ATLSS) model of the region.
- Because fishes appear to exhibit seasonal movement in a unilateral direction from the Rocky Glades (Loftus, pers. observ.), document and quantify this phenomena by pilot testing the use of drift fences and funnel traps to measure directional dispersal.
- Test a visual survey method for sampling fish communities in open, rugged terrain, where other methods fare poorly, to follow community dynamics in the Rocky Glades in the wet season.
- Collect life history data for the Miami cave crayfish from a captive population.

Several pilot studies have been preformed that examined the best trap design for capturing animals from groundwater in wells, tested the use of ground-penetrating radar to detect the existence of subterranean cavities, and designed a surveying approach to characterize the depth-distribution of solution holes near fish-sampling sites. A series of wells on east-west transects across the coastal ridge into the Everglades have been chosen for use as long-term monitoring wells for animal collections (see sample data in fig. 1). Four drift fence arrays have been erected to measure fish dispersal with the arrival of the wet season, and 16 visual survey plots have been set up. A life-history study of the Miami cave crayfish, a species that may become a candidate for federal listing, has also begun. A

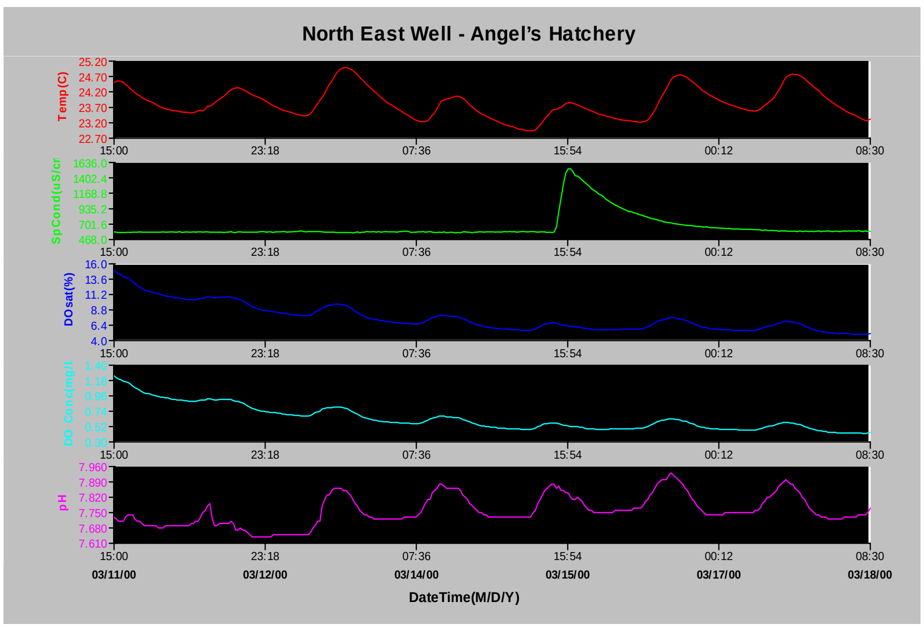
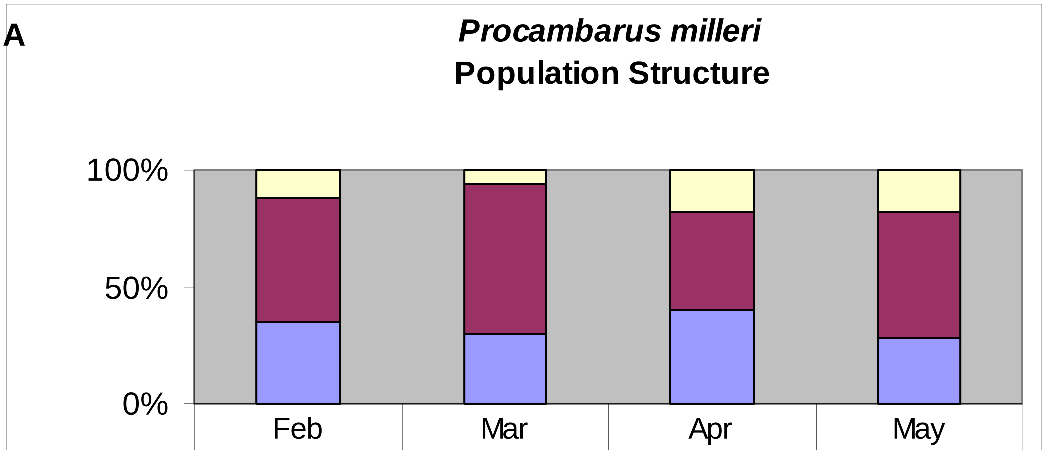


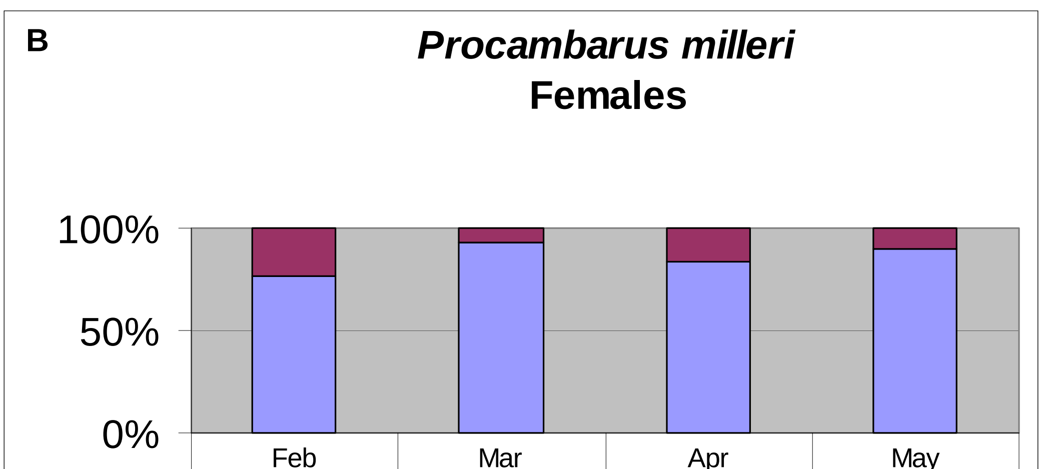
Figure 1. Five-day plot, form top to bottom of graph, of water temperature (° C), specific conductance (µS/cm^3), percent O_2 saturation, dissolved oxygen level (mg/L), and pH, from a well on the atlantic Coastal Ridge north of Homestead.

substantial population of subterranean crayfish is being raised in tanks at the well locations, and preliminary information is shown in figures 2, 3, and 4. Presently, the female of this species has not yet been described. Information will be gathered on sex ratios, fecundity and life stages. Different colored eggs and occasional albinos have been observed, so that this phenomenon will also be noted and documented.

This series of project elements combine to answer questions about the ecological interrelations of surface and subterranean habitats to address how management has adversely affected this region and what benefits hydrologic restoration will produce.



	Feb	Mar	Apr	May
Juveniles	7	3	13	10
Females	30	30	30	30
Males	20	14	29	16



	Feb	Mar	Apr	May
Gravid	7	2	5	3
Not Gravid	23	28	25	27

Figure 2. A: Proportion of the captive Miami Cave Crayfish population comprised by juveniles, females and males. N of 30 for females is the sample size sought during each month's random sample, after which that month's sampling ceases; B: Proportion of the females sampled that held eggs or larvae.

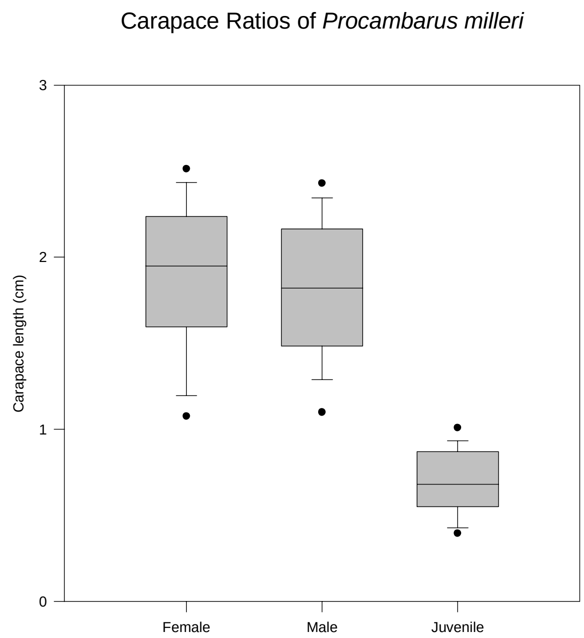


Figure 3. Mean carapace lengths of female, male, and juvenile Miami Cave Crayfish.

Figure 4. Gravid female Miami Cave Crayfish with newly extruded egg mass.

Influence of Hydrology on Life-History Parameters of Common Freshwater Fishes from Southern Florida

By William F. Loftus[1], Leo Nico[2], Joel Trexler[3], Jeff Herod[2], Tim Connert[3]

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[3]Florida International University, Miami, Florida

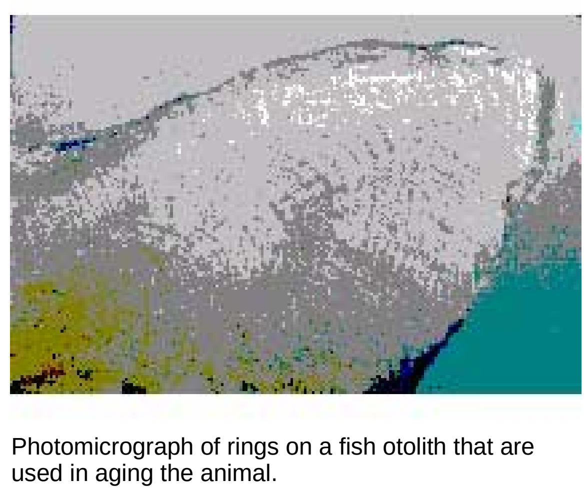
Fishes are essential to the successful functioning of wetland food webs in south Florida through their roles as prey and predators. Any changes that reduce the population sizes, community composition, or availability of aquatic animals will affect all facets of the ecology of these wetlands. In particular, small and medium-size fishes are important food items for most wading bird species. For this reason, fishes have been recognized as key indicators by which to measure restoration success.

Despite the importance of fish for resource management, gaps in baseline knowledge remain. Basic demographic information, termed life-history parameters, is needed to make predictions about their resilience under alternative management scenarios. These parameters include growth rate, age at maturation, fecundity, and life expectancy. However, basic life-history parameters remain to be characterized, even for abundant fish species. Adding to the challenge, life-history characteristics of important Everglades species are known to be plastic in response to environmental conditions and survivorship and recruitment schedules are certain to be influenced by variation in hydroperiod. The effect of hydroperiod will be studied on recruitment, size/age structure, growth, and fecundity, which, in turn, determine fish population dynamics.

At present, data on fish reproduction, age and growth, and other life history characteristics are confined to a few species from a limited area of long-hydroperiod marsh in central Shark River Slough. As the analysis and synthesis of data from the long-term fish collections continue, life-history information will help explain patterns of fluctuations in the time series. Accurate life-history data are also very important in building credible simulation models like the Across Trophic Level Systems Simulation. Without empirical life-history data from a range of environments, the model will be simplistic and inadequate.

To document the life history parameters of Everglades fishes, target fishes were dividedinto small- and large-bodied fishes. Small-bodied fishes are typically short-lived and are most common in shallow marsh habitats. Large-bodied fishes are generally long-lived and are common in canal habitats and other deepwater areas. The present study takes advantage of existing or newly funded fish studies in south Florida. These include the throw-trap program for small-fish monitoring and an electrofishing study of larger native and introduced species in canals.

Age and growth information has been collected for a few of the target species, but reproductive characteristics of most south Florida populations have not been investigated previously. For aging fishes, a standard method is to count daily and annual rings deposited on otolith bones and other hard structures (fig. 1). However, environmental variation can affect the pattern of otolith ring deposition, so calibration of otolith ring deposition is an important first step in using ring counts to age fish.

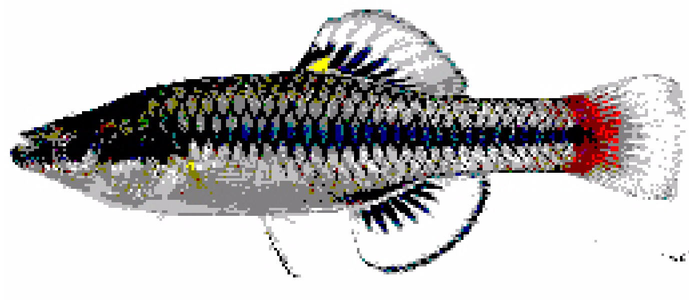


Photomicrograph of rings on a fish otolith that are used in aging the animal.

The present work involves counts of daily rings on otoliths from small fishes and of annual rings on otoliths from large fishes, as well as size-frequency analyses of all target fishes. Ultimately, the results will allow creation of an age-at-size table for each species, and to estimate growth in two different seasons. Furthermore, life-tables will be constructed for the species under different conditions in the Everglades. In addition to new field fish collections, we will analyze past data from extensive spatial and temporal marsh and canal study collections for reproductive analyses of fecundity, size at maturity, seasonality of reproduction, and sex ratios.

Investigations on small fishes began in winter 2000. For small-bodied species, age-to-size relationships are being established for three marsh fishes not yet studied: sailfin molly (*Poecilia latipinna*); flagfish (*Jordanella floridae*); and spotted sunfish (*Lepomis punctatus*). These relationships will be estimated at one representative short (at Shark Valley) and one representative long hydroperiod location (at Shark River Slough).

For small fishes, experimental rearing of each species to a known age in field cages is planned in anticipation of otolith removal and interpretation. In past efforts, this approach has demonstrated a very high fidelity of daily ring deposition in sailfin mollies up to the age of 21 days. This result needs to be repeated and expanded to other species.



Example of a common small-bodied Everglades fish, *Lucania goodei*, the bluefin killifish, which will be analyzed for reproductive state in this project.

Reproductive phenology and output in six marsh fish species will be documented: least killifish (*Heterandria formosa*); bluefin killifish (*Lucania goodei*) (fig. 2); golden topminnow (*Fundulus chrysotus*); eastern mosquitofish (*Gambusia holbrooki*); sailfin molly; and flagfish.

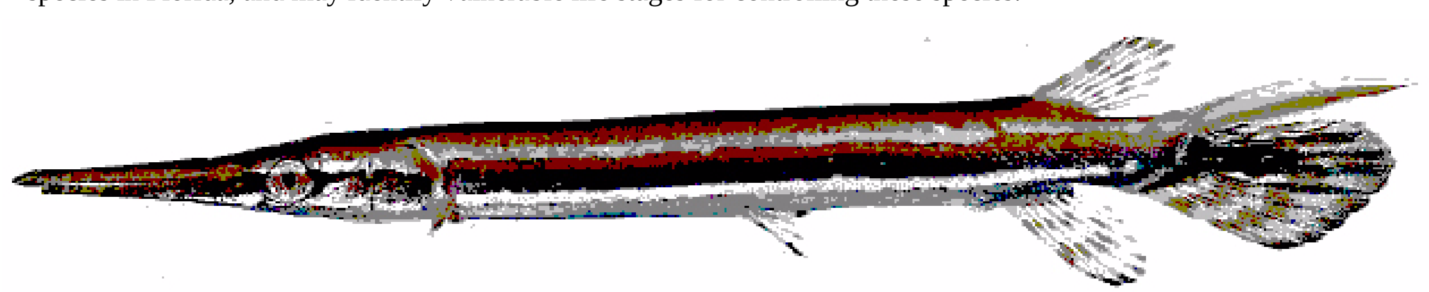
For large-bodied fishes, age-to-size frequencies and reproductive phenology are being established for five target species, including one non-indigenous fish, the spotted tilapia (*Tilapia mariae*), and four native fishes, Florida gar (*Lepisosteus platyrhincus*) (fig. 3), yellow bullhead (*Ameiurus natalis*), warmouth (C*haenobyttus gulosus*), and spotted sunfish (*Lepomis punctatus*). All five species are common to abundant in many south Florida freshwater habitats and most are predators that prey on other fishes and various crustaceans (that is, crayfish and shrimp).

Quarterly sampling of fishes began in January 2000 in three major south Florida waterways: Canal L-31W, Tamiami Canal (C-4), and Snake Creek Canal (C-9). Reaches sampled in the first two canals have direct surface water connections to adjacent marsh habitats. The C-9 reach is located in a heavily disturbed urban area and is not associated with a natural marsh.

In the field, the length and weight of all target fishes are recorded. A subset of fishes representing various size classes are sacrificed and the heads are removed and preserved on ice for later otolith removal. The bodies are preserved in formalin for later analysis of gonad condition. Experimental rearing of three of the five target fishes; Florida gar, warmouth, and spotted tilapia; has recently begun to document changes in size with age and to aid in interpretation of otolith work and size frequency results.

By applying fish models to restoration alternatives and predicting fish-community responses, the alternatives can be chosen that result in biotic characteristics that approximate historical conditions. The iterative process of evaluating and testing the fish-community simulation model in ATLSS also helps identify important data gaps to guide future research. One of the most obvious gaps is the absence of good life-history data, critical to model performance, for most of the fishes. The benefits to restoration include having more confidence in improved tools, like the ATLSS models and performance measures from conceptual models, that are used to evaluate alternatives for ecological effects of the Comprehensive Everglades Restoration Plan, C-111 Project, and Modified Water Deliveries Plan to Shark Slough.

In addition to the application of the life-history data to modeling and to interpretation of the data time-series, these data represent new information about the adaptations of many of these species in wetland habitats that form the southern extent of their geographic ranges. These also represent the first life-history data for some of the most abundant introduced species in Florida, and may identify vulnerable life stages for controlling these species.



The Florida gar, *Lepistosteus platyrhicus*, is an abundant predator in the Everglades that will be used in the analysis of aging, growth, and reproduction.

Impacts of Hydrological Restoration on Three Estuarine Communities of the Southwest Florida Coast and on Associated Animal Inhabitants

By Carole C. McIvor[1], Thomas J. Smith III[2], Michael B. Robblee[2], and Lynn Lefebvre[2]

[1]U.S. Geological Survey, St. Petersburg, Florida;
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A primary goal of Everglades restoration is the recreation of water flows and water quality more closely approximating pre-drainage conditions in both freshwater and estuarine ecosystems within Everglades National Park. These estuarine systems include submerged aquatic vegetation, mangroves (tidal forests), and brackish marshes. Three primary groups of animals are closely associated with, and often dependent upon, one or more of these ecosystems: fish and decapod crustaceans (shrimp, crabs), manatees, and wading birds. Herein we focus on fish and decapod crustaceans, and manatees. This study focuses on how hydrological changes upstream affect: (1) the distribution, abundance and composition of submerged aquatic vegetation and selected animal inhabitants; and (2) the distribution and abundance of fish and decapod crustaceans associated with mangroves and brackish marshes.

Submerged aquatic vegetation (SAV) is an integral part of many shallow-water estuarine and coastal systems worldwide. Such vegetation (generally termed seagrass when it occurs in near-marine salinities) provides many benefits to society including sediment stabilization, habitat for estuarine animals including manatees, and direct and indirect support of commercial and recreational fisheries. Very little is known of the submerged aquatic vegetation of the southwest coast of Florida and the associated rivers draining the Ten Thousand Islands where riverine water flows are projected to change as a result of Everglades Restoration. Importantly, the species composition and standing stocks of SAV (and macroalgae) appear to be quite sensitive to salinity variation such as that caused by seasonal and anthropogenic changes to freshwater inflow.

West Indian manatees are endangered aquatic mammals that inhabit the coastal rivers, canals, and estuaries on both coasts of South Florida year-round. Because manatees are reliant on submerged aquatic vegetation for feeding, it is likely that manatee distribution, relative abundance, habitat use, and movement patterns will change as a result of altered water management regimes and resulting changes in nearshore salinity. These issues are being addressed through (1) the development of a spatially-explicit, individual-based model that will predict manatee response to different restoration scenarios, and (2) comprehensive field studies in southwest Florida that provide data for the model and that document the current distribution and status of the manatee population prior to implementation of restoration activities.

Concern about the fate of mangrove ecosystems derives from their known use as habitat for a wide range of both terrestrial and aquatic animal species, especially fishes and decapod crustaceans of forage as well as of commercial and recreational importance. Additionally, mangroves at the mangrove/marsh boundary in southwestern Everglades National Park were historically the sites of extensive colonial wading bird nesting areas. Birds apparently foraged and fed their young primarily from adjacent brackish marshes. One of the goals of Everglades Restoration is return of extensive wading bird rookeries to these headwater mangroves. It is therefore essential that we understand the dynamics of fish (and decapod crustaceans) in mangrove and adjacent marsh habitats in order to judge the effectiveness of restoration of the forage base necessary to support wading bird rookeries.

Since project initiation in April 2000, study sites have been chosen and instrumented in all Shark River locations and in one-third of the mangrove locations in Lostmans River. Brackish marshes at mid- and upstream locations are being sampled. Submerged aquatic vegetation surveys and preliminary mapping are underway. Aerial surveys for manatees are being conducted, and an individual-based population model is being developed. Analogous sampling is underway in Lostmans River; however, Everglades restoration is likely to change the quantity and timing of freshwater inflows to this river far less than it will change freshwater inflows to Shark River.

In the mangrove forests of Shark River, we have performed pilot studies were performed to determine the best design for capturing fishes and decapod crustaceans using flooded forests. A two-pronged approach was applied to this technical challenge. We are using 2X3 m^2 pull-up nets buried in the forest floor are being used to quantify the density, biomass and population dynamics of a unique mangrove fish, mangrove rivulus, that remains in the forest even during low tide events. The remainder of the fish and decapod assemblage is being targeted with 1.5X1.0 m block nets placed over the mouths of intertidal rivulets at slack flood tide. These nets capture fishes and crustaceans leaving the forest on the ebb tide. Results are expressed as catch per unit effort (CPUE). Future plans call for development of a curve of stage height versus area inundated for each block net location so that results may be expressed as density and biomass per m^2. Currently, there are nine nets of each type arrayed along the estuarine salinity gradient as follows: three of each type near the freshwater/oligohaline interface in Tarpon Bay, three each midway along the salinity gradient on the Harney River, and three each about 3 km up from the mouth of the Shark River near Ponce de Leon Bay, our site of highest (near marine) salinity (fig. 1). Nets are being sampled bi-monthly to capture patterns of juvenile recruitment and changes in relative abundance of species influenced by wet and dry season changes.

Figure 1. Close-up photograph of mangrove rivulus (actual size of fish is two inches).

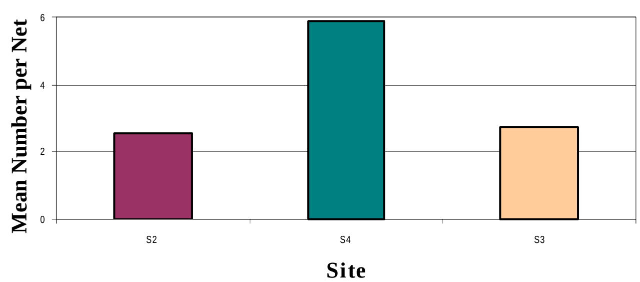

Figure 2. Average number of mangrove rivulus in fringing forests along the Shark River.

Only very preliminary results are available. Despite the fact that mangrove rivulus is being considered for listing, it is quite abundant in fringing mangroves along the entire Shark River gradient investigated. Decapod crustaceans routinely using flooded mangrove forests include three species of caridean shrimp and less commonly, blue crabs. A range of estuarine fishes has been captured including schooling silversides and anchovies, two species of killifishes, and gerrids of the genus Eucinostomus. Less common are predaceous toadfishes and needlefishes, and the exotic Mayan cichlid. Two species of gobies are present, one of which (Bathygobius soporator) is sufficiently abundant and widespread that it might prove a useful integrator of broad scale salinity patterns. Interestingly, young-of-year gray snapper are present although in low numbers. This finding contrasts with fringing mangroves in the Taylor Slough drainage that contain only subadult and adult gray snapper. Continued sampling will elucidate the extent to which these forests are an important nursery area for this recreationally important species.

Table 1. Fish species captured in fringing mangrove forests along Shark and Harney Rivers. Lift net data for March - July 2000; rivulet net data for May - July 2000. S2 is on Tarpon Bay and is <5 ppt salinity; S4 is 5.1-18 ppt midway along the Harney River; S3 is ca 3 km upstream from Ponce de Leon Bay on Shark River and is near marine salinity.

	Site Number:	S2	S2	S4	S4	S3	S3	
	Type of net used:	Lift	Rivulet	Lift	Rivulet	Lift	Rivulet	
Family								**TOTAL**
Genus Species	**Common Name**							**NUMBER**
Engraulidae-anchovies								
Anchoa mitchilli **(Valenciennes, 1848)**	bay anchovy	0	0	0	0	0	30	30
Clariidae-labyrinth catfishes								
Clarius batrachus **(Linnaeus)**	walking catfish	0	0	0	2	0	0	2
Batrachoididae-toadfishes								
Opsanus beta **(Goodes and Bean)**	gulf toadfish	0	0	0	0	0	1	1
Belonidae-needlefishes								
Strongylura timucu **(Walbaum, 1792)**	timucu	0	0	0	0	1	0	1
Strongylura spp.		0	1	0	1	0	1	3
Aplocheilidae-rivulins								
Rivulus marmoratus **(Poey, 1880)**	mangrove rivulus	23	0	53	0	41	0	117
Fundulidae-killifishes								
Fundulus confluentus **(Goode and Bean 1879)**	marsh killifish	2	22	0	1	0	2	27
Fundulus grandis **(Baird and Girard, 1853)**	gulf killifish	0	2	1	5	0	0	8
Fundulus spp.		0	32	0	1	0	1	34
Lucania parva **(Baird and Girard, 1855)**	rainwater killifish	1	9	0	11	0	5	26
Poeciliidae-livebearers								
Belonesox belizanus **(Kner, 1860)**	pike killifish	0	3	0	1	0	0	4
Gambusia holbrooki **(Girard, 1859)**	mosquitofish	0	1	0	2	0	13	16
Poecilia latipinna **(Lesueur, 1821)**	sailfin molly	6	0	5	0	0	0	11
Atherinidae-silversides								
Menidia beryllina **(Cope, 1866)**	inland silverside	0	113	0	2	0	0	115
Lutjanidae-snappers								
Lutjanus griseus **(Linnaeus, 1758)**	gray snapper	0	0	0	2	0	1	3
Gerreidae-mojarras								
Eucinostomus harengulus **(Goode and Bean, 1879)**	tidewater mojarra	0	75	0	0	0	7	82
Eucinostomus spp.		2	37	0	147	9	81	276
Sparidae-porgies								
Lagodon rhomboides **(Linnaeus, 1766)**	pinfish	0	0	0	2	0	0	2
Cichlidae-cichlids								
Cichlasoma urophthalmus **(Gunther, 1862)**	Mayan cichlid	2	3	2	7	0	0	14
Gobiidae-gobies								
Bathygobius soporator **(Valenciennes, 1937)**	frillfin goby	0	0	2	6	6	136	150
Lophogobius cyprinoides **(Pallas, 1770)**	crested goby	0	0	0	0	4	31	35
TOTAL NUMBER OF FISH COLLECTED		36	298	63	190	61	309	957
NUMBER OF NETS SAMPLED		12	9	12	9	18	9	69
NUMBER OF DATES SAMPLED		4	3	4	3	6	3	

Individual Based Spatially Explicit Model of the Cape Sable Seaside Sparrow Population in the Florida Everglades

By M. Philip Nott
The Institute for Bird Populations, Point Reyes Station, California

The Cape Sable seaside sparrow *(Ammodramus maritima mirabilis)* is an ecologically isolated subspecies of the seaside sparrow. Recent surveys estimate its population at fewer than 6,000 individuals, and its range to be restricted to the extreme southern part of the Florida Peninsula, almost entirely within the boundaries of the Everglades National Park and Big Cypress National Preserve. The sparrow breeds in marl prairies typified by dense stands of graminoid species usually below 1 meter in height and naturally inundated by freshwater part of the year. As water levels recede during the dry season in late winter and spring, the sparrows establish territories and start nesting in the grass. Pairs may produce up to three broods if their nesting sites remain dry. If water levels do not recede early enough in spring, nesting may be delayed and if reflooding occurs during the nesting season, eggs or nestlings may be lost.

Declines have occurred in the sparrow population across its entire range, probably due to higher water levels in recent years. Because the current range of the sparrow is limited to a few hundred square kilometers and because it is subject to flooding and fires, the population is highly vulnerable. Changes to the hydrology of the southern Everglades, planned as part of an Everglades restoration project, could increase the water levels in parts of the sparrow's range and inadvertently increase the risk to the reproductive success of the sparrow in certain areas. Figure 1 shows some of these risks in the "western" habitat area of the Cape Sable seaside sparrow. It is critical to predict how serious these risks are.

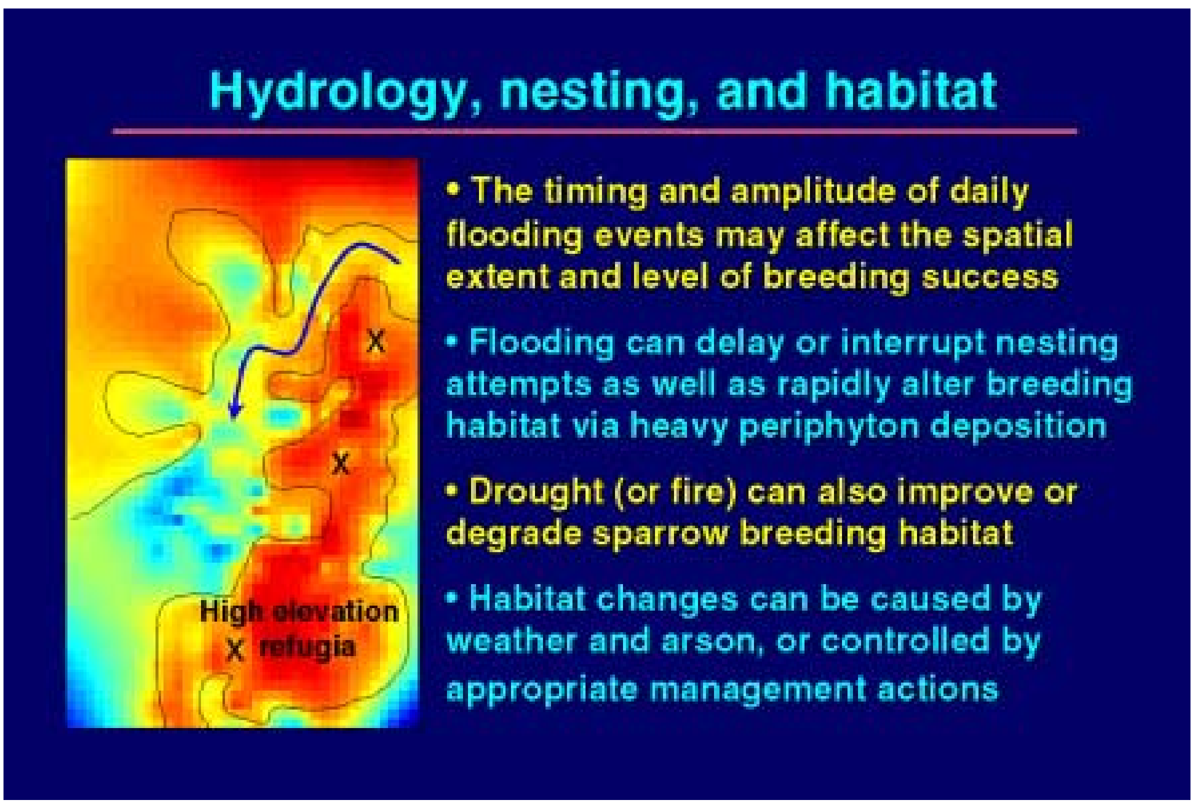

Figure 1. Topography of the western Cape Sable seaside sparrow habitat. Description of the effects of flooding and fire on sparrow habitat.

A model for the Cape Sable sparrow subpopulation in the nesting area northwest of Shark Slough has been developed and has the following features:
1.—The landscape of the sparrow's range is modeled explicitly as a set of spatial cells of fine enough resolution to represent areas of similar vegetation, topography, and hydrology.
2.—Each individual sparrow in the population is modeled during a breeding period. In particular, the model tracks the sex, age, breeding status, of each model individual from egg to the end of its life. For mature males, the model tracks his search for an available territory, his finding a mate, the start of nesting, and the status of eggs and nestlings on a daily basis.
3.—The relation of sparrow breeding activity to water depth is modeled. Water depth in spatial cells is kept track of daily through a hydrologic model. A spatial cell is not available for nesting until water depth in that cell falls below about 5 cm. Any increase in water depth above 10 cm in a particular spatial cell during the nesting season is assumed to cause nest abandonment to the sparrows that have nests in that cell. The “variability” incorporated in this model is that of the specific spatial locations of sparrows' nests in different spatial cells, and thus the elevation of an individual sparrow nests. This elevation relative to the water stage determines the length of the effective reproductive season for the pair of sparrows and the vulnerability of the nest to flooding.
4.—The sparrows are not modeled in detail during the nonbreeding season. Age-specific mortalities are assigned probabilistically to individuals during that period, based on empirical data. The following spring, when the next breeding season begins, older males search for nesting territories as close as possible to the site they used last year (if it was successful), whereas new adult males begin their search close to their natal site.

The above conceptual model has been implemented as a Monte Carlo simulation model called SIMSPAR (M.P. Nott, Ph.D. dissertation, 1998). The model has been applied to a main subpopulation of the Cape Sable seaside sparrows on the western side of Shark Slough in the Everglades. The size of this subpopulation has reached as high as 3,000 sparrows, and the model is capable of keeping track of the locations and breeding status of all these birds during the breeding season. The model increases the age of an individual each day and updates its status according to movement

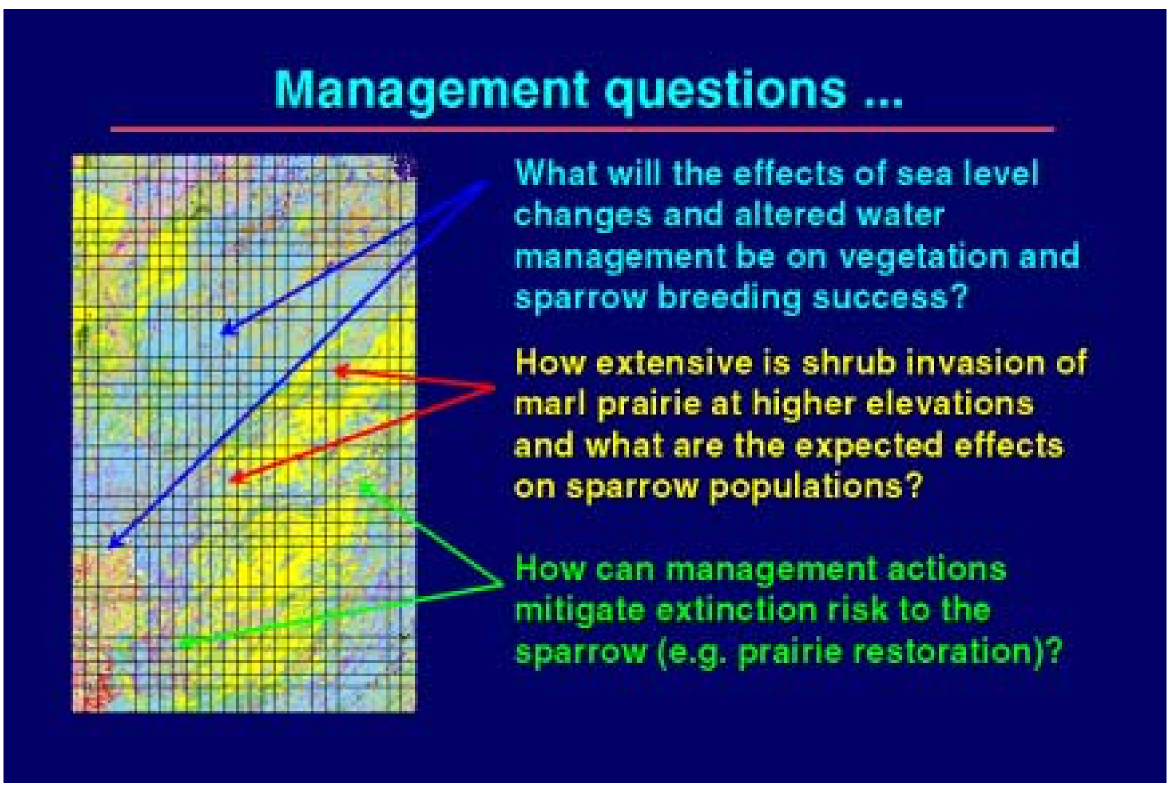

Figure 2. Management questions related to the effects of hydrology on Cape Sable seaside sparrow habitat.

and behavior rules. The core of the model is a simple flow of decisions and actions that affect individuals in relation to abiotic factors and other individuals. At each step the model updates the breeding status and tracks associations between individuals. Figure 2 shows some of the management questions to which this model is being applied.

Subsequently, to address the question of uncertainty in model parameters affecting results, a sensitivity analysis was performed on SIMSPAR. The sensitivity analysis was done in the following way.
Step 1.—Each of the parameters was varied individually relative to the field estimate and 20 Monte Carlo simulations over 21 years was performed for each using the same hydrologic sequence experienced during the period 1976-96. For each simulation the highest population number and endpoint population number was detected. Overall, for a set of simulations the mean and coefficient of variation associated with each of these numbers was determined.
Step 2.—The 5 to 10 parameters to which population size is most sensitive were sampled from distributions about their means. Model runs were made with all of the parameters of this subset able to vary simultaneously. At least 200 simulations were performed. Again, means and 95 percent confidence intervals were plotted for the 31-year runs.

The sensitivy analyses have been extended to determine the relative contributions of each parameter to the overall response using generalized linear modeling. It is also possible that the model will be used to explore the evolutionary consequences of inherited dispersal behaviors.

Another objective of this work will be to design and edit web-based documentation of the model and the assumptions behind the mechanics. Such a design would mimic the experience of an individual bird as it proceeds through the model and the outcome would depend upon the course of action and status at any stage. This objective has also been extended to provide web-based documentation understandable at various levels of technical ability.

The most sensitive parameters and the biological or biophysical realities they correspond to are as follows:
Mortality.—Adult and juvenile (post fledging) mortality may vary as a result of food availability over the non-breeding season and predation pressure by hawks or snakes throughout the year. Egg and nestling mortality includes components of drowning risk during high-water events and extreme weather conditions causing desiccation or heat stress. Flooding may also affect the availability of food during this critical stage of the life cycle by drowning less vagile invertebrate species (for example, Orthopteran and Lepidopteran instars).
Number of clutches.—Although up to three clutches (with associated probabilities) have been attempted by breeding pairs during a potentially long breeding season (90-100 dry days) it is possible that fewer could be attempted. Reducing the maximum number might simulate a behavioral response to a lack of nestling food or a uniform decrease in the "window of opportunity" for breeding that might result from late drydown or early summer flooding periods.
Dispersal.—Sexual dimorphism is apparent in the dispersal strategies of individual sparrows. Males own territories for life so, once a territory has been established, the owner returns year after year. Females, on the other hand, choose a different mate year after year and therefore must search within a given range.
Habitat quality.—Degradation of sparrow habitat resulted in a greater than proportional decrease in overall breeding population size and an increased coefficient of variation in population size. When degradation of habitat and male dispersal were altered in a factorial set of runs, habitat degradation decreased population numbers whereas increased dispersal range increased population numbers. However, with increased dispersal, the coefficient of variation increased to asymptote at a dispersal distance of 1,000 meters.
Habitat changes.—Spatial pattern of degradation relevant to habitat type also affected overall numbers. If high elevation breeding habitat was degraded systematically, the population number declined to a greater extent than if low elevation breeding habitat was degraded by marsh expansion, or if all breeding habitat was degraded by spatially random processes.

These parameters all have a significant effect on population trajectories. However, it appears that dispersal behavior is a very crucial factor in population persistence, especially when linked to habitat degradation. Finding new, recently available, or restored habitat is crucial if small populations are to recover. An important question is: What is the impact of imposing an observed dispersal-distance distribution on a deterministic or simpler population model when the actual dispersal-distance distribution resulting may change as the result of an evolutionary stable strategy? We need much more information concerning age- and sex-specific dispersal behaviors in this species and how these might change dependent upon the hydrologic conditions experienced over a number of years. Only by utilizing an individual based approach can we explore the limits of these relations and guide field studies.

Estimating Suspended Solids Concentrations in Estuarine Environments Using Acoustic Instruments

By Eduardo Patino[1] and Michael Byrne[1]

[1]U.S. Geological Survey, Fort Myers, Florida

As part of a cooperative study between the South Florida Water Management District (SFWMD) and the U.S. Geological Survey (USGS), acoustic Doppler instruments were installed at three sites with within the St. Lucie River Estuary system (fig. 1). Information on flow, salinity, water-quality, and channel cross-section characteristics were collected at these sites.

The Doppler instruments were installed to measure an index of the mean water velocity at surface-water monitoring sites. These instruments also record information related to the received strength of the velocity signal, acoustic backscatter (ABS), a parameter affected primarily by the amount of material in suspension. This study involves the development of total suspended solids (TSS) to ABS relations in order to estimate time-series records of TSS concentrations for the monitored sites. In addition to suspended solids, water density also has an effect on the strength of acoustic signals traveling through it. Therefore, salinity and temperature data are also collected at the monitoring sites and used as secondary variables in the estimation model for suspended solids. Sediment samples are collected using a point sampler lowered between the probes that measure water quality and near the Doppler face (fig. 2). The samples are analyzed for TSS and volatile suspended solids (VSS) at the U.S. Geological Survey laboratory in Ocala, Fla.

The results are promising for use of this technique in environments with high organic content in the suspended material. At all of the study sites, measured TSS concentrations ranged from 3 to 23 milligrams per liter with an organic content of between 50 and 70 percent, temperature varied from about 18 to 32 degrees Celsius, and salinities ranged from less than 1 to about 25 parts per thousand. At the North Fork site, TSS concentrations ranged from 3 to 18 milligrams per liter, and salinities ranged from greater than 1 to 15 parts per thousand. The resultant equation currently used for estimating TSS concentrations represents a relation in the "local" space (point samples collected near the instruments). The relation for the North Fork monitoring station is as follows:

$$TSS = 10^{\{ABS[0.06232 + 0.00118*\log(sal) - 0.02212*\log(temp)] -1.32321\}}$$

R^2 (correlation coefficient) = 0.86

The relation of estimated to measured TSS concentrations is shown in figure 3. Measured concentrations used in the regression analysis for the development of the estimating equation and verification measurements are presented.

At the present time, this project includes an expansion of the "local" TSS to ABS relation to represent a relation to the mean cross-sectional concentrations at monitoring sites. Preliminary data suggest that results similar to the local relation will be possible in the future. At that time, TSS fluxes will be calculated.

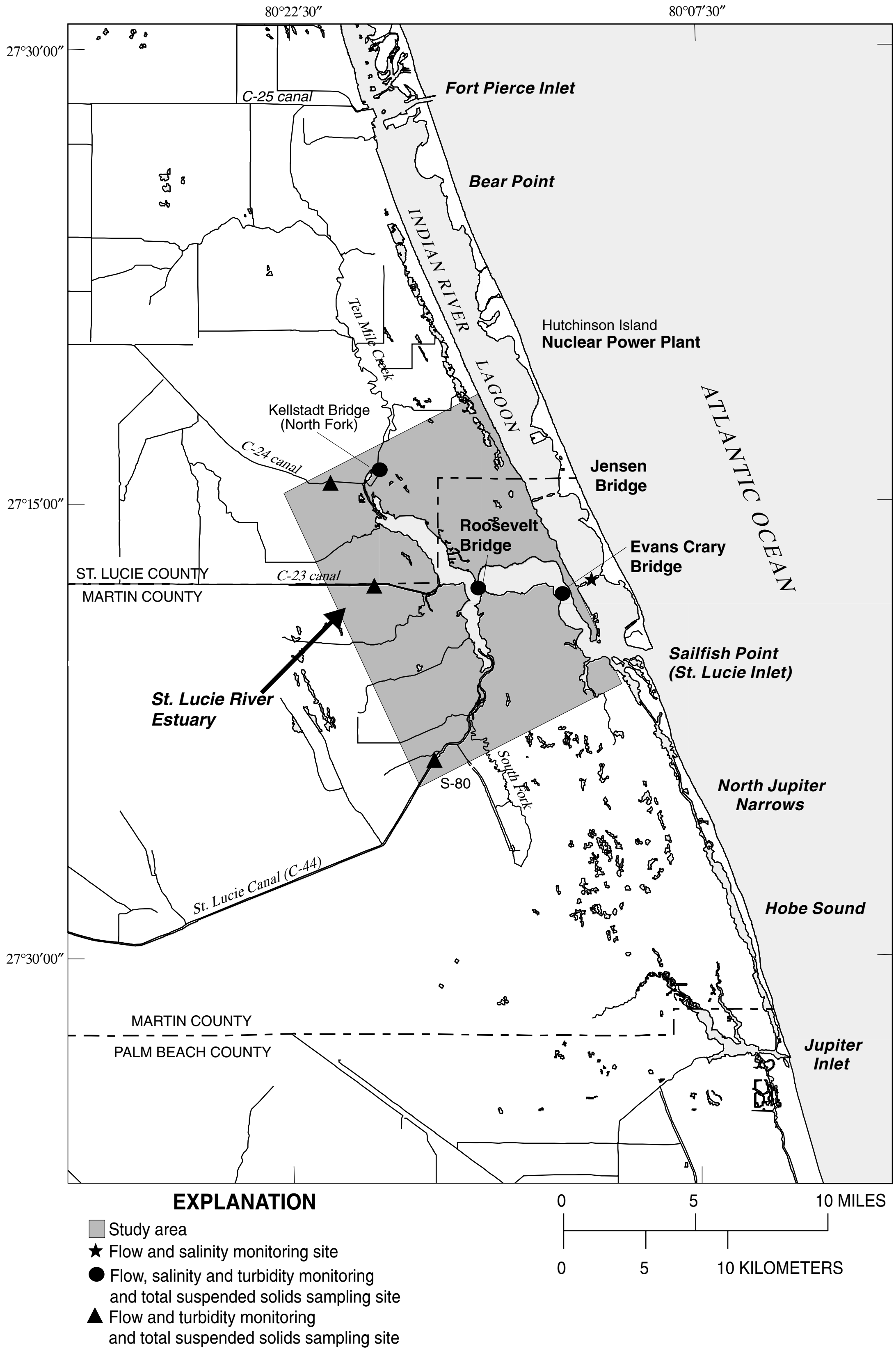

Figure 1. Location of monitoring sites within the St. Lucie River Estuary, Florida.

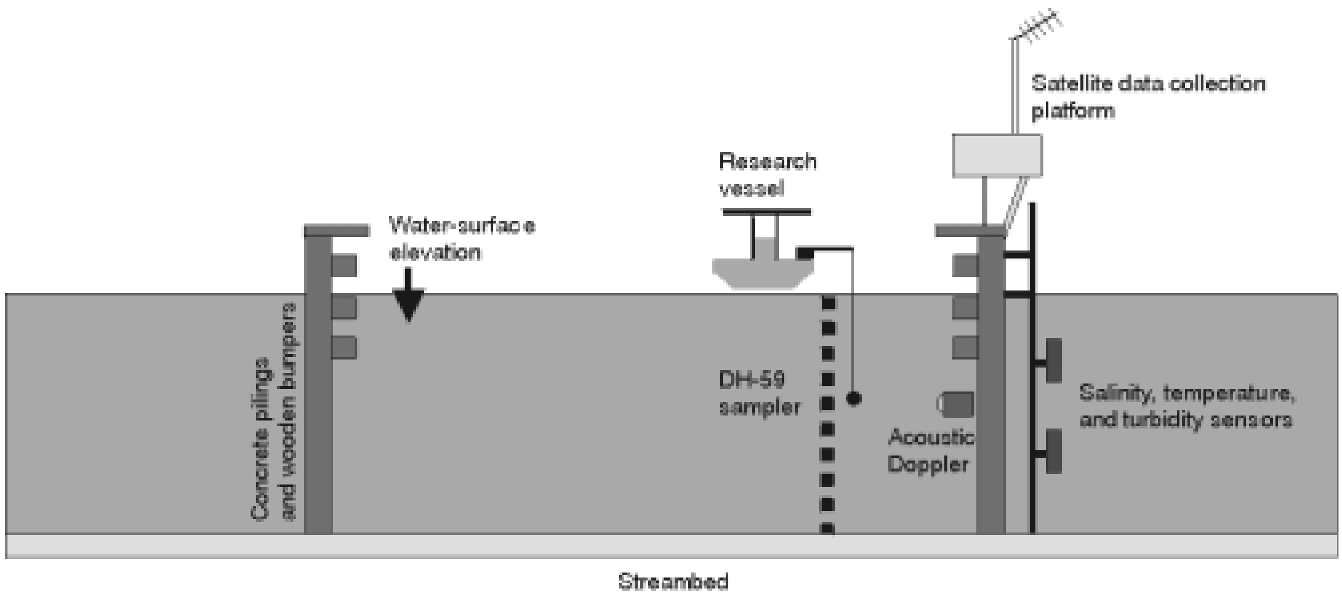

Figure 2. Instrument setup for monitoring sites at the St. Lucie River Estuary.

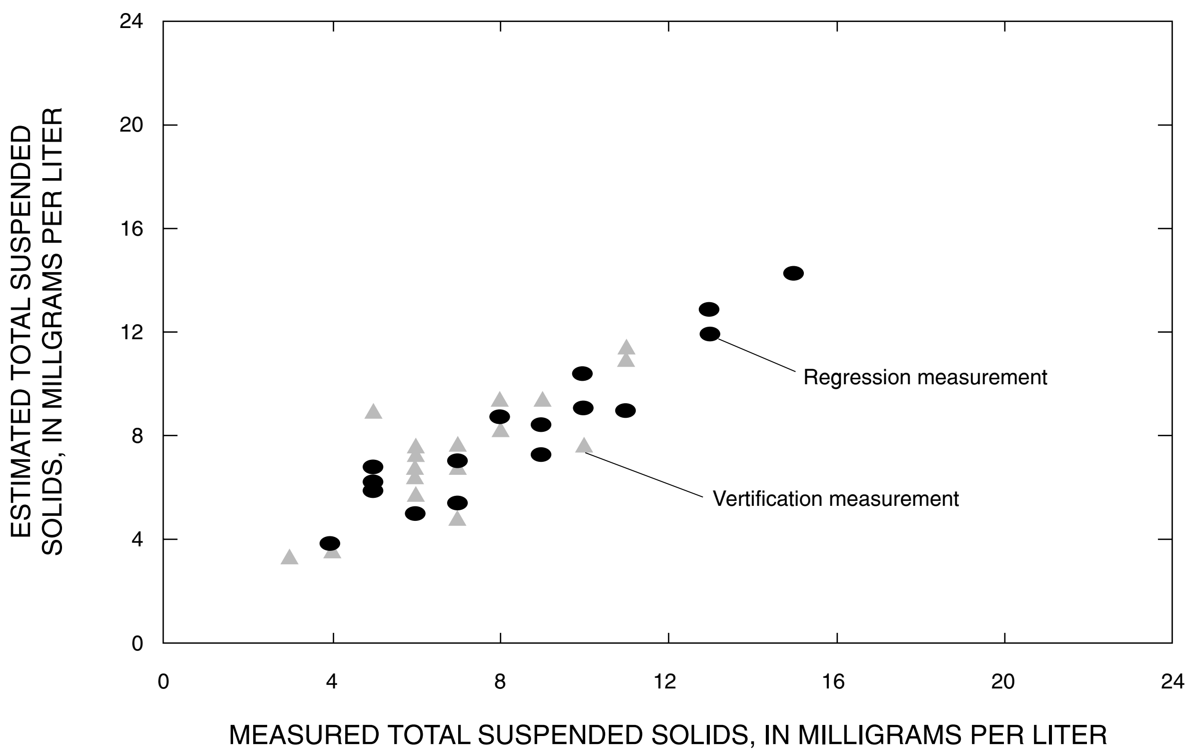

Figure 3. Measured to estimated total suspended solids concentrations comparison at the North Fork site.

Compilation of American Alligator Data Sets in South Florida for Restoration Needs

By Dr. Kenneth G. Rice[1], Dr. Frank J. Mazzotti[2], *and* Dr. Clarence L. Abercrombie[3]

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Alligators have been identified as a key component of the Everglades ecosystem. Long-term changes in alligator numbers, nesting effort, growth, condition, and survival can be used as indicators of the health of the Everglades marsh system. Due to their sensitivity to hydrologic conditions, an alligator population model is underway in the Across Trophic Level Systems Simulation (ATLSS) program to evaluate restoration alternatives.

Evaluating long-term trends and developing population models require a large amount of data collected over a number of years and a number of locations. Information on alligator densities, nesting, and growth have been collected in south Florida since the 1950s by rangers and researchers in Everglades National Park and Big Cypress National Preserve as well as Florida Fish and Wildlife Conservation Commission personnel, University researchers, and private consultants. Many of the most critical data sets (those having the largest amount of data or those from particular areas or years) are not accessible for use in evaluating restoration alternatives or developing models. The data are not available in a centralized, easily accessible, well documented data base. Further, the size and scope of these data sets are not fully known. Certainly, thousands of individual records need to be evaluated, compiled, and entered into an appropriate data base.

It is critical that these data sets are accessible to establish restoration targets for alligator populations, develop models, and design short- and long-term monitoring tools for evaluating restoration success. An example of the kind of data that would be made available is shown in figure 1.

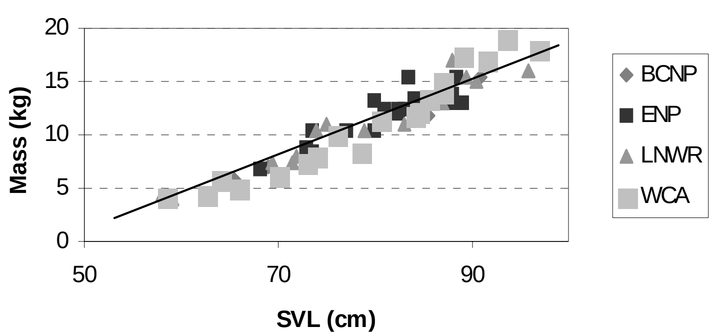

Figure 1. Mass versus snout-vent length for subadult American alligators captured and released during September, 1999 in the Everglades of South Florida.

American Alligator Distribution, Thermoregulation, and Biotic Potential Relative to Hydroperiod in the Everglades

By Kenneth G. Rice[1], H. Franklin Percival[2], Timothy S. Gross[2]

[1]U.S. Geological Survey, Homestead, Florida; [2]U.S. Geological Survey, Gainesville, Florida

During the last 100 years, the hydrology of the Everglades has been greatly altered by mankind. Efforts to repair the functioning of the ecosystem are using a multicomponent model, the Across Trophic Level Systems Simulation (ATLSS), to predict the response of native flora and fauna to alterative water delivery scenarios. This study was designed to provide information on the natural history and population functioning of the American alligator in the Everglades for construction of an ATLSS American alligator population model and to investigate restoration needs and status of the alligator in the Everglades ecosystem.

A 5-year study has been initiated on the home range, daily movement, habitat use, thermoregulation, and body temperature patterns of alligators in both Shark Slough, Everglades National Park, and in Water Conservation area 3A North. A total of 66 alligators were captured and surgically implanted with radio-transmitters. A subset of 29 of these also were implanted with temperature recording data loggers. Data loggers recorded core body temperature simultaneously at 72 minute intervals for 1 year.

Weekly aerial telemetry locations were collected beginning January 1, 1997, to estimate home range size. Week-long intensive sampling efforts conducted from November 7, 1997, to July 31, 1998, were used to estimate daily movement and habitat use. Some home-range and body temperature results are shown in figure 4.

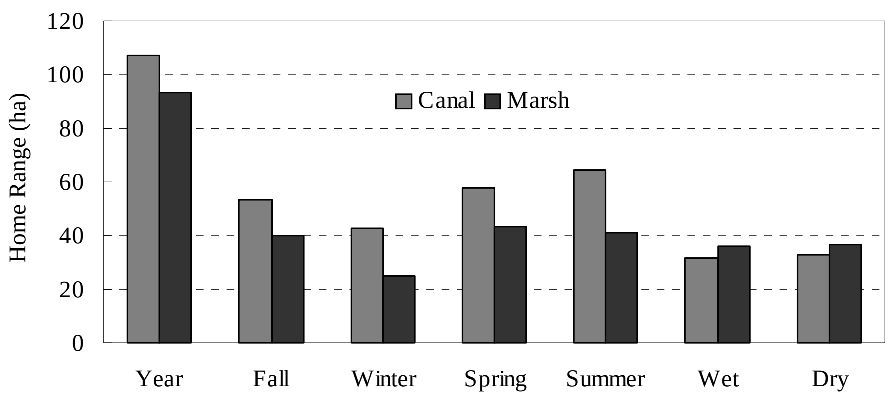

Figure 1. Mean annual and seasonal home range size (95 percent adaptive kernel) of radio-tagged male and female alligators located in Water Conservation Area 3A North and Everglades National Park from November 1996 to August 1999.

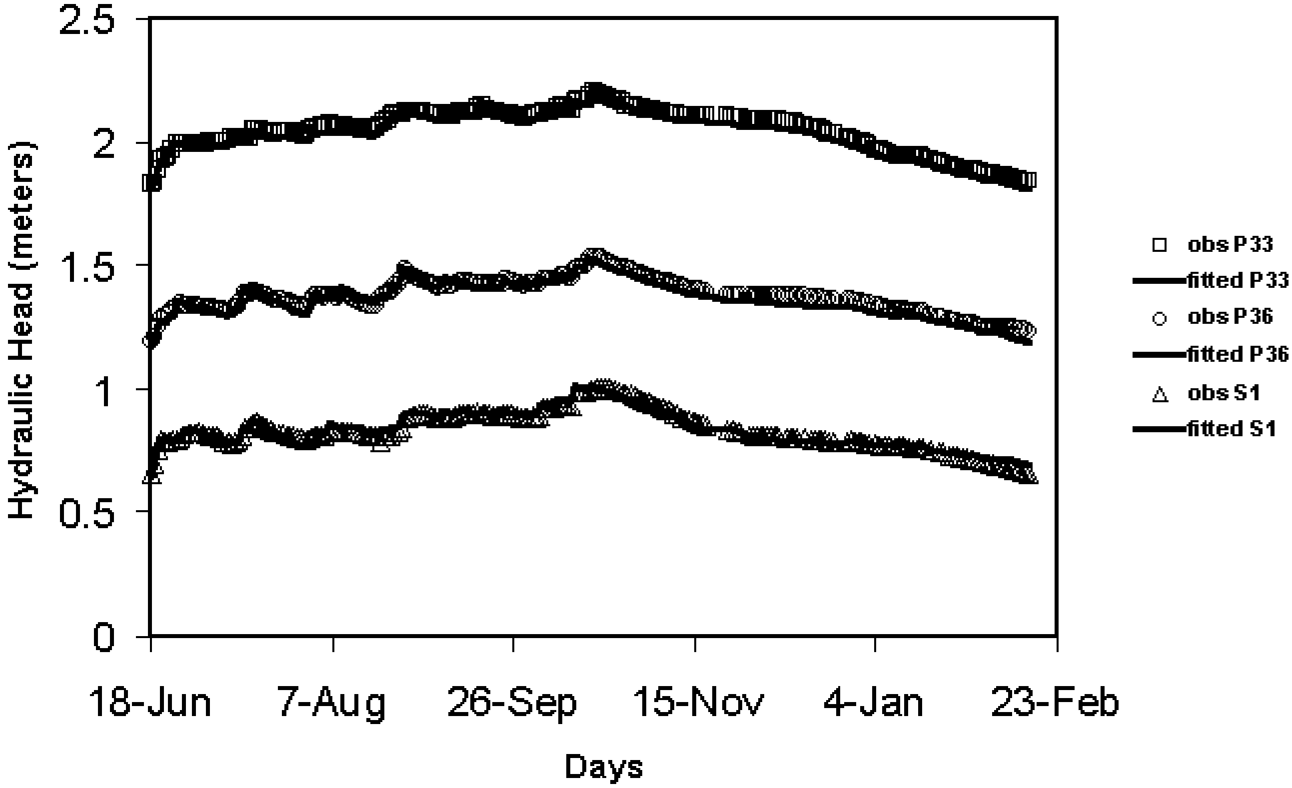

Figure 2. Mean annual and seasonal home range size (95 percent adaptive kernel) of radio-tagged canal and marsh alligators located in Water Conservation Area 3A North and Everglades National Park from November 1996 to August 1999.

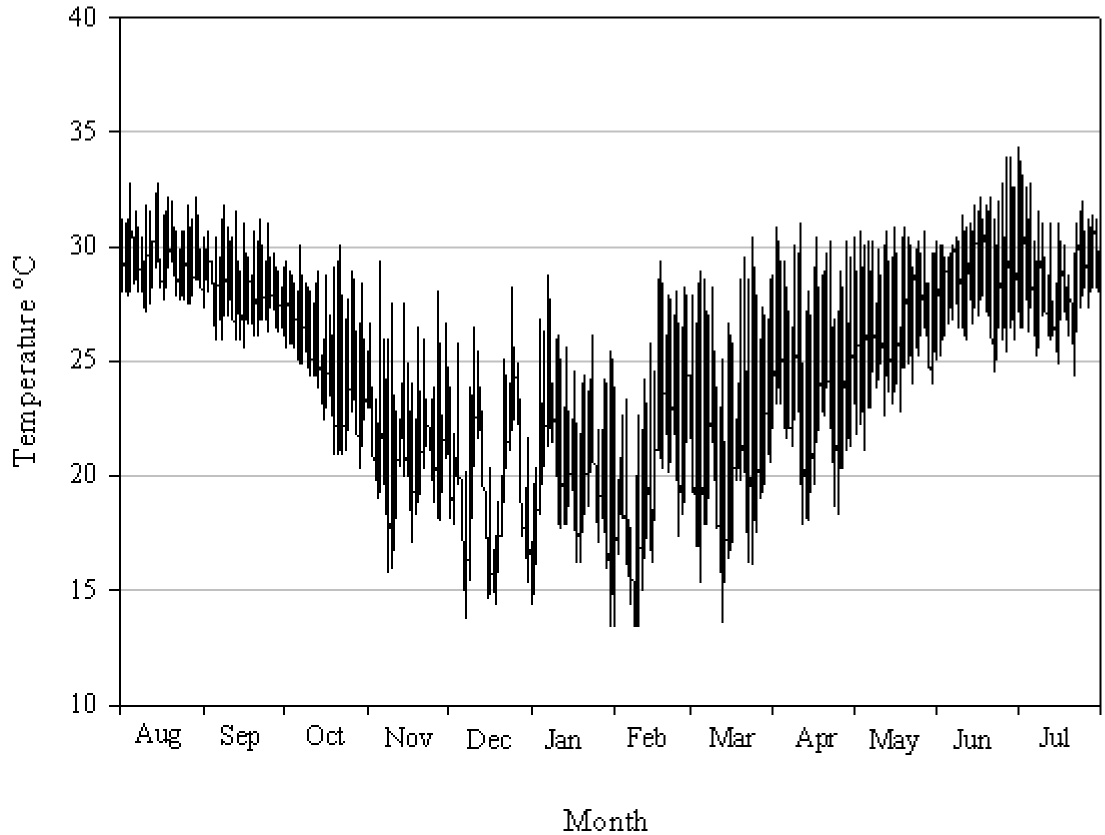

Figure 3. The typical pattern of body temperature of an alligator from the Everglades from August 1, 1997, to July 31, 1998.

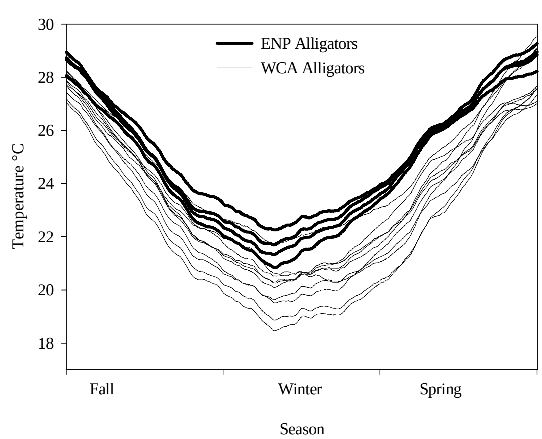

Figure 4. Seasonally smoothed body temperatures of 10 alligators from WCA and 4 alligators from ENP from August 1, 1997, to July 11,1998.

Hydrologic Variation and Ecological Processes in the Mangrove Forests of South Florida: Response to Restoration

By James E. Saiers[1] and Thomas J. Smith III[2]

[1]Yale University, School of Environmental Studies, New Haven, Connecticut
[2]U.S. Geological Survey, Miami, Florida

This project focuses on the hydrology of the mangrove-marsh ecotone of Everglades National Park and on the linkages between hydrologic characteristics and mangrove ecosystem function. The objectives of this research are to: (1) quantify groundwater and surface-water flow dynamics within the coastal mangrove zone and within the adjacent freshwater marsh; (2) define the response of fluid flow characteristics to changes in weather and water management practices; and (3) derive relationships between hydrologic conditions and vegetation indices of the mangrove-marsh ecotone. Objectives (1) and (2) center on the development and testing of mathematical models for the coupled flow of surface and subsurface water; objective (3) is interdisciplinary in nature and relies on cooperation with researchers conducting a concurrent vegetation dynamics study. Since the project's inception in November 1999, we have constructed a two-dimensional finite-difference model that accurately predicts the temporal variability in water levels across a 20-mile long region, situated in the central portion of Shark River Slough has been constructed. The domain of this fine-resolution model is being extended to include the coastal mangrove zone and the model formulation is being modified to account for complications associated with the mixing of fresh and saline waters. Results of this work will provide new information and tools critical in guiding Everglades restoration, including estimates of freshwater flows into estuaries within the Park and a tested means to forecast how these freshwater discharges are affected by changes in system structure and operational procedures.

Long-Term Experimental Study of Fire Regimes in South Florida Pinelands

By James R. Snyder and Holly A. Belles
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South Florida slash pine forests represent one of the region's most fire-dependent and imperiled ecosystems. Some 65 vascular plant taxa are endemic to south Florida and more than half are herbs and low shrubs restricted to pine forests (Avery and Loope, 1980). These species are quickly shaded out in the absence of fire (Robertson, 1953). The fire regime that created this system is not fully known. While lightning-ignited fires during the May to July period surely burned substantial areas before the arrival of Europeans, the indigenous people had most likely been burning at other seasons for thousands of years (Snyder, 1991). Even in large natural areas like Everglades National Park, a lightning-driven fire regime cannot be allowed to operate because of human health and safety concerns. Prescribed fire will be required to restore and maintain South Florida pinelands. While restoring the natural fire regime is frequently posed as a restoration goal, a more realistic goal is to use prescribed fire to restore and maintain the desired species composition and structure of south Florida ecosystems.

This long-term study will document the ecological effects of a wide range of potential fire management strategies on south Florida pinelands (Snyder, 1991). The main objective of the current project is to establish the baseline conditions and begin the experimental treatments for a long-term study of season and frequency of burning in south Florida pinelands. The research will provide detailed data on vegetation responses (such as changes in species composition, biomass, and demography of pines) to different burning regimes that will be considered along with wildlife, public safety, and other management concerns in refining prescribed burning programs on Department of Interior lands in south Florida. Because many of the effects of fire regime will not become evident until after several repetitions of the experimental treatments, this study must be treated as a long-term ecological study. An example of this type of research is a >40-year study by the U.S. Forest Service in South Carolina (Waldrop 1992). Specific objectives for the initial phase of the long-term study include: (1) describing the vascular plant communities of all treatment units to document initial conditions: (2) conducting all the initial experimental burning treatments: (3) documenting the short-term effects (<1 year) of season of burning and fire intensity on selected vegetation parameters; and (4) institutionalizing burning and data collection schedules and protocols for study of long-term effects of season and frequency of burning.

Figure1. Raccoon Point pinelands, Big Cypress National Preserve, site of long-term study of season and frequency of burning. Note understory cabbage palms and saw palmettos and cypress tree in right foreground.

The experimental study has been set up in eastern Big Cypress National Preserve, where the most extensive unlogged stands of south Florida slash pine (*Pinus elliottii* var. *densa*) remain (fig. 1). The pinelands exist as a mosaic of slightly elevated "islands" within a matrix of cypress domes and dwarf cypress prairies. The substrate is a shallow layer of sand over limestone bedrock, making these pinelands transitional between the true rockland pine forests of the Miami Rock Ridge and the widespread pine flatwoods to the north (Snyder and others, 1990). The study site of 2,573 hectares (ha) surrounds the Raccoon Point oil field and is divided into 18 experimental burn units. Each burn unit includes at least 50 ha of pine forest. Within each unit, three permanent 1.0 ha tree plots were established. In each plot, trees with diameter at breast height (dbh) >5.0 cm are tagged and mapped.

Smaller 0.1 ha vegetation plots are located in the center of each tree plot and at two additional locations to sample herbaceous and shrubby vegetation. There are a total of 54 tree plots and 90 vegetation plots. The tree plots (containing a total of 16,370 trees) show the Raccoon Point pinelands to have average stand densities (trees/ha) of 227 pines, 53 cabbage palms, and 24 cypress. All but five of the tree plots contain at least one cypress tree, indicating the hydric nature of these pinelands. The understory vegetation also is frequently dominated by wetland indicators.

The experimental treatments consist of burning at three seasons: (1) spring, or early wet season, when the largest human-caused or lightning-caused wildfires occur; (2) summer, or mid wet season when there are frequent, but generally small, lightning-ignited fires; and (3) winter, or mid-dry season when conditions are frequently favorable for prescribed burning) and two frequencies (every 3 years and every 6 years) for a total of six treatment combinations. Each treatment is replicated three times, with one replicate being burned per year for three years. The project is a cooperative effort of the U.S. Geological Survey (USGS) and the National Park Service (NPS) and all the experimental prescribed burns are conducted by the Big Cypress National Preserve Fire Management Division. Beginning in 1996, two units have been burned at each season, representing both short- and long-frequency treatments. Some treatment burns have been postponed to subsequent years because of abnormally wet conditions or because of state-wide burning bans brought on by drought conditions. By spring 2000, all 18 of the initial experimental prescribed burns were completed and the second cycle of burns of the 3-year treatments was begun.

The severity of each burn is quantified several ways, because fire behavior may vary significantly within a given treatment. Fuel consumption is measured by collecting 50 fuel samples before and after each burn. Fire temperature is measured by placing in the plots 148 small steel plates with spots of temperature-sensitive paints. And lastly, the proportion of scorched needles and the height of bark charring on the stem of each pine tree is measured after the burn. Tree mortality is evaluated one year after burning.

Based on the data from the first 16 burns, fuel loadings average 1,055 g/m^2. Fine litter, dominated by pine needles, comprised 78 percent of the mass consumed while herbs, palms, and coarse litter (>0.6 cm and <2.5 cm in diameter) each made up 5 to 10 percent (fig. 2). Fuel consumption averaged 717 g/m^2 and was lowest during the mid wet-season burns. Fire temperatures were relatively mild, with means ranging from a low of 212^{o}C during mid wet-season burns to a high of 222^{o}C after early wet-season burns (fig. 3). Mortality of pine trees >5 cm diameter in the first year after the burns was very low, including trees in which all the needles were scorched. The greatest number of trees (2.9 percent) died after mid wet-season burns. South Florida slash pine is extremely resistant to fire at any season. Patterns of mortality are often associated with localized fuel conditions rather than season of burning. Results to date do not support the argument that all prescribed burning should be done during the lightning-fire season.

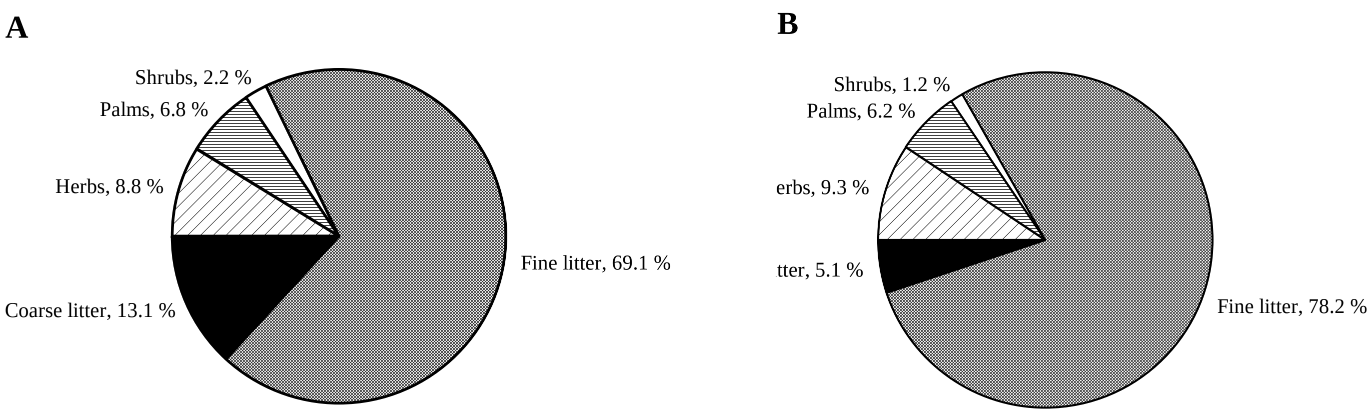

Figure 2. Mean fuel composition (percent total dry mass) in Raccoon Point long-term fire ecology study. Pre-burn fuel (A) and fuel consumed (B) in 16 initial burns.

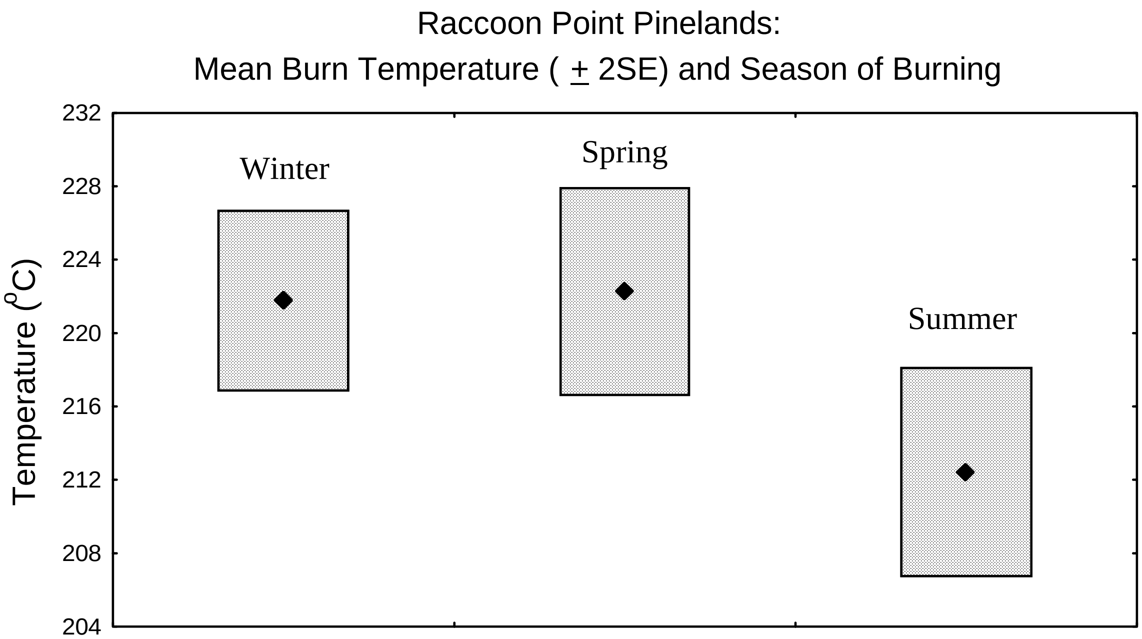

Figure 3. Fire temperatures as measured by temperature plates. Based on 6 burns for summer and winter treatments and four burns for spring treatment.

Population Structure and Spatial Delineation of Consumer Communities in Everglades National Park

By Joel C. Trexler
Florida International University, Miami, Florida

Population genetic structure and spatial scaling are critical parameters for management of animal and plant populations. Population structure is largely the result of dispersal and migration, and is very susceptible to alteration by environmental change. Analysis of genetic markers provides a cost-effective approach to examine landscape-level patterns of animal movement. Population genetic structure reflects patterns of movement, breeding, and genetic interchange by individuals integrated over a number of past generations. Population genetic structure of three aquatic species provide an indication of the effects of water management on animal movement. Species studied (mosquitofish, spotted sunfish, and grass shrimp) were chosen because of ubiquity and having potentially different population responses to hydrological
variation.

In small aquatic animals, migration rate and pattern are not easily revealed by direct measures, so indirect techniques must be employed. Direct methods generally involve following the movements of marked individuals. Indirect methods include examination of patterns of genetic diversity and patterns of stable-isotopic markers. Most Everglades aquatic animals are small and mobile, such that direct observation of marked individuals has limited application. Data have been gathered to permit hypothesis testing hypothesis about the effects of levees and canals on animal movement, and on the role of long-hydroperiod marshes as aquatic refugia and as a source of colonists for nearby short-hydroperiod marshes. Both protein electrophoresis and DNA microsatellite analysis in these studies, as appropriate. Dry conditions in 1999 were used to advantage to sample extensively from animals crowded in dry-season refugia. Research in the remaining project period will focus on larger-bodied species in alligator ponds.

The fact that mosquitofish populations in Water Conservation Area (WCA) 3B were genetically isolated was used in analysis of the Comprehensive Everglades Restoration Plan (CERP) affecting that area. General information on sink/source areas and about fish movements with relation to levees and canals is useful to other CERP-related projects such as MODWATERS, C-111 and Everglades Expansion Area work.

This project addresses a number of items identified by the Science Information Needs Report (1996) including: (1) the need to look at the effect of hydropattern on trophic structure and energy flow; (2) the role of compartmentalization of the once-continuous Everglades system; (3) collection of genetic and demographic data to provide estimates of migration rates for parameterizing the Across Trophic Level Systems Simulation (ATLSS) model; and (4) the quantification and modeling of the dynamics of productivity and composition of fish communities across the landscape.

Additionally, this project includes analysis of population migration between short and long-hydroperiod marshes indicating the ecological linkage of these habitats. This affects planning of water-management structures and their operation and development of performance measures for habitat connectivity. Future needs include estimates of migration rates and population structure for more types of aquatic organisms, including the direct marking and radio-tagging of larger-bodied fish species. Finally, the Everglades Conceptual models for the Ridge and Slough and Marl Prairie habitats use fishes as key indicators, and we anticipate that they will be selected as a group to be monitored to gauge the progress and success of the CERP.

Long-Term Aquatic Biota Data-Base Analysis

By Joel C. Trexler[1], Willaim F. Loftus[2], and Sue Perry[3]

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[3]National Park Service, Homestead, Florida

Changes in the physical character of the Everglades region have been detrimental to native animal and plant communities, and have helped demonstrate the need for regional restoration of the system. To reverse the trend in declining and changing biotic communities, a scientifically based restoration plan for the entire ecosystem is being developed. The restoration will restructure the physical and operational aspects of the Central and South Florida Project. Despite the attention focused on the Everglades system in recent years, the structure and functioning of many components of the wetlands remain unclear. The goal of this project is the understanding of short- and long-term responses of Everglades aquatic communities to natural and anthropogenic environmental changes. This knowledge will find application during the restoration process.

The studies of fishes and invertebrates are providing information to guide and evaluate the restoration process. The rationale is that marsh animals are easy to sample with standard protocols, and that their short life spans and rapid turnover rates make them responsive to short- and long-term environmental changes. Long-term data collections are necessary in this hydrologically variable environment because every year is idiosyncratic, and "average" years are rare. When sampling is done over short time periods, different pictures of the community emerge, depending on the segment of the time-series sampled. The data analyses allow evaluation of seasonal and long-term dynamics, reveal shifts in relative abundance and size-structure, and produce correlations of abundance and biomass to water depth, hydroperiod, and plant-community structure.

This project has employed a process of empirical data collection and hypothesis-testing under field and laboratory conditions, in combination with mesocosm studies. The factors that limit population growth and affect community dynamics are major uncertainties in modeling these communities. Our data are used to construct and evaluate ecological simulation models that will extend the information from site- or processed-based studies to the landscape. The data on community responses to environmental conditions across the present-day landscape also provide the empirical background from which the simulation models are used to make backcasted estimates of community parameters under modeled premanagement conditions. This process allows the establishment of restoration targets for the Everglades region where there are no historical data for aquatic communities. By using these aquatic-animal models to predict community responses to alternative restoration scenarios, the alternative that results in biotic characteristics that most closely approximate preproject conditions can be identified and tested further. The results from the fish-community monitoring program have clearly demonstrated that a well-designed and consistently funded program can not only track the status and responses of the community to anthropogenic and natural disturbances, but also can provide biological and ecological data to understand community dynamics. The system restoration will proceed using an adaptive-management strategy; therefore, aquatic-animal communities should continue to be monitored across the region to evaluate model output and help guide the restoration.

We presently have a 20-year record of fish communities collected at a short and a long hydroperiod site in Shark River Slough with which to examine the persistent effects of extreme hydrological events. The data were gathered by use of standard sampling method for wetlands, a 1-m square throw trap. Monthly samples were collected between 1977 and 1986, followed by approximately bimonthly sampling through 1999. Small species, including poeciliids and fundulids, are sampled well by this technique and dominate the Everglades community. Larger species, such as centrarchids, were sampled mostly as juveniles. Of several physical variables measured throughout the study, annual minimum water depth was found to provide the most power in explaining fish absolute and relative abundance. Also, there was a lag of greater than 1 year in the recovery of community composition following a multiyear drought. Fish abundance was related to hydroperiod in a nonlinear, decelerating pattern at the long hydroperiod site, possibly as a result of increasing piscivore density in multiyear periods lacking a regional dry-down. The presence of lags and multi-year responses to changing hydrology in this wetland ecosystem underscores the importance of community analysis over extended time periods.

In addition to the long record of fish data for a few locations, there is a spatially extensive network of sampling sites in Shark and Taylor Sloughs and in the Water Conservation Areas. Those sites have been sampled for various periods from 4 to 15 years. They are well placed to provide baseline data before restoration actions and can be used to track changes when actions occur. The studies conducted on Everglades wetland ecology advance the understanding of the ecological structure and function of this large, freshwater marsh system, but also have wider implications for comparison with other tropical and subtropical wetlands worldwide. Such systems have received little descriptive or experimental study, despite providing vital regional and local functions for water supply, wildlife and fishery habitat, etc. In view of the human activities that threaten to degrade many freshwater wetlands, understanding their ecological function and how that might be restored after damage has occurred is critical. Lessons learned from this project in the Everglades may provide information, sampling guidelines, and models for other wetland systems.

Those results, in the form of data, model rules, and life tables, will be used to improve the Across Trophic Land Systems Simulation (ATLSS) fish model used to suggest and evaluate the restoration alternatives. Use of the experimental data from the mesocosm study will enhance the interpretation of these time series data from research and monitoring projects, before and during restoration, by explaining the processes behind the patterns in the field data. The long-term data are also being used to develop Conceptual Models and Performance Measures for the Comprehensive Everglades Restoration Plan, and these aquatic communities and sampling locations will most likely be used to monitor the progress of restoration actions.

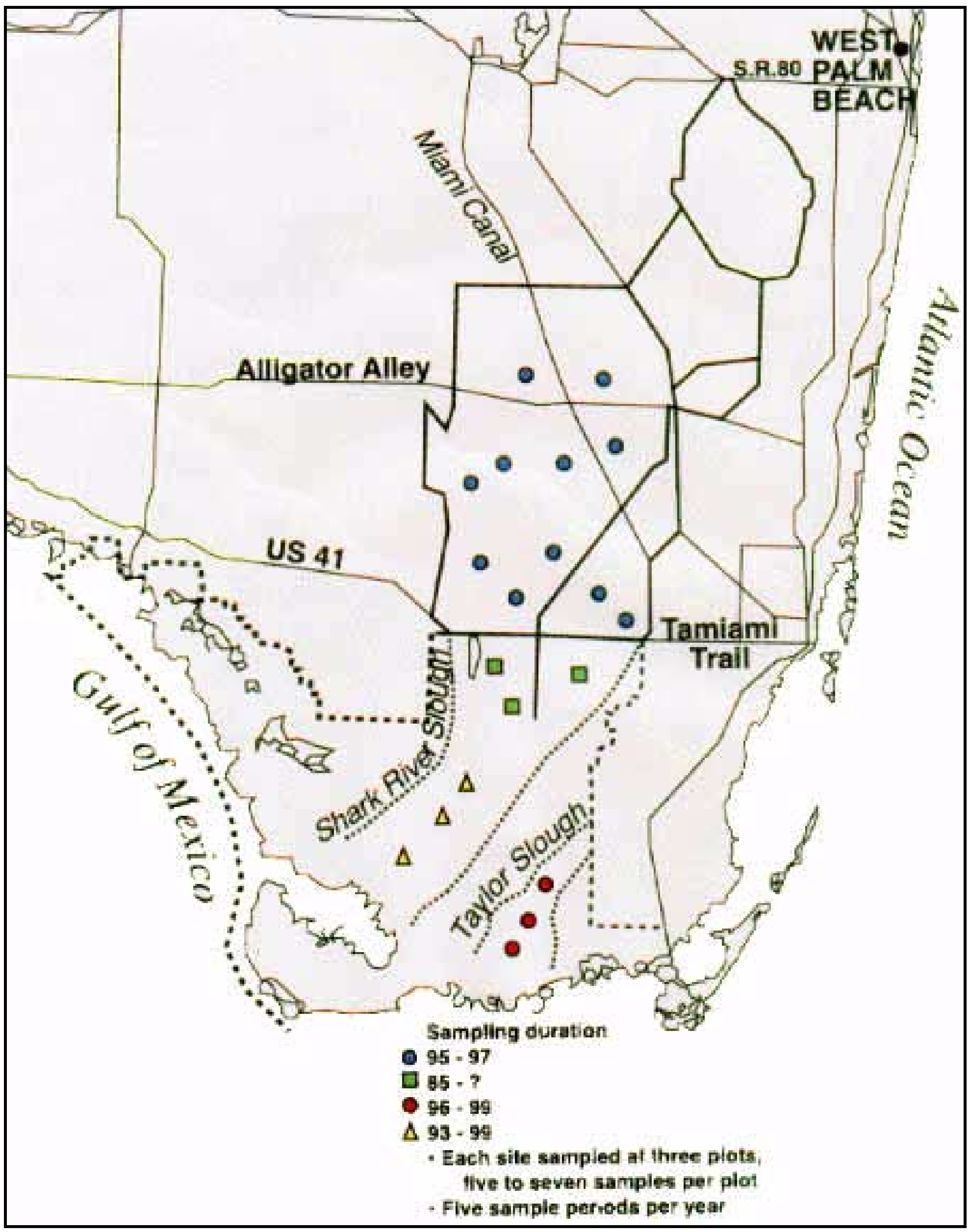

Figure 1. Long-term sampling sites for aquatic communities in the greater Everglades.

Experimental Studies of Population Growth and Predator-Prey Interactions of South Florida Fishes

By Joel C. Trexler[1] and William F. Loftus[2]

[1]Florida International University, Miami, Florida; [2]U.S. Geological Survey, Homestead, Florida;

Fishes are important prey for most species of wading birds in the Everglades, and provide a critical link between water management and restoration of wading bird populations. The Across Trophic Level Systems Simulation (ATLSS) model of fish population dynamics was developed to evaluate the ecological effects of hydrological restoration alternatives on fish productivity. The model incorporates assumptions regarding predator-prey and population growth parameters, which are poorly understood because of the difficulty of studying them under field conditions. Controlled experiments in large outdoor tanks and field cages will provide improved estimates of some of these parameters, and will explore some important biological interactions that must be included in future model versions to improve credibility. These include predator-prey interactions involving the mosquitofish *(Gambusia holbrooki)*, an abundant and highly predatory species throughout the Everglades. This is the “model” small fish on which the ATLSS fish model is based. It is known to prey upon the young of other fish, even driving some fish species to extinction where it has been introduced. They also feed on their own offspring when possible. Mosquitofish are also important predators on the eggs and larvae of nesting sunfishes. These interactions are being explored experimentally.

There are three research objectives for this study: (1) document the extent, patterns, and results of cannibalism and predation by mosquitofish on mosquitofish juveniles and those of other small fishes. Limitation of growth through intraguild actions is a potential feedback relations that must be included in the ATLSS and similar management models; (2) test the relations of water depth and small-fish predation with the survival of eggs and larvae of nesting sunfish, also a potentially important feedback in community regulation; (3) by the addition of nutrients to tanks, test the effects of variations in primary production through an experimental food web. Primary productivity varies naturally and along anthropogenic gradients in the Everglades, affecting both food availability and habitat structure.

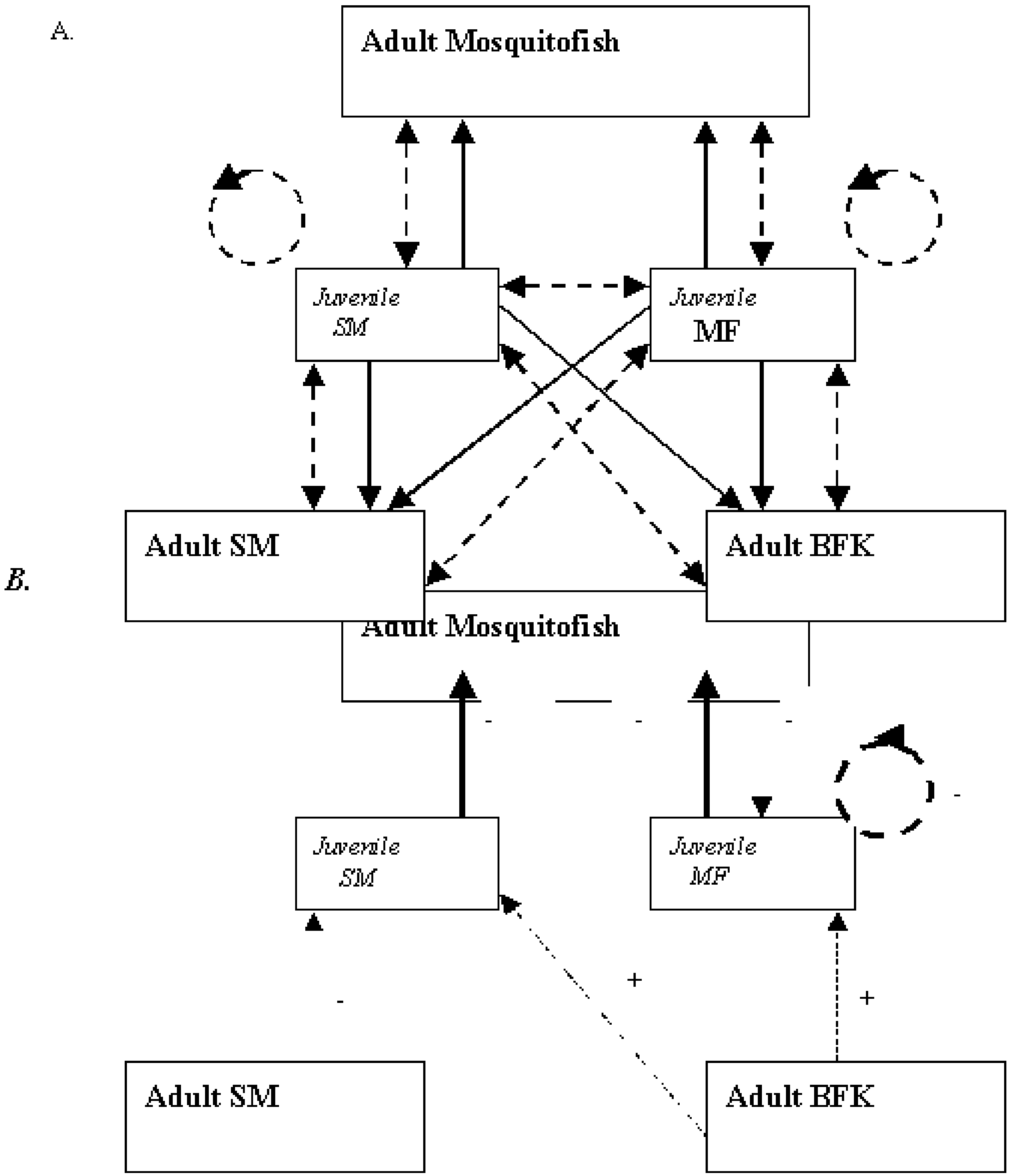

Figure 1. A. Conceptual model of interactions among fish species examined in this study. This model does not address all possible, or even all likely, interactions. For example, we were unable to obtain enough juvenile BFK to include them in the study. One-way solid arrows indicate predation of adult fish on juveniles, and two-way dotted arrows indicate competition for food resources.
B. Conceptual model indicating interactions among fish species found to be significant in this study. The strength of interactions, based on the effect sizes measured, is indicated by thickness of arrows. Strong interactions are depicted with bold arrows, weak interactions are depicted with thin arrows. The +/ - indicates a positive or negative interaction.

Network Analysis of Trophic Dynamics in South Florida Ecosystems

By Robert E. Ulanowicz *and* Johanna J. Heymans
University of Maryland, Chesapeake Biological Laboratory, Solomons, Maryland

The primary purpose of this project is to support the modeling efforts of the Across Trophic Level Systems Simulation (ATLSS) Project by providing quality data on the workings of the south Florida wetland ecosystems that can be used to calibrate and verify that the ATLSS model is a reasonable simulation of how these ecosystems work.

Its secondary purpose could well surpass the primary goal in importance – namely, by discovering several major facets of ecosystem behavior, the network analysis could provide very important strategic information useful to those engaged in management and restoration efforts.

The full suite of eight networks (wet and dry season networks for each of the four major biomes) are completed and on the Web at http://cbl.umces.edu/~atlss/.

The first step in any modeling project is the "lexical" phase, or the identification of the primary biological components that are to be modeled. The next step involves connecting the selected compartments to one another via feeding and detrital pathways. This topology is determined from information about the diets of each taxon. The purpose here is not merely to formulate a qualitative "foodweb", but also to *quantify* the connections. Toward this end, it is useful to concentrate first on assessing the densities, or stocks of the participating taxa. Knowing the concentration of biomass is the key to scaling all the activities of a particular population.

The biomasses of most species are known to reasonable precision. It is usually just necessary to find those estimates from the available literature or from the opinions of experts. For example, the number of animals per cubic meter or liter is available for many of the compartments. As the standard units used in network analysis (NA) are grams of carbon per square meter, the available data had to be transformed to maintain dimensional consistency. Towards this end, information on the average weight (grams) of animals was gathered from technical manuals. The percentage of carbon per gram of dry weight was then combined with wet weight/dry weight ratio to obtain gC/m^3 (in the case of number of animals per liter we just need a simple equation to transform gC/l in gC/m^3). By assuming an average water depth, the carbon biomasses in the required units (g/m^2) was calculated. In the case of primary producers, most sources reported data on biomass in grams per hectare or square meter. In this case only the wet weight/dry weight ratio and the percentage of carbon per gram of dry weight were necessary to convert the biomasses into the correct units.

Once the biomasses had been estimated, the total demand by each compartment was estimated by searching for data on consumption per unit biomass. This total consumption then had to be apportioned among the various items in that taxon's diet. On the output side, the fraction of the consumption that is dissipated was estimated from data on respiration per unit biomass. The remainder was available as either production to meet the demands of predators or was recycled into the detrital pools. Unfortunately, the dietary components of some taxa were available only as a list of species. In such cases the total input was apportioned to the list of prey in proportion to the standing stocks or production of those populations.

The two seasonal networks were assumed to balance over each period. Although this assumption is not entirely realistic, balance is required for the critical input/output phase of NA.

At this point, the balance is almost complete. It remains to estimate the exchanges of carbon with the outside world. Exogenous imports occur in three different ways: (1) Carbon from the atmosphere may be fixed as biomass through the process of photosynthesis. The magnitude of this import is assessed by multiplying the standing stock of the autotroph by its primary productivity per unit carbon, as mentioned above. (2) Biomass may enter or leave the system advected by water flow into and out of the study area. These exchanges can be estimated from the overall water budget for the wetland area, which includes figures for gross advective water exchange with the surrounding areas. Multiplying these water exchanges by the concentrations of carbon suspended in the water column provided an approximation for these exogenous transfers. (3) Biomass may enter and leave the system as animal populations migrate across the boundaries of the study area.

Proceeding in this manner, it was usually possible to balance carbon around each taxon to within a few percent. Final balance was cast using a software routine DATBAL, which forces balance using the assumption of donor control. (It should be borne in mind that this unrealistic assumption was invoked only for the purpose of obviating very small discrepancies.)

Once the networks had been estimated, they were analyzed using a suite of algorithms, collectively known as NETWRK. Four types of analyses are performed by NETWRK. First, so-called input-output structure matrices are calculated. These allow the user to look in detail at the effects, both direct and indirect, that any particular flow or transformation might have on any other given species or flow. Next, the graph is mapped into a concatenated trophic chain (after Lindeman, 1942). Then, global variables describing the state of development of the network are presented. Finally, all the simple, directed biogeochemical cycles are identified and separated from their supporting dissipative flows. NETWRK 4.2a and its accompanying documentation may be downloaded from the World Wide Web at: http://www.cbl.umces.edu/~ulan/ntwk/network.html.

Predicting Salinity in Florida Bay

By Bruce R. Wardlaw and G. Lynn Brewster-Wingard
U.S. Geological Survey, Reston, Virginia

Biotic and chemical proxies for salinity in Florida Bay show that salinity values for the last century are strongly correlated with climate, specifically, rainfall (Brewster-Wingard and others, 1998; Cronin and others, 1998). Elemental chemistry of ostracode shells provides a methodology to discern salinity values of the past (Dwyer and Cronin, 1999). Adult tests of the ostracode *Loxoconcha matagordensis* are grown essentially instantaneously in the late spring and early summer. For the purpose of this paper, salinity values derived from adult *Loxoconcha matagordensis*, generally grown between May and July each year, serve as proxies for June salinities. Because *Loxoconcha matagordensis* growth shows a very tight normal distribution, population studies from one sample can provide data on salinity changes occurring at the beginning of the rainy season (usually June). The purpose of this study was to establish if a relation exists between rainfall and Mg/Ca derived salinities, and if so, to mathematically express this relation. In this initial attempt, the record from the Russell Bank Core (Brewster-Wingard and others, 1997) was utilized. Russell Bank has a long record and relatively abundant Loxoconcha matagordensis. Biotic indicators were analyzed from every other 2-cm sample and elemental chemistry of the ostracodes was performed on every sample. The calculated sedimentation rate of the core is 1.22 cm + 0.05, each sample represents about 1.5 to 2 years.

The assumptions and values for the model:

Monthly rainfall information is available from NOAA (www.ncdc.noaa.gov) dating back to 1895. The eastern part of Florida Bay is influenced by rainfall and surface run-off. To compare rainfall to salinity values on a monthly basis, averages of the three southern districts (southwest (Everglades), southeast coast, and Bay and Keys) were taken, because rainfall to all three may influence salinity in Florida Bay. Because the focus is June salinity, rainfall from the five preceding months was examined to establish a relation. During El Nino years, high winter rainfall is usually recorded in January; therefore, January rainfall was included in the data set to indicate the occurrence of these events.

Age models for specific cores can be very good for the latter half of the century because ^{210}Pb derived ages can be calibrated to the cesium spike of the early sixties caused by atmospheric nuclear testing. Some historical salinity data is available dating back to 1955. So for these two reasons, samples from 1955 to the date the core was taken (1994) were examined.

January-May total rainfall and Mg/Ca-derived salinity values for a given calculated year correlate extremely well for the period 1955-1970, showing a strong negative correlation of –0.90. The regression line provided a formula for predicting salinity, given the January-May rainfall for a specific year (fig. 1).

For 1971-1994, January-May total rainfall showed little correlation to the Mg/Ca derived salinity values (fig. 1). The relation was a weak positive correlation which was certainly counter-intuitive and suggested disruption. The core could possibly have been mixed, but comparison to historical monthly salinity data compiled for the eastern zone of Florida Bay by M.B. Roblee (USGS, written commun., 2000) matched well with the Mg/Ca-derived salinities for June over this time span, suggesting that there was a strong disconnect between rainfall and salinity post-1971 compared to pre-1971.

Initial results are promising in that pre-1971 strong correlations between salinity and January-May rainfall provide a predictive tool for salinity that appears to represent a relation prior to disruption of the system.

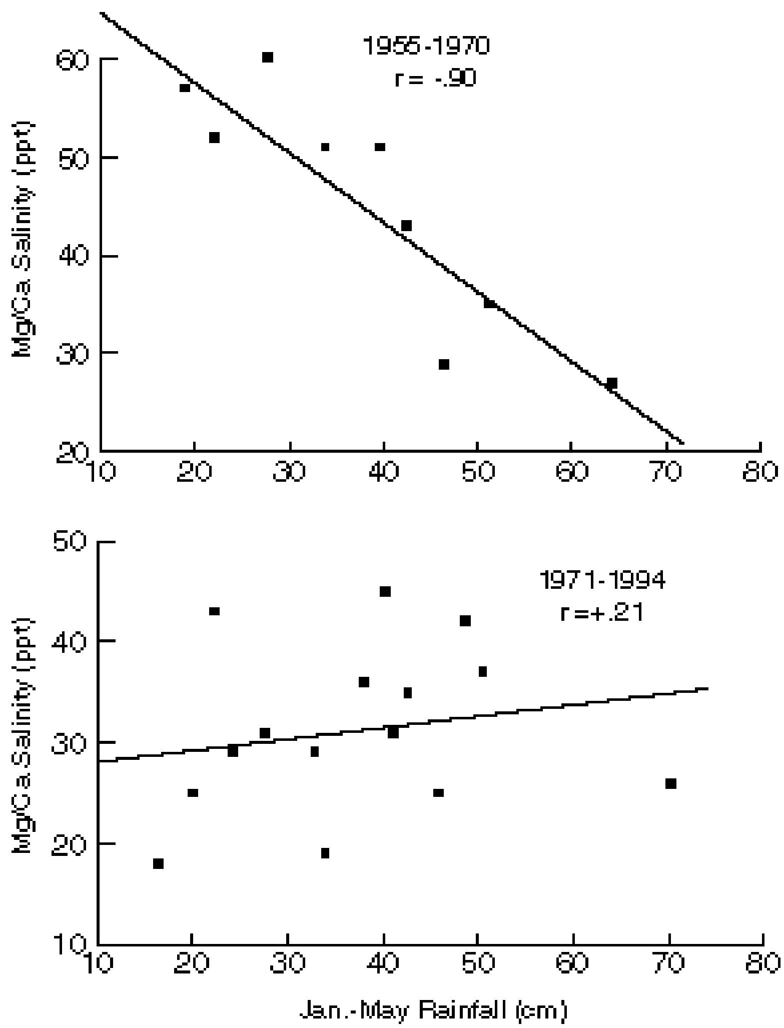

Figure 1. Scatter plots of the relation of Mg/Ca salinity derived from Loxoconcha matagordensis tests from the Russell Bank Core 19B and total average rainfall for January-May for South Florida for the years 1955-1970 and 1971-1994 including the least squared means correlation (regression) line and r value of correlation (Pearson correlation).

Introduction to Paleoecological Studies of South Florida and the Implications to Land Management Decisions

By Bruce R. Wardlaw
U.S. Geological Survey, Reston, Virginia

The Florida Everglades developed from the interplay of sea level and climate. The subtle balance of these two factors over the last two millennia is important to understanding restoration strategies. During the Medieval Warm Period and the Little Ice Age, the Everglades show a general drying trend. The Medieval Warm Period trend is due to a significant decrease in annual precipitation while sea level was rising. The Little Ice Age trend is due to the combined effect of reduced precipitation and the slowing in the relative rate of sea level rise, failing to keep base level with Everglades sediment and peat accumulation, yielding shorter hydroperiods and dryer conditions. Sea level has been steadily rising over the last century and should be considered in water flow modeling. Land use and water management practices over the last century have greatly partitioned the Everglades compounding its ability to respond ecosystem-wide in predictable ways to climate and sea level change.

Salinity in Florida Bay is affected by marine circulation, climate (rainfall) and runoff. Marine circulation was reduced in the early 20th century by intense construction connecting the Keys. Rainfall and runoff appeared coupled until the late 1960's. A restoration goal should be to couple rainfall and runoff again. Salinity in central, western and southern (Atlantic transitional) zones of the Bay is influenced by direct rainfall; salinity in the northern (northern transitional) and eastern zones is influenced to a large extent by runoff. These latter zones need to be monitored to ascertain that rainfall and runoff are indeed coupled to the degree that they have been in the past.

The Florida Everglades Ecosystem: Climatic and Anthropogenic Impacts Over the Last Two Millennia

By Debra A. Willard[1], Charles W. Holmes[2], and Lisa M. Weimer[1]

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[2] U.S. Geological Survey, Center for Coastal and Marine Geology, Florida

The response of the Everglades ecosystem to climatic and environmental changes are documented over the last two millennia using pollen records. From A.D. 0-800, marsh and slough vegetation characteristic of deeper water and longer hydroperiods (annual duration of inundation) than today dominated the region. Drier conditions between about A.D. 800 and A.D. 1200 resulted in shallower water depths and shorter, fluctuating hydroperiods in Everglades marshes as well as salinity increases near Florida Bay. After a recovery to deep-water conditions in the 14th century, slightly drier conditions are indicated from the 17th through 19th centuries. These climatically-induced periods of relative dryness are correlated with regional droughts during the intervals known as the Medieval Warm Period (9th -14th centuries) and Little Ice Age (15th -19th centuries).

Broad-scale vegetational changes are documented in Everglades wetlands beginning by 1930, indicating shallower water depths and shorter hydroperiods, even though regional precipitation increased concomitantly. Further, more localized changes occurred after 1960, when the Central & South Florida (C&SF) Project was completed. Thus, restoration goals of achieving pre-C&SF Project hydrologic regimes are aimed at an already disrupted system; a more "natural" restoration target would be the 19th century Everglades, which had been stable for the past few centuries. Recent land-use changes have resulted in localized rather than system-wide ecosystem responses, at least in part because of the fragmentation of the wetland. This artificially induced ecological heterogeneity makes prediction of future wetland responses to climatic changes problematic.

Trends in Tree-island Development in the Florida Everglades

By Debra A. Willard and William H. Orem
U.S. Geological Survey, Reston, Virginia

Tree-island formation and development are influenced by a number of environmental factors, including hydrologic regime, nutrient influx, and underlying geologic structure. Design of management strategies to maximize the health of tree islands and the Everglades wetland as a whole requires an understanding of how changes in these parameters affect the diverse plant and animal communities on these features. To determine how tree-island communities have responded to past climatic and environmental changes, transects of sediment cores have been collected from tree islands in the Everglades to determine: the timing of tree-island formation throughout the region; underlying controls on tree-island formation; patterns of vegetational development on tree islands; nutrient trends on and around tree islands; and the use of sediment phosphorus as a tracer of historic bird populations in the Everglades.

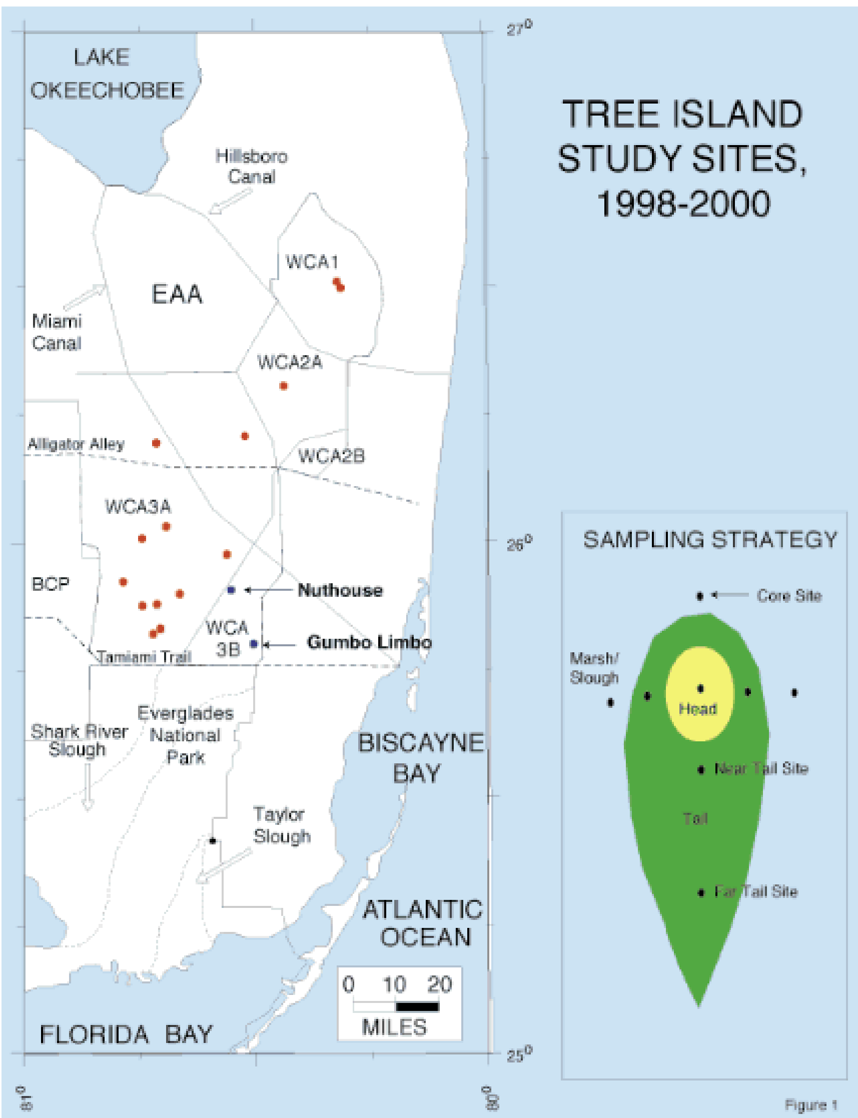


Figure 1. Location of tree islands sampled between 1998 and 2000. The sampling strategy for core transects along tree islands is shown in the inset; modified versions of this sampling were used on each island.

To date, sediment cores have been collected on sixteen tree islands: two in Arthur R. Marshall Loxahatchee National Wildlife Refuge, one in WCA 2A, eleven in WCA 3A, and two in Water Conservation Area (WCA) 3B (fig. 1). Sediments in these cores are described lithologically, dated using radiometric techniques (^{14}C and ^{210}Pb), and analyzed palynologically and geochemically. Integration of these data with field evidence for peat/sediment thickness and elevation, bedrock elevation, and existing vegetation are being used to develop models of tree island formation and development.

Palynological and geochemical analyses of cores collected on the head, near tail, far tail, and adjacent wetland have been completed for two tree islands in WCA 3B, Gumbo Limbo island and Nuthouse island (fig. 1). Both are elongate, teardrop-shaped tree islands, with trees clustered at the north end of the island on the head and a tapering tail to the south with shrubs and thick marsh vegetation. Sediment cores collected in transects across the head and along the length of both islands contain records of the last 4.3 thousand years (ka) and predate tree island formation. Three stages of tree-island development have been identified from both cores (fig. 2). Prior to tree-island formation, sites on the tree island were covered by sawgrass marsh vegetation with common weedy annuals, indicating moderate water depths and hydroperiods with periodic intervals of drought. In the wetlands adjacent to the head, however, slough vegetation, characteristic of deeper water depths and longer hydroperiods grew concomittantly. In the early stage of tree-island development (beginning at 1200 BC on Gumbo Limbo and 300 AD on Nuthouse), ferns, trees, and shrubs became more abundant; this stage persisted for 1,000 to 2,000 years. Mature tree-island vegetation is indicated in the pollen record by strong dominance of fern spores and increased abundance of tree and shrub pollen. Such vegetation has been in place on Gumbo Limbo island since 800 A.D. and on Nuthouse Island since 1500 A.D. Thus, these features are geologically old, with formation occurring as long ago as 1200 BC, early tree-island vegetation lasting 1,000 to 2,000 years, and mature tree-island vegetation persisting for the last 500-1,200 years.

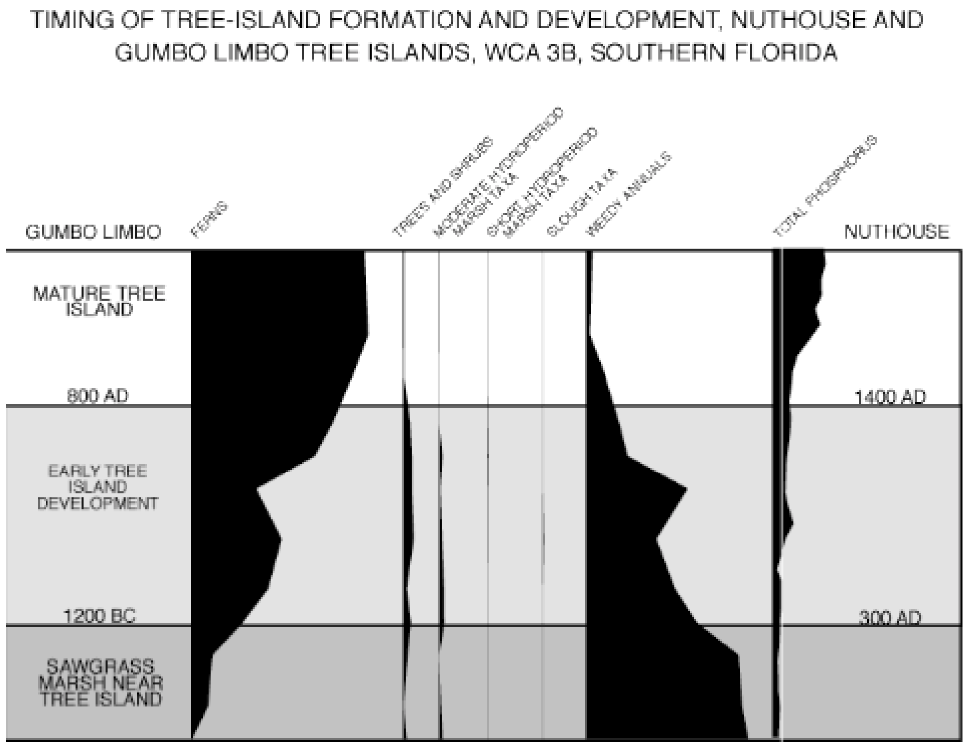


Figure 2. General trends in abundance of pollen and spores of major plant groups and total phosphorus in tree-island cores from Water Conservation Area 3B. Approximate dates are given for each vegetational phase on both tree islands.

Vegetational reconstructions from transects along the length of these tree islands indicate that sites on the island were drier than the surrounding wetlands throughout their histories, with shallowest water depths on the heads and progressive deepening of water depths with increasing distance along the tail. Thus, relatively localized hydrologic conditions appear to have played a major role in determining where tree islands formed; ongoing research on topography and lithology of the underlying limestone should clarify the roles of climate and geologic framework in influencing tree-island formation. The impact of artifically altered water depths on tree-islands is illustrated by preliminary results from a “drowned” tree island in WCA 2A. Vegetational reconstructions indicate an abrupt change from vegetation characteristic of a tree-island head to that similar to a far tail site, with much deeper water (fig. 3). Based on the current age model, this change occurred within the last fifty years, after high water levels were maintained for more than a decade. Thus, a tree island that had existed for about 2,000 years was altered to an unprecedented degree over a span of a few decades, highlighting the sensitivity of tree islands to extreme hydrologic change.

Sediments collected on these tree island heads are characterized by extremely high phosphorus content, both before and after tree-island formation. Sediments from the surrounding wetlands, in contrast, have relatively low phosphorus content, similar to marshes elsewhere in the Everglades. In tree-island tails, phosphorus levels were low prior to tree-island formation and increased after formation, when water depths decreased. We hypothesize that these phosphorus records may be a tracer of historic bird populations in the Everglades and are analyzing additional cores from rookeries to establish the validity of this hypothesis.

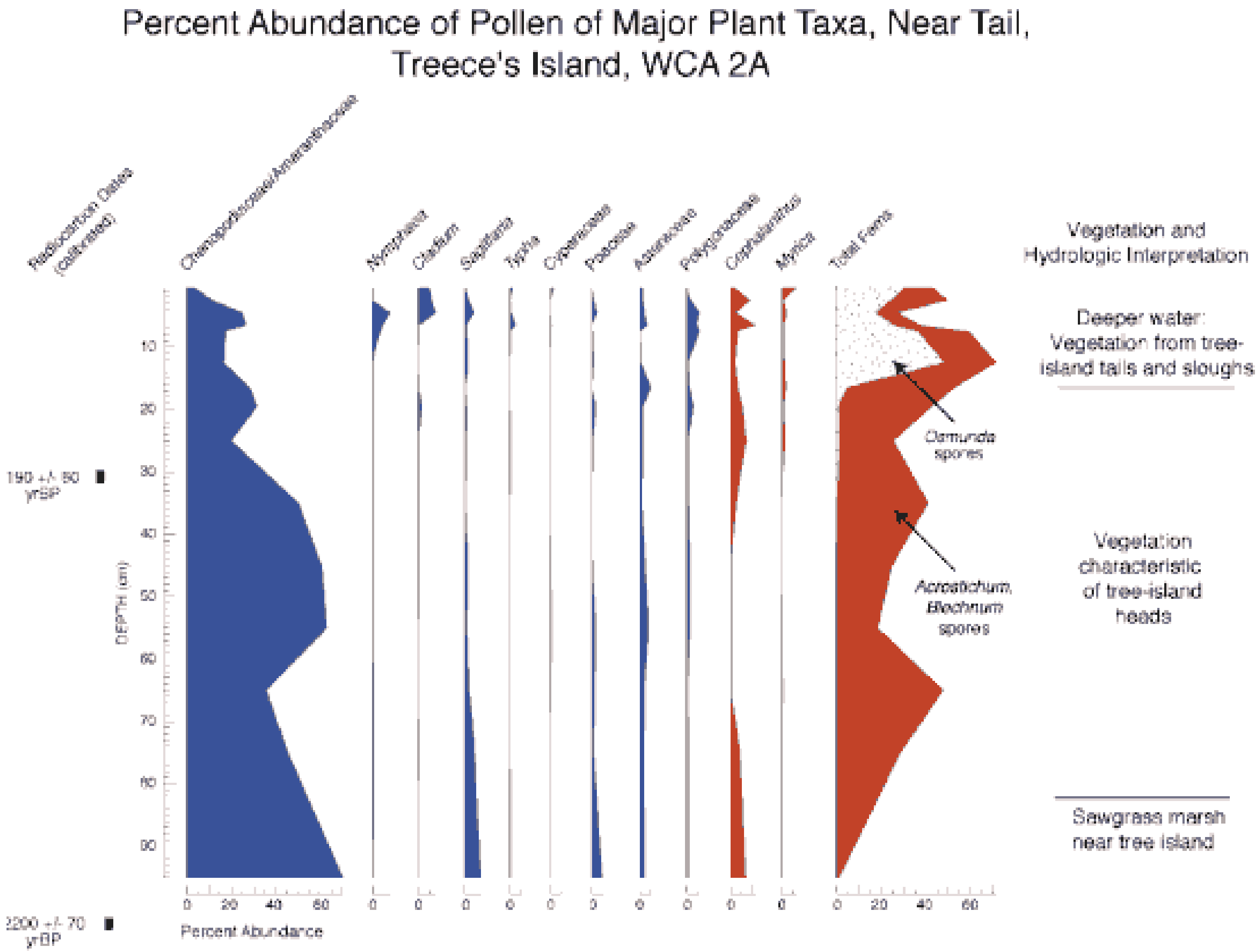
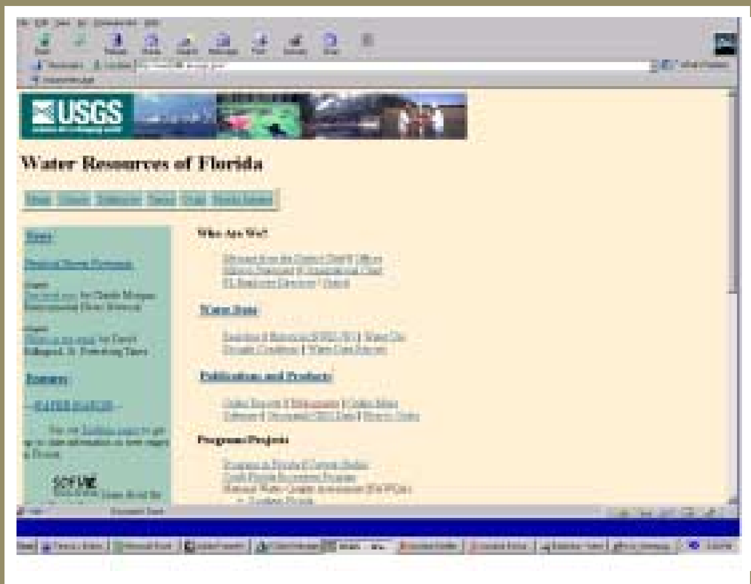


Figure 3. Percent abundance of pollen of major plant taxa in core from head of Treece's Island, Water Conservation Area 2A.

Hydrology, Vegetation, and Climate Change in the Southern Everglades During the Holocene

By Marjorie Green Winkler, Patricia R. Sanford, and Samantha W. Kaplan
University of Wisconsin, Madison, Wisconsin

Paleoecological study of 17 Accelerated Mass Spectrometer (AMS)-dated sediment cores from the southern Everglades provides evidence of a shifting mosaic of biotic communities in the past analogous to those present on the Everglades landscape today. Results also indicate initiation of Everglades peatlands at 5000 yr before present (B.P.), the importance of fire (from charcoal analysis) as a structuring agent in the tropical Everglades, and evidence of past plant communities (*Isoetes* marshes) not present in the modern landscape. Past vegetation changes are documented by pollen and sclereid changes. Past water level changes are documented by plant community changes, diatom species, habitat changes and by intervals of peat (wet) or marl (dry) deposition in the sediment cores. Marl deposition dominates today at these sites in the southern Everglades, a long-term trend exacerbated by human impacts. The Everglades may become less complex in the near future as decreased water levels result in decreased peat production. A rewatering plan must include both wet and dry seasonal cycles in order to preserve the shifting mosaic nature of the landscape and to maintain the Everglades as a functional habitat for both plants and animals.



Section IV

Information Systems

Contents

Section IV: Information Systems

Development of a Digital Bio/Geo-Library for the Greater Everglades Ecosystem

By Gail Clement[1] and Charles Boydstun[2]

[1]Southeast Environmental Research Center, Florida International University, Miami, Florida;
[2]U.S. Geological Survey, Florida Caribbean Science Center, Gainesville, Florida

To enable all stakeholders of the south Florida community to use *sound science as a basis for informed planning decisions and resolution/prevention of resource-management problems* (USGS Place-Based Studies Program, "Program Priorities", 1999), efforts to synthesize, manage and disseminate high-quality scientific information about the greater Everglades ecosystem have gained increasing support and urgency. The information systems project presented here addresses the need for timely, high-quality and relevant information through the development of a biologically- and geographically-referenced digital library for the greater Everglades. This digital library focuses on textual and multimedia scientific information concerned with water, minerals, biota, and land in the south Florida ecosystem. The digital services of the system include tools for searching, evaluation, visualization and acquisition of needed information resources from any Internet-connected computer. In combination, the collections and services of this digital library provide a comprehensive and coherent information system that facilitates the exchange, analysis and use of high-quality information resources across the diverse agencies, disciplines, and communities concerned with Everglades research, restoration and resource management.

The "digital library" approach encompassed in this project recognizes the importance of users' needs, skills, and concerns in designing and developing a large-scale information system. Modeled on the concept of a library—the institution most experienced in putting relevant, high-quality information into the hands of users—the digital library approach enhances users' abilities to identify, find, browse, and retrieve information by combining powerful information and publishing technologies with the convenience and ease of the Internet. Through the processes of selection, classification, indexing, and archiving, the digital library developed in this project provides coherent access to, and long-term preservation of, a comprehensive knowledgebase about the south Florida ecosystem – from field studies and records of the early 20th century to the latest results reported by scientists and managers today.

The design and architecture of this digital bio-geolibrary reflects the specific needs and issues relating to Everglades research and restoration. Digital collections are primarily place-based, referencing specific locations or regions within the greater Everglades by geographic coordinates or by place name. A large part of the collections are also biotic, referencing specific plant or animal species, habitats, or the biotic and abiotic factors impacting their survival or eradication. Ensuring access to these collections based on their geographic and biotic (in addition to the more 'traditional' attributes of topic or author) is a key design feature of digital library development in this project.

The design and architecture of the system is based on sound information standards and practices, including the application of extended Markup Language (XML) for structured text files; the Federal Geographic Data Committee (FGDC) /National Biological Information Infrastructure Content Standard for descriptive metadata; and the Integrated Taxonomic Information System (ITIS) for taxonomic nomenclature. Best practices from existing digital libraries such as the Alexandria Digital Library Project at the University of Santa Barbara; the Florida State University System's Digital Library; and the Florida Data Directory's Automated Library System maintained by the Florida Geographic Board provide proven methodologies for describing content and digital objects. Adherence to standards will ensure that the digital library is extensible, enduring, secure, and interoperable with related information systems maintained by other agencies.

The digital bio/geo-library for the greater Everglades ecosystem comprises four principal elements, tiered as follows:

Repository.—The foundation of the digital library is the repository, providing storage of the digital objects and associated metadata files. Services for loading and storing files, generating derivative versions for browsing and access, and digital archiving and back-up are also provided in the Repository. Delivery of files into the Repository is designed to occur through two possible events: either by direct loading by project personnel, using secure file transfer procedures, or by disposition of digital files as a final step in an electronic publishing process. The latter process is being developed as an enhancement to agency document management and media asset systems, in cooperation with the USGS Domino Development Team.

Applications and Services.—The applications operating in the "middle tier" of the digital library system include services in support of information retrieval, including indexing of text files, parsing and indexing of metadata records; on-the-fly conversion of digital objects for on-demand Web viewing or publishing; and tools for displaying and visualizing items retrieved from the repository.

In support of effective indexing and metadata services of the digital library, two specialized tools are being developed in this project to facilitate retrieval in a biotic/place-based context. The *South Florida Ecosystem Thesaurus* provides a set of keywords and phrases used to describe digital items on the supply side, and to search for information resources on the user side (fig. 1). The *South Florida Ecosystem Gazetteer,* a geospatial dictionary of geographic names, includes entries for place name; location (coordinates representing a point, line, or other footprint); and feature type (selected from a controlled list of categories for places/features) (fig. 2). Each of these tools will be incorporated into the digital library system for use both by humans (information providers and online searchers), and by machines (in automated query processing, indexing and searching).

Access Services/Interface.—Given the broadly defined user base with diverse needs, interests, and skills, it is recognized that the digital library must provide multiple views of the same information from various perspectives. A user friendly interface is being designed to allow searches by geographical location (coordinates or place name); by subject theme or time period; and by taxonomic classification. Due to the fuzziness and varying scale of some geospatial footprints, geographic querying needs to support spatial relationships such as intersection, containment, boundary, adjacency, and proximity. Biotic searches need to support queries by scientific or common names. Several "browse" views of the digital library contents, including a hierarchical subject tree and a clickable map showing the geographic extent of the collections, will also be provided in the user interface.

User Support.—The library model of information services provides significant support for users, including online help; electronic reference service; training; and assessment and feedback by users. There is certain to be a need for such user support in a digital library, particularly using the biologically and geographically referenced services under development in this project. Project planning includes a future phase focusing on the design of a user support program for the digital library.

Early prototypes from this project demonstrate the power and ease of using a digital library to identify, evaluate, and retrieve information resources on demand, from the convenience of one's own desktop. A test set of over 4000 records is already available through the *Everglades Online* database (fig. 3). Initial collections include materials from Florida International University, the University of Miami, the Historical Museum of South Florida, Everglades National Park, the USGS Florida Caribbean Science Center, and the USGS South Florida Place-Based Program.

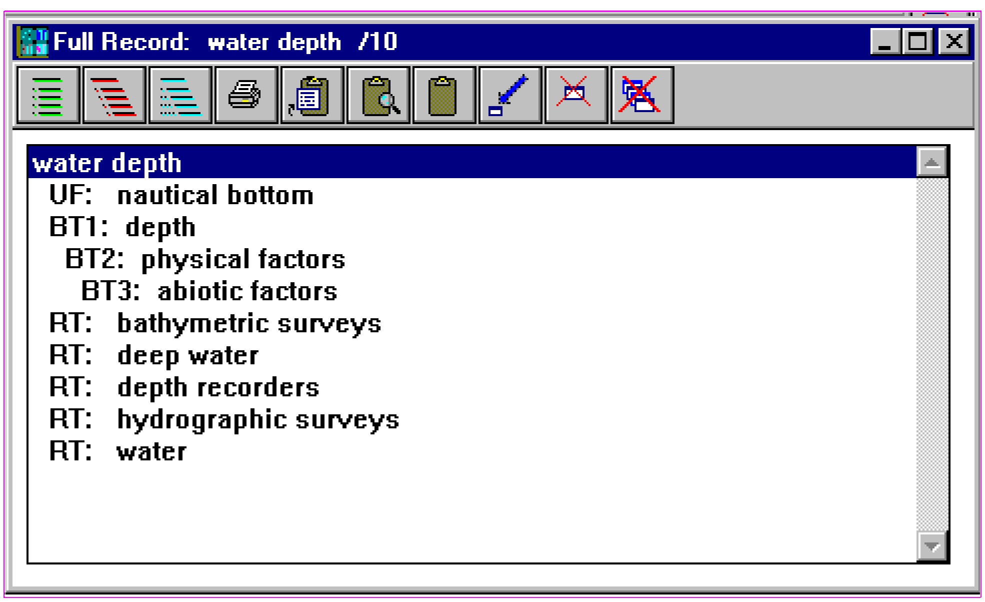


Figure 1. Sample entry from the South Florida Ecosystem Thesaurus, showing the preferred term and its relation to synonymous (nonpreferred) and related terms.

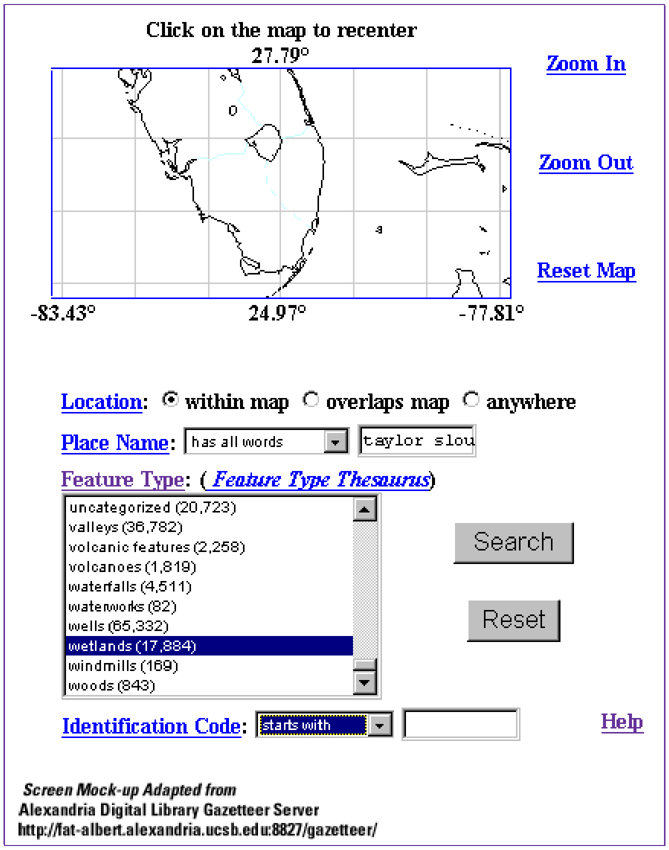


Figure 2. Sample search screen from the *South Florida Ecosystem Gazetteer*, showing capability of searching by placename, feature type, and geographic location.

Figure 3. Sample screen from *Everglades Online* database, showing existing search capabilities by author, title, keyword and subject. Enhancements to the interface enabling searches by geographic and biotic attributes are under development.

The Web Pages of the Tides and Inflows in the Mangroves of the Everglades (TIME) Project

By Michael P. Duff and Harry L. Jenter

U.S. Geological Survey, Reston, Virginia

The Tides and Inflows in the Mangroves of the Everglades (TIME) project of the U.S. Geological Survey (USGS) South Florida Place-Based Studies Program is a joint research endeavor to investigate the interacting effects of freshwater inflows and tides in and along the mangrove ecotone of south Florida. This effort is being accomplished through the use of coupled, numerical, surface-water and ground water flow models of the region. The investigation is facilitated, in part, by the TIME web site, http://time.er.usgs.gov.

The primary purposes of the TIME web site are: (1) to provide project scientists ready access to all data required as input to the models; (2) to provide project scientists with an efficient mechanism for sharing data, model output and other information; and (3) to disseminate project findings to other interested researchers. The TIME web site is organized into several sections, including "TIME Data" for sharing data, "What's New?" for displaying timely results, and "Scientific Links" for directing users to additional sites of scientific interest in south Florida. Each of these sections can be viewed by selecting an appropriate link on the main TIME web page.

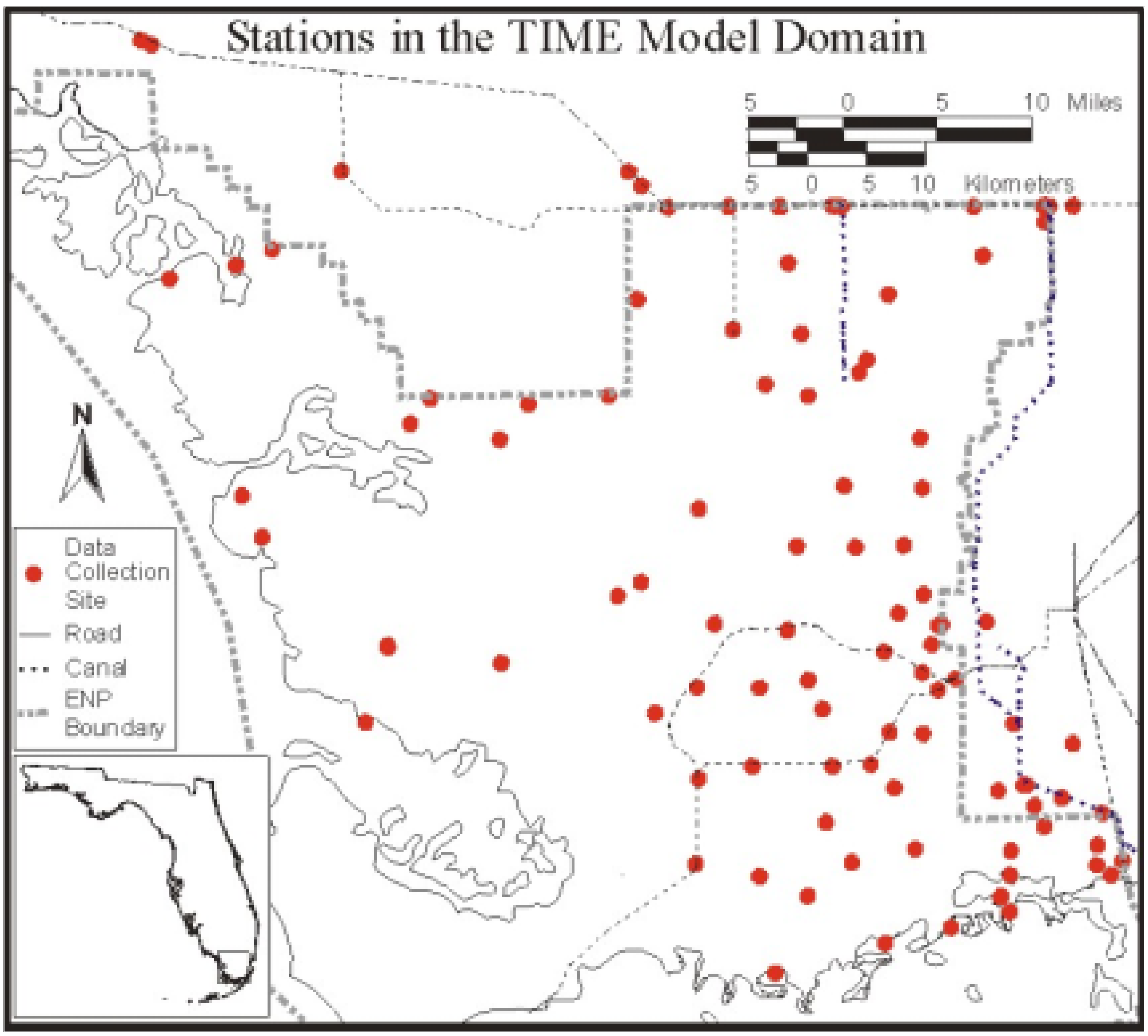


Figure 1. Map indicating location of each station within the TIME Data database.

Data from more than 100 gaging stations in the TIME modeling domain can be viewed and downloaded from the "TIME Data" web pages (fig. 1). The user may choose to: (1) view and/or download data from an individual station for a user-specified time period (fig. 2); (2) download data from multiple stations for a user-specified time period; (3) view a map of the previous day's rainfall throughout the TIME domain; (4) view a map of the relative water-level change over the last week at stations throughout the TIME domain; or (5) view a map of measured winds throughout the TIME domain for a user-specified date. Each of these views or downloads can be obtained by selecting a link on the main TIME data page or by selecting a station on a map of the TIME domain in the case of viewing and/or downloading data from an individual station for a user-specified time period.

The TIME Data database is designed to store all data that is available for a gaging station during the time period January 1, 1995 to present. Data frequencies are typically hourly, but the database can, and does, store data at other frequencies as well. A majority of the stations' data are updated daily.

The TIME Data system is designed to store time series of scalar variables. At present, these include stage, rainfall, discharge, salinity, conductivity, wind speed, and wind direction. However, there is no practical limit to the number of different types of time series data that the data system can accommodate, and more types are planned.

Data in the TIME Data system are collected by the USGS, the National Park Service, the U.S. Army Corps of Engineers, the National Oceanic and Atmospheric Administration, and the South Florida Water Management District. Information regarding a data point's source, and any disclaimer provided by the source, is stored with each data point in the system.

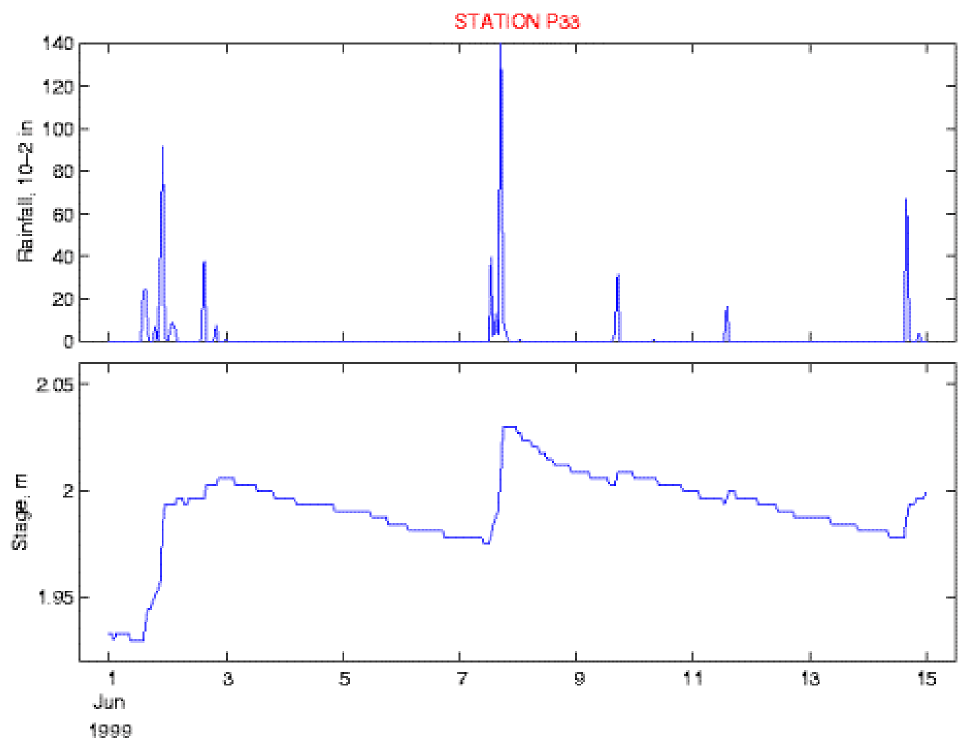


Figure 2. Plot of rainfall and stage collected at one station within the TIME Data database for a user-specified time period.

South Florida Information Access (SOFIA) Website

By Heather S. Henkel
U.S. Geological Survey, St. Petersburg, Florida

South Florida is one of several study areas within the United States Geological Survey's Place-Based Studies (PBS) Program. This program was established to provide scientific assistance to resource managers and policy makers, who require an improved scientific information base to resolve or avert complex resource conflicts or environmental problems. The information is designed to have a direct, significant, and immediate impact on management and policy decisions.

The South Florida Information Access (SOFIA) website (fig. 1), which is part of the PBS program, was created as a "one-stop-shopping" access point for scientific research information in south Florida. The site was designed around the research projects within the program. Each project on the SOFIA site addresses a specific problem or issue in south Florida. Every project in the program is online at this site, complete with project publications, abstracts of conference presentations, contact information, and links to online project data that are stored on the associated data exchange pages and on the data base website. But the site is not merely a centralized warehouse of material for the research community.

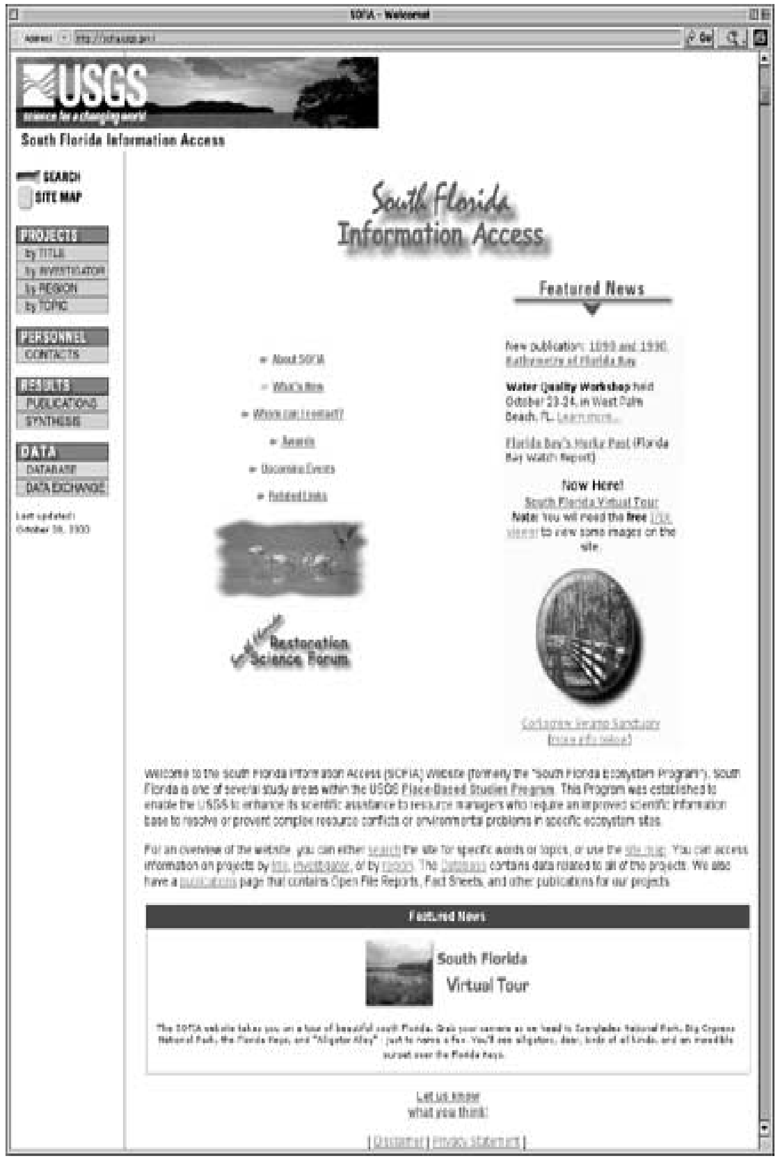


Figure 1. SOFIA website, http://sofia.usgs.gov/.

The SOFIA website was designed to be accessible to all visitors and usable by anyone. We provide contextual navigation at the top of every page, which shows the user exactly where they are within the site. This not only clues the visitor in to where they are, but it also allows them to move up through as many levels within that section as they would like. Each individual project page contains the same set of links - proposals, abstracts, data, metadata, publications, biographies, and related links - which gives the visitor access to each section of that project (fig. 2). The visitor can immediately see what information is available for that specific project. The website also has a fully functional search engine that allows visitors to search the entire site for specific information. In addition, this site also has a text-based site map, which allows the visitor to view the entire site at a glance. We also provide contacts for various parts of the SOFIA program. Should a visitor have a question or comment about any aspect of the site, this page provides direct access to the right person.

SOFIA is also the host website for the South Florida Restoration Science Forum (Forum) held in May 1999 (fig. 3). The Forum website highlights the powerful connection between science and management decisions in restoration efforts. This site affords a unique opportunity for everyone to see highlights of the most significant restoration science and management efforts underway. Hundreds of scientists from numerous organizations have prepared over 500 posters and exhibits to show the strength of the science that is being done to aid science-based decisions in managing the restoration effort. This website houses over 400 pages (including online versions of the posters that were presented at the forum) and audio and video clips of presentations. This site is organized into 10 topics, such as coastal ecosystems, nutrients, wildlife and wetland ecology, and hydrology.

There are several future directions for the SOFIA website. In addition to adding new scientific information daily, we more educational materials will be added to the site. Part of this initiative will include working with the students at Forest Hill High School in West Palm Beach, Florida. The USGS has helped install a state-of-the-art weather station on the Forest Hill campus that students collect meteorological and groundwater data. The students of Forest Hill will use these data to help forecast weather and will publish their findings in the school newspaper. The SOFIA web site staff will also collaborate with the school to help develop a similar web site for their project. An interactive tour of the SOFIA site is also planned which will allow visitors to experience the sights and sounds of the south Florida ecosystem. This tour will also highlight USGS research projects in the south Florida region, including the Everglades and the Florida Keys.

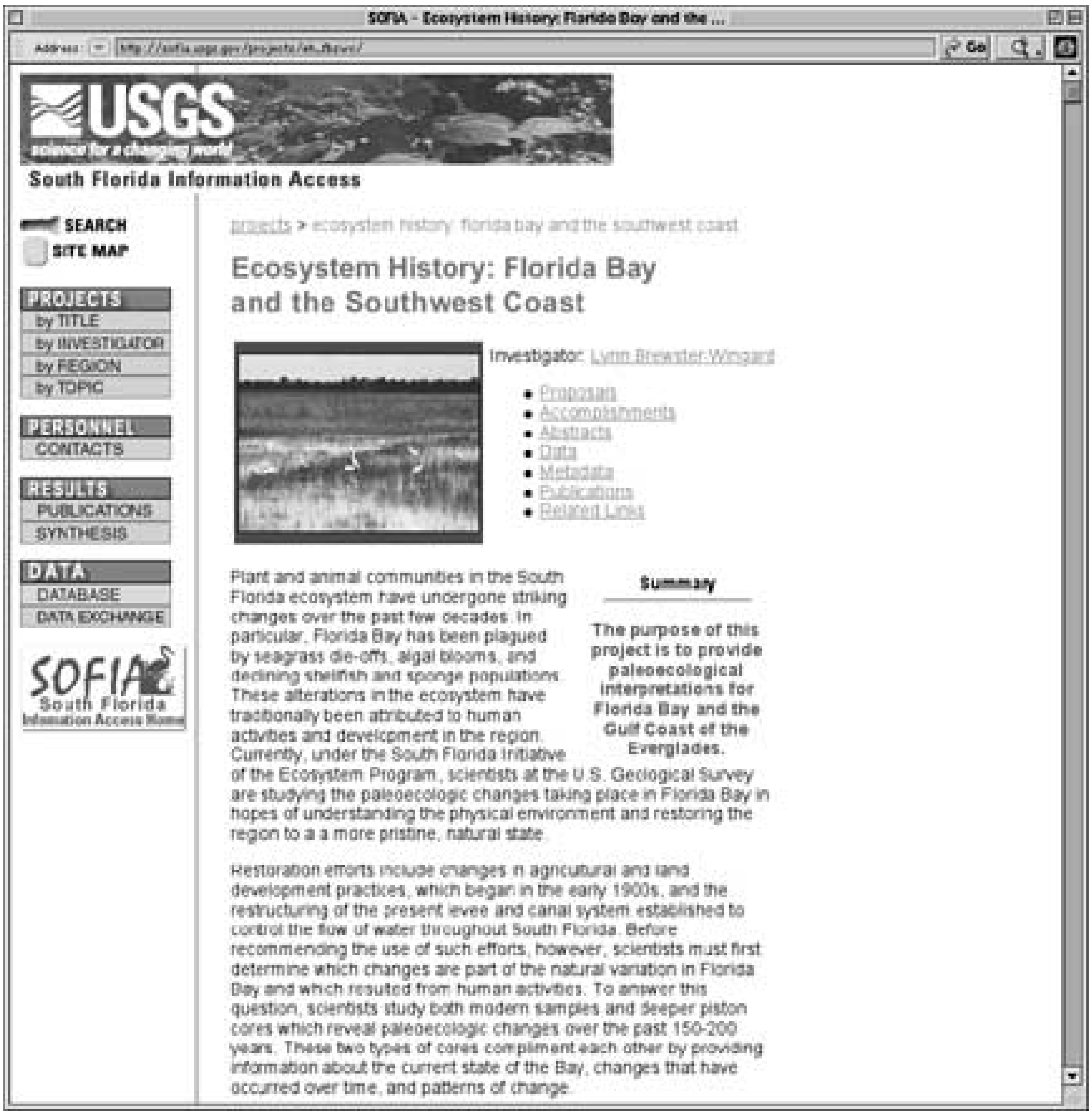


Figure 2. Example project page on SOFIA.

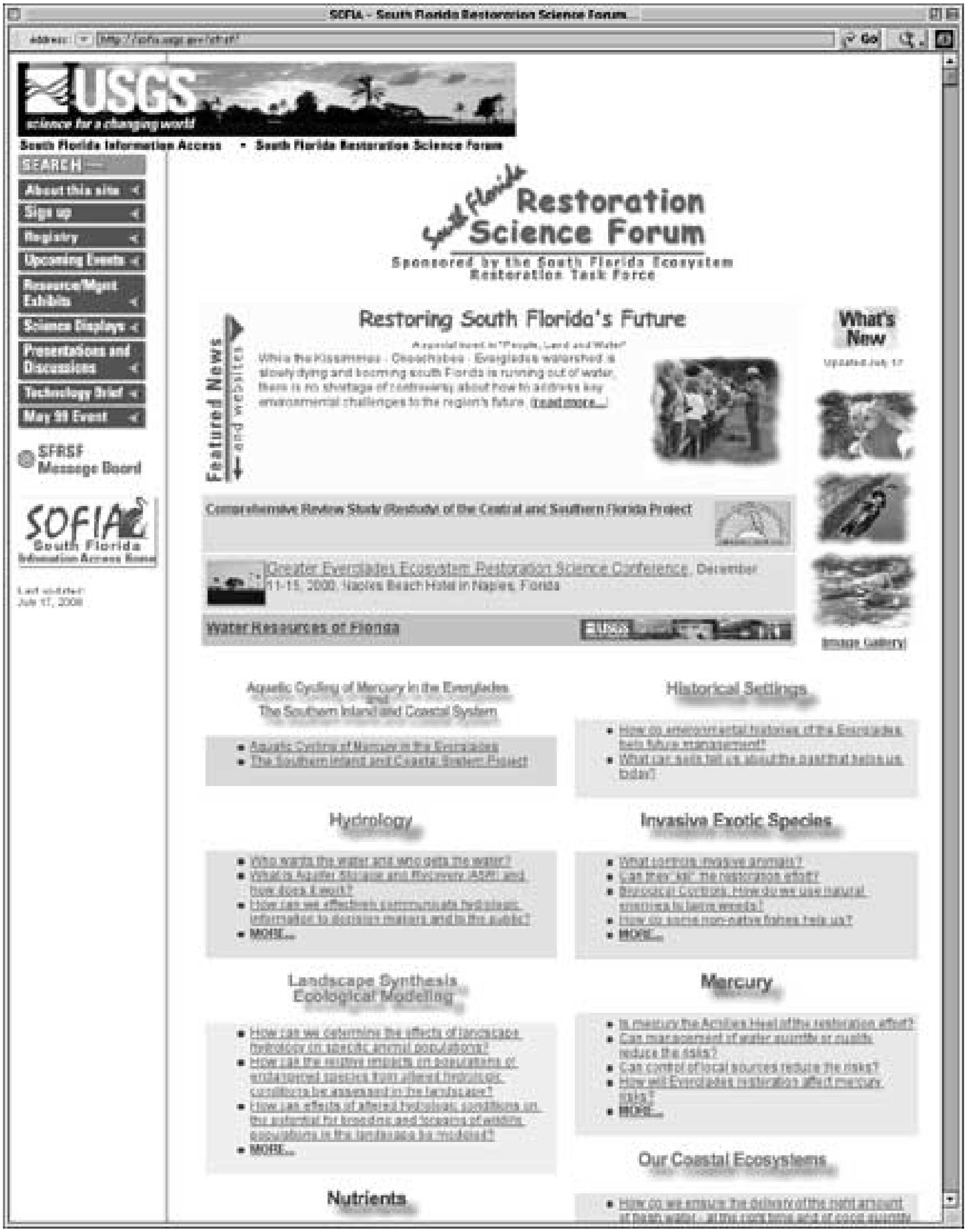


Figure 3: South Florida Restoration Science Forum website, http://sofia.usgs.gov/sfrsf/.

Development of an Internet Based GIS to Visualize ATLSS Datasets for Resource Managers

By James Johnston, Antonio Martucci, and Steve Hartley
National Wetland Research Center, Lafayette, Louisiana

This is an ESRI-ArcView project that has been customized with a graphical user interface (GUI) and which has sufficient functionality to become a spatial query and visualization tool for Across Trophic Level Systems Simulation (ATLSS) generated output data (fig. 1).

The overall goal is to provide an easy-to-use tool capable to access the vast amounts of data produced by the ATLSS models. The system allows users to display and integrate spatial and non-spatial information from different sources; interactively extract statistics for user-specified areas; produce outputs in form of maps, charts, tables, and reports.

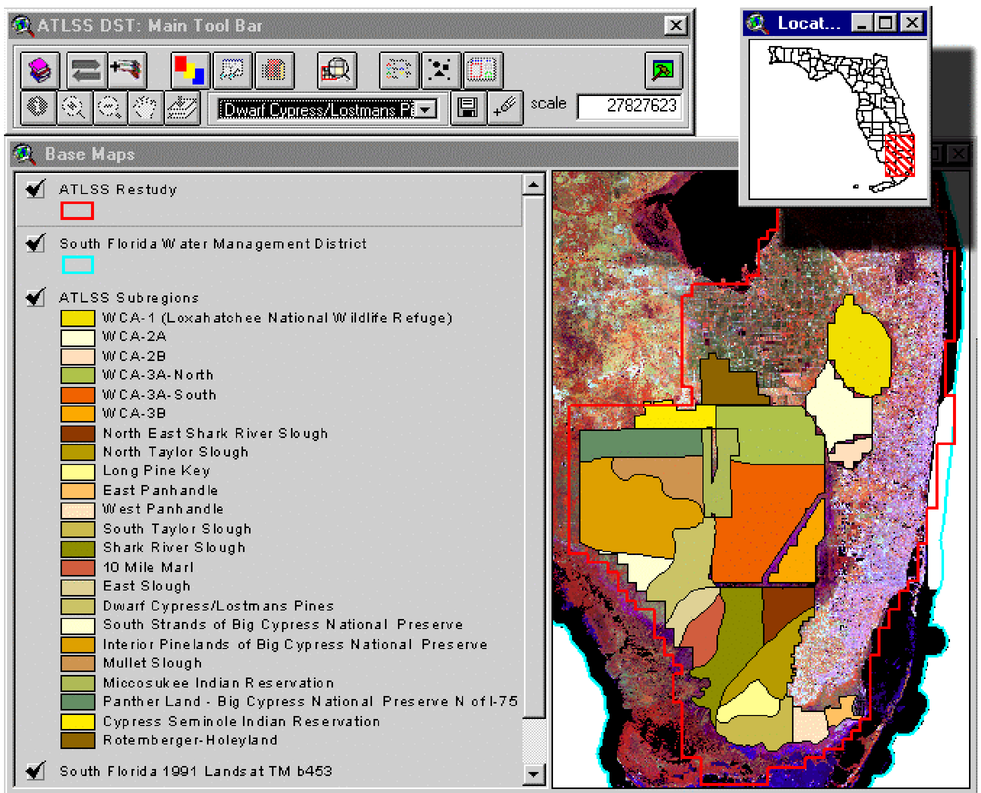


Figure 1. Base map depicting study area.

Model descriptions are any time available at any time (fig. 2) for the user by simply selecting the species from the list of pictures, and clicking the button(s) (FCI in fig. 2) available on the lower part of the window.

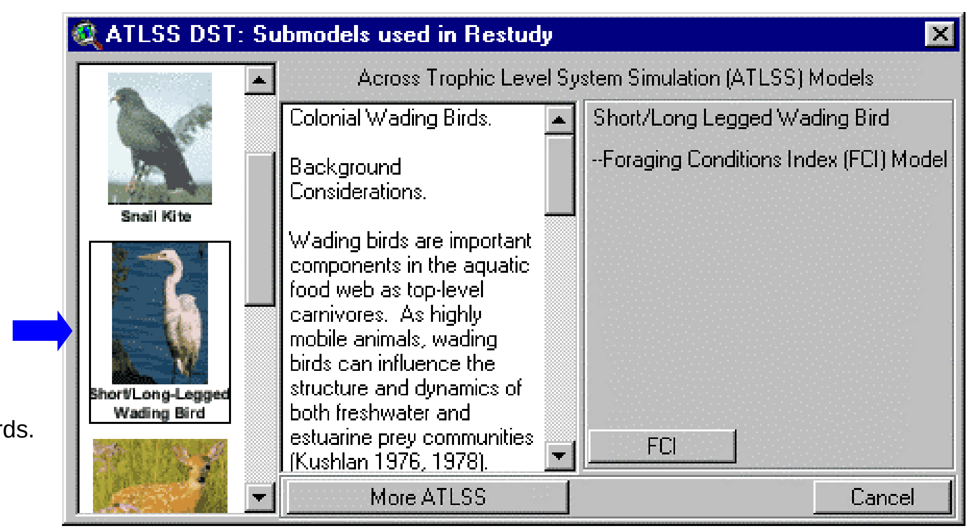
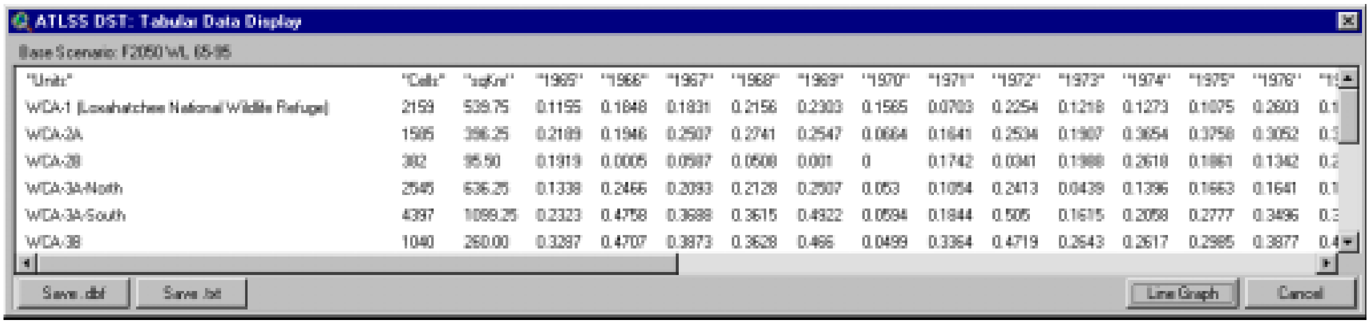


Figure 2. Example of submodel for wading birds.

ATLSS model output data can be compared by selecting the species of interest, two available hydrologic scenarios and time interval (continuous or discontinuous range of years). The result is a set of three comparison maps (CM) that can be subject to further investigations like displaying summarized index values by areas for each year (fig. 3).


ATLSS DST: Tabular Data Display

Base Scenario: F2050 WL 65-95

"Units"	"Cells"	"sqKm"	"1965"	"1966"	"1967"	"1968"	"1969"	"1970"	"1971"	"1972"	"1973"	"1974"	"1975"	"1976"	"1
WCA-1 (Loxahatchee National Wildlife Refuge)	2159	539.75	0.1155	0.1848	0.1831	0.2156	0.2303	0.1565	0.0703	0.2254	0.1218	0.1273	0.1075	0.2603	0.1
WCA-2A	1585	396.25	0.2189	0.1946	0.2507	0.2741	0.2547	0.0664	0.1641	0.2534	0.1907	0.3654	0.3758	0.3052	0.3
WCA-2B	382	95.50	0.1919	0.0005	0.0587	0.0508	0.001	0	0.1742	0.0341	0.1988	0.2618	0.1861	0.1342	0.2
WCA-3A-North	2545	636.25	0.1338	0.2466	0.2093	0.2128	0.2507	0.053	0.1054	0.2413	0.0439	0.1396	0.1663	0.1641	0.1
WCA-3A-South	4397	1099.25	0.2323	0.4758	0.3688	0.3615	0.4922	0.0594	0.1844	0.505	0.1615	0.2058	0.2777	0.3496	0.3
WCA-3B	1040	260.00	0.3287	0.4707	0.3873	0.3628	0.466	0.0499	0.3364	0.4719	0.2643	0.2617	0.2985	0.3877	0.4

Save .dbf | Save .txt | Line Graph | Cancel

Figure 3. Summary of index values for areas by year.

Line graphs can also be generated from this information (fig. 4). Frequency histograms can also be generated for user specified spatial boundaries (fig. 5). The user can easily change the visual representation of the comparison maps (color scheme and classes of index values. The user can also add graphics (boundary and labels for a better representaiton of the analyzed area. Figure 6 shows an example of a user-defined lable and graphic boundary. One of the available outputs is a quick print layout containing the comparison maps and general information about the data and the analysis.

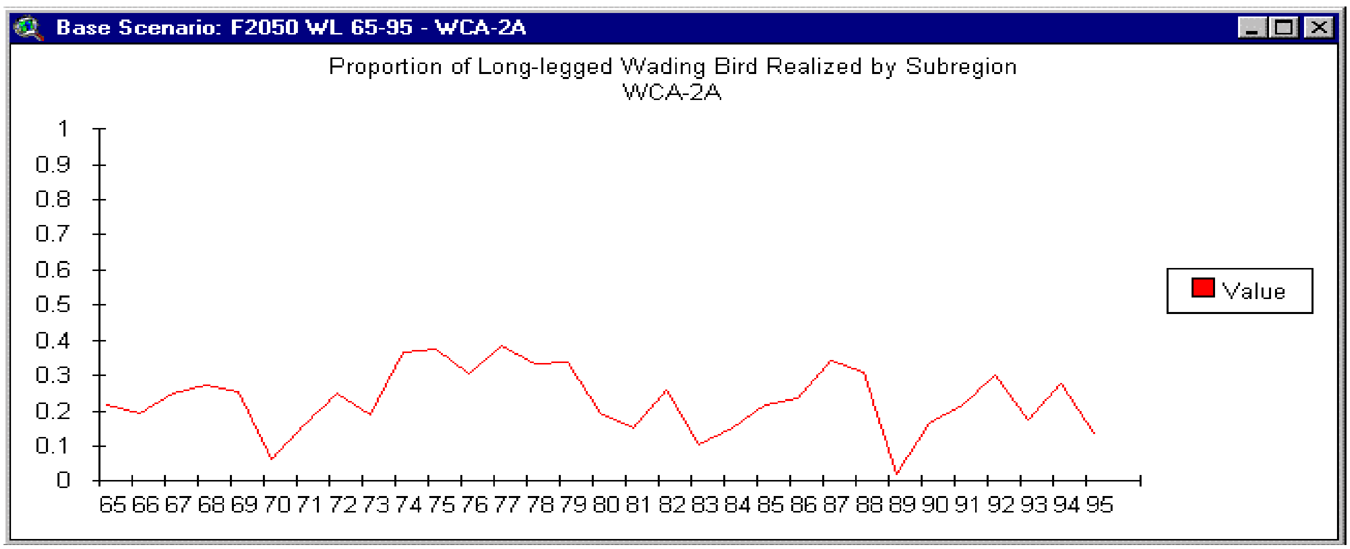


Figure 4. Proportion of long-legged wading birds in subregion WCA-2A.

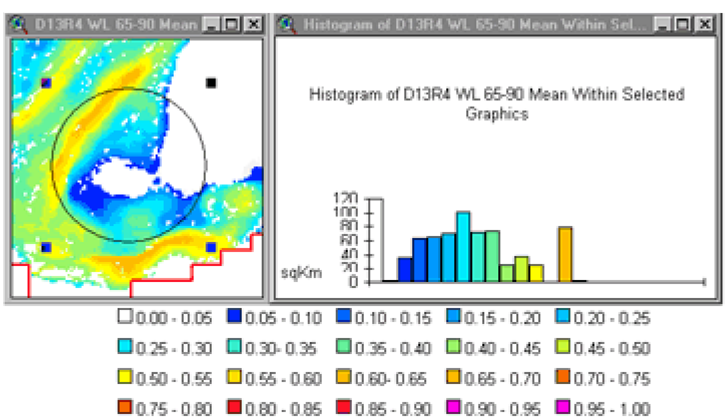


Figure 5. Frequency histogram for user specified boundary.

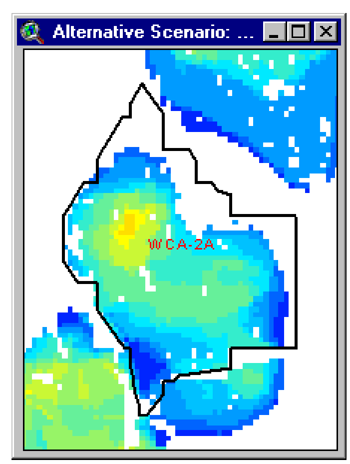


Figure 6. Example of a user-defined label and graphic boundary.

South Florida Ecosystem Data-Base Access

By Roy S. Sonenshein
U.S. Geological Survey, Miami, Florida

The South Florida Ecosystem Restoration Program is an intergovernmental effort to restore, preserve, and protect the fragile ecosystems of south Florida. One goal of the restoration effort is to develop a firm scientific basis for resource decision-making. Information required for the decision-making process includes biologic, cartographic, geologic, and hydrologic data that relate to the ecosystems of the mainland of south Florida, Florida Bay, the Florida Keys, and the Florida Reef tract. Numerous Federal, State, and local agencies and other scientific organizations individually collect, analyze, and store data in separate data bases, making access to the information difficult.

The U.S. Geological Survey (USGS) has developed the South Florida Information Access (SOFIA) website and data base (http://sofia.usgs.gov) as a central location for storing, maintaining, and retrieving data, metadata, and geospatial introduction by referenced data sets produced by participating Federal, State, regional, and local agencies. All data being collected by the USGS as part of the south Florida Place-Based Studies (PBS) Program will be included in the data base, either in data tables or as related files. The data base currently holds information for 64 projects, 53 stations, and more than 3 million data values for 48 environmental parameters. This is a dynamic data base with new projects and data added daily.

The PBS data base is online and available through the SOFIA public web site or directly at URL http://www.envirobase.usgs.gov. The web-based interface allows direct query and retrieval of project information, data collected, findings, and summaries. Although most of the data is stored in the data base, the interface also provides access to the project information found on the main SOFIA website and to USGS data stored in other data bases. Project information can be retrieved by title, geographic area, principal investigator, investigating agency, or ecosystem topic (fig. 1). Data are retrieved through a multistep process such as by data type (fig. 2), station name, county, parameter, or collecting agency (fig. 3). The data are output as text files, along with a base map with the designated station locations. Users can register on the site to receive updates when new information becomes available.

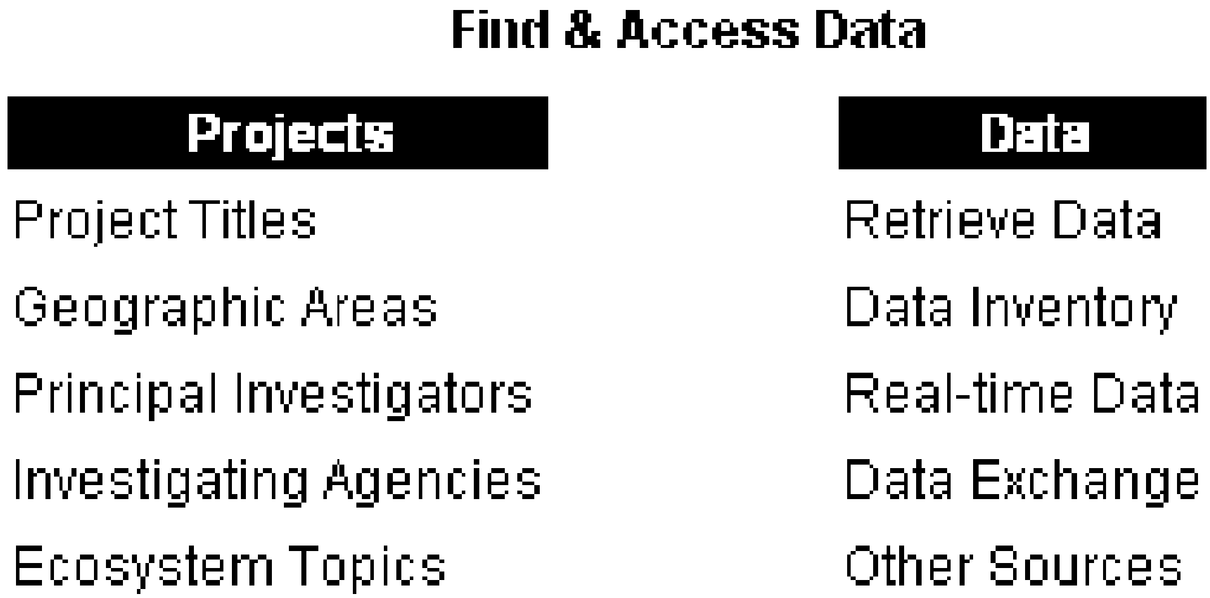


Figure 1. Retrieval of project and data from the SOFIA data-base website.

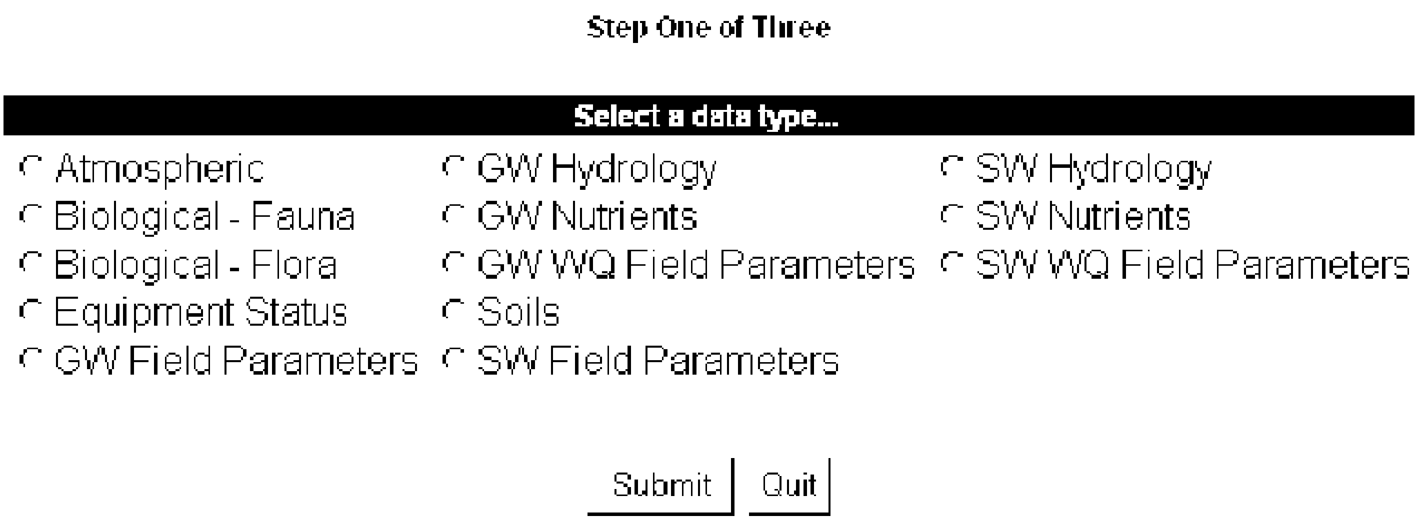


Figure 2. Menu for selection of data type for retrieval from the SOFIA data-base website.

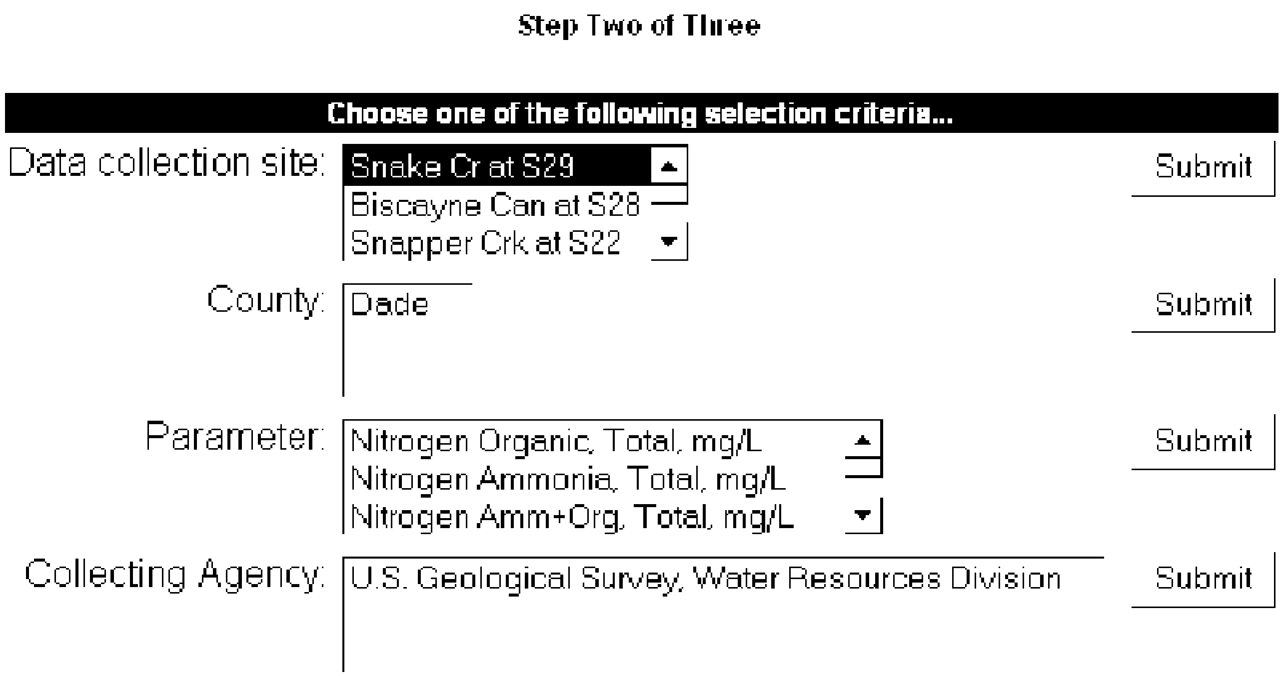
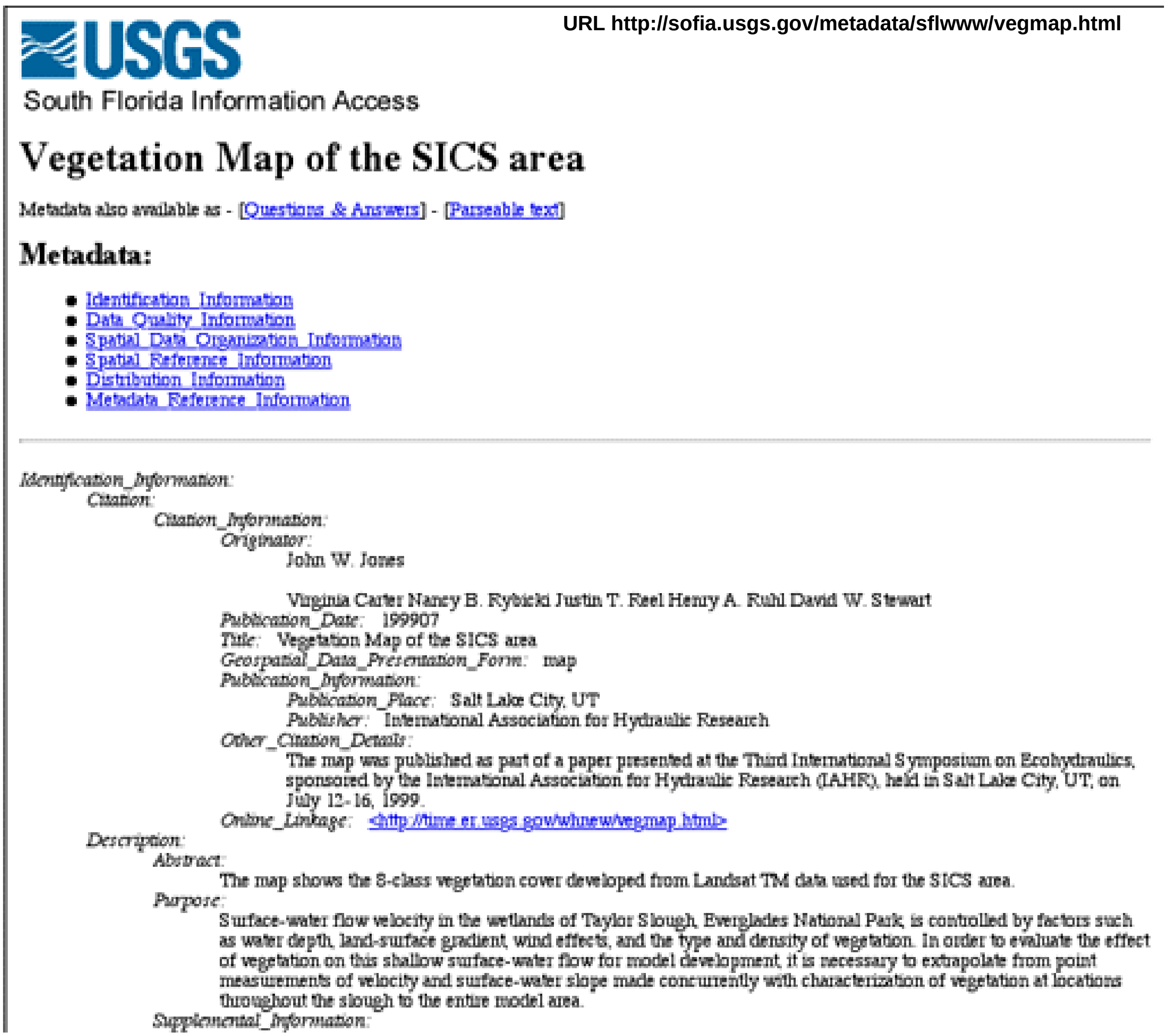


Figure 3. Menu for selection of criteria for retrieval from the SOFIA data-base website.

South Florida Information Access (SOFIA) Metadata

By Jo Anne Stapleton
U.S. Geological Survey, Reston, Virginia

The south Florida ecosystem, encompassing Everglades National Park, urban areas on the coast, intensely developed agricultural areas, rangelands, and wetlands, has been altered greatly during the last 100 years. Resource managers within Federal, State, and local agencies and other groups are seeking to reverse environmentally damaging actions of the past. The U.S. Geological Survey (USGS) began a research program in support of the restoration of the Everglades and south Florida ecosystem in 1995. USGS scientists have been conducting research projects designed to provide sound scientific information on which resource managers can base their decisions. The USGS also has recognized the


URL http://sofia.usgs.gov/metadata/sflwww/vegmap.html

South Florida Information Access

Vegetation Map of the SICS area

Metadata also available as - [Questions & Answers] - [Parseable text]

Metadata:

- Identification_Information
- Data_Quality_Information
- Spatial_Data_Organization_Information
- Spatial_Reference_Information
- Distribution_Information
- Metadata_Reference_Information

Identification_Information:
Citation:
Citation_Information:
Originator: John W. Jones

Virginia Carter Nancy B. Rybicki Justin T. Reel Henry A. Ruhl David W. Stewart
Publication_Date: 199907
Title: Vegetation Map of the SICS area
Geospatial_Data_Presentation_Form: map
Publication_Information:
Publication_Place: Salt Lake City, UT
Publisher: International Association for Hydraulic Research
Other_Citation_Details:
The map was published as part of a paper presented at the Third International Symposium on Ecohydraulics, sponsored by the International Association for Hydraulic Research (IAHR), held in Salt Lake City, UT, on July 12-16, 1999.
Online_Linkage: <http://time.er.usgs.gov/whnew/vegmap.html>
Description:
Abstract:
The map shows the 8-class vegetation cover developed from Landsat TM data used for the SICS area.
Purpose:
Surface-water flow velocity in the wetlands of Taylor Slough, Everglades National Park, is controlled by factors such as water depth, land-surface gradient, wind effects, and the type and density of vegetation. In order to evaluate the effect of vegetation on this shallow surface-water flow for model development, it is necessary to extrapolate from point measurements of velocity and surface-water slope made concurrently with characterization of vegetation at locations throughout the slough to the entire model area.
Supplemental_Information:

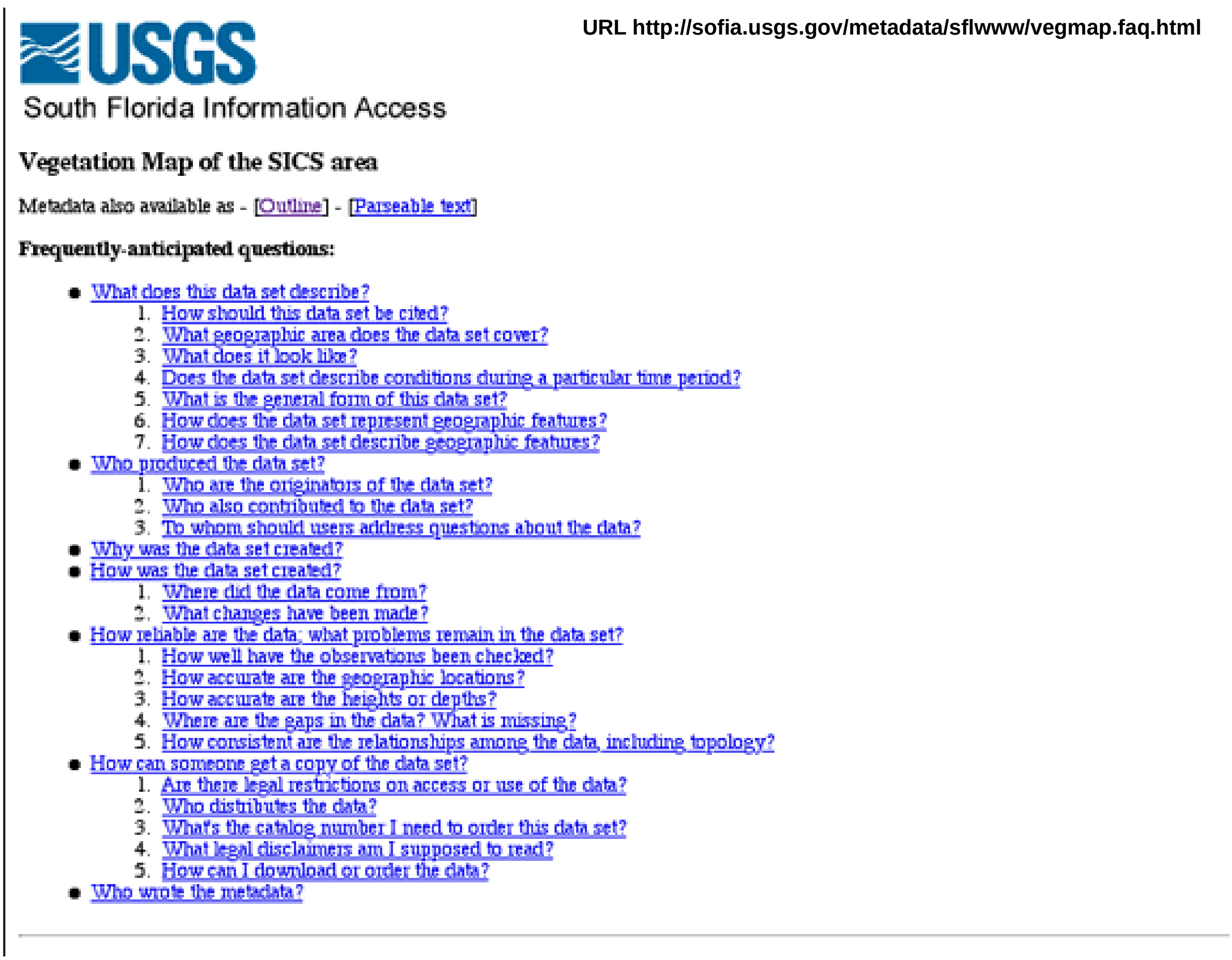
Figure 1. Sample of the outline format for FGDC metadata.

need for a central site to provide all interested parties with information from this research and access to the data. The south Florida Information Access website (SOFIA) was created as a "one-stop-shopping" access point for research on south Florida. All USGS South Florida Place-Based Studies (PBS) Program research projects, ranging from monitoring mercury contamination in the Everglades to investigating coral reef decline, are online at this site. The website provides project descriptions, publication references, data, presentations, and contact information, as well as general interest items, such as photographs and posters.

A primary goal of the USGS PBS Program is providing sound scientific data and synthesis of research results to aid managers in making responsible decisions regarding restoration of the Everglades and the ecosystems of south Florida. The next major effort is to make the research data and synthesis easily accessible to managers, scientists, and the public.

A tool for doing this is metadata. The Federal Geographic Data Committee (FGDC) developed a common set of definitions and terminology for geospatial data to be used for documenting the data and for searching to identify potentially useful data sets. Metadata provide information about the data, such as the name of the data set, the reason it was created, who created it, how accurate the data are, the physical location of the data on the ground, restrictions on using the data, and how to obtain the data.

The format for FGDC-compliant metadata is often confusing to generate and read unless the user is familiar with the document that gives the metadata element names and definitions. The most common format for FGDC metadata records is referred to as the outline form (fig. 1). It was designed for ease in searching on specific elements, such as


USGS

South Florida Information Access

URL http://sofia.usgs.gov/metadata/sflwww/vegmap.faq.html

Vegetation Map of the SICS area

Metadata also available as - [Outline] - [Parseable text]

Frequently-anticipated questions:

- What does this data set describe?
  1. How should this data set be cited?
  2. What geographic area does the data set cover?
  3. What does it look like?
  4. Does the data set describe conditions during a particular time period?
  5. What is the general form of this data set?
  6. How does the data set represent geographic features?
  7. How does the data set describe geographic features?
- Who produced the data set?
  1. Who are the originators of the data set?
  2. Who also contributed to the data set?
  3. To whom should users address questions about the data?
- Why was the data set created?
- How was the data set created?
  1. Where did the data come from?
  2. What changes have been made?
- How reliable are the data; what problems remain in the data set?
  1. How well have the observations been checked?
  2. How accurate are the geographic locations?
  3. How accurate are the heights or depths?
  4. Where are the gaps in the data? What is missing?
  5. How consistent are the relationships among the data, including topology?
- How can someone get a copy of the data set?
  1. Are there legal restrictions on access or use of the data?
  2. Who distributes the data?
  3. What's the catalog number I need to order this data set?
  4. What legal disclaimers am I supposed to read?
  5. How can I download or order the data?
- Who wrote the metadata?

Figure 2. Sample of the question part of the Question and Answer format for FGDC metadata.

geographic coordinates, places, topics, or even an individual project chief's name. Peter Schweitzer of the USGS has developed an alternate format to make the metadata more user friendly. This format is called Question and Answer and presents the metadata as a series of questions and responses to the questions. (Figure 2 shows the question part of the format, and figure 3 shows the answers with the questions.)

The metadata part of the SOFIA website documents current and previous research conducted by the USGS. Most of the projects have FGDC-compliant metadata, with the exception of some projects started in fiscal year 2000. Work is continuing on using FGDC-compliant metadata to document data sets available on the SOFIA Data Exchange pages. Eventually historical data sets will be included to allow time-series studies to be conducted. The collection of metadata for relevant data from other Federal, State, and local agencies is in progress. The metadata for projects and data sets will be updated as new information is obtained from project chiefs.

FGDC-compliant metadata records on the SOFIA site are in three formats – HTML, plain text, and the Question and Answer format. It is hoped that making metadata available in the latter, more readable format will encourage users to browse and discover what types of data are available through the SOFIA site.

Visit the SOFIA website at **http://sofia.usgs.gov/**. The outline form of the metadata is also available through the FGDC Clearinghouse (**http://clearinghouse1.fgdc.gov/FGDCgateway.html**) by searching on the South Florida Ecosystem Project database.

What does this data set describe?

Title: Vegetation Map of the SICS area
Abstract:
The map shows the 8-class vegetation cover developed from Landsat TM data used for the SICS area.
Supplemental_Information:
The SICS study area is located in the southeast quadrant of Everglades National Park (ENP). It encompasses the interface of the wetlands of the Taylor Slough and southern C-111 canal drainage basins with nearshore tidal embayments of Florida Bay. The study area is bounded on the east by U.S. Highway 1, and C-111 canal and levee; on the north and west by ENP Road (SR27) and Old Ingraham Highway; and on the south by Florida Bay.

1. **How should this data set be cited?**

   John W. Jones Virginia Carter Nancy B. Rybicki Justin T. Reel Henry A. Ruhl David W. Stewart, 199907, Vegetation Map of the SICS area: International Association for Hydraulic Research, Salt Lake City, UT.

   Online Links:
   - <http://time.er.usgs.gov/whnew/vegmap.html>

   Other_Citation_Details:
   The map was published as part of a paper presented at the Third International Symposium on Ecohydraulics, sponsored by the International Association for Hydraulic Research (IAHR), held in Salt Lake City, UT, on July 12-16, 1999.

2. **What geographic area does the data set cover?**

   West_Bounding_Coordinate: -81
   East_Bounding_Coordinate: -80.33
   North_Bounding_Coordinate: 25.5
   South_Bounding_Coordinate: 25

3. **What does it look like?**

4. **Does the data set describe conditions during a particular time period?**

   Beginning_Date: 1997
   Ending_Date: 1999
   Currentness_Reference: ground condition

5. **What is the general form of this data set?**

   Geospatial_Data_Presentation_Form: map

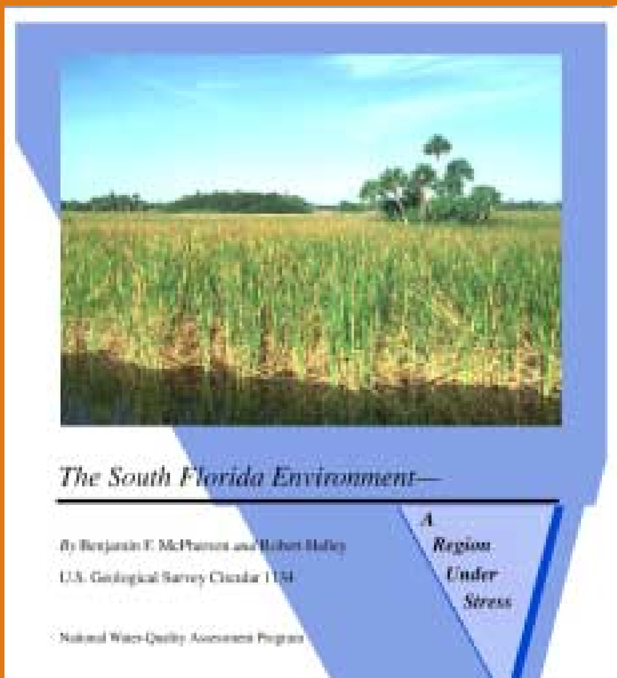
6. **How does the data set represent geographic features?**

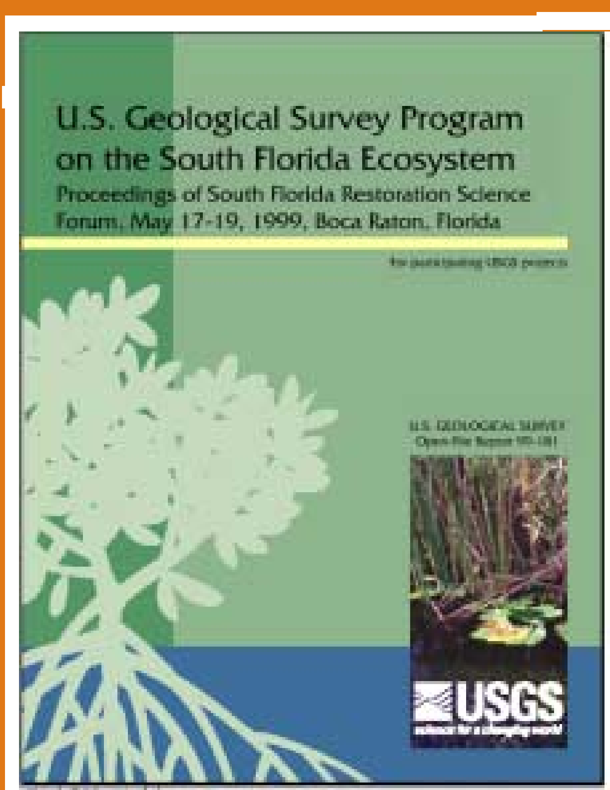
   a. **How are geographic features stored in the data set?**

      Indirect_Spatial_Reference: SICS area
      This is a Raster data set. It contains the following raster data types:
      - Dimensions, type Grid Cell

   b. **What coordinate system is used to represent geographic features?**

Figure 3. Sample of the answer parts of the Question and Answer format for metadata.





Section V

Bibliography

McPherson, B.F., Higer, A.L., Gerould, Sarah, and Kantrowitz, I.H., 1995, South Florida ecosystem program of the U.S. Geological Survey: U.S. Geological Survey Fact Sheet FS-134-95, 4 p.

McPherson, B.F., and La Rose, H.R., 1982, Algal conditions in the Caloosahatchee River (1975-79), Lake Okeechobee to Franklin Lock, Florida: U.S. Geological Survey Water-Resources Investigations 81-81, 28 p.

Contents

Section V: Bibliography

This bibliography contains selected products relevant to current and historic studies in south Florida published or in progress by the U.S. Geological Survey, State agencies, journals, and associations. An online bibliography of these entries and future publishings is available on the World Wide Web at:

http://sofia.usgs.gov

BIBLIOGRAPHY

Abercrombie, C.L., Howarter, S., Morea, C.R., Rice, K.G., and Perciva, H.F., in press, Thermoregulation of alligators *(Alligator mississippiensis)* in southern Florida: Journal of Thermal Biology.

Abercrombie, C.L., Rice, K.G., Brandt, L.A., Wilkinson, P., Hite, K.A., and Mazzotti, F.J., 2000, Clarifying the conundrum of crocodilian condition: Telling thick from thin: Poster presentation at the 15th Working Meeting of the Crocodile Specialist Group, IUCN, Varadero, Cuba.

Abercrombie, C.L., Rice, K.G., and Hope, C.A., 1999, The great alligator-caiman debate: Meditations on crocodilian life-history strategies: Proceedings of the Crocodilian Biology and Evolution Conference, Brisbane, Australia, 21 p.

Ackerman, B.B., S.D. Wright, R.K. Bonde, D.K. Odell, and D.J. Banowetz, 1995, Trends and patterns in mortality of manatees in Florida, 1974-1991, *in* O'Shea, T.J., Ackerman, B.B., and Percival, H.F., eds., Population Biology of the Florida Manatee *(Trichechus manatus latirostris):* U.S. Department of the Interior, National Biological Service, Information and Technology Report 1: p. 223-258

Adams, D.B., and Stoker, Y.E., 1985, Hydrology of Lake Placid and adjacent area, Highlands County, Florida: U.S. Geological Survey Water-Resources Investigations Report 84-4149, 1 sheet.

Aiken, G.R., Ravichandran, M., Reddy, M.M., and Ryan, J., 1999, Inhibition of precipitation of metacinnabar (Mercuric sulfide) by dissolved organic matter isolated from the Florida Everglades (abs.): Presented at the 1999 American Geophysical Union Spring Meeting, June 1-4, 1999, Boston, Mass.

Aiken, G.R., Ravichandran, M., Reddy, M.M., Ryan, J.N., and Tregellas, J., 1998, Interactions of dissolved organic carbon with mercury in the Everglades, Florida: American Chemical Society, Division of Environmental Chemistry: Preprints of extended abstracts, presented at the 216th ACS National Meeting, Boston, Mass., August 23-27, 1998, v. 38, no. 2, p. 76-78.

Aiken, G.R., and Reddy, M.M., 1996, Interactions of mercury with dissolved organic carbon in the Florida Everglades: U.S. Geological Survey Fact Sheet FS-186-96.

Aiken, G.R., and Reddy, M.M., 1997, Dissolved organic carbon in the Everglades, Florida, *in* Gerould, Sarah, and Higer, A.L., eds., U.S. Geological Survey Program on the South Florida Ecosystem—Proceedings of the Technical Symposium in Ft. Lauderdale, Florida, August 25-28, 1997: U.S. Geological Survey Open-File Report 97-385, p. 4.

Aiken, G.R., and Reddy, M.M., 1998, Dissolved organic carbon in the Everglades, Florida (abs.): Presented during the 1998 American Geophysical Union Spring Meeting, May 26-29, 1998, Boston, Mass.

Aiken, G.R., and Reddy, M.M., Mahalingam, R., and Ryan, J., 2000, Interactions between dissolved organic matter and mercury (abs.): Presented at the Refractory Organic Substances in the Environment Conference, August 1-3, 2000, University of Karlsruhe, Germany.

Aiken, G.R., Reddy, M.M., Tregellas, J., and Ravichandran, M., 1997, Dissolved Organic Carbon in the Everglades, Florida (abs.): Presented during the Symposium on Refractory Organic Substances in the Environment, October 6-8, 1997, University of Karlsruhe, Germany.

Allen, G.R., and Smith-Vaniz, W.F., 1994, Fishes of the Cocos (Keeling) Islands, Atoll Research Bulletin, 412:1-21.

Allen, J.A., Ewel, K.C., Keeland, B.D., Tara, T., and Smith, T.J., III, 2000, Downed wood in Micronesian mangrove forests. Wetlands, 20(1):169-176.

Allen, L.H., Jr. Sinclair, T.R., Bennett, J.M., 1997, Evapotranspiration of vegetation in Florida: Perpetuated misconceptions versus mechanistic processes, *in* Soil Crop Science Society Florida Proceedings: v. 56, p. 1-10.

Anders, R.B., and Heath, R.C., 1953, A brief report on the progress of the Manatee County, Florida, ground-water investigation: U.S. Geological Survey Open-File Report FL-53003.

Anderson, G.H., and others, 1999, Data Summary for the 1997 Water Year: Mangrove Hydrology Project: U.S. Geological Survey, Everglades Field Station.

Anderson, J.E., Desmond, G.B., Lemeshewsky, G.P., and Morgan, D.R., 1997, Reflectance calibrated digital multispectral video: A test bed for high spectral and spatial resolution remote sensing: PE&RS, v. 63, no. 3, p. 224-229.

Appel, C.A., 1973, Electrical-analog model study of a hydrologic system in southeast Florida: U.S. Geological Survey Open-File Report FL-73004, 51 p.

Appel, C.A., and Klein, Howard, 1969, Hydrogeologic data related to establishment of a pumping station in the Everglades National Park, Florida: U.S. Geological Survey Open-File Report FL-69010, 36 p.

Armbruster, J.T., 1972, Land use in the Big Cypress area, southern Florida: Tallahassee, Florida Bureau of Geology Map Series 50.

Asa, C.S., Read, B., Houston, E.W., Gross, T.S., Parfet, J., and Boever, W.J., 1993, Serum estradiol and progesterone levels during the ovulatory cycle and pregnancy in banteng *(Bos javanicus):* Theriogenology, v. 39, no. 6, p. 154-163, 1993.

Atkeson, T., Parks, P., Fink, L. and Drabbenhoft, D.P., 1997, The South Florida Mercury Science Program: Tallahassee, Florida Department of Environmental Protection Fact Sheet [unumbered], 4 p.

ATLSS, 2000, American Alligator Production Index Model: http://www.atlss.org/.

Avery, G.N., and Loope, L.L., 1980, Endemic taxa in the flora of south Florida: National Park Service, South Florida Research Center Report T-558.

Bales, J.D., Fulford, J.M., and Swain, Eric, 1996, Review and evaluation of a model for simulating the natural hydrology of south Florida: U.S. Geological Survey Fact Sheet FS-180-96.

Bales, J.D., Fulford, J.M., and Swain, E.D., 1997, Review of selected features of the natural system model, and suggestions for applications in south Florida: U.S. Geological Survey Water-Resources Investigations Report 97-4039, 42 p.

Ball, M.H., and Schaffranek, R.W., 2000, Flow-velocity data collected in the wetlands adjacent to canal C-111 in south Florida during 1997 and 1999: U.S. Geological Survey Open-File Report 00-56, 42 p.

Ball, M.H., and Schaffranek, R.W., 2000, Regional simulation of inundation patterns in the south Florida Everglades (abs.): Presented during the Greater Everglades Ecosystem Restoration Conference, Naples, Florida, December 11-15, 2000.

Ball, M.H., and Schaffranek, R.W., 2000, Water-surface elevation and water depth analysis using a GIS application, *in* Proceedings of the American Geophysical Union Spring Meeting, Washington, DC, May 30–June 3, 2000.

Barker, Michael, Bowman, Geronia, and Sutcliffe, Horace, Jr., 1981, Hydrogeologic data from test drilling near Verna Beach, Florida, 1978: U.S. Geological Survey Open-File Report 81-634, 26 p.

Barnett, J., Rice, K.G., Percival, H.F., and Cardeilhac, P.T., 1997, A method for the intramuscular implantation of transmitters in alligators: Proceedings of the International Association of Aquatic Animal Medicine, v. 28, p. 45-48.

Barr, B., 1997, Food habits of the American alligator, *alligator mississippiensis*, *in* the southern Everglades: University of Miami, Coral Gables, Florida, Ph.D. Dissertation.

Barr, G.L., 1996, Hydrogeology of the surficial and intermediate aquifer systems in Sarasota and adjacent counties, Florida: U.S. Geological Survey Water-Resources Investigations Report 96-4063, 81 p.

Basset, A.D., DeAngelis, D.L., and Diffendorfer, J.E, 1997, The effect of functional response on stability of a grazer population: Ecological Modeling, v. 101, p. 153-162.

Bates, A.L., Orem, W.H., Harvey, J.W., and Spiker, E.C., 1999, Sources of sulfate to the northern Everglades, Florida, USA: Nature, in review.

Bates, A.L., Orem, W.H., and Harvey, J.W., 1998, Tracing sources of sulfate in the northern Everglades using sulfur isotopic compositions (abs.), *in* American Geophysical Union Meeting, May 26-29, 1998, Boston., Massachusetts: EOS, Transactions of the American Geophysical Union, v. 79, no. 17, p. S93.

Bates, A.L., Orem, W.H., Harvey, J.W., and Spiker, E.C., 2001, Geochemistry of Sulfur in the Florida Everglades: 1994 through 1999. U.S. Geological Survey Open File Report 01-7. 54 p.

Bates, A.L., Spiker, E.C., and Holmes, C.W., 1998, Speciation and isotopic composition of sedimentary sulfur in the Everglades, Florida, USA: Chemical Geology, v. 146, p. 155-170.

Bauer, B.H., Etnier, D.A., and Burkhead, N.M., 1995, Etheostoma *(Ulocentra)* scotti *(osteichthys:percidae)*, a new darter from the Etowah River system in Georgia: Alabama Museum of Natural History Bulletin, v. 17, p. 1-16.

Bearden, H.W., 1972, Ground water in the Hallandale area, Florida: Tallahassee, Florida Bureau of Geology Information Circular 77, 32 p.

Bearden, H.W., 1973, Hydrologic data for 1971, Broward County, Florida: U.S. Geological Survey Open-File Report FL-73016, 87 p.

Bearden, H.W., 1974, Ground-water resources of the Hollywood area, Florida: Tallahassee, Florida Bureau of Geology Report of Investigations 77, 35 p.

Bearden, H.W., 1974, Hydrologic data for 1972, Broward County, Florida: U.S. Geological Survey Open-File Report FL-74005, 97 p.

Bearden, H.W., 1974, Hydrologic data for 1973, Broward County, Florida: U.S. Geological Survey Open-File Report FL-74028, 64 p.

Bearden, H.W., 1975, Hydrologic data for 1974, Broward County, Florida: U.S. Geological Survey Open-File Report FL-75006, 76 p.

Beaven, T.R., 1979, Hydrologic conditions in Broward County, Florida, 1976: U.S. Geological Survey Open-File Report 79-1258, 93 p.

Beaven, T.R., and McPherson, B.F., 1978, Quality of the water in borrow ponds near a major highway interchange, Dade County, Florida, October-November, 1977: U.S. Geological Survey Open-File Report 78-1029, 15 p.

Beaven, T.R., and Meyer, F.W., 1978, Record of wells in the Floridan aquifer in Dade and Monroe Counties, Florida: U.S. Geological Survey Open-File Report 78-881, 30 p.

Beck, C.A., 1994, Book Review of Marine Mammals Ashore: A Field Guide for Strandings, by Geraci, J.R, and Lounsbury, V.J., 1993, Texas A&M University Sea Grant Publication TAMU-SG-93-601: Journal of Wildlife Diseases 30(4).

Beck, C.A., and Barros, N.B., 1991,The impact of debris on the Florida manatee: Marine Pollution Bulletin 22(10):508-510.

Beck, C.A, and Reid, J.P., 1995, An automated photo-identification catalog for studies of the life history of the Florida manatee, *in* O'Shea, T.J., Ackerman, B.B., and Percival, H.F., eds., Population Biology of the Florida Manatee *(Trichechus manatus latirostris):* U.S. Department of the Interior, National Biological Service, Information and Technology Report 1, p. 120-134.

Belles, R.G., and Martin, E.H., 1985, Hydrology of Lake June in Winter, Highlands County, south-central Florida: U.S. Geological Survey Water-Resources Investigations Report 84-4303, 1 sheet.

Bennett, M.W., 1992, A three dimensional finite difference groundwater flow model of western Collier County, Florida: West Palm Beach, South Florida Water Management District, Technical Publication 92-04, 358 p.

Bennetts, R.E., Collopy, M.W., and Rodgers, J.A., Jr, 1994, The Snail Kite in the Florida Everglades: A food specialist in a changing environment, *in* Davis, S.M., and Ogden, J.C., eds., Everglades: The System and its Restoration: Delray Beach, Fla., St. Lucie Press, p. 507-532.

Bennetts, R.E., and Kitchens, W.M., in press, Population dynamics and conservation of snail kites in Florida: The importance of spatial and temporal scale: Colonial Waterbirds, v. 20, no. 2, p. 324-329.

Bennetts, R.E., Kitchens, W.M., and DeAngelis, D.L.,1998, Recovery of the snail kite in Florida: Beyond a reductionist paradigm: Transactions of the 63rd North American Wildlife and Natural Resources Conference: p. 486-501.

Benoit, J.M., Gilmour, C.C., Mason, R.P., and Heyes, A., 1999, Sulfide Controls on Mercury Speciation and Bioavailability to Methylating Bacteria in Sediment and Pore Waters: Environmental Science Technology, v. 33, p. 951-957.

Benoit, J.M., Mason, R.P., and Gilmour, C.C., 1999, Estimation of mercury-sulfide speciation and bioavailability in sediment pore waters using octanol-water partitioning: Environmental Toxicology & Chemistry, v. 18, p. 2138-2141.

Benson, M.A., and Gardner, R.A., 1974, The 1971 drought in south Florida and its effect on the hydrologic system: U.S. Geological Survey Water-Resources Investigations Report 12-74, 46 p.

Bevans, H.E., S.L.Goodbread, J. Miesner, S.A Watkins, T.S. Gross, N.D. Denslow and T Schoeb, 1996, The occurance of semivolatile organic compounds and assessments of carp endocrinology and histology in Las Vegas Wash and Las Vegas and Callville Bays of Lake Mead, Nevada: U.S. Geological Survey Water-Resources Investigations Report 96-4266, p. 1-12.

Bezdek, J.C., 1993, A review of probabilistic, fuzzy and neural models for pattern recognition: Journal of Intelligent and Fuzzy Systems, v. 1, no. 1, p. 1-25.

Bidlake, W.R., and Boetcher, P.F., 1997, Simulation of the soil water balance of an undeveloped prairie in west-central Florida: U.S. Geological Survey Water-Supply Paper 2472, 57 p.

Blaine, T.W, and D.L. DeAngelis, 1997, The interaction of spatial scale and predator-prey functional response: Ecological Modeling 95:319-328.

Blalock, H.N, 1999, Factors affecting juvenile and adult unionid community structure in the New River, Suwannee River System, Florida: Final report to the U.S. Fish and Wildlife Service, Jacksonville, Fla., 34 p.

Blalock, H.N, and J.J. Herod, 1999, A comparative study of stream habitat and substrate utilized by *Corbicula fluminea* in the New River, Florida: Florida Scientist 62(2):145-151.

Blalock, H.N., J.J. Herod, and R.S. Butler, 1999, Summary of a preliminary freshwater mollusk survey conducted within O'Leno State Park, Florida: Technical summary to Florida Department of Environmental Protection, Division of Recreation and Parks. 3 p.

Blalock, H.N., J.J. Herod, and J.D. Williams, 1998, Freshwater mussels *(Unionacea: Bivalvia)* of the Pea River Watershed of Alabama and Florida: Final report to U.S. Fish and Wildlife Service, Jacksonville, Fla., 61 p.

Blalock, H.N, and J.B. Sickel, 1996, Changes in mussel *(Bivalvia: Unionidae)* fauna within the Kentucky portion of Lake Barkley since impoundment of the lower Cumberland River: American Malacological Bulletin, 13(1-2):111-116.

Blalock-Herod, H.N. 2000, Community ecology of three freshwater mussel species *(Bivalvia: Unionidae)* from the New River, Suwannee Drainage, Florida: Gainesville, Unpublished Master's Thesis, University of Florida, 72 p.

Blalock-Herod, H.N., J.J. Herod, and J.D. Williams. 2000, Interim Report: Freshwater mussels of the Choctawhatchee River Drainage in Alabama and Florida. Report to U.S. Fish and Wildlife Service, Panama City, Fla.,. 60 p.

Bogan, A.E., Williams, J.D., and Fuller, S.L.H., 1990, Comments on the proposed conservation of *Proptera Rafinesque,* 1819 *(Mollusca, Bivalvia)*, Bulletin Zoological Nomenclature 47(3):206-207.

Boggess, D.H., 1968, Water-supply problems in southwest Florida: U.S. Geological Survey Open-File Report FL-68003, 27 p.

Boggess, D.H., 1970, A test of flushing procedures to control salt-water intrusion at the W.P. Franklin Dam near Ft. Myers, Florida: Tallahassee, Florida Bureau of Geology Information Circular 62, part 1, p. 1-15.

Boggess, D.H., 1970, The magnitude and extent of salt-water contamination in the Caloosahatchee River between La Belle and Olga, Florida: Tallahassee, Florida Bureau of Geology Information Circular 62, part 2, p. 17-39.

Boggess, D.H., 1972, Controlled discharge from the W.P. Franklin Dam as a means of flushing saline water from the fresh-water reach of the Caloosahatchee River, Lee County, Florida: U.S. Geological Survey Open-File Report FL-72028, 45 p.

Boggess, D.H., 1973, The effects of plugging a deep artesian well on the concentration of chloride in water in the water-table aquifer at Highland Estates, Lee County, Florida: U.S. Geological Survey Open-File Report FL-73003, 20 p.

Boggess, D.H., 1974, Saline ground-water resources of Lee County, Florida: U.S. Geological Survey Open-File Report 74-247, 62 p.

Boggess, D.H., 1974, The shallow fresh-water system of Sanibel Island, Lee County, Florida, with emphasis on the sources and effects of saline water: Tallahassee, Florida Bureau of Geology Report of Investigations 69, 52 p.

Boggess, D.H., 1975, Effects of a landfill on ground-water quality: U.S. Geological Survey Open-File Report 75-594, 44 p.

Boggess, D.H., and Missimer, T.M., 1975, A reconnaissance of hydrogeologic conditions in Lehigh Acres and adjacent areas of Lee County, Florida: U.S. Geological Survey Open-File Report 75-55, 106 p.

Boggess, D.H., Missimer, T.M., and O'Donnell, T.H., 1977, Saline-water intrusion related to well construction in Lee County, Florida: U.S. Geological Survey Water-Resources Investigations Report 77-33, 29 p.

Boggess, D.H., Missimer, T.M., and O'Donnell, T.H., 1981, Hydrogeologic sections through Lee County and adjacent areas of Hendry and Collier Counties, Florida: U.S. Geological Survey Water-Resources Investigations Open-File Report 81-638, 1 sheet.

Boggess, D.H., and O'Donnell, T.H., 1982, Deep artesian aquifers of Sanibel and Captiva Islands, Lee County, Florida: U.S. Geological Survey Open-File Report 82-253, 32 p.

Boggess, D.H., and Watkins, F.A., Jr., 1986, Surficial aquifer system in eastern Lee County, Florida: U.S. Geological Survey Water-Resources Investigations Report 85-4161, 59 p.

Böhlke, E.B, and Smith-Vaniz, W.F., 1993, Nomenclatural changes and additions, Pages xi- xxvi, *in* Böhlke, J.E, and Cahplin C.C.G., Fishes of the Bahamas and adjacent tropical eaters (2nd ed.), University of Texas Press, Austin.

Bonde, R.K, 1993, Manatees in Florida: A personal perspective, Whalewatcher 27(1):16- 18.

Bonde, R.K., and Beck, C.A., 1990, How the Florida manatees fare today, Whalewatcher 24(1):8-9.

Boscence, D., 1989, Biogenic carbonate production in Florida Bay: Bulletin of Marine Science, v. 44, pt. 1, p. 419-433.

Boydstun, C. P., P. L. Fuller, and J. D. Williams, 1995, Nonindigenous fish, *in* LaRoe, E.T., Farris, G.S., Puckett, C.E., Doran, P.D., and Mac, M.J., eds., Our living resources: A report to the nation on the distribution, abundance, and health of U.S. plants, animals, and ecosystems: U.S. Department of the Interior, National Biological Service, Washington, DC, p. 431-433.

Boyer, J.N., Fourqurean J.W., and Jones, R.D., 1999, Seasonal and long-term trends in the water quality of Florida Bay, 1989-1997): Estuaries, v. 22, no. 2b, p. 417-430.

Bradner, L.A., 1994, Ground-water resources of Okeechobee County, Florida: U.S. Geological Survey Water-Resources Investigations Report 92-4166, 41 p.

Brewster-Wingard, G.L., 1996, Ecosystem history of Florida Bay: U.S. Geological Survey Fact Sheet, FS-144-96.

Brewster-Wingard, G.L., Cronin, T., Wardlaw, B., Stone, J., Schwede, S., Ishman, S., Holmes, C.W., Halley R., Marot, M., Dwyer, G., and Huvane, J., 1999, Long-term Florida Bay salinity history: A synthesis of multi-proxy evidence from sediment cores, *in* Proceedings, 1999 Florida Bay and Adjacent Marine Systems Science Conference, Key Largo Florida, November 1-5, 1999: p. 182-183.

Brewster-Wingard, G.L., and Ishman, S.E., 1999, Historical trends in salinity and substrate in central and northern Florida Bay: A paleoecological reconstruction using modern analogue data: Estuaries, v. 22, no. 2b, p. 369-383.

Brewster-Wingard, G.L., Ishman, S.E., Cronin, T.M., 1998, Historical salinity and seagrass trends in Florida Bay derived from benthic faunal data, *in* Proceedings of the Florida Bay Science Conference.

Brewster-Wingard, G.L., Ishman, S.E., Cronin, T.M., Halley, R.B., Willard, D.A., Holmes C.W., Huvane, J.K., and Orem, W.H., 1999, Providing a framework for assessment and restoration of the Everglades ecosystem: An example of the use of paleoecologic and geochemical data in Florida Bay: U.S. Department of the Interior conference on the environment, Denver Colorado.

Brewster-Wingard, G.L., Ishman, S.E., Edwards, L.E., and Willard, D.A., 1996, Preliminary report on the distribution of modern fauna and flora at selected sites in north-central and northeastern Florida Bay: U.S. Geological Survey Open-File Report 96-732, 34 p.

Brewster-Wingard, G.L., Ishman, S.E., Holmes, C.W., 1998, Environmental impacts on the southern Florida coastal waters: A history of change in Florida Bay: Journal of Coastal Research, Special Issue 26, p. 162-172.

Brewster-Wingard, G.L., Ishman, S.E., Holmes, C.W., Willard, D.A., and Edwards, L.E., 1997, Environmental change in the Florida Bay Ecosystem: Patterns over the last 150 years, *in* Gerould, Sarah, and Higer, A.L., eds., U.S. Geological Survey Program on the South Florida Ecosystem—Proceedings of the Technical Symposium in Ft. Lauderdale, Florida, August 25-28, 1997: U.S. Geological Survey Open-File Report 97-385, p. 8-9.

Brewster-Wingard, G.L., Ishman, S.E., Waibel, N.J., Willard, D.A., Edwards, L.E., and Holmes, C.W., 1998, Preliminary Paleontologic Report on Core 37 from Pass Key, Everglades National Park, Florida Bay: U.S. Geological Survey Open-File Report 98-122, 24 p.

Brewster-Wingard, G.L., Ishman, S.E., Willard, D.A., Edwards, L.E., and Holmes, C.W., 1997, Preliminary paleontologic report on Cores 19A and 19B, from Russell Bank, Everglades National Park, Florida Bay: U.S. Geological Survey Open-File Report 97-460, 29 p.

Brewster-Wingard, G.L., Ishman, S.E., Willard, D.A., Halley, R.B., and Holmes, C.W., 1996, The biotic record of change in Florida Bay and the south Florida Ecosystem, *in* Proceedings, 1996 Florida Bay and Science Conference, Key Largo Florida, December 10-12, 1996: p. 25-26.

Brewster-Wingard, G.L., Stone, J.R., and Cronin, T.S., 2000, The present is the key to the past and the past is the key to the future: The role of paleoecology in reconstructing the ecosystem of Florida Bay: Geological Society of America, Abstracts with Programs, southeastern section, v. 32, no. 2, p. A-8.

Brewster-Wingard, G.L., Stone, J.R., and Holmes, C.W., in review, Molluscan faunal distribution in Florida Bay, past and present: An integration of down-core and modern data: Bulletins of American Paleontology, Special Volume, 39 p.

Brewster-Wingard, G.L., Willard, D.A., and Ishman, S.E.; 1996, Paleoecology as a tool in the restoration of modern ecosystems: An example from south Florida: Geologic Society of America, Abstracts with Programs, Southeastern Section, v. 28, n. 2, p. 4-5.

Brim Box, J., and J. Mossa, 1999, Sediment, land use and freshwater mussels: prospects and problems: Journal of the North American Benthological Society, v. 18, no. 1, p. 9-117.

Brim Box, J., and J.D. Williams, 2000, Unionid mollusks of the Apalachicola Basin in Alabama, Florida, and Georgia: Bulletin of the Alabama Museum of Natural History, v. 21, p. 1-143.

Brim Box, J., Williams, J.D., Lattimore, R.C., and Ocampo, N.F., 1994, The freshwater mussels of the Apalachicola, Chattahoochee, and Flint rivers: An imperiled fauna, Abstract, Bulletin North American Benthological Society 11(1):111.

Brinkley, K., J. Sickel, L. Duobinis-Gray, and J. Herod, 1997, Histological analysis of gonad development in zebra mussels (Bivalvia: Dreissenidae) from the Tennessee and Ohio Rivers, *in* Scott, A.F., Hamilton, S.W., Chester, E.W., and White, D.S., eds., Proceedings of the Seventh Symposium on the Natural History of Lower Tennessee and Cumberland River Valleys. The Center for Field Biology, Austin Peay State University, Clarksville, Tennessee, p. 67-73.

Broska, J.C., and Knochenmus, L.A., 1996, Assessment of the hydrogeology and water quality in a near-shore well field, Sarasota, Florida: U.S. Geological Survey Water-Resources Investigations Report 96-4036, 64 p.

Browder, J.A., Restrepo, V.R., Rice, J.K., Robblee, M.B., and Zein-Eldin, Zoula, 1999, Environmental influences on potential recruitment of pink shrimp, *Penaeus duorarum*, from Florida Bay nursery grounds: Estuaries, v. 22, no. 2b, v. 484-499.

Brown, C.E., Krulikas, R.K., and Brendle, D.L., 1996, Hydrogeologic assessment of shallow clastic and carbonate rock aquifers in Hendry and Collier Counties, Southwestern Florida: U.S. Geological Survey Open-File Report 96-556, 56 p.

Brown, D.P., 1982, Water resources and data-network assessment of the Manasota basin, Manatee and Sarasota Counties, Florida: U.S. Geological Survey Water-Resources Investigations Report 82-37, 80 p.

Brown, D.P., 1983, Water resources of Manatee County, Florida: U.S. Geological Survey Water-Resources Investigations Report 81-74, 112 p.

Brown, Eugene, 1956, Quality of surface waters of Lee County, Florida: Tallahassee, Tallahassee, Florida Geological Survey Information Circular 7, part 2, p. 23-69.

Brown, Eugene, and Crooks, J.W., 1955, Chemical character of surface waters in the Central and Southern Florida Flood Control District: U.S. Geological Survey Open-File Report FL-55002.

Brown, R.H., and Parker, G.G., 1944, Saltwater encroachment in limestone at Silver Bluff, Miami, Florida: Economic Geology, v. 39.

Brown, R.H., and Parker, G.G., 1945, Saltwater encroachment in limestone at Silver Bluff, Miami, Florida: Economic Geology, v. 40, no. 4, p. 235-262.

Bruno, M.C., Loftus, W.F., and Perry, S., in press, Relationships of freshwater copepods to hydrological patterns in the southern Everglades: Hydrobiologia.

Buchanan, T.J., and Hartwell, J.H., 1972, Analysis of water level data for Everglades National Park, Florida: U.S. Geological Survey Open-File Report FL-72004, 30 p.

Buchanan, T.J., and Klein, Howard, 1976, Effects of water management on freshwater discharge to Biscayne Bay: University of Miami Sea Grant Special Report no. 5.

Buckingham, C.A., L. W. Lefebvre, J. M. Schaefer, and H. I. Kochman, 1999, Manatee response to boating activity in a thermal refuge: Wildlife Society Bulletin, 27(2):514-522.

Buergelt, C.D., Bonde, R.K., Beck, C.A., and O'Shea, T.J., 1990, Myxomatous transformation of heart valves in Florida manatees *(Trichechus manatus latirostris)*, Journal of Zoo and Wildlife Medicine 21(2):220-227.

Buono, Anthony, Causseaux, K.W., and Moore, J.E., 1978, Summary of U.S. Geological Survey investigations and hydrologic conditions in the Southwest Florida Water Management District for 1977: U.S. Geological Survey Open-File Report 78-331, 88 p.

Buono, Anthony, and Rutledge, A.T., 1979, Configuration of the top of the Floridan aquifer, Southwest Florida Water Management District and adjacent areas: U.S. Geological Survey Water-Resources Investigations Open-File Report 78-34, 1 sheet.

Buono, Anthony, Spechler, R.M., Barr, G. L., and Wolansky, R. M., 1979, Generalized thickness of the confining bed overlying the Floridan aquifer, Southwest Florida Water Management District: U.S. Geological Survey Water-Resources Investigations Open-File Report 79-1171, 1 sheet.

Burkhead, N.M, and H.L. Jelks. 2000, Essay 1. Diversity, levels of imperilment, and cryptic fishes in the southeastern United States, *in* Abell, R.A., Olson, D.M., Dinerstein, E., Hurley, P.T., Diggs, J.T., Eichbaum, W., Walters, S., Wettengel, W., Allnutt, T., Loucks, C.J., and Hedao, P., Freshwater ecoregions of North America: A conservation assessment: Covelo, Calif., Island Press, p. 30-32.

Burkhead, N.M., and Jenkins, R.E., 1991, Fishes, *in* Terwilliger, K., (comp.), Virginia's Endangered Species: Blacksburg, Va., McDonald and Woodward Publishing Company, p. 321-409

Burkhead, N. M., S. J. Walsh, B. J. Freeman, and J. D. Williams, 1997, Status and restoration of the Etowah River, an imperiled Southern Appalachian Ecosystem, *in* Benz, G.W., and Collins, D.E., eds., Aquatic Fauna in Peril: The Southeastern Perspective: Southeast Aquatic Research Institute, Decatur, Ga., Lenz Design and Communications, Special Publication 1, 553 p.

Burkhead, N.M., and Williams, J.D., 1990, Current tank useful for observing small stream fishes: U.S. Fish and Wildlife Service Research Information Bulletin No. 90-68.

Burkhead, N.M., and Williams, J.D., 1990, Research on the Okaloosa darter focuses on competition and habitat use: U.S. Fish and Wildlife Endangered Species Technical Bulletin, v. IX, no. 11.

Burkhead, N.M., and Williams, J.D., 1991, An intergeneric hybrid of a native minnow, the golden shiner, and an exotic minnow, the rudd, Transactions American Fisheries Society 120:781-795.

Burkhead, N.M., and Williams, J.D., 1992, Captive spawning behavior of the endangered boulder darter *Etheostoma wapiti* (abs.): American Society of Ichthyologists and Herpetologists, p. 76,

Burkhead, N.M., and Williams, J.D., 1992, Okaloosa darter Etheostoma okaloosae, *in* Gilbert, C.R, ed., Rare and Endangered Biota of Florida, Volume II, Fishes, University Press of Florida, Gainesville, p. 23-30.

Burkhead, N.M., and Williams, J.D., 1992, The boulder darter: A conservation challenge: U.S. Fish and Wildlife Service Endangered Species Technical Bulletin 17(3-8):4-6.

Burkhead, N.M., Williams, J.D., and Freeman, B.J., 1992, The Etowah: A river under siege, Georgia Wildlife 2(2):10-17.

Bury, R.B., P.S. Corn, C.K. Dodd, Jr., R.W. McDiarmid, and N.J. Scott, 1995, Amphibians, *in* LaRoe, E.T., Farris, G.S., Puckett, C.E., Doran, P.D., and Mac, M.J., eds., Our Living Resources: U.S. Department of the Interior, National Biological Service, p. 124-126.

Busch, D.E., Loftus, W.F., and Bass, O.L., Jr., 1998, Long-term hydrologic effects on marsh plant community structure in the southern Everglades: Wetlands, v. 18, p. 230-241.

Butler, M.J., IV, Hunt, J.H., Herrnkind, W.F., Childeress, M.J., Bertelsen, R., Sharp, Matthews, T., Field, J.M., and Marshall, H.G., 1995, Cascading disturbances in Florida Bay, USA--Cyanobacterial blooms, sponge mortality, and implications for juvenile spiny lobsters Panulirus argus: Marine Ecology Progress Series, v. 129, p. 119-125.

Cahoon, D.R., and others, 1995, Estimating shallow subsidence in microtidal salt marshes of the southeastern United States: Kaye and Barghoorn revisited: Marine Geology, v. 128, p. 1-9.

Cahoon, D.R., and Lynch, J.C., 1997, Vertical accretion and shallow subsidence in a mangrove forest of southwest Florida: Mangroves and Saltmarshes, v. 1, p. 173-186.

Cardeilhac, P.T., 1991, Diagnosis and treatment of infertility in captive alligators—Final reports for the Aquaculture Market Development Aid Program: Tallahassee, Florida Department of Agriculture, v. I-III, 1987-1991.

Cardeilhac, P.T., Fleming, M.O., and Bass, O.L., 1996, An evaluation of egg quality and hatchling growth potential for American alligators in the Southern Everglades, *in* Proceedings of International Association for Aquatic Animal Medicine: v. 27, p. 72-76.

Carr, T and R. K. Bonde, 2000, Tucuxi *(Sotalia fluviatilis)* occurs in Nicaragua, 800 km north of its previously known range. Marine Mammal Science 16(2):447-452.

Carter, Virginia, 1996, Vegetative Resistance to Flow: U.S. Geological Survey Fact Sheet FS-147-96.

Carter, Virginia, Reel, J.T., Rybicki, N.B., Ruhl, H.A., Gammon, P.T., and Lee, J.K., 1999, Vegetative Resistance to Flow in South Florida: Summary of Vegetation Sampling at Sites NESRS3 and P33 Shark River Slough, November, 1996: U.S. Geological Survey Open-File Report 99-218, 97 p.

Carter, Virginia, Reel, J.T., Rybicki, N.B., Ruhl, H.A., Stewart, D.W., and Jones, J.W., in press, Classification of Vegetation for Surface-Water Flow Models in Taylor Slough, Everglades National Park: U.S. Geological Survey South Florida Ecosystem Program paper, 14 p.

Carter, Virginia, Ruhl, H.A., Rybicki, N.B., Reel, J.T., and Gammon, P.T., 1999, Vegetative Resistance to Flow in South Florida: Summary of Vegetation Sampling at Sites NESRS3 and P33 Shark River Slough, April, 1996: U.S. Geological Survey Open-File Report 99-187, 80 p.

Carter, Virginia, Rybicki, N.B., Reel, J.T., Ruhl, H.A., and Lee, J.K., 1999, Vegetative characterization for Everglades studies, *in* Gerould, Sarah, and Higer, A.L., eds., U.S. Geological Survey Program on the south Florida ecosystem—Proceedings of South Florida Restoration Science Forum, May 17-19, 1999, Boca Raton, Florida: U.S. Geological Survey Open-File Report 99-181, p. 10-11.

Carter, V.C., Rybicki, N.B., Reel, J.T., Ruhl, H.A., Stewart, D.W., and Jones, J.W., 1999, Classification of vegetation for surface-water flow models in Taylor Slough, Everglades National Park, *in* Proceedings of the Ecohydraulics Symposium, July 13-16, 1999.

Causaras, C.R., 1982, Annotated bibliography of the geology and hydrology of the surficial aquifers in Dade, Broward, and Palm Beach Counties, Florida: U.S. Geological Survey Open-File Report 82-154, 59 p.

Causaras, C.R., 1985, Geology of the surficial aquifer system, Broward County, Florida: U.S. Geological Survey Water-Resources Investigations Report 84-4068, 167 p., 2 sheets.

Causaras, C.R., 1987, Geology of the surficial aquifer system, Dade County, Florida: U.S. Geological Survey Water-Resources Investigations Report 86-4126, 240 p., 3 sheets.

Chambers, G, and Garrison, V., 1996, Proposed environmental monitoring plan for the Bird Island Marine Reserve, Antigua: An Island Resources Foundation Report for the Organization of American States (Performance Contract No.WSC14721), p 23.

Charlton, S.R., Macklin, C.L. and Parkhurst, D.L., 1997, PHREEQCI – A graphical user interface for the geochemical computer program PHREEQC: U.S. Geological Survey Water-Resources Investigations Report 97-4222, and at http://wwwbrr.cr.usgs.gov/projects/GWC_coupled/phreeqci/index.html.

Chick, J.H, and C.C. McIvor, 1997, Habitat selection by three littoral zone fishes: effects of predation pressure, plant density and macrophyte type: Ecology of Freshwater Fish, v. 6, p. 27-35.

Chin, D.A., 1990, A method to estimate canal leakage to the Biscayne aquifer, Dade County, Florida: U.S. Geological Survey Water-Resources Investigations Report 90-4135, 32 p.

Choi, J., and Harvey, J.W., 2000, Effect of water management in the Everglades Nutrient Removal Area (ENR) on hydrologic interactions with groundwater (abs.): Presented during the Greater Everglades Ecosystem Restoration Conference, Naples, Florida, December 11-15, 2000.

Choi, J., and Harvey, J.W., 2000, Quantifying time-varying groundwater discharge and recharge in wetlands: A comparison of methods in the Florida Everglades: Wetlands, v. 20, no. 3, p. 500-511.

Christmas, J., Eades, R., Cincotta, D., Shiels, A., Miller, R., Siemien, M.J., Sinnott, T., Fuller, P., 1998, History, management, and status of introduced fishes in the Chesapeake Bay Basin: Proceedings of the Conference on Conservation and Biological Diversity.

Churchill, S.W., 1988, Viscous flows: The practical use of theory: Stoneham, Mass., Butterworth Publishers, 602 p.

Clark, D.R., Jr., C.M Bunck, and R.J. Hall, 1997, Female reproductive dynamics in a Maryland population of ringneck snakes *(Diadophis punctatus):* Journal of Herpetology. 31:476-483.

Clark, W.E., 1964, Possibility of salt-water leakage from proposed intracoastal waterway near Venice, Florida well field: Tallahassee, Florida Geological Survey Report of Investigations 38, 33 p.

Cleckner, L.B., Garrison, P.J., Hurley, J.P., Olson, M.L., Krabbenhoft, D.P., 1998, Trophic transfer of methyl mercury in the northern Florida Everglades: Biogeochemistry, v. 40, p. 347-361.

Cleckner, L.B., Gilmour, C.C., Hurley, J.P., and Krabbenhoft, D.P., 1999, Mercury methylation by periphyton in the Florida Everglades: Limnology and Oceanography 44, p. 1815-1825.

Coker, A.E., 1969, Application of remote sensing to occurrence of collapse sinkholes in the Alafia and Peace River basins, Florida: NASA Earth Resources Aircraft Program Status Review, v. 3, 14 p.

Compeau, G.C., and Bartha, R., 1985, Sulfate-reducing bacteria—Principal methylators of mercury in anoxic estuarine sediment: Applied Environmental Microbiology, v. 50, no. 2, p. 498-502.

Cooper, H.H., Jr., 1959, A hypothesis concerning the dynamic balance of freshwater and saltwater in a coastal aquifer: Journal of Geophysical Research, v. 64, no. 4, p. 461-467.

Cordes, E.H., and Gardner, R.A., 1976, Analog-model simulations for secondary canal controls and forward pumping water-management schemes in southeast Florida: U.S. Geological Survey Water-Resources Investigations Report 76-93, 60 p.

Corral, M.A., Jr., 1983, Distribution of selected chemical constituents in water from the Floridan aquifer, Southwest Florida Water Management District: U.S. Geological Survey Water-Resources Investigations Report 83-4041, 1 sheet.

Correa-Viana, M., O'Shea, T.J., Ludlow, M.E., and Robinson, J.G., 1990, Distribucion y abundancia del manati, Trichechus manatus, en Venezuela, Biollania 7:101-123.

Corser, J.D. 2001, Decline of disjunct green salamander, Aneides aeneus, populations in the southern Appalachians: Biological Conservation, v. 97, no. 1, p. 119-126.

Cosby, B.J., Nuttle, W.K., and Fourqurean, J.W., 1999, FATHOM: Model description and initial application to Florida Bay: Washington, National Park Service Project completion report, 106 p.

Cosner, G. C., DeAngelis, D.L., Ault, J.S., and Olson, D.B., 1999, Effects of spatial grouping on the functional response of predators. Theoretical Population Biology 56:65-75.

Costanza, Robert., and others, 1997, The value of the world's ecosystem services and natural capital: Nature, v. 387, no. 5, p. 253.

Costello, T.J,. and Allen, D.M., 1966, Migrations and geographic distribution of the pink shrimp, *Penaeus duorarum*, of the Tortugas and Sanibel grounds, Florida: U.S. Fish and Wildlife Service, Fishery Bulletin 65, p. 449-459.

Costello, T.J., Allen, D.M., and Hudson, J.H., 1986, Distribution, seasonal abundance, and ecology of juvenile northern pink shrimp, *Penaeus Duorarum*, in the Florida Bay area: Miami, Florida, U.S. Department of Commerce, NOAA Technical Memorandum, NMFS-SEFC-161, 84 p.

Courtenay, W.R., Jr., Jennings, D.P., and Williams, J.D., 1991, Common and scientific names of fishes from the United States and Canada: Appendix 2, Exotic Fishes., *in* Robins, C. R., and others, American Fisheries Society Special Publication 20, p. 97-107.

Courtenay, W.R., Jr., and Williams J.D., 1992, Dispersal of exotic species from aquaculture sources, with emphasis on freshwater fishes, *in* Rosenfield, A., and Mann, R., eds., Dispersal of living organisms into aquatic ecosystems, University of Maryland Sea Grant Program, p. 49-81.

Cowart, J.B., Kaufman, M.I., and Osmond, J.K., 1978, Uranium-isotope variations in groundwaters of the Floridan aquifer and boulder zone of south Florida: Journal of Hydrology, v. 36, p. 161-172.

Craft, C.B, and Richardson, C.J., 1993, Peat accretion and phosphorus accumulation along a eutophication gradient in the northern Everglades: Biogeochemistry, v. 22, no. 2, p. 133-156.

Craighead, F.C., Jr., 1964, Land, mangroves, and hurricanes: Bulletin of the Fairchild Tropical Garden, v, 19, p. 5-32.

Craighead, F.C., Jr., 1964, Trees of South Florida, Vol. 1, The natural environments and their succession: Coral Gables, University of Miami Press, 212 p.

Crain, D.A., A.B. Bolten, Bjorndahl, L.J. Guillette and T.S. Gross, 1995, Size-dependent, sex-dependent and seasonal changes in insulin-like growth-factor-I in the loggerhead sea turtle *(Caretta caretta):* General and Comparative Endocrinology, v. 98, p. 219-226.

Cronin, T.M., Halley, R.B., Brewster-Wingard, G.L., Holmes, C.W., Dwyer, G.S., Ishman, S.E., 1998, Climatic and anthropogenic influence on Florida Bay Salinity over the past century, *in* Proceedings, 1998 Florida Bay and Adjacent Marine Systems Science Conference, Key Largo Florida.

Cronin, T.M., Holmes, C.W., Brewster-Wingard, G.L., Ishman, S.E., Dowsett, H., Keyser, D., Waibel, N., IN REVIEW, Historical Trends in Epiphytal Ostracodes from Florida Bay: Implications for Seagrass and Macro-benthic Algal Variability: Bulletins of American Paleontology, Special Volume.

Cronin, T.M., Wagner, R.S., and Moira Slattery, 1999, Microfossils from Chesapeake Bay Sediments: Illustrations and Species Database: U.S. Geological Survey Open-File Report 99-0045, 160 p.

Cronin, T.M., Wingard, L., Ishman, S., Dowsett, H., Holmes, C., 1999, Historical trends in epiphytal ostracodes from Florida Bay: Implications for seagrass and macro-benthic algal variablility, *in* Proceedings, 1999 Florida Bay and Adjacent Marine Systems Science Conference, Key Largo Florida, November 1-5, 1999: p. 184-185.

Cross, W.P., and Love, S.K., 1942, Ground water in southeastern Florida: American Water Works Association Journal, v. 34, no. 4, p. 490-504.

Cross, W.P., Love, S.K., Parker, G.G., and Wallace, D.S., 1940, Progress report on water-resources investigations in southeastern Florida: U.S. Geological Survey Open-File Report FL-40002.

Davis, J.H., 1940, The ecology and geologic role of mangroves in Florida: Papers from Tortugas Laboratory: Carnegie Institute of Washington Publication, v. 32, no. 517, p. 303-412.

Davis, M.M., S.W. Sprecher, J.S. Wakeley and G.R. Best, 1996, Environmental gradients and identification of wetlands in North-Central Florida. Wetlands, 16(4):512-523.

DeAngelis, D.L, 1996, Indirect effects: Concepts and approaches from ecological theory, *in* Baird, D.J., Maltby, L., Greig-Smith, P.W., and Douben, P.E.T., eds., Ecotoxicology: Ecological demensions: Chapman and Hall, New York, p. 25-41.

DeAngelis, D.L, 1998, Book review of Pelagic Nutrient Cycles: Herbivores as Sources and Sinks, by T. Anderson: Trends in Ecology and Evolution 13:127.

DeAngelis, D.L, 1999, The use of modeling in restoration ecology: The Everglades case, *in* Farino, A., ed., Perspectives in Ecology: A Glance at the VII International Congress in Ecology (INTECOL). Florence, Italy, 19-25 July 1998: Backhuys, Leiden, The Netherlands.

DeAngelis, D.L., 2000, Book review of "Nonlinear Dynamics of Interacting Populations" by Alexander D. Bazykin. The Quarterly Review of Biology 75:213-214.

DeAngelis, D.L., in press, Book review of "An Illustrated Guide to Theoretical Ecology" by Ted J. Case: BioScience.

DeAngelis, D.L, in press, Community Food Webs, *in* Encyclopedia of Environmetrics: John Wiley & Sons.

DeAngelis, D.L., Bellmund, S., Mooij, W.M., ott, M.P., Comiskey, E.J., Gross, L.J., and Wolff., W.F., in press, Modeling ecosystem and population dynamics on the South Florida hydroscape, *in* Porter, J.W., and Porter, K.G., eds., Linkages Between Ecosystems in the South Florida Hydroscape: CRC Press, Delray Beach, Florida.

DeAngelis, D.L., and Curnutt, J.L., in press, Integration of population, community, and landscape indicators for assessing effects of stressors, *in* Adams, S.M., ed., Biological Indicators of Stress in Fish (2nd ed.).

DeAngelis, D.L., Gross, L.J., Huston, M.A., Wolff, W.F., Fleming, D.M., Comiskey, E.J., Sylvester, S.M., 1998, Landscape modeling for Everglades Ecosystem Restoration: Ecosystems, v. 1, no. 2, p. 64-75.

DeAngelis, D.L., Loftus, W.F., Trexler, J.C., and Ulanowicz, R.E., 1997, Modeling fish dynamics and effects of stress in a hydrologically pulsed ecosystem: Journal of Aquatic Ecosystem Stress and Recovery, v. 6, p. 1-13.

DeAngelis, D. L., Mooij, W.M., Nott, M.P., and DeAngelis, D.L., in press, Individual-based models: The importance of variability among individuals, *in* Franklin A., and Schenk, T., eds., Modeling in Natural Resource Management: Development, Interpretation, and Application: Island Press, Covello, California.

DeAngelis, D. L., and P. J. Mulholland, in press, Dynamic consequences of allochthonous nutrient input into freshwater systems, *in* Anderson, W.B., and Polis, G.A., eds., Food Webs and Landscapes. University of Chicago Press.

DeAngelis, D. L., L. Persson, and A.D. Rosemond, 1996, Interaction of productivity and consumption, *in* Polis, G.A., and Winemiller, K.O., eds., Food Webs: Integration of patterns and dynamics: Chapman and Hall, New York, p. 109-112.

Deegan, L.A., Peterson, B.J., Golden, H., McIvor, C.C., and Miller, M.C., 1997, Effects of fish density and river fertilization on algal standing stocks, invertebrates communites, and fish production in an Arctic River: Canadian Journal of Fisheries and Aquatic Sciences 54(2):269-283.

DelCharco, M.J., 1998 Tidal flow in selected areas of Tampa Bay and Charlotte Harbor, Florida, 1995-96: U.S. Geological Survey Water-Resources Investigations Report 97-4265, 44 p.

Deszcz-Pan, M., Fitterman, D.V., and Labson, V.F., 1998, Reduction of inversion errors in helicopter EM data using auxiliary information: Exploration Geophysics, v. 29, p. 142-146.

Deutsch, C. J, 1995, Book review of Antarctic Seals: Research Methods and Techniques, R.M., ed., Animal Behaviour: Cambridge University Press, Laws, 49(5):1422-1425.

Deutsch, C.J., Bonde, R.K., and Reid, J.P., 1998, Radiotracking manatees from land and space: Tag design, implementation, and lessons learned from longterm study: Marine Technology Society Journal 32(1):18-29.

Dodd, C.K., Jr., 1990, (Review of) Amphibians and Roa, Langton, T.E.S., ed.: Conservation Biology 4:210-211.

Dodd, C.K., Jr., 1990, *Caretta caretta (Linnaeus),* Catalogue of American Amphibians and Reptiles 483.1-483.7.

Dodd, C.K., Jr., 1990, *Caretta Rafinesque,* Catalogue of American Amphibians and Reptiles 482.1-482.2.

Dodd, C.K., Jr., 1990, Postures associated with immobile woodland salamanders, genus *Plethodon:* Florida Scientist 53:43-49.

Dodd, C.K., Jr., 1990, Effects of habitat fragmentation on a stream-dwelling species, the flattened musk turtle *Sternotherus depressus,* Biological Conservation 54:33-45.

Dodd, C.K., Jr., 1990, Line transect estimation of Red Hills salamander burrow density using a Fourier series Copeia no. 2, p. 555-557.

Dodd, C.K., Jr., 1990, The influence of temperature and body size on duration of immobility in salamanders of the genus *Desmognathus,* Amphibia-Reptilia 11:401-410.

Dodd, C.K., Jr., 1991, Drift fence-associated sampling bias of amphibians at a Florida sandhills temporary pond, Journal of Herpetology 25(3):296-301.

Dodd, C.K., Jr., 1991, The status of the Red Hills salamander *Phaeognathus hubrichti,* Alabama, USA, 1976-1988, Biological Conservation 55:57-75.

Dodd, C.K., Jr., 1992, Biological diversity of a temporary pond herpetofauna in north Florida sandhills, Biodiversity and Conservation, v. 1, no. 3, p. 25-142.

Dodd, C.K., Jr., 1992, Fluorescent powder is only partially successful in tracking movements of the six-lined racerunner (Cnemidophorus sexlineatus), Florida Field Naturalist 20:8-14.

Dodd, C.K., Jr., 1992, (Review of) Life History and Ecology of the Slider Turtle by J.W. Gibbons, Wildlife Review No. 229: 241-242.

Dodd, C.K., Jr., 1992, Loggerhead sea turtle *Caretta caretta (Linnaeus), in* Moler, P.E., ed., Rare and Endangered Biota of Florida, Volume III, Amphibians and Reptiles, 2nd ed. Univ. Press of Florida, Gainesville, Fla., p. 128-134.

Dodd, C.K., Jr., 1993, Cost of living in an unpredictable environment: The ecology of striped newts Notophthalmus perstriatus during a prolonged drought, Copeia 1993(3):605-614.

Dodd, C.K., Jr., 1993, The effects of toeclipping on sprint performance of the lizard *Cnemidophorus sexlineatus,* Journal of Herpetology 27(2):209-213.

Dodd, C.K., Jr., 1993, Population structure, body mass, activity, and orientation of an aquatic snake *(Seminatrix pygaea)* during a drought, Canadian Journal of Zoology 71(7):1281- 1288.

Dodd, C.K., Jr., 1993, Strategies for snake conservation, *in* Seigel, R.A., and Collins, J.T., eds., Snakes: Ecology and Behavior, McGraw-Hill Book Co., New York, p. 363-393.

Dodd, C.K., Jr, 1994 [1995], Culebra Island giant anole Anolis roosevelti, in Emanoil, M., ed., Encyclopedia of Endangered Species, Gale Research Inc., Detroit, p. 813-814.

Dodd, C.K., Jr., 1994, The effects of drought on population structure, activity, and orientation of toads (*Bufo-quercicus and B. terrestris)* at a temporary pond, Ethology Ecology & Evolution 6(3):331-349.

Dodd, C.K., Jr., 1994, (Review of) Keeping all the Pieces, Perspectives on Natural History and the Environment by Gibbons, W.: Copeia 1994:1064-1065.

Dodd, C.K., Jr., 1994, Monitoring and protecting biotic diversity, *in* Majumdar, S.K., Brenner, F.J., Lovich, J.E., Schalles, J.F., and Miller, E.W., eds., Biological Diversity: Problems and Challenges, Pennsylvania Academy of Science, Easton, Pa., p. 1-11.

Dodd, C.K., Jr, 1995, Disarticulation of turtle shells in north- central Florida: How long does a shell remain in the woods? American Midland Naturalist 134(2):378-387.

Dodd, C.K., Jr, 1995, Marine turtles in the Southeast, *in* LaRoe, E.T., Farris, G.S., Puckett, C.E., Doran, P.D., and Mac, M.J., eds., Our Living Resources: U.S. Department of the Interior, National Biological Service, p. 121-123.

Dodd, C.K., Jr, 1995, North American box turtles *(Terrapene)* listed under CITES Appendix II. Box Turtle Newsletter (2):1-3.

Dodd, C.K., Jr, 1995, Reptiles and amphibians in the endangered longleaf pine ecosystem, *in* LaRoe, E.T., Farris, G.S., Puckett, C.E., Doran, P.D., and Mac, M.J., eds., Our Living Resources: U.S. Department of the Interior, National Biological Service, Washington, D.C., p. 129-131.

Dodd, C.K., Jr, 1995, The ecology of a sandhills population of the eastern narrow-mouthed toad, Gastrophryne carolinensis, during a drought: Bulletin of the Florida Museum of Natural History 38:11-41.

Dodd, C.K., Jr, 1995, (Review of) The Natural History of West Indian Boas, by Tolson, P.J., and Henderson, R.W.: Caribbean Journal of Science 31:157-158.

Dodd, C.K., Jr, 1995, The rare newt of Trail Ridge: Reptile & Amphibian Magazine (July/Aug):36-37, p. 39-45.

Dodd, C.K. Jr, 1996, Use of terrestrial habitats by amphibians in the sandhill uplands of north-central Florida: Alytes 14:42-52.

Dodd, C.K., Jr, 1997, Clutch size and frequency in Florida box turtles *(Terrapene carolina bauri)*: Implications for conservation: Chelonian Conservation and Biology 2(3):370-377.

Dodd, C.K., Jr, 1997 [1998], Imperiled amphibians: A historical perspective, *in* Benz, G.W., and Collins, D.E., eds., Aquatic Fauna in Peril: The Southeastern Perspective Special Publication No. 1, Southeast Aquatic Research Institute, Lenz Design and Communications, Decatur, Ga., p. 165-200.

Dodd. C.K., Jr, 1997, Population structure and the evolution of sexual size dimorphism and sex ratios inan insular popultion of Florida box turtles *(Terrapene carolina bauri):* Canadian Journal of Zoology 75(9):1495-1507.

Dodd, C.K., Jr, 1997, The jumping crocs of the Adelaide River: Reptile and Amphibian Magazine (Jan/Feb): 24-28.

Dodd, C.K., Jr, 1998, Biomass of an island population of Florida box turtles *(Terrapene carolina bauri)*: Journal of Herpetology, 32:150-152.

Dodd, C.K., Jr, 1998, Desmognathus auriculatus at Devil´s Millhopper State Geological Site, Alachua County, Florida: Florida Scientist 61:38-45.

Dodd, C.K., Jr, 1998, NIEHS sponsors workshop on amphibian deformities. Froglog 26:2-3.

Dodd, C.K., Jr, 1999, (Review of) The Bone Sharp. The Life of Edward Drinker Cope, by Jane P. Davidson. Herpetol. Rev. 30:60-61.

Dodd, C.K., Jr, 1999, Herpetology in the Federal Government: A personal view. Herp. League Commun. 6(1):7-9.

Dodd, C.K., Jr, 1999, (Review of) Monitoring Vertebrate Populations, by W.L. Thompson, G.C. White, and C. Gowan: Copeia 1999:540-541.

Dodd, C.K., Jr. 2000, A landmark publication on the amphibians of northern Eurasia: Alytes.

Dodd, C.K., Jr. 2000, An unusually patterned spotted python, *Antaresia maculosa,* from Jourama Falls, Queensland. Herpetofauna.

Dodd, C.K., Jr. 2000, Sternotherus depressus Tinkle and Webb 1955. Flattened musk turtle, *in* Pritchard, P.C.H., and Rhodin, A.J., eds., The Conservation Biology of Freshwater Turtles. Vol. 2: Chelonian Research Monographs.

Dodd, C.K., Jr. 2001, North American Box Turtles: A Natural History. Univ. Oklahoma Press, Norman.

Dodd, C.K., Jr., Ashton, Jr., R.E., Franz, R., and Wester, E., eds., 1990, Burrow associates of the gopher tortoise, Proceedings of the 1987 Symposium of the Gopher Tortoise Council, Gainesville, Florida Museum of Natural History, 134 p.

Dodd, C.K., Jr., and Byles, R.A., 1991 [1992], The status of loggerhead, *Caretta caretta;* Kemp's ridley, *Lepidochelys kempi;* and green, *Chelonia mydas*, sea turtles in U.S. waters: A reconsideration: Marine Fisheries Review 53(3):30-31.

Dodd, C.K., Jr., and B.A. Cade, 1998, Movement patterns and the conservation of amphibians breeding in small, temporary wetlands: Conservation Biology 12:331-339.

Dodd, C.K., Jr., and Dawes, C.J., 1993, Bluegreen and red algae identified from Florida loggerhead turtle: Marine Turtle Newsletter 60:14-15.

Dodd, C.K., Jr., and Franz, R., 1993, The need for status information on common herpetofaunal species, Herpetological Review 24:47-50.

Dodd, C.K., Jr., and R. Franz, 1995, Seasonal abundance and habitat use of selected snakes trapped in xeric and mesic communities of north-central Florida: Bulletin of the Florida Museum of Natural History 38:43-67.

Dodd, C.K. Jr., and R. Franz, 1996, Species richness and biogeography of the herpetophauna in the Exuma Cays Land and Sea Park, Bahamas, *in* Powell, R., and Henderson, R.W., eds., Contributions to West Indian Herpetology–A tribute to Al Schwartz: Ithaca, N.Y., SSAR Contributions to Herpetology, no. 12, p. 359-369.

Dodd, C.K. Jr., and R. Franz, 1996, The life-history and conservation biology of an island population of Florida box turtles Terrapene carolina bauri, *in* Proceedings of the International Congress of Chelonian Conservation, Editions SOPTOM, Gonfaron, France, p. 247-249.

Dodd. C.K., Jr., Franz, R., and Johnson, S.A., 1997, Shell injuries and anomalies in an insular population of Florida box turtles *(Terrapene carolina bauri):* Herpetological Natural History 51(1):66-72.

Dodd, C.K., Jr., Franz, R., and Smith, L., 1994, Activity patterns and habitat use of box turtles *(Terrapene carolina bauri)* on a Florida island, with recommendations for management: Chelonian Conservation & Biology 1:97-106.

Dodd, C.K., Jr., and M.L. Griffey, 1999, Geographic distribution: *Ambystoma talpoideum* (Mole salamander). Herpetological Review 30:105.

Dodd, C.K., Jr., and L.V. LaClaire, 1995, Biogeography and status of the striped newt *(Notophthalmus perstriatus)* in Georgia, USA. Herpetological Natural History 3:37-46.

Dodd, C.K., Jr., and Morgan, G.S., 1992, Fossil sea turtles from the early Pliocene Bone Valley Formation, central Florida, Journal of Herpetology 26(1):1-8.

Dodd. C.K., Jr., and M.L. Griffey, 1997, Natural history notes: *Scinella lateralis*. (Ground Skink). Predation. Herpetological Review 28:89.

Dodd, C.K., Jr., and Scott, D.E., 1994, Drift fences encircling breeding sites, *in* Heyer, W.R., Donnelly, M.A., McDiarmid, R.W., Hayek, L.C., and Foster, M.S., eds., Measuring and Monitoring Biological Diversity: Standard Methods for Amphibians, Smithsonian Institution Press, Washington, D.C., p. 125-130

Dodd, C.K., Jr., and Seigel, R.A., 1991, Relocation, repatriation, and translocation of amphibians and reptiles: Are they conservation strategies that work? Herpetologica 47(3):336-350.

Dong, Q., and DeAngelis, D.L., 1998, Consequences of cannibalism and competition for food in a smallmouth bass population: An individual-based modeling study. Transactions of the American Fisheries Society 127:174-191.

Dorazio, R.M, 1993, Prerelease stratification in tag-recovery models with time dependence, Canadian Journal of Fisheries and Aquatic Sciences 50(3):535-541.

Dorazio, R.M, 1995, Mortality estimates of striped bass caught in Albemarle Sound and Roanoke River, North Carolina. North American Journal of Fisheries Management 15:290-299.

Dorazio, R.M, 1997, Modelling heterogeneity in the recoveries of marked animal populations with covariates of individual animals, groups of animals, or recovery time: Environmental and Ecological Statistics 4:235-246.

Dorazio, R.M, 1999, Design-based and model-based inference in surveys of freshwater mollusks: Journal of the North American Benthological Society 18(1):118-131.

Dorazio, R.M., Florence, B.M., and Wooley, C.M., 1991, Stocking of hatchery-reared stripedbass in the Patuxent River, Maryland: survival, relative abundance, and cost-effectiveness, North American Journal of Fisheries Management 11:435-442.

Dorazio, R.M., Hattala, K.A., McCollough, C.B., and Skjeveland, J.E., 1994, Tag recovery estimates of migration of striped bass from spawning areas of the Chesapeake Bay, Transactions of the American Fisheries Society 123: 950-963.

Dorazio, R.M., and Rago, P.J., 1991, Evaluation of a mark-recapture method for estimating mortality and migration rates of stratified populations, Canadian Journal of Fisheries and Aquatic Sciences 48: 254-260.

Doyle, T.W., Smith, T.J., III, and Robblee, M.B., 1995, Wind damage effects of Hurricane Andrew on mangrove communities along the southwest coast of Florida, USA: Journal of Coastal Research (Special Issue #18), p. 159-168.

Duerr, A.D., 1995, Types of secondary porosity in carbonate injection intervals and overlying rocks in southern peninsular Florida: U.S. Geological Survey Water-Resources Investigations Report 94-4013, 78 p.

Duerr, A.D., and Enos, G.M., 1991, Hydrogeology of the intermediate aquifer system and upper Floridan aquifer, Hardee and De Soto Counties, Florida: U.S. Geological Survey Water-Resources Investigations Report 90-4104, 46 p.

Duerr, A.D., Hunn, J.D., Lewelling, B.R., and Trommer, J.T., 1988, Geohydrology and 1985 water withdrawals of the aquifer systems in southwest Florida, with emphasis on the intermediate aquifer system: U.S. Geological Survey Water-Resources Investigations Report 87-4259, 115 p.

Duerr, A.D., and Trommer, J.T., 1981, Estimated water use in the Southwest Florida Southwest Florida Water Management District and adjacent areas, 1979: U.S. Geological Survey Open-File Report 81-56, 58 p.

Duerr A.D., and Sohm, J.E., 1983, Estimated water use in southwest Florida, 1981, and summary of water use, 1970, 1975, and 1977-81: U.S. Geological Survey Open-File Report 83-45, 75 p.

Duerr, A.D., and Trommer, J.T., 1981, Estimated water use in the Southwest Florida Water Management District and adjacent areas, 1980: U.S. Geological Survey Open-File Report 81-1060, 60 p.

Duerr, A.D., and Trommer, J.T., 1982, The benchmark farm program--A method for estimating irrigation water use in southwest Florida: U.S. Geological Survey Water-Resources Investigations Report 82-17, 49 p.

Duerr, A.D., and Wolansky, R.M., 1986, Hydrogeology of the surficial and intermediate aquifers of central Sarasota County, Florida: U.S. Geological Survey Water-Resources Investigations Report 86-4068, 48 p.

Dwyer, G.S., and Cronin, T.M., 1999, Reconstructing the salinity history of Florida Bay using Ostracode shell chemistry, *in* Proceedings, 1999 Florida Bay and Adjacent Marine Systems Science Conference, Key Largo Florida, November 1-5, 1999: p. 158-159.

Dwyer, G.S., and Cronin, T.M., in review, Ostracode Shell Chemistry as a Paleosalinity Proxy in Florida Bay: Bulletins of American Paleontology, Special Volume.

Earle, J.E., 1975, Progress report on the water resources investigation of Martin County, Florida: U.S. Geological Survey Open-File Report FL-75521, 20 p.

Earle, J.E., and Meyer, F.W., 1973, Reconnaissance of the water resources in the vicinity of proposed deep-well injection sites in southeast Dade County, Florida: U.S. Geological Survey Open-File Report FL-73031, 20 p.

Easton, R.S., Orth, D.J., and Burkhead, N.M., 1993, First collection of rudd, Scardinius erythrophthalmus (*Cyprinidae)*, in the New River, West Virginia, Journal Freshwater Ecology 8(3):263-264.

Eberhardt, L.L, and O’Shea, T.J., 1995, Integration of manatee life-history data and population modeling, *in* O'Shea, T.J., Ackerman, B.B., and Percival, H.R., eds., Population Biology of the Florida Manatee *(Trichechus manatus latirostris*): U.S. Department of the Interior, National Biological Service, Information and Technology Report 1., p. 269-279.

Edwards, L.E., Weedman, S.D., Simmons, K.R., Scott, T.M., Brewster-Wingard, G.L., Ishman, S.E., and Carlin, N.M., 1998, Lithostratigraphy, Petrography, Biostratigraphy, and Strontium-Isotope Stratigraphy of the Surficial Aquifer System of Western Collier County, Florida: U.S. Geological Survey Open-File Report 98-205, 79 p.

Effort, I. E., C. Macias Garcia, and J. D. Williams, 1997, Facing the challenges of invasive alien species in North America. Global Biodiversity Canadian Museum of Nature 7(1):25-30.

Eisemann, J.D., Beyer, W.N., Bennetts, R.E., Morton, A., 1997, Mercury residues in south Florida apple snails *(Pomacea paludosa)*: Bulletin of Environmental Contamination & Toxicology, v. 58, p. 739-743.

Enge, K.M, and Dodd, Jr., C.K., 1992, An indexed bibliography of the herpetofauna of Florida: Florida Game and Fresh Water Fish Commission, Nongame Wildlife Progress Technical Report No, 11, 231 p.

Enge, K.M., Rice, K.G., Percival, H.F., Jennings, M.L., Masson, G.R., and Woodward, A.R., 1999, Summer nesting of turtles in alligator nests in Florida: Journal of Herpetology.

Enos, P., and Perkins, R.D., 1979, Evolution of Florida Bay from island stratigraphy: Geological Society of America Bulletin, v. 90, pt. 1, p. 59-83.

Eros, C., R.K. Bonde, O'Shea, T.J., C. Beck, H. Marsh, C. Recchia, and K. Dobbs, 2000, Procedures for the Salvage and Necropsy of the Dugong (Dugong dugon). GBRMPA Technical Report, Great Barrier Reef Marine Park Authority. Research Publication No. 64. 74 p.

Eschmeyer, W. N., B. Weibrecht and W. F. Smith-Vaniz, 1998, Appendix B. Opinions and other actions of the International Commission involving fishes, *in* Eschmeyer, W.N., ed., Catalog of Fishes, California Academy of Sciences, 2905 p. 2283-2905.

Estevez, E.D., 1986, Infaunal macroinvertebrates of the Charlotte Harbor estuarine system and surrounding inshore waters, Florida: U.S. Geological Survey Water-Resources Investigations Report 85-4260, 116 p.

Ewel, K.C., Twilley, R.R., and Ong, J.E., 1998, Different kinds of mangrove forests provide different goods and services: Global Ecology & Biogeography Letters 7, no. 1, p. 83-94.

Facemire, C.F., T.S. Gross and L.J. Guillette, 1995, Reproductive impairment in the Florida panther: Environmental Health Perspectives. 103(4):79-86

Fairbridge, R.W., 1984, The Holocene sea-level record in South Florida, *in* Gleason, P.J., ed., Environments of South Florida, Present and Past: Miami Geological Society of America Memoir 2, p. 223-231.

Ferguson, G.E., 1942, The plan and progress of recent surface water studies in the Everglades, *in* Proceedings of the The Soil Science Society of Florida: v. 4A, p. 77-85.

Ferguson, G.E., 1943, Summary of three years of surface water studies in the Everglades, *in* Proceedings of the The Soil Science Society of Florida: v. 5A, p. 18-23.

Ferguson, G.E., 1944, Symposium: Natural factors affecting water conservation and flood control in the Kissimmee valley--The surface water resources of the Kissimmee River basin, *in* Proceedings of the The Soil Science Society of Florida: v. 6, p. 16-18.

Fiedler, A.G., 1933, Deep-well salinity exploration: American Geophysical Union Transactions, p. 478-480.

Finucane, J.H., and Dragovitch, A., 1959, Counts of red tide organisms, *Gymnodinum breve*, and associated oceanographic data from Florida west coast 1954-1957: U.S. Fish and Wildlife Service Special Scientific Report—Fisheries, no. 289, p. 202-295.

Fischer, J.N., 1980, Evaluation of a cavity-riddled zone of the shallow aquifer near Riviera Beach, Palm Beach County, Florida: U.S. Geological Survey Water-Resources Investigations Report 80-60, 39 p.

Fish, J.E., 1988, Hydrogeology, aquifer characteristics, and ground-water flow of the surficial aquifer system, Broward County, Florida: U.S. Geological Survey Water-Resources Investigations Report 87-4034, 92 p, 10 sheets.

Fish, J.E., Causaras, C.R., and O'Donnell, T.H., 1983, Records of selected wells and lithologic logs of test holes, Hendry County and adjacent areas, Florida: U.S. Geological Survey Open-File Report 83-134, 116 p.

Fish, J.E., and Stewart, Mark, 1991, Hydrogeology of the surficial aquifer system, Dade County, Florida: U.S. Geological Survey Water-Resources Investigations Report 90-4108, 50 p, 11 sheets.

Fishman, M.J., and Friedman, L.C., 1989, Methods for determination of inorganic substances in water and fluvial sediments: U.S. Geological Survey Techniques of Water-Resource Investigations, book 5, chap. A1, 545 p.

Fitterman, D.V., 1995, Geophysical mapping of fresh/saltwater interface [abs.], *in* Proceedings of the Florida Bay Science Conference: A Report by Principal Investigators, October 17-18, 1995, Gainesville, Fla.: p. 44-46.

Fitterman, D.V., [1996], Geophysical Mapping of Freshwater/Saltwater Interfaces: U.S. Geological Survey Fact Sheet FS-173-96, 1 p.

Fitterman, D.V., 1997, Analysis of errors in HEM bird calibration: U.S. Geological Survey Open-File Report 97-742, 28 p.

Fitterman, D.V., 1998, Sources of calibration error in helicopter EM data: Exploration Geophysics, v. 29, p. 65-70.

Fitterman, D.V., 1999, Mapping saltwater intrusion without touching the ground: Experiences from Everglades National Park, *in* American Geophysical Union Meeting, December 17-17, 1999, San Francisco: American Geophysical Uniion, v. 80, no. 46, p. 371-372.

Fitterman, D.V., and Deszcz-Pan, M., 1997, Geophysical mapping of the freshwater/saltwater interface in Everglades National Park, *in* Gerould, Sarah, and Higer, A.L., eds., U.S. Geological Survey Program on the South Florida Ecosystem—Proceedings of the Technical Symposium in Ft. Lauderdale, Florida, August 25-28, 1997: U.S. Geological Survey Open-File Report 97-385, p. 13-14.

Fitterman, D.V., and Deszcz-Pan, M., 1998, Airborne geophysical estimation of water quality in Everglades National Park, *in* American Geophysical Union Meeting, May 26-29, 1998, Boston., Massachusetts: EOS, Transactions of the American Geophysical Union, v. 79, no. 17, p. S94.

Fitterman, D.V., and Deszcz-Pan, M., 1998, Helicopter EM mapping of saltwater intrusion in Everglades National Park, Florida: Exploration Geophysics, v. 29, p. 240-243.

Fitterman, D.V., and Deszcz-Pan, M., 1999, Geophysical mapping of saltwater intrusion in Everglades National Park, *in* Proceedings of the 3rd International Symposium on Ecohydraulics, 12-16 July 1999, Salt Lake City, Utah: 18 p, 7 figs. (on CD-ROM).

Fitterman, D.V., and Deszcz-Pan, M., 1999, Geophysical mapping of saltwater intrusion in Everglades National Park, *in* Gerould, Sarah, and Higer, A.L., eds., U.S. Geological Survey program on the south Florida ecosystem--Proceedings of South Florida Restoration Science Forum, May 17-19, 1999, Boca Raton, Florida: U.S. Geological Survey Open-File Report 99-181, p. 16-17.

Fitterman, D.V., Deszcz-Pan, Maria, 1999, Geophysical Mapping of Saltwater Intrusion in the Everglades National Park: U.S. Geological Survey South Florida Ecosystem Program paper, 18 p.

Fitterman, D.V., Deszcz-Pan, M., and Stoddard, C.E., 1999, Results of time-domain electromagnetic soundings in Everglades National Park, Florida: U.S. Geological Survey Open-File Report 99-426, 152 p., 3 plates (on CD-ROM).

Fitterman, D.V., Fennema, R.J., Fraser, D.C., and Labson, V.F., 1995, Airborne electromagnetic resistivity mapping in Everglades National Park, Florida, *in* Ball, R.S., ed., Proceedings of the Symposium on the Application of Geophysics to Engineering and Environmental Problems, April 23-27, 1995, Orlando, Florida: p. 657-670.

Fitterman, D.V., and Stewart, M.T., 1986, Transient electromagnetic sounding for groundwater: Geophysics, v. 51, no. 4, p. 995-1005.

Fitzpatrick, D.J., 1982, Hydrologic data from monitoring of saline-water intrusion in the Cape Coral area, Lee County, Florida: U.S. Geological Survey Open-File Report 82-772, 48 p.

Fitzpatrick, D.J., 1986, Hydrogeologic conditions and saline-water intrusion, Cape Coral, Florida, 1978-81: U.S. Geological Survey Water-Resources Investigations Report 85-4231, 89 p.

Fitzpatrick, D.J., 1986, Tests for injecting, storing, and recovering freshwater in a saline artesian aquifer, Lee county, Florida: U.S. Geological Survey Water-Resources Investigations Report 85-4249, 53 p.

Flippo, H.N., Jr., and Joyner, B.F., 1968, Low streamflow in the Myakka River basin area in Florida: Tallahassee, Florida Division of Geology Report of Investigations 53, 34 p.

Florida Bay Program Management Committee, 1997, Strategic plan for the Interagency Florida Bay Science Plan, 43 p.

Folmar, L.D., N.D. Denslow, R.A. Wallace, G. LaFleur, T.S. Gross, S. Bonomelli and C.V. Sullivan, 1995, A highly conserved N-terminal sequence for teleost vitellogenin with potential value to the biochemistry, molecular biology and pathology of vitellogenesis: Journal of Fish Biology, 46(2):255-263.

Foody, G.M., Lucas, R.M., Curran, P.J., and Honzak, M., 1997, Non-linear mixture modeling without end-members using an artificial neural network: International Journal of Remote Sensing, v. 18, no. 4, p. 937-953.

Foster, A.M, and J.P. Clugston, 1997, Seasonal migration of Gulf sturgeon in the Suwannee River, Florida. Transactions of the American Fisheries Society 126(2):302-308.

Foster, A.M., Williams, J.D., and Macurdy, H.M., 1992, Feeding trials of juvenile Gulf sturgeon, *Acipenser oxyrinchus desotoi* (abs.): American Society of Ichthyologists and Herpetologists, p. 101.

Fourqurean, J.W, and Robblee, M.B., 1999, Florida Bay: A history of recent ecological changes: Estuaries. 22, no. 2b, p. 345-357.

Francis-Floyd, F., and J. D. Williams, 1995, Behavioral research on captive endangered fishes of North America, *in* Gibbons, E.F., Jr., Durrant, B.S., and Demarest, J., eds., Conservation of Endangered Species in Captivity: p. 105-23.

Franz, R., and Dodd, C.K., Jr., 1994, Geographic distribution: Ameiva auberi obsoleta *(Exuma Islands Ameiva),* Herpetological Review 25:163-164.

Franz, R., and Dodd, C.K., Jr., 1994, Geographic distribution: Anolis sagrei ordinatus *(Bahamian Brown Anole),* Herpetological Review 25:164.

Franz, R., and Dodd, C.K., Jr., 1994, Geographic distribution: Leiocephalus carinatus virescens *(Exuma Islands Curlytail Lizard),* Herpetological Review 25:165.

Franz, R., and Dodd, C.K., Jr., 1994, Geographic distribution: *Sphaerodactylus nigropunctatus nigropunctatus* (Exuma Islands Black-spotted Ground Gecko), Herpetological Review 25:166.

Franz, R., and Dodd, C.K., Jr., 1994, Geographic distribution: *Sphaerodactylus notatus amaurus* (Great Bahama Bank Ground Gecko), Herpetological Review 25:166.

Franz, R., and Dodd, C.K., Jr., 1994, Life history notes: *Alsophis vudii vudii* (Brown runner), Diet and Growth, Herpetological Review 25:28.

Franz, R., Dodd, Jr., C.K., and Bard, A.M., 1992, The non-marine herpetofauna of Egmont Key, Hillsborough County, Florida: Florida Scientist 55:179-183.

Franz, R., C.K. Dodd, Jr., and S.D. Buckner, 1996, A review of herpetology of the Bahamian archipelago. Bahamas Journal of Science 3(3):22-30.

Franz, R., Dodd, Jr., C.K., and Buden, D.W., 1993, Distributional records of amphibians and reptiles from the Exuma Islands, Bahamas, including the first reports of a freshwater turtle and an introduced gecko, Caribbean Journal of Science 29:165-173.

Fraser, T.H., 1986, Long-term water-quality characteristics of Charlotte Harbor, Florida: U.S. Geological Survey Water-Resources Investigations Report 86-4180, 43 p.

Frederick, P. C., Spalding, M.G., Sepulveda, M.S., Williams, G.E., Nico, L.G., and Robins, R., 1999, Exposure of great egret *(Ardea albus)* nestlings to mercury through diet in the Everglades ecosystem: Environmental Toxicology and Chemistry 18(9):1940-1947.

Freiberger, H.J., 1972, Nutrient survey of surface waters in southern Florida during a wet and a dry season, September 1970 and March 1971: U.S. Geological Survey Open-File Report FL-72008, 29 p.

Freiberger, H.J., 1972, Streamflow variation and distribution in the Big Cypress watershed during wet and dry periods: Tallahassee, Florida Bureau of Geology Map Series 45, 1 sheet.

Freiberger, H.J., 1973, Effects of back pumping from south New River Canal at Pump Station S-9 on quality of water in Water-Conservation Area 3, Broward County, Florida: U.S. Geological Survey Open-File Report FL-73026, 64 p.

Freiberger, H.J., and McPherson, B.F., 1972, Water quality at Miami International Airport, Miami, Florida, 1971-72: U.S. Geological Survey Open-File Report FL-72023, 50 p.

Freiberger, H.J., and Steele, T.D., 1972, A preliminary assessment of water quality in south Florida: American Geophysical Union Transactions, v. 53, no. 4, p. 377.

Fry, B., 1983, Fish and shrimp migrations in the northern Gulf of Mexico analyzed using C, N, and S isotope ratios. Fishery Bulletin, v. 81, no. 4, p. 789-801.

Fry, B., Mumford, P.L., and Robblee, M.B., 1999, Stable isotope studies of pink shrimp *(Penaeus duorarum* Burkenroad) migrations on the southwestern Florida shelf: Bulletin of Marine Science, 65(2):419-430.

Fry, B., Robblee, M.B., and Mumford, P.L., 1997, Relationships between inshore nursery habitats of the pink shrimp, *Penaeus duorarum*, and offshore Tortugas and Sanibel fisheries, *in* Gerould, Sarah, and Higer, A.L., eds., U.S. Geological Survey Program on the South Florida Ecosystem—Proceedings of the Technical Symposium in Ft. Lauderdale, Florida, August 25-28, 1997: U.S. Geological Survey Open-File Report 97-385, p. 15-16.

Fuller, P.L, 1998, Nonindigenous species: methods of introduction and impacts. Transactions of the 63rd North American Wildlife and Natural Resources Conference. Wildlife Management Institute, Washington, D.C.

Fuller, P.L, 1999, The USGS Nonindigenous Aquatic Species Program: A drainage-based approach to tracking introductions: Aquatic Nuisance Species Digest.

Fuller, P. L., C. P. Boydstun, L. G. Nico, J. D. Williams, and A. J. Benson, 1996, National data base of nonindigenous fishes: A summary of fish introductions in the western United States (abs.): Proceedings Desert Fishes Council, 1995 Annual Symposium, November 16-19, 1995: Volume XXVII, p. 37-39.

Fuller, P.L., L.G. Nico, and J.D. Williams, 1999, Nonindigenous Fishes Introduced Into Inland Waters of the United States: American Fisheries Society Special Publication 27. Bethesda, MD. 613 p.

Gaff, H. D., J. Chick, DeAngelis, D.L., L. J. Gross, and R. Salinas, in press, Validation of ALFISH: Ecological Modeling.

Gaff, H., DeAngelis, D.L., Gross, L.J., Salinas, R., and Shorrosh, M., 1999, A dynamic landscape model for fish in the Everglades and its application to restoration: Ecological Modeling, v. 127, p. 33-52.

Gagen, C.J., Stoeckel, J.N., Beadel, R.K., Herod, J.J., and McCollum, D.O., 1994, Standard operating procedures for the fish monitoring project with ENTERGY Corporation, 18 p.

Gain, W.S., 1997, An optimized network for phsophorus load monitoring for Lake Okeechobee, Florida: U.S. Geological Survey Water-Resources Investigations Report 97-4011, 29 p.

Galliher, C.F., 1969, Development of water-control system in southeast Florida: American Society of Civil Engineers, v. 95, no. IR4.

Galliher, C.F., 1969, Water accounting at Pumping Station S-5A in Florida: American Society of Civil Engineers, Irrigation and Drainage Division, December 1969, p. 517-524.

Galliher, C.F., and Hull, J.E., 1969, Hydrologic conditions during 1967 in Dade County, Florida: U.S. Geological Survey Open-File Report FL-69001, 46 p.

Garcia-Rodriguez, A.I., B.W. Bowen, D. Domning, A.A. Mignucci-Giannoni, M. Marmontel, R.A. Montoya-Ospina, B. Morales-Vela, M. Rudin, R.K. Bonde, and P.M. McGuire, 1998, Phylogeography of the West Indian manatee *(Trichechus manatus)*: How many populations and how many taxa? Molecular Ecology 7(9):1137-1149.

Garmestani, A.S., Percival, H.F., Portier, K.M., and Rice, K.G., 2000, Nest-site selection by the loggerhead sea turtle in Florida's Ten Thousand Islands: Journal of Herpetology, 34(4):504-510.

Garrison, V.H, 1996, New records of fishes at Isla del Coco, Costa Rica: Bulletin of Marine Science, 58(3):861-864.

Garrison, V.H, 1998, Reef fishes of St. John, U.S. Virgin Islands, *in* Mac, M.J., Opler, P.A., C.E. Puckett, C.E., and Doran, P,D., eds., Status and trends of the Nation's biological resources: U.S. Geological Survey, 1:325-327.

Garrison, G. 2000, Isla del Coco Fishes: .Institito Nacional de Biodiversedad, 392 p.

Garrison, V.H., C.S. Rogers and J. Beets, 1998, Of reef fishes, overfishing and in situ observations of fish traps in St. John, USVI: Revista de Biologia Tropical, 46(5):41-59.

Garrison, G., E.A. Shinn, J. Miller, M. Carlo, R. Rodriguez, K. Koltes. 2000, Isla de Culebra, Puerto Rico—Changes in benthic cover on three reefs (1991-1998): U.S. Geological Survey, Water-Resources Investigations Report, 22 p.

German, E.R., 1996, Regional evaluation of evapotranspiration in the Everglades: U.S. Geological Survey Fact Sheet FS-168-96, 4 p.

German, E.R., 1996, Regional evaluation of evapotranspiration in the Everglades: U.S. Geological Survey Water-Resources Investigations Report 00-4217.

German, E.R., and Schiffer, D.M., 1988, Application of National Stream Quality Accounting Network (NASQAN) station data for assessing water quality in the Peace River basin, Florida: U.S. Geological Survey Water-Resources Investigations Report 87-4167, 73 p.

Gerould, Sarah, and Higer, A.L., eds., 1997, U.S. Geological Survey program on the south Florida ecosystem—Proceedings of the Technical Symposium in Ft. Lauderdale, Florida, August 25-28, 1997: U.S. Geological Survey Open-File Report 97-385, 99 p.

Gerould, Sarah, and Higer, Aaron, compilers, 1999, U.S. Geological Survey program on the South Florida Ecosystem—Proceedings of South Florida Restoration Science Forum, May 17-19, 1999, Boca Raton, Florida: U.S. Geological Survey Open-File Report 99-181, 121 p.

Gillen, D.F., 1996, Determination of roughness coefficients for streams in west-central Florida: U.S. Geological Survey Open-File Report 96-226, 93 p.

Gilmour, C.C., Riedel, G.S., Ederington, M.C., Bell, J.T., Benoit, J.M., Gill, G.A., and Stordal, M.C., 1998, Methylmercury concentrations and production rates across a trophic gradient in the northern Everglades: Biogeochemistry, v. 40, p. 327-345.

Gleason, P.J., and Stone, P., 1994, Age, origin and landscape evolution of the Everglades peatland, *in* Davis, S.M., and Ogden, J.C., Everglades: The ecosystem and its restoration: Delray Beach, Florida, St. Lucie Press, p. 149-197.

Goodkin, L.O., Crisman, T.L., and Williams, J.D., 1994, Temperature and salinity tolerance of selected nonindigenous fishes established or collected in Florida (abs.): Florida Scientist 57 (supplement), p. 25.

Goodwin, C.R., 1991, Simulation of the effects of proposed tide gates on circulation, flushing, and water quality in residential canals, Cape Coral, Florida: U.S. Geological Survey Open-File Report 91-237, 43 p.

Goodwin, C.R., 1996, Simulation of tidal-flow circulation, and flushing of the Charlotte Harbor estuarine system, Florida: U.S. Geological Survey Water-Resources Investigations Report 93-4153, 92 p.

Goolsby, D.A., Mattraw, H.C., Lamonds, A.G., Maddy, D.V., and Rollo, J.R., 1976, Analysis of historical water-quality data and description of plan for a sampling network in central and southern Florida: U.S. Geological Survey Water-Resources Investigations Report 76-52, 124 p.

Grantham, R.G., and Sherwood, C.B., 1968, Chemical quality of waters of Broward County, Florida: Tallahassee, Florida Division of Geology Report of Investigations 51, 52 p.

Gross, T.S., Armstrong, D.L., Simmons, L.G., and Schwartz, J.R., 1993, Estrus synchronization and successful artificial insemination in gaur *(Bos gaurus)*, J. Zoo Wildlife Med. 17:193-206.

Gross, T.S., K.A. Bjorndal, A.B. Bolten, L.J. Guillette Jr., R. Carthy, and D.A. Crain, 1995, Development of a non-invasive procedure for the determination of sex in loggerhead turtle hatchlings: General and Comp. Endo. 99:204-210.

Gross, L. J., and DeAngelis, D.L., 2001. Multimodeling: New approaches for linking ecological models, *in* Scott, J.M., Heglund, P.J., Morrison, M. Raphael, M., Haufler, J., and Wall, B., eds., Island Press, Covello, California.

Gross, L.J., DeAngelis, D.L., and Huston, M.A., 1998, Approaches to large-scale ecosystem modeling across multiple trophic levels: Some early lessons from the South Florida ATLSS Experience, *in* Waide, J.B., and Gandy, L.M., eds., Proceedings of the Workshop on Aquatic Ecosystem Modeling and Assessment Techniques for Application within the U.S. Army Corps of Engineers: Waterways Experiment Station: Miscellaneous Paper EL-98-1.

Gross, T.S., Guillette, L.J., Percival, H.F., Mason, G.R., Matter, J.M., Woodward, A.R., 1994, Contaminant induced reproductive anomalies in Florida alligators: Comp. Path. Bulletin 4:2-8.

Gross, T.S., Wieser, C., and Patton, M., 1993, Analysis of the ovarian cycle in black-footed ferrets *(Mustela nigripes)* by vaginal cytology and fecal hormone measurement: Biolological Reproduction 45:647-656.

Guillette, L.J., T.S. Gross, D.A. Gross, A.A. Rooney and H.F. Percival, 1995, Gonadal steroidogenesis in-vitro from juvenile alligators obtained from contaminated or control lakes: Environmental Health Perspectives. 103(4):31-36.

Guillette, L.J., A.R. Woodward, Q. You-Xiang, M.C. Cox, J.H. Matter and T.S. Gross, 1995, Formation and regression of the corpus luteum of the American alligator: Journal of Morphology, 224(1):97-110.

Gunderson, L.H., and Snyder, J.R., 1994, Fire patterns in the southern Everglades, *in* Davis, S.M., and Ogden, J.C, eds., Everglades: The ecosystem and its restoration, St. Lucie Press, Delray Beach, Florida, p. 291-305.

Haag, K.H., Bernard, B.A., Bradner, L.A., McCulloch, D.S., McPherson, B.R., and Miller, R.L., 1998, National water-quality assessment program: Study design for data collection in the southern Florida study unit, 1996-98: U.S. Geological Survey Fact Sheet FS-061-98, 4 p.

Haag, K.H., and McPherson, B.F., 1997, Organochlorine pesticides and PCBs in southern Florida fishes: Then and now: U.S. Geological Survey Fact Sheet FS-110-97, 4 p.

Haag, K.H., Miller, R.L., Bradner, L.A., and McCulloch, D.S., 1996, Water- Quality assessment of southern Florida: An overview of available information on surface- and ground-water quality and ecology: U.S. Geological Survey Water-Resources Investigations Report 96-4177, 42 p.

Hall, R.J., 1999, Monitoring change in protected areas: Problems of scope, scale, and power, *in* On the Frontiers of Conservation, *in* Harmon, D., ed., Proceedings of the 10th Conference on Research and Resource Management in Parks and on Public Lands: George Wright Society, Hancock, Mich., p. 271-277.

Hall, R.J., Henry, P.F.P., and Christine M. Bunck, C.M., 1999, Fifty year trends in a box turtle population in Maryland. Biological Conservation. 88:165-172.

Hall, F.G., Huemmrich, K.F., Goetz, S.J., Sellers, P.J., and Nickerson, J.E., 1992, Satellite remote sensing of surface energy balance: success, failures and unresolved issues in FIFE: Journal of Geophysical Research Atmospheres, v. 97, (d17), p. 19061-19090.

Halley, R.B., [1996], Sedimentation, Sea-Level Rise, and Circulation in Florida Bay: U.S. Geological Survey Fact Sheet FS-156-96.

Halley, R.B., Cronin, T.M., Wingard, G.L., and Ishman, S.E., 1998, Increased salinity of Florida Bay and saltwater intrusion of the Biscayne Aquifer during the early 20th century: Simultaneous consequences of falling water tables along the margins of the Everglades, *in* Proceedings, 1998 Florida Bay and Adjacent Marine Systems Science Conference, Key Largo Florida.

Halley, R.B., Prager, E.J., Yates, K.K., Holmes, C.W., and Stumpf, R.P, 1999, Modern sediment budgets and mudbank growth in Florida Bay, *in* Proceedings of the Geological Society of America 1999 Annual Meeting, October 25-28, 1999, Denver, Colorado: v. 31, no. 7, p. A-242.

Halley, R.B., Robbins, J.A., and Holmes, C.W., in preparation, Finding the recent past in Florida Bay.

Halley, R.B., Smith, D., and Hansen, M., 1996, Florida Bay salinity maps, surface and bottom salinity, 11/1994; 1,4,6,8,10,12/1995; 2,4,6/1996: U.S. Geological Survey Open-File Report 95-634, various monthly map sheets.

Hammett, K.M., 1981, Hydrologic description of Lake Jackson, Sebring, Florida: U.S. Geological Survey Water-Resources Investigations Open-File Report 81-494.

Hammett, K.M., 1988, Land use, water use, streamflow, and water-quality characteristics of the Charlotte Harbor inflow area, Florida: U.S. Geological Survey Open-File Report 87-472, 104 p.

Hammett, K.M., 1990, Land use, water use, streamflow characteristics, and water-quality characteristics of the Charlotte Harbor inflow area, Florida: U.S. Geological Survey Water-Supply Paper 2359-A, 64 p.

Hammett, K.M., 1992, Physical Processes, salinity characteristics, and potential salinity changes due to freshwater withdrawals in the tidal Myakka River, Florida: U.S. Geological Survey Water-Resources Investigations Report 90-4054, 20 p.

Hammett, K.M., Turner, J.F., Jr., and Murphy, W.R., Jr., 1978, Magnitude and frequency of flooding on the Myakka River, southwest Florida: U.S. Geological Survey Water-Resources Investigations Report 78-65, 40 p.

Hamilton, H., J.B. Box, and R.M. Dorazio, 1997, Effects of habitat suitability on the survival of relocated freshwater mussels. Regulated Rivers 13:537-541.

Hansen, M.L., and Dewitt, N.T., [1998], Modern and Historical Bathymetry of Florida Bay: U.S. Geological Survey Fact Sheet FS-98-096, 2 p.

Hanson, C.E., 1980, Freshwater resources of Big Pine Key, Florida: U.S. Geological Survey Open-File Report 80-447, 36 p.

Hardee, Jack, 1979, Instrumentation of urban hydrology monitoring sites in southeast Florida: U.S. Geological Survey Water-Resources Investigations Report 79-37, 38 p.

Hardee, Jack, Miller, R.A., and Mattraw, H.C., Jr., 1978, Stormwater-runoff data for a highway area, Broward County, Florida: U.S. Geological Survey Open-File Report 78-612, 166 p.

Hardee, Jack, Miller, R.A., and Mattraw, H.C., Jr., 1979, Stormwater-runoff data for a multifamily residential area, Dade County, Florida: U.S. Geological Survey Open-File Report 79-1295, 68 p.

Harrigan, P., Zieman, J.C., and Macko, S.A., 1989, The base of nutritional support for the gray snapper *(Lutjanus griseus)*: An evaluation based on combined stomach content and stable isotope analysis: Bulletin of Marine Science, v. 44, p. 65-77.

Hart, D. R., P. J. Mulholland, E. R. Marzolf, DeAngelis, D.L., and S. P. Hendricks, 1999, Relationships between hydraulic parameters in a small stream under varying flow and seasonal conditions. Hydrological Processes 13(10):1497-1510.

Hartwell, J.H., 1970, Some aspects of the availability of water from the Everglades to the Everglades National Park, Florida: U.S. Geological Survey Open-File Report FL-70007, 36 p.

Hartwell, J.H., and Klein, Howard, 1970, Preliminary appraisal of the hydrologic effect of the proposed Gum Slough Drainage District on Everglades National Park: U.S. Geological Survey Open-File Report FL-70009, 15 p.

Hartwell, J.H., Klein, Howard, and Joyner, B.F., 1963, Preliminary evaluation of hydrologic situation in Everglades National Park, Florida: U.S. Geological Survey Open-File Report FL-64002.

Harvey, J.W., [1996], Vertical Exchange of Ground Water and Surface Water in the Florida Everglades: U.S. Geological Survey Fact Sheet FS-162-96.

Harvey, J.W., 2000, Scale dependence of wetland and groundwater interactions in the Florida Everglades (abs.): Presented during the Annual Meeting of the Geological Society of America, November 9-18, 2000, Reno, Nevada.

Harvey, J.W., and Choi, J., 2000, Hydrologic interactions between surface and ground water in Taylor Slough, Everglades National Park (abs.): Presented during the Greater Everglades Ecosystem Restoration Conference, Naples, Florida, December 11-15, 2000.

Harvey, J.W., Jackson, J.M., Mooney, R.H., and Choi, J., 2000, Interactions between ground water and surface water in Taylor Slough and Vicinity, Everglades National Park, south Florida: study methods and appendixes: U.S. Geological Survey Open-File Report 00-483, 67 p.

Harvey, J.W., King, S.A., Fink, L.E., Krabbenhoft, D.P., Krupa, S.L., and Reddy, M.M., 2000, Role of interactions between groundwater and surface water in recharging and storing mercury within the surficial aquifer system of the northern Everglades (abs.): Presented during the American Geophysical Union Spring Meeting, May 30-June 3, 2000.

Harvey, J.W., and Krupa, S.L., 2000, Wetland and ground water interactions affected by water management in the Florida Everglades, *in* Proceedings of the Society of Wetland Scientists Annual Meeting, August 6-12, 2000, Quebec City, Canada, p. 396.

Harvey, J.W., Krupa, S.L., Choi, J., Gefvert, C., Mooney, R.H., Schuster, P.F., Bates, A.L., King, S.A., Reddy, M.M., Orem, W.H., Krabbenhoft, D.P., and Fink, L.E, 1999, Hydrologic exchange of surface water and ground water and its relation to surface water budgets and water quality in the Everglades, *in* Gerould, Sarah, and Higer, A.L., eds., U.S. Geological Survey Program on the south Florida ecosystem—Proceedings of South Florida Restoration Science Forum, May 17-19, 1999, Boca Raton, Florida: U.S. Geological Survey Open-File Report 99-181, p. 36.

Harvey, J.W., Krupa, S.L., and Fink, L., 1996, Hydrologic exchange between groundwater and surface water in the northern Everglades (abs.): Presented during the American Chemical Society Annual Meeting, August 25-29, 1996, Orlando, Fla.

Harvey, J.W., Krupa, S.L., Gefvert, C.G., Choi, J., Mooney, R.H., and Giddings, J.B., 2000, Interaction between ground water and surface water in the northern Everglades and relation to water budget and mercury cycling: study methods and appendixes: U.S. Geological Survey Open File Report 00-168. 411 p.

Harvey, J.W., Krupa, S.L., and Mooney, R.H., 1997, Spatial and seasonal variation in surface-groundwater exchange in the northern Everglades, *in* Gerould, Sarah, and Higer, A.L., eds., U.S. Geological Survey Program on the South Florida Ecosystem—Proceedings of the Technical Symposium in Ft. Lauderdale, Florida, August 25-28, 1997: U.S. Geological Survey Open-File Report 97-385, p. 30.

Harvey, J.W., Krupa, S.L., Mooney, R.H., Schuster, P., 1998, Are groundwater and surface water connected by vertical hydrologic fluxes through peat? (abs.): Presented during the 1998 American Geophysical Union Spring Meeting, May 26-29, 1998, Boston, Mass.

Hayes, A., Gilmour, C.C., and Benoit, J.M., 1998, Controls on the distribution of methylmercury in the Florida Everglades (abs.): Presented at the American Geophysical Union Meeting, June 1-4, 1999, Boston, Mass.

Haynes, R.R. and C. C. Jacono. 2000, Status of Salvinia *(Salviniaeceae)* in Alabama. Castanea.

Hendrix, A.N., and Loftus, W.F., 2000, Distribution and relative abundance of the crayfishes *Procambarus alleni* (Faxon) and *P. fallax* (Hagen) in southern Florida: Wetlands, v. 20, no.1, p. 194-199.

Hendrix, A.N., and Loftus, W.F., in preparation, Life-history parameters for *Procambarus fallax* in the Everglades system: Journal of Crustacean Biology.

Henry, H.R., and Kohout, F.A., 1972, Circulation patterns of saline groundwater affected by geothermal heating--As related to waste disposal: The American Association of Petroleum Geologists, Memoir no. 18, p. 202-221.

Herod, J.J., T.L. Frye, and J.B. Sickel, 1997, Blue catfish (Ictalurus furcatus ; Ictaluridae) predation on the zebra mussel in the Ohio River near Paducah, Kentucky. Transactions of the Kentucky Academy of Science. 58(2):96.

Herod, J.J., D.P. Reed, and J.B. Sickel, 1997, Distribution and population characteristics of zebra mussels, Dreissena polymorpha, *(Bivalvia: Dreissenidae)* in Kentucky Lake, Kentucky, *in* Scott, A.F., Hamilton, S.W., Chester, E.W., and White, D.S., eds., Proceedings of the Seventh Symposium on the Natural History of Lower Tennessee and Cumberland River Valleys. The Center for Field Biology, Austin Peay State University, Clarksville, Tennessee, p. 74-84.

Hickey, J.J., 1981, Borehole data-collection methods applicable for the Regional Observation and Monitor Well Program, Southwest Florida Water Management District: U.S. Geological Survey Water-Resources Investigations Report 81-57, 10 p.

Higer, A.L., Coker, A.E., and Cordes, E.H., 1976, Ecological model in Florida: U.S. Geological Survey Professional Paper 929, p. 150-152.

Higer, A.L., Cordes, E.H., and Coker, A.E., 1976, Water management model of the Florida Everglades: U.S. Geological Survey Professional Paper 929, p. 159-161.

Higer, A.L., Kolipinski, M.C., Thomson, N.S., and Thomson, F.J., 1970, Applications of multispectral data collection and processing techniques applied to hydro-biological investigations in Everglades National Park, Florida, March 1970: American Society of Photogrammetry.

Hite, L.R., Carlson, M.J., Wolfe, P.J., and Richard, B.H., 1997, Electromagnetics delineates aquifers between wells in southwest Florida: South Florida Ecosystem Meeting, Ft. Lauderdale, Florida, August 25-28, 1997.

Hittle, C.D., 1999, Delineation of saltwater intrusion in the surficial aquifer system in eastern Palm Beach, Martin, and St. Lucie Counties, Florida, 1997-98: U.S. Geological Survey Water-Resources Investigations Report 99-4214, 1 sheet.

Hoch, A.R., Reddy, M.M., and Aiken, G.R., 1998, Calcite crystal growth inhibition by organic acids isolated from the Florida Everglades, *in* Proceedings of the 216th American Chemical Society National Meeting, Boston, Mass., August 23-27, 1998: v. 38, no. 2, p. 78-81.

Hoch, A.R., Reddy, M.M., and Aiken, G.R., 1998, Inhibition of calcite growth by natural organic material from the Florida Everglades at pH = 8.5 and 25°C (abs.): Presented during the 1998 American Geophysical Union Spring Meeting, May 26-29, 1998, Boston, Mass.

Hoch, A.R., Reddy, M.M., and Aiken, G.R., 1999, Inhibition of calcite growth by dissolved organic carbon (DOC) isolated from the Florida Everglades (abs.): Presented during the American Chemical Society National Meeting, August 22-26, 1999, New Orleans.

Hoch, A.R., Reddy, M.M. and Aiken, G.R., 2000, Calcite crystal growth inhibition by humic substances with emphasis on hydrophobic acids from the Florida Everglades: Geochimica et Cosmochimica Acta, v. 64, no. 1, p. 61-72.

Hoch, A.R., Reddy, M.M., and Aiken, G.R., 2000, Inhibition of calcite crystal growth by natural organic acids from the Florida Everglades at pH 8.5 and 25°C (abs.): Presented at the Refractory Organic Substances in the Environment Conference, August 1-3, 2000, University of Karlsruhe, Karlsruhe, Germany.

Hofstetter, R.H., and Sonenshein, R.S., 1990, Vegetative changes in a wetland in the vicinity of a well field, Dade County, Florida: U.S. Geological Survey Water-Resources Investigations Report 89-4155, 16 p.

Holland, T.W., 1992, Water-use data collection techniques in the southeastern United States, Puerto Rico, and the U.S. Virgin Islands: U.S. Geological Survey Water-Resources Investigations Report 92-4028, 76 p.

Holmes, C.W., Marot, Marci, Willard, D.A., Weimer, Lisa, and Brewster-Wingard, G.L., 1997, Methods to establish the timing of ecological changes in south Florida—Good, Better, Best, *in* Gerould, Sarah, and Higer, A.L., eds., U.S. Geological Survey Program on the South Florida Ecosystem—Proceedings of the Technical Symposium in Ft. Lauderdale, Florida, August 25-28, 1997: U.S. Geological Survey Open-File Report 97-385, p. 33-34.

Holmes, C.W., Willard, D.A., and Brewster-Wingard, G.L., 1997, The geology of the Buttonwood Ridge and its historical significance, *in* Gerould, Sarah, and Higer, A.L., eds., U.S. Geological Survey Program on the South Florida Ecosystem—Proceedings of the Technical Symposium in Ft. Lauderdale, Florida, August 25-28, 1997: U.S. Geological Survey Open-File Report 97-385, p. 35-36.

Howard, K.S., Loftus, W.F., and Trexler, J.C., 1995, Seasonal dynamics of fishes in artificial culvert pools in the C-111 basin, Dade County, Florida: Final Report to the U.S Army Corps of Engineers as Everglades National Park Cooperative Agreement #CA5280-2-9024.

Howarter, S.R., 1999, Thermoregulation of the American alligator in the Everglades: Gainesville, University of Florida, M.S. Thesis, 73 p.

Howarter, S.R., Morea, C.R., Percival, H.F., Rice, K.G., and Abercrombie, C.L., 1999, Thermal ecology of the American alligator in the Everglades, *in* Managing Biodiversity: Orlando, Florida Chapter of the Wildlife Society.

Howarter, S.R., Rice, K.G., Percival, H.F., Portier, K.M., and Morea, C.R., 2000, Thermal ecology of the American alligator in the Everglades: Poster presentation at the 15th Working Meeting of the Crocodile Specialist Group, IUCN, Varadero, Cuba.

Howarter, S.R., Rice, K.G., Percival, H.F., Portier, K.M., and Morea, C.R., 2000, Thermal ecology of the American alligator in the Everglades, *in* Crocodiles—Proceedings of the15th Working Meeting of the Crocodile Specialist Group, IUCN, Gland, Switzerland: 18 p.

Howarter, S.R., Rice, K.G., Percival, H.F., and Morea, C.R., 2000, Alligator thermal ecology in the Everglades: Journal of Herp.

Howie, Barbara, 1987, Chemical characteristics of water in the surficial aquifer, Broward County, Florida: U.S. Geological Survey Water-Resources Investigations Report 86-4330, 2 sheets.

Howie, Barbara, 1992, Effects of dried wastewater-treatment sludge application on ground-water quality in south Dade County, Florida: U.S. Geological Survey Water-Resources Investigations Report 91-4135, 48 p.

Howie, Barbara, and Waller, B.G., 1986, Chemical effects of highway runoff on the surficial aquifer, Broward County, Florida: U.S. Geological Survey Water-Resources Investigations Report 86-4200, 41 p.

Hoy, N.D., 1948, Some important geologic problems to be encountered in the development of a fully effective water control program for south Florida, Proceedings: The Soil Science Society of Florida, v. 9.

Hoy, N.D., 1952, Map of Dade County, Florida, showing the approximate average annual water levels for 1945: U.S. Geological Survey Open-File Report FL-52002.

Hoy, N.D., 1952, Two maps of Dade County, Florida, showing approximate position of the 1,000-PPM isochlor as of 1951 and approximate area of potential saltwater penetration under 1945 conditions: U.S. Geological Survey Open-File Report FL-52001.

Hoy, N.D., 1952, Two maps of Dade County, Florida, showing the average annual water levels, 1950 and the approximate average water levels for the period 1940-1950: U.S. Geological Survey Open-File Report FL-52003.

Hoy, N.D., 1964, Generalized water-table contours in southern Florida: Tallahassee, Florida Division of Geology Map Series 7.

Hoy, N.D., and others, 1951, Six cross sections and an index map of the Miami area, Florida, showing changes in the position of the salt front in the Biscayne aquifer from 1946 to 1950: U.S. Geological Survey Open-File Report FL-51002.

Hoy, N.D., and Schroeder, M.C., 1952, Age of subsurface "Tamiami" Formation near Miami, Florida: The Journal of Geology, v. 60, no. 3, p. 283-286.

Hull, J.E., 1971, Hydrologic conditions during 1969 in Dade County, Florida: U.S. Geological Survey Open-File Report FL-71008, 50 p.

Hull, J.E., 1972, Hydrologic conditions during 1970 in Dade County, Florida: U.S. Geological Survey Open-File Report FL-72006, 80 p.

Hull, J.E., 1975, Summary of hydrologic data collected during 1974 in Dade County, Florida: U.S. Geological Survey Open-File Report FL-75012, 128 p.

Hull, J.E., 1978, Summary of hydrologic data collected during 1976 in Dade County, Florida: U.S. Geological Survey Open-File Report 78-883, 83 p.

Hull, J.E., 1979, Summary of hydrologic data collected during 1977 in Dade County, Florida: U.S. Geological Survey Open-File Report 79-514, 91 p.

Hull, J.E., and Beaven, T.R., 1977, Summary of hydrologic data collected during 1975 in Dade County, Florida: U.S. Geological Survey Open-File Report 77-803, 120 p.

Hull, J.E., and Galliher, C.F., 1968, Hydrologic conditions during 1966 in Dade County, Florida: U.S. Geological Survey Open-File Report FL-69002, 41 p.

Hull, J.E., and Galliher, C.F., 1970, Hydrologic conditions during 1968 in Dade County, Florida: U.S. Geological Survey Open-File Report FL-70002, 46 p.

Hull, J.E., and McKenzie, D.J., 1974, Summary of hydrologic data collected during 1973 in Dade County, Florida: U.S. Geological Survey Open-File Report FL-74029, 122 p.

Hull, J.E., McKenzie, D.J., and Meyer, F.W., 1973, Summary of hydrologic data collected during 1972 in Dade County, Florida: U.S. Geological Survey Open-File Report FL-73032, 109 p.

Hull, J.E., and Meyer, F.W., 1973, Salinity studies in East Everglades Agricultural Area, southeastern Dade County, Florida: Tallahassee, Florida Bureau of Geology Report of Investigations 66, 39 p.

Hull, J.E., and Wimberly, E.T., 1972, Hydrologic conditions during 1971 in Dade County, Florida: U.S. Geological Survey Open-File Report FL-72024, 104 p.

Hurley, J.P., Krabbenhoft, D.P., Cleckner, L.B., Olson, M.L., Aiken, G., and Rawlik, P.J., Jr., 1998, System controls on the aqueous distribution of mercury in the northern Florida Everglades: Biogeochemistry, v. 40, p. 293-310.

Hutchinson, C.B., 1984, Hydrogeology of the Verna well-field area and management alternatives for improving yield and quality of water, Sarasota County, Florida: U.S. Geological Survey Water-Resources Investigations Report 84-4006, 53 p.

Hutchinson, C.B., 1991, Assessment of hydrogeologic conditions with emphasis on water quality and wastewater injection, southwest Sarasota and west Charlotte Counties, Florida: U.S. Geological Survey Open-File Report 90-709, 102 p.

Hutchinson, C.B., 1992, Assessment of hydrogeologic conditions with Emphasis on water quality and wastewater injection, southwest Sarasota and west Charlotte Counties, Florida: U.S. Geological Survey Water-Supply Paper 2371, p. 74.

Hutchinson, C.B., Sanders, G.L., and Duerr, A.D., 1993, Underground injection in southwest Florida: U.S. Geological Survey Open-File Video Report 93-450.

Hutchinson, C.B., and Wilson, W.E., 1974, Evaluation of a proposed connector well, northeastern De Soto County, Florida: U.S. Geological Survey Water-Resources Investigations Report 5-74, 41 p.

Huvane, J.K., 1999, Diatoms as indicators of environmental change in Florida Bay, *in* Proceedings, 1999 Florida Bay and Adjacent Marine Systems Science Conference, Key Largo Florida, November 1-5, 1999: p. 186-188.

Huvane, J.K., in review, Modern Diatom Distributions in Florida Bay: A preliminary analysis in Linkages between ecosystems in the south Florida hydroscape, *in* Porter, K., and Porter, J., eds., The river of grass continues.

Huvane, J.K., Pyle, Laura, and Cooper,. S.R., 1998, Diatoms as paleoecological indicators of environmental change in the Florida Bay ecosystem, *in* Proceedings, 1998 Florida Bay and Adjacent Marine Systems Science Conference, Key Largo Florida.

Isbrücker, I.J., Nijssen, H., and Nico, L.G., 1992, Leporacanthicus triactis, a new loricariid fish from upper Orinoco River tributaries in Venezuela and Colombia (Pisces, Siluriformes, Loricariidae) (in German), Die Aquarien- und Terrarienzeitschrift (DATZ) 46(1):30-34.

Ishman, S.E., [1996], Ecosystem History of Biscayne Bay and the Southeast Coast: U.S. Geological Survey Fact Sheet FS-145-96.

Ishman, S.E., 1997, Ecosystem History of South Florida: Biscayne Bay Sediment Core Descriptions: U.S. Geological Survey Open-File Report 97-437, 15 p.

Ishman, S.E., Brewster-Wingard, G.L., Willard, D.A., Cronin, T.M., Edwards, L.E., and Holmes, C.W., 1996, Preliminary Paleontologic Report on Core T-24, Little Madeira Bay, Florida: U.S. Geological Survey Open-File Report 96-543, 27 p.

Ishman, S.E., Graham, Ian, and D'Ambrosio, Jill, 1997, Modern Benthic Foraminifer Distributions in Biscayne Bay: Analogs for Historical Reconstructions: U.S. Geological Survey Open-File Report 97-034, 20 p.

Jacob, P.G., 1980, Some aspects of the hydrogeology of coastal Collier County, Florida, *in* Gleason, P.J., ed., Water, Oil, and Geology of Collier, Lee, and Hendry Counties, Miami Geological Society, 1980 Field Experience Guidebook, p. 21-26.

Jacono, C.C., 1999, Salvinia molesta *(Salviniaceae),* new to Texas and Louisiana. Sida 18(3):927-928.

Jacono, C.C., T.R. Davern and T.D. Center, 2000, The adventive status of *Salvinia minima* and *S. molesta* in the southern United States and the related distribution of the weevil *Cyrtobagous salviniae*: Castanea (in press).

Jenkins, R.E., and Burkhead, N.M., 1994, The Freshwater Fishes of Virginia: American Fisheries Society, Bethesda, Md., 1079 p.

Jennings, D.P., and Williams, J.D., 1990, Don't release exotic fish, U.S. Fish and Wildlife Service Circular 886.

Jennings, D.P., and Williams, J.D., 1990, Status of exotic fish in the United States, U.S. Fish and Wildlife Service Research Information Bulletin No. 90-50.

Jennings, D.P., and Williams, J.D., 1993, Factors influencing the distribution of blackchin tilapia, *Sarotherodon melanotheron,* in the Indian River system, Florida, Northeast Gulf Science 12(2):111-117.

Jennings, M.E., and Doyle, W.H., Jr., 1978, Deterministic modeling of urban storm-water processes, Broward County, Florida: University of Kentucky Bulletin 116, p. 275-281.

Jenter, H.L., and Duff, M.P., in press, Locally Forced Wind Effects on Shallow Waters with Emergent Vegetation: U.S. Geological Survey South Florida Ecosystem Program paper, 9 p.

Jodice, P.G.R, and Snyder, J.R., 1992, Study links Big Cypress fox squirrel to golf courses, Park Science 12(4):20-21.

Jones, J.W., 2000, Image and *in situ* data integration to derive sawgrass density for surface flow modeling in the Everglades: International Association of Hydrologic Sciences Special Publication.

Joyner, B.F., 1971, Appraisal of chemical and biological conditions of Lake Okeechobee, Florida, 1969-70: U.S. Geological Survey Open-File Report FL-71006, 111 p.

Joyner, B.F., 1973, Nitrogen, phosphorus, and trace elements in Florida surface waters, 1970-71: U.S. Geological Survey Open-File Report FL-73028, 30 p.

Joyner, B.F., 1974, Chemical and biological conditions of Lake Okeechobee, Florida, 1969-72: Tallahassee, Florida Bureau of Geology Report of Investigations 71, 94 p.

Joyner, B.F., and Sutcliffe, Horace, Jr., 1967, Saltwater contamination in wells in the Sara-Sands area on Siesta Key, Sarasota County, Florida: American Water Works Association Journal, v. 59, no. 12, p. 1504-1512.

Joyner, B.F., and Sutcliffe, Horace, Jr., 1976, Water resources of the Myakka River basin area, southwest Florida: U.S. Geological Survey Water-Resources Investigations Report 76-58, 87 p.

Kane, R.L., 1992, Altitude of the water table in the surficial aquifer system, shallow zone, in easten Palm Beach County, Florida, May 1-5, 1989: U.S. Geological Survey Open-File Report 92-86, 1 sheet.

Kane, R.L., 1992, Altitude of the water table in the surficial aquifer system in St. Lucie and Martin Counties, Florida, May 1-5, 1989: U.S. Geological Survey Open-File Report 92-96, 1 sheet.

Kane, R.L., 1992, Altitude of the water table in the surficial aquifer system, shallow zone, in eastern Palm Beach County, Florida, May 13-23, 1988: U.S. Geological Survey Open-File Report 92-97, 1 sheet.

Kane, R.L., 1992, Altitude of the water table in the surficial aquifer system in St. Lucie and Martin Counties, Florida, May 13-23, 1988: U.S. Geological Survey Open-File Report 92-98, 1 sheet.

Kane, R.L., 1992, Altitude of the water table in the surficial aquifer system in St. Lucie and Martin Counties, Florida, October 27-31, 1988: U.S. Geological Survey Open-File Report 92-99, 1 sheet.

Kane, R.L., 1992, Altitude of the water table in the surficial aquifer system, shallow zone, in eastern Palm Beach County, Florida, October 24-26, 1988: U.S. Geological Survey Open-File Report 92-100, 1 sheet.

Kane, R.L., 1992, Potentiometric surface of the surficial aquifer system, deep zone, in eastern Palm Beach County, Florida, May 1-5, 1989: U.S. Geological Survey Open-File Report 92-102, 1 sheet.

Kane, R.L., 1992, Potentiometric surface of the surficial aquifer system, deep zone in eastern Palm Beach County, Florida, May 16-19, 1988: U.S. Geological Survey Open-File Report 92-101, 1 sheet.

Kane, R.L., 1992, Potentiometric surface of the surficial aquifer system, deep zone, in eastern Palm Beach County, Florida, October 24-26, 1988: U.S. Geological Survey Open-File Report 92-103, 1 sheet.

Kapadia, Amit, and Swain, E.D., 1996 South Florida Ecosystem Program: Quantifying freshwater discharge for coastal structures in eastern Dade County, Florida: U.S. Geological Survey Fact Sheet FS-123-96.4 p.

Kaufman, M.I., 1967, Hydrologic effects of ground-water pumpage in the Peace and Alafia River basins, Florida, 1934-1965: Tallahassee, Florida Division of Geology Report of Investigations 49, 32 p.

Kaufman, M.I., and Dion, N.P., 1967, Chemical character of water in the Floridan aquifer in southern Peace River basin, Florida: Tallahassee, Florida Division of Geology Map Series 27.

Kaufman, M.I., and Dion, N.P., 1968, Ground-water resources data of Charlotte, De Soto, and Hardee Counties, Florida: Tallahassee, Florida Division of Geology Information Circular 53, 24 p.

Kaufman, M.I., and McKenzie, D.J., 1975, Upward migration of deep-well waste injection fluids in Floridan aquifer, south Florida: U.S. Geological Survey Journal of Research, v. 3, no. 3, p. 261-271.

Kenner, W.E., and Brown, Eugene, 1956, Surface water resources in Lee County, Florida: Tallahassee, Florida Geological Survey Information Circular 7, part 1, 22 p.

King, S.A., Harvey, J.W., Krabbenhoft, D.P., Hunt, R.J., Armstrong, D.E., DeWild, J.F., and Olson, M.L., 1999, Distribution and transport mechanisms of mercury and methylmercury in peat of the Everglades nutrient removal area, *in* Gerould, S., and Higer, A., compilers, U.S. Geological Survey Program on the South Florida Ecosystem—Proceedings of South Florida Restoration Science Forum, May 17-19, 1999, Boca Raton, Florida: U.S. Geological Survey Open-File Report 99-181, p. 50-51.

Klein, Howard, 1954, Ground-water resources of the Naples area, Collier County, Florida: Tallahassee, Florida Geological Survey Report of Investigations 11, 64 p.

Klein, Howard, 1957, Interim report on salt-water encroachment in Dade County, Florida: Tallahassee, Florida Geological Survey Information Circular 9, 17 p.

Klein, Howard, 1958, Expansion of permanent water-supply facilities for the city of Miami, Florida: U.S. Geological Survey Open-File Report FL-58005.

Klein, Howard, 1965, Probable effect of Canal 111 on salt-water encroachment, southern Dade County, Florida: U.S. Geological Survey Open-File Report FL-65002, 26 p.

Klein, Howard, 1970, Preliminary evaluation of availability of potable water on Elliott Key, Dade County, Florida: U.S. Geological Survey Open-File Report FL-70010, 15 p.

Klein, Howard, 1972, The shallow aquifer of southwest Florida: Tallahassee, Florida Bureau of Geology Map Series 53.

Klein, Howard, 1973, Managing the water system, *in* Resource and land information, south Dade County, Florida: U.S. Geological Survey Investigation I-850, p. 18-25.

Klein, Howard, 1976, Simulations of water-level drawdowns in proposed well-field areas, Dade County, Florida: U.S. Geological Survey Open-File Report 76-651, 14 p.

Klein, Howard, 1980, Water-resources investigations, Collier County, Florida: U.S. Geological Survey Open-File Report 80-1207, 29 p.

Klein, Howard, 1985, Potentiometric surface of the Biscayne aquifer, northwest well field, Dade County, Florida, May 24, 1984: U.S. Geological Survey Open-File Report 86-60, 1 sheet.

Klein, Howard, 1985, Potentiometric surface of the Biscayne aquifer, northwest well field, Dade county, Florida, October 16, 1984: U.S. Geological Survey Open-File Report 86-59, 1 sheet.

Klein, Howard, Armbruster, J.T., McPherson, B.F., and Freiberger, H.J., 1975, Water and the south Florida environment: U.S. Geological Survey Water-Resources Investigations Report 24-75, 165 p.

Klein, Howard, and Hull, J.E., 1978, Biscayne aquifer, southeast Florida: U.S. Geological Survey Water-Resources Investigations Report 78-107, 52 p.

Klein, Howard, and Ratzlaff, K.W., 1989, Changes in saltwater intrusion in the Biscayne aquifer, Hialeah-Miami Springs area, Dade county, Florida: U.S. Geological Survey Water-Resources Investigations Report 87-4249, 1 sheet.

Klein, Howard, Schneider, W.J., McPherson, B.F., and Buchanan, T. J., 1970, Some hydrologic and biologic aspects of the Big Cypress Swamp drainage area, southern Florida: U.S. Geological Survey Open-File Report FL-70003, 94 p.

Klein, Howard, Schroeder, M.C., Lichtler, W.F., 1964, Geology and ground-water resources of Glades and Hendry Counties, Florida: Tallahassee, Florida Geological Survey Report of Investigations 37, 101 p.

Klein, Howard, and Sherwood, C.B., 1961, Hydrologic conditions in the vicinity of Levee 30, northern Dade County, Florida: Tallahassee, Florida Geological Survey Report of Investigations 24, part 1, 24 p.

Klein, Howard, and Sherwood, C.B., 1961, Under seepage along Levee 30, Dade County, Florida: U.S. Geological Survey Professional Paper 424-D.

Klein, Howard, and Waller, B.G., 1985, Synopsis of saltwater intrusion in Dade County, Florida through 1984: U.S. Geological Survey Water-Resources Investigations Report 85-4101, 1 sheet.

Knapp, Michael, Burns, W.S., and Sharp, T.S., 1986, Preliminary assessment of the groundwater resources of western Collier County, Florida: West Palm Beach, South Florida Water Management District, Technical Publication 86-1, 142 p.

Knochenmus, L.A., and Bowman, Geronia (Moe), 1998, Transmissivity and water quality of water-producing zones in the intermediate aquifer system, Sarasota county, Florida: U.S. Geological Survey Water-Resources Investigations Report 98-4091, 27 p.

Kohout, F.A., 1960, Cyclic flow of salt water in the Biscayne aquifer of southeastern Florida: Journal of Geophysical Research, v. 65, no. 7, p. 2133-2141.

Kohout, F.A., 1960, Flow pattern of fresh and salt water in the Biscayne aquifer of the Miami area, Florida: International Association of Science Hydrology Publication no. 52.

Kohout, F.A., 1961, Case history of salt water encroachment caused by a storm sewer in Miami: American Water Works Association Journal, v. 53, no. 11, p. 1406-1416.

Kohout, F.A., 1964, Flow of fresh water and salt water of the Biscayne aquifer of the Miami area, Florida: U.S. Geological Survey Water-Supply Paper 1613-C.

Kohout, F.A., 1965, A hypothesis concerning cyclic flow of salt water related to geothermal heating in the Floridan aquifer: New York Academy of Sciences, series II, v. 28, no. 2, p. 249-271.

Kohout, F.A., 1966, Submarine springs: A neglected phenomenon of coastal hydrology: Central Treaty Organization's Symposium on Hydrology and Water Resources Development, p. 391-413.

Kohout, F.A., 1967, Ground-water flow and the geothermal regime of the Floridan Plateau: Gulf Coast Association of Geological Societies, Transactions, v. XVII, p. 339-354.

Kohout, F.A., 1967, Relation of seaward and landward flow of ground water to the salinity of Biscayne Bay at Miami, Florida: U.S. Geological Survey Open-File Report FL-67012.

Kohout, F.A., and Hartwell, J.H., 1965, The Area B flood-control plan--Its influence on the future water resources of the Miami area, Florida: U.S. Geological Survey Open-File Report FL-65003.

Kohout, F.A., and Hartwell, J.H., 1967, Hydrologic effects of Area B flood control plan of urbanization of Dade County, Florida: Tallahassee, Florida Geological Survey Report of Investigations 47, 61 p.

Kohout, F.A., and Hoy, N.D., 1953, Research on salt-water encroachment in the Miami area, Florida: U.S. Geological Survey Open-File Report FL-53004, 20 p.

Kohout, F.A., and Hoy, N.D., 1963, Some aspects of sampling salty ground water in coastal aquifers: Ground Water, v. 1, no. 1., p. 28-32.

Kohout, F.A., and Klein, Howard, 1967, Effect of pulse recharge on the zone of diffusion in the Biscayne aquifer: International Association of Scientific Hydrology, v. 70, p. 252-270.

Kohout, F.A., and Kolipinski, M.C., 1967, Biological zonation related to groundwater discharge along the shore of Biscayne Bay, Miami, Florida: American Association for the Advancement of Science, p. 488-499.

Kohout, F.A., and Leach, S.D., 1964, Salt-water movement caused by control-dam operation in the Snake Creek Canal, Miami, Florida: Tallahassee, Florida Geological Survey Report of Investigations 24, part 4, 49 p.

Kohout, F.A., and Meyer, F.W., 1959, Hydrologic features of the Lake Placid area, Highlands County, Florida: Tallahassee, Florida Geological Survey Report of Investigations 19, pt. II, 38 p.

Kolipinski, M.C., and Higer, A.L., 1966, Ecological Research in Everglades National Park: National Parks Magazine, v. 40, no. 229, 5 p.

Kolipinski, M.C., and Higer, A.L., 1968, Applications of aerial photography and remote sensing to hydrobiological research in south Florida: U.S. Geological Survey Open-File Report FL-68009, 7 p.

Kolipinski, M.C., and Higer, A.L., 1969, Effects of mineralized artesian water on the fresh-water biota of Taylor Slough, Everglades National Park, Florida: U.S. Geological Survey Open-File Report FL-69009, 39 p.

Kolipinski, M.C., and Higer, A.L., 1969, Some aspects of the effects of the quantity and quality of water on biological communities in Everglades National Park: U.S. Geological Survey Open-File Report FL-69007, 97 p.

Kolipinski, M.C., Higer, A.L., and Yates, M.L., 1971, Organochlorine insecticide residues in Everglades National Park and Loxahatchee National Wildlife Refuge, Florida: Pesticides Monitoring Journal, v. 5, no. 3, p. 281-288.

Koszalka, E.J., 1995, Delineation of saltwater intrusion in the Biscayne aquifer, eastern Broward County, Florida, 1990: U.S. Geological Survey Water-Resources Investigations Report 93-4164, 1 sheet.

Krabbenhoft, D.P., [1996], Mercury Studies in the Florida Everglades: U.S. Geological Survey Fact Sheet FS-166-96, 4 p.

Krabbenhoft, D.P., Hurley, D.P., Olson, M.L., and Cleckner, L.B., 1998, Diel variability of mercury phase and species distributions in the Florida Everglades: Biogeochemistry, 40, p. 311-325.

Krabbenhoft, D.P., and Rickert, D.A., in review, Mercury Contamination of Aquatic Ecosystems: U.S. Geological Survey Fact Sheet.

Krest, J.M., and Harvey, J.W., 2000: Quantifying hydrologic exchange between surface and ground water in the Florida Everglades, WCA-2A (abs.): Presented during the Greater Everglades Ecosystem Restoration Conference, Naples, Florida, December 11-15, 2000.

Krulikas, R.K., and Giese, G.L., 1995, Recharge to the surficial aquifer system in Lee and Hendry Counties, Florida: U.S. Geological Survey Water-Resources Investigations Report 95-4003, 21 p.

Krupa. S.L., Harvey, J.W., Gefvert, C., and Giddings, J., 1998, Geologic and anthropogenic influences on groundwater-surface water interactions in the northern Everglades, *in* American Geophysical Union Meeting, May 26-29, 1998, Boston., Massachusetts: EOS, Transactions of the American Geophysical Union, v. 79, no. 17, p. S176.

Kushlan, J.A., Ogden, J.C., and Higer, A.L., 1975, Relation of water level and fish availability to wood stork reproduction in the southern Everglades, Florida: U.S. Geological Survey Open-File Report 75-434, 56 p.

Kustas, W.P., and Norman, J.M., 1996, Use of remote sensing for evapotranspiration monitoring over land surfaces: Hydrological Sciences Journal, v. 41, no. 4, p. 495-516.

Kuzmin, S.L, and C.K. Dodd, Jr., eds., 1997, Advances in Amphibian Research in the Former Soviet Union, Vol. 1: Sofia, Bulgaria, Pensoft Publishing., 190 p.

Kuzmin, S.L, and C.K. Dodd, Jr., eds., 1997, Advances in Amphibian Research in the Former Soviet Union.,Vol 2: Sofia, Bulgaria, Pensoft Publishing, 233 p.

Kuzmin, S.L., C.K. Dodd, Jr., and M.M. Pikulik., eds., 1995, Amphibian Populations in the Commonwealth of Independent States: Current Status and Declines. Pensoft Publishing, Moscow, Russia. 159 p.

Florida manatees *(Trichechus manatus latirostris):* Ecology 79(3):981-997.

Land L.F., 1972, Progress report on water-resources investigations in Palm Beach County, Florida: U.S. Geological Survey Open-File Report FL-72014, 40 p.

Land, L.F., 1975, Effects of lowering interior canal stages on salt-water intrusion into the shallow aquifer in southeast Palm Beach County, Florida: U.S. Geological Survey Open-File Report 75-74, 59 p.

Land, L.F., 1977, Ground-water resources of the Riviera Beach area, Palm Beach County, Florida: U.S. Geological Survey Water-Resources Investigations Report 77-47, 38 p.

Land, L.F., 1977, Utilizing a digital model to determine the hydraulic properties of a layered aquifer: Ground Water, v. 15, no. 2.

Land, L.F., Rodis, H.G., and Schneider, J.J., 1973, Appraisal of the water resources of eastern Palm Beach County, Florida: Tallahassee, Florida Bureau of Geology Report of Investigations 67, 64 p.

Langtimm, C.A., Dodd, C.K., Jr., and Franz, R., 1996, Estimates of abundance of box turtles *(Terrapene carolina bauri)* on a Florida island. Herpetologica 52(4):496-504.

Langtimm, C.A., TO'Shea, T.J., Pradel, R., and Beck, C.A., 1998, Estimates of annual survival probabilities for adult La Rose, H.R., 1977, Fluctuations of ground-water levels in Lee County, Florida, in 1976 water year: U.S. Geological Survey Open-File Report 77-771, 98 p.

La Rose, H.R., 1990, Geohydrologic framework and an analysis of a well- plugging program, Lee County, Florida: U.S. Geological Survey Water-Resources Investigations Report 90-4063, 26 p, 1 pl.

La Rose, H.R., and McPherson, B.F., 1980, Hydrologic and land-cover features of the Caloosahatchee River basin, Lake Okeechobee to Franklin Lock, Florida: U.S. Geological Survey Water-Resources Investigations Open-File 80-732, 1 sheet.

La Rose, H.R., and McPherson, B.F., 1983, Chemical and hydrologic assessment of the Caloosahatchee River basin, Lake Okeechobee to Franklin Lock, Florida: U.S. Geological Survey Water-Resources Investigations Report 83-4126, 63 p.

Leach, S.D., and Grantham, R.G., 1966, Salt-water study of the Miami River and its tributaries, Dade County, Florida: Tallahassee, Florida Geological Survey Report of Investigations 45, 36 p.

Leach, S.D., Klein, Howard, and Hampton, E.R., 1972, Hydrologic effects of water control and management of southeastern Florida: Tallahassee, Florida Bureau of Geology Report of Investigations 60, 115 p.

Leach, S.D., and Sherwood, C.B., 1963, Hydrologic studies in the Snake Creek Canal area, Dade County, Florida: Tallahassee, Florida Geological Survey Report of Investigations 24, pt. 3, 33 p.

Lee, H.L, and D.L. DeAngelis, 1997, A simulation study of the spatio-temporal dynamics of the Unionid mussels: Ecological Modeling 95(2-3):171-180.

Lee, H.L., DeAngelis, D.L., and H.-L. Koh, 1998, Modeling spatial distribution of the unionid mussels and the core-satellite hypothesis. Water Science and Technology 7:73-79.

Lee, J.K., 1996, Vegetation affects water movement in the Florida Everglades, U.S. Geological Survey Fact Sheet FS-147-96.

Lee, J.K., and Carter, Virginia, 1997, Vegetative resistance to flow in the Florida Everglades, *in* Gerould, Sarah, and Higer, A.L., eds., U.S. Geological Survey Program on the South Florida Ecosystem—Proceedings of the Technical Symposium in Ft. Lauderdale, Florida, August 25-28, 1997: U.S. Geological Survey Open-File Report 97-385, p. 49-50.

Lee, J.K. and Carter, Virginia, 1999, Field measurements of flow resistance in the Florida Everglades, *in* Gerould, Sarah, and Higer, A.L., eds., U.S. Geological Survey Program on the south Florida ecosystem—Proceedings of South Florida Restoration Science Forum, May 17-19, 1999, Boca Raton, Florida: U.S. Geological Survey Open-File Report 99-181, p. 60-61.

Lee, J.K., Visser, H.M., and Jenter, H.L., 2000, Velocity and stage data collected in a laboratory flume for water-surface slop determination using a pipe manometer: U.S. Geological Survey Open-File Report.

Lefebvre, L.W., B.B. Ackerman, K.M. Portier, and K.H. Pollock, 1995, Aerial survey as a technique for estimating manatee population size and trend--problems and prospects, *in* O'Shea T.J., Ackerman, B.B., and Percival, H.F., eds., Population Biology of the Florida Manatee *(Trichechus manatus latirostris):* U.S. Department of the Interior, National Biological Service, Information and Technology Report 1, p. 63-74.

Lefebvre, L.W., and Kochman, H.I., 1991, An evaluation of aerial survey replicate count methodology to determine trends in manatee abundance, Wildlife Society Bulletin 19:298-809.

Lefebvre, L.W., and O’Shea, T.J., 1995, Florida manatees, *in* Our Living Resources--Coastal and Marine Ecosystems: U.S. Department of the Interior, National Biological Service, p. 267-269.

Lefebvre, L.W., and Powell, J.A., 1990, Manatee grazing impacts on seagrasses in Hobe Soundand Jupiter Sound in southeast Florida during the winter of 1988-1989, National Technical Information Service, #PB90-271883, Springfield, Va, 36 p.

Lefebvre, L.W., J.P. Reid, W.J. Kenworthy, and J.A. Powell, 2000, Characterizing manatee habitat use and seagrass grazing in Florida and Puerto Rico: implications for conservation and management. Pacific Conservation Biology 5(4):289-298.

LeGrand, H.E., and Stringfield, V.T., 1966, Development of permeability and storage in the Tertiary limestones of the southeastern United States, USA: International Association of Scientific Hydrology, v. 11, no. 4, p. 61-73.

Lemeshewsky, G.P., 1997, Neural network-based sharpening of Landsat thermal-band images: Proc. SPIE, v. 3387, Visual Information Processing VII, p. 378-386,

Lemeshewsky, G.P., 1997, Neural network method for sharpening LANDSAT thermal data from higher resolution multispectral data, U.S. Geological Survey Open-File Report 97-301.

Lemeshewsky, G.P., 1999, Multispectral multisensor image fusion using wavelet transforms: Proc. SPIE, v. 3716, Visual Information Processing VIII, p. 214-222,

Lemeshewsky, G.P., 1999, Speckle noise reduction in RADARSAT imagery using wavelet transform techniques: Abstract and Poster Session, ASPRS Annual Conference, May 17-21, 1999.

Lemeshewsky, G.P., 2000, Landsat thermal infrared image sharpening using artificial neural network techniques: Abstract and Presentation, ASPRS Annual Conference, May 22-26, 2000.

Levesque, V.A., 1996, Water flows and nutrient loads to the southwest coast of Florida: U.S. Geological Survey Fact Sheet FS-179-96, 2 sheets.

Levesque, V.A., 1997, Water flows and nutrient loads to the southwest coast of Florida, *in* Gerould, Sarah, and Higer, A.L., eds., U.S. Geological Survey Program on the South Florida Ecosystem—Proceedings of the Technical Symposium in Ft. Lauderdale, Florida, August 25-28, 1997: U.S. Geological Survey Open-File Report 97-385, p. 53-54.

Lewelling, B.R., Tihansky, A.B., and Kindinger, J.L., Assessment of the hydraulic connection between ground water and the Peace River, west-central Florida: U.S. Geological Survey Water-Resources Investigations Report 97-4211, 96 p.

Ley, J.A., C.C. McIvor and C. Montague, 1999, Fishes in mangrove prop-root habitats of northeastern Florida Bay: distinct assemblages across an estuarine gradient: Estuarine, Coastal and Shelf Science 48(6):701-703.

Lichtler, W.F., 1957, Ground-water resources of the Stuart area, Martin County, Florida: Tallahassee, Florida Geological Survey Information Circular 12, 47 p.

Lichtler, W.F., 1960, Geology and ground-water resources of Martin County, Florida: Tallahassee, Florida Geological Survey Report of Investigations 23, 149 p.

Lietz, A.C., 1991, Altitude of water table in the Biscayne aquifer, Broward County, Florida, April 26-29, 1988: U.S. Geological Survey Open-File Report 92-31, 1 sheet.

Lietz, A.C., 1991, Altitude of water table in the Biscayne aquifer, Dade County, Florida, April 25-28, 1988: U.S. Geological Survey Open-File Report 92-32, 1 sheet.

Lietz, A.C., 1996, Assessment of water quality in the South Indian River Water Control District, Palm Beach County, Florida, 1989-94: U.S.Geological Survey Open-File Report 96-495, 63 p.

Lietz, A.C., 1996, South Florida Ecosystem Program: Methodology for the determination of nutrient loads from east coast canals to Biscayne Bay: U.S. Geological Survey Fact Sheet FS-129-96, 2 p.

Lietz, A.C., 1997, Determination of nutrient loads to Biscayne Bay, Dade County, Florida, *in* Gerould, Sarah, and Higer, A.L., eds., U.S. Geological Survey Program on the South Florida Ecosystem—Proceedings of the Technical Symposium in Ft. Lauderdale, Florida, August 25-28, 1997: U.S. Geological Survey Open-File Report 97-385, p. 55.

Lietz, A.C., 1999, Methodology for estimating nutrient loads discharged from the east coast canals to Biscayne Bay, Miami-Dade County, Florida: U.S. Geological Survey Water-Resources Investigations Report 99-4094, 36 p.

Loftus, W.F., 1995, An annotated inventory of the fishes of Everglades National Park, Florida, *in* An annotated inventory of the vertebrates of Everglades National Park, Report to Everglades National Park.

Loftus, W.F., 2000, An inventory of the fishes of Everglades National Park: Florida: Florida Scientist, v. 63, no. 1, p. 27-47.

Loftus, W.F., Bass, O.L., and Trexler, J.C., 1997, Long-term fish monitoring in the Everglades: Looking beyond the park boundary, *in* Harmon, D. ed., Making protection work: Proceedings of the ninth conference on research and resource management in parks and on public lands: The George Wright Society Biennial Conference: p. 389-392.

Loftus, W.F., and Eklund, A.M., 1994, Long-term dynamics of an Everglades fish community, *in* Davis, S., and Ogden, J.C. eds., Everglades: The System and its Restoration: St. Lucie Press, Delray Beach, Florida, Chapter 19, p. 461-483.

Loftus, W.F., and Reid, J.W., 2000, Copepod *(Crustacea)* emergence from soils from Everglades marshes with different hydroperiods: Journal of Freshwater Ecology, v. 15, no. 4, p. 515-523.

Loope, L., Duever, M., Herndon, A., Snyder, J., and Jansen, D., 1994, Hurricane impact on uplands and freshwater swamp forest: Large trees and epiphytes sustained the greatest damage during Hurricane Andrew: BioScience 44(4):238-246.

Loreau, M, and D.L. DeAngelis, 1997, Source-sink dynamics and the coexistence of species on a single resource. Theoretical Population Biology 51(2):79-93.

Lorenz, J.J., C.C. McIvor, G.V.N. Powell, and P.C. Frederick, 1997, Drop net for quantitatively sampling fishes over wetland surfaces in the dwarf mangrove of the southern Everglades. Wetlands 17(3):346-359.

Love, S.K., 1945, Cation-exchange in ground water contaminated with sea water, Miami, Florida: American Geophysical Union Transactions, part 6, 1944.

Love, S.K., and Petretic, G.J., 1942, Memorandum on the chemical character of water in the Miami, North New River, and South New River Canals near Miami, Florida: U.S. Geological Survey Open-File Report FL-42001.

Love, S.K., and Swenson, H.A., 1942, Chemical character of public water supplies in southeastern Florida: American Water Works Association Journal, v. 34, no. 11, p. 1624-1628.

Ludlow, M.E, and Walsh, S.J., 1991, Occurrence of a South American Armored Catfish in the Hillsborough River, Florida: Florida Scientist 54(1):48-50.

Lugo, A.E., Rogers, C.S., and Nixon, S.W., 2000, Hurricanes, coral reefs and rainforests: resistance, ruin and recovery in the Caribbean: Ambio 29(2):106-114.

Lydeard, C., Garner, J.T., Hartfield, P., and Williams, J.D., 1999, Freshwater mussels in the Gulf region: Alabama. Gulf of Mexico Science 17(2):125-134.

Maddy, D.V., 1978, Dissolved-solids budget of Lake Okeechobee, Florida, October 1964 to September 1974: U.S. Geological Survey Water-Resources Investigations Report 77-97, 36 p.

Madeira, P.T., Jacono, C.C., and Van, T.K., 2000, Monitoring hydrilla using two RAPD procedures and the Nonindigenous Aquatic Species Database: Journal of Aquatic Plant Management, v. 38, p. 33-40.

Mahon, G.L., 1989, Potential for saltwater intrusion into the upper Floridan aquifer, Hernando and Manatee Counties, Florida: U.S. Geological Survey Water-Resources Investigations Report 88-4171, 47 p.

Manheim, F.T., 1967, Evidence for submarine discharge of water on the Atlantic continental slope of the southern United States and suggestions for further research: New York Academy of Sciences Transactions, v. 29, no. 7.

Marella, R.L., 1998, Water-quality assessment of southern Florida--Wastewater discharges and runoff: U.S. Geological Survey Fact Sheet FS-032-98, 6 p.

Marmontel, M., Humphrey, S.R., and O'Shea, T.J., 1997, Population viability analysis of the Florida manatee (Trichechus manatus latirostris), 1976-1991: Conservation Biology 11(2):467-481.

Marmontel, M., O'Shea, T.J., and Humphrey, S.R., 1990, An evaluation of bone growth layer counts as an age-determination technique in Florida manatees, National Technical Information Service, #PB91-103564, Springfield, Va., 94 p.

Marmontel, M., O'Shea, T.J., Kochman, H.I., and Humphrey, S.R., 1996, Age determination in manatees using growth-layer-group counts in bone. Marine Mammal Science 12(1):54-88.

Marvin-DiPasquale, M.C., Agee, J., McGowan, C., Oremland, R.S., Thomas, M., Krabbenhoft, D.P., and Gilmour, C.C., 2000, Methyl-Mercury Degradation Pathways—A Comparison Among Three Mercury Impacted Ecosystems: Environmental Science and Technology, v. 34, no. 23, p. 4908-4916.

Marvin-DiPasquale, M.C., Oremland, R.S., 1998, Bacterial methylmercury degradation in Florida Everglades peat sediment: Environmental Science & Technology, v. 32, no. 17, p. 2556-2563.

Marsh, H., Beck, C.A., and Vargo, T., 1999, Comparison of the capabilities of dugongs and West Indian manatees to masticate seagrasses. Marine Mammal Science 15(1):250-255.

Marsh, H., and Lefebvre, L.W., 1994, Sirenian status and conservation efforts, Aquatic Mammals 20(3):155-170, O'Shea, T.J, 1994, Manatees, Scientific American, July 1994, 271(1):66-72.

Marsh, H., and Rathbun, G.B., 1990, Development and application of conventional and satellite radio tracking techniques for studying dugong movements and habitat use, Australian Wildlife Research 17:83-100.

Marsh, H., Rathbun, G.B., O'Shea, T.J., Shea, and Preen, A.R., 1995, Can Dugongs Survive in Palau? Biological Conservation 72:85-89.

Matheson, R.E., Jr., Camp, D.K., Sogard, S.M., and Bjorgo, K.A., 2000, Changes in seagrass-associated fish and crustacean communities on Florida Bay mud banks: The effects of recent ecosystem changes?: Estuaries, 22(2B):534-551.

Matsinos, Y.G., Wolff, W.F., and DeAngelis, D.L., in press, Can individual-based models yield a better assessment? in, Ferson, S., ed., Quantitative Methods in Conservation Biology, Springer-Verlag, New York.

Mattraw, H.C., Jr., 1975, Occurrence of chlorinated hydrocarbon insecticides, southern Florida, 1968-72: Pesticides Monitoring Journal, v. 9, no. 2, p. 106-114.

Mattraw, H.C., Jr., 1976, Ground-water quality in the Davie landfill, Broward County, Florida: U.S. Geological Survey Water-Resources Investigations Report 76-56, 29 p.

Mattraw, H.C., Jr., 1978, Quality and quantity of storm-water runoff from three land-use areas, Broward County, Florida: University of Kentucky Bulletin 116, p. 253-257.

Mattraw, H.C., Jr., Hardee, Jack, and Miller, R.A., 1978, Urban storm-water runoff data for a residential area, Pompano Beach, Florida: U.S. Geological Survey Open-File Report 78-324, 108 p.

Mattraw, H.C., Jr., Hull, J.E., and Klein, Howard, 1978, Ground-water quality near the N.W. 58th Street solid-waste disposal facility, Dade County, Florida: U.S. Geological Survey Water-Resources Investigations Report 78-45, 61 p.

Mattraw, H.C., Jr., and Miller, R.A., 1981, Stormwater quality processes for three land-use areas in Broward County, Florida: U.S. Geological Survey Water-Resources Investigations Report 81-23, 56 p.

Mattraw, H.C., Jr., Scheidt, D.J., and Federico, A.C., 1987, Analysis of trends in water-quality data for water conservation area 3A, The Everglades, Florida: U.S. Geological Survey Water-Resources Investigations Report 87-4142, 52 p.

Mattraw, H.C., Jr., and Sherwood, C.B., 1977, Quality of stormwater runoff from a residential area, Broward County, Florida: U.S. Geological Survey, Journal of Research, v. 5, no. 6, p. 823-834.

McCann, J. A., L. N. Arkin, and J. D. Williams, 1996, Nonindigenous aquatic and selected terrestrial species of Florida. Report to U.S. Fish and Wildlife Service, Washington, DC. 301 p.

McCoy, H.J., 1962, Ground-water resources of Collier County, Florida: Tallahassee, Florida Geological Survey Report of Investigations 31, 82 p.

McCoy, H.J., 1967, Ground water in the Immokalee area, Collier County, Florida: Tallahassee, Florida Geological Survey Information Circular 51, 31 p.

McCoy, H.J., 1972, Hydrology of western Collier County, Florida: Tallahassee, Florida Bureau of Geology Report of Investigations 63, 32 p.

McCoy, H.J., 1973, Effects of the Feeder Canal on the water resources of the Fort Lauderdale prospect well-field area: U.S. Geological Survey Open-File Report FL-73019, 24 p.

McCoy, H.J., 1973, Summary of hydrologic conditions in Collier County, Florida, 1972: U.S. Geological Survey Open-File Report FL-73022, 118 p.

McCoy, H.J., 1974, Summary of hydrologic conditions in Collier County, Florida, 1973: U.S. Geological Survey Open-File Report FL-74030, 99 p.

McCoy, H.J., 1975, Summary of hydrologic conditions in Collier County, Florida, 1974: U.S. Geological Survey Open-File Report FL-75007, 103 p.

McCoy, H.J., and Hardee, Jack, 1970, Ground-water resources of the lower Hillsboro Canal area, southeastern Florida: Tallahassee, Florida Bureau of Geology Report of Investigations 55, 44 p.

McCoy, H.J., and Sherwood, C.B., 1968, Water in Broward County, Florida: Tallahassee, Florida Division of Geology Map Series 29.

McIvor, C.C, and Smith, T.J., III, 1995, Difference in the crab fauna of mangrove areas at a southwest Florida and a northeast Australia location: Implications for leaf litter processing: Estuaries, 18(4):591-597.

McIvor, C.C, and M. Thieme, 1999, Flannelmouth suckers: Movement in the Glen Canyon reach and spawning in the Paria River, *in* Webb, R., Schmidt, J.C., Marzolf, R., and Valdez, R., eds., Floods and River Management: The 1996 Flood in the Colorado River in Grand Canyon: American Geophysical Union Monograph 110, p. 289-295.

McKenzie, D.J., 1973, Lake Okeechobee seepage monitoring network (progress report), January 1970-June 1972: U.S. Geological Survey Open-File Report FL-73018, 64 p.

McKenzie, D.J., 1976, Injection of acidic industrial waste into the Floridan aquifer near Belle Glade, Florida: Upward migration and geochemical interactions, 1973-75: U.S. Geological Survey Open-File Report 76-626, 54 p.

McKenzie, D.J., 1982, Water-quality reconnaissance of the north Dade County solid-waste disposal facility, Florida: U.S. Geological Survey Open-File Report 82-753, 38 p.

McKenzie, D.J., 1983, Water quality at and adjacent to the south Dade County solid-waste disposal facility, Florida: U.S. Geological Survey Water- Resources Investigations Report 83-4003, 37 p.

McKenzie, D.J., 1990, Water-resources potential of the freshwater lens at Key West, Florida: U.S. Geological Survey Water-Resources Investigations Report 90-4115, 24 p.

McKenzie, D.J., 1995, Water quality of the Boca Raton canal system and effects of the Hillsboro Canal inflow, southeastern Florida, 1990-91: U.S. Geological Survey Water-Resources Investigations Report 94-4128, 14 p.

McKenzie, D.J., and Irwin, G.A., 1983, Water quality assessment of stormwater runoff from a heavily used urban highway bridge in Miami, Florida: U.S. Geological Survey Water-Resources Investigations Report 83-4153, 45 p.

McKenzie, D.J., and Irwin, G.A., 1984, Quality of water recovered from a municipal effluent injection well in the Floridan aquifer system, Pompano Beach, Florida: U.S. Geological Survey Water-Resources Investigations Report 84-4100, 23 p.

McKenzie, D.J., Irwin, G.A., 1988, Effects of two stormwater management methods on the quality of water in the upper Biscayne aquifer at two commercial areas in Dade County, Florida: U.S. Geological Survey Water-Resources Investigations Report 88-4069, 22 p.

McKnight, M.L., Dodd, Jr., C.K., and Spolsky, C.M., 1991, Protein and mitochondrial DNA variation in the salamander Phaeognathus hubrichti, Herpetologica 47:440-447.

McPherson, B.F., 1969, Preliminary determinations of hydrobiological and chemical conditions in the vicinity of the proposed jetport and other airports in south Florida: U.S. Geological Survey Open-File Report FL-69004, 42 p.

McPherson, B.F., 1970, Hydrobiological characteristics of Shark River estuary, Everglades National Park, Florida: U.S. Geological Survey Open-File Report FL-71002, 113 p.

McPherson, B.F., 1970, Preliminary determinations of hydrobiological conditions in the vicinity of the proposed jetport and other airports in south Florida, July 1969: U.S. Geological Survey Open-File Report FL-70004, 31 p.

McPherson, B.F., 1971, Water quality at the Dade-Collier Training and Transition Airport, Miami International Airport, and Cottonmouth Camp--Everglades National Park, Florida, November 1969: U.S. Geological Survey Open-File Report FL-70011, 29 p.

McPherson, B.F., 1973, Vegetation in relation to water depth in Conservation Area 3, Florida: U.S. Geological Survey Open-File Report FL-73025, 62 p.

McPherson, B.F., 1973, Vegetation map of southern parts of subareas A and C, Big Cypress Swamp, Florida: U.S. Geological Survey Hydrologic Investigations Atlas HA-492.

McPherson, B.F., 1973, Water quality in the conservation areas of the Central and Southern Florida Flood Control District, 1970-72: U.S. Geological Survey Open-File Report FL-73014, 39 p.

McPherson, B.F., 1994, National water-quality assessment program--Southern Florida: U.S. Geological Survey Open-File Report 94-57, 2 p.

McPherson, B.F., Gerould, Sarah, and Higer, Aaron, 1999, U.S. Geological Survey Science for Restoration of South Florida: The South Florida Ecosystem Program: U.S. Geological Survey Fact Sheet FS-061-99, 4 p.

McPherson, B.F., and Halley, R.B.,1997, The south Florida environment—A region under stress: U.S. Geological Survey Circular 1134, 61 p.

McPherson, B.F., Hammett, K.M., Miller, R.L., and Stoker, Y.E., 1997, Physical, chemical, and biological characteristics of the Charlotte Harbor basin and estuarine system in southwestern Florida: U.S. Geological Survey Water-Supply paper 2486.

McPherson, B.F., Hendrix, G.Y., Klein, Howard, and Tyus, H.M., 1976, The environment of south Florida, a summary report: U.S. Geological Survey Professional Paper 1011, 81 p.

McPherson, B.F., Higer, A.L., Gerould, Sarah, and Kantrowitz, I.H., 1995, South Florida ecosystem program of the U.S. Geological Survey: U.S. Geological Survey Fact Sheet FS-134-95, 4 p.

McPherson, B.F., and La Rose, H.R., 1982, Algal conditions in the Caloosahatchee River (1975-79), Lake Okeechobee to Franklin Lock, Florida: U.S. Geological Survey Water-Resources Investigations 81-81, 28 p.

McPherson, B.F., Mattraw, H.C., Freiberger, H.J., Altschuler, Z.S., and Zen, C.S., 1973, Environmental quality in Resource and land information, south Dade County, Florida: U.S. Geological Survey Investigation I-850, p. 26-37.

McPherson, B.F., and McCoy, H.J., 1974, Physiographic map of the Okaloacoochee Slough in Collier County, Florida: U.S. Geological Survey Open-File Report FL-74022.

McPherson, B.F., and Miller, R.L., 1990, Nutrient distribution and variability in the Charlotte Harbor estuarine system, Florida: American Water Resources Association, Water Resources Bulletin, v. 26, no. 1, p. 67-80.

McPherson, B.F., and Miller, R.L., 1994, Causes of light attenuation in Tampa Bay and Charlotte Harbor, Southwestern Florida: Water Resources Bulletin, American Water Resources Association, v. 30, no. 1, p. 43-53.

McPherson, B.F., Miller, R.L., and Stoker, Y. E., 1996, Physical, chemical, and biological characteristics of the Charlotte Harbor basin and estuarine system in southwestern Florida—A summary of the 1982-89 U.S. Geological Survey Charlotte Harbor assessment and other studies: U.S. Geological Survey Water-Supply Paper 2486, 32 p.

McPherson, B.F., Montgomery, R.T., and Emmons, E.E., 1990, Phytoplankton productivity and biomass in the Charlotte Harbor estuarine system, Florida: American Water Resources Association, Water Resources Bulletin, v. 26, no. 5, p. 787-800.

McPherson, B.F., and O'Donnell, T.H., 1979, Quality of surface water on Sanibel Island, Florida, 1976-77: U.S. Geological Survey Open-File Report 79-1478, 50 p.

McPherson, B.F., and Sabanskas, Maryann, 1980, Hydrologic and land-cover features of the Loxahatchee River basin, Florida: U.S. Geological Survey Water-Resources Investigations Open-File Report 80-1109, 1 sheet.

McPherson, B.F., Sabanskas, Maryann, and Long, W.A., 1982, Physical, hydrological, and biological characteristics of the Loxahatchee River estuary, Florida: U.S. Geological Survey Water-Resources Investigations Open-File Report 82-350, 1 sheet.

McPherson, B.F., and Sonntag, 1984, Transport and distribution of nutrients in the Loxahatchee River estuary, southeastern Florida, 1979-81: American Water Resources Association Bulletin, v. 20, no. 1, p. 27-34.

McPherson, B.F., Sonntag, W.H., and Sabanskas, Maryann, 1984, Fouling community of the Loxahatchee River estuary, Florida, 1980-81: Estuaries, v. 7, no. 2, p. 149-157.

McPherson, B.F., Waller, B.G., and Mattraw, H.C., Jr., 1976, Nitrogen and phosphorus uptake in the Everglades Conservation Areas, Florida, with special reference to the effects of backpumping runoff: U.S. Geological Survey Water-Resources Investigations Report 76-29, 120 p.

McVoy, Christopher, Park, Winnie, and Obeysekera, Jayantha, 1996, Comparison of the south Florida natural system model with pre-canal everglades hydrology estimated from historical sources: U.S. Geological Survey Fact Sheet FS-187-96, 1 p.

Merritt, M.L., 1982, Subsurface storage of freshwater, south Florida, *in* Proceedings of the American Society of Civil Engineers, National Specialty Conference on Environmentally Sound Water and Soil Management: Orlando, Florida, p. 242-250.

Merritt, M.L., 1985, Subsurface storage of freshwater in south Florida: A digital model analysis of recoverability: U.S. Geological Survey Water-Supply Paper 2261, 44 p.

Merritt, M.L., 1994, Tests of subsurface storage of fresh-water at Hialeah, Dade County, Florida, and digital simulation of the salinity of recovered water: U.S. Geological Survey Open-File Report 93-155, 112 p.

Merritt, M.L., 1995, Simulation of the water-table altitude in the Biscayne aquifer, southern Dade County, Florida, 1945-89: U.S. Geological Survey Open-File Report 95-337, 160 p., 9 pls.

Merritt, M.L., 1995, Numerical simulation of a plume of brackish water in the Biscayne aquifer originating from a flowing artesian well, Dade County, Florida: U.S. Geological Survey Open-File Report 95-402.

Merritt, M.L., 1996, Assessment of saltwater intrusion in southern coastal Broward County, Florida: U.S. Geological Survey Water-Resources Investigations Report 96-4221, 133 p.

Merritt, M.L., 1996, Numerical simulation of a plume of brackish water in the Biscayne aquifer originating from a flowing artesian well, Dade County, Florida: U.S. Geological Survey Water-Supply Paper 2464, 74 p.

Merritt, M.L., 1997, Computation of the time-varying flow rate from an artesian well in central Dade County, Florida, by analytical and numerical simulation methods: U.S. Geological Survey Water-Supply Paper 2491, 44 p.

Merritt, M.L., 1997, Simulation of the water-table altitude in the Biscayne aquifer, southern Dade County, Florida, Water Years 1945-89: U.S. Geological Survey Water-Supply Paper 2458, 148 p., 9 plates.

Merritt, M.L., 1997, Tests of subsurface storage of freshwater at Hialeah, Dade County, Florida, and numerical simulation of the salinity of recovered water: U.S. Geological Survey Water-Summary Paper 2431, 114 p.

Merritt, M.L., Meyer, F.W., Sonntag, W.H., and Fitzpatrick, D.J., 1983, Subsurface storage of freshwater in south Florida: A prospectus: U.S. Geological Survey Water-Resources Investigations Report 83-4214, 69 p.

Meshaka, W., Loftus, W.F., and Steiner, T.M., 2000, The *Herpetofauna* of Everglades National Park, Florida: Florida Scientist, v. 63, no. 2, p. 84-103.

Metz, P.A., 1995, Hydrogeology and simulated effects of ground-water withdrawals for citrus irrigation, Hardee and De Soto Counties, Florida: U.S. Geological Survey Water-Resources Investigations Report 93-4158, 83 p.

Metz, P.A., Mattie, J.A., Torres, A.E., and Corral, M.A., 1998, Potentiometric surface of the upper Floridan aquifer, west-central Florida, September 1997: U.S. Geological Survey Open-File Report 98-100, 1 sheet.

Meyer, F.W., 1969, Hydrologic maps, eastern Dade County, Florida, 1959-67: U.S. Geological Survey Open-File Report FL-69005.

Meyer, F.W., 1971, Preliminary evaluation of the hydrologic effects of implementing water and sewerage plans, Dade County, Florida: U.S. Geological Survey Open-File Report FL-71003, 110 p.

Meyer, F.W., 1971, Saline artesian water as a supplement: American Water Works Association Journal, v. 63, no. 2, p. 65-71.

Meyer, F.W., 1971, Seepage beneath Hoover Dike, southern shore of Lake Okeechobee, Florida: Tallahassee, Florida Bureau of Geology Report of Investigations 58, 98 p.

Meyer, F.W., 1972, Preliminary evaluation of infiltration from the Miami Canal to well fields in the Miami Springs-Hialeah area, Dade County, Florida: U.S. Geological Survey Open-File Report FL-72027, 84 p.

Meyer, F.W., 1974, Availability of ground water for the U.S. Navy well field near Florida City, Dade County, Florida: U.S. Geological Survey Open-File Report FL-74014, 50 p.

Meyer, F.W., 1974, Evaluation of hydraulic characteristics of a deep artesian aquifer from natural water-level fluctuations, Miami, Florida: Tallahassee, Florida Bureau of Geology Report of Investigations 75, 32 p.

Meyer, F.W., 1984, Disposal of liquid wastes in cavernous dolostones beneath southeastern Florida, *in* Burger, A., and Dubertret, L., eds., Hydrogeology of karstic terrains: International Association of Hydrogeologists, v. 1, p. 211-216.

Meyer, F.W., 1988, Summary of well construction, testing, and preliminary findings from the Alligator Alley test well, Broward County, Florida: U.S. Geological Survey Open-File Report 87-551, 68 p.

Meyer, F.W., 1989, Hydrogeology, ground-water movement, and subsurface storage in the Floridan aquifer system in Southern Florida: U.S. Geological Survey Professional Paper 1403-G, 59 p.

Meyer, F.W., 1989, Subsurface storage of liquids in the Floridan aquifer system in south Florida: U.S. Geological Survey Open-File Report 88-477, 25 p.

Meyer, F.W., and Hull, J.E., 1967, Hydrologic conditions in the Canal 111 area, May 8, 1967: U.S. Geological Survey Open-File Report FL-67006, 27 p.

Meyer, F.W., and Hull, J.E., 1967, Hydrologic conditions in the Canal 111 area, June 5, 1967: U.S. Geological Survey Open-File Report FL-67007, 25 p.

Meyer, F.W., and Hull, J.E., 1967, Hydrologic conditions in the Canal 111 area, July 11, 1967: U.S. Geological Survey Open-File Report FL-67008, 28 p.

Meyer, F.W., and Hull, J.E., 1967, Hydrologic conditions in the Canal 111 area, August 8, 1967: U.S. Geological Survey Open-File Report FL-67009, 24 p.

Meyer, F.W., and Hull, J.E., 1967, Hydrologic conditions in the Canal 111 area, southeastern Dade County: U.S. Geological Survey Open-File Report FL-67005, 12 p.

Meyer, F.W., and Hull, J.E., 1967, Hydrologic conditions in the Canal 111 area, October 10, 1967: U.S. Geological Survey Open-File Report FL-67010, 28 p.

Meyer, F.W., and Hull, J.E., 1968, Hydrologic conditions in the Canal 111 area, December 5, 1967: U.S. Geological Survey Open-File Report FL-67011, 25 p.

Meyer, F.W., and Hull, J.E., 1968, Hydrologic conditions in the Canal 111 area, December 6, 1967-February 1, 1968: U.S. Geological Survey Open-File Report FL-68011, 30 p.

Meyer, F.W., and Hull, J.E., 1968, Hydrologic conditions in the Canal 111 area, February 2, 1968-April 15, 1968: U.S. Geological Survey Open-File Report FL-68012, 29 p.

Meyer, F.W., and Hull, J.E., 1968, Hydrologic conditions in the Canal 111 area, April 16-June 11, 1968: U.S. Geological Survey Open-File Report FL-68013, 36 p.

Meyer, F.W., and Hull, J.E., 1968, Hydrologic conditions in the Canal 111 area, June 12-August 21, 1968: U.S. Geological Survey Open-File Report FL-68014, 35 p.

Meyer, F.W., and Hull, J.E., 1968, Hydrologic conditions in the Canal 111 area, August 22-October 15, 1968: U.S. Geological Survey Open-File Report FL-68015, 32 p.

Meyer, F.W., and Hull, J.E., 1969, Hydrologic conditions in the Canal 111 area, December 20, 1968-February 13, 1969: U.S. Geological Survey Open-File Report FL-69012, 33 p.

Meyer, F.W., and Hull, J.E., 1969, Hydrologic conditions in the Canal 111 area, February 14-June 27, 1968: U.S. Geological Survey Open-File Report FL-69013, 44 p.

Meyer, F.W., and Hull, J.E., 1969, Hydrologic conditions in the Canal 111 area, October 16-December 19, 1969: U.S. Geological Survey Open-File Report FL-69011, 31 p.

Meyer, F.W., and Hull, J.E., 1969, Seepage tests in L-D1 borrow canal at Lake Okeechobee, Florida: Tallahassee, Florida Bureau of Geology Information Circular 59, 31 p.

Meyer, F.W., and Wimberly, E.T., 1972, Summary of data collected for the Miami River restoration project during March and September 1971: U.S. Geological Survey Open-File Report FL-72020, 15 p.

Michener, W.K., Blood, E.R., Brim Box, J., Couch, C.A., Golladay, S.W., Hippe, D.J., Mitchell, R.J., and Palik, B.J., 1998, Tropical storm flooding of a coastal plain landscape: Bioscience 48(9):696-705.

Mignucci-Giannoni, A.A., and Beck, C.A., 1998, The diet of the manatee *(Trichechus manatus)* in Puerto Rico: Marine Mammal Science 14(2)394-397.

Mignucci-Giannoni, A.A., Beck, C.A., Montoya-Ospina, R.A., and Williams, E.H., 1999, Parasites and commensals of the West Indian manatee from Puerto Rico: Journal of the Helminthological Society of Washington 66(1):67-69.

Mignucci-Giannoni, A.A., Montoya-Ospina, R.A., Jiménez-Marrero, N.M., Rodríguez-López, M.A., Williams, E.H., Jr., and Bonde, R.K., 2000, Manatee Mortality in Puerto Rico: Environmental Management 25(2):189-198.

Miller, K.E., Ackerman, B.B., Lefebvre, L.W., and Clifton, K.B., 1996, Use of aerial survey and aerophotogrammetry methods in monitoring manatee populations. Florida Cooperative Fish and Wildlife Research Unit RWO No. 116 Final Report. University of Florida, Gainesville. 45 p.

Miller, K.E., Ackerman, B.B., Lefebvre, L.W., and Clifton, K.B., 1998, An evaluation of striptransect aerial survey methods for monitoring manatee populations in Florida. Wildlife Society Bulletin 26(3):561-570.

Miller, R.A., 1978, The hydraulically effective impervious area of an urban basin, Broward County, Florida: University of Kentucky Bulletin 116, p. 259-261.

Miller, R.A., 1978, Water-resources setting, Martin County, Florida: U.S. Geological Survey Water-Resources Investigations Report 77-68, 37 p.

Miller, R.A., 1979, Characteristics of four urbanized basins in south Florida: U.S. Geological Survey Open-File Report 79-694, 45 p.

Miller, R.A., 1984, Rainfall-runoff mechanics for developed urban basins, south Florida, *in* Proceedings of the International Symposium on Urban Hydrology, Hydraulics, and Sediment control, Lexington, Kentucky, July 1984: p. 135-141.

Miller, R.A., 1985, Percentage entrainment of constituent loads in urban runoff, south Florida: U.S. Geological Survey Water-Resources Investigations Report 84-4329, 44 p.

Miller, R.A., and Benson, M.A., 1976, Hydrologic effects of storms of June 24-28, 1974, in Lee and Collier Counties, Florida: U.S. Geological Survey Water-Resources Investigations Report 57-75, 30 p.

Miller, R.A., Doyle, W.H., Jr., and Wilson, L.D., 1979, Urban stormwater data management system with applications to south Florida studies: U.S. Geological Survey Water-Resources Investigations Report 79-93, 113 p.

Miller, R.A., and Mattraw, H.C., Jr., 1982, Stormwater runoff quality from three land-use areas in south Florida: American Water Resources Association Bulletin, v. l8, no. 3, p. 513-519.

Miller, R.A., Mattraw, H.C., Jr., and Hardee, Jack, 1979, Stormwater runoff data for a commercial area, Broward County, Florida: U.S. Geological Survey Open-File Report 79-982, 127 p.

Miller, R.A., Mattraw, H.C., Jr., and Jennings, M.E., 1978, Statistical modeling of urban storm-water processes, Broward County, Florida: University of Kentucky Bulletin 116, p. 269-273.

Miller, R.L., 1978, Application of four input-output models for nutrients in Lake Okeechobee, Florida: U.S. Geological Survey Journal of Research, v. 6, no. 6, p. 821-828.

Miller, R.L., Kraemer, T.F., and McPherson, B.F., 1990, Radium and radon in Charlotte Harbor Estuary, Florida in Estuarine, Coastal and Shelf Science: v. 31, no. 4, p. 439-457.

Miller, R.L., and McPherson, B.F., 1991, Estimating estuarine flushing and residence times in Charlotte Harbor, Florida, via salt balance and a box model: Limnology and Oceanography, v. 36, no. 3, p. 602-612.

Miller, R.L., McPherson, B.F., and Haag, K.H., 1999, Water quality in the southern Everglades and Big Cypress Swamp in the vicinity of the Tamiami Trail, 1996-97: U.S. Geological Survey Water-Resources Investigations Report 99-4062, 16 p.

Miller, R.L., and Sutcliffe, Horace, Jr., 1985, Occurrence of natural radium-226 radioactivity in ground water of Sarasota County, Florida: U.S. Geological Survey Water-Resources Investigations Report 84-4237, 34 p.

Miller, W.L., 1975, Nutrient concentrations of surface waters in southern Florida, September 1970 to April 1975: U.S. Geological Survey Open-File Report FL-75010, 44 p.

Miller, W.L., 1978, Effects of bottom sediments on infiltration from the Miami and tributary canals to the Biscayne aquifer, Dade County, Florida: U.S. Geological Survey Water-Resources Investigations Report 78-36, 63 p.

Miller, W.L., 1979, Hydrologic and geologic data from the upper East Coast Planning Area, southeast Florida: U.S. Geological Survey Open-File Report 79-1543, 99 p.

Miller, W.L., 1980, Geologic aspects of the surficial aquifer in the upper East Coast Planning Area, southeast Florida: U.S. Geological Survey Water-Resources Investigations Open-File Report 80-586, 2 sheets.

Miller, W.L., 1985, Altitude of water table, surficial aquifer, Palm Beach County, Florida, April 24-26, 1984: U.S. Geological Survey Open-File Report 85-336, 1 sheet.

Miller, W.L., 1986, Altitude of water table, surficial aquifer, Palm Beach County, Florida, November 9-14, 1984: U.S. Geological Survey Open-File Report 85-637, 1 sheet.

Miller, W.L., 1986, Lithology and base of the surficial aquifer system, Palm Beach County, Florida: U.S. Geological Survey Water-Resources Investigations Report 86-4067, 1 sheet.

Miller, W.L., 1988, Description and evaluation of the surficial aquifer system: Flow directions and water quality, Palm Beach County, Florida: U.S. Geological Survey Water-Resources Investigations Report 88-4056, 58 p.

Miller, W.L., 1992, Hydrogeology and migration of septic-tank effluent in the surficial aquifer system in the northern Midlands area, Palm Beach County, Florida: U.S. Geological Survey Water-Resources Investigations Report 91-4175, 69 p.

Miller, W.L., and Alvarez, J.A., 1984, Public supply water use, Palm Beach County, Florida, 1978-82: U.S. Geological Survey Open-File Report 84-240, 14 p.

Miller, W.L., and Lietz, A. C., 1976, Quality-of-water data, Palm Beach County, Florida, 1970-75: U.S. Geological Survey Open-File Report 76-784, 100 p.

Missimer, T.M., and Boggess, D.H., 1974, Fluctuations of the water table in Lee County, 1969-73:U.S. Geological Survey Open-File Report FL-74019, 41 p.

Missimer, T.M., and Gardner, R.A., 1976, High-resolution seismic reflection profiling for mapping shallow aquifers in Lee County, Florida: U.S. Geological Survey Water-Resources Investigations Report 76-45, 30 p.

Missimer, T.M., and O'Donnell, T.H., 1976, Fluctuations of ground-water levels in Lee County, Florida, in 1974: U.S. Geological Survey Open-File Report FL-75008, 75 p.

Montgomery, R.T., McPherson, B.F., and Emmons, E.E., 1991, Effects of nitrogen and Phosphorus additions on Phytoplankton productivity and chlorophyll a in a subtropical estuary, Charlotte Harbor, Florida: U.S. Geological Survey Water-Resources Investigations Report 91-4077, 33 p.

Mooij, W.M., and DeAngelis, D.L., 1999, Error propagation in spatially explicit population models: A reassessment: Conservation Biology 13(4):930-933.

Mooij, W.M., and DeAngelis, D.L., 1999, Individual-based modelling as an integrative approach in theoretical and applied population dynamics and food web studies, *in* Olff, H., Brown, V.K., and Drent, R.H., eds., Herbivores Between Plants and Predators: 38th Symposium Volume of the British Ecological Society, p. 551-575.

Morea, C.R., 1999, Home range, movement, and habitat use of the American alligator in the Everglades: Gainesville, University of Florida, M.S. thesis, 88 p.

Morea, C.R., Howarter, S.R., Rice, K.G., Percival, H.F., and Abercrombie, C.L., 1999, Habitat preference and movement of the American alligator in the Everglades ecosystem, *in* Managing Biodiversity: Orlando, Florida Chapter of Wildlife Society.

Morea, C.R., Rice, K.G., Percival, H.F., and Howarter, S.R., 2000, Habitat use of the American alligator in the Everglades: Proceedings of the Florida Lake Management Society 2000 Annual Conference.

Morea, C.R., Rice, K.G., Percival, H.F., and Howarter, S.R., 2000. Home range and daily movement of the American alligator in the Everglades: Poster presentation at the 15th Working Meeting of the Crocodile Specialist Group, IUCN, Varadero, Cuba.

Morea, C.R., Rice, K.G., Percival, H.F., and Howarter, S.R., 2000, Home range and daily movement of the American alligator in the Everglades, *in* Crocodiles—Proceedings of the15th Working Meeting of the Crocodile Specialist Group, IUCN, Gland, Switzerland: 19 p.

Morea, C.R., Rice, K.G., Percival, H.F., and Howarter, S.R., 2000, Movement of the American alligator in the Everglades: Wildlife Society Bulletin.

Morris, M.A, and Walsh, S.J., 1991, Reproduction in a Western Smooth Earth Snake (Virginia valeriae elegans) from Western Kentucky, Bulletin of the Chicago Herpetological Society 26(6):133.

Mou-Sue, L., Chen, D.H., Bonde, R.K., and O'Shea, T.J., 1990, Distribution and status of manatees *(Trichechus manatus)* in Panama: Marine Mammal Science, v. 6, no. 3, p. 234-241.

Mulholland, P. J., and DeAngelis, D.L., 1999, Effect of surface/subsurface exchange on nutrient spiralling in streams, *in* Jones, J.B., Jr., and Mulholland, P.J., eds., Surface-Subsurface Interactions in Streams, Landes Bioscience, Austin, Texas: chap. 12.

Mulvey, M., C. Lydeard, D. L. Pyer, K. M. Hicks, J. Brim-Box, J. D. Williams, and R. S. Butler, 1997, Conservation genetics of North American freshwater mussels Amblema and Megalonaias: Conservation Biology 11(4):868-878.

Murphy, W.R., Jr., 1968, Causes of flooding of Little Charley Bowlegs Creek upstream from Highlands Hammock State Park, Florida: U.S. Geological Survey Open-File Report FL-68004, 16 p.

Murphy, W.R., Jr., Hammett, K.M., and Reeter, C.V., 1978, Flood profiles for Peace River, south-central Florida: U.S. Geological Survey Water-Resources Investigations Report 78-57, 35 p.

Murray, M.H., 1994, Storm-tide elevations produced by Hurricane Andrew along the southern Florida coasts, August 24, 1992: U.S. Geological Survey Open-File Report 94-116, 27 p, 19 pl.

Murray, M.H., 1996, Internal surface-water flows: South Florida ecosystem program: U.S. Geological Survey Fact Sheet FS-175-96, 2 p.

Murray, M.H, 1997, Quantifying internal canal flows in southern Florida, *in* Gerould, Sarah, and Higer, A.L., eds., U.S. Geological Survey Program on the South Florida Ecosystem—Proceedings of the Technical Symposium in Ft. Lauderdale, Florida, August 25-28, 1997: U.S. Geological Survey Open-File Report 97-385, p. 59.

Nance, J.M., 1994, A biological review of the Tortugas pink shrimp fishery through December 1993: Unpublished report of the Galveston Laboratory, Southeast Fisheries Science Center, National Marine Fisheries Service, Galveston, Texas, 2 p., 9 figs.

Nelson, J. S., E. J. Crossman, H. Espinosa-P,rez, C. R. Gilbert, R. N. Lea, and J. D. Williams, 1998, Recommended changes in common fish names: Pikeminnow to replace squawfish *(Ptychocheilus* spp.). Fisheries, v. 9, p. 37.

Nepf, H.M., 1999, Drag, turbulence, and diffusion in flow through emergent vegetation: Water Resources Research, v. 35, no. 2, p. 479-489.

Neves, R. J., A. E. Bogan, J D. Williams, S.A. Ahlstedt, and P. D. Hartfield, 1997, Status of aquatic mollusks in the southeastern United States: A downward spiral of diversity, *in* Benz, G.W., and Collins, D.E., eds., Aquatic Fauna in Peril: The Southeastern Perspective. Special Publication 1, Southeast Aquatic Research Institute, Lenz Design and Communications, Decatur, Ga., p. 43-86

Nico, L.G., and P.L. Fuller, 1999, Spatial and Temporal patterns of nonindigenous fish introductions in the United States. Fisheries 24(1):16-27

Nico, L.G, and Morales, M., 1994, Nutrient content of piranha *(Characidae: Serrasalminae)* prey items, Copeia (2):524-528.

Nico, L.G., and Pinna, M.C.C., 1996, Confirmation of Glanapteryx anguilla *(Siluriformes, Trichomycteridae)* in the Orinoco River Basin, with notes on the distribution and habitats of the Glanapteryginae: Ichthyological Exploration of Freshwaters 7(1):27-32.

Nico, L.G., Schaeffer, D.J., Taphorn, D.C., and Barbarino-Duque, A., 1994, Agricultural chemical screening and detection of chlorpyrifos in fishes from the Apure drainage, Venezuela, Fresenius Environmental Bulletin 11(3):685-690.

Nico, L.G., and Taphorn, D.C., 1994, Mercury in fish from gold mining regions in the upper Cuyuni River system, Venezuela, Fresenius Envionmental Bulletin 3:287-292.

Nico, L. G., S. J. Walsh, and R. H. Robins, 1996, An introduced population of the South American callichthyid catfish *Hoplosternum littorale* in the Indian River Lagoon system, Florida: Florida Scientist 59:189-200.

Nico, L. G., and J. D. Williams, 1996, Risk assessment on black carp *(Pisces: Cyprinidae):* Inhouse Report to the Risk Assessment and Management Committee of the Aquatic Nuisance Species Task Force, U.S. Fish and Wildlife Service, Washington, DC. 71 p

Norberg, J, and D.L. DeAngelis, 1997, Temperature effects on stocks and stability of a phytoplankton-zooplankton model and the dependence on light and nutrients: Ecological Modeling 95(1):75-86.

Nordlie, F.G., Haney, D.C., and Walsh, S.J., 1992, Comparisons of salinity tolerances and osmotic regulatory capabilities in populations of sailfin molly *(Poecilia latipinna)* from brackish and fresh waters, Copeia 1992(3):741-746.

Nordlie, F.G., Walsh, S.J., Haney, D.C., and Nordlie, T.F., 1991, The influence of ambient salinity on routine metabolism in the teleost Cyprinodon variegatus Lacepède, Journal of Fish Biology 38(1):115-122.

Nuttle, W.K., Fourqurean, J.W., Cosby, B.J., Zieman, J.C., and Robblee, M.B., 2000, Influence of net freshwater supply on salinity in Florida Bay: Water Resources Research, v. 36, no. 7, p. 1805-1822.

Nuttle, W.K, Brinson, M.M., and others, 1997, Conserving coastal wetlands despite sea-level rise. EOS.Transactions American Geophysical Union, 78:257-261.

O´Brien, C.A, and J. Brim Box, 1999, Reproductive biology and juvenile recruitment of the Shinyrayed pocketbook, Lampsilis subangulata *(Bivalvia:Unionidae)* in the Gulf Coastal Plain: American Midland Naturalist 142 (1):129-140.

O'Donnell, T.H., 1976, Fluctuations of ground-water levels in Lee County, Florida in 1975 water year: U.S. Geological Survey Open-File Report 76-854, 77 p.

O'Donnell, T.H., 1977, Municipal water supplies in Lee County, Florida, 1974: U.S. Geological Survey Open-File Report 77-277, 96 p.

Odum, W.E., McIvor, C.C., 1990, Mangroves, *in* Myers, R.L., and Ewel, J.J., eds., Ecosystems of Florida: Chapter 15, p. 517-548.

Orem, W.H., 1996, South Florida Wetlands Ecosystem: Biogeochemical Processes in Peat: U.S. Geological Survey Fact Sheet-177-96, 4 p.

Orem, W.H., in review, Taylor Slough and Eastern Florida Bay: Geochemical Studies in Support of Ecosystem Restoration in South Florida: U.S. Geological Survey Fact Sheet.

Oremland, R.S., in review, Methyl-Mercury Degredation in Florida Everglades Peat-Sediment: U.S. Geological Survey Fact Sheet.

Oremland, R.S., Culbertson, C.W., Winfrey, M.R., 1991, Methylmercury decomposition in sediments and bacterial cultures—Involvement of methanogens and sulfate reducers in oxidative demethylation: Applied Environmental Microbiology, v. 57, no. 1, p. 130-137.

Orlando, S.P., M.B. Robblee, and C.J. Klein, 1998, Salinity Characteristics of Florida Bay: A Review of the Archived Data Set (1955-1995). Silver Spring MD: National Oceanic and Atmospheric Adminsitration, Office of Ocean Resources Conservation and Assessment. 32. p.

Orr, R., G. McClung, R. Peoples, J. D. Williams, and M. A. Meyer, 1999, Nonindigenous species, in Ecological Risk Assessment in the Federal Government: Committee on Environment and Natural Resources of the National Science and Technology Council, Washington, DC., p. 4-1 to 4-20.

Orth, D.J., and Payne, R.L., 1997, Principles, policies, and procedures: Domestic geographic names: Preliminary Online Edition, URL: http://mapping.usgs.gov/www/gnis/pppdgn.html, accessed July 18, 2000.

O'Shea, T.J, 1995, Waterborne recreation and the Florida manatee, *in* Knight, R.L., and Gutzwiller, K.J., eds., Wildlife and Recreationists: Coexistence Through Management and Research. Island Press, Washington, D.C., p. 297-311.

O'Shea, T.J, and B.B. Ackerman, 1995, Population biology of the Florida manatee: An overview, *in* O'Shea, T.J., Ackerman, B.B., and Percival, H.F., eds., Population Biology of the Florida Manatee *(Trichechus manatus latirostris):* U.S. Department of the Interior, National Biological Service, Information and Technical Report 1, p. 269-279.

O'Shea, T.J., Ackerman, B.B., and Percival, H.F., (eds), 1992, Interim report of the technical workshop on manatee population biology, Manatee Population Research Report No. 10, Florida Cooperative Fish & Wildlife Research Unit, University of Florida, Gainesville, FL, 83 p.

O'Shea, T.J, and W.C. Hartley, 1995, Reproduction and early-age survival of manatees at Blue Spring, Upper St. Johns River, Florida, *in* O'Shea, T.J., Ackerman, B.B., and Percival, H.F., eds., Population Biology of the Florida Manatee *(Trichechus manatus latirostris):* U.S. Department of the Interior, National Biological Service, Information and Technical Report 1, p. 157-170.

O'Shea, T.J., and Kochman, H.I., 1990, Florida manatees: distribution, geographically referenced data sets, and ecological and behavioral aspects of habitat use, *in* Reynolds, J.E., III, and Haddad, K.D., eds.,Report of the Workshop on Geographic Information Systems as an Aid to Managing Habitat for West Indian manatees in Florida and Georgia: Florida Marine Research Publications, v. 49, p. 11-22.

O'Shea, T.J, and Langtimm, C.A., 1995, Estimation of survival of adult Florida manatees in the Crystal River, at Blue Spring, and on the Atlantic Coast, *in* O'Shea, T.J., Ackerman, B.B., and Percival, H.F., eds., Population Biology of the Florida Manatee *(Trichechus manatus latirostris):* U.S. Department of the Interior, National Biological Service, Information and Technical Report 1, 194-222.

O'Shea, T.J., and Ludlow, M.E., 1992, The Florida manatee, Trichechus manatus latirostris, *in* Humphrey, S.R., ed., Rare and Endangered Biota of Florida, Vol. I. Mammals, University Press Florida, Gainesville, 392 p. 190-200.

O'Shea, T.J., Rathbun, G.B., Bonde, R.K., Buergelt, C.D., and Odell, D.K., 1991, An epizootic of Florida manatees associated with a dinoflagellate bloom: Marine Mammal Science 7(2):165-179.

O'Shea, T.J., and Reep, R.L., 1990, Encephalization quotients and life-history traits in the Sirenia, Journal of Mammalogy 71(4):534-543.

O'Shea, T.J., and Salisbury, C.A., 1991, Belize--A last stronghold for manatees in the Caribbean, Oryx 25(3):156-164.

Paillet, F.L., 1997, Using geophysical measurements in boreholes to calibrate surface electromagnetic soundings in south Florida, *in* Gerould, Sarah, and Higer, A.L., eds., U.S. Geological Survey Program on the South Florida Ecosystem—Proceedings of the Technical Symposium in Ft. Lauderdale, Florida, August 25-28, 1997: U.S. Geological Survey Open-File Report 97-385, p. 66-67.

Paillet, F.L., Hite, Laura, and Carlson, Matt, 1999, Integrating surface and borehole geophysics in ground water studies—an example using electromagnetic soundings in south Florida: Journal of Environmental and Engineering Geophysics, v. 4, no. 1, p. 45-55.

Paillet, F.L., and Reese, R.S., 2000, Integrating borehole logs and aquifer tests in aquifer characterization: Ground Water, v. 38, no. 5, p. 713-725.

Paillet, F.L., and Weedman, S.D., 1996, Using borehole logs and core to identify and characterize confining units in the surficial aquifer sytem of south Florida, *in* Proceedings of the Geological Society of America 1999 Annual Meeting, 1996, Denver, Colorado: v. 31, no. 7.

Parham, J.F., C.K.Dodd, Jr., and G.R. Zug, 1996, Skeletochronological age estimates for the Red Hills salamander, Phaeognathus hubrichti: Journal of Herpetology 30(3):401-404.

Parker, G.G., 1941, Memorandum on ground water of Key West and Big Pine Key, Florida: U.S. Geological Survey Open-File Report FL-41001, 11 p.

Parker, G.G., 1942, Notes on the geology and ground water of the Everglades in southern Florida, Proceedings: The Soil Science Society of Florida, v. 4A, p. 47-76.

Parker, G.G., 1945, Saltwater encroachment in southern Florida: American Water Works Association Journal, v. 37, no. 6, p. 526-542.

Parker, G.G., 1945, The effect of Pleistocene epoch on the geology and ground water of southern Florida: Florida Academy of Sciences Journal, v. 8, no. 2, p. 119-143.

Parker, G.G., 1946, Municipal water-supply problems of southern Florida, Proceedings: The Soil Science Society of Florida, v.8, p. 72-88.

Parker, G.G., 1948, Geology and ground water of the Everglades Region: University of Florida Agricultural Experiment Station, Bulletin 442.

Parker, G.G., 1951, Geologic and hydrologic factors in the perennial yield of the Biscayne aquifer: American Water Works Association Journal, v. 43, no. 10, p. 817-835.

Parker, G.G., 1960, Ground water in the central and Southern Florida Flood Control District: The Soil and Crop Science Society of Florida, Proceedings, v. 20, p. 211-231.

Parker, G.G., and Cooke, C.W., 1944, Late Cenozoic geology of southern Florida, with a discussion of the ground water: Tallahassee, Florida Geological Survey Bulletin no. 27, 119 p.

Parker, G.G., Ferguson, G.E., Love, S.K., and others, 1955, Water resources of southeastern Florida, with special reference to the geology and ground water of the Miami area: U.S. Geological Survey Water-Supply Paper 1255, 965 p.

Parker, G.G., and Hoy, N.D., 1943, Additional notes on the geology and ground water of southern Florida, Proceedings: The Soil Science Society of Florida, v. 5A, p. 33-55.

Parker, G.G., and Hoy, N.D., 1944, Geology and ground water of the Kissimmee River-Lake Okeechobee area, Florida, Proceedings: The Soil Science Society of Florida, v. 6, p, 19-70.

Parker, G.G., and Stringfield, V.T., 1950, Effects of earthquakes, trains, tides, winds, and atmospheric pressure changes on water in the geologic formations of southern Florida: Economic Geology, v. 45, no. 5, p. 441-459.

Parkinson, R.W., and Meeder, J.F., 1991, Mud-bank destruction and the formation of a transgressive sand sheet, southwest Florida inner shelf: Geological Society of America Bulletin 103, p. 1543-1551.

Patino, Eduardo, 1995, South Florida ecosystem program-Freshwater flows into Florida Bay: U.S. Geological Survey FS-135-95, 2 p.

Patino, Eduardo, 1996, Feasibility of using acoustic velocity meters for estimating highly organic suspended-solids concentrations in streams: U.S. Geological Survey Open-File Report 96-137, 28 p.

Patino, Eduardo, [1996], Freshwater Discharge to Florida Bay: U.S. Geological Survey Fact Sheet FS-135-96, 1 p.

Patino, Eduardo, 1996, South Florida ecosystem program: Gaging flows in northeastern Florida Bay: U.S. Geological Survey Fact Sheet FS-130-96, 2 p.

Patino, Eduardo, 1997, Determining flows into northeastern Florida Bay, Dade and Monroe Counties, Florida, *in* Gerould, Sarah, and Higer, A.L., eds., U.S. Geological Survey Program on the South Florida Ecosystem—Proceedings of the Technical Symposium in Ft. Lauderdale, Florida, August 25-28, 1997: U.S. Geological Survey Open-File Report 97-385, p. 68.

Pedrono, M., A. Sarovy, L. Smith, and R. Bour. 2000, The status and conservation on endemic Malagasy chelonians: An historic perspective, *in* W.R. Lourenco and S.M. Goodman (eds.), Diversite et Endemisme a Madagascar: Memoires de la Societe de Biogeographie, Paris, p. 249-260.

Pedrono, M., Smith, L.L., Sarovy, A., Bourou, R., and Tiandray, H., in press. Reproductive ecology of the ploughshare tortoise *(Astrochelys yniphora)*: Journal of Herpetology.

Peek, H.M., 1958, Ground-water resources of Manatee County, Florida: Tallahassee, Florida Geological Survey Report of Investigations 18, 99 p.

Peek, H.M., 1958, Record of wells in Manatee County, Florida: Tallahassee, Florida Geological Survey Information Circular 19, 199 p.

Peek, H.M., and Anders, R.B., 1955, Interim Report on the ground-water resources of Manatee County, Florida: Tallahassee, Florida Geological Survey Information Circular 6, 38 p.

Percival, H.F., Rice, K.G., and Howarter, S.R., 2000, American alligator distribution, thermoregulation, and biotic potential relative to hydroperiod in the Everglades: Gainesville, Fla., U.S. Geological Survey Biological Resources Division, Contract Final Report, 155 p.

Percival, H.F., Rice, K.G., Morea, C.R., and Howarter, S.R., 1997-1999, American alligator distribution, thermoregulation, and biotic potential relative to hydroperiod in the Everglades: Gainesville, Fla., U.S. Geological Survey Biological Resources Division, Interim/Annual Reports.

Petersen, J.H., and DeAngelis, D.L., 2000, Dynamics of prey moving through a predator field: A model of migrating juvenile salmon: Mathematical Biosciences 165:97-114.

Peterson, C.J., 1988, Direct-current resistivity data from 94 sites in northeastern Palm Beach County, Florida: U.S. Geological Survey Open-File Report 88-464, 101 p.

Pimm, S.L., Davis, G.E., Loope, L., Roman, C.T., Smith III, T.J., and Tilmant, J.T., 1994, Hurricane Andrew, Bioscience, 44:224-229.

Pitt, W.A.J., Jr., 1972, Sediment loads in Canals 18, 23, and 24 in southeastern Florida: U.S. Geological Survey Open-File Report FL-72013, 48 p.

Pitt, W.A.J., Jr., 1974, Effects of septic tank effluent on ground-water quality, Dade County, Florida--An interim report: U.S. Geological Survey Open-File Report FL-74010, 79 p.

Pitt, W.A.J., Jr., 1975, Effects of a landfill operation on ground-water quality in north Broward County, Florida: U.S. Geological Survey Open-File Report 75-405, 48 p.

Pitt, W.A.J., Jr., 1976, Response of ground-water levels to flood control operations in three basins, southeastern Florida: U.S. Geological Survey Open-File Report 74-86, 69 p.

Pitt, W.A.J., Jr., 1977, Management alternatives in controlling saltwater intrusion in southeast Florida, Proceedings: American Society of Civil Engineers.

Pitt, W.A.J., Jr., Mattraw, H.C., Jr., and Klein, Howard, 1975, Ground-water quality in selected areas serviced by septic tanks, Dade County, Florida: U.S. Geological Survey Open-File Report 75-607, 82 p.

Pitt, W.A.J., Jr., and Meyer, F.W., 1976, Ground-water quality at the site of a proposed deep-well injection system for treated wastewater, West Palm Beach, Florida: U.S. Geological Survey Open-File Report 76-91, 43 p.

Pitt, W.A.J., Jr., Meyer, F.W., and Hull, J.E., 1977, Disposal of saltwater during well construction: Problems and solutions: Ground Water, v. 15, no. 4, p. 276-283.

Prager, E.J., and Halley, R.B., 1997, Bottom types of Florida Bay: U.S. Geological Survey Open-File Report 97-526.

Prager, E.J., and Halley, R.B., 1999, The influence of seagrass on shell layers and Florida Bay mud banks: Journal of Coastal Research, v. 15, no. 4, p. 1151-1162.

Pyle, Laura, Cooper, S.R., and Huvane, J.K., 1998, Diatom Paleoecology Pass Key Core 37, Everglades National Park, Florida Bay: U.S. Geological Survey Open-File Report 98-522, 41 p.

Quinones-Aponte, Vicente, 1996] Groundwater Discharge to Biscayne Bay: U.S. Geological Survey Fact Sheet FS-131-96, 3 p.

Quinones-Aponte, Vicente, 1997, Geochemical analysis of ground-water flow to Biscayne Bay, *in* Gerould, Sarah, and Higer, A.L., eds., U.S. Geological Survey Program on the South Florida Ecosystem—Proceedings of the Technical Symposium in Ft. Lauderdale, Florida, August 25-28, 1997: U.S. Geological Survey Open-File Report 97-385, p. 71-72.

Quinones-Aponte, Vicente., and Medina, M.A., 1996, Solute transport through a single conduit type flow aquifer using "equivalent hydraulic characteristics": Hydrological science and technology: American Institute of Hydrology, v. 11, November 1-4, 1995, p. 122-139.

Quinones-Aponte, Vicente, Kotun, Kevin, and Whitley, Joseph F., 1996, Analysis of tests of subsurface injection, storage, and recovery of freshwater in the Lower Floidan aquifer, Okeechobee County, Florida: U.S. Geological Survey Open-File Report 95-765, 32 p.

Quinones-Aponte, Vicente, and Wexler, E.J., 1995, Preliminary assessment of injection, storage, and recovery of freshwater in the lower Hawthorn aquifer, Cape Coral, Florida: U.S. Geological Survey Water-Resources Investigations Report 94-4121, 102 p.

Radell, M.J., and Katz, B.G., 1991, Major-ion and selected trace-metal chemistry of the Biscayne aquifer, southeast Florida: U.S. Geological Survey Water-Resources Investigations Report 91-4009, 18 p.

Rathbun, G.B., J.P. Reid, R.K. Bonde, and J.A. Powell, 1995, Reproduction in free- ranging Florida manatees, *in* O'Shea, T.J., Ackerman, B.B., and Percival, H.F., eds., Population Biology of the Florida Manatee *(Trichechus manatus latirostris):* U.S. Department of the Interior, National Biological Service, Information and Technology Report 1, p. 135-156.

Rathbun, G.B., Reid, J.P., and Carowan, G., 1990, Distribution and movement patterns of manatees (Trichechus manatus) in northwestern peninsular Florida, Florida Marine Research Publications 48:1-33.

Ratzlaff, K.W., 1981, Altitude of water table, Biscayne aquifer, Dade County, Florida, March 1979: U.S. Geological Survey Open-File Report 81-647, 1 sheet.

Ratzlaff, K.W., 1981, Altitude of water table, Biscayne aquifer, Dade County, Florida, October 1979: U.S. Geological Survey Open-File Report 81-807, 1 sheet.

Ratzlaff, K.W., 1981, Altitude of water table, Biscayne aquifer, Dade County, Florida, May 1980: U.S. Geological Survey Open-File Report 81-808, 1 sheet.

Ravichandran, M., Aiken, G.R., Reddy, M.M., and Ryan, J.N., 1998, Enhanced dissolution of cinnabar (mercuric sulfide) by aquatic humic substances, *in* Proceedings of the 216th American Chemical Society National Meeting, Boston, Mass., August 23-27, 1998: v. 38, no. 2, p. 253-256.

Ravichandran, M., Aiken, G.R., Reddy, M.M. and Ryan, J.N., 1998, Enhanced dissolution of cinnabar (mercuric sulfide) by dissolved organic matter from the Florida Everglades (abs.): Presented during the 1998 American Geophysical Union Spring Meeting, May 26-29, 1998, Boston, Mass.

Ravichandran, M., Aiken, G.R., Reddy, M.M., and Ryan, J.N., 1998, Enhanced dissolution of cinnabar (mercuric sulfide) by dissolved organic matter isolated from the Florida Everglades: Environmental Science and Technology, v. 32, no. 21, p. 3305-3311.

Ravichandran, M., Aiken, G.R., Ryan, J.N., and Reddy, M.M., 1999, Inhibition of precipitation and aggregation of metacinnabar (HgS) by humic substances isolated from the Florida Everglades, *in* Proceedings of the the 217th American Chemical Society National Meeting, Anaheim, California, March 21- 25, 1999: v. 39, no. 1, p. 316-317.

Ravichandran, M., Aiken, G.R., Ryan, J.N., and Reddy, M.M., 1999, Inhibition of precipitation and aggregation of metacinnabar (mercuric sulfide) by dissolved organic matter isolated from the Florida Everglades: Environmental Science & Technology, v. 33, no. 9, p. 1418-1423.

Reddy, M.M., 1998, Complexation modeling studies (abs.): Presented during the South Florida Mercury Science Program Annual Workshop, May 18-20, 1998, West Palm Beach, Florida.

Reddy, M.M., 1998, Recent developments in modeling mercury fractionation (abs.): Presented during the South Florida Mercury Science Program Annual Workshop, May 18-20, 1998, West Palm Beach, Florida.

Reddy, M.M., and Aiken, G.R., 1997, Speciation and fractionation modeling studies—Dissolved organic carbon (DOC)-mercury interaction, *in* Gerould, Sarah, and Higer, A.L., eds., U.S. Geological Survey Program on the South Florida Ecosystem--Proceedings of the Technical Symposium in Ft. Lauderdale, Florida, August 25-28, 1997: U.S. Geological Survey Open-File Report 97-385, p. 73.

Reddy, M.M., and Aiken, G.R., 1998, Recent developments in Everglades dissolved organic carbon characterization and mercury complexation: Presented during the South Florida Mercury Science Program Annual Workshop, May 18-20, 1998, West Palm Beach, Florida.

Reddy, M.M., and Aiken, G.R., 1998, Speciation and fractionation modeling studies—Dissolved Organic Carbon (DOC)-mercury interaction (abs.): Presented during the 1998 American Geophysical Union Spring Meeting, May 26-29, 1998, Boston, Mass.

Reddy, M.M., and Aiken, G.R., 1999, Speciation and fractionation modeling studies—Dissolved organic carbon (DOC)-mercury interaction (abs.): Presented during the American Society of Limnology and Oceanography Aquatic Sciences Meeting, February 1-5, 1999, Santa Fe, New Mexico.

Reddy, M.M., and Aiken, G.R., 2000, Fulvic acid-sulfide ion competition for mercury ion binding in the Florida Everglades (abs.): Presented at the 43rd Annual International Conference on Great Lakes Research, May 21-26, 2000, Cornwall, Ontario, Canada.

Reddy, M.M., and Aiken, G.R., 2000, Fulvic acid-sulfide ion competition for mercury ion binding in the Florida Everglades: Water, Air, and Soil Pollution.

Reddy, M.M., Aiken, G.R., Harvey, J.W., Orem, W.H., 1996, Dissolved organic carbon (DOC)/fulvic acid ionic mercury interactions in the Everglades Water Conservation Areas—Surface and sediment pore water DOC concentrations and fulvic acid mercury binding potentials (abs.): Presented during the American Chemical Society Meeting, August 25-29, 1996, Orlando, Florida.

Reddy, M.M., Aiken, G.R., and Schuster, P.F., 1999, Hydroperiod-driven solute transport at the peat-water interface in the Florida Everglades—Hydrophobic acid diffusion from peat, *in* Proceedings of the Geological Society of America 1999 Annual Meeting, October 25-28, 1999, Denver, Colorado: v. 31, no. 7.

Reddy, M.M., Aiken, G.R. and Schuster, P.F., 1999, Mercury-dissolved organic carbon interactions in the Florida Everglades: A field and laboratory investigation, *in* Gerould, Sarah, and Higer, A.L., eds., U.S. Geological Survey Program on the south Florida ecosystem—Proceedings of South Florida Restoration Science Forum, May 17-19, 1999, Boca Raton, Florida: U.S. Geological Survey Open-File Report 99-181, p. 86.

Reddy, M.M., Aiken, G.R., Schuster, P.F., Gunther, C.D., Charlton, S.R., and Tregellas, J., 1995, Summary of Data From Onsite and Laboratory Analyses of Surface Water and Marsh Porewater from South Florida Water Management District Water Conservation Areas, The Everglades, South Florida: U.S. Geological Survey Fact Sheet.

Reddy, M.M., Aiken, G.R., Schuster, P.F., Gunther, C.D., Charlton, S.R., and Tregellas, J., 1996, Summary of data from onsite and laboratory analyses of surface water and marsh porewater from South Florida Water Management District water conservation areas, the Everglades, South Florida, March 1995: U.S. Geological Survey electronic publication available on the World Wide Web at http://wwwbrr.cr.usgs.gov/projects/SW_corrosion/fweb/index.html.

Reed, D.P., J.J. Herod, and J.B. Sickel, 1997, A comparison of larval development in the zebra mussels, Dreissena polymorpha, (Bivalvia: Dreissenidae) up to the free-swimming trochophore stage in Tennessee and Ohio River water, *in* Scott, A.F., Hamilton, S.W., Chester, E.W., and White, D.S., (eds.), Proceedings of the Seventh Symposium on the Natural History of Lower Tennessee and Cumberland River Valleys: The Center for Field Biology, Austin Peay State University, Clarksville, Tennessee, p. 85-98.

Reed, D.P., J.J. Herod, and J.B. Sickel, 1998, Variations in zebra mussel *(Dreissena polymorpha)* veliger densities throughout 1996 at Dam 52 on the lower Ohio River: Journal of Freshwater Ecology 13(3):255-261.

Reep, R.L., and O'Shea, T.J., 1990, Regional brain morphometry and lissencephaly in the Sirenia: Brain, Behavior and Evolution 35(4):185-194.

Reese, R.S., 1994, Hydrogeology and the distribution and origin of salinity in the Floridan aquifer system, southeastern Florida: U.S. Geological Survey Water-Resources Investigations Report 94-4010, 56 p.

Reese, R.S., and Memberg, S.J., 2000, Hydrogeology and the distribution of salinity in the Floridan aquifer system, Palm Beach County, Florida: U.S. Geological Survey Water-Resources Investigations Report 99-4061, 52 p., 2 plates.

Reid, J.P., Bonde, R.K., Easton, D.E., and Kochman, H.I., 1994, 1993 Annual report on the radio telemetry of manatees in Puerto Rico: U.S. Department of the Interior, National Biological Service, Gainesville, FL, 24 p.

Reid, J.P., R.K. Bonde, and O'Shea, T.J., 1995, Reproduction and mortality of radio- tagged and recognizable manatees on the Atlantic Coast of Florida, *in* O'Shea, T.J., Ackerman, B.B., and Percival, H.F., eds., Population Biology of the Florida Manatee *(Trichechus manatus latirostris):* U.S. Department of the Interior, National Biological Service, Information Technology Report 1, p. 171-191.

Reid, J.P., Rathbun, G.B., and Wilcox, J.R., 1991, Distribution patterns of individually identifiable West Indian manatees (Trichechus manatus) in Florida: Marine Mammal Science 7(2):180-190.

Retzer, M., L. G. Nico, and F. Provenzano, 1999, Two new species of Acestridium (Siluriformes: Loricariidae) from southern Venezuela, with observations on camouflage and color change: Ichthyological Exploration of Freshwaters 10(4):313-326.

Rice, K.G., 2000, ATLSS—American alligator production index model: Presentation at the FFWCC Alligator Section Meeting, Bokeelia, Florida.

Rice, K.G., Mazzotti, F.J., and Percival, H.F., 1999, Effects of restoration on alligators and crocodiles in the Greater Everglades Ecosystem: Poster presentation at the South Florida Restoration Science Forum, Boca Raton, Florida.

Rice, K.G., Palmer, M.R., and Gross, L.J., 2000, Modeling crocodilian production probabilities on a regional scale: Poster presentation at the 15th Working Meeting of the Crocodile Specialist Group, IUCN, Varadero, Cuba.

Rice, K.G., Percival, H.F., and Woodward, A.R., 2000, Estimating sighting proportions of American alligator nests during helicopter survey: SEAFWA.

Rice, K.G., Percival, H.F., Woodward, A.R., and Jennings, M.L., 1999, Effects of egg and hatchling harvest on American alligators in Florida: Journal of Wildlife Management, v. 63, no. 4, p. 1193-1200.

Robbin, D.M., 1984, A new Holocene sea-level curve for the upper Florida Keys and Florida reef tract, *in* Gleason, P.J., ed., Environments of South Florida, Present and Past: Miami Geological Society of America Memoir 2, p. 437-459.

Robbins, J.A., Holmes, C.W., Halley, R.B, Bothner, M., Shinn, E., Graney, J., Keeler, G., TenBrink, M., Orlandini, K.A., Rudnick, D., 2000, Time-averaged fluxes of lead and fallout radionuclides to sediments in Florida Bay: Journal of Geophysical Research Oceans, 105(c12)28805-28821.

Robblee, M.B., Barber, T.R., Carlson, P.R., Durako, M.J., Fourqurean, J.W., Muehlstein, L.K., Porter, D., Yarbo, L.A., Zieman, R.T., and Zieman, J.C., 1991, Mass mortality of the tropical seagrass *Thalassia testudinum* in Florida Bay (USA): Marine Ecology Progress Series, v. 71, no. 3, p. 297-299.

Robblee, M.B,. and DiDomenico, W.J., 1992, Seagrass die-off in Florida Bay, Everglades National Park: Park Science, v. 11, no. 4, p. 21-23.

Robblee, M.B., Jewell, S.D., and Schmidt, T.W., 1991, Temporal and spatial variation in the pink shrimp, *Penaeus duorarum*, in Florida Bay and adjacent waters of Everglades National Park, Annual Report, October 1, 1991: Homestead Florida, South Florida Research Center, Everglades National Park, 34 p.

Robblee, M.B., Tilmant, J.T., and Emerson, J., 1989, Quantitative observations on salinity: Bulletin of Marine Science, v. 44, no. 1, p. 523.

Robertson, W.B., 1953, A survey of the effects of fire in Everglades National Park: Homestead, Fla., National Park Service, 169 p.

Robinson, J.B., Tuovinen, O.H., 1984, Mechanisms of microbial resistance and detoxification of mercury and organomercury compounds—Physiological, biochemical, and genetic analyses: Microbiology, 48(2):95-124.

Rodis, H.G., 1973, Encroaching salt water in northeast Palm Beach County, Florida: Tallahassee, Florida Bureau of Geology Map Series 59.

Rodis, H.G., 1973, The Loxahatchee--A river in distress: U.S. Geological Survey Open-File Report FL-73017, 9 p.

Rodis, H.G., and Land, L.F., 1976, The shallow aquifer--A prime freshwater resource in eastern Palm Beach County, Florida: U.S. Geological Survey Water-Resources Investigations Report 76-21, 12 p.

Roelke, M., Schultz, D., Facemire, C., Sundlof, S., and Royals, H., 1991, Mercury contamination in Florida panthers: Gainesville, Florida Game and Fresh Water Fish Commission.

Rogers, C., 1999, Dead Porites patch reefs, St. John, U.S. Virgin Islands: Coral Reefs, v. 18, p. 254.

Rogers, C., 1999, Sampling may be haphazardous to your reef monitoring program, *in*: Maragos J.E., Grober-Dunsmore, R., eds., Proceedings of Hawaii Coral Reef Monitoring Workshop: A Tool for Management. June 1998: p. 57-64.

Rogers, C.R., V.H. Garrison and L.E. Grober-Dunsmore, 1997, A fishy story about hurricanes and herbivory: Seven years of research on a reef in St. John, U.S. Virgin Islands: Eighth International Coral Reef Symposium, p. 555-560.

Rogers, C.S., in press, Is *Acropora palmata* making a comeback in the Virgin Islands? Reef Encounter 27:15-17

Rogers, C.S., Garrison, G.H., Grober, R., Hillis, Z., and Franke, M.A., 1994, Coral reef monitoring manual for the Caribbean and Western Atlantic, p. 114.

Russell, G.M., and Goodwin, C.R., 1988, Simulation of tidal flow and circulation patterns in the Loxahatchee River estuary, southeastern Florida: U.S. Geological Survey Water-Resources Investigations Report 87-4201, 32 p.

Russell, G.M., Hanson, C.E., and Pitt, W.A.J., Jr., 1978, Water quality in the Old Plantation Water Control District, Broward County, Florida--Progress report, July 1976-June 1977: U.S. Geological Survey Open-File Report 78-411, 29 p.

Russell, G.M., and Higer, A.L., 1988, Assessment of ground-water contamination near Lantana landfill, southeast Florida: Ground Water, v. 26, no. 2, p. 156-164.

Russell, G.M., and Kane, R.L., 1995, Bathymetric and salinity characteristics of Matlacha Pass, southwestern Florida: U.S. Geological Survey Water-Resources Investigations Report 93-4057, 2 sheets.

Russell, G.M., and McPherson, B.F., 1984, Freshwater runoff and salinity distribution in the Loxahatchee River estuary, southeastern Florida, 1980-82: U.S. Geological Survey Water-Resources Investigations Report 83-4244, 36 p.

Russell, G.M., and Wexler, E.J., 1993, Hydrogeology and simulation of ground-water flow near the Lantana landfill, Palm Beach County, Florida: U.S. Geological Survey Water-Resources Investigations Report 92-4107, 55 p.

Russo, T.N., 1974, Indicators of organic contamination in Plantation Canal, Broward County, Florida, 1971-72: Tallahassee, Florida Bureau of Geology Report of Investigations 70, 38 p.

Russo, T.N., and McQuivey, R.S., 1975, Simulation of dissolved oxygen and biochemical oxygen demand, Plantation Canal, Broward County, Florida with an evaluation of the QUALI-I model for use in south Florida: U.S. Geological Survey Water-Resources Investigations Report 59-75, 49 p.

Rybicki, N.B., Reel, Justin, Ruhl, H.A., Gammon, P.T., Carter, Virginia, and Lee, J.K., 1999, Biomas and vegetative characteristics of sawgrass grown in a tilting flume as part of a study of vegetative resistance to flow: U.S. Geological Survey Open-File Report 99-230, 29 p.

Rybicki, N.B., Reel, Justin, Ruhl, H.A., Gammon, P.T., Carter, Virginia, and Lee, J.K., 2000, Sawgrass Density, Biomass, and Leaf Area Index: A Flume Study in Support of Research on Wind Sheltering Effects in the Florida Everglades: U.S. Geological Survey Open-File Report 00-172, 48 p.

Sacks, L.A., Herman, J.S., and S.J. Kauffman, 1995, Controls on high sulfate concentrations in the Upper Floridan aquifer in southwest Florida: Water Resources Research, October 1995, v. 31, no. 10, p. 2541-2551.

Sacks, L.A., and Tihansky, A.B., 1996, Geochemical and isotopic composition of ground water, with emphasis on sources of sulfate, in the Upper Floridan aquifer and intermediate aquifer system in southwest Florida: U.S. Geological Survey Water-Resources Investigations Report 96-4146, 67 p.

Salisbury, C.L, and Beck, C.A., 1993, Regional West Indian manatee 1992 Studbook, Lowry Park Zoological Garden, Tampa, Fla., 38 p.

Schaffranek, R.W., [1996], Canal and Wetland Flow/Transport Interaction. Fact Sheet FS-139-96.

Schaffranek, R.W., 1996, Coupling models for canal and wetland interactions in the south Florida ecosystem: U.S. Geological Survey Fact Sheet FS-139-96, 4 p.

Schaffranek, R.W., 1997, Coupling models for simulating canal and wetland interactions, *in* Gerould, Sarah, and Higer, A.L., eds., U.S. Geological Survey Program on the South Florida Ecosystem—Proceedings of the Technical Symposium in Ft. Lauderdale, Florida, August 25-28, 1997: U.S. Geological Survey Open-File Report 97-385, p. 79-80.

Schaffranek, R.W., 1999, Analysis of sheet flows to Florida Bay from C-111 canal, *in* Gerould, Sarah, and Higer, A.L., eds., U.S. Geological Survey Program on the south Florida ecosystem—Proceedings of South Florida Restoration Science Forum, May 17-19, 1999, Boca Raton, Florida: U.S. Geological Survey Open-File Report 99-181, p. 98-99.

Schaffranek, R.W., 1999, Hydrologic studies in support of south Florida ecosystem restoration: Proceedings of American Society of Civil Engineers Water Resources Planning and Management Conference, Tempe, Arizona, June 6-9, 1999, 8 p.

Schaffranek, R.W., and Ball, M.H., 2000, Flow velocities in wetlands adjacent to canal C-111 in south Florida: Presented during the Greater Everglades Ecosystem Restoration Conference, Naples, Florida, December 11-15, 2000.

Schaffranek, R.W., Jenter, H.L., Langevin, C.D., and Swain, E.D., (in review), The tides and inflows in the mangroves of the Everglades (TIME) project, *in* Proceedings, 2000 Florida Bay and Adjacent Marine Systems Science Conference, Key Largo Florida April 23-26, 2001.

Schaffranek, R.W., Ruhl, H.A., and Hansler, M.E., 1999, An overview of the southern inland and coastal system project of the U.S. Geological Survey south Florida ecosystem program, *in* Proceedings of the International Association of Hydraulic Research Third International Symposium on Ecohydraulics, Salt Lake City, Utah, July 13-16, 1999, 11 p.

Schill, W.B., and Dorazio, R.M., 1990, Immunological discrimination of Atlantic striped bass, Transactions of the American Fisheries Society 119: 77-85.

Schmoker, J.W., Halley, R.B., Meyer, F.W., and Robbins, S.L., 1979, Preliminary porosity estimates of south Florida Cenozoic carbonate rocks based on borehole gravity measurements: U.S. Geological Survey Open-File Report 79-1652, 17 p.

Schneider, J.J., 1969, Tidal relations in the south Biscayne Bay area, Dade County, Florida: U.S. Geological Survey Open-File Report FL-69008, 16 p.

Schneider, J.J., 1970, Tidal relations along the intracoastal waterway, Broward County, Florida: U.S. Geological Survey Open-File Report FL-70006, 17 p.

Schneider, J.J., 1973, Effects on water quality in the shallow aquifer due to the operation of the Cross State Dump, Palm Beach County, Florida: U.S. Geological Survey Open-File Report FL-73011, 42 p.

Schneider, J.J., 1973, Tidal relations along the intracoastal waterway, Palm Beach County, Florida: U.S. Geological Survey Open-File Report FL-73021, 22 p.

Schneider, J.J., 1976, Geologic data from test drilling in Palm Beach County, Florida since 1970: U.S. Geological Survey Open-File Report 76-713, 99 p.

Schneider, J.J., 1977, Water-table contours in Palm Beach County, Florida, October 5-6, 1976: U.S. Geological Survey Open-File Report 77-364, 1 sheet.

Schneider, J.J., 1980, Summary of water-level and discharge records for the East Everglades area, Dade County, Florida: U.S. Geological Survey Open-File Report 80-215, 33 p.

Schneider, J.J., and Waller, B.G., 1980, Summary of hydrologic data for the East Everglades, Dade County, Florida: U.S. Geological Survey Open-File Report 80-1292, 73 p.

Schneider, W.J., 1966, Water and the Everglades: Natural History, November 1966, p. 32-40.

Schneider, W.J., 1966, Water resources in the Everglades: Photogrammetric Engineering, v. 32, no. 6, p. 958-965.

Schoell, D.W., 1964, Recent sedimentary record in mangrove swamps and rise in sea level over the southwestern coast of Florida, Parts I and II: Journal of Marine Geology, v. 1, p. 344-366.

Schoell, D.W., Craighead, F.C., and Stuiver, M., 1966, Florida submergence curve, revised: Its relation to coastal sedimentation rates: Science, v. 163, p. 562-564.

Schowengerdt, R.A., 1983: Digital image classification—Techniques for image processing and classification in remote sensing, Orlando, Academic Press, chap. 3, p. 129-207.

Schroeder, M.C., and Bishop, E.W., 1953, Notes on Foraminifera from the Cenozoic period in southern Florida, *in* Journal of Paleontology, v. 28, no. 2, March 1954, p. 210-213 and Bulletin of the American Association of Petroleum Geologists, 1953, v. 37, no. 9, September 1953, p. 2178-2182.

Schroeder, M.C., and Klein, Howard, 1954, Geology of the western Everglades area, southern Florida: U.S. Geological Survey Circular 314, 26 p.

Schroeder, M.C., Klein, Howard, Hoy, N.D., 1958, Biscayne aquifer of Dade and Broward Counties, Florida: Tallahassee, Florida Geological Survey Report of Investigations 17, 56 p.

Schroeder, M.C., Milliken, D.L., and Love, S.K., 1954, Water Resources of Palm Beach County, Florida: Tallahassee, Florida Geological Survey Report of Investigations 13, 63 p.

Schuster, P.F., Reddy, M.M., Aiken, G.R., Hurley, J., and Krabbenhoft, D.F., 1998, Diel sulfide and dissolved oxygen concentration gradients at two sites in the Everglades (abs.): Presented during the 1998 American Geophysical Union Spring Meeting, May 26-29, 1998, Boston, Mass.

Schuster, P.F., Reddy, M.M., Aiken, G.R., Hurley, J., and Krabbenhoft, D.P., 2000, Diel sulfide and dissolved oxygen concentration gradients at two sites in the Florida Everglades, USA (abs.): Presented at the American Society of Limnology and Oceanography meeting, June 5-9, 2000, Copenhagen, Denmark.

Scott, T.M., Means, G.H., and Brewster-Wingard, G.L., 1997, Progress report on sediment analyses at selected faunal monitoring sites in north-central and northeastern Florida Bay: U.S. Geological Survey Open-File Report 97-534, 52 p.

Scott, W.B., 1977, Hydraulic conductivity and water quality of the shallow aquifer, Palm Beach County, Florida: U.S. Geological Survey Water-Resources Investigations Report 76-119, 22 p.

Scott, W.B., Land, L.F., and Rodis, H.G., 1977, Saltwater intrusion in the shallow aquifer in Palm Beach and Martin Counties, Florida: U.S. Geological Survey Water- Resources Investigations Report 76-135, 1 sheet.

Seigel, R, and Dodd, Jr., C.K., 2000, Manipulation of turtle populations: Half-way technologies or viable options?, *in* Klemens, M., ed., Turtle Conservation: A Blueprint for Survival, Smithsonian Inst. Press, Washington, D.C.

Shen, G.T., and Boyle, E.A., 1988, Determination of lead, cadmium, and other trace metals on annually banded corals: Chemical Geology, v. 67, no. 1-2, p. 47-62.

Sheridan, P., McMahan, G., Williams, A., Conley, C., and Grose, M., 1993, Response of fishery communities in western Florida Bay to the die-off of seagrasses: Vol. I. Bank-Top Habitats, 12th Biennial International ERF Conference, p. 116.

Sherwood, C.B., 1959, Ground-water resources of the Oakland Park area of eastern Broward County, Florida: Tallahassee, Florida Geological Survey Report of Investigations 20, 40 p.

Sherwood, C.B., and Grantham, R.G., 1966, Water control vs. seawater intrusion, Broward County, Florida: Tallahassee, Florida Bureau of Geology Leaflet 5, 16 p.

Sherwood, C.B., and Klein, Howard, 1958, Maps of Dade County, Florida, showing contours on the average yearly high water table, the average water table, and the average water table for October, 1940-57: U.S. Geological Survey Open-File Report FL-58004.

Sherwood, C.B., and Klein, Howard, 1960, Water-table contour map, Dade County, Florida, September 30, 1960: U.S. Geological Survey Open-File Report FL-60001.

Sherwood, C.B., and Klein, Howard, 1961, Ground-water resources of northwestern Collier County, Florida: Tallahassee, Florida Geological Survey Information Circular 29, 44 p.

Sherwood, C.B., and Klein, Howard, 1963, Saline ground water in southern Florida: Ground Water, v. 1, no. 2, 5 p.

Sherwood, C.B., and Klein, Howard, 1963, Surface-and ground-water relation in a highly permeable environment: International Association of Scientific Hydrology, v. 63, p. 454-468.

Sherwood, C.B., and Leach, S.D., 1962, Hydrologic studies in the Snapper Creek Canal area, Dade County, Florida: Tallahassee, Florida Geological Survey Report of Investigations 24, pt. 2, 32 p.

Sherwood, C.B., and Mattraw, H.C., Jr., 1976, Quantity and quality of urban stormwater in southeast Florida, *in* Proceedings of the International Seminar on Modern Development in Hydrometry, World Meteorological Organization, Padua, Italy, September 8-13, 1975: WMO 427, v. II, p. 94-108.

Sherwood, C.B., McCoy, H.J., and Galliher, C.F., 1973, Water resources of Broward County, Florida: Tallahassee, Florida Bureau of Geology Report of Investigations 65, 141 p.

Sickel, J.B., Herod, J.J., and Blalock, H.N., 1996, Biological assessment of the commercial mussel resources in Kentucky and Barkley Lakes, Kentucky. Final Report to Kentucky Dept. Fish and Wildlife Resources. No. 1 Game Farm Road.

Sickel, J.B., J.J. Herod, and H.N. Blalock, 1997, Potential for the Kentucky Dam tailwater of the Tennessee River to serve as a mussel refuge from invading zebra mussels, *in* Cummings, K.S., Buchanan, A.C., Mayer, C.A., and Naimo, T.J., eds., Conservation and management of freshwater mussels II—Initiatives for the future: Proceedings of a UMRCC symposium, 16-18 October 1995, St. Louis, Missouri: Upper Mississippi River Conservation Committee, Rock Island, Illinois, p. 214-219.

Sinclair, W.C., 1982, Hydrogeologic data from two wells at Myakka Head, Manatee County, Florida:U.S. Geological Survey Open-File Report 81-1070, 21 p.

Sirenia Project, November 1993, Atlantic Coast manatee telemetry 1986-1993 Progress Report, Vols. I and II: U.S. Department of the Interior, National Biological Service, v, 1, 232 p.

Smith, C.A., Lidz, Lauralee, and Meyer, F.W., 1982, Data on selected deep wells in south Florida: U.S. Geological Survey Open-File Report 82-348, 144 p.

Smith, L.L., Bourou, R., Joby, M., and Sibo, C., 1999, Home range and microhabitat use in the angonoka tortoise *(Geochelone yniphora)* in western Madagascar: Chelonian Conservation and Biology 3:393-400.

Smith, L.L., Franz, R., and Dodd, Jr., C.K., 1993, Additions to the herpetofauna of Egmont Key, Hillsborough County, Florida: Florida Scientist 56:231-234.

Smith, L.L., Reid, D., Bourou, R., Joby, M., and Sibo, C., 1999, Status and distribution of the angonoka tortoise *(Geochelone yniphora)* of western Madagascar: Chelonian Conservation and Biology 91(1):23-33.

Smith, T.J., III, 1998, Imperiled Wetlands [Review of] Mangroves & Salt marshes: Nature 395:131-132.

Smith, T.J., III, and others, 1989, Freshwater flow from the Everglades to Florida Bay: A historical reconstruction based on fluorescent banding in the coral in the coral *Solenastrea bournoni*: Bulletin of Marine Science, v. 44, p. 274-282.

Smith, T.J., III, Robblee, M.B., Wanless, H.R., and Doyle, T.W., 1994, Mangroves, hurricanes and lightning strikes: BioScience, v. 44, no. 4, p. 256-262.

Smith-Vaniz, W.F., 1991, [Review of] Edwards, A., Fish and Fishes of Saint Helena Island, Copeia, 1991 (4):1155-1156.

Smith-Vaniz, W.F, 1993, [Review of] Randall, J.E. Diver's guide to fishes of the Maldives, Copiea, 1993 (4):1196-1197.

Smith-Vaniz, W.F, 1995, Caranigidae, *in* Fischer, W., Krupp, F., Schneider, W., Sommer, C., Carpenter, K.E., and Nien, V.H., Guia FAO para la indetificacion de especies paplos Pacifico central-oriental, Vol.II: Vertebrados—Pt 1 Roma, FAO, p. 940-986.

Smith-Vaniz, W.F, 1997, Five new species of jawfishes *(Opistognathus: Opistognathidae)* from the western Atlantic Ocean: Bulletin of Marine Science 60(3):1074-1128.

Smith-Vaniz, W. F. 2000, A new species of pikeblenny, Chaenopsis megalops, from the southwestern Caribbean *(Teleostei: Chaenopsidae)*: Proceedings of the Biological Society of Washington, 113(4):918-925.

Smith-Vaniz, W.F. 2000, Family Carangidae, in Carpenter, K., ed., FAO species identification sheets for fishery purposes: Western Central Pacific, Food and Agricultural Organization of the United Nations, Rome, v. 3, p. 2659-2756.

Smith-Vaniz, W.F. 2000, Family Cepolidae, *in* Carpenter, K., ed., FAO species identification sheets for fishery purposes: Western Central Pacific, Food and Agricultural Organization of the United Nations, Rome, v. 4, p. 3329-3330

Smith-Vaniz, W.F, and Böhlke, E.B., 1991, Additions to the ichthyofauna of the Bahama Islands, with comments on endemic species, Proceedings of the Academy of Natural Sciences of Philadelphia, 142: 193-206.

Smith-Vaniz, W. F., J. A. Bohnsack, and J. D. Williams, 1995, Reef fishes of the Florida Keys, *in* LaRoe, E.T., Farris, G.S., Puckett, C.E., Doran, P.D., and Mac, M.J., eds., Our living resources: A report to the nation on the distribution, abundance, and health of U.S. plants, animals, and ecosystems: U.S. Department of the Interior, National Biological Service, Washington, DC., p. 279-284.

Smith-Vaniz, W.F., B.B. Collette and B.E. Luckhurst, 1999, Fishes of Bermuda: history, zoogeography, annotated checklist, and identification keys: American Society of Ichthyologists and Herpetologists, Special Publication 4, Allen Press, Lawrence, Kansas: 424 p.

Smith-Vaniz, W.F., L.S. Kaufman and J. Glowacki, 1995, Species-specific patterns of hyperostosis in marine teleost fishes. Marine Biology. 121(4):573-580.

Smith-Vaniz, W.F, and Peck, R.M., 1991, Contribution of Henry Weed Fowler (1878-1965), with a brief early history of ichthyology at the Academy of Natural Sciences of Philadelphia, Proceedings of the Academy of Natural Sciences Philadelphia, 143:173-191.

Smith-Vaniz, W.F, and R.M. Peck, 1997, Contributions of Henry Weed Fowler (1878-1965), with a brief early history of ichthyology at the Academy of Natural Sciences of Philadelphia, *in* Pietsch, T.W, and Anderson, W.D., eds., Collection building in ichthyology and herpetology: American Society of Ichthyologists and Herpetologists, Special Publication No. 3, Allen Press, Lawrence, Kansas, p. 377-389.

Smith-Vaniz, W.F., Quero, J.C, and Desoutter, M., 1991, Carangidae, *in* Check-list of fishes of the eastern tropical Atlantic (CLOFETA), vol. 2, ORSTOM Paris, p. 729-755.

Smith-Vaniz, W.F, and J.E. Randall, 1994, Scomer dentex Bloch & Schneider, 1801 (currenly *Caranx or Pseudocaranx)* and Caranx lugubris Poey, 1860 *(Osteichthyes, Percuriformes)*: proposed conservation of the specific names, Bulletin of Zoological Nomenclature, 51(4):323-329.

Smith-Vaniz, W.F., in press, [Review of] Sanders, A. E, and W. D. Anderson, Jr. Natural History Investigations in South Carolina from Colonial Times to the Present: Copeia.

Snyder, J.R., 1991, Fire regimes in subtropical south Florida, *in* Proceedings of the Tall Timbers Fire Ecology Conference: v. 17, p. 303-319.

Snyder, J.R., Herndon, A., and Robertson, W.B., 1990, South Florida rockland, *in* Myers, R.L., and Ewel, J.J., eds., Ecosystems of Florida: Orlando, University Presses of Florida, p. 230-277.

Soares-Port, L. M., S. J. Walsh, L. G. Nico and J. M. Netto, 1999, A new species of Gelanoglanis from the Orinoco and Amazon river basins, with comments on miniaturization within the genus *(Siluriformes: Auchenipteridae: Centromochlinae):* Ichthyological Exploration of Freshwaters 10(1):63-72.

Sonenshein, R.S., 1992, Documentation of a digital spatial data base for hydrologic investigations, Broward County, Florida: U.S. Geological Survey Water-Resources Investigations Report 92-4061, 55 p.

Sonenshein, R.S., 1995, A hydrogeologic approach to identify land uses that overlie ground-water flow paths, Broward County, Florida: U.S. Geological Survey Water- Resources Investigations Report 94-4167, 59 p.

Sonenshein, R.S., 1996, Seepage beneath levee 30 in northern Dade County: South Florida Ecosystem Program: U.S. Geological Survey Fact Sheet FS-132-96, 3 p.

Sonenshein, R.S., 1997, Delineation and extent of saltwater intrusion in the Biscayne aquifer, eastern Dade County, Florida, 1995:U.S. Geological Survey Water- Resources Investigations Report 96-4285, 1 sheet.

Sonenshein, R.S., 1997, Evaluation of the design of a regional ground-water quality monitoring network, Broward County, Florida: U.S. Geological Survey Water-Resources Investigations Report 97-4175, 57 p.

Sonenshein, R.S., 1997, Quantifying seepage beneath Levee 30, Dade County, Florida, *in* Gerould, Sarah, and Higer, A.L., eds., U.S. Geological Survey Program on the South Florida Ecosystem—Proceedings of the Technical Symposium in Ft. Lauderdale, Florida, August 25-28, 1997: U.S. Geological Survey Open-File Report 97-385, p. 87-88.

Sonenshein, R.S., and Hofstetter, R.H., 1990, Hydrologic effects of well-field operations in a wetland, Dade County, Florida: U.S. Geological Survey Water-Resources Investigations Report 90-4143, 16 p.

Sonenshein, R.S., Causaras, C.R., and Fish, J.E., 1984, Index of hydrologic data for selected sites in Dade County, Florida, 1923-80: U.S. Geological Survey Open-File Report 84-430, 3 sheets.

Sonenshein, R.S., Causaras, C.R., and Fish, J.E., 1986, Index of hydrologic data for selected sites in Palm Beach County, Florida, 1928-80: U.S. Geological Survey Open-File Report 86-54, 3 sheets.

Sonenshein, R.S., Fish, J.E., Causaras, C.R., and Poore, D.M., 1982, Index of hydrologic data for selected sites in Broward County, Florida, 1939-80: U.S. Geological Survey Open-File Report 82-920, 39 p, and 4 sheets.

Sonenshein, R.S., and Koszalka, E.J., 1996, Trends in water-table altitude (1984-93) and saltwater intrusion (1974-93) in the Biscayne aquifer, Dade County, Florida: U.S. Geological Survey Open-File Report 95-705, 2 sheets.

Sonntag, W.H., 1980, Water-quality data for canals in eastern Broward County, Florida, 1975-78: U.S. Geological Survey Open-File Report 80-68, 161 p.

Sonntag, W.H., 1982, Surface water for underground storage, south Florida, *in* Proceedings of the American Society of Civil Engineers Specialty Conference on Environmentally Sound Water and Soil Management, Orlando, Florida.

Sonntag, W.H., 1984, Subsurface storage of freshwater in south Florida: Evaluation of surface-water discharge data at selected sites: U.S. Geological Survey Water- Resources Investigations Report 84-4008, 75 p.

Sonntag, W.H., 1987, Chemical characteristics of water in the surficial aquifer system, Dade County, Florida: U.S. Geological Survey Water-Resources Investigations Report 87-4080, 42 p, 2 plates.

Sonntag, W.H., and McPherson, B.F., 1984, Nutrient input from the Loxahatchee River Environmental Control district sewage-treatment plant to the Loxahatchee River estuary, southeastern Florida: U.S. Geological Survey Water-Resources Investigations Report 84-4020, 23 p.

Sonntag, W.H., and McPherson, B.F., 1984, Sediment concentrations and loads in the Loxahatchee River estuary, Florida, 1980-82: U.S. Geological Survey Water-Resources Investigations Report 84-4157, 30 p.

Spier, L.P, and J. R. Snyder, 1998, Effects of wet- and dry-season fires on Jacquemontia curtisii, a south Florida pine forest endemic. Natural Areas Journal 18(4):350-357.

Sprinkle, C.L., 1982, Chloride concentration in water from the upper permeable zone of the Tertiary limestone aquifer system, southeastern United States: U.S. Geological Survey Water-Resources Investigations Open-File Report 81-1103, 1 sheet.

Sprinkle, C.L., 1982, Dissolved-solids concentration in water from the upper permeable zone of the Tertiary limestone aquifer system, southeastern United States: U.S. Geological Survey Water-Resources Investigations Open-File Report 82-94, 1 sheet.

Sprinkle, C.L., 1982, Sulfate concentration in water from the upper permeable zone of the Tertiary limestone aquifer system, southeastern United States: U.S. Geological Survey Water-Resources Investigations Open-File Report 81-1101, 1 sheet.

Sprinkle, C.L., 1982, Total hardness of water from the upper permeable zone of the Tertiary limestone aquifer system, southeastern United States: U.S. Geological Survey Water-Resources Investigations Open-File Report 81-1102, 1 sheet.

Sproul, C.R., Boggess, D.H., and Woodard, H.J., 1972, Saline-water intrusion from deep artesian sources in the McGregor Isles area of Lee County, Florida: Tallahassee, Florida Bureau of Geology Information Circular 75, 30 p.

Stallman, R.W., 1956, Preliminary findings on ground-water conditions relative to area B flood-control plans, Miami, Florida: U.S. Geological Survey Open-File Report FL-56001, 42 p.

Stapor, F.W., Jr., Mathews, T.M., and Linfors-Kearsin, F.E., 1991, Barrier-island progradation and Holocene sea-level history in southwest Florida: Journal of Coastal Research, v. 7, no. 3, p. 815-838.

Steinkampf, W.C., 1982, Origins and distribution of saline ground waters in the Floridan aquifer in coastal southwest Florida: U.S. Geological Survey Water-Resources Investigations Report 82-4052, 34 p.

Stoeckel, J.N., Gagen, C.J., Herod, J.J., Beadel, R.K., Shook, S.D., Howell, C.S., and Penny, P., 1994, 1994 Annual summary: ENTERGY Lake Dardanelle fish and zebra mussel study, 136 p.

Stoeckel, J.N., Gagen, C.J., McCollum, D.O., Beadel, R.K., Herod, J.J., Shook S.D., 1993, 1993 Annual summary: ENTERGY Lake Dardanelle fish and zebra mussel study, 125 p.

Stoker, Y.E., 1986, Water quality of the Charlotte Harbor estuarine system, Florida, November 1982 through October 1984: U.S. Geological Survey Open-File Report 85-563, 213 p.

Stoker, Y.E., 1992, Salinity distribution and variation with freshwater inflow and tide, and potential changes in salinity due to altered freshwater inflow in the Charlotte Harbor estuarine system, Florida: U.S. Geological Survey Water-Resources Investigations Report 92-4062, 30 p.

Stoker, Y.E., Henderson, S.E., and B.F. McPherson, 1989, Hydraulic and salinity characteristics of the tidal reach of the Peace River, southwestern Florida: U.S. Geological Survey Water-Resources Investigations Report 88-4162, 37 p.

Stoker, Y.E., and Karavitis, G.A., 1983, Literature assessment of the Charlotte Harbor estuarine system and surrounding area, southwest Florida: U.S. Geological Survey Open-File Report 83-127, 143 p.

Stone, J.R., and Brewster-Wingard, G.L., 1998, The south Florida Ecosystem history database, *in* Proceedings, 1998 Florida Bay and Adjacent Marine Systems Science Conference, Key Largo Florida.

Stone, J.R., and Brewster-Wingard, G.L., 1998, URL http://geology.er.usgs.gov/eespteam/fla/home. Links to all OFR's, project database, all field data, and an educational outreach page.

Stoyer, C.H, 1988, TEMIX-G-User's Manual: Golden, Colo., Interpex Limited.

Streeter, V.L., and Wylie, E.B., 1979, Fluid mechanics (7th ed.): New York, McGraw-Hill, 562 p.

Stringfield, V.T., 1933, Exploration of artesian wells in Sarasota County, Florida: Tallahassee, Florida Geological Survey Twenty-Third and Twenty-Fourth Annual Report, p. 199-227.

Stringfield, V.T., 1933, Ground water in Lake Okeechobee area, Florida: Tallahassee, Florida Geological Survey Report of Investigations 2, 31 p.

Stringfield, V.T., 1940, Ground water in the southeastern states: American Water Works Association Journal, 9(1).

Stringfield, V.T., 1966, Artesian water in Tertiary limestone in the southeastern states: U.S. Geological Survey Professional Paper 517, 226 p.

Stringfield, V.T., and LeGrand, H.E., 1966, Hydrology of limestone terranes in the Coastal Plain of southeastern United States: Geological Society of America Special Paper no. 93.

Stumpf, R.P., and Frayer, M.L., 1997, Temporal and spatial change in coastal ecosystems using remote sensing: Example with Florida Bay, USA, emphasizing AVHRR Imagery, *in* Proceedings of the 4th International Conference on Remote Sensing for Marine and Coastal Environments: Michigan, Ann Arbor, Environmental Research Institute, v. 1, p. 65-73.

Stumpf, R.P., and Frayer, M.L., in press, Use of AVHRR imagery to examine long-term trends in water clarity in coastal estuaries: Example in Florida Bay, *in* Kahru, M., and Brown, C., eds., Monitoring Algal Blooms—New Techniques for Detecting Large-Scale Environmental Change: Landes Bioscience, p. 1-23.

Stumpf, R.P., Frayer, M.L., Durako, M.D., and Brock, J.C., 1999, Variations in water clarity in Florida Bay from 1985 to 1997: Estuaries, v. 22, p. 431-444.

Sutcliffe, Horace, Jr., 1975, Appraisal of the water resources of Charlotte County, Florida: Tallahassee, Florida Bureau of Geology Report of Investigations 78, 53 p.

Sutcliffe, Horace, Jr., 1979, Hydrologic data from a deep test well, City of Sarasota, Florida: U.S. Geological Survey Open-File Report 79-1275, 23 p.

Sutcliffe, Horace, Jr., and Buono, Anthony, 1979, Hydrologic records, Verna well- field area, city of Sarasota, Florida, 1962-76--A data report: U.S. Geological Survey Open-File Report 79-1259, 141 p.

Sutcliffe, Horace, Jr., and Joyner, B.F., 1966, Packer testing in water wells near Sarasota, Florida: Ground Water, v. 4, no. 2, 5 p.

Sutcliffe, Horace, Jr., and Joyner, B.F., 1968, Test well exploration in the Myakka River basin area, Florida: Tallahassee, Florida Division of Geology Information Circular 56, 61 p.

Sutcliffe, Horace, Jr., and Miller, R.L., 1981, Data on ground-water quality with emphasis on radionuclides, Sarasota County, Florida: U.S. Geological Survey Open-File Report 80-1223, 13 p.

Sutcliffe, Horace, Jr., and Thompson, T.H., 1983, Occurrence and use of ground water in the Venice-Englewood area, Sarasota and Charlotte Counties, Florida: U.S. Geological Survey Open-File Report 82-700, 59 p.

Swain, E.D., [1996], Quantifying freshwater discharge for coastal hydraulic control structures in eastern Dade County, Florida: U.S. Geological Survey Fact Sheet FS-123-96, 4 p.

Swain, E.D., 2000, Numerical representation of dynamic flow and transport at the Everglades/Florida Bay interface: U.S. Geological Survey South Florida Ecosystem Program paper, 9 p., URL http://sflwww.er.usgs.gov/publications/papers/numeric.pdf.

Swain, E.D., Howie, Barbara, and Dixon, Joann, 1996, Description and field analysis of a coupled ground-water/surface-water flow model (MODFLOW/BRANCH) with modifications for structures and wetlands in southern Dade County, Florida: U.S. Geological Survey Report 96-4118, 67 p.

Swain, E.D., Kapadia, Amit, Kone, Siaka, Damisse, Emile, Mutndu, Davies, and Tillis, G.M., 1997, Determining discharge-coefficient ratings for coastal structures in Dade County, Florida: U.S. Geological Survey Water-Resources Investigations Report 97-4079, 61 p.

Swain, E.D., and Sonenshein, R.S., 1994, Spatial and temporal statistical analysis of a ground-water level network, Broward County, Florida: U.S. Geological Survey Water-Resources Investigations Report 94-4076, 67 p.

Swain, E.D., Tillis, G.M., and Kapadia, Amit, Determining freshwater discharge through coastal structures in southeastern Florida, *in* Gerould, Sarah, and Higer, A.L., eds., U.S. Geological Survey Program on the South Florida Ecosystem—Proceedings of the Technical Symposium in Ft. Lauderdale, Florida, August 25-28, 1997: U.S. Geological Survey Open-File Report 97-385, p. 92.

Swancar, Amy, 1996, Water quality, pesticide occurrence, and effects of irrigation with reclaimed water at golf courses in Florida: U.S. Geological Survey Water-Resources Investigations Report 95-4250, 86 p.

Swarenski, P.W., and Holmes, C.W., [1999], Examining Freshwater-Saltwater Interface Processes with Four Radium Isotopes: U.S. Geological Survey Fact Sheet FS-65-99.

Swayze, L.J., 1979, Water-level contour map of the Biscayne aquifer, Alexander Orr and southwest well-field areas, Dade County, Florida, October 12, 1978: U.S. Geological Survey Open-File Report 79-1266.

Swayze, L.J., 1980, Altitude of water table and saline-water front, Hialeah-Miami Springs well field area, Biscayne aquifer, Dade County, Florida, May 12, 1980: U.S. Geological Survey Open-File Report 80-1211, 1 sheet.

Swayze, L.J., 1980, Altitude of water table and saline-water front, Hialeah-Miami Springs well field area, Dade County, Florida, May 3, 1978: U.S. Geological Survey Open-File Report 80-588, 1 sheet.

Swayze, L.J., 1980, Altitude of water table and saline-water front Hialeah-Miami Springs well field area, Dade County, Florida, October 5, 1979: U.S. Geological Survey Open-File Report 80-559, 1 sheet.

Swayze, L.J., 1980, Water-level contour and salt-front map, Hialeah-Miami Springs well field area, Dade County, Florida, October 13, 1978: U.S. Geological Survey Open-File Report 80-8, 1 sheet.

Swayze, L.J., 1980, Water-level contour map of the Biscayne aquifer, Alexander Orr and southwest well-field area, Dade County, Florida, May 2, 1978: U.S. Geological Survey Open-File Report 80-221, 1 sheet.

Swayze, L.J., 1981, Altitude of water table and chloride concentration at selected wells, Alexander Orr and southwest well-field areas, Biscayne aquifer, Dade County, Florida, May 9, 1980: U.S. Geological Survey Open-File Report 81-54.

Swayze, L.J., 1981, Altitude of water table, Biscayne aquifer, Dade County, Florida, April 1978: U.S. Geological Survey Open-File Report 81-225.

Swayze, L.J., 1981, Altitude of water table, Biscayne aquifer, Dade County, Florida, October 1978: U.S. Geological Survey Open-File Report 81-327.

Swayze, L.J., 1981, Annotated selected references on natural resources investigations, Collier County, Florida: U.S. Geological Survey Open-File Report 81-1184, 45 p.

Swayze, L.J., 1988, Ground-water flow beneath levee 35A from Conservation Area 2B, Broward County, Florida: U.S. Geological Survey Water-Resources Investigations Report 87-4280, 22 p.

Swayze, L.J., McGovern, M.D., and Fischer, J.N., 1980, Lithologic logs and geophysical logs from test drilling in Palm Beach County, Florida, since 1974: U.S. Geological Survey Open-File Report 81-68, 93 p.

Swayze, L.J., and McPherson, B.F., 1977, The effect of the Faka Union Canal system on water levels in the Fakahatchee Strand, Collier County, Florida: U.S. Geological Survey Water-Resources Investigations Report 77-61, 19 p.

Swayze, L.J., and Miller, W.L., 1984, Hydrogeology of a zone of secondary permeability in the surficial aquifer of eastern Palm Beach County, Florida: U.S. Geological Survey Water-Resources Investigations Report 83-4249, 38 p.

Swift, D.R., Anclade, Cathy, and Kantrowitz, I.H., Algal blooms in Lake Okeechobee, Florida, and management strategies to mitigate eutrophication, *in* Carr, J.E., and others, compilers, National Water Summary, 1987--Hydrologic Events and Water Supply and Use: U.S. Geological Survey Water-Supply Paper 2350, p. 57-64.

Tarver, G.R., 1964, Hydrology of the Biscayne aquifer in the Pompano Beach area, Broward County, Florida: Tallahassee, Florida Geological Survey Report of Investigations 36, 47 p.

Taylor, R.C., Trexler, J.C., and Loftus, W.F., in press, Experimental evidence for the roles of intraguild competition and predation as structuring agents of Everglades fish communties: Oecologia.

Thagard, M.E., and Seaber, P.R., 1987, Location of potential ground-water quality monitoring wells, 1 x 2 quadrangle, Florida: U.S. Geological Survey Water-Resources Investigations 85-4136 (Key West), 85-4137 (Miami) 85-4144 (West Palm Beach), 1 sheet each.

Thayer, G.W., LaCroix, M.W., and Murphey, P.L., 1993, Response of fisheries communities in western Florida Bay to the die-off of seagrasses: Vol. II. Basin Habitats, 12th Biennial International ERF Conference, p. 123-124.

Thayer, G.W., Powell, A.B., and Hoss, D.E., 1999, Composition of larval, juvenile, and small adult fishes relative to changes in environmental conditions in Florida Bay: Estuaries, 22(2B):518-533.

Tihansky, A.B., Arthur, J.D., and DeWitt, D.W., 1996, Sublake geologic structure from high-resolution seismic-reflection data from four sinkhole lakes in the Lake Wales Ridge, central Florida: U.S. Geological Survey Open-File Report 96-224, 72 p.

Tihansky, A.B., and Sacks, L.A., 1997, Evaluation of nitrate sources using nitrogen-isotope techniques in shallow ground water within selected Lake Basins in the central Lakes District, Polk and Highlands Counties, Florida: U.S. Geological Survey Water-Resources Investigations Report 97-4207, 28 p.

Tillis, G.M., and Swain, E.D., 1998, Determining discharge-coefficient ratings for selected coastal structures in Broward and Palm Beach Counties, Florida: U.S. Geological Survey Water-Resources Investigations Report 98-4007, 37 p.

Titus, J.G., and Narayanan, V.K., 1995, The probability of sea level rise: U.S. Environmental Protection Agency Report 230-R-95-008, 186 p.

Toler, L.G., 1967, Fluoride in water in the Alafia and Peace River basins, Florida: Tallahassee, Florida Geological Survey Report of Investigations 46, 46 p.

Trommer, J.T., DelCharco, M.J., and Lewelling, B.R., 1999, Water budget and water quality of Ward Lake, flow and water-quality characteristics of the Braden River Estuary, and the effects of Ward Lake on the hydrologic system, west-central Florida: U.S. Geological Survey Water-Resources Investigations Report 98-4251, 33 p.

Trommer, J.T., Loper, J.E., and Hammett, K.M., 1996, Evaluation and modification of five techniques for estimating stormwater runoff for watersheds in west-central Florida: U.S. Geological Survey Water-Resources Investigations Report 96-4158, 37 p.

Trexler, J.C., Loftus, W.F., Jordan, C.F., Lorenz, J., Chick, J., and Kobza, R., in press, Empirical assessment of fish introductions in southern Florida: An evaluation of contrasting views: Biological Invasions, 26 p.

Turgeon, D.D., Quinn, J.F., Jr., Bogan, A.E., Coan, E.V., Hochberg, F.G., Lyons, W.G., Mikkelsen, P.M., Neves, R.J., Roper, C.F.E., Rosenberg, G., Roth, B., Scheltema, A., Thompson, F.G., Vecchione, M., and Williams, J.D., 1998, Common and Scientific Names of Aquatic Invertebrates from the United States and Canada: Mollusks (2d ed.): Bethesda, Md., American Fisheries Society Special Publication 26.

Turner, A.M., Trexler, J.C., Jordan, F., Slack, S.J., Geddes, P., Chick, J., and Loftus, W.F., 1999, Targeting ecosystem features for conservation: Standing crops in the Florida Everglades: Conservation Biology, v. 13, p. 898-911.

U.S. Fish and Wildlife Service, 1996, Florida Manatee Recovery Plan Second Revision: U.S. Fish and Wildlife Service, Atlanta, Georgia. 160 p.

U.S. Geological Survey, 1973, Resource and land information for south Dade County, Florida: U.S. Geological Survey Miscellaneous Investigation Series I-850.

U.S. Geological Survey, [1996], Color infared digital orthophoto quadrangles for the south Florida ecosystem area: U.S. Geological Survey Fact Sheet FS-163-96, 1 p.

Vanlier, K.E., Armbruster, J.T., Altschuler, Z. S. and Mattraw, H. C., 1973, Natural hazards, in Resource and land information, south Dade County, Florida: U.S. Geological Survey Investigation I-850, p. 14-15.

Vanni, M. J., DeAngelis, D.L., and D. E. Schindler, in press, Introduction: Fluxes of nutrients and detritus across habitats, *in* Anderson W.B., and Polis, G.A., eds., Food Webs and Landscapes. University of Chicago Press.

Vorhis, R.C., 1948, Geology and ground water of the Fort Lauderdale, Florida, area: Tallahassee, Florida Geological Survey Report of Investigations 6, 43 p.

Waldrop, T.A., White, D.L., and Jones, S.M., 1992, Fire regimes for pine-grassland communities in the southeastern United States: Forest Ecology and Management, v. 47, no. 1-4, p, 195-210.

Waller, B.G., 1975, Distribution of nitrogen and phosphorus in the conservation areas in south Florida from July 1972 to June 1973: U.S. Geological Survey Water-Resources Investigations Report 5-75, 33 p.

Waller, B.G., 1976, Analysis of selected benthic communities in the Florida Everglades with reference to their physical and chemical environment: U.S. Geological Survey Water-Resources Investigations Report 76-28, 33 p.

Waller, B.G., 1978, Effects of land use and water management on water quality in the western South New River Canal basin, southeast Florida, 1974-75: U.S. Geological Survey Water-Resources Investigations Report 78-30, 56 p.

Waller, B.G., 1981, Water-quality data for selected stations in the East Everglades, Florida: U.S. Geological Survey Open-File Report 81-821, 77 p.

Waller, B.G., 1982, Areal extent of a plume of mineralized water from a flowing artesian well in Dade County, Florida: U.S. Geological Survey Water-Resources Investigations Report 82-20, 20 p.

Waller, B.G., 1982, Effects of land use on surface-water quality in the East Everglades, Dade County, Florida: U.S. Geological Survey Water-Resources Investigations Report 82-4093, 67 p.

Waller, B.G., 1982, Water-quality characteristics of Everglades National Park, 1959-77 with reference to the effects of water management: U.S. Geological Survey Water-Resources Investigations Report 82-34, 51 p.

Waller, B.G., 1985, Drought of 1980-82 in southeast Florida with comparison to the 1961-62 and 1970-71 droughts: U.S. Geological Survey Water-Resources Investigations Report 85-4152, 29 p.

Waller, B.G., 1986, Flood reduction efficiency of the water management system in Dade County (Miami), Florida, *in* Proceedings of American Society of Civil Engineers Conference, Long Beach, California, August 4-6, 1986: p. 897-902.

Waller, B.G., and Cannon, F.L., 1986, Water-quality data for the ground-water network in eastern Broward County, Florida, 1983-84: U.S. Geological Survey Open-File Report 86-313, 68 p.

Waller, B.G., and Earle, J.E., 1975, Chemical and biological quality of water in part of the Everglades, southeastern Florida: U.S. Geological Survey Water-Resources Investigations Report 56-75, 157 p.

Waller, B.G., and Howie, Barbara, 1988, Determining nonpoint source contamination by agricultural chemicals in an unconfined aquifer, Dade County, Florida: Procedures and preliminary results, *in* Collins, A.G., and Johnson, A.I., eds., Ground-water Contamination Field Methods: American Society for Testing and Materials 1988, p. 459-467.

Waller, B.G., Howie, Barbara, and Causaras, C.R., 1987, Effluent migration from septic tank systems in two different lithologies, Broward County, Florida: U.S. Geological Survey Water-Resources Investigations Report 87-4075, 22 p.

Waller, B.G., Klein, Howard, and Lefkoff, L.J., 1984, Attenuation of stormwater contaminants from highway runoff within unsaturated limestone, Dade County, Florida: U.S. Geological Survey Water-Resources Investigation Report 84-4083, 13 p.

Waller, B.G., and Miller, W.L., 1982, Assessment of water quality in canals of eastern Broward County, Florida, 1969-74: U.S. Geological Survey Water-Resources Investigations Report 82-3, 70 p.

Waller, B.G., Miller, W.L., and Beaven, T.R., 1975, Water-quality data for canals in eastern Broward County, Florida, 1969-1974: U.S. Geological Survey Open-File Report FL-75009, 156 p.

Walsh, S.J, 1991, A Systematic Revision of the Neotropical Catfish Family Ageneiosidae *(Teleostei: Ostariophysi: Siluriformes),* PhD Dissertation, University of Florida, 364 p.

Walsh, S.J, 1999, [review of] Bardach, J.E, ed., Sustainable Aquaculture, John Wiley & Sons, Inc.: Quarterly Review of Biology 74(3):359.

Walsh, S.J, 2000, Conservation of Aquatic Karst Biotas: Shedding Light on Troubled Waters, *in* Abell, R.A., and others, eds., Freshwater Ecoregions of North America: A Conservation Assessment. World Wildlife Fund and Island Press, Washington, D.C., p. 106-108.

Walsh, S. J., N. M. Burkhead, and J. D. Williams, 1995, Southeastern freshwater fishes, *in* LaRoe, E.T., Farris, G.S., Puckett, C.E., Doran, P.D., and Mac, M.J., eds., Our living resources: A report to the nation on the distribution, abundance, and health of U.S. plants, animals, and ecosystems: U.S. Department of the Interior, National Biological Service, Washington, DC., p. 144-147.

Walsh, S.J., L.J. Chapman, A.E. Rosenberger, and C.A. Chapman, 2000, Redescription of Amphilius jacksonii *(Siluriformes: Amphiliidae)* with Habitat and Life-History Notes: Ichthyological Exploration of Freshwaters 11(2):163-174.

Walsh, S.J., D.C. Haney, C.M. Timmerman, and R.M. Dorazio, 1998, Physiological tolerances of juvenile robust redhorse, Moxostoma robustum: Conservation implications for an imperiled species: Environmental Biology of Fishes 51:429-444.

Walsh, S.J, and C.R. Gilbert, 1995, New Species of Troglobitic Catfish of the Genus Prietella (Siluriformes: Ictaluridae) from Northeastern Mexico: Copeia 1995(4):850-861.

Walsh, S.J. [Review of] Minckley, W.L, and Deacon, J.E., 1993, Battle Against Extinction: Native Fish Management in the American West (University of Arizona Press, 1991, Tucson, 517 p.), Copeia 1993(2):572-573.

Walsh, S.J. [Review of] Newson, M, 1994, Land, Water and Development: River Basin Systems and Their Sustainable Management (Routledge, 1992, London, 351 p.), The Quarterly Review of Biology, 69(2):287.

Walter, L.M., and Burton, E.A., 1990, Dissolution of recent platform carbonate sediments in marine pore fluids: American Journal of Science, v. 290, no. 6, p. 601-643.

Wanless, H.R., and others, 1994, Sea level control on stability of Everglades wetlands, *in* Davis, S.M., and Ogden, J.C., eds., Everglades--The ecosystem and its restoration: Delray Beach, Florida, St. Lucie Press, p, 199-224.

Wanless, Harold, Rossinsky, Victor, Jr., and McPherson, B.F., 1984, Sedimentologic history of the Loxahatchee River estuary, Florida: U.S. Geological Survey Water- Resources Investigations Report 84-4120, 58 p.

Wanless, H.R., and Tagett, M.G., 1989, Origin, growth, and evolution of carbonate mudbanks in Florida Bay: Bulletin of Marine Science, v. 44, no.1, p. 454-489.

Wardlaw, B.R., ed., in press, Paleoecology studies of south Florida: American Bulletin of Paleontology.

Ware, F., Royals, H., Lange, T., 1990, Mercury contamination in Florida largemouth bass, *in* Proceedings of the American Conference, Southeastern Association Fish and Wildlife Agency: 5 p.

Warren, M.L., Jr., B.M. Burr, S.J. Walsh, H.L. Bart, Jr., R.C. Cashner, D.A. Etnier, B.J. Freeman, B.R. Kuhajda, R.L. Mayden, H.W. Robison, S.T. Ross, and W.C. Starnes, 2000, Diversity, Distribution, and Conservation Status of the Native Freshwater Fishes of the Southern United States. Fisheries, v. 25, no. 10, p. 7-31.

Weedman, S.D., 1996, Hydrogeology of the surficial aquifer system of southwest Florida: U.S. Geological Survey Fact Sheet FS-158-96, 1 p.

Weedman, S.D., Paillet, F.L., Edwards, L.E., Simmons, K.R., Scott, T.S., Wardlaw, B.R., Reese, R.S. and Blair, J. L., 1999, Lithostratigraphy, geophysics, biostratigraphy, and strontium-isotope stratigraphy of the surficial aquifer system of Eastern Collier County and Northern Monroe County, Florida: U.S. Geological Survey Open File Report 99-432, 125 p.

Weedman, S.D., Paillet, F.L, Means, G.H., and Scott, T.M., 1997, Lithology and geophysics of the surficial aquifer system in western Collier County: U.S. Geological Survey Open File Report 97-436, 167 p.

Welch, R., Madden, M., and Doren, R.F., 1999, Mapping the Everglades: PE & RS, v. 65, no. 2, p. 163-170.

White, P. S., S. P. Wilds, G. A. Thunhorst, J. M. Alderman, M. Barnett-Lawrence, J. Whitfield Gibbons, T. C. Gibson, D. S. Lee, M. R. Pelton, D. Penrose, and J. D. Williams, 1998, Southeast, *in* Mac, M.J., Opler, P.A., C.E. Puckett, C.E., and Doran, P,D., eds., Status and Trends of the Nation's Biological Resources. 2 Vols: U.S. Geological Survey, p. 255-314.

Wicklein, S.M., and Gain, W.S., 1999, Probability analysis of the relation of salinity to freshwater Discharge in the St. Sebastian River, Florida: U.S. Geological Survey Water-Resources Investigations Report 99-4003, 37 p.

Wilkinson, P.M., and Rice, K.G., 2000, Determining the size of American alligators using hind-foot track length: SEAFWA.

Willard, D.A., [1996], Ecosystem History: Terrestrial and Fresh-Water Ecosystems of Southern Florida: U.S. Geological Survey Fact Sheet FS-146-96.

Willard, D.A., and Malin, P. E., 1997, Pollen Census Data From Southern Florida: Sites Along a Nutrient Gradient in Water Conservation Area 2A: U.S. Geological Survey Open-File Report 97-0497, 25 p.

Willard, D.A., and Brewster-Wingard, G.L., [1995], South Florida Ecosystems: Changes Through Time: U.S. Geological Survey Fact Sheet FS-171-95.

Willard, D.A., Brewster-Wingard, G.L., Cronin, T.M., Ishman, S.E., and Holmes, C.W., 1999, Impact of hydrologic changes on the Everglades/Florida Bay ecosystem: A regional, paleoecological perspective, *in* Proceedings, 1999 Florida Bay and Adjacent Marine Systems Science Conference, Key Largo Florida, November 1-5, 1999: p.196-197.

Willard, D.A., Brewster-Wingard, G.L., Fellman, Claire, and Ishman, S.E., 1997, Paleontological Data from Mud Creek Core 1, Southern Florida: U.S. Geological Survey Open-File Report 97-0736, 14 p.

Willard, D.A., and Holmes, C.W., 1997, Pollen and geochronological data from south Florida Taylor Creek Site 2: U.S. Geological Survey Open-File Report 97-35, 28 p.

Willard, D.A., and Weimer, L.M., 1997, Palynological Census Data From Surface Samples in South Florida: U.S. Geological Survey Open-File Report 97-0867, 22 p.

Wilson, L.D., Miller, R.A., and Doyle, W.H., Jr., 1978, Urban storm-water data management system, Broward County, Florida: University of Kentucky Bulletin 116, p. 263-268.

Wilson, S.C., Armstrong, D.L., Simmons, L.G., Morris, D.J, and Gross, T.S., 1993, Evaluation of Telazol as an immobilization agent for captive gaur (Bos gaurus), J. Zoo Wildlife Med, 17:65-72.

Wilson, W.E., 1977, Ground-water resources of De Soto and Hardee Counties, Florida: Tallahassee, Florida Bureau of Geology Report of Investigations 83, 102 p.

Wimberly, E.T., 1973, Reconnaissance of water quality in the vicinity of Sunniland oil field, Collier County, Florida, 1971-72: U.S. Geological Survey Water-Resources Investigations Report 35-73, 10 p.

Wimberly, E.T., 1974, Quality of surface water in the vicinity of oil exploration sites, Big Cypress area, south Florida: U.S. Geological Survey Open-File Report FL-74012, 26 p.

Wimberly, E.T., 1975, Satellite relay and processing of hydrologic data in south Florida: U.S. Geological Survey Water-Resources Investigations Report 12-75, 19 p.

Wingard, G.L., Cronin, T.M., Willard, D.A., Ishman, S.E., Edwards, L.E., Holmes, C., and Weedman, S.D., 1995, Florida Bay ecosystem: Measuring historical change, *in* Proceedings of the Florida Bay Science Conference: A Report by Principal Investigators, October 17-18, 1995, Gainesville, Fla.: p. 118-120.

Wingard, G.L., Ishman, S.E., Cronin, T.M., Edwards, L.E. Willard, D.A., and Halley, R.B., 1995, Preliminary analysis of down-core biotic assemblages: Bob Allen Keys, Everglades National Park, Florida Bay: U.S. Geological Survey Open-File Report 95-628, 35 p.

Wingard, G.L., and Willard, D.A., 1996, South Florida ecosystem reconstruction: The past is the key to the present (and future): Florida Scientist, Program Issue, 60th Annual Meeting Florida Academy of Sciences, v. 59, supplement 1, p. 22-23.

Wingard, G.L., Willard, D.A., Cronin, T.M., Ishman, S.E., Edwards, L.E., Weedman, S.D., 1995, South Florida ecosystem history: Floral and faunal response to environmental changes during the last 100 years, *in* Proceedings of the Geological Society of America 1995 Annual Meeting, October 25-28, 1999, Denver, Colorado: v. 27, no. 6, p. 296.

Wingard, G.L., Willard, D.A., Ishman, S.E., Cronin, T.M., and Edwards, L.E., 1995, Measuring historical change in the Everglades ecosystem: microfauna and flora as tools: The First SEPM Congress on Sedimentary Geology, St. Petersburg, Florida, August 13-16, 1995, Congress Program and Abstracts, v. 1, p. 129.

Wolansky, R.M., 1978, Feasibility of water-supply development from the unconfined aquifer in Charlotte County, Florida: U.S. Geological Survey Water-Resources Investigations Report 78-26, 34 p.

Wolansky, R.M., 1983, Hydrogeology of the Sarasota-Port Charlotte area, Florida: U.S. Geological Survey Water-Resources Investigations Report 82-4089, 48 p.

Wolansky, R.M., Haeni, F.P., and Sylvester, R.E., 1983, Continuous seismic-reflection survey defining shallow sedimentary layers in the Charlotte Harbor and Venice areas, southwest Florida: U.S. Geological Survey Water-Resources Investigations Report 82-57, 77 p.

Wolff, N., Grober-Dunsmore R, Rogers C, Beets J, 1999, Management implications of fish trap effectiveness in adjacent coral reef and gorgonian habitats: Environmental Biology of Fishes 55(1-2):81-90.

Wright, S.D., B.B. Ackerman, R.K. Bonde, Beck, C.A., and D.J. Banowetz, 1995, Analysis of watercraft-related mortality of manatees in Florida, 1979-1991, *in* O'Shea, T.J., Ackerman, B.B., and Percival, H.F., eds., Population Biology of the Florida Manatee *(Trichechus manatus latirostris)*: National Biological Service, Information Technology Report 1, p 259-268.

Wu, H.P., and Schowengerdt, R.A., 1993, Improved estimation of fraction images using partial image restoration: IEEE Transactions on Geoscience and Remote Sensing, v. 31 no. 4, p. 771-778.

Yates, K., and Halley, R., 1999, Geochemical measurements of carbonate sedimentation and organic productivity in Florida Bay: A potential measure of restoration progress, *in* Proceedings, 1999 Florida Bay and Adjacent Marine Systems Science Conference, Key Largo Florida, November 1-5, 1999: p.109.

Yobbi, D.K., and Knochenmus, L.A., 1989, Effects of river discharge and high-tide stage on salinity intrusion in the Weeki Wachee, Crystal, and Withlacoochee River estuaries, southwest Florida: U.S. Geological Survey Water-Resources Investigations Report 88-4116, 63 p.

Yobbi, D.K., and Knochenmus, L.A., 1989, Salinity and flow relations and effects of reduced flow in the Chassahowitzka River and Homosassa River estuaries, southwest Florida: U.S. Geological Survey Water-Resources Investigations Report 88-4044, 38 p.

Yobbi, D.K., and Schiner, G.R., 1981, Potentiometric surface of the Floridan aquifer, Southwest Florida Water Management District, September 1981: U.S. Geological Survey Open-File Report 82-101, 1 sheet.

Yobbi, D.K., Woodham, W.M., and Laughlin, C.P., 1979, Potentiometric surface of the Floridan aquifer, Southwest Florida Water Management District, September 1979: U.S. Geological Survey Open-File Report 80-46, 1 sheet.

Yobbi, D.K., Woodham, W.M., and Schiner, G.R., 1980, Potentiometric surface of the Floridan aquifer, Southwest Florida Water Management District, May 1980: U.S. Geological Survey Open-File Report 80-587, 1 sheet.

Yobbi, D.K., Woodham, W.M., and Schiner, G.R., 1980, Potentiometric surface of the Floridan aquifer, Southwest Florida Water Management District, September 1980: U.S. Geological Survey Open-File Report 80-1280, 1 sheet.

Yobbi, D.K., Woodham, W.M., and Schiner, G.R., 1981, Potentiometric surface of the Floridan aquifer, Southwest Florida Water Management District, May 1981: U.S. Geological Survey Open-File Report 81-1006, 1 sheet.

Websites:

U.S. Geological Survey, DATE, **http://sofia.usgs.gov/sfrsf/rooms/coastal/bisc_bay/NAME OF .pdf** “Biscayne Bay: How can the quantity, timing, and quality of freshwater inflow be improved to sustain healthy ecosystems in all parts of this bay that stretches from urban areas to wilderness? poster.”

U.S. Geological Survey DATE, **http://sofia.usgs.gov/sfrsf/rooms/mercury/manage/ NAME OF .pdf** “Can management of water quantity or quality reduce the risks? poster.”

U.S. Geological Survey, DATE, **http://sofia.usgs.gov/publications/posters/freshflow/NAME OF .pdf** “Freshwater Flow Data Sites poster.”

U.S. Geological Survey, 1999, **http://sofia.usgs.gov/projects/gw_coop/wrd_gw.pdf**, “Ground-water data,”48 p.

U.S. Geological Survey, DATE, **http://sofia.usgs.gov/publications/posters/hydro_flkeys/NAME OF .pdf** “Hydrogeology of a Dynamic System in the Florida Keys: A Tracer Experiment poster.”

U.S. Geological Survey, DATE, **http://sofia.usgs.gov/sfrsf/rooms/acme_sics/acme/NAME OF .pdf** “Mercury Studies in the Florida Everlades poster.”

U.S. Geological Survey, DATE, **http://sofia.usgs.gov/publications/posters/paleohydro/NAME OF .pdf** “Paleo-hydrology of Southern Florida? poster.”

U.S. Geological Survey, 1999, **http://sofia.usgs.gov/projects/sw_coop/wrd_sw.pdf**, “Surface-water data,”45 p.

U.S. Geological Survey, DATE, **http://sofia.usgs.gov/sfrsf/rooms/historical/soils/NAME OF .pdf** “What can soils tell us about the past that helps us today? poster.”

U.S. Geological Survey, DATE, **http://sofia.usgs.gov/sfrsf/rooms/coastal/flbay/NAME OF .pdf** “The Florida Keys: What is happening to the reef tract and why? poster.”

No author listed:

DATE, Remote Sensing of Water Turbidity and Sedimentation in Florida Bay and Biscayne Bay: U.S. Geological Survey Fact Sheet.