U.S. Geological Survey Program on the South Florida Ecosystem— Proceedings of the Technical Symposium in Ft. Lauderdale, Florida, August 25-27, 1997

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U.S. DEPARTMENT OF THE INTERIOR
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CONVERSION FACTORS AND VERTICAL DATUM

Multiply	By	To obtain
	Length	
inch (in)	2.54	centimeter
inch (in)	25.4	millimeter
foot (ft)	0.3048	meter
mile (mi)	1.609	kilometer
mile, nautical (nmi)	1.852	kilometer
yard (yd)	0.9144	meter
	Area	
acre	4,047	square meter
acre	0.4047	hectare
acre	0.4047	square hectometer
acre	0.004047	square kilometer
square foot (ft^2)	929.0	square centimeter
square foot (ft^2)	0.09290	square meter
square inch (in^2)	6.452	square centimeter
section (640 acres or 1 square mile)	259.0	square hectometer
square mile (mi^2)	259.0	hectare
square mile (mi^2)	2.590	square kilometer
	Volume	
barrel (bbl), (petroleum, 1 bbl = 42 gal)	0.1590	cubic meter
ounce, fluid (fl. oz)	0.02957	liter
pint (pt)	0.4732	liter
quart (qt)	0.9464	liter
gallon (gal)	3.785	liter
gallon (gal)	0.003785	cubic meter
gallon (gal)	3.785	cubic decimeter
million gallons (Mgal)	3,785	cubic meter
cubic inch (in^3)	16.39	cubic centimeter
cubic inch (in^3)	0.01639	cubic decimeter
cubic inch (in^3)	0.01639	liter
cubic foot (ft^3)	28.32	cubic decimeter
cubic foot (ft^3)	0.02832	cubic meter
cubic yard (yd^3)	0.7646	cubic meter
cubic mile (mi^3)	4.168	cubic kilometer
acre-foot (acre-ft)	1,233	cubic meter
acre-foot (acre-ft)	0.001233	cubic hectometer
	Flow rate	
acre-foot per day (acre-ft/d)	0.01427	cubic meter per second
acre-foot per year (acre-ft/yr)	1,233	cubic meter per year
acre-foot per year (acre-ft/yr)	0.001233	cubic hectometer per year
foot per second (ft/s)	0.3048	meter per second
foot per minute (ft/min)	0.3048	meter per minute
foot per hour (ft/hr)	0.3048	meter per hour
foot per day (ft/d)	0.3048	meter per day
foot per year (ft/yr)	0.3048	meter per year
cubic foot per second (ft^3/s)	0.02832	cubic meter per second
cubic foot per second per square mile [$(ft^3/s)/mi^2$]	0.01093	cubic meter per second per square kilometer
cubic foot per day (ft^3/d)	0.02832	cubic meter per day
gallon per minute (gal/min)	0.06309	liter per second
gallon per day (gal/d)	0.003785	cubic meter per day
gallon per day per square mile [$(gal/d)/mi^2$]	0.001461	cubic meter per day per square kilometer

Multiply	By	To obtain
million gallons per day (Mgal/d)	0.04381	cubic meter per second
million gallons per day per square mile [(Mgal/d)/mi^2]	1,461	cubic meter per day per square kilometer
inch per hour (in/h)	0 .0254	meter per hour
inch per year (in/yr)	25.4	millimeter per year
mile per hour (mi/h)	1.609	kilometer per hour
Mass		
ounce, avoirdupois (oz)	28.35	gram
pound, avoirdupois (lb)	0.4536	kilogram
ton, short (2,000 lb)	0.9072	megagram
ton, long (2,240 lb)	1.016	megagram
• ton per day (ton/d)	0.9072	metric ton per day
ton per day (ton/d)	0.9072	megagram per day
ton per day per square mile [(ton/d)/mi^2]	0.3503	megagram per day per square kilometer
ton per year (ton/yr)	0.9072	megagram per year
ton per year (ton/yr)	0.9072	metric ton per year
Pressure		
atmosphere, standard (atm)	101.3	kilopascal
bar	100	kilopascal
inch of mercury at 60 °F (in Hg)	3.377	kilopascal
pound-force per square inch (lbf/in^2)	6.895	kilopascal
pound per square foot (lb/ft^2)	0.04788	kilopascal
pound per square inch (lb/in^2)	6.895	kilopascal
Density		
pound per cubic foot (lb/ft^3)	16.02	kilogram per cubic meter
pound per cubic foot (lb/ft^3)	0.01602	gram per cubic centimeter
Energy		
kilowatthour (kWh)	3,600,000	joule
Radioactivity		
picocurie per liter (pCi/L)	0.037	becquerel per liter
Specific capacity		
gallon per minute per foot [(gal/min)/ft)]	0.2070	liter per second per meter
Hydraulic conductivity		
foot per day (ft/d)	0.3048	meter per day
Hydraulic gradient		
foot per mile (ft/mi)	0.1894	meter per kilometer
***Transmissivity**		
foot squared per day (ft^2/d)	0.09290	meter squared per day
Application rate		
pounds per acre per year [(lb/acre)/yr]	1.121	kilograms per hectare per year
Leakance		
foot per day per foot [(ft/d)/ft]	1	meter per day per meter
inch per year per foot [(in/yr)/ft]	83.33	millimeter per year per meter

Temperature in degrees Celsius (°C) may be converted to degrees Fahrenheit (°F) as follows:

$$°F=1.8\ °C+32$$

Temperature in degrees Fahrenheit (°F) may be converted to degrees Celsius (°C) as follows:

$$°C=(°F-32)/1.8$$

Sea level: In this report, "sea level" refers to the National Geodetic Vertical Datum of 1929 (NGVD of 1929)--a geodetic datum derived from a general adjustment of the first-order level nets of both the United States and Canada, formerly called Sea Level Datum of 1929.

Altitude, as used in this report, refers to distance above or below sea level.

***Transmissivity**: The standard unit for transmissivity is cubic foot per day per square foot times foot of aquifer thickness $[(ft^3/d)/ft^2]ft$. In this report, the mathematically reduced form, foot squared per day (ft^2/d), is used for convenience.

Specific conductance is given in microsiemens per centimeter at 25 degrees Celsius (µS/cm at 25 °C).

Concentrations of chemical constituents in water are given either in milligrams per liter (mg/L) or micrograms per liter (µg/L).

NOTE TO USGS USERS: Use of hectare (ha) as an alternative name for square hectometer (hm^2) is restricted to the measurement of small land or water areas. Use of liter (L) as a special name for cubic decimeter (dm^3) is restricted to the measurement of liquids and gases. No prefix other than milli should be used with liter. Metric ton (t) as a name for megagram (Mg) should be restricted to commercial usage, and no prefixes should be used with it.

ABBREVIATIONS

ACME	-	aquatic cycling of mercury in the Everglades
ADP	-	acoustic Doppler profiler
ADV	-	acoustic Doppler velocity meter
ATLSS	-	across-trophic-level systems simulation
AVHRR	-	advanced very high resolution radiometer
CFC	-	chlorofluorocarbon
CIR	-	color infra red
dbh	-	diameter at breast height
DGM	-	dissolved gaseous mercury
DIC	-	dissolved inorganic carbon
DIN	-	dissolved inorganic nitrogen
DOC	-	dissolved organic carbon
EAA	-	Everglades agricultural area
ELM	-	Everglades Landscape Model
EM	-	electromagnetic
ENP	-	Everglades National Park
ENR	-	Everglades nutrient removal area
ET	-	evapotranspiration
FGDC	-	Federal Geographic Data Committee
FWSWI	-	freshwater/saltwater interface

GIS	-	Geographic Information System
GPS	-	Global Positioning System
GW	-	ground water
HEM	-	helicopter electromagnetic
IFOV	-	instantaneous field of view
NAD83	-	North American Datum 1983
NAPP	-	Naional Aerial Photography Program
NN	-	neural network
NSM	-	natural system model
KML	-	Keys Marine Lab
RDBMS	-	relational database management system
SANDS	-	system for accurate nearshore depth surveying
SFE	-	South Florida Ecosystem
SFEP	-	South Florida Ecosystem Program
SFWMM	-	South Florida Water Management District's Water Management Model
STP	-	standard temperature and pressure
SUVA	-	specific ultraviolet absorbance
TDEM	-	time-domain electromagnetics
TDS	-	total dissolved solids
TEM	-	transient electromagnetic
TM	-	Landsat thematic mapper
USEPA	-	U.S. Environmental Protection Agency
USGS	-	U.S. Geological Survey
USGS, BRD	-	U.S. Geological Survey, Biological Resources Division
USGS, GD	-	U.S. Geological Survey, Geologic Division
USGS, NMD	-	U.S. Geological Survey, National Mapping Division
USGS, WRD	-	U.S. Geological Survey, Water Resources Division
UTM	-	Universal Transverse Mercator
UV	-	ultraviolet
WCA	-	Water Conservation Area
WHAM	-	Windermere Humic Aqueous Model
‰	-	permil

U.S. Geological Survey Program on the South Florida Ecosystem—Proceedings of the Technical Symposium in Ft. Lauderdale, Florida, August 25-27, 1997

By

Sarah Gerould[1] and Aaron Higer[2]

INTRODUCTION

One of the country's most significant environmental initiatives is the restoration of the South Florida Ecosystem including the Everglades. This vast region, which is home to more than six million Americans, seven of the ten fastest growing cities in the country, a huge tourism industry, and a large agricultural economy, also encompasses one of the world's unique environmental resources.

U.S. Department of the Interior, Strategic Plan Overview, 1997

Over the past 100 years, man-made changes to the region's water flow have provided important economic benefits to the region but have also altered populations of native flora and fauna throughout south Florida. These changes have resulted in a call for restoration of ecosystem functions that support native plants and animals and sustain the quality of life for us all.

The Department of the Interior has a leadership role in the restoration through its chairmanship of the South Florida Ecosystem Restoration Task Force. The U.S. Geological Survey (USGS), as the science agency of the Department of the Interior, provides scientific information to land and resource managers in cooperation with researchers in academia, State Government, and elsewhere in the Federal Government. The availability of relevant, high-quality, impartial scientific information enables land and resource-managers within the Department and within other Federal, State and local agencies to use sound science as a basis for planning and executing restoration actions and resolving resource-management problems.

Within the USGS, the Ecosystem Program was established to enable the USGS to intensify, nationwide, its scientific assistance to ecosystem restoration activities in areas such as south Florida. The Program provides scientific information from the wide array of disciplines within the USGS, information that is tailored to the specific management needs of the ecosystem, and designed to have a direct, significant, and immediate impact on management and policy decisions. The Program brings together scientists from appropriate operational units within the USGS to apply their diverse expertise to common problems.

In fiscal year 1995, the USGS began its Ecosystem Program activities in south Florida with a diverse body of projects encompassing cartographic, geologic, and hydrologic disciplines. The USGS program has been guided from the start by the scientific demands of ecosystem restoration. Projects have been selected based on the needs of the agencies involved in the restoration, as demonstrated through the ranking of the proposals by those agencies, or based on the results of scientific review processes which highlighted additional scientific needs. When the National Biological Survey joined the USGS and became its Biological Resources Division in Fiscal Year 1997, the USGS was able to provide a more integrated and comprehensive scientific service for land and resource managers involved in restoration of south Florida.

[1]U.S. Geological Survey, GD, Reston, VA 20192.

[2]U.S. Geological Survey, WRD, West Palm Beach, FL 33416-4680.

The USGS Ecosystem Program hosted an annual symposium to describe results to date and plans for future activities in south Florida. The purposes for the symposium are multifold. The symposium encourages collaboration between scientists within and outside of south Florida by providing scientists with a opportunity to learn of the research being done by the USGS. Collaboration and communication between scientists helps the entire scientific community in south Florida avoid unnecessary duplication and strengthen the results of the research. The Symposium also offers managers and others interested in restoration an opportunity to learn first hand of scientific findings that relate to their management goals, and to foster communication and coordination between scientists and those involved in managing the restoration. This communication helps managers make decisions based on current scientific understanding of the ecosystem and helps scientists better target their research to answer questions that are most important to managers.

This report contains abstracts of the oral and poster presentations made at the symposium held in Fort Lauderdale, August 25-27, 1997. Further information on the USGS Ecosystem Program activities in south Florida is available electronically on the World Wide Web at http://sflwww.er.usgs.gov or by contacting either Sarah Gerould, Bureau Ecosystem Coordinator, or Aaron Higer, Coordinator of the USGS South Florida Ecosystem Program.

AGENDA
South Florida Ecosystem Symposium
August 25 -27, 1997
Embassy Suites Hotel Conference Room

Monday, August 25, 1997

1:00 - 1:15 pm	Welcome - Sarah Gerould, Bureau Ecosystem Coordinator
1:15 - 3:00 pm	Regional Mercury, Geochemistry and Water Quality Assessment Moderator: David Krabbenhoft
3:00 - 3:20 pm	Break
3:20 - 4:50 pm	Florida Bay, Florida Keys, and Coral Reefs Moderator: Ellen Prager
4:50 - 7:30 pm	Poster session

Tuesday, August 26, 1997

9:00 - 10:30 am	Ecological Processes and Ecosystem Modeling Moderator: Ronnie Best
10:30 - 10:50 am	Break
10:50 am - 12:20 pm	Ecological and Geological Studies of South and Southwest Florida Moderator: Deb Willard
12:20 - 1:20 pm	Lunch
1:20 - 5:00 pm	Poster Session

Wednesday, August 27, 1997

8:30 am - 12:00 pm	Poster Session
12:00 - 1:00 pm	Lunch
1:00 - 3:40 pm	Modeling and Support Studies for Southern Inland Coastal Systems Moderator: Ray Scheffranek
3:40 - 4:00 pm	Wrap-up

Dissolved Organic Carbon in the Everglades, Florida

By

George Aiken[1] and Mike Reddy[1]

The spatial and temporal variability of dissolved organic carbon (DOC) in surface and pore waters is being studied in the Everglades in an effort to define the effect of DOC on the transport and reactivity of mercury (Hg). It is hypothesized that the organic sulfur content, molecular weight, functional group chemistry, and lability of the organic matter have a controlling influence on Hg cycling processes such as methylation and volatilization. Specific ultraviolet absorbance (SUVA) measurements, in combination with DOC and DOC fractionation analyses, were used to determine both the amount and nature of DOC along a north-south transect (approximately 40 mi.). 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, pore waters were found to contain greater DOC concentrations than overlying surface waters. The pore waters in the eutrophic areas to the north were found to contain the highest DOC concentrations. DOC concentrations and SUVA were found to be lower in those areas with higher concentrations of methyl mercury. Nonvolatile hydrophobic and hydrophilic organic acids were found to be the major fractions of the DOC at all locations along the transect. Isolated samples were found to be highly aromatic and to contain greater amounts of organic sulfur compared to similar samples from other environments. Preliminary results of laboratory studies indicate strong interactions between the isolated samples and Hg^{+2}.

[1]U.S. Geological Survey, WRD, Boulder, CO 80303.

Sulfur and Mercury in the South Florida Ecosystem

By

Anne L. Bates[1], William H. Orem[1], and Elliott C. Spiker[1]

Mercury contamination is a concern in the Florida Everglades because mercury in the form of methyl mercury (MeHg) can biomagnify and become concentrated to toxic levels in species near the top of the food chain. Although the principal source of mercury is atmospheric deposition, processes occurring in oxygen-deficient (anoxic) wetlands such as the Everglades can enhance the toxicity of mercury through production of the methyl mercury species. One process is sulfur cycling, which is inferred to be linked with the transport, accumulation, and cycling of mercury through oxidation-reduction processes mediated by microbes. Therefore, the amount and rate of sulfate reduction and sulfide oxidation may correlate with mercury species concentrations in the Everglades. We are studying trends in sulfur speciation and isotopic composition in sediments and surface waters which may be related to location, season, nutrient loading, and rates of sedimentary deposition. We are analyzing these trends to interpret how they relate to mercury cycling in the Florida Everglades. Our studies have focused mainly on determining trends in sulfate contents and isotopic composition in surface waters in the Water Conservations Areas (WCAs) and their bordering canals. These data have been correlated with mercury contents determined by other researchers (D. Krabbenhoft, USGS, WRD, Madison, Wisconsin).

Results suggest that both sulfur and mercury cycling display trends which are related to sampling localities along transects in WCA 2A from the Hillsboro Canal out into the interior of the WCA. Sulfate concentration trends and sulfate-oxygen isotopic ratios reveal that, during periods of low rainfall, sulfide oxidation to sulfate appears to be greater at sampling sites in the interior of the WCA far from the Hillsboro Canal than at sites close to the canal. Isotopic ratios in reduced sulfur species indicate that sulfate reduction rates are higher at nutrient impacted areas near the canal. We hypothesize that MeHg formation is related to sulfate reduction rates. Both total mercury and MeHg fixation are greater at sites far from the Hillsboro Canal where we believe sulfate reduction rates are lower. The sulfate reduction rates may be stimulated by high organic productivity in nutrient enriched areas near the Hillsboro Canal. If this is the case, high rates of sulfate reduction appear to suppress rather than stimulate MeHg production. Possibly, MeHg production may be optimized at lower sulfate reduction rates. A buildup of hydrogen sulfide in sediments with high sulfate reduction rates may actually poison the MeHg production process, or mercuric sulfide precipitation may be favored over MeHg production at high sulfate reduction rates.

Currently, our efforts are focused on determining the sources of sulfate in the WCA in the Everglades. Our data at this time are limited; however, results appear to indicate that sulfate concentrations in surface water from the Hillsboro and New North River Canals in the Everglades Agricultural Areas (EAAs) are slightly higher than in the canals bordering the WCA. Sulfate-sulfur isotopic ratios in the surface water in the EAA canals ($\delta^{34}S \sim 17$ per mil) are close to that of sulfur fertilizer ($\delta^{34}S \sim 15$ per mil) and sulfate in the EAA soil ($\delta^{34}S \sim 15$ per mil). These isotopic ratios are lower than those found in the canals bordering the WCAs ($\delta^{34}S$ from 18 to 21 per mil). A single ground-water sample has been analyzed to date. The sulfate concentration (1.04 meq/L) is higher than in most surface water samples in the WCAs. The sulfate-sulfur isotopic ratio in ground water ($\delta^{34}S \sim 29$ per mil) is higher than in sulfate from most surface water samples ($\delta^{34}S$ from 20 to 26 per mil). Understanding the source of sulfate to the wetlands of South Florida may be key to understanding why mercury methylation rates are high in certain areas of the Everglades.

[1]U.S. Geological Survey, WRD, Reston, VA 20192.

Origins, Residence Times, and Nitrogen Chemistry of Marine Ground Waters Beneath the Florida Keys and Nearby Offshore Areas

By

J.K. Bohlke[1], L.N. Plummer[1], E. Busenberg[1], T.B. Coplen[1], E.A. Shinn[2], and P.L. Schlosser[3]

Ground waters (GW) are potential sources, sinks, and carriers of nutrients and other contaminants beneath the Florida Keys and nearby offshore regions to the north and south. Although small-scale tracer studies indicate rapid local lateral movement of water in the subsurface, and water level monitoring studies indicate that some hydraulic potential may exist for GW flow from the bay side to the ocean side, those results do not address directly the large-scale extent of GW transport and the origin of nutrients observed in ground waters far offshore. We are testing the use of environmental isotopes and tracers, combined with geochemical modeling, to provide new data on the sources, flow directions, exchange rates, and chemical characteristics of ground waters underlying the region at depths of about 3 to 20 m below the sediment surface. The empirical approaches being tested include: (1) analyses of chlorofluorocarbons (CFCs), SF_6, ^{14}C, ^{3}H, and He isotopes for information about the residence times of water and dissolved species in the subsurface; (2) analyses of stable isotopes of H, O, C, N, and S for information about sources of, and chemical reactions among, waters, nutrients, and other species; and (3) modeling of chemical reactions and residence time distributions.

A set of representative samples of surface waters and ground waters was collected in 1996 in the Keys and offshore areas to the north and south. Measurements of H- and O-isotope ratios and salinities of those samples indicate at least four mixing components: seawater, meteoric water, evaporated seawater, and evaporated meteoric water. Oceanside GW had values of $\delta^{2}H$ (+10 ± 2 ‰), $\delta^{18}O$ (+1.15 ± 0.15 ‰), and salinity (36 ± 1 ‰) values generally equal to those of offshore marine surface waters, consistent with recharge of normal seawater. Bayside GW generally had higher values of $\delta^{2}H$ (+13 to +20 ‰), $\delta^{18}O$ (+1.5 to +2.7 ‰), and salinity (36-41 ‰) compared to offshore marine surface waters, consistent with recharge of evaporated bay water during times of relatively high bay salinity. Several GW samples from the Keys and from short distances (less than a few hundred meters) offshore had isotopic compositions consistent with transport of bay water to the ocean side, and one nearshore sample indicated transport of seawater to the bay side. However, the salinity and isotopic results so far do not support long-distance transport (more than a few hundred meters) of evaporated bay water to sites far offshore on the ocean side (for example, to the reef), within the depth range investigated. Isotopic data for tap water, wastewater, and injected wastewater all were consistent with a common freshwater source on the Florida mainland, and with mixing of wastewater and bay-type marine GW in the subsurface near the waste-water injection site at the Keys Marine Lab (KML).

[1]U.S. Geological Survey, WRD, Reston, VA 20192.
[2]U.S. Geological Survey, GD, St. Petersburg, FL 33701.
[3]Lamont-Doherty Earth Observatory, Palisades, NY 10964.

Concentrations of the chlorofluorocarbon CFC-12 in marine GW on both sides of the Keys were consistent with atmospheric equilibration and subsequent isolation (recharge) at times ranging from the present to more than 50 years ago. Degradation apparently had altered significantly the concentrations of CFC-11 and CFC-113 in most samples. Minor CFC contamination was detected in water from a canal on Key Largo and in wastewater at the KML site, but it did not appear to be widespread (though degradation may have altered some occurrences). Apparent recharge ages, derived from analyses of ^3H and He isotopes, ranged from 0 to more than 30 years, and reconstructed values of initial ^3H were in the range of 0 to 10 TU. ^3H-^3He ages and CFC-12 ages generally correlated, but the CFC-12 ages commonly were in the order of 10 to 50 percent larger. Apparent ages derived from both CFC and ^3H-^3He methods were consistently stratified; wherever more than one depth could be sampled at the same site, the deeper waters appeared to be older. Total concentrations of ^4He were between about 3.7 and 4.9 x 10^{-8} ccSTP/g; whereas the estimated concentrations of non-atmospheric radiogenic ^4He were in the order of 0-1 x 10^{-8} ccSTP/g. The concentrations and $\delta^{13}C$ values of dissolved inorganic carbon (DIC) indicate varying contributions from both organic carbon oxidation and carbonate mineral recrystallization. Unnormalized ^{14}C abundances in DIC (mainly bicarbonate) range from less than 10 percent to about 115 percent "modern," consistent with a large range of apparent radiocarbon ages. However, much of the variation in apparent ages can be accounted for by chemical reactions between seawater with relatively high ^{14}C and carbonate sediments with relatively low ^{14}C.

Nutrient analyses confirmed that reduced marine GW throughout the area contained significant amounts of ammonium (10-80 µM). Concentrations of sulfide, methane, and bicarbonate also were elevated in the reduced waters. The $\delta^{15}N$ values of ammonium in ground waters near the KML injection site were relatively high (+9 to +12 ‰) and could be consistent with a wastewater source. The $\delta^{15}N$ values of ammonium in all other ground waters were relatively low, but variable (+3 to +8 ‰). There was not a strong correlation between ammonium concentrations and $\delta^{15}N$ values. It is possible that much of the GW ammonium is from anaerobic degradation of N-bearing organic matter in sediments. Nitrate concentrations in most samples were low (< 1 µM). Concentrations between 5 and 120 µM were detected only in a few samples, all of which contained low-salinity water components. The highest nitrate concentrations were in treated waste water and in a shallow mixture of waste water and saline ground water at KML. Unused tap waters collected from faucets at several different times and places on Key Largo also contained significant amounts of both ammonium (40 ± 10 µM) and nitrate (50 ± 10 µM) and may represent an unappreciated source of N in the Keys. Concentrations and isotopic compositions of dissolved nitrogen gas in most samples were approximately consistent with atmospheric equilibration between 20 and 28 °C. There was evidence in some samples for small amounts of excess N_2 that may have been derived from denitrification (reduction of nitrate to N_2). Relatively large amounts of excess N_2 in wastewater and in mixed ground waters near the KML injection site apparently were the result of denitrification of nitrate in the wastewater.

Environmental Change in the Florida Bay Ecosystem: Patterns Over the Last 150 Years

By

G. Lynn Brewster-Wingard[1], Scott E. Ishman[1], Charles W. Holmes[2], Debra A. Willard[1], and Lucy E. Edwards[1]

The U.S. Geological Survey Ecosystem History of Florida Bay Project and the Southwest Coast Project have completed analyses of the faunal and floral record in short sediment cores from three sites in the central portion of Florida Bay. These analyses were undertaken to determine the biological, physical, and chemical parameters of the ecosystem prior to significant human impact on the south Florida region, and to determine the natural versus human-induced changes that have occurred within the ecosystem. Molluscs, benthic foraminifera, pollen, and dinocysts have been examined at 2 cm intervals in cores from the Bob Allen mudbank (core 6A), from Russell Bank (cores 19B and 19A), and from the mouth of Taylor Creek in Little Madeira Bay (core T24). Lead-210 analysis provides the age model for the cores. Analyses of ostracodes and diatoms have not been completed, and geochemical analysis of the ostracode and mollusc tests are currently being conducted. Data collected on the distributions and habitat preferences of the fauna and flora at 20 monitoring sites within Florida Bay provide the proxy data for interpreting down-core environmental conditions (Brewster-Wingard and others, 1996).

The initial emphasis of the analyses was to determine the salinity history of north-central Florida Bay, as recorded at the core sites. The benthic faunal data from Bob Allen core 6A indicate that the 1800's were a time of fluctuating, but relatively low, average salinity (Brewster-Wingard and others, 1995). In the early 1900's, a significant increase in the average salinity occurred at Bob Allen mudbank. Russell Bank core 19B also records an increase in salinity through the 1900's; polyhaline and euhaline benthic fauna increase up-core and the number of mesohaline species decreases. Taylor Creek core T24 indicates an increase in polyhaline to euhaline benthic fauna up-core (Ishman and others, 1996). The lower portion of core T24 is dominated by oligohaline to mesohaline species.

In addition to salinity history, patterns of substrate change, as indicated by the benthic fauna, have been examined. Bob Allen core 6A and Russell Bank core 19B show very similar patterns of substrate change, although at different time periods. The lower portions of both cores show a mixture of sediment dwelling and grass dwelling molluscs, whereas the upper portions are dominated by grass and/or algae dwelling molluscs. Additional data from our monitoring sites should allow us to further refine the substrate history at the individual sites.

The flora present in the cores provide links between the benthic and pelagic systems within Florida Bay and between the terrestrial and marine systems in south Florida. The pollen present in the cores link changes in the terrestrial ecosystem to changes occurring within the marine environment, allowing the determination of factors that might be affecting the entire south Florida ecosystem. In Bob Allen core 6A the pollen and dinocyst assemblages changed at approximately the same point in the core that the benthic fauna showed significant change; this implies consequential events occurred around the turn of the century that induced change in the entire south Florida ecosystem. Floral assemblages within Taylor Creek core T24 also are consistent with benthic faunal data, indicating increasing salinity up-core.

[1]U.S. Geological Survey, GD, Reston, VA 20192.
[2]U.S. Geological Survey, WRD, St. Petersburg, FL 33701.

Additional analyses of the distribution of dinocysts and diatoms within the cores may provide information on planktonic blooms, current patterns, and nutrient supply.

During the next year we will complete our analyses of replicate cores from Bob Allen and Russell Banks in order to address questions of reproducibility within sites. In addition, we will examine a core from Pass Key and possibly Whipray Basin to determine if the patterns of salinity and substrate change are repeated at other sites. Geochemical analyses of ostracode and mollusc shells will provide additional data on salinity and nutrients within Florida Bay. The results obtained from the analyses of cores collected in Florida Bay will be compared to similar data from the Biscayne Bay and the Southeast Coast Ecosystem History Project, from the Terrestrial Everglades Ecosystem History Project, and from the Buttonwood Embankment Project, to determine if corresponding changes occurred and, if so, can these changes be linked to human activity, to natural events, or to a combination of factors.

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U.S. Geological Survey South Florida Ecosystem Program Digital Orthophoto Program

By

G. Michael Callahan[1]

The National Mapping Division of the U.S. Geological Survey has completed the production of 1:12,000 scale Digital Orthophotoquads for the South Florida Ecosystem Program study area. These products were produced in cooperation with the Florida Department of Environmental Protection, the South Florida Water Management District, and the National Park Service. The Digital Orthophotoquads were produced from the latest National Aerial Photography Program's color infrared photography (CIR), flown during the period, 1994-96.

The Digital Orthophotoquads were cast on the North American Datum 1983 (NAD83), using the Universal Transverse Mercator (UTM) projection, with a resolution of 1 meter. They are being used by the program cooperators to support a variety of program requirements from digital revision of planimetric features, such as roads and streams, to the compilation and revision of land use and land cover information for the program area.

These products are currently available from the U.S. Geological Survey's Earth Science Information Center in Reston, Virginia. To obtain additional information on media options and delivery schedules call 1-800-USA-MAPS.

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The Role of Periphyton in Mercury Bioaccumulation in the Florida Everglades

By

Lisa B. Cleckner[1], J.P. Hurley[2], David P. Krabbenhoft[3], and Mark L. Olson[3]

Fish consumption advisories have been issued for Southern Florida including the Everglades due to high mercury (Hg) levels in sport fish such as largemouth bass (*Micropterus salmoides*). In addition, deleterious health effects in wading birds, alligators and the Florida panther have been associated with high Hg levels. Since these animals can derive a significant portion of their diet from aquatic organisms, it is important to determine how Hg is bioaccumulating through the trophic structure of this region. The trophic structure of the Everglades, and wetlands in general, is much different from planktonic structures typically encountered in lacustrine and marine systems. Specifically for the Everglades, periphyton serves as the base of the food web rather than phytoplankton. Also, invertebrates associated with this periphyton, in addition to zooplankton, provide a link between the primary producers and the fish. These potentially include freshwater shrimp (*Palaemonetes paludosa*), amphipods (*Hyalella*) and mayfly nymphs.

A component of the U.S. Geological Survey project, Aquatic Cycling of Mercury in the Everglades (ACME), is focused on determining the extent of bioconcentration of methyl mercury (MeHg) and total mercury (Hg_T) in the lower levels of the food web in the northern Everglades. The specific objectives are (1) to measure methyl and total Hg in biota from the primary producer level to small fish; (2) to determine spatial and temporal changes in these Hg levels; and (3) to integrate Hg measurements of the organisms with stable isotope and gut analyses to begin to examine Hg biomagnification in the food web of the Everglades. The following represents the preliminary results from this investigation and focuses primarily on the first two objectives.

The concentrations of Hg in water, periphyton, and fish from ACME sampling sites in December 1995 show an increase in Hg concentration in all three components as one moves from north to south in the study area. However, there are exceptions to this trend. The MeHg level in periphyton at our northern site (F1) is higher than at the more southern site, F4, and is similar in magnitude to the MeHg level in periphyton at the WCA 2B sites. The Hg concentration in fish at 2BS is lower than at U3 and 2BN. Nonetheless, Hg levels in water, periphyton, and fish were highest at the most southern site, 3A. This particular location has been identified by other investigators as having very high Hg concentrations in fish, although the exact mechanisms have not been identified.

A relationship between the percent of Hg_T as MeHg in periphyton and the Hg concentrations in fish is also apparent. Both increase as one moves from north to south with the exception of F1 periphyton. Most likely, there are site-specific differences, and these trends will continue to be investigated in the future. It is possible that the percent of Hg_T as MeHg is driving Hg dynamics at the entry levels of the food web. Thus, it appears that an increase in the percent of Hg_T as MeHg in the lower food web is associated with higher Hg levels in fish and other invertebrates.

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The relationship between MeHg in the water column and periphyton at our study sites is seasonally dynamic. At our pristine site in Water Conservation Area 2A (U3), the highest levels of MeHg in water and periphyton were seen in March 1996, while at the eutrophied site (F1), highest MeHg concentrations were observed in the summer months, July 1995 and June 1996. Additionally, there is a strong association between filtered MeHg in the water column and periphyton at U3 (r^2=0.991). The same trend is not evident for F1 (r^2=0.178), once again suggestive of site-specific and/or seasonal processes that warrant further exploration. There have been very few recent studies of MeHg levels in periphyton, although in earlier work periphyton was shown to be an indicator organism for Hg levels in fish, but not in water. For the ACME study area in the Everglades, it appears that the periphyton is a useful indicator for aqueous MeHg levels at U3, but not at F1.

Geophysical Mapping of the Freshwater/Saltwater Interface in Everglades National Park

By

David V. Fitterman[1] and Maria Deszcz-Pan[1]

Water quality in Everglades National Park (ENP) and the discharge of freshwater into Florida Bay are influenced by water use and management policies in South Florida. The flow of freshwater through the Everglades into Florida Bay is critical to the well being of the South Florida Ecosystem (SFE). Restoration activities by Federal agencies are aimed at mitigating the effect of increased demand for water, farming, and flood control practices in South Florida on the SFE. Assessing the effectiveness of restoration efforts is difficult because of inaccessibility of much of this area.

This project employs a variety of electromagnetic geophysical techniques to map the location of the freshwater/saltwater interface (FWSWI). Of special note is the use of airborne electromagnetic measurements to rapidly and economically survey large areas where ground access is difficult.

Electrical conductivity is the physical property describing how easily a material conducts electricity. The conductivity of water is controlled by the concentration of dissolved ions. Freshwater typically found in ENP has a conductivity of 0.450 μS/cm and a chloride ion concentration of 40 mg/L. In contrast, the saline water of Florida Bay has a conductivity of 20 to 50 μS/cm and chloride levels of 15,000 to 35,000 mg/L. Geologic materials saturated with these waters will have resistivities (the reciprocal of conductivity) which vary by a factor of 40 to 100, with the more saline waters producing lower rock resistivities.

In our study of the Everglades we employ a variety of electromagnetic (EM) geophysical methods to measure rock resistivity. These techniques make use of a transmitter, which induces electrical current flow in the ground, and a receiver, which measures the electromagnetic field produced by these induced currents. By analyzing the electromagnetic fields, variations of electrical conductivity with depth below the Earth's surface from and location to location can be determined. From these results, we can map the freshwater/saltwater interface.

We employ three EM techniques: 1) helicopter electromagnetic (HEM) resistivity mapping to produce regional resistivity maps, 2) transient electromagnetic (TEM) soundings to provide additional information on resistivity-depth variations and to calibrate the HEM results, and 3) borehole induction logging to calibrate the HEM results and to determine the relationship between rock resistivity and pore water conductivity.

HEM resistivity mapping uses a 10-meter-long instrument pod slung below a helicopter which flies back and forth over the survey area along parallel lines about 400 m (1/4 mi) apart, making a measurement approximately every 8 m along the flight line. The instrument pod contains five pairs of transmitter and receiver coils which measure the electromagnetic response of the ground at different frequencies to obtain information from different depths. The raw data are processed to produce apparent resistivity maps which show several interesting features, including a prominent transition from higher resistivities in the landward direction to lower resistivities toward the shore, which is interpreted as the freshwater/saltwater interface (FWSWI). The FWSWI interface is very sharp in the region of Taylor

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Slough where there is a relatively high flow of water. In contrast, the FWSWI in Shark River Slough follows the terminus of rivers that have tidal flow. The influence of manmade features is apparent where the FWSWI crosses the C-111 canal. Downstream of the FWSWI, the canal recharges freshwater into the saltwater saturated surface aquifer. A very distinctive resistivity low associated with portions of the now blocked canal adjacent to the Old Ingraham Highway has been mapped. Saltwater formerly flowed through the canal from Florida Bay near Flamingo toward Royal Palm. The modern road through the ENP to Flamingo also influences the hydrology, as revealed in the HEM maps. It inhibits the westward flow of freshwater coming from Taylor Slough producing a four-fold change in resistivity across the road near Nine Mile Pond.

To date, three HEM surveys have been flown. The first was flown in April 1994 and covered 362 km^2 centered on Taylor Slough. The second survey, flown in December 1994, reflew this area and extended coverage west beyond Tarpon Bay for a total survey area of 1,036 km^2. The third survey (November 1996) covered the core Taylor Slough area and expanded coverage (1,010 km^2) north of the main Park Road toward the headwaters of Taylor Slough. Comparison of the first two surveys reveals resistivity variations associated with seasonal hydrologic changes. Data collected in the wet season (December 1994) shows an increase in apparent resistivity at the location of the FWSWI, reflecting increased freshwater in the system, compared to results from the dry season survey (April 1994). The ability of the HEM surveys to detect seasonal resistivity variations suggests the potential for use of this technique in monitoring long-term changes in the ground-water system.

While the HEM apparent resistivity maps show interesting and significant features, they provide no depth information. We have developed a method of inverting the HEM data to obtain resistivity-depth information at each measurement point. To accomplish this task, we analyzed the errors in the HEM data produced by the standard calibration procedures. A technique to remove these errors from the data was developed. This procedure uses transient electromagnetic soundings to determine the resistivity-depth function at about fifty points scattered over the survey area. We then compute the HEM electromagnetic response produced by these resistivity-depth models. Finally, we determine correction factors needed to bring the computed and measured HEM responses into agreement. The correction factors are applied to all the survey data. By using this procedure we are able to compute stable resistivity-depth estimates for the entire HEM survey. The inversion models are presented as resistivity-depth slices at selected depths. Interpreted depths to the saltwater saturated zone range from less than 1 m seaward of the FWSWI deepening to 15 to 20 m or more landward of the interface.

Because of their extensive coverage in areas which are otherwise difficult to impossible to access from the ground, HEM surveys provide a means of assessing regional ground-water quality in the Everglades. From well log data, we have established a relationship between rock resistivity and pore fluid conductivity, which allows the interpreted resistivity-depth models to be converted into estimated water quality models. This provides a basis for developing ground-water flow models which incorporate solute transport.

Relationships Between Inshore Nursery Habitats of the Pink Shrimp, *Penaeus Duorarum*, and the Offshore Tortugas and Sanibel Fisheries

By

Brian Fry[1], Michael B. Robblee[2], and Patricia L. Mumford[1]

South Florida's seagrass and mangrove dominated estuaries serve prominently as nursery habitats for the pink shrimp, *Penaeus duorarum,* and support two offshore fisheries. The Tortugas fishery is the larger of the two and is the largest commercial fishery in Florida, with landings of approximately 9 million pounds annually. The Sanibel fishery is smaller, with a harvest averaging about 4 percent of the Tortugas Grounds. During the middle to late 1980's, a sharp decline in Tortugas landings occurred roughly coincident with seagrass die-off and the subsequent onset of extensive and persistent algal blooms in Florida Bay. These events focused increased attention on the interdependence of south Florida's estuaries and the productivity of Florida's offshore shrimping grounds and the role that the pink shrimp might play in restoration related research activities for Florida Bay.

Linkages between inshore estuaries and offshore fishing grounds are complex. Initially, following seagrass die-off, it was convenient to hypothesize that loss of habitat and declining environmental conditions in Florida Bay explained fishery declines. This approach was supported by tagging studies in the 1960's, which indicated that western and southwestern Florida Bay, the middle Florida Keys, Whitewater Bay, Coot Bay, and the Ten Thousand Islands served as nursery grounds, supporting the Tortugas fishery. Florida Bay was considered the principal inshore nursery ground. However, over the last several years, harvest has improved to near historic levels on the Tortugas Grounds, while conditions in Florida Bay have not changed significantly. This suggests that assuming a principal role for the Bay may be inappropriate. Other evidence supports this as well. Recruitment of pink shrimp into the offshore fishery occurs throughout the year with two peaks of recruitment, a Fall recruitment period measured from July through December peaking between August and October, and a Spring recruitment period measured from January through June, peaking between March and May.

Analysis of harvest data indicate that fishery decline in the 1980's has been associated with a loss of the Fall recruitment peak. Available data on inshore abundance of juvenile pink shrimp in Florida Bay and Whitewater Bay suggests the prominence of single, late Summer to early Winter (August-December) peaks of recruitment. These shrimp would presumably contribute to the Spring recruitment peak in the offshore grounds.

Solving these questions regarding the relative importance of inshore nursery areas in south Florida and the timing of movements between inshore nurseries and offshore spawning grounds is considered critical to determining the cause of recent declines in Florida's pink shrimp fishery as well as to setting and evaluating restoration objectives for the Bay. In this project, we propose to use natural stable C, N, and S isotope ratios to link inshore pink shrimp stocks with the offshore Tortugas and Sanibel fisheries.

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Our objectives are to: 1) determine if inshore pink shrimp populations differ isotopically among south Florida nursery areas and if shrimp entering the Tortugas (fall and spring peaks) and Sanibel fisheries differ isotopically; 2) determine the relative importance of various inshore nursery areas to the Tortugas and Sanibel grounds using isotope tags to establish linkage; and 3) determine the relative importance of pink shrimp source nursery areas for the Fall and Spring peak recruitment periods in the Tortugas fishery, using isotope analysis of young recruits collected in different seasons.

Shrimp acquire carbon isotopes from their diets, which differ according to habitat in south Florida, with $\delta^{13}C$-enriched values found in shrimp from seagrass meadows, intermediate values found in shrimp from offshore, and $\delta^{13}C$-depleted values in shrimp from mangrove areas. We have thus far analyzed 60 small offshore shrimp in the 3 to 11 g wet weight range (70-120 mm TL), and find that most shrimp (75 percent) caught in both the Tortugas and Sanibel fisheries exhibit $\delta^{13}C$ characteristic of shrimp that have spent extended periods feeding and growing offshore. This may mean that on average, most shrimp recruit offshore at sizes considerably smaller than 5 g wet weight (80 mm TL), or that shrimp are growing offshore without an inshore life stage. The remaining 25 percent of the shrimp clearly do not have offshore, intermediate $\delta^{13}C$ values, and most (20 of the 25 percent) show an inshore signal consistent with migration from seagrass meadows such as those sampled in Johnson Key Basin. The remaining 5 percent of the offshore-collected shrimp have $\delta^{13}C$-depleted values similar to those observed in shrimp collected in open bays that are lined with mangroves, such as Coot and Whitewater Bays. Based on these limited initial analyses, we come to the preliminary conclusion that seagrass areas may supply 80 percent of recruiting pink shrimp, and open bays and mangroves may supply the remaining 20 percent. We will be analyzing some 120 samples this summer, beyond the 60 already processed, to see if this preliminary conclusion holds for shrimp caught offshore in the main Spring harvest.

Computer Simulation Modeling of Intermediate Trophic Levels Selected Species for Across-Trophic-Level Simulation of Everglades/Big Cypress Region: Fish Functional Group Model

By

Michael Gaines[1] and D.L. DeAngelis[2]

Fish biomass constitutes a major energy resource for the wading bird communities and other top-level predators of the Everglades and Big Cypress ecosystems of southern Florida. Fish communities are exposed to annual fluctuations in water level. Fish populations expand during the period of flooding, while the annual drydown concentrates many of the fishes in shallow waterbodies, where they are easily available to predators. The purpose of the fish computer simulation model in ATLSS is to predict the fish population responses to this seasonal pattern of water levels in all the spatial cells across the landscape, and thereby the pattern of prey availability for wading birds.

Long-term hydrology can have important effects on this pattern, so modeling is important to predict changes that various restoration water management scenarios would produce. For example, droughts can produce massive losses of fish numbers, and threaten the residual "seed" populations of fishes needed to repopulate marshes in the next wet season. Among the factors helping to mitigate the severity of the effects of drought are the quasi-permanent waterbodies that exist in many areas, such as creek channels, alligator holes, solution holes, and other depressions, that are refugia for fish during these "drydowns." However, the small fish are exposed to high predation, mostly from larger fishes in the larger refugia. Prediction of speed of recovery of the fish population in a cell following a drought is one of the primary goals of the model.

The model describes the seasonal dynamics of the community of small fishes (for example, mosquitofish and killifishes) as water levels change through the year for each 500 x 500 meter cell in the Everglades/Big Cypress region. Each cell is modeled as having a statistical distribution of depressions that can serve as refugia for fish if the cell dries down during a year.

There are two fish functional groups in the model: small fishes, which are a primary prey of wading birds, and large fishes, which are predators on the small fishes. The fish in each of these two functional types are modeled as 1-month age classes. Growth in age, growth in size, and mortality occurs on these 5-day time steps, but an increase to the next age class occurs only on the first time step within a given month. For a given age, the size of the fish is calculated from a von Bertalanffy equation and weight in grams dry weight is given by a weight-length relationship.

The changes in water level are modeled, as are the interactions of the fishes with their resource base of periphyton, macrophytes, mesoinvertebrates, macroinvertebrates, and detritus. The simulation also includes the interaction of large and small fishes to address the question of whether the larger fishes may be a major regulating factor for the small fishes. Movement of fish into and out of ponds and depressions is modeled as a function of changing water levels. Intercell movement can also occur. Reproduction and probability of mortality of fish are modeled as dependent on the age of the fish, the season of the year, and water depth.

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The model has been used to demonstrate changes in fish population and biomass numbers over multi-year periods under a variety of hydrologic conditions. The model makes two predictions that appear to us to be fairly robust in the model system. First, there appears to be a threshold of about nine months in the length of the hydroperiod. If the hydroperiod is less than this, the small-fish-type population stays small, no more than a few fish per square meter. For longer hydroperiods, the fish population can reach levels of 10 to 20 fish per square meter (averaged over the whole spatial cell) by the end of the hydroperiod, roughly what the population would be under continuous flooding. However, during the drydown, these fish will be concentrated by the receding waters to much higher local densities. The second prediction made by the model is that the repopulation of the marsh by small fishes following a drydown, even a prolonged drydown, occurs very rapidly, within a little less than a year (though this year could be a critical one for wading birds dependent on fish prey).

The ATLSS fish model has been combined with the general landscape structure code to produce an integrated model that may be run across any suitable portion of the South Florida landscape. Thus far, it has been applied to WCA 3A.

Computer Simulation Modeling of Intermediate Trophic Levels Selected Species for Across-Trophic-Level Simulation of Everglades/Big Cypress Region: Snail Kite Model

By

Michael Gaines[1] and D.L. DeAngelis[2]

The snail kite (*Rostrhamus sociabilis*) is a wetland hawk whose distribution in United States is limited to the freshwater marshes of southern and central Florida (Bennetts and others, 1994). It is listed as an endangered species in the United States. Because the snail kite feeds almost exclusively on the apple snail (*Pomacea paludosa*), it is an example of an extreme prey specialist, and would, therefore, be expected to be at high risk from environmental variations that affect apple snail dynamics. Apple snails occur in areas of extended inundation and their availability to kites is greatly reduced during droughts. Frequent droughts may also reduce the long-term densities of apple snails.

Bennetts and Kitchens (1997) have suggested that snail kites undertake exploratory movements and that individuals may have mental maps of potential habitats over wide areas. The question then is how much the snail kite's ability to move and find good conditions compensates for temporal variability in habitat condition. This depends on whether the array of potential habitats is large enough to ensure the viability of the snail kite population. There is some reason for concern, because reports from earlier times indicate that snail kites are not as widespread in Florida now as they were in the 1800's up through the 1930's.

Predictions concerning the viability of the snail kite under altered conditions require that the population be modelled in a spatially explicit manner, using realistic models for the hydrology over the population's range. A spatially-explicit, individual-based model of the dynamics of the snail-kite population has been developed within the ATLSS project. The dynamics of the kite population under different management regimes will be analyzed by means of a spatially-explicit individual-based model. Given the total size of the kite population (order of magnitude 100-1,000), it is possible to represent each individual kite in the model.

Empirical information for the model comes from a detailed study performed by Bennetts and Kitchens (1997) on the demography and movements of the kites. Fecundity and fledgling survival have been estimated through nest studies. Radio telemetry (282 birds) and mark-resighting of banded snail kites (913 birds) are being used to estimate survival, to evaluate the influences of environmental conditions (for example, hydrology) on survival, and to evaluate the movement patterns of snail kites in Florida, including what environmental conditions are correlated with these movements. At present, density dependence has not been incorporated in any of the model parameters, as there is no evidence yet of density-dependent limitations on the snail kite.

The snail kite model aims at predicting the viability of the snail kite population in southern and central Florida under a range of future hydrologic scenarios. It is hypothesized that the viability critically depends on the frequency of droughts, but also on the spatial extent of these droughts. The model snail

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kites inhabit an array of fifteen major wetlands of southern and central Florida, represented on a GIS map layer. The habitat quality within each of these areas is assumed to be relatively uniform, and maximum carrying capacities are assigned to each area. There is also one aggregated "peripheral" habitat, representing areas of inferior quality that snail kites may use temporarily. Hydrological status and the availability of apple snail prey in these wetlands are based on information from hydrologic models.

A system-wide drought is likely to result in an increased mortality, but local droughts are unlikely to have such an effect, because the birds can respond to a local drought by migration. The specific aim of the present model is to study the dynamics of the snail kite in relation to the following two parameters: the interval between droughts and the spatial correlation between the droughts.

The model shows that high drought frequencies lead to reduced numbers of snail kites. The effect of habitat degradation after a prolonged period of inundation, however, had no effect within the range of drought intervals that was studied. The most interesting aspect of the current version of the model is that it allows for the evaluation of spatial correlations between droughts and the unpredictability in the number of kites over longer time spans. When the spatial correlation between droughts is low, the model shows narrow ranges of predicted numbers of kites. When the droughts tend to be system-wide, the effect of environmental stochasticity strongly increases the unpredictability of future numbers of snail kites and, in the worst case, the viability of the kite population is threatened.

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Evapotranspiration Measurement and Modeling in the Everglades

By

Edward R. German[1]

A network of nine sites provides evapotranspiration (ET) and related meteorological data at locations in the Everglades representative of the natural Everglades system in terms of plant communities, duration of water inundation, and geographic extent. Eight of the nine sites have been in operation since December 1995; the ninth site was added in January 1997 to expand coverage in drier parts of the Everglades. Site locations and other details including study objectives, methodology, and timeframe are described in a previous publication (German, 1996).

Daily ET values have been estimated for five of the nine sites through March 1997 and annual ET values have been compared among the sites. One site is in a slough that has sparse, emergent vegetative and lily-pad coverage. Three sites are in perennially wet sawgrass prairies; one of the three sites (P33) has relatively sparse sawgrass coverage and the other two sites have sawgrass coverage of medium height and density. The fifth site (Old Inghram Highway) has a relatively sparse coverage of rushes and is dry for several months each year. Preliminary estimates of ET at the five sites for 1996 ranged from 54.4 in. at the slough station to 42.1 in. at the Old Inghram Highway site. Among the perennially wet sites, ET ranged from 48.0 to 52.3 in. during 1996. The low ET determined at the relatively dry Old Inghram Highway site indicates that water level probably is more important than vegetative cover type in determining ET. Locations where water levels are always above land surface probably will have ET rates that are largely a function of solar energy input and not greatly affected by type or density of vegetative cover.

Net solar radiation is the most significant term in the energy budget and, thus, in the determination of ET. However, at times, the heat stored in water can contribute significantly to ET for a few hours or days. This generally occurs during the passing of cold fronts, when heat stored in the surface water is released partially as latent heat. The presence of surface water also can moderate the transformation of solar energy to latent heat (ET) by storing energy during the day (as the water is heated) and releasing the energy at night, partly by evaporation, as the water cools. An example of the effect on ET from the passing of a cold front is evident in the data from site P33. The net solar radiation at site P33 on February 4, 1996, averaged 86.4 watts/m^2. The surface water, in cooling from a mean temperature of 23.7 °C on February 3 to a mean temperature of 19.5 °C on February 4, released heat energy at an average rate of 140 watts/m^2. The net result of this water cooling was to boost the evaporation rate from 0.11 in. on February 3 to 0.21 in. on February 4. Further cooling on February 5 contributed to an ET of 0.16 in. The next day, water cooling was nearly complete and ET decreased to a more seasonal 0.09 in. An example of the moderating effect of surface water on ET in a daily timeframe is illustrated by data from the P33 site in July 1996. At this site, an average of 47 percent of ET occurred during the 5-hour period from 1000 to 1500 during July 1996, whereas an average of 70 percent of the daily net solar radiation occurred during the same time period.

Use of the Priestley-Taylor model of ET was investigated for the purpose of filling in periods of missing ET data at existing sites. The Priestley-Taylor model expresses ET as a function of temperature-

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dependent atmospheric properties, available energy, and a semi-empirical coefficient (Priestley-Taylor coefficient). The theoretical Priestley-Taylor coefficient is 1.26 for a free water surface or a dense well-watered plant canopy; sites with lower water availability will have lower coefficients.

The Priestley-Taylor model was fitted to daily ET for the 1996 calendar year for the five sites where preliminary estimates of daily ET have been made. The model explains at least 90 percent of the variation in daily ET at each site. The Priestley-Taylor coefficient ranged from 0.97 to 1.03 at the three perennially wet sawgrass prairie sites, was 0.80 at the partially dry site (Old Ingraham Highway) and was 1.19 at the slough site. The difference between the coefficients at the vegetated sites and the open-water site (slough) indicates that the presence of aquatic vegetation tends to decrease ET relative to rates that occur at less-vegetated, open-water sites for a selected level of net radiation. However, net radiation at a given solar intensity appears to be lower at the open-water site than at the perennially wet vegetated sites, possibly because of a greater amount of reflection and long-wave radiation from the water surface. The net effect of the higher Priestly-Taylor coefficient and lower net radiation at the open-water site may be to make ET at the open-water site the same as that occurring at some perennially wet, vegetated sites.

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Development of Selected Model Components of an Across-Trophic-Level Systems Simulation for the Wetlands of South Florida: Landscape Structure

By

Louis J. Gross[1] and M.A. Huston[1]

Each of the individual-based models for indicator species in the ATLSS Program uses information from models describing abiotic conditions or their prey base on the landscape. This is done through a "landscape structure" in which all static and dynamic information is stored. This includes such standard static GIS information as surface elevations, soil types, and road locations, as well as dynamic information, such as water levels across the landscape. The individual-based models for indicator species in ATLSS are designed to make specific predictions. These predictions can only be accurate and useful if the model landscape on which they are simulated is accurately represented. It is crucial, in particular, that the water depths at locations across the landscape are accurate, since reproductive success of the wading birds and Cape Sable seaside sparrows, in particular, ishighly dependent on the details of seasonal water level rise and fall in particular spatial cells across the landscape.

The ATLSS Program has not attempted to develop an independent hydrologic model for the region. Rather, the landscape model is designed to use standard stage height output from scientifically-reviewed and accepted hydrologic models, such as the South Florida Water Management District's Water Management Model (SFWMM) and Everglades Landscape Model (ELM). The spatial scale at which hydrology is modeled (with 2 x 2 mi cells in SFWMM and 1 x 1 km in ELM) is much larger than the scales at which the landscape must be modeled to predict ecological responses. Because of this ATLSS landscape model has taken the approach of inferring the land surface elevation from current vegetation patterns. This approach generates "pseudotopography," which is ground surface elevations that are predicted on the basis of vegetation maps, rather than being measured directly. As direct measurements of topography become available at the scales of resolution needed by biological models, direct topographic data will replace "pseudotopography."

In addition to the dynamic information on water depth, the landscape structure stores biological information from GIS maps or models of relevant abiotic and biotic processes. In particular, the following information is critical to the performance of the individual-based models described above.

Currently, the model uses a vegetation map prepared for the Florida GAP Analysis Project, with a spatial resolution of 28 x 28 m spatial cells, which we have aggregated to 100 x 100 m cells. The map seems adequate for most purposes and will be continuously updated as it is improved. There are some cases where it is not yet clear that the map allows a fine enough discrimination of various vegetative classes important to the indicator species (for example, *Muhlenbergia* grass for the Cape Sable sparrow). In these cases, the map is supplemented with onsite information.

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Development of Selected Model Components of an Across-Trophic-Level Systems Simulation for the Wetlands of South Florida: Florida Panther

By

Louis J. Gross[1] and M.A. Huston[1]

The Florida panther (*Felis concolor coryii*) represents one of the most challenging problems in conservation. This population is the remnant of a population that once occurred throughout the Gulf and Atlantic coastal plains of southeastern United States. The total population of panthers in southern Florida probably includes no more than 50 adults, and this subspecies was listed as endangered in 1973. The Everglades/Big Cypress system is not high quality panther habitat compared with upland areas farther north, but its relative freedom from human impact makes it currently the only available area for the panther population. The question is whether this area is adequate to sustain a population of panthers in the long run.

Models can be used to help determine the carrying capacities of various landscapes within southern Florida for the panther, and assess the usefulness of protection of land not currently protected that may increase the overall carrying capacity. Therefore, as part of the ATLSS Program, a model has been developed that will allow us to determine the potential long-term impacts (for example, over 30 years or more) of spatially-explicit modifications in habitat (particularly hydrology) on the panther population (Comiskey and others, in press). The spatio-temporal dynamics of habitat coupled with small population size and long-distance movements of panthers, implies that an individual-based modeling approach offers the best hope to utilize the extensive available empirical data on panthers to produce a model which appropriately tracks the effects of alternative hydrologic scenarios. Additionally, such a model offers the capability of providing cost-effective methods to help guide any potential captive release program, by comparing the effect of alternative release programs on the model population.

Individual panther success (for example, survival and reproduction) in South Florida is closely linked to a panther's ability to obtain large prey items, notably white-tailed deer (*Odocoileus virginianus seminolus*) and feral hogs. Thus, in order to produce a panther model, it was essential to develop an individual based model of white-tailed deer to determine how hydrologic changes would affect these key prey resources, and link this to the panther model. White-tailed deer, the only large (native) herbivore in the region, has a significant localized impact on vegetation, so including it as a major component of the project is justified independent of the importance of deer to panthers. Accounting for the impacts on vegetation of feral hogs in the system would also be appropriate, however at present hogs are represented only as a static density. The main objective of this modeling component is to allow for prediction of the relative impacts of alternative hydrologic scenarios over a 30-year timeframe on the spatial and temporal (for example, seasonal) distribution of panther and deer across South Florida, and to produce relative comparisons of mortality, reproduction, individual movement patterns and territory size across the landscape for both species.

The model operates on a daily time step, although within this time step, deer and panther movement are simulated, taking account of local water conditions, forage and prey availability. Spatially, the model makes use of vegetation data to calculate forage availability on a 100 m scale, but tracks deer and panther locations on the daily time step at 500 m scale.

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The primary inputs to the Florida panther/white-tailed deer model are daily hydrology data at the 100 m scale (available through a pseudotopography model, see below), a vegetation map (from which three classes of dynamic forage maps are constructed), a landuse map, a map of feral hog density, and a road map. The primary environmental factors driving the model are, therefore, hydrology and vegetation, which vary temporally.

The first version of this model is now complete and produces highly detailed spatial information on deer and panther distribution pattern changes over time that appear reasonable based upon consultation with experts. Validation efforts include detailed comparisons of deer distributions with historical data, comparison of aggregated variables such as age-dependent mortality, age-structure, body weight distribution and birth rates with available data, and comparison of model individual-movement patterns with radio collar data.

Florida Bay Mudbanks: Relatively New Piles of Mostly Old Sediment

By

Robert B. Halley[1], Chuck W. Holmes[1], and Ellen J. Prager[1]

The study of Florida Bay mudbanks provides two different, but important sources of information for ecosystem restoration. First, they are the primary physiographic (bathymetric) features of Florida Bay. The banks act as partial barriers to circulation and influence water quality, in particular salinity and turbidity. Second, mudbanks are localized accumulations of biologically produced debris resting on a relatively flat, much older, limestone floor. They are the primary repository for sediment formed within the Bay and they contain sedimentological, paleontological, and geochemical records of past conditions in the Bay.

<u>Mudbanks are barriers</u>. Surveys of bank-top elevation, together with recent surveys of ENP tide gauges, allow records of bank exposure and water depth to be calculated from tide data. During a year, these records provide a means of correlating bank-top exposure with climatic events such as still, hot summer days or windy, winter cold fronts. Over several years, tide records reveal extensive inter-annual variation of water depth over the banks, suggesting significant inter-annual variation in circulation throughout the Bay. Understanding long-term (decades to centuries) influence of the mudbanks on circulation requires knowledge of sea-level change as well as changes in mudbank elevation.

Sediment transport and accumulation result in mudbanks with extremely flat tops, probably the result of a balance between physical processes (waves, currents, periodic exposure, sediment properties) and biological influences (sediment trapping by seagrass and bioturbation). Mudbanks in the eastern bay are typically eroding on exposed margins and accumulating on protected margins, resulting in net migration. Most of the transported sediment is carbonate mud, silt, and fine sand. Coarse sand and shell material form erosional lags on eroding margins and may accumulate as ridges, particularly where wave-damping by grass has been eliminated due to seagrass mortality. Coarse lag deposits also occur on some basin floors, the result of repeated winnowing of fine sediment. Fine sediment accumulates in the mudbanks, and on protected margins covered by seagrass. Regions of erosion and deposition are best defined by bottom mapping and wave modeling, both projects currently underway in the USGS and summarized by Prager elsewhere in this symposium.

Lead-210 dating of sediment cores from mudbanks in eastern Florida Bay yields carbonate sedimentation rates on the order of a meter per century. If this rate had been realized for the entire 3,000-year history of the Bay, mudbanks would be 30 m thick. In fact, they are 2 m thick in the eastern Bay, a thickness limited by sea level. The observed sedimentation rates are controlled by transport and redeposition of old sediment. C-14 dating of bulk sediment confirms this interpretation, yielding apparent surface dates many hundreds to thousands of years old.

The importance of seagrass in trapping and binding sediment during the formation of mudbanks has been long-debated. The recognition that much of the sediment in mudbanks is transported to the site of accumulation does not diminish the importance of seagrass trapping as a mechanism for bank construction. The absence of seagrass facies in cores has previously been interpreted to suggest that

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seagrass is of minor importance in bank construction. However, seagrass has a dampening effect on waves beyond the immediate vicinity of the grass bed, similar to the effect a snowfence has on drifting snow. Grassless deposits may be considered a part of a grass-bed deposit if it is downcurrent from a seagrass bed. Open mud areas on Florida Bay mudbanks, termed "blowouts" appear to be the result of this snowfence-like behavior of grass beds. Elsewhere, blowouts are the result of erosion during storms, but blowouts on mudbanks are bare mud areas shielded by a fence of seagrass and accumulating sediments. These areas accumulate only transported sediment, in contrast to the grass beds around them that accumulate an additional component of skeletal material from organisms living in and on the grass.

Mudbanks are record keepers. At first glance it may seem that because the bulk of mudbank sediments are transported, there would be little opportunity for preservation of a sedimentological record of the ecosystem. But in protected areas, the local contribution of sediment from grass includes a fraction that is more coarse-grained than transported sediment. The local fraction that has accumulated during the last 35 years can be identified because it incorporates excess C-14 produced by atmospheric nuclear bomb testing in the 1960's, an excess still present in shallow surface waters of the Bay.

As bomb-produced C-14 accumulated in the surface water of the oceans, it was also incorporated into the skeletons of annually-banded corals. Analyses of individual annual bands from corals in the Florida Keys, provides a detailed local record of the rapid accumulation and subsequent slow decrease of radiocarbon in sea water. Coral and mudbank chronologies are independent, the former derived from counting bands back from the living surface of the coral, and the latter chronology established from lead-210 dates. This local coral C-14 history can be used as an ideal scale for comparison with the C-14 record from the coarse, *in-situ* portion of mudbank sediments. The comparison shows good agreement and indicates that 1) a portion of the sediment in mudbanks originates locally in grass beds (as originally proposed by Ginsburg in the 1950's) and 2) there is relatively little mixing in the coarse fraction. The composition of the coarse fraction reflects the ecosystem at the time of growth and deposition.

Seagrass beds in protected areas accumulate both transported (allochthonous) sediment and sediment from the organisms that live there (autochthonous sediment). The transported sediments are generally fine-grained because the energy of these areas is insufficient to move coarse-grained material. For sediments deposited since the late 1960's, allochthonous material has much less C-14 than autochthonous sediment which contains bomb produced radiocarbon. C-14 analyses of size fractions indicated that sediment coarser than about 250 μm is not transported, sediment between 250 and 62 μm is partially transported, and sediment less than 62 μm is almost entirely transported and includes much older material. This data indicates coarse fractions of Florida Bay cores reflect local conditions near the core site. The fine fraction represents conditions over a much broader region of the bay and is diluted by large contributions of transported older material.

The recognition that the bulk of Florida Bay sediment is old (more than 1,000 years) and has been deposited in mudbanks relatively recently (past few hundreds of years) attests to the importance of sediment transport processes in the Bay. Mudbank formation requires sediment transport, and in turn requires erosion, suspension, turbidity, and redeposition. The very existence of mudbanks is evidence that periodic turbidity is a long-standing characteristic of the estuary.

High-Resolution Bathymetry of Florida Bay

By

Mark E. Hansen[1]

Land development and alterations of the natural system in South Florida have decreased fresh water flow and increased nutrients into Florida Bay. As a result, there has been a decrease in the water quality of the Bay which has prompted seagrass die offs and reduced fish populations. Restoration of Florida Bay will depend upon numerical circulation and sediment transport models to establish water quality targets and assess progress toward obtaining these targets. Application of these models is complicated due to the complex sea-floor topography (basin/mudbank morphology) of the Bay. The only complete topography data set of the Bay is 100 years old. Consequently, an accurate and modern sea-floor or bathymetry map of the Bay is critical for numerical modeling research.

A modern bathymetry data set will also permit a comparison to historical data in order to help assess sedimentation rates within the Bay. Previous research suggests that the mudbanks are dynamic features which migrate, accrete and erode. Less is known about the sedimentation rates in the basins. Some experts suggest the basins are filling, in association with sea-level rise, while others suggest the basins are deepening relative to sea-level.

The objective of this research is to collect new bathymetry for all of Florida Bay, digitize the historical shoreline and bathymetric data, compare previous data to modern data, and produce maps and digital grids of historical and modern bathymetry. This information will be provided to other researchers involved in the South Florida Ecosystem Restoration Program so they can better address the water quality issues of Florida Bay.

The strategy is to systematically map the bathymetry in Florida Bay to aid in the assessment of Bay sedimentation rates and to provide an accurate sea-floor surface for numerical models. The Bay is being mapped using a shallow draft boat equipped with a high-precision GPS coupled with a high-precision sounder. Data is being collected on a USGS 7.5-minute quad-by-quad basis proceeding westward from Blackwater Sound. Sounding trackline spacing vary depending upon the relief of the sea-floor, that is, closer spacing in near mud banks - wider spacing in the basins. Digital sea-floor grids are being produced from the trackline data. Historical bathymetric data (1890) have been obtained from NOS archives, digitized, and entered into a GIS. Digital comparisons will be made between the historical data and the new data. The project will produce both hardcopy and digital map products and professional papers. Historical and modern bathymetric maps will be produced as well as maps of bathymetric change. All maps will be produced at a scale of 1:24,000 and will conform to USGS I-Map standards. Map production will be performed using ARC/Info and data archiving will comply with SDTS standards.

The parts of the Bay which are accessible by a shallow draft boat have been mapped using the System for Accurate Nearshore Depth Surveying (SANDS). This system, developed by the USGS, utilizes geodetic differential Global Positioning System (GPS) receivers, a digital fathometer, a digital heave/roll/pitch sensor, and a shallow draft boat. The system is accurate to ~10 cm vertically, ~4 cm horizontally, and can collect data in water depths as shallow as 50 cm. To achieve this accuracy, the boat must not rove more than 10 km from any one GPS reference receiver. Therefore, approximately 10 new ground control points (with 1-2 cm accuracy) will be established throughout the Bay for use as reference

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receiver sites. For areas not accessible by boat, mud bank tops and sensitive seagrass areas, other non-intrusive (remote sensing based) methods must be employed to fully map the bathymetry of the Bay. One non-intrusive technique to map the boat inaccessible areas is the U.S. Army Corps of Engineers SHOALS helicopter LIDAR system. Another method utilizes vertical photography or imagery in combination with water stage data to determine the elevations of the mud banks. These two techniques and others are being investigated at this time. Utilizing a non-intrusive method(s) in conjunction with the SANDS system will provide basin and mud bank elevations for the entire Bay.

To date, Florida Bay has been systematically surveyed for the area from Long Sound west to Whipray Key. The data has been checked for errors, entered into a GIS, and digitally contoured. All historical shoreline and bathymetric data of Florida Bay has been digitized, projected into a modern datum, and digitally contoured. Comparison of the modern data set to the historical has been initiated. Preliminary results (for the aforementioned area) suggests that basin depths have not changed dramatically in the past 100 years. The most noticeable changes have occurred in the cuts, for example, "The Bogies", Grouper Creek, Dusenbury Creek, and Baker Cut. Many islands in this part of the Bay changed in their areal extent. We plan to quantify the amount of change and produce sea-floor change maps for this area in the near future.

Spatial and Seasonal Variation in Exchange Between Surface and Ground Water in the Northern Everglades, Florida

By

Judson W. Harvey[1], Steven L. Krupa[2], and Robert H. Mooney[3]

The lack of reliable information about exchange between surface and ground water in the Everglades not only leaves the water balance uncertain in many areas of the Everglades, but it also hampers progress in determining chemical sources, chemical residence times, and the fate of nutrients and mercury in the Everglades. The present project recently completed emplacement of hydrological instrumentation at 17 sites in interior areas of the Everglades where nutrient and mercury dynamics are being investigated. The sites are located in the Everglades Nutrient Removal Area in Palm Beach County (ENR) and in Water Conservation Area 2a in Palm Beach and Broward Counties (WCA-2a). Two seepage meters were installed near existing research platforms at each site and two to four research wells were emplaced nearby to depths that range between 15 and 180 feet below ground surface. Surface-water level recorders and data logging instrumentation were also added. Measurement of vertical hydraulic gradients and vertical water fluxes demonstrated that significant vertical exchange occurs between the surficial aquifer system, wetland peat, and surface water at many of the research sites. Exchange fluxes ranged from as low as 0.03 centimeters per day (the limit of detection for seepage meters in this system) to as high as 30 cm/d in some areas, which is approximately two orders of magnitude higher than average daily precipitation and evapotranspiration for the area. The direction of exchange varied spatially at ENR (upward on the eastern side, downward on the western side) and varied seasonally at WCA-2a (upward flow in the mid-summer through fall during the wet season and downward flow in winter, spring, and early summer during the dry season). Why do exchange fluxes between surface and ground water predominantly vary spatially at the ENR and temporally in WCA-2a? ENR is a relatively small constructed wetland (4,000 acres) reclaimed from agricultural land that has been subjected to considerable excavation of drainage canals. The ENR wetland site is located between an impoundment where water is retained at high level (WCA-1) and a region in the Everglades Agricultural Area (EAA) where ground water is pumped away to maintain a low water table. WCA-2a is much larger in extent (105,000 acres) and is affected less by local pumping, drainage, excavation, or managed water levels in canals. Our interpretation is that the predominance of spatial variation in vertical exchange fluxes in the ENR reflects the proximity of its interior areas to canals, where surface-water levels are stabilized at high levels in some areas and low levels in other areas and then are maintained at those levels to achieve management goals. At the ENR the trend in upflow on the eastern side of the project and downflow on the western side varies only minimally with time because of the nearly constant water levels in WCA-1 and the EAA. The pronounced seasonal variability in vertical exchange at WCA-2a may also reflect management influences; for example the timing of water releases from WCA-1 into WCA-2a. However, the fact that the highest upward hydraulic gradients occur in WCA-2a in the wet season, when surface-water levels are highest, is not consistent with a control on vertical fluxes in WCA-2a that is imposed by the release of surface water from WCA-1. In contrast to the situation at ENR, seasonal changes in fluxes at WCA-2A suggest an overriding influence of regional climatic variability and the regional water balance rather than local management of water levels.

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Electromagnetics Delineate Aquifers Between Wells in Southwest Florida

By

Laura F. Hite[1], Matthew J. Carlson[1], Paul J. Wolfe[1], and Benjamin H. Richard[1]

In southwest Florida, the surficial aquifer system is a primary source of fresh water. These water-bearing sedimentary rocks are the result of periodic sea level fluctuations that resulted in the deposition of alternating sands, silts, and clays and marine carbonate sediments. The surficial aquifer system is predominantly unconfined, receives recharge directly from precipitation and is composed of materials of Miocene to recent age (Knapp and others, 1986).

The surficial aquifer system is characterized by a near-surface, water-table aquifer containing freshwater and a lower brackish to saline aquifer termed the lower Tamiami aquifer (Bennett, 1992; Jacob, 1980). The lower Tamiami aquifer has variable formation conductivity values of several thousand microsiemens per centimeter due to the upward movement of waters with high chloride ion content. An aquitard separates these aquifers of distinct water quality. Accurate models of aquifer geometry and estimates of aquifer parameters are needed in planning the restoration and management of natural ecosystems in the parklands of Collier County.

This study developed after it was determined that surface geophysical mapping was needed to correlate data from individual boreholes within Collier County, Florida. Time-domain electromagnetics (TDEM) was chosen as the surface geophysical tool based on agreement between core descriptions, water sample data, geophysical logs, and TDEM soundings near coreholes. Surface geophysics would help provide a better understanding of the lateral continuity of the aquifers and aquitard(s) between borehole locations. The ultimate goals of this study are as follows: (1) to create electrical conductivity profiles from the results of modeling 64 soundings along transacts of the surficial aquifer system and (2) to determine where encroachment by the lower Tamiami aquifer may exist and therefore infer where the aquitard may be discontinuous.

Time-domain electromagnetic soundings measure the apparent conductivity of the layers below the transmitter loop by measuring the strength of the signal returned to the receiver as a function of time when the equipment is operated in a pulsed mode (Fitterman and Stewart, 1986). The equipment response in millivolts as a function of time is used to generate models of conductivity versus depth. A Geonics Protem TEM 47/P system was used for data collection. In central Collier County west of Big Cypress National Preserve, 33 TDEM soundings were completed on a north-south 17 kilometer (10. 5 mile) transect along Miller Boulevard. Twenty-six soundings were completed along Stewart Boulevard and Janes Memorial Scenic Drive covering approximately 28 km (17.5 mi) to determine the east-west variations in the aquifer system. The computer program TEMIX (Stoyer, 1988) was used to model the results.

The TDEM models were interpreted in relation to the geology and the hydrology evidenced in the boreholes. Whether using a 2, 3, 4, or 5 layer model the prominent feature was a lower conductivity layer on a higher conductivity half space. We interpret this as the water-table aquifer ranging in thickness from 7 to 50 m overlying the brackish-to-saline lower Tamiami aquifer. Soundings that were made in the vicinity of boreholes were found to agree closely with the profiles of subsurface conductivity given by the induction logs.

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The north-south profile along Miller Boulevard shows a gentle southward dip of the interface from approximately 25 m at the north end to about 50 meters at a location 5,000 m north of State Route 41. This is interpreted to be the result of the aquitard dipping to the south. At the southern end of the profile, near State Route 41, the depth to the conductivity increase is at approximately 7 m. This is interpreted as the edge of the water-table aquifer because south of State Route 41, the surface water is saline. The shallow depth to the interface in the south is a direct result of lateral sea water intrusion above the aquitard, as this portion of the profile is nearest the coast. The east-west transact shows a fairly constant interface at a depth of approximately 35 meters. Localized variation in the conductivity of the underlying formations along the profiles may be due to upward movement of saline water into underlying aquifers, lateral variation in lithology and permeability, or undetected interference with electrically conductive debris.

This study has shown that TDEM soundings can be related to well logs and provide an efficient method to interpolate the information from a small number of boreholes over a relatively large area. This combination of TDEM soundings with logged boreholes is effective for studying the hydrostratigraphy of the surficial aquifer system of south Florida.

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Methods to Establish the Timing of Ecological Changes in South Florida - Good, Better, Best

By

Charles W. Holmes[1], Marci Marot[1], Debra Willard[2], Lisa Weimer[2], and Lynn Brewster-Wingard[2]

In order to manage a changing ecosystem, it is necessary to ascertain its rate of change. The lack of historical records documenting ecological change in south Florida requires that other methods be used to define the rates. A common method is to use the decay of naturally occurring radioactive nuclides. The usefulness of any radioactive nuclide requires that 1) the chemistry of the nuclide (element) is known, 2) the half-life has a range which is long enough to span the time of interest, 3) the nuclide, once incorporated into the substrate, changes only by decay, and 4) the nuclide is relatively easy to measure. In south Florida, where the period of interest is the last 200 years, there are four nuclides which fit these criteria, ^{7}Be, ^{14}C, ^{137}Cs, and ^{210}Pb. Two of these are natural, ^{7}Be and ^{210}Pb; one has both a natural and anthropogenic contribution, ^{14}C; one is solely anthropogenic, ^{137}Cs.

In the South Florida Program, natural nuclides were measured at all study sites. ^{7}Be, with a half-life of 53.3 days, is formed by cosmic ray spallation of nitrogen and oxygen within the earth's atmosphere. It is subsequently transferred via washout from the atmosphere to the marine and terrestrial environment. A highly reactive element, it is rapidly incorporated into a sedimentary substrate. This nuclide is very useful in determining if the sediment was in communication with the atmosphere within a year and if the surface sample was deposited within the past year.

^{210}Pb, with a half-life of 22.8 years, is one of the isotopes in the ^{238}U series. The disequilibrium between ^{210}Pb and its distant relative is caused by the intermediate progenitor, ^{222}Rn. Radon escapes into the atmosphere at a rate of about 42 atoms per minute per square centimeter of earth's surface. This isotope rapidly decays to form ^{210}Pb. The newly formed lead, with a residence time in the atmosphere of about 10 days, is removed by rain or snow. Like ^{7}Be, ^{210}Pb is tightly bound to the sediment forming at the earth's surface. This flux produces a concentration of "unsupported" ^{210}Pb. "Unsupported" lead is the ^{210}Pb whose activity is greater than any activity that may be produced by ambient radon progenitors present within the sediment. "Dates" of the sediment are calculated by determining the decrease in "unsupported" ^{210}Pb activity with depth. If the initial concentration is known, or is estimated using ^{7}Be data, then the age of a horizon can be calculated. Ideally, a plot of ^{210}Pb activity with a log scale versus depth will be a straight line. The slope of the line indicates the relative sedimentation rate. A steep slope represents a site of slow accumulation. The combination of ^{7}Be and ^{210}Pb produces **good** "dates" and very accurate rates of accumulation. But like all dating procedures, this method relies on reasonable assumptions for validity. To narrow the degree of uncertainty, concordance is sought with "ages" either by an independent "dating" method or by other independent measurements of time.

The most common nuclide used to verify the ^{210}Pb dates is ^{137}Cs. ^{137}Cs, with a half-life of 30.3 years, is a thermonuclear by-product. Robbins (personnal commun., 1995) has plotted the thermonuclear fallout in South Florida based on NOAA data. This curve shows that the detection of fallout began in about 1954, peaking in 1960-61. The distribution of ^{137}Cs, under ideal conditions, provides a

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chronometer for the last forty years. At most localities within Florida Bay and the Everglades, the ^{137}Cs and ^{210}Pb ages were synchronous and the "dates" at these sites are **better** than relying on one method alone. However, in the mangrove fringe of Florida Bay and at sites near the northern border of Water Conservation Area 2A, there was a significant discrepancy between the two methods. It has been demonstrated that in some cases the cesium will become mobile. In order to determine if this was happening, ^{14}C measurements were made. ^{14}C has two sources; the primary source is cosmogenic, similar to ^{7}Be. The other source is from atmospheric testing of thermonuclear devices. Although cosmogenically-derived ^{14}C makes up most of the total radiogenic carbon, the thermonuclear component is significant and readily measured. The importance of this component is that it provides a time-line in the carbon signal which is recognized in carbon-based sediment. The distribution of ^{14}C was determined using AMS techniques, which measure the activity of radiocarbon on extremely small samples. The small samples were necessary to circumvent problems that arise with descending roots, and to isolate material that represents the time the sample was deposited. Results of these measurements confirm that cesium is migrating in the mangrove fringe sediment but not in the WCA sediments. The discrepancy in the latter is the result of physical disturbances around the sample locations.

Even with ages determined by multiple radiometric methods, there is still some reservation about the establishment of a chronology. To alleviate these concerns, confirmation of the chronology can be established based on independent observations. In Florida Bay, a comparison was made between the distribution of total atmospheric-derived lead within a coral, "dated" by counting the annual bands, and the total lead distribution within radiometrically dated sediment cores. Results of the comparison demonstrated concordance. In the emergent portion of the study area, radiometric "dates" were confirmed by comparison of the paleobotanical record to geographic changes recorded in areal photographs. These comparisons yield the **best** "dates", because they were established by three independent methods.

In summary, at sites where only naturally occurring radionuclide (^{210}Pb and ^{7}Be) data is available, rates of sediment accumulation can be accurately determined but "dates" are limited in accuracy because of the assumptions required. These sites are the **good** sites. At sites where there is additional radiometric information, such as ^{137}Cs, for verification, the sediment "dates" are **better**. The **best** "dates", however, are those that are confirmed by other procedures in addition to radiometric dating. It is at these sites that the radiometric "dates" can fill in the gaps and detail changes in the ecology of the area over time.

The Geology of the Buttonwood Ridge and Its Historical Significance

By

Charles W. Holmes[1], Debra Willard[2], and Lynn Brewster-Wingard[2]

Craighead (1964) defines the Buttonwood Ridge or embankment as the greatest inland extension of the marine shoreline. This feature stretches approximately 60 kilometers (km) across the southern tip of Florida, averages 1 km in width, and lies a few centimenters (cm) above the present sea level. It appears to form a barrier between the terrestrial environment (Everglades) to the north and the marine environment (Florida Bay) to the south. This study was undertaken to define the historical environmental changes that have occurred within this critical ecological zone along the south Florida shoreline and to determine the influence of the Buttonwood Ridge in these changes.

Borings and cores through the Buttonwood Ridge along Taylor Creek and across Crocodile Point show that the ridge is dominated by fine carbonate mud inter-layered with 5 to 10-cm peat layers. Along Taylor Creek, a three-core transect revealed a unique developmental stratigraphy. The cores were taken at 10, 500, and 1000 m from the shoreline. The basal sediment in each of the three cores is a cream colored marl overlain by a grey carbonate mud. The faunal record indicates that the basal marl is freshwater in origin. It yields a carbon date of 1920 ± 150 years BP. The basal marl is overlain by a carbonate mud containing a diverse faunal assemblage suggestive of an upper estuarine environment. This zone is overlain by peat, which pollen and petrographic analyses indicate is a mangrove peat. At the site closest to the shoreline, the peat is 100 cm below present sea level but no ^{14}C age is available from this core. At the center of the ridge, the peat layer is 100 cm below sea level and has a ^{14}C age of 1430 ± 70 BP. At the inland-most site, the peat layer is 80 to 93 cm below sea level and has a ^{14}C age of 1750 ± 70 BP.

In the three-core transect normal to the shoreline across Crocodile Point, the two cores closest to Florida Bay, one 10 m from the shoreline and the other 50 m from the shoreline, contain two distinct peat layers. One peat layer is 30 to 40 cm below sea level and the other is 140 to 150 cm below sea level. Below the lower peat layer is a thin marl with a basal organic peat. The carbon dates are 280 ± 70 BP for the upper peat layer and 370 ± 80 for the lower peat layer. Both peats are much younger than the peat in the Taylor Creek transect. Sediment between these peat layers is a shelly marl and differs from the fine carbonate mud found along the Taylor Creek transect. Both peat layers across Crocodile Point have a very heavy ^{13}C signature (-24 ‰), as compared to -27 ‰ for the mangrove peat in the Taylor Creek transect. This heavy signature is indicative of a subaqueous plant such as sea grass. The third core, 100 m from the Florida Bay shoreline, is similar to the Taylor Creek cores. The stratigraphic relationship at Crocodile Point indicates that a significant amount of material recently was accreted onto an older ridge in this area. The geometry of this feature may be a key to the process of bank formation and could explain the difference in carbon ages between the peats along the Taylor Creek traverse.

In addition to the two vibracore traverses, four cores in the marsh landward of Buttonwood Ridge were analyzed. Sediment in the lower sections of the two inland marsh cores nearest Florida Bay is dominated by saw grass pollen, whereas sediment in the upper parts of these cores is dominated by mangrove pollen. On the marine to non-marine traverse up Taylor Creek into the saw grass plain, ^{210}Pb profiles demonstrate two episodes of sediment accumulation. Based upon 210 Pb "dating," the transition

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from saw grass to mangrove began around 1950. Comparison of areal photographs of the area in 1940, 1950, 1970 and 1990, confirms that the inland marsh site nearest Florida Bay changed from a lake to a mangrove swamp around 1950. This transition suggests an incursion of seawater landward and/or a reduction in freshwater input into the lake over the past 50 years.

Offshore, the "dating" of cores situated at the mouths of Little Madeira Bay and Joe Bay, and on Pass Key Bank, indicate an increase in sediment accumulation over the past few decades. At Pass Key, it appears that the banks have closed up, which could have an affect on circulation in this portion of Florida Bay. The rapid sediment accumulation at the mouth of the fringing bays is most likely the result of decreased circulation in the bays and/or a decrease in freshwater input from the mainland.

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System Controls on Water Column Total and Methyl Mercury in the Northern Everglades

By

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In 1995, the U.S. Geological Survey, in cooperation with several State, Federal and private agencies, initiated the project Aquatic Cycling of Mercury in the Everglades (ACME) to evaluate mercury (Hg) cycling processes. Anthropogenic activities have affected hydrology, nutrient status and the quality of atmospheric deposition in the Everglades. In the late 1980's, an analysis of game fish from across Florida revealed elevated levels of Hg in fish statewide, with some of the highest levels ($> 1.5\ \mu g\ g^{-1}$) in the Everglades. In response, a fish consumption advisory was issued for almost the entire Everglades system. The ACME project was designed to evaluate the factors responsible for Hg bioaccumulation in this unique ecosystem. The specific goals of the ACME project are to evaluate fluxes, rates and factors affecting Hg transport through the Everglades wetland system. The project has two phases which run simultaneously. The first phase evaluates seasonal distributions of Hg species in the aqueous phase at fixed canal and marsh sites in the northern Everglades. Our sampling frequency precludes a detailed analysis of season cycling at a given site, however, data from water column sampling at these sites aids in identifying contrasting sites for detailed process-level studies. Our initial goals were to evaluate the forms and species of Hg entering Water Conservation Area 2A (WCA-2A) from canal inputs and to identify trends in Hg distribution across the eutrophication gradient in WCA-2A. We further compare the eutrophied northern canal system to a less impacted southern canal system. Next, we evaluate aqueous Hg dynamics in the marsh system by comparing nutrient-impacted to unimpacted sites (including sites in WCA 2A and WCA-3A). Finally, we examine the relationship of Hg with dissolved organic carbon of this subtropical wetland to that of a northern temperate wetland system.

Our observations of aqueous Hg speciation in the Northern Everglades canals and marshes reveal strong spatial and seasonal patterns. These observed trends in aqueous speciation of Hg are a result of numerous formative, degradative and bioaccumulative processes. In canals feeding WCA-2A, HgT associated with soil-derived particles from EAA presumably settle from the system. Reduced flows and stagnation of waters within canals lead to increases in both $MeHg_U$ and particle-associated MeHg. Unfiltered HgT in surface water entering the marsh of WCA-2A ranged from about 1 to 1.5 ng L^{-1} while $MeHg_F$ exhibited a sixfold increase from winter to summer.

Transects across the marshes of WCA-2A, coupled with measurements in WCA-2B and WCA-3A reveal no apparent north to south trends in HgT_U. Unfiltered MeHg, however, does appear to show enrichment at southern sites for individual sampling periods. Additional analyses of HgR and DGM also suggest greater reactivity of aqueous Hg species at the southern sites. The strong relationship of HgT_F and $MeHg_F$ observed in northern Wisconsin is not apparent, suggesting differences in DOC type between regions. These general observations on aqueous trends in Hg speciation in the Northern Everglades form the basis for process-designed studies. Our future efforts are directed at obtaining a better understanding of speciation, partitioning, methylation and the temporal extent of biotransformation and bioaccumulation of Hg in this unique environmentally-sensitive ecosystem.

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A Paleosalinity Record from Manatee Bay, Barnes Sound, Florida

By

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The Biscayne Bay region of southern Florida has been affected by natural events such as steadily increasing sea level, droughts and hurricanes. In addition, anthropogenic alterations of the south Florida region, urbanization, increased agricultural activity, dredging of natural waterways, pollution, and water management of the Everglades, have changed the setting of south Florida. These events and modification of the south Florida geography have driven the evolution of the Biscayne Bay ecosystem. However, the magnitude at which each of these factors affects the ecosystem remains unknown.

The "Ecosystem History of Biscayne Bay and the Southeast Coast" project of the U.S. Geological Survey was initiated to determine changes in the Biscayne Bay ecosystem over the last 150 to 200 years and evaluate natural, as well as anthropogenic causal mechanisms. Faunal (foraminifera, ostracodes, and molluscs), floral (palynomorphs) and geochemical data (stable isotope, radioisotopes and trace elements) from modern environments are applied to shallow core sediment samples to infer a variety of historical environmental information (salinity, nutrients, substrate and productivity). This paper presents results from a survey of modern foraminiferal assemblages and their application to the historic record from a 120 cm core (MB1) collected in Manatee Bay to infer environmental changes during the past 150 to 200 years.

Modern benthic foraminiferal distributions in Biscayne Bay were determined to provide modern analogs to which down-core assemblages could be compared. The distribution of modern benthic foraminifera within Biscayne Bay was analyzed using 23 surficial sediment sample sites, each collected in June and August, 1996. The foraminiferal data were compared to hydrologic data (temperature, salinity, nutrients, clarity, dissolved oxygen and redox potential) also collected at each site to determine significant environmental controls on the foraminiferal distributions. A total of 69 taxa of benthic foraminifers common to the North American southeast coast and Gulf of Mexico were identified from the Biscayne Bay modern sediment samples. Species diversity, as measured using Simpson's Index, ranges from 0.080 to 0.493. The Simpson's Index represents diversity by reflecting species dominance with 1 signifying a monospecific assemblage and values decreasing with increased species number and equability. The foraminiferal assemblages are dominated by calcareous forms with agglutinated taxa constituting a minor component in most of the assemblages. Species dominance varies considerably throughout the Bay with *Ammonia parkinsoniana* forms *typica* and *tepida* and *Elphidium galvestonense mexicanum* constituting over 50 percent of the assemblage in restricted regions of Biscayne Bay. Conversely, *Archaias angulatus* is dominant (up to 45 percent) in samples collected from the open regions of Biscayne Bay. Other calcareous hyaline forms include *Bolivina* spp., *Elphidium delicatulum, Rosalina floridana* and *R. globularis*. Common miliolids include *Articulina mucronata, Miliolinella circularis, M. labiosa, Peneroplis proteus, Pyrgo subsphaerica, Quinqueloculina agglutinans, Q. bosciana, Q. poeyana, Q. polygona, Q. seminulum, Q. tenagos and Triloculina tricarinata*. Agglutinated taxa in Biscayne Bay include *Ammobaculites* sp., *Clavulina* sp., *Pseudoclavulina gracilis, Textularia candeiana, T. conica*, and *Trochammina* spp.

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Three dominant benthic foraminiferal assemblages are present within modern Biscayne Bay: *Ammonia-Elphidium* assemblage, *Archaias*-miliolid assemblage, and Bolivinid assemblage. The *Ammonia-Elphidium* assemblage occurs in restricted environments with relatively low salinities (<35 ppt) and regions with frequent point-source fresh water input. The *Archaias*-miliolid assemblage is associated with marine salinities (37-38 ppt), high water clarity, and well circulated environments. The Bolivinid assemblage occurs in the northernmost Biscayne Bay and is associated with diatomaceous muds that are rich in organic matter, suggesting high productivity.

Six shallow sediment cores were collected along a northeast-southwest coring transect in Biscayne Bay; MB1, MB2, CB1, FB1, BP1, and PB1, in November 1996 and February 1997 for faunal, floral and geochemical analyses. Preliminary benthic foraminiferal analyses were conducted on core MB1 collected from Manatee Bay, Barnes Sound (25° 15.69′ N, 80° 24.06′ W) in November 1996. Forty-one benthic foraminiferal species were identified from 60 samples of core MB1. The assemblages are dominated by calcareous forms and include *Ammonia parkinsoniana* formas *typica* and *tepida*, *Elphidium galvestonense* formas *mexicanum* and *typicum* and *Quinqueloculina* spp. Three distinct foraminiferal faunal zones are identified in MB1 that correlate strongly with the sedimentology. The *Ammonia-Elphidium* assemblage dominates (>95 percent) the lowermost part of core MB1 (84-120 cm) where the sediments consist of a yellow-gray peaty marl. The next assemblage shows an increase in species diversity with *Ammonia* spp. and *Elphidium* spp. remaining the dominant components (50-90 percent) and occurs from 66 cm to 84 cm in core MB1, within a light olive-gray shelly mud. The third assemblage is the *Quiqueloculina* spp. assemblage, similar to the modern *Archaias*-miliolid assemblage in modern Biscayne Bay, that is dominant (>50 percent) from 6 cm to 66 cm within a sandy mud (32-66 cm) through a vegetation-rich, yellow-brown mud (6-32 cm). The upper part of the core (0-6 cm) displays a trend of increasing *Ammonia-Elphidium* assemblage components.

The foraminiferal trends observed in core MB1 indicate a progressive increase in salinity up-core with the upper-most part of the core showing a reversed trend toward freshening conditions, consistent with the sediment observed. More detailed faunal analyses of core MB1 are underway, as well as floral and geochemical analyses. Radioisotope analyses (^{210}Pb) are currently being conducted to provide an age model for the core. The remaining cores are being processed for similar analyses to provide an overall record of ecosystem/environmental change within Biscayne Bay. These results, in addition to the ecosystem history records from cores collected in Florida Bay will result in a more comprehensive understanding of the South Florida ecosystem.

Preliminary Spatially Distributed Estimates of Evapotranspiration Using *In-situ* and Satellite Remote Sensing Data

By

John W. Jones[1]

Evapotranspiration (ET) is the term applied to the removal of water from the land surface through a combination of direct evaporation and vegetation transpiration. As it is in many ecosystems, ET is a primary component of the Everglades water budget. ET varies widely through both space and time along with the biological and meteorological factors that drive it. Spatial and temporal heterogeneity of vegetation type and function, as well as differences in available energy and water, all influence the rate at which ET occurs. Determining appropriate ways to account for the variation in these factors, and therefore in ET itself, is one of the pressing research issues facing those who need to describe, understand, and predict the behavior of hydrologic and climate systems - especially at regional scales for which sparse *in-situ* meteorological data are inadequate. Satellite remote sensing systems offer the promise of providing repetitive, synoptic views of variables related to ET.

Methods currently being developed that use satellite systems for ET modeling and mapping span a broad range of complexity. Empirically derived statistical relationships, physically based analytical approaches, numerical models, and the exploitation of observed relationships between radiant surface temperatures (Tr) and spectral vegetation indexes like the Normalized Difference Vegetation Index (NDVI) are all being developed (Kustas and Norman, 1996). However, many factors complicate the use of satellite data for ET estimation. Satellite-measured fluxes of energy are distorted by the mixture of land cover type and vegetation amount within the instantaneous field of view. Variability in the condition as well as the thermal and reflective properties of the materials being imaged complicates the derivation of important information. In addition to variability in the surface targets of interest, materials in the atmosphere block, absorb, and reflect energy differently through space and time, introducing additional noise in the measurements recorded by the sensor.

This poster presents preliminary attempts to use satellite remote sensing technology for extrapolating point measurements of ET over broader spatial scales. For this analysis, atmospheric corrections were applied to Landsat thematic mapper (TM) multispectral data spanning the visible, near-infrared, and thermal regions of the electromagnetic spectrum. These data were processed to yield reflectance, NDVI, and Tr values. Detailed meteorological and hydrologic data collected at nine locations as part of the South Florida Ecosystem Program (German, 1996) were used to model ET. Assuming the proportion of available energy going to latent heat of vaporization is constant (that is, a constant ET fraction) throughout the day (Hall and others, 1992), the values for reflectance, NDVI, and Tr for the areas of sufficient distances surrounding ground meteorological sites were regressed against the daily total ET for the date of the satellite overpass. The observed relation was used to extrapolate ET to all locations within the scene.

For longer term monitoring and modeling, the ability to estimate ET by means of satellite remote sensing without the need for extensive ground-based data collection is desirable. The methods and data sets developed through the analysis reported here will serve as one measure of spatially distributed ET against which subsequently developed techniques can be compared.

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Evaluating Food Chain Relations Using Stable Isotopes

By

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Analysis of the C, N, and S stable isotope compositions of plants, invertebrates, and vertebrates can be used to establish relative trophic levels among various organisms because at each ascending trophic level, there is an increase of about 1 ‰ in $\delta^{13}C$ and 3 ‰ in $\delta^{15}N$. Traditional methods for determining food web relations include direct observation and gut content analysis; both of these methods are tedious, time consuming, and emphasize food which is not digested and may not constitute important contributors to body mass. Stable isotope analysis provides a complementary and perhaps alternative method for testing hypotheses about animal diets. Its major strength is that the isotope compositions provide relatively easy and precise information about what was actually assimilated over the life-time of the organism. This information is critical to evaluating how methyl mercury (MeHg) gets into food chains. As part of several investigations, some 600 fish, periphyton, and invertebrate samples have been analyzed for $\delta^{13}C$ and $\delta^{15}N$; a smaller subset has also been analyzed for $\delta^{34}S$. Most of these samples have also been analyzed for MeHg and gut contents.

For C and N isotopic analysis, samples are dried, ground to a fine powder, 0.2 to 2 mg of the powder is weighed into tiny tin or silver foil boats, the boats are crimped, and they are loaded into an autosampler. If the samples contain calcite, silver boats are used instead of tin, and the weighed-out samples are acidified by exposure to HCl vapor for 18 h in a desiccator prior to crimping. Samples are combusted and the resultant N_2 and CO_2 gases separated chromatographically on an elemental analyzer. These gases are then automatically analyzed for C and N abundances and isotope ratios on the attached Optima continuous flow stable isotope mass spectrometer. Analysis for S isotope ratios requires combustion of a second larger aliquot and different processing. The analytical precision is about 0.15 ‰ for C, N, and S isotope ratios of solid samples >0.5 mg. The reproducibility of duplicate aliquots of samples analyzed on different days is better than 0.3 ‰; much of the variability is due to inhomogeneity of the samples.

Surveys of organisms at USGS sites in the Water Conservation Areas (WCAs) generally show that samples from canals have higher $\delta^{15}N$ values (+9 to +18 ‰) than samples from marshes (+1 to +14 ‰). This difference probably reflects a persistently higher value of the $\delta^{15}N$ of dissolved inorganic nitrogen (DIN) at the canal sites than at marsh sites. One likely explanation for this pattern is denitrification in anoxic waters and sediments in stagnant parts of the canals, which would cause the resultant DIN to increase in $\delta^{15}N$. The compositions at individual sites show some seasonal variability in composition. In general, the $\delta^{15}N$ values of *gambusia* are 7 to 9 ‰ higher than co-existing periphyton. If periphyton is an important component of the *gambusia* food chain, this is equivalent to 2 to 3 trophic levels above the periphyton.

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The $\delta^{13}C$ values for samples range from about -17 to -36 ‰; these values provide valuable clues about trophic relations among consumers. Different sites appear to have different food chains. At many sites, the $\delta^{13}C$ values of omnivorous *gambusia* are 1 to 4 ‰ lower than co-existing periphyton and some herbivores. This apparent lack of isotope enrichment at higher trophic levels suggests that carbon from bulk periphyton is not the base of the *gambusia* and many other consumer food chains. This is puzzling because periphyton constitutes a major component of *gambusia* gut contents, and had been considered a major source of carbon to consumers. Likely candidates for bottom of the food chain include plankton (zoobenthos), partially degraded detrital organic matter, or some more readily digestible component of the periphyton community that has a lower $\delta^{13}C$ value than the bulk total. Organisms such as diatoms and green algae have been positively identified in Everglades periphyton through pigment analysis. The few samples of *utricularia*, which feeds on plankton, that have been analyzed have low $\delta^{13}C$ values consistent with plankton being an important carbon source. Additional sampling will be required to resolve this issue.

Approximately 10 samples of large-mouth bass were collected at each of 10 sites across the Everglades to determine local variability in diet within a population. Bass at some sites (for example, the ENR outlet, L-7, and a mid-marsh site in WCA1) have narrow and distinctive ranges in isotopic compositions. These compositions suggest that the bass at the WCA1 do not migrate in or out of L-7, and that L-7 and the ENR have significantly different environmental conditions. The larger and overlapping ranges in $\delta^{13}C$ and $\delta^{15}N$ values at sites in WCA 2 and 3 are consistent with movement of bass between canal and marsh sites, probably in response to fluctuations in water levels. These data indicate that for adjacent canal and marsh sites where the primary producers have distinguishable isotope compositions, the isotope compositions of fish can be used to determine whether the fish migrate in and out of the marshes in response to changes in water levels or food availability. These findings should prove useful for determining where some populations of game fish are acquiring elevated levels of MeHg.

Spatial Distributions of Isotopic Compositions of *Gambusia* and Periphyton at REMAP Marsh Sites in the Everglades

By

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Because of their small size, ubiquity, and omnivorous habits, *Gambusia* have been proposed as a suitable indicator species for tracing the bioaccumulation of methyl mercury (MeHg) in Florida Everglades food webs. The USEPA REMAP program collected multiple samples of *Gambusia* in September 1996 at over 100 marsh sites throughout the Everglades, and analyzed them for MeHg and gut contents. As part of a USGS-USEPA collaboration, an additional subset of 5 *Gambusia* plus a representative periphyton sample were collected at each site to assess the local and regional ranges in their C, N, and S stable isotope ratios. Analysis of the C, N, and S stable isotope compositions of organisms can be used to trace nutrient sources and to establish relative trophic levels because at each ascending trophic level, there is an increase of about 1 ‰ in $\delta^{13}C$ and 3 ‰ in $\delta^{15}N$ in the organisms. These isotopic compositions can also provide valuable information about biogeochemical processes in the local environments.

The *Gambusia* were transported chilled to the lab, frozen, and later filleted to remove the gut contents, heads, scales, and vertebrae. The fillets were dried and processed according to the method described in the other Kendall and others abstract. At 6 sites, duplicate sets of 5 fish each were collected and processed whole; these samples were analyzed before and after being acidified to eliminate carbonate in the bones. The $\delta^{13}C$ and $\delta^{15}N$ values of the fillets and whole fish samples (untreated and acidified) are identical within experimental error, indicating that future filleting of *Gambusia* is unnecessary. All periphyton samples were acidified to remove calcite prior to isotopic analysis. Previous experiments have shown that acidification has no significant effect on the C or N isotopic composition.

Both *Gambusia* and periphyton had a wide range of isotopic compositions. *Gambusia* $\delta^{13}C$ values ranged from -35 to -20 ‰, and $\delta^{15}N$ values ranged from +5 to +14 ‰. Periphyton $\delta^{13}C$ values ranged from -32 to -17 ‰, and $\delta^{15}N$ values ranged from about -2 to +5 ‰. Despite the wide range of values among sites, there was extremely little variation among the *Gambusia* collected at the same site; the average standard deviation for sets of *Gambusia* at the same site was +/- 0.7 ‰ for C and +/- 0.5 ‰ for N. These narrow ranges indicate that all the *Gambusia* collected at the same site are within the same trophic level and presumably have similar diets. These data also suggest that marsh populations within a single site are sufficiently homogeneous in diet that few members need be sampled to adequately characterize trophic relations.

The $\delta^{15}N$ values of *Gambusia* and periphyton show a moderate correlation ($r^2 = 0.6$). On average, the $\delta^{15}N$ values of *Gambusia* are 7 to 9 ‰ higher than those of the co-existing periphyton samples. If periphyton is an important source of N to *Gambusia*, this difference is equivalent to 2 to 3 trophic levels. However, at almost every site, the $\delta^{13}C$ values of omnivorous *Gambusia* are 1 to 4 ‰ lower than those of the co-existing periphyton samples. This apparent lack of carbon isotope enrichment at higher trophic levels suggests that carbon from bulk periphyton is not the base of the *Gambusia* and other consumer

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food chains. Likely alternative candidates for the base of the carbon food chain include plankton, detrital organic material, or some readily assimilated component within the periphyton community which has a much lower $\delta^{13}C$ value than bulk periphyton.

Contour plots of the isotopic compositions of periphyton and *Gambusia* show similar regional patterns. There is a broad area of lower $\delta^{13}C$ values (-28 to -32 ‰ for *Gambusia*) that extends southeast from the Everglades Agricultural Area (EAA) to L-67 and then southwest towards Shark Slough, with sharply increasing values to the west. Although the correlation coefficient between *Gambusia* and periphyton $\delta^{13}C$ values is less than 0.1, their general spatial patterns are very similar. It is presently unclear what processes are controlling the distribution of $\delta^{13}C$ values, but we note that the low $\delta^{13}C$ values roughly correlate with areas where thick peats are present. Several factors could explain these C isotope patterns, including regional differences in the contributions of C3 and C4 plants to local biomass, water turbulence, and redox conditions within the underlying peats which could cause oxidation of peats in some places and methane production in others.

The $\delta^{15}N$ values of *Gambusia* and periphyton are highest in the same general area where $\delta^{13}C$ values are lowest, extending southwest along L-67 towards Shark Slough, with lower $\delta^{15}N$ values to the northwest and southeast of this broad zone. Some of the areas with the highest $\delta^{15}N$ values (+3 ‰ for periphyton and +10 ‰ for *Gambusia*) correspond to locations with low sulfate and high MeHg values. One likely explanation for the high $\delta^{15}N$ values is denitrification in the sediments, resulting in dissolved inorganic N with higher $\delta^{15}N$ values. This ^{15}N-enriched nitrate and ammonium is then incorporated into the biomass.

The similarities between the distributions of isotopic compositions and the spatial distributions of several parameters measured by the REMAP program are very encouraging, and hold the promise of providing a valuable linkage between the larger scale REMAP program and the more site-specific process-based research at USGS sites. The isotopic compositions may prove to be more cost-effective and reliable indicators of prevailing environmental conditions that generally favor MeHg production than other parameters currently being considered because biomass isotopic compositions are much more difficult to perturb than the more transient concentrations of aqueous species. Hence, the spatial isotope patterns are likely to provide a valuable integration of long-term environmental conditions in the Everglades.

Geochemistry of Mercury and Trace Elements in Organic-Rich Sediments, Surface Water, and Sawgrass—A Progress Report for the 1996 and 1997 Field Seasons

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Concern for elevated levels of mercury in biota as well as nutrient enrichment in south Florida aquatic ecosystems has provided an impetus for studies of the geochemical processes influencing the distribution and cycling of mercury and other environmentally important elements. Knowledge of element variation patterns with depth in sediment, pore water chemistry, and sawgrass chemistry is essential for a comprehensive understanding of these processes. Preliminary results from peat-dominated sediment samples and sawgrass (*Cladium jamaicensis*) samples show that metabolic elements (for example, K, P, Cu, Fe and Zn) are concentrated in living tissue relative to the sediment whereas non-essential metals (for example, Cr, Co, Pb and Hg) are concentrated mainly in the sediment relative to the sawgrass. Accumulation rates for metals in sediment show a general decrease with depth in the peat cores. For a suite of cores accumulation rates for different elements appear to vary along a 45 mi northeast-southwest transect beginning in Water Conservation Area (WCA)-2A and progressing into Everglades National Park (ENP). For example, accumulation rates for Ni, V, and Zn show only subtle differences between sampling sites, whereas Pb accumulation rates are highest in the near surface layers of cores from the southern part of the transect. Detailed field studies in 1996 and 1997 focused on the processes governing metal accumulation rates in sediments and metal transport in sediment, water and sawgrass from (a) the Taylor Slough region, ENP (including the Buttonwood Embankment), and (b) from a mercury "hotspot" (elevated fish tissue mercury levels) from WCA-2B. Analyses of these materials are ongoing and results will be presented. Baseline values for metal concentrations in sediments collected in the south Florida study area seem to be attained in core material that is about 100 years old. The geochemistry of upper core material from sediment collection sites further west in the Big Cypress National Preserve show lower levels of trace metals relative to eastern sites and may be reflective of more pristine conditions.

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Mercury Transformation Processes in the Everglades: Temporal Variations in Mercury Phase and Species Distribution and Controlled Exposure Experiments

By

David P. Krabbenhoft[1], James P. Hurley[2], Mark L. Olson[1], and Lisa B. Cleckner[3]

The phase and species distribution of mercury (Hg) in an aquatic system has a controlling influence on its toxicity, transport mechanisms, and ultimate fate. Previous researchers working primarily on lakes, streams, and estuaries have demonstrated significant changes in the aqueous phase and species distribution of mercury on a seasonal or annual basis, while shorter term variations (hours to days) are less well documented. In ecosystems with minimal water depths, such as wetlands, short-term changes in aqueous Hg species concentrations are likely to be more pronounced. Concentration changes in the water column result from atmosphere/water/sediment exchange processes (deposition, evasion, particle settling, resuspension, and advection/diffusion), bio-uptake, methylation and demethylation at the sediment/water interface, and processes operating in the water column such as particle scavenging and photochemical reduction. The Florida Everglades with a shallow water column, year-round warm temperatures, high degree of sun incidence, and a documented mercury accumulation problem is an ideal location to study short-term changes in mercury speciation. Two different types of field efforts have been conducted during 1995 and 1996 to examine short-term variability in mercury speciation in the Everglades: diel sampling, and sunlight exposure/incubation experiments. The studies were conducted in the relatively pristine areas of Water Conservation Area (WCA) 2A, where high methylmercury concentrations in water and biota had been observed previously.

Diurnal studies were designed to determine extent to which total mercury (Hg_T), methyl mercury (MeHg), elemental mercury (Hg^0), and reactive mercury (Hg_R) varied in concentration in response to environmental factors that vary on a daily basis such as sun intensity, temperature (air and water), redox, pH, and precipitation events. Samples for these Hg species were collected at about 90 minute intervals. All of the Hg species showed significant variations during the diel sampling periods. Elemental mercury showed a 100 percent increase in concentration at maximum sun intensity (near noon) compared to samples collected at night, emphasizing the importance of photochemical reduction in this environment. Night time Hg^0 concentrations in the water column were calculated to be in equilibrium with the air mass above the water, suggesting Hg^0 production and evasion ceases at night. Seasonally, Hg^0 concentrations do not appear to be controlled by the pool of Hg_T in the water column, but rather appears to be a primarily a function of sunlight intensity. This suggests that photochemical reduction of Hg(II) to Hg^0 is the primary process leading to Hg^0 production in the Everglades. A simple mass balance shows that the flux of Hg to the atmosphere from diel DGM production and evasion represents about 10 percent of the annual input from atmospheric deposition.

While the diel response of Hg^0 was somewhat anticipated, surprisingly Hg_T, Hg_R, and MeHg also showed substantial, short-term variability during diel sampling. Variability in Hg_T and Hg_R appear to be

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controlled by two factors: inputs from rainfall and a process that is tied to the solar cycle. Inputs from rainfall result in "spike" increases of water-column Hg_T concentrations and to a lesser degree Hg_R. During one diel sampling when a significant storm occurred, concentrations of Hg_T rose by 50 percent, but had re-equilibrated to pre-storm concentrations within eight hours. Overlain on this incremental signal from rainfall is a nearly sinusoidal trend that appears to be related to solar intensity. The observed trend in Hg_T (filtered and unfiltered) indicates the total mass of Hg in the water column is changing on a diel basis, with greater concentrations observed during daylight. This observation leads us to conclude that a portion of the total mass of Hg in the water column at this study site is moving into and out of solution on a diel basis. A model that can possibly explain this observation is photochemically driven sorption and desorption, which has been shown for other trace metals. Future research efforts will seek to reveal the details of this process. Diel variability in MeHg concentrations, although substantial, did not appear to be directly linked to photolysis reactions nor rainfall.

The sunlight exposure/incubation experiments were conducted to determine the precise mechanisms of Hg^0 production. Each experiment was conducted by uniformly filling pre-cleaned Teflon bottles with filtered surface water from a pristine sampling site in WCA2A. At time = 0, 0.5, 1, 2, 3, and 4 days, bottles were collected for Hg^0, Hg_T, MeHg, and Hg_R analyses. Results from these experiments show that Hg^0 production is a dissolved phase process, and that it is primarily driven by sunlight in the ultraviolet range of the solar spectrum. Methyl mercury shows an initial rapid loss in the first 24 hours, but little loss after that time. Each incubated sample shows a steady loss of Hg_T from solution, of which only about 50 percent could be accounted for by loss to evasion of Hg^0. Future experiments will be performed to determine the fate of this "missing" mercury.

Vegetative Resistance to Flow in the Florida Everglades

By

Jonathan K. Lee[1] and Virginia Carter[1]

U.S. Geological Survey (USGS) hydrologists and ecologists are conducting studies to quantify vegetative flow resistance in the Florida Everglades. These studies are needed to improve the mathematical representation of the physical processes that influence flow resistance and the values of associated parameters in numerical models of surface-water flow used to evaluate alternative proposals for restoration of the Everglades. For use in numerical models, vegetative flow resistance must be expressed in terms of parameters that describe the flow and the vegetation. These parameters include the flow velocity through the vegetation, the water depth, the slope of the water surface, and the type, geometric characteristics, and density of the vegetation. Both indoor flume and field measurements were made to develop methods for evaluating the resistance of nearly uniform stands of vegetation and to identify the most appropriate parameters for representing resistance due to vegetation types that are typically found in the Everglades.

Indoor flume measurements were made in the USGS tilting flume at Stennis Space Center, Mississippi. The flume was used to determine the flow resistance of a uniform stand of sawgrass (*Cladium jamaicense*). Uniform, dense stands of sawgrass were grown in pans that were fit snugly into the flume to form a 61-m-long, 1.8-m-wide artificial sawgrass ecosystem. The depth of water in the flume was controlled by adding or removing metal plates (stop logs) at the downstream end. Experiments were conducted for five flow depths between 0.15 and 0.76 m and for mean cross sectional velocities between 0.03 and 4.6 cm/s. Series of measurements were made between September 1995 and April 1997. As the plants matured, their height increased from about 1 m to more than 2 m, their density decreased, and culms (basal stems that are composed of many closely packed leaves) and leaves became wider and less flexible. Also, the amount of dead plant material in the water column and near the bed increased. The measurement program provided the data needed to evaluate the effects of changes in plant maturity on flow resistance. To simulate the flow-resistance effects of periphyton, which is a thick floating mat of algae, the water surface in the final series of experiments was partially covered with sponges.

For each flume experiment, the flow rate, flow depths, and water-surface elevations were measured. Because the water-surface slope (equivalent to the energy loss per unit length of channel), which is calculated from the water-surface elevations, is very small, on the order of 1 cm/km, it was important to measure water-surface elevations as accurately and precisely as possible. Water-surface elevations were measured 0.46 m from each wall of the flume at each of five longitudinal positions. Hook gages were used for accuracy, and readings were made with calipers precise to 0.01 mm. A level water surface, which was attained with no flow in the flume, was used as the horizontal reference datum. Both a small amount of leakage from the flume and evapotranspiration had to be accounted for to obtain an accurate measurement of the water surface. During each experimental series, vegetation in the flume was sampled to determine biomass per unit area, number of stems and leaves per unit area, and leaf and stem width as a function of distance from the bed. The hydraulic and vegetation data are being analyzed to determine and quantify the relation between vegetation characteristics and flow resistance.

In addition to the flume experiments, field experiments were conducted to obtain information on the relation between flow and vegetation characteristics. Multiple measurements were made at two sites in the Everglades National Park where sawgrass is the dominant plant. Measurement of flow depth, flow

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velocity, and water-surface slope was necessary to evaluate flow resistance. Vegetation was sampled wherever hydraulic measurements were made. The same vegetation characteristics were measured in the field as in the flume. An acoustic Doppler velocity meter (ADV) was used to measure flow velocities that are often less than 1 cm/s. Because the sampling volume of the ADV is smaller than 1 cm^3, the meter is considered a point-velocity-measurement device. The meter is mounted on a tripod and lowered in increments of 5 or 10 cm to obtain a vertical velocity profile. The current meter is equipped with a compass/tiltmeter, and east, north, and vertical velocity components are plotted in real time on the screen of a notebook computer connected to the meter.

A method was developed for the local measurement in the field of water-surface slopes on the order of 1 cm/km. A 2.4-m-long, 7.6-cm-diameter plastic pipe with a short elbow at one end is positioned horizontally just below the water surface and parallel to the flow direction with the elbow at the upstream end and pointing down. The velocity of water in the pipe is a function of the characteristics of the pipe and the difference in water-surface elevation at the entrance and exit. The centerline flow velocity in the pipe is measured by inserting an acoustic Doppler velocity meter that is equipped with a side-looking probe into the downstream end of the pipe. The pipe was calibrated in the flume at the hydraulics laboratory at Stennis Space Center, Mississippi, and has proven to be an efficient, accurate method for the local measurement of water-surface slopes for the low-velocity, small-gradient flows of the Everglades.

Preliminary analysis was performed for the flow-resistance and vegetation data that were collected in the flume between September 1995 and January 1996. The January 1996 vegetation measurements characterized the vegetation when the plants were about a year old and had not been thinned. There were, on the average, 11, 9, 6, and 1 sawgrass culms in four 20-cm layers counted from the bed. An average of 13, 31, 52, and 67 leaves and 55, 37, 32, and 19 percent dead biomass was measured in the same layers. For each experiment, the water-surface slope was calculated by use of linear regression from the average water-surface-elevation values that were obtained at the 10 water-surface-elevation measurement points. The Manning's n coefficient and the Darcy-Weisbach friction factor, which are empirical expressions that are commonly used to express flow resistance in open channels, were computed from the flow rate, mean depth, and water-surface slope. For the January 1996 measured flow data, Manning's n was found to be nearly constant at a fixed depth of flow for velocities between 1.5 and 4.5 cm/s, but increased as the flow velocity approached zero. For flow velocities between 1.5 and 4.5 cm/s, Manning's n averaged 0.33, 0.43, 0.50, 0.55, and 0.61 for flow depths of about 0.15, 0.30, 0.46, 0.61, and 0.76 m, respectively. On the other hand, at a depth of 0.61 m and a flow velocity of 0.19 cm/s, a Manning's n of 1.14 was calculated, and at a depth of 0.76 m and a flow velocity of 0.14 cm/s, a Manning's n of 1.78 was calculated. Because flow velocities in the Everglades are frequently 1 cm/s or less, these results show that the Manning's n coefficient for Everglades marsh depends on both the flow depth and the flow velocity as well as on the characteristics of the vegetation. Similar results were obtained for the Darcy-Weisbach friction factor.

Vegetation Density Classification from Clustered Multispectral and Resolution-Enhanced Thermal Data Using a Neural Network

By

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Multispectral remote sensing techniques are being used to characterize vegetation cover in the Florida Everglades. Information on vegetation cover, such as type, density, and mixture composition is needed at scales appropriate for large-scale hydrodynamic models to help quantify the resistance that vegetation gives to water flow (Lee, 1996).

In this application, the classification of vegetation cover from moderate-resolution sensor systems, such as LANDSAT thematic mapper (TM), is difficult because the requisite categories are mixtures of cover types at various densities; for example, sparse sawgrass and water. These mixture proportions, and thus the respective multispectral signatures, vary throughout the scene. Consequently, there may be significant overlap between the distributions of spectral signatures, such as from water and vegetation (Schowengerdt, 1983). These mixture distributions can make accurate classification difficult, for example, when using Bayes' classification methods.

Unsupervised clustering techniques can help to determine natural groupings of the spectral signatures that correspond to these mixture categories. Commonly, subsequent manual assignment of individual clusters or groups of clusters to particular cover classes is used to create the final vegetation classification.

In contrast, the classification technique described here is a combination of unsupervised, fuzzy clustering followed by the supervised classification of fuzzy clustered data by means of a trained multilayer perceptron neural network (NN) classifier. A major advantage is that by means of an automated (that is, the NN learning phase) instead of a manual process, the NN learns how to group the fuzzy clustered data so that classification error is minimized.

First, a fuzzy clustering technique (Bezdek, 1993) is applied to preprocessed TM multispectral data. The result, for each multispectral data sample vector, is a set of fuzzy membership values to all cluster prototype vectors. The next step is the supervised, nonparametric statistical classification of the fuzzy membership data by multilayer NN. The NN was trained during a learning phase to develop a mapping between the fuzzy clustered data and the desired output class by means of teaching/training pair examples.

NN training data consist of pairs of input data samples and the desired class. Vegetation class type and density ground truth information at the 30-m spatial resolution of the TM sensor were inferred by aggregating very high spatial resolution (0.5 m) vegetation class samples. The class information was derived from data collected by an airborne, digital multispectral video system (Anderson and others, 1997). Multispectral and derived feature data used as input to the classification process are TM band 3 (*tm*3), normalized difference vegetation index (*tm*4-*tm*3)/(*tm*4+*tm*3), and spatial resolution-enhanced thermal-infrared (T-IR) data, *tm*6 (Lemeshewsky, 1997).

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This classification process is similar to the supervised merging (consistent with ground truth) of hard clustered data into classes with, however these distinctions: the process of grouping, or merging, fuzzy (instead of hard) clustered membership feature data by means of the NN is such that the classification error is minimized, and this process is automatically learned during the NN training process.

Six TM multispectral data bands have 30-by-30-m instantaneous field of view (IFOV), but the T-IR band has 120- by- 120-m IFOV. In this study, an NN-based technique was developed to enhance the spatial resolution of the T-IR data to 30 m. In a multistep process, a multilayer NN was trained so that its output approximates T-IR data at 120-m sample distance as a function of TM bands 7, 5, and 4 input data that have been resampled (reduced in resolution) to 120-m sample distance. The output of this trained NN, for 30-m resolution input, gives an approximation of T-IR data at a higher resolution; that is, 30 m. This output was then used to enhance the resolution of the raw T-IR data to 30 m.

Preliminary results of vegetation classification tests were obtained and benefits of using the improved resolution T-IR data were evaluated. Benefits of this classification technique include the automated (and optimal in terms of minimal mean square error) mapping of clustered data to vegetation density classes and the potential for improving results by integrating other data into the classifier by means of NN training.

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Water Flows and Nutrient Loads to the Southwest Coast of Florida

By

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The estuaries of Florida's southwest coast are an integral part of the south Florida ecosystem. Nutrients are transported to these coastal waters by surface-water and ground-water flows from Everglades National Park (ENP) and Big Cypress Preserve, and by nearshore and offshore tidal currents. The quantities of water and nutrients discharged from streams and sloughs that flow to the coastal area from upland areas of ENP and Big Cypress Preserve currently are unknown.

As an element of the U.S. Geological Survey South Florida Ecosystem Program, water flows and nutrient loads for three major streams along the southwest coast of South Florida are currently (1997) being monitored. The three streams that were selected for continuous monitoring receive water from the Shark Slough drainage area and discharge to the Gulf of Mexico. Data collection began in 1996 and will end in 1998.

Continuous monitoring stations were established on the Broad, Harney, and Shark Rivers. The stations use *in-situ* sensors to measure stream velocity, water level, specific conductance, and temperature. Stream velocity is measured using an upward-looking acoustic Doppler profiler (ADP). Water level is measured using a pressure transducer. Specific conductance is measured using two four-electrode conductance sensors near the surface and bottom of the water column. Temperature is measured using an integral thermistor in the specific conductance sensors.

The Harney and Shark River stations were installed in October and November 1996. The Harney River station ADP malfunctioned and was replaced in January 1997. The Broad River station was installed in December 1996 to January 1997.

The *in-situ* sensors are calibrated and cleaned monthly. Stream discharge is measured monthly using an acoustic Doppler current profiler. Water-quality samples are collected monthly using a modified equal width increment method and are analyzed for total and dissolved nitrogen and phosphorus. The discharge measurements, water-quality, and *in-situ* sensor data will be used to compute velocity/water-level/discharge relations and discharge/nutrient load relations, which will then be used to estimate continuous discharge and nutrient loads for the three rivers.

The Broad River is the northernmost of the three rivers, and its monitoring station is located approximately 15 river kilometers from the river mouth. Stream-velocity data for January through May, 1997, ranged from approximately +40 cm/s downstream to approximately -40 cm/s upstream. The range in water level during this period was approximately 1.1 m. Specific conductance ranged from approximately 1,000 to 40,000 µS/cm for the same period. Measured discharge ranged from +20 to approximately -20 m^3/s.

Total nitrogen concentrations for six samples from the Broad River ranged from 0.83 to 1.42 mg/L and dissolved nitrogen concentrations ranged from 0.71 to 1.12 mg/L. Total phosphorus concentrations were consistently 0.020 mg/L and dissolved phosphorus concentrations ranged from 0.002 to 0.010 mg/L.

The Harney River is located south of the Broad River and connects to Tarpon Bay. The monitoring station is located approximately 7 km from the river mouth. Stream velocity during January to May 1997

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ranged from approximately +60 to -70 cm/s. The range in water level was approximately 1.8 m. Specific conductance ranged from approximately 1,200 to 50,000 μS/cm. Discharge ranged from approximately +140 to -150 m^3/s.

Total nitrogen concentrations for five samples from the Harney River ranged from 0.70 to 1.26 mg/L and dissolved nitrogen concentrations ranged from 0.63 to 1.06 mg/L. Total phosphorus concentrations ranged from 0.020 to 0.030 mg/L, and dissolved phosphorus concentrations ranged from 0.009 to 0.020 mg/L.

The Shark River is the southernmost of the three rivers, and connects to Tarpon Bay, which provides a common link between the Harney and Shark Rivers. The monitoring station is located approximately 10 km from the river mouth. Stream velocity ranged from approximately +70 cm/s to -70 cm/s. The range in water level was approximately 1.4 m. Specific conductance ranged from approximately 1,200 to 50,000 μS/cm. Discharge ranged from approximately +120 to -120 m^3/s.

Total nitrogen concentrations for four samples from the Shark River ranged from 0.63 to 1.03 mg/L and dissolved nitrogen concentrations ranged from 0.55 to 0.87 mg/L. Total phosphorus concentrations ranged from 0.010 to 0.020 mg/L, and dissolved phosphorus concentrations ranged from 0.006 to 0.020 mg/L.

Measurement of stream discharge and nutrient loads for the three rivers is still in its initial stages and will continue through 1998. These data will be used to identify flow and water quality changes in the rivers as water releases and pollution control methods for the Everglades are altered. Additionally, data from this study can be used by other scientists conducting ecological or hydrodynamic studies in the estuarine area. Initial data are available on a provisional basis from the USGS.

Determination of Nutrient Loads to Biscayne Bay, Dade County, Florida

By

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Biscayne Bay, a shallow, oligotrophic, subtropical estuary along the southeastern coast of Florida, provides habitat for a wide range of plant and animal species. Increased nutrient loads in discharges from the east coast canals, as a result of agricultural and urban processes, are a potential threat to the health of Biscayne Bay. Dissolved-oxygen concentrations average about 5 mg/L in Biscayne Bay, but hypoxic conditions exist in the east coast canals along with nutrient enrichment. Plans are being formulated to reestablish natural flow to Everglades National Park by diverting water that now flows through the agricultural/urban corridor and then discharges by way of the canals to Biscayne Bay. An understanding of nutrient loading to Biscayne Bay is needed for the assessment of the ecological health of the Bay as well as an evaluation of the water-quality impact of the diverted water to Everglades National Park.

The U.S. Geological Survey is presently conducting a study to: (1) determine whether point samples (historically collected at 1 m below the surface near the centroid of flow) accurately represent water quality in the stream cross section, and (2) determine estimates of nitrogen and phosphorus loads discharging from the east coast canals to Biscayne Bay. This study uses a statistical approach to compare point with depth-integrated samples collected using the equal-width-increment method, and the use of regression models to develop relations between loads or concentrations and instantaneous discharge.

During the 1996 water year, water samples were collected at five canal sites (Biscayne Canal, Little River Canal, Miami Canal, Tamiami Canal and Snapper Creek Canal) to determine concentrations of total ammonia nitrogen, total organic nitrogen, total nitrate nitrogen, total nitrite nitrogen, total phosphorus and orthophosphate. Instantaneous discharge was determined from field data collected concurrently with each sampling event; discharge ratings were obtained from another South Florida Ecosystem Project. Preliminary analysis, as determined by the Wilcoxson signed rank test, indicates that statistical differences exist between point and depth-integrated samples. Regression equations were developed at one site using an ordinary least squares technique to relate loads of total nitrogen and total phosphorus with discharge. The coefficients of determinations were 0.86 and 0.57, respectively, indicating that 86 percent of the variation in the total nitrogen load and 57 percent of the variation in the total phosphorus load are accounted for by the variation in discharge.

Currently, water samples are being collected during periods of varying flow conditions upstream of the coastal structures at 10 sites in eastern Dade County. These sites are located in Snake Creek Canal, Arch Creek Canal, Comfort Canal, Coral Gables Canal, Cutler Drain Canal, Black Creek Canal, Princeton Canal, Military Canal, Mowry Canal and Model Land Canal. Similar analysis is being conducted on the water samples from these sites.

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Mercury Transfer Through an Everglades Aquatic Food Web

By

William F. Loftus[1]

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. This project consists of two study elements that examine the biological aspects of mercury contamination in the southern Everglades: 1) an analysis of mercury in plants, invertebrates and fishes that comprise the aquatic food web of a Shark Slough marsh, and the relationship of mercury levels to the trophic positions of the fishes determined by food-habits and stable-isotope data; 2) a descriptive and an experimental phase in examining the relationship of mercury concentrations and uptake by wild and captive-reared eastern mosquitofish (*Gambusia holbrooki*) from marshes with different hydroperiods. The project objectives are to 1) use food habits and stable-isotope data to construct an aquatic food web for a Shark Slough marsh; 2) describe mercury concentrations at various trophic levels of a Shark Slough aquatic food web; relate mercury levels to the trophic positions of the fishes; 3) test the effect of marsh hydroperiod on mercury concentrations and uptake by wild eastern mosquitofish (*Gambusia holbrooki*); and 4) measure seasonal uptake of mercury by placing captive-reared, "clean" mosquitofish in field cages.

More than 2,000 fishes and invertebrates have been analyzed for total mercury concentration for Element 1, after methods evaluations and statistical power/sample size testing, estimation of contamination, and precision of homogenate subsamples of large fishes. Samples of biota have been collected for stable-isotope analysis, and gut contents are being characterized to provide independent estimates of trophic placement of the fishes. There are large differences in total mercury concentrations among groups of the 29 fish species, and these appear to have some relationship to the diet. The fishes belonged to several functional groups that include herbivores, herbivores/detritivores, invertivores, omnivores, and piscivores. Similarly, the concentrations of total mercury varied among the 40 invertebrate taxa collected.

For Element 2, nine collections of wild mosquitofish for total mercury (1,700 specimens) from the six study marshes have been made and processed. Simultaneous collections of wild mosquitofish (1,500) for dietary analysis to examine differences in food webs between marshes of the two hydroperiod classes are being processed. Smaller samples of mosquitofish have been collected for stable-isotope analysis. A pilot study of the caged-fish experiment was completed, and five subsequent trials have been run. Data are being analyzed by time period and hydroperiod class for fish growth, survival, mercury uptake, and final concentration in the cages. The fish are produced in captivity and are released in the cages when about one week old (7.5-10 mm). Mercury level of the neonates is less than 10 ng/g. When harvested, the pilot-study fish were nearly an order of magnitude higher after one month at large. Survival in the cages has normally exceeded 80 percent. Growth has varied with the time of year, being highest in summer and slowing in the autumn. Sample processing and analysis, and data processing are proceeding well, and the project is running close to schedule. The stable-isotope analyses and gut work on the mosquitofish will receive work emphasis in the near future.

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Long-Term Fish Monitoring in the Everglades: Looking Beyond the Park Boundary

By

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Freshwater fish monitoring in Everglades National Park, Florida has been continued at some sites for twenty years, using the same methodology. The objective is to understand the short- and long-term responses of small-fish communities to natural and anthropogenic environmental changes. Until recently, areas outside the park received little study, even though hydrological modifications affected all segments of the ecosystem, whether protected or not. With the recent impetus to restore the Everglades ecosystem, fishes are being recognized as good indicators of environmental change by the multiagency groups responsible for guiding and measuring restoration success. The results from the fish community monitoring program clearly demonstrate that a well-designed and consistently funded program cannot 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 Everglades National Park program has resulted in several major scientific achievements with relevance to management and restoration. The analysis of throw-trap data resulted in the revision of a widely accepted view of Everglades fish-community dynamics based on a biased sampling method. Our analyses of fish community changes in areas east of the park helped lead to the acquisition of those lands by the park, and their hydrologic restoration. Fish community responses to drought and hurricane disturbances, to high-water events, and to ecological effects of artificial deep-water pools in wetlands have led to a better understanding of community function. The empirical data have been used to construct the fish-community simulation model for restoration evaluations.

Long-term ecological studies are necessary in highly variable environments like the Everglades. The present fish communities of the marsh reflect past conditions of drought and flood, as well as ambient conditions. Managers and scientists have learned that when regional management activities affect a protected area, restoration also must focus on the regional ecosystem. Attempts to restore only the park while ignoring the effects on surrounding marshes would probably fail, particularly in the case of such charismatic fish predators as wading birds, which forage regionally. The park fish-monitoring program is serving as the core model for an expanded regional monitoring network. The most important aspect of the expanded program is a standardized and consistent sampling design to enable data comparisons across the region. We strongly suggest that regional monitoring of the Everglades fish communities receive consistent and continued funding to provide the data to evaluate and guide the process towards ecosystem restoration.

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Soil-Based Estimation of Historic Landscapes and Hydrology of the Everglades Prior to Canals, 1840-1880

By

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As background to Everglades restoration planning, historical sources were extensively researched to characterize and map the major Everglades landscapes which existed prior to canal development. Vegetation, soil type, topographic relief, and hydrology were estimated for each landscape. Particular attention was placed on hydrology, including water depths, hydroperiods, flow directions and velocities.

The research consisted of three major components: determination of the lateral extent of each of the landscapes during pre-canal conditions; description of each landscape; and estimation of long-term average annual low and high water depths. The major wetland landscapes are closely linked to specific soil types. The extent of each pre-canal landscape was therefore estimated by "hindcasting" a 1940's soil map to 1880's conditions, using knowledge of patterns of soil and vegetation change in response to canal drainage. Direct observations made at identifiable locations and taken from Township surveys, expedition accounts, and early maps, enhanced the accuracy of the "hindcasting" effort.

Landscape descriptions were synthesized from multiple sources. Three key base maps, a 1948 soil map and a 1943 and 1948 vegetation map, were used, along with information gathered from scientific discussions of patterns of drainage-induced change. Considerable material was gathered to quantitatively estimate widths and elevations of the components of the most topographically diverse landscape, the Ridge and Slough mosaic.

The third component of the research, estimation of average water depths for each pre-canal landscape, was based on direct point observations, navigable routes, vegetation requirements, and general information from the landscape descriptions. Water depth observations were classified by landscape and plotted versus time of year. They were then compared against a simple linear model of hydropattern, consisting of an average annual low water depth in May and an average annual high in October. Other information suggested an average annual range of approximately two feet. Average hydroperiod was estimated, using these models, as the months per year with above-ground water levels.

The most laterally extensive Everglades landscape was a Ridge and Slough mosaic, somewhat like the southern portion of the present Water Conservation Area 3A, with the important exception that in the former, water was in a natural flowing system while in the latter, water is impounded. In addition to tree islands, sloughs and sawgrass ridges, narrow channels or creeks were reported, usually with perceptible flow. Average annual low and high water depths in the sloughs were 1 and 3 feet, respectively. Water was deeper in the channels. Water depths on the sawgrass ridges were slightly lower than for the extensive sawgrass plain to the north. Depths were approximately 1 foot below ridge surface for the annual low, and 1 foot above for the annual high.

Estimates of Everglades water depths were somewhat deeper and hydroperiods somewhat longer in this study than was previously simulated by the South Florida Natural System Model (NSM v.4.4). Spatial patterns were similar between this study and the NSM. Although this study provides useful estimates of average annual low and high water depths, models such as the NSM can probably best simulate the ecologically important patterns of weather-driven hydrologic variability, which were not addressed in this study.

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Quantifying Internal Canal Flows in Southern Florida

By

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Historical changes in water-management practices to accommodate a large and rapidly growing urban population along the Atlantic Coast, 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 both 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 has traditionally emphasized the eastern coastal areas of Florida. Recently, more emphasis has been placed on providing more accurate accounting of canal flows in the interior. The implementation and development of strategically placed streamflow and water-quality gaging sites in the interior will provide information for determining future surface-water flow requirements in the internal canal system. Subsequent studies based on accurate flow determinations from these sites will be used for computation of nutrient loadings in the internal canal system. Providing continuous-flow data at selected impact points for internal basins will complement the eastern flow canal discharge network and allow for surface-water releases that are more accurately timed to deliver water when and where it is needed.

The U.S. Geological Survey is presently conducting a study to accurately gage flows in canals entering and leaving Tribal Lands, the Big Cypress National Preserve, and WCA 3A. These flows will then be used in a multiagency effort to calculate nutrient loadings in the canals used by Native American Tribes and on Federal lands. Three real-time acoustic velocity flow weighted nutrient autosampler sites have been established, two on the L-28 and L-28 Intercepter canals at the southern border of the Seminole Tribe of Florida lands and one on the L-28 Intercepter canal where flows enter the western lands of the Miccosukee Tribe of Indians from the Big Cypress National Preserve. Acoustic Doppler Current Profiler calibration of the insitu acoustic velocity meter indexes has begun at all sites, and development of a technique utilizing the "sum of least squares regression" has begun on data for two of the three sites. Verification of the regression models has been limited by the availability of specific stage and velocity conditions. Velocity data collected during the dry season have shown a phenomenon known as acoustic refraction or ray bending produced by thermal stratification in the water column during extended periods of very slow flow. A South Florida Water Management District ancillary product of this effort will be a quality assurance template for future acoustic flow weighted nutrient sample station installation, ***in-situ*** calibration of acoustic equipment, and nutrient sample collection protocols based on weighting of flows.

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Across-Trophic-Level System Simulation (ATLSS) Program Cape Sable Seaside Sparrow Modeling

By

M. Philip Nott[1]

The Cape Sable seaside sparrow (*Ammodramus maritimus mirabilis*) is an important component of the suite of species being modeled under the ATLSS and is a key concern of the Everglades Restoration Project. This ecologically distinct sub-species of the seaside sparrow is endangered and represents the primary indicator species of the health of short-hydroperiod marl prairies in the southern Everglades. The marl prairies are typified by dense mixed stands of graminoid species usually below 1 meter in height and naturally inundated by freshwater for two to four months annually. It remains the sole known breeding habitat of the sparrow. The spatial extent of this habitat is limited and subject to regimes of hydrology, fire and catastrophic events (hurricane or frost). The breeding range is restricted to the extreme southern portion of the Florida peninsula almost entirely within the boundaries of the Everglades National Park and Big Cypress National Preserve.

Recent declines have occurred in the sparrow population across its entire range, especially the western portion. In 1992 half of the total population resided in this area, but by 1996 around 85 percent of an estimated 2,800 individuals had disappeared. The remaining core of the population occupies approximately 60 to 70 km^2 in the area adjacent to the southeast edge of Mahogany hammock. This sub-population currently represents 73 percent of the total population (1996 estimate), and because of the spatial restriction it is seriously at risk to the effects of hurricane or wildfire. Changes to the hydrology of the southern Everglades may increase the risk of extinction. Increased hydroperiods affect the sparrow breeding potential in two ways: 1) directly they shorten or interrupt the potential breeding season, and 2) indirectly they cause changes in the vegetation and reduce the extent of potential breeding habitat.

The Cape Sable seaside sparrow model adopts an individual-based spatially-explicit approach in which the model parameters reflect the findings of extensive field studies of sparrow demographics, responses to changes in the biotic and abiotic environment, and especially breeding behavior. We feel that this is the best approach, given that the sparrows breed on a known topography whereby lower elevations are more susceptible to flooding, which results in the destruction of their nests. The duration of flooding events may last for one day, a portion or the whole of the breeding season. In short, the success of a breeding pair is dependent upon the elevation at which they nest, when they nest, and the breeding success of males in previous years. It is difficult to account for such differences between individuals and the effect of variable water levels upon density dependent population dynamics using other modeling approaches.

We modeled the western sparrow population to investigate the effects of the hydrology regime since 1977 upon various measurements of the sparrow population. These include lifetime reproductive success of individuals, movement patterns and spatial distributions of the population, fluctuations in the size and structure of the population and local densities. We compared the output from this model with long-term sparrow census data.

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We showed that the model accurately predicts sparrow census data collected over the last fifteen years and that annual productivity is extremely sensitive to temporal hydrologic patterns. We repeatedly modeled the population to investigate the inherent stochasticity of the model. We concluded that this model provides us with an effective management tool with which to ensure the future of sparrow populations.

Resolution of Matrix Effects on Analysis of Total and Methyl Mercury in Aqueous Samples from the Florida Everglades

By

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The Aquatic Cycling of Mercury in the Everglades (ACME) project is a large multidisciplinary effort that is focusing on the processes that lead to mercury contamination of predatory game fish in the Florida Everglades. As such, this project required the establishment of a mercury analysis laboratory capable of low level mercury (Hg) analysis for water, sediment, and biota. In addition, to fully understand the major fate and toxic controlling process of mercury in the environment, it is necessary to perform these low-level analysis with speciation. However, aqueous samples from the Everglades present several problems for the analysis of total mercury (HgT) and methyl mercury (MeHg). Surface water samples are analyzed for HgT, reactive Hg, MeHg, and dissolved gaseous Hg (DGM) while porewater and biotic components (plankton, insects, zooplankton, fish) are analyzed for HgT and MeHg. Constituents such as dissolved organic carbon (DOC) and sulfide at selected sites present particular challenges due to interferences with standard analytical techniques. This is manifested by 1) the inability to discern when bromine monochloride (BrCl) addition is sufficient for sample oxidation for HgT analysis; and 2) incomplete spike recoveries using the distillation/ethylation technique for MeHg analysis. In our study, we found that for samples with DOC concentrations above 35 mg L^{-1}, BrCl addition is insufficient for complete oxidation of HgT. Also, during high-water periods and anoxic conditions, porewaters and eutrophied surface waters have resulted in low spike recoveries for MeHg analysis. Thus, we present additions and modifications to current HgT and MeHg methodologies to deal with challenges associated with Everglades samples.

To overcome the incomplete oxidation of water samples, we devised a ultraviolet (UV) oxidation box for pre-oxidation of samples. The UV light box consists of three Spectroline X-series UV lights in a plastic box lined with aluminum foil for reflective purposes. Two of the lights are placed to shine directly into the sides of the sample bottles while a third is mounted on the inside of the lid of the box. Up to ten 500 ml bottles can be treated in the UV box at a time. Water samples from the Everglades generally require two to five days of pretreatment with UV light to remove the visible color. Once the samples clarify, the samples are oxidized using blanked BrCl (< 15 ng L^{-1}) and placed into an oven at 50 °C overnight. Results from the UV box oxidation show an average increase in HgT concentration of 17 percent in the UV treated samples relative to the non-UV treated samples. This indicates that BrCl alone is not sufficient to release all of the dissolved Hg from organic matrices or ligands in the sample. Based on this evidence, all aqueous HgT samples from the Everglades for the ACME project are oxidized using the two step UV box-BrCl digestion.

Anoxic samples collected during high water periods from eutrophic areas of WCA 2A have shown the effects of a matrix interferant. Methyl mercury analysis of these Everglades water samples showed

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reduced spike recoveries between 25 to 35 percent. A temporary solution to the problem was first implemented by collecting a bulk sample, analyzing it and testing for the spike recovery interferant. If the interferant was present, the samples was then distilled in 50 ml aliquots rather than the usual 100 ml, and $CuSO_4$ was added as a reagent in the distillation. If the interferant was not present, the sample was distilled and analyzed using typical 100 ml volumes.

Sulfide has not been shown to interfere with MeHg analysis because it is assumed that it is converted to hydrogen sulfide (H_2S) after acidification (addition of H_2SO_4 during distillation setup) and lost during distillation [9]. Everglades samples are frequently high in sulfide, with concentrations as high as 300 μM observed in the porewaters of WCA 2A [6]. Since a noticeable H_2S odor was present at the sites with spike recovery problems, an experiment was performed to determine the effects of H_2S on MeHg spike recoveries. An Everglades surface water sample collected from site U3 in July 1996 with a MeHg concentration of 0.515 ng L^{-1} was split into five aliquots and the sulfide concentration was increased by 0, 100, 200, 300, and 500 μM using a saturated sodium sulfide (Na_2S) solution. Samples were allowed to equilibrate overnight. Prior to distillation on the next day, samples were spiked with 50 pg of MeHg standard. An identical set of samples was also treated with $CuSO_4$ (2 ml of 1 M) prior to distillation. Since $CuSO_4$ was previously used to separate MeHg from matrices [20], it was added to the Everglades samples in this experiment. The sulfide-treated samples were analyzed for spike recoveries comparing them to the original sample concentration. Spike recoveries dropped from 118 to -110 percent with increasing sulfide in the samples not treated with $CuSO_4$. The negative percent recoveries result from incomplete recovery of the original sample concentration. Meanwhile, the samples treated with $CuSO_4$ yielded acceptable percent recoveries up to a sulfide addition of 300 μM. However, even with the addition of $CuSO_4$, the sample spiked with 500 μM of sulfide yielded a spike recovery of only 67 percent.

These modifications to accepted analytical techniques represent substantial advances for these high DOC and occasionally sulfidic waters. These adaptations maybe be important for other wetland systems and porewaters.

Biogeochemical Cycling of P, S, C, and N in Sediments from Wetlands of South Florida

By

William H. Orem[1], Anne L. Bates[1], Ann T. Boylan[1], Margo Corum[1], Cheryl Hedgman[1], Harry E. Lerch[1], and Robert A. Zielinski[2]

Under natural conditions, biogeochemical processes in sediments attain a steady state, with recycling of important nutrient elements matching the needs of the wetland plant community. Perturbation of this natural balance with an influx of contaminants may cause dramatic changes in the wetland ecosystem structure. In south Florida wetlands, contamination from P, S, and other elements and changes in the hydrology of the system have unbalanced the natural system in many areas. Some well known changes include the replacement of oligotrophic sawgrass by eutrophic cattails, a significant reduction in hydrologic period, and mercury contamination of fish. However, a detailed analysis of the ecosystem's response to this perturbation and the potential effects of proposed remediation are lacking. P is considered to be the principal nutrient element limiting plant growth in south Florida wetland environments, and the introduction of excess P into the ecosystem from canals draining the Everglades Agricultural Area (EAA) is presumed to be a principal cause of changes in plant growth patterns. The cycling of S in the south Florida ecosystem is of interest because of the central role sulfate reduction plays in the methylation of mercury, and the bioaccumulation of methyl mercury (a potent neurotoxin) in fish.

The principal objectives of this project are to examine the sources, sinks, and recycling of the biologically important elements P, S, C, and N in wetland sediments of south Florida. A secondary goal is to develop a geochemical history of the ecosystem from chemical studies of dated sediment cores. Our work on the geochemical history of the ecosystem is closely linked to other USGS paleoecology and sediment dating projects. Two aspects of this project component that we are currently focused on are: 1) historical salinity changes in the lower Taylor Slough area, and 2) the use of organic marker compounds to trace seagrass history in Florida Bay sediments.

The sources of P, S, C, and N to the ecosystem are being investigated principally through the use of isotopic methods. Uranium concentration and isotopic composition in sediment and water samples are being used as a proxy to trace fertilizer-derived P from canals draining the EAA to marshes of the Water Conservation Areas (WCAs) (see abstract by Zielinski and others in this volume). Similarly, stable isotopes of S are being used to trace the sources of sulfate to freshwater marshes of the WCAs, and the transformation of S between reduced and oxidized forms in wetland sediments and waters (see abstract by Bates and others in this volume).

Geochemical modeling of data obtained by chemical analyses of pore water and sediments is being used to establish the major biogeochemical processes in the sediments, to estimate rates of nutrient recycling and biodegradation, to estimate fluxes of chemical species between the sediment and the surface water, and to determine major sinks for P, S, C, and N in the sediments. Our results suggest that background concentrations of total P in surface sediments from freshwater wetland areas of south Florida range from 300 to 500 5 µg/g, which is similar to ranges from other freshwater wetlands of the eastern United States. (Okefenokee Swamp and Great Dismal Swamp). In contrast, highly contaminated areas of

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the WCAs near the canals draining the agricultural areas have total P concentration in surface sediments that exceed 5,000 5 μg/g, or more than 10 times greater than pristine areas. Accumulation rates of P at contaminated sites are 20-50 times higher than those in pristine areas (200 gm cm^{-2} yr^{-1} and 4 to 9 gm cm^{-2} yr^{-1}, respectively). Geochemical modeling of pore water data suggests that recycling of sedimentary P and fluxes back to the surface water are also higher at contaminated sites. The higher recycling rates of P, as well as C, N, and S, in P-contaminated areas may be due to the stimulation of microbial biodegradation processes by the much greater input of "fresh" organic matter from the quick-growing, eutrophic macrophytes (cattails)

Current work is focused on the fate of the large "plug" of excess P stored in the sediments of contaminated areas. We wish to determine if this excess P will ultimately be buried at the sites, or if it will be recycled to surface waters for transport elsewhere. In large part, this question is linked to the relative biodegradation rates of organic detritus from cattails and sawgrass. We are currently using organic geochemical methods such as ^{13}C nuclear magnetic resonance spectroscopy and lignin phenol analysis to examine the biodegradation rates of cattail and sawgrass peat in carefully collected cores at sites with known accumulation rates. Results also indicate that the mangrove fringe area of Taylor Slough is an important zone for concentration of P. However, the mechanism of this concentration effect is unclear.

Sulfur accumulation rates are up to 5 times higher at P-contaminated sites in WCA 2A compared to pristine areas of the freshwater Everglades (5,000 gm cm^{-2} yr^{-1} and 1,000 gm cm^{-2} yr^{-1}, respectively). The excess S in the sediments of contaminated areas results from the reaction of microbially produced H_2S with organic matter to form organic sulfur compounds. High sulfate concentrations are common for freshwater marsh areas in the WCA 2A near the Hillsboro Canal. Pore water profiles of sulfate and sulfide may be useful predictors of methyl mercury production. In P-contaminated areas, high rates of sulfate reduction produce high levels of pore water sulfide. High sulfide content may poison the bacteria involved in methyl mercury production and also immobilize Hg in the sediments as insoluble HgS. In pristine freshwater marsh areas, low levels of sulfate would limit sulfate reduction and thus methyl mercury production. Freshwater marsh areas with moderate levels of sulfate and intermediate sulfide content may represent zones of maximum methyl mercury production. This issue is discussed further in the abstract by Bates and others (this volume).

Using Geophysical Measurements in Boreholes to Calibrate Surface Electromagnetic Soundings in South Florida

By

Frederick L. Paillet[1]

Surface geophysical soundings provide a useful, noninvasive technique for mapping the subsurface properties of geological formations. In this study we demonstrate how careful analysis of formation electrical conductivity data from induction logs can be used to calibrate time-domain electromagnetic (TDEM) soundings of subsurface electrical conductivity in units of pore water conductivity. A primary limitation on the application of surface TDEM techniques in ground water studies is the unknown relationship between the measured formation conductivity and such subsurface parameters as sediment mineralogy, permeability, and the electrical conductivity of pore water (Fitterman and Stewart, 1986). When interpreting TDEM soundings, hydrologists would like to know pore water salinity, which can be inferred from pore water conductivity (σ_w) using standard empirical relations. Geophysical measurements in boreholes (well logs) provide the information needed to relate water samples obtained over specific intervals in boreholes to the formation electrical conductivity (σ_f) of the same sampled volumes *in-situ.*

Geophysical logs were obtained in seven boreholes in western Collier County, Florida. The boreholes were completed with fully slotted PVC casing prior to flushing, so that all of the borehole was available for logging, and formation water was allowed to enter the borehole under ambient hydraulic-head conditions. However, this completion method allowed voids and intervals of open annulus outside of the PVC casing over significant intervals of borehole. The possibility of water movement in the annulus and presence of flow in the open borehole made it impossible to relate the electrical conductivity of water sampled at a given point in the borehole to natural formation water in the adjacent formation at that same nominal depth.

Once a general conceptual model for the distribution of water quality with depth was established, this model was calibrated using a combination of induction, fluid column conductivity, and high-resolution borehole flow logs. The flow profiles indicated that there was upflow ranging from less than 0.1 to more than 2.0 liters per minute in all seven boreholes. Although water samples from boreholes could not be directly compared with formation conductivity at a given depth, we could use flow logs to identify the discrete intervals where water entered the borehole under ambient conditions. The fluid column conductivity could be directly related to the conductivity of water (σ_w) flowing in from that interval. The seven paired data points of formation and pore water conductivity established from these inflow depths could be used to generate a statistically significant regression ($r^2 = 0.97$); the slope and intercept given by the analysis can be used to represent the regression in the form of a standard equation in the geophysical literature:

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$$\sigma_w = a(\sigma_f - \sigma_0) \quad a = 2.4 \text{ and } \sigma_0 = 39$$

where σ_w is the electrical conductivity of pore water (given by the fluid column log), σ_f is the electrical conductivity of the formation (given by the induction log), and σ_0 is the electrical conductivity of the aquifer mineral framework (given by the intercept in the regression), each in units of µS/cm; and a is the dimensionless formation factor (given by the slope in the regression). This relation provides the desired equation directly relating the electrical conductivity of the subsurface given by the TDEM soundings (σ_f) to the electrical conductivity of the water at that depth in the formation (σ_w). One commonly cited equation relates the electrical conductivity of water samples at standard temperature and pressure to the total dissolved solids (TDS) in parts per million (Fishman and Friedman, 1989):

$$TDS = 0.67\sigma_w$$

Thus, we can use the TDEM soundings to estimate the salinity of subsurface waters by using geophysical logs to calibrate the TDEM measurements.

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Determining Flows into Northeastern Florida Bay, Dade and Monroe Counties, Florida

By

Eduardo Patino[1]

During the last decade, Florida Bay has experienced ecological deterioration that has been partly attributed to an increase in salinity. Salinity is directly related to the amount and quality of water that enters Florida Bay from the mainland and to flow patterns within the Bay. Restoration of the Florida Bay ecosystem requires a better understanding of the linkage between the amount of water flowing into the Bay and the salinity and quality of the Bay environment. As sheetflow is reestablished by flow management in the wetlands of the Everglades, it is expected that these changes will be reflected in the amount of water exiting the mainland through the principal streams or as sheetflow into Florida Bay. Several agencies, including the U.S. Geological Survey, U.S. Army Corps of Engineers, and the South Florida Water Management District, are now developing and calibrating models to simulate and predict the movement of water in the mainland, flows in to Florida Bay, and circulation patterns within the Bay.

The U.S. Geological Survey is conducting a study to determine flows into northeastern Florida Bay. This study will provide essential flow and salinity data for models along the mangrove zone, where data have not been previously available. Flow through the mangrove zone in northeastern Florida Bay is naturally controlled by the wet and dry conditions of the Everglades wetlands, regional wind patterns, and, to some extent, by tidal action in the Gulf of Mexico toward the western part of the Bay. The flow of water from the mainland into northeastern Florida Bay is confined to several streams or creeks, except during extreme high-water conditions, when significant sheetflow can be observed through low-lying mangrove areas between the streams. Acoustic technology is being used to determine the flows in streams that discharge water into Florida Bay.

Ten sites located between U.S. Highway 1 to the east and Terrapin Bay to the west are being studied in northeastern Florida Bay in Dade and Monroe Counties. These sites are: Jewfish Creek, culverts under U.S. Highway 1, East Highway Creek, West Highway Creek, a small unnamed creek in Long Sound, Trout Creek, Mud Creek, East Creek, Taylor River, and McCormick Creek. Velocity and water-level data collected from the sites indicate that flows through creeks draining into northeastern Florida Bay are greatly affected by regional wind patterns and do not present tidal signatures typical of most estuarine streams. Salinity data indicate that, at times, there is a vertical stratification; however, this does not occur frequently nor does it last for extended periods of time. Analysis of discharge data suggests that low-pass filters, commonly used to calculate "net flows" by smoothing the tidal effects, are not suitable for use at these sites, given the "noisy" flow patterns. Further study of the effects of wind and the "storage" factor of uplands is needed to better understand the flow system along the mangrove zone of northeastern Florida Bay.

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Sediment Resuspension, Surface Properties and Seagrass in Florida Bay

By

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Resuspension of Florida Bay sediments is not a simple process, it is the result of a complex set of parameters and processes, including wind strength and direction, the presence and density of seagrass growth, local basin geometry, exposure to incoming wave energy, depth, and sediment composition. Investigation of the characteristics of the modern sediment surface, distribution of seagrass, and the typical wind/wave regime reveal how these influences interact within the Florida Bay system. An understanding of these processes will allow us to better explain the spatial and temporal patterns of turbidity in the Bay, how sediments have and will periodically be redistributed, and to predict how the ecosystem will respond to future alterations.

Previous research indicates that resuspension within Florida Bay is principally controlled by wind generated waves. Computer simulation of wave generation in Florida Bay reveals that in addition to wind strength and direction, the depth and geometry of local basins within the Bay exerts a strong control on wave derived near-bottom flow. Because of the limited depth and fetch within some of the smaller basins in Florida Bay, only relatively weak near-bottom flow occurs, even under relatively high wind conditions. In basins that have a larger fetch in the direction of strong winds, downwind mud banks are subjected to higher wave energy, and stronger flow in the central portion of the basin is expected. These results may explain why some of the smaller, central basins have thicker accumulations of mud, as compared to other larger basins, floored by sand and bare bedrock.

Observations and modeling results indicate the importance of wave damping by seagrass growth. An extensive survey was conducted in Florida Bay to determine the distribution of seagrass and other bottom types which would effect wave propagation. Based on over 650 surveyed sites, combined with aerial photography and satellite imagery, a map of Florida Bay bottom types was completed. The major bottom types delineated are hardbottom, open mud or sand, sparse seagrass coverage, intermediate seagrass, dense seagrass, and a bank top suite. Observations suggest that seagrass growth is often concentrated along bank margins. Using data acquired during a brief deployment of pressure gauges in the Bay and from the results of previous research, variations in bottom friction in the Bay were assigned relative to the mapped bottom type distributions and incorporated into the wave model. Model results and observations in the Bay both suggest that bank margin seagrass significantly dampens incoming wave energy, thus greatly reducing the potential erodibility of the mud banks. Seagrasses also modify the composition of the sediments; they baffle fine-grained muds and support a mollusk community which becomes a source of gravel-sized shell material.

As a result of the multiple effects of seagrass, mortality events probably have several consequences. When seagrass dies, the wave energy which can potentially impinge on a bank edge is greatly increased. At the same time, the surface sediments, mud, sand, and gravel (shell) are more readily available for transport. It is hypothesized that emergent shell ridges found in the Bay and coarse layers observed in mud bank cores may be the result of seagrass die-off, intensified wave energy and the increased supply of readily transported shell material. A shell ridge which has formed on the bank north of Calusa Key

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since 1970 may be the end product of this sequence of events. If this process is reflected by coarse shell layers found in cores throughout Florida Bay, then periodic seagrass mortality may have occurred in the past and be a characteristic of naturally varying Bay conditions.

Analysis of 120 surface sediment samples suggests 12 distinct sediment types in Florida Bay. Grain size distribution, mud, water, organic and carbonate content have been analyzed for each sediment sample. Using cluster analysis techniques, sediments were differentiated and classified. Approximately 60 percent of the surface sediments are dominated by sand, and 40 percent by mud. Current research is underway to investigate how each of these sediment types responds to turbulent flow. Once this aspect of the investigation is complete, the findings will be combined with wave modeling results to map the resuspension potential throughout Florida Bay. It will also then be possible to quantify annual resuspension of sediments and predict how changes in bottom type or depth will affect patterns of turbidity, sediment stability, and longer-term accumulation processes within the Bay.

Geochemical Analysis of Ground-Water Flow to Biscayne Bay

By

Vicente Quiñones-Aponte[1]

Construction of canals and levees in south Florida has altered the natural hydrologic conditions of the Everglades. The canals and levees were constructed to convey water, prevent flooding, and store water in conservation areas for future use. The U.S. Army Corps of Engineers is evaluating various structural and operational changes to the canal system in an attempt to restore natural sheetflow conditions to Everglades National Park. Questions related to these potential changes are: (1) Is ground water flowing to Biscayne Bay a significant component of the water budget in south Florida? (2) Would the quantity of ground water flowing to Biscayne Bay be greatly affected by changes in the operation of gates and control structures in canals? and (3) How much change in ground-water discharge to Biscayne Bay has occurred due to the present modifications to the hydrologic system?

The U.S. Geological Survey is conducting a study to: (1) define the geohydrologic characteristics of the surficial aquifer system adjacent to and beneath Biscayne Bay, (2) estimate ground-water discharge to Biscayne Bay using geochemical and numerical modeling techniques, and (3) assess the potential effects of some proposed water-management operations in canals and water-conservation areas on ground-water discharge to Biscayne Bay. Preliminary results from the geochemical analysis only are presented here.

During May 1-17, 1997, personnel of the U.S. Geological Survey drilled test holes and installed 29 water-quality/water-level monitoring wells in Biscayne Bay. The wells are arranged in three transects, with two or three sites per transect, beginning 164 to 246 ft from shore opposite Coconut Grove to the north, Cutler in central Biscayne Bay, and Mowry Canal to the south, and extending 3,000 to 6,000 ft into Biscayne Bay. Each site consists of one shallow well, 6.5 to 10 ft into the limestone and above a major unconformity, and one deep well, 23 to 39 ft into the limestone and below the major unconformity.

Water samples were collected from all wells for analysis of major inorganic constituents, nutrients, and oxygen-18 and deuterium stable isotopes. The presence of freshwater in some of the offshore wells was reflected by the specific conductance, which ranged from 16,300 to 29,000 microsiemens per centimeter in certain water samples. Oxygen-18 and deuterium stable isotopes are influenced by processes affecting the water (rather than the solutes) and can be used to identify the source of water. A graphical analysis was made of the relation between oxygen-18 and deuterium in water samples collected from wells open to varying depth intervals under Biscayne Bay (0 to 10 ft, 10 to 20 ft, and greater than 20 feet) and in canal water, bay water, and open ocean water samples. Water samples that were collected from the different sources plotted in clusters that can be taken as representative of the sources. Some of the clusters overlap, which might indicate mixing or movement of water from one source to the other. Oxygen-18 values ranged from -2.1 to -0.97 per mil in canal water samples and from +2.51 to +2.56 per mil in ocean water samples. Deuterium values ranged from -9.3 to -3.3 per mil in canal water samples and from +6.9 to +12.4 per mil in ocean water samples. The graphical analysis showed a cluster of water samples collected from four sites in Biscayne Bay, three along the Mowry Canal transect and one along the Cutler transect at the site farthest from shore. This cluster of water samples consists of oxygen-18

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values ranging from -0.13 to +0.34 per mil and deuterium values ranging from -7.3 to -5.0 per mil. For purposes of analysis, this cluster is considered to be representative of bay water, which actually is a mix of ocean, canal, and ground waters.

Water samples collected from Biscayne Bay along the Coconut Grove transect plotted within the range of values that is representative of ground water (oxygen-18 values from -1.5 to +2.19 per mil and deuterium values from -6.1 to +15.1 per mil), with oxygen-18 values of +1.23 and +1.30 per mil and deuterium values of +8.9 and +7.9 per mil. This result suggests that a significant quantity of ground water is discharging to Biscayne Bay along the Coconut Grove transect. Two water samples collected from Biscayne Bay along the Cutler transect plotted mainly within the range of values that is representative of canal water, with oxygen-18 values of -1.23 and -1.55 per mil and deuterium values of -8.5 and -7.4 per mil. However, the previously mentioned water sample (collected from the site most distant offshore along the Cutler transect) departed to the left of the graph, plotting on the cluster that is considered to be representative of bay water (oxygen-18 values from -0.13 to +0.34 per mil and deuterium values from -7.3 to -5.0 per mil) with an oxygen-18 value of -0.13 per mil and a deuterium value of -5.0 per mil. This shift to the left of the graph can be interpreted as a result of evaporation, which is characteristic of bay and ocean water.

In summary, it appears from the geochemical analysis that ground water is discharging offshore along the Coconut Grove transect (north transect). Water of canal origin represents a significant part of the ground water discharging along the Cutler transect (central transect). An insignificant amount of ground water is discharging along the Mowry Canal transect (south transect).

Speciation and Fractionation Modeling Studies - Dissolved Organic Carbon (DOC)-Mercury Interaction

By

Michael Reddy[1] and George Aiken[1]

The chemical form in which mercury exists in water is its speciation. Mercury species are distinguishable from one another, stoichiometrically, and with respect to their bioavailability. In addition, mercury can exist in different phases, for example, as gaseous species, as solid phases, or in adsorbed states. The concept of chemical speciation is central to the equilibrium, kinetic and biogeochemical aspects of mercury in the Everglades ecosystem.

We have used the computer ionic speciation model WHAM (Windermere Humic Aqueous Model) to characterize the mercury-organic species present in Everglades surface water. WHAM focuses on humic and fulvic acid-metal interactions. These calculations indicate that the major mercury species in solution changes from uncharged chloro- and hydroxy-complexes to DOC-bound complexes in the presence of high DOC concentrations (that is, greater than about 10 milligrams per liter). Inorganic speciation calculated using WHAM has been compared to speciation determined with PHREEQC (pH-redox-equilibrium-equations) with good agreement. WHAM has also been satisfactorily tested using laboratory measurements of calcium ion binding to a soil fulvic acid. The presence of sulfide and sulfur-containing ligands shifts mercury speciation to mercury-sulfur and mercury-organosulfur complexes. Mercury sulfide solid phases appear to be supersaturated in some Everglades' surface and pore waters. Analysis of DOC and sulfide competition for mercury binding is in progress as well as measurement of Everglades fulvic acid mercury interaction, in cooperation with the Department of Civil Engineering, University of Colorado at Boulder.

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The Relation Between Vegetation and Water-Flow Velocity Profiles in a Sawgrass Marsh, Everglades National Park, Florida

By

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The relation between the height, density, and composition of vegetation and flow-velocity profiles in a sawgrass marsh was determined as part of a study of the movement of water in the Everglades National Park. Measurements were made at two sites, first in April and then again in November 1996. Vegetation at one site consisted primarily of dense sawgrass that was 1.5 to 3 m in height. Vegetation at the other site consisted of sparse sawgrass that was 1 to 1.5 meters in height, rushes, bladderwort, and periphyton. An Acoustic Doppler Velocity meter was used to measure horizontal flow velocities in 5-cm vertical increments through the entire water column, from the water surface to the bed at 10 to 15 sample locations at each site, where the depth of the water column varied between .2 and .5 m. In addition, 0.5-m square plots of vegetation were harvested in 10-cm vertical layers through the water column at each sample location. The vertical layers of each plot were harvested to determine the density and composition of the vegetation contained in each layer. Measurement results indicate that flow velocities at sample locations at both sites generally were larger in the middle part of the water column compared with those near the bed or the surface. Small flow velocities near the surface reflect the affects of vegetative drag caused by dense vegetation, such as sawgrass leaves, and bladderwort, and periphyton near the surface. Small velocities near the bed reflect drag caused by the high density of decaying plant litter near the bed. Few sawgrass culms rise through the middle part of the water column and create little vegetative drag; this, consequently, permits the larger flow velocities that occur in the middle of the water column.

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Historical Salinity Conditions in Florida Bay: Qualitative and Quantitative Observations

By

Michael B. Robblee[1]

The purpose of this project has been to compile existing salinity observations from the diverse literature on Florida Bay and to use this information to characterize salinity dynamics in Florida Bay over the available period-of-record. Salinity along with associated temperature, DO, and pH observations from all sources were combined in a single database relating each observation to time and place. A salinity observation was included in the database if the following criteria were met: 1) the observation had been made within Florida Bay waters or in waters adjacent to the Bay; 2) the measurement was a discrete observation (for example, the observation was not part of a fine interval time series or an average value taken over time or space); 3) the date and time that the observation had been made was known; 4) the latitude/longitude coordinates of the location at which the salinity observation had been made was available or could be estimated; and 5) the depth at which the observation had been made could be determined.

The quantitative record of salinity in Florida Bay begins in 1936. Earlier references to salinity in the Bay are qualitative. To date salinity observations have been gathered from sixty-one published and unpublished studies. The resulting salinity record includes over 18,000 discrete salinity observations from within Florida Bay. The temporal and spatial distributions of the data largely reflect long-term research interests and concern over perceived conditions and related management issues within the Bay. Effectively, a usable database exists from the mid-1950's. In 1981, long-term monitoring of salinity was initiated by Everglades National Park in northeastern Florida Bay. By 1988, this monitoring network was spatially extensive with good coverage over much of Florida Bay inside Park boundaries.

Since 1955, Florida Bay has behaved generally as a marine lagoon which is often hypersaline. Salinities within the Bay can be described along a southwest/west to northeast gradient. The Gulf of Mexico and Taylor Slough/C-111 Canal, the latter being the Bay's primary freshwater sources, serve as extremes, respectively. Generally at a site in Florida Bay, variation in salinity conditions decreases from east to west. In the west marine salinities have prevailed. Mean monthly salinity has averaged 36.1 ± 1.6 ‰ at Long Key and 35.9 ± 5.1 ‰ in Johnson Key Basin. In southwestern Florida Bay at Long Key, where Atlantic and Gulf conditions dominate, the range of salinity observed has been 28.7 to 40.2 ‰. In Johnson Key Basin, also in the west but a basin enclosed by shallow water banks, the range of salinity has been greater, 20.0 to 53.2 ‰. Persistent estuarine conditions in Florida Bay have been largely confined to the embayments and bays characterizing the Bay's northern margin. In the fringing bays bordering northeastern Florida Bay mean monthly salinities in Long Sound, Joe Bay, and Little Madeira Bay, immediately downstream of Taylor Slough and the C-111 Canal, have averaged 23.2 ± 11.6 ‰. Variation in salinity has been greatest in these shallow fringing bays where the observed range of mean monthly salinities has been 0 to 57.6 ‰ over the period-of-record. In contrast mean monthly salinities in the vicinity of Duck Key, immediately downstream of Joe Bay in Florida Bay proper, have averaged 34.2 ± 8.6 ‰ with a period-of-record range of 13.3 to 51.3 ‰.

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Over the period-of-record, Florida Bay has often been hypersaline. Hypersalinity in the Bay occurs with cyclic drought conditions in South Florida. The highest reported salinity for openwaters in Florida Bay was 70 ‰. This salinity has been observed twice near Buoy Key, east of Flamingo, at the end of the dry season, once in 1956 and again in 1991. Hypersaline conditions in Florida Bay appear first and have been most severe and persistent in its center near Whipray Basin where mean monthly salinities have averaged 40 ‰ (range = 21.2 to 57.3 ‰) over the period-of-record. During this period salinities in Whipray Basin have reached or exceeded 40 for almost 60 percent of the months when data was available. In contrast, estuarine conditions across Florida Bay are rare and usually associated with high rainfall episodic events such as tropical waves, depressions, and hurricanes or with periods of above average rainfall like the 1994 to 1995 period. Water management has influenced these processes as well. Increased flows through the C-111 Canal due to upstream operational requirements lowered salinities across the Bay during a period of below average rainfall in South Florida, 1983 to 1985.

Generally, interannual variation in salinity exceeds seasonal variation in Florida Bay. This results due to the complex geometry of the Bay, the relative dominance of marine influence over freshwater inflow, and the importance of the wet/dry cycle in south Florida. Variation in salinity due to water management is weak when compared to natural variation in salinity.

Temporal and Spatial Variation in Seagrass Associated Fish and Invertebrates in Western Florida Bay: A Decadal Comparison

By

Michael B. Robblee[1] and André Daniels[1]

In the fall of 1987, a widespread, rapid die-off of turtle grass, *Thalassia testudinum*, began in Florida Bay. This disturbance was thought to threaten the Bay's water quality, sport fishery, and nursery function. It was hypothesized that over the short-term, grass canopy loss and declining environmental conditions would lead to shifts in species composition and reduced abundance of grass canopy dependent organisms. Over a longer-term increasing seagrass habitat heterogeneity resulting from recolonization of denuded bottom by algae and *Halodule wrightii*, shoalgrass, would lead to enhanced nursery function and an improved sport fishery.

A detailed quantitative database, covering the period October 1984 through April 1987, is available from Johnson Key Basin in western Florida Bay prior to the onset of seagrass die-off. These data describe community dynamics and spatial relationships among seagrass associated caridean shrimp, fishes and the pink shrimp, *Penaeus duorarum*, in relation to an undisturbed seagrass habitat. As such, the database serves as a baseline against which to assess the response of a seagrass fauna to habitat changes occurring in Florida Bay following seagrass die-off. The experimental design and sampling protocols employed previously in Johnson Key Basin have been duplicated between October 1994 to April 1997 in order to address the following objectives: 1) to document changes in grass bed structure and habitat complexity in Johnson Key Basin since the mid-1980's; 2) to compare the seasonality of characteristic seagrass associated shrimp and fish populations in Johnson Key Basin prior to and following seagrass die-off; and 3) to compare quantitative relationships between grass bed structure and animal density and species composition observed in an undisturbed versus a disturbed seagrass system.

Quantitative animal samples were collected using a 1 m^2 throw trap. At each station four replicate throw trap samples were collected. All fishes, caridean shrimp and pink shrimp were removed from each throw trap and identified, counted and sized as appropriate in the laboratory. Thirty stations in Johnson Key Basin had been sampled originally and associated with quantitative estimates of grass bed micro-habitat were associated with each throw trap sample. These measures included: seagrass standing crop and blade density; algal biomass; sediment texture, depth, compaction, sediment organic content; root and rhizome biomass; and water depth.

A comparison with habitat data collected in 1985 indicated that the character of the seagrass community in Johnson Key Basin has changed significantly over the past ten years. Combined 1995 January and May estimates of the standing crop of *Thalassia*, indicate that turtlegrass has declined by 72.3 percent in Johnson Key Basin when compared to 1985. No significant difference in the standing crop of *Halodule* was observed between 1985 and 1995 at the thirty stations sampled. *Syringodium*, relatively widespread (present at 12 of 30 stations in May 1985, dominant at 1 station) but never abundant, was absent in 1995. Following the decline of *Thalassia*, living root and rhizome biomass among these thirty stations also declined, 49.8 percent when compared to 1985. These changes resulted in a marked shift in

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seagrass species community dominance in Johnson Key Basin. In May of 1985, *Thalassia* was the dominant seagrass at 24 of 30 stations in Johnson Key Basin. *Halodule* dominated at 5 stations, all of them near-key stations. By May of 1995, Thalassia dominated at 14 stations while *Halodule* had expanded its presence into deeper water and was the dominant seagrass present at 14 of 30 stations. A new habitat, bare sediment, not present in 1985, dominated at 2 stations in 1995.

Observed patterns of abundance and species composition between 1985 and 1995 are in line with hypothesized short-term expectations following loss of seagrass habitat. The abundances of caribbean shrimp and fish were lower in 1995 when compared to either January or May of 1985. These patterns of abundance in Johnson Key Basin are similar to those observed when comparing animal densities in adjacent patches of die-off and undamaged seagrass habitat.

Differences in the species composition of fish and caridean shrimp were observed. The rainwater killifish, *Lucania parva*, the most abundant fish in the Johnson Key Basin seagrass bed prior to seagrass die-off, representing over 62 percent of catch in 1985, dropped to less than 3 percent of catch in 1995. Since fish abundance in the Basin in 1995 was less than half that observed in 1985, *L. parva* experienced over a 98 percent decline in abundance over the ten year period. Similarly, *Thor Floridanus*, the numerically dominant caridean shrimp in Johnson Key Basin in 1985, representing over 81 percent of the caridean shrimp captured, dropped to 26.6 percent of catch in 1995, experiencing over a 93 percent decline in abundance. Other animals declined in abundance following seagrass die-off as well, notably the killifish, *Floridichthys carpio*, and the toadfish, *Opsanus beta*, and the caridean shrimp, *Periclimenes longicaudis*. In contrast, the code goby, *Gobiosoma robustum*, the bay anchovy, *Anchoa mitchilli* and the burrowing caridean shrimp, *Alpheus herterochaelis*, were found in greater numbers in 1995. The appearance of the bay anchovy and the Spanish sardine, *Sardinella aurita*, for the first time in throw trap collections is thought to be a response to the algal blooms which now characterize the formerly clear water Johnson Key Basin. The distinct changes in species dominance in the Johnson Key Basin seagrass bed can not be completely explained by loss of seagrass habitat since substantial seagrass is still present in the Basin and at the thirty stations sampled and both *L. parva* and *T. floridanus* were most abundant in shoalgrass habitats in 1985.

Coupling Models for Simulating Canal and Wetland Interactions

By

Raymond W. Schaffranek[1]

Quantification of dynamic flow conditions within the south Florida ecosystem is vital to understanding implications of the flux and residence time of water--potentially nutrient-enriched (with nitrates or phosphates) or contaminant-laden (with metals or pesticides)--that can alter plant life and affect biological communities. Nutrients, carried by canals draining agricultural areas and directly discharging, over-topping levees, or seeping into neighboring wetlands, are considered to be a major contributor to changes in the types of vegetation found in the Everglades. Freshwater inflows, typically of varying magnitudes and durations, also affect the salinity of Florida Bay and potentially carry toxic substances that can affect the Bay's aquatic biota. Improved numerical techniques are needed, not only to more accurately evaluate flow-forcing functions in the discrete canals and wetlands, but also to simulate their complex interaction, which will facilitate coupled representation of transport processes that affect constituent cycling and exchange mechanisms. This project of the South Florida Ecosystem Program of the U.S. Geological Survey is focused on the development of a generic computer model to simulate the flow of water and analyze the movement of constituents between canals and wetlands. The resultant coupled flow and transport model can be used to investigate the cause-and-effect relation between discharge sources, flow magnitudes, transport processes, and changes in vegetation and biota.

Flow mechanisms and transport processes in low-relief environments, such as south Florida, are complex. Flow velocities in the Florida Everglades are extremely low, which makes the water movement highly susceptible to external forces such as wind that can even cause a wetland area to drain or flood. Wetlands near Florida Bay are also subject to tidal and meteorological effects that further complicate analyses of transport processes. Additional flow complexities are introduced in the south Florida ecosystem by a diversity of natural and man-made controls, such as canals that constitute a major water-delivery component of the system. A complex canal and levee system, designed to control flooding and provide a continuous supply of fresh water for household and agricultural use, has altered natural flow patterns. Flow depths and velocities in the canals are typically more than an order of magnitude greater than in the wetlands. Flows in the typically straight, uniform canals are predominately in the streamwise direction and are well characterized in terms of mean cross-sectional properties. By contrast, flows in the wetlands are highly variable in the horizontal plane in response to varied topographical patterns, vegetative features, and external forces. Flows from canals to neighboring wetlands and reciprocal runoff flows are the combined result of hydraulic, inertial, and meteorological forcing functions.

An area of particular interest, in terms of canal and wetland flow distribution, is the C-111 canal and its associated wetlands between Florida City and Florida Bay in southern Dade County. The C-111 drainage system--a major source of freshwater flow to Florida Bay--is comprised of the C-111 canal, which traverses the wetlands in a southeast direction and subdivides them into northeast and southwest components; a dam and water-control structure, identified as S-197, at the downstream end of the canal, which regulates freshwater outflows and prevents saltwater intrusion from Florida Bay; and a control structure 6.7 miles upstream, identified as S-18C, which regulates inflow to this segment of the canal.

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A series of eleven culverts, with removable stop risers, connect the canal to wetlands to the northeast. Spoil mounds along the southwest bank of the canal between the control structures currently contain gaps cut in them in an attempt to distribute overbank flows to wetlands to the southwest. Tree islands and other physiographic features, as examined in aerial photography, clearly indicate that the historical direction of shallow surface-water flow, referred to as sheet flow, to the Bay has been altered by the construction of roads, canals, levees, and hydraulic control structures. Alternative flow-control measures, such as the ongoing effort to entirely remove the spoil mounds, are continually being explored, proposed, and evaluated to restore the C-111 drainage system to more natural flow conditions.

A generic flow-simulation model, formulated using an extended form of the one-dimensional de Saint Venant equations of unsteady flow, is being augmented to include solution of the convection-dispersion transport equation to produce a tool to investigate canal and wetland interactions in complex ecosystem environments such as the C-111 drainage system. The generic model is fully capable of simulating unsteady flow throughout a system of open channels connected in a dendritic or looped pattern. The model solution method accommodates dynamic tributary inflows and controlled diversions as well as lateral overbank flows. The weighted four-point, implicit, finite-difference approximation of the unsteady-flow equations employed in the model permits solutions at large time steps that are consistent with wetland flow rates while also allowing for simulation of dynamic flow-controlled diversions. A mixed Eulerian/Lagrangian approach is being used to solve the one-dimensional convection-dispersion equation for solute transport. The one-dimensional, open-channel model is being coupled to a wetland model that solves the two-dimensional, vertically averaged, conservation of mass, momentum, and constituent transport equations. Highly accurate land-surface elevations and bathymetric soundings, determined using GPS as well as conventional surveying techniques, are being obtained for model implementation on the C-111 drainage system. Synoptic measurements of flow velocities in the canals, wetlands, and culverts, obtained using acoustic Doppler velocity meters, are being collected for model calibration and verification. The generic coupled model is being developed and tested as a means for post assessment of primary cause-and-effect factors affecting the south Florida ecosystem habitat, as well as a developmental tool by which to study the potential effect of remedial restoration plans.

Geology and Hydrology of the Florida Keys: Ground Water Flow and Seepage

By

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More than 80 shallow (5-20 m) water monitoring wells have been installed off the Florida Keys. Twenty are configured in a cluster that has been used for three tracer studies. The studies provide new data on the subsurface movement, flow rate and seepage of saline ground water in Florida Bay and the reef tract. Three dye tracer tests and one sulfur hexafloride (SF_6) tracer study show that 1) flow rates range from 1 to 3.5 m/day, and 2) flow is mainly eastward (perpendicular to the Keys) and away from Florida Bay. Reverse flow was measured during a period of strong easterly winds.

Measurement of pressure heads in monitoring wells indicates that tidal pumping, combined with higher average sea level in Florida Bay than oceanside, is the major cause of cross-Keys ground water movement and dispersal. Low tide east of the Keys (Atlantic side) results in a 1 m or more head on the bay side of Key Largo. Under these conditions, ground water head pressure under Florida Bay is negative (even though surface water head is positive), causing eastward "downhill" flow toward the Atlantic. Negative head pressure develops because the upper meter or two of the limestone under Florida Bay is relatively less permeable than the underlying rock. Thus, water in the permeable zone can flow "downhill" toward the Atlantic faster than water can leak through the relatively impermeable surface zone. High tide on the Atlantic side of the Keys produces the opposite situation. Under these conditions, subsurface flow is generally "downhill" toward Florida Bay. Because mean sea level in Florida Bay is 10 to 20 cm above mean Atlantic sea level, net flow is toward the Atlantic. The exception is during periods of sustained easterly winds combined with high spring Atlantic tides. Water is "blown" westward in Florida Bay, reducing water level by as much as 30 cm along the west side of the Florida Keys while water is piled 30 cm or more on the eastern side of the Keys. During these events, which can last several days to weeks, ground water flow is mainly westward into Florida Bay.

Because the upper 1 to 2 m of limestone are relatively impermeable compared to the underlying limestone, tidal springs occur wherever there are small sinkholes, fractures, or manmade breaks in the upper surface, such as our monitoring wells, canals, or dredged channels. These saline tidal springs are often reported as freshwater boils. Boils occur on both sides of the Florida Keys but only during the 6-hour period when tidal phase produces positive ground water heads. Slower seepage, not visible as boils, also occurs through smaller pores but only where an impermeable blanket of modern sediment is absent.

Tracer tests in well clusters also show upward movement associated with lateral transport. Tracers placed in the deep 13.6 m (45 ft) center well invariably appear in the shallow 6 m (20 ft) peripheral wells faster than in the 13.6 m (45 ft) peripheral wells, regardless of flow direction. In addition, tracers injected into the shallow 6 m (20 ft) central wells first appear in shallow peripheral wells. These observations indicate that deeper ground water moves more slowly than near-surface ground water and ground water migrates both laterally and upward. Near-surface ground water eventually seeps into the

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overlying water column. These observations are compatible with systematic ground-water tidal head measurements. In all wells tested, tidal pumping heads have been found to decrease with depth.

New flexible seepage meters were devised and successfully tested because the 50 "hard" fiberglass meters previously installed were found to pump water from the ground. Though the results are preliminary (data based on only 4 m), seepage rates range from 5 to 13 l/m^2/day, a range of flow sufficient to replace or recycle Florida Bay water one or more times/year. The pumping action of rigid seepage meters, including those constructed from the ends of oil drums, occurs only in the presence of waves.

Nutrient levels of saline ground water in the Keys is everywhere greater than that of surface waters. Total phosphorous (TP) and nitrite and nitrate (NO_2+NO_3) are generally in the range of surface waters, whereas ammonium (NH_4) is generally 20 to 40 times greater in the same anoxic H_2S-rich ground waters. The exception is fresh water from quartz sands underlying a thin limestone cap in the Shark River slough. TP in these fresh ground waters is elevated 6 or more times than that in surface waters. Seepage of nutrient-rich ground waters is most pronounced in areas close to the Keys because of tidal pumping. Tidal pumping is present but much reduced in central Florida Bay.

Distribution of Mercury in the Periphyton Mats of the South Florida Ecosystem

By

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A primary producer of organic carbon in the south Florida ecosystem is periphyton. Periphyton is an aggregate that includes algae, associated bacteria and, in the case of much of the cyanobacteria (blue-green algae) of the south Florida ecosystem, calcium carbonate. Often, periphyton in the south Florida ecosystem is attached to the aquatic plant utricularia and is present as a floating mat on the surface of the water.

The value of periphyton in the study of the geochemical cycling of metals in the environment is related to the ability of algae in the periphyton to accumulate metal ions from the water column and to integrate over time water column concentrations of metals and other dissolved species. A high level of bacterial activity in the periphyton of south Florida is anticipated due to labile organic carbon in the mats and the elevated temperatures of this subtropical area. The mats offer food and shelter to many organisms, both macroscopic and microscopic.

Results are reported for samples that were collected in March, July, August, and December 1995, and June, August, and December 1996. Parameters that were measured include total mercury, methyl mercury, phosphorus, total carbon, organic carbon, and total nitrogen in the periphyton, and water column parameters including pH and concentrations of major cations and anions, including alkalinity. In 1966, mats that were collected were frozen on site, brought back to the laboratory, and, before drying, sectioned into horizontal layers. The individual layers were analyzed.

One of the questions that must be resolved before differences in concentrations of total mercury, methyl mercury and other geochemical species can be evaluated between sites in the Florida ecosystem in the statistical variation in concentrations of species of interest at any one site among samples collected at the same location. To evaluate this variation, two sets of samples from sites in south Florida were collected on the circumference of a circle having a diameter of 2 meters. Triplicate samples were collected at 60° intervals. These samples were analyzed for total mercury, methyl mercury, phosphorus, organic carbon, inorganic carbon and total nitrogen. The variation among sample concentrations in material collected from site U-3 in WCA2A for organic carbon and total mercury ranged from 30.7 ± 0.2 percent for organic carbon, which was the least variable parameter, to 0.12 ± 0.07 $\mu g\ g^{-1}$ for total mercury, which was the most variable parameter. All concentration are reported on a dry weight basis. The analyses for methylmercury showed that the presence of methylmercury in the periphyton samples was patchy at the detection limits of the method that was used (0.01 $\mu g\ g^{-1}$ dry weight). Spatial variation suggests that the reporting of trends rather than absolute concentrations of constituents in the mats might be desirable.

If an average of the total mercury concentrations determined for samples collected at various times of the year is used to compare mercury concentrations from site to site, difference between sites are less clear than if concentrations of samples collected during the same field trip are compared. Trends in

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mercury concentrations in a north to south direction are more clear among samples collected at approximately the same time. With this caveat in mind, it appears that the tendency is for total mercury concentrations in the periphyton mats to decrease as samples are taken in a more southerly direction, or in a direction from a canal into the marsh.

Mercury concentrations in periphyton are correlated with phosphorus concentrations. The linear correlation coefficient (r) is 0.62 (n=120) for a comparison of total mercury concentrations in all of the whole periphyton samples that were analyzed with the phosphorus concentration in the same samples. If the samples that are compared are limited to whole periphyton material from WCA2A, the linear correlation coefficient between total mercury and total phosphorus is 0.76 (n=19). While the concentrations of phosphorus in the mats from a given site are generally larger early in the calendar year as compared with later in the calendar year, this is not necessarily true for the concentrations of total mercury.

Trends in chemical concentrations in periphyton mats fall into two categories: (1) between sites, and, (2) within sectioned mats. Total mercury concentrations in the mats are inversely correlated with the inorganic carbon concentrations in the mats. This observation is true for comparisons of mercury concentrations calculated on a whole sample basis and for mercury concentrations corrected for the inorganic carbon content in the sample. This suggests that the decreased concentration of mercury in the mat might be due to coating of sorption sites by calcium carbonate. The agreement between mercury and inorganic carbon concentrations is better for whole samples than it is for sectioned mats. Total mercury concentrations are positively correlated with organic carbon and nitrogen concentrations in the mats. It is known that mercury is readily sorbed by organic matter. The mat materials that were collected from the south Florida ecosystem were 13 to 39 percent organic carbon, much of which is algae that provides active sites for the partitioning of mercury from the water to the solid mat material. Concentrations of total mercury tend to correlate positively with methyl mercury concentrations in whole mat material. Within mats, the largest total mercury and methyl mercury concentrations tend to be localized and not necessarily correlated with the same geochemical parameters as total mercury in the whole mats. Factors that affect the distribution of mercury in the mats are being investigated.

It's Been Five Years Since Hurricane Andrew: Long-Term Growth and Recovery in Mangrove Forests Following Catastrophic Disturbance

By

T.J. Smith III[1]

Hurricane Andrew crossed the south Florida coastline on the morning of August 24, 1992. Winds in excess of 140 mph lashed the mangrove forests on both the east and west coasts of the peninsula. Research into the impacts of the hurricane began almost immediately. Initial estimates of tree mortality were made using aerial and on-the-ground surveys. Permanent forest monitoring plots were established to measure long-term trends in forest growth and recovery (and in some instances lack of recovery). Almost all trees in areas crossed by the eyewall had been damaged to some extent, from defoliation to loss of major limbs to breakage of the main stem. Initial tree mortality was highly size specific. Tree stems over 5 cm diameter at breast height (dbh) were much more likely to have been killed than stems <5 cm dbh. Interestingly, most of these smaller sized individuals were concentrated in patches in what had been gaps in the forest canopy created by a small scale disturbance: lightning. This was true for all mangrove species. However, initial mortality was also species specific with *Rhizophora* suffering greater mortality than *Laguncularia* and *Avicennia*. Initial mortality exceeded 60 percent for intermediate size classes (15-30 cm dbh) of all species in areas crossed by the eyewall of the storm. The largest size classes (>35 cm dbh) also suffered high mortality (20-40 percent) but less than the intermediate size classes. Mortality decreased moving to the north and south away from the eyewall of the storm, but was still up to 15 percent (depending on size class) as far north as Rookery Bay, near Naples.

Long-term monitoring has revealed that significant amounts of continuing mortality is occurring. Trees which had been damaged, but appeared to have survived the storm, are now dying. For example, larger *Avicennia* (>35 cm dbh) suffered 20 percent initial mortality. This had risen to 50 percent some 12 months after the hurricane and, in eyewall plots, is now over 70 percent.

Recruitment also has varied dramatically between plots. *Laguncularia* invaded several heavily damaged plots very rapidly, notably along the middle reaches of the Broad and Lostmas Rivers. At north Highland Beach recruitment was dominated by *Rhizophora* at first. This initial wave of recruits suffered high mortality, probably as a result of extreme sediment sulfide concentrations at this site. A second wave of recruitment occurred at NHB which included a large proportion of *Laguncularia*. *Avicennia* has not recruited into the population at any plot in large numbers.

Attempts to relate patterns of growth following the hurricane to measurements of sediment porewater nutrients have been only partially successful. Plots with higher rates of growth tend to be those with higher sediment phosphorus concentrations and low levels of sulfide. Higher porewater ammonium appears to positively influence the regrowth of *Avicennia*. The amount of initial damage from the hurricane has the strongest relationship to the amount of regrowth. Plots with very high initial mortality have very low growth, whereas plots which had intermediate disturbance have higher rates of growth. This shows that in areas of catastrophic disturbance that recovery has been slow, if any recovery has occurred at all. There are large areas of mangrove forest on the west coast of Everglades National Park where there has not been recovery, even five years after Hurricane Andrew.

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Hurricanes are not the only agent of disturbance in mangroves. Recent observations indicate that subsequent disturbance events may alter the trajectory of recovery which was in place following the disturbance due to Hurricane Andrew. The recent freeze of January 1997 selectively killed small individuals of *Laguncularia* and *Rhizophora* which had recruited into many damaged areas. *Avicennia*, however, is much more cold tolerant than other mangrove genera. The few smaller sized *Avicennia* which had recruited were the only survivors of the freeze in some areas. Whether this interaction among disturbance events is what maintains *Avicennia* in the mangrove forest community warrants further research.

Quantifying Seepage Beneath Levee 30, Dade County, Florida

By

Roy S. Sonenshein[1]

To manage water levels in the water conservation areas and freshwater deliveries to Everglades National Park, it is important to determine the volume of water seeping from the water conservation areas to the underlying aquifers. An accurate water budget to meet the competing natural and anthropogenic needs cannot be determined without this information. The U.S. Geological Survey is presently conducting a study to evaluate methods for quantifying these seepage losses. The study site is located along the 14-mile long Levee 30 and adjacent canal in north-central Dade County. Completed in 1954, Levee 30 is part of the eastern boundary of Water Conservation Area 3B. From this water conservation area, water seeps into the Biscayne aquifer, which is about 80 feet thick directly beneath Levee 30 and thickens to the east. Water flows relatively fast in the aquifer (due to high permeability of the aquifer) toward the urban and agricultural areas to the east. This seepage to the aquifer from Water Conservation Area 3B is critical for water-supply wells to the east and for preventing the inland movement of saltwater from the coast. However, lowering of ground-water levels to the east resulted in greater ground-water flow eastward from Water Conservation Area 3B and reduction of surface-water flows to the south. As a result, Levees 67A and 67C were constructed west of Levee 30 to direct water southward toward the central region of Everglades National Park. This water-management scheme has been effective in delivering water to the southwest; however, it reduced the flow to the southeast (northeastern part of Everglades National Park). The altering of historical flow directions and water-level durations has caused significant adverse effects to parts of the Everglades ecosystem.

Ground-water flow models are being developed to calculate a water budget, including seepage losses, for a transect perpendicular to Levee 30. Data required for input to and calibration of the models have been obtained from: (1) previous studies conducted in the area, (2) analysis of a geologic core and geophysical logs from new monitor wells drilled along the transect, (3) ground-water-level data from monitor wells along the transect, (4) surface-water stage data in Water Conservation Area 3B and in the Levee 30 canal, (5) discharge measurements made at several locations under varying conditions in the Levee 30 canal, and (6) vertical seepage rates obtained from seepage meters installed in Water Conservation Area 3B under varying hydrologic gradients.

A continuous geologic core from land surface to a depth of 78 feet was obtained during the drilling of a monitor well completed in February 1995. The surface soils consist of about 5 feet of Everglades peat, with the remaining 73 feet consisting almost entirely of very porous limestone and shells. Tests performed on 10 plugs from the core indicated porosities as high as 45 percent and permeabilities as high as 9,500 millidarcys; both values are indicative of the extremely high permeabilities associated with the Biscayne aquifer. Of particular interest was a thin, very hard, impermeable limestone layer at 7 feet below land surface with a very low porosity (less than 5 percent) and very low permeability (less than 0.001 millidarcy). This layer is believed to be areally extensive and constitutes a semiconfining layer that retards the seepage of water from Water Conservation Area 3B into the underlying Biscayne aquifer.

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Twenty-one continuous recording ground-water-level monitor wells were installed along the transect, running about 500 feet both east and west of Levee 30. The wells are located in six different clusters; each cluster has two to five wells, with depths ranging from 10 to 80 feet below land surface. Continuous surface-water-level (stage) recorders were also installed along the transect, one in Water Conservation Area 3B and one in the Levee 30 canal. Data were collected from February to December 1996 to obtain information for both wet- and dry-season conditions. The data are being used to select boundary conditions for the ground-water flow models and to calibrate the models.

Initial data indicate a significant difference between the stage in Water Conservation Area 3B and the water levels in the Biscayne aquifer--as much as 0.5-foot head difference between the water conservation area wetlands and the aquifer during periods of high water. This ponding of the surface water is believed to be the result of the thin, low-permeability, limestone layer located near the top of the aquifer. The head difference between the water conservation area and the canal is even greater, with an average difference of 0.84 foot for the period of data collection. Data from the vertical seepage meters show the effects of these head differences. An increased head difference, a result of the lowering of the canal stage when the gate to the south is open, results in the vertical seepage flux increasing from 0.04 to 0.09 foot per day at the meter located 500 feet west of the levee.

Water in the aquifer flows into and beneath the canal along the eastern side of Levee 30. The rate of ground-water seepage into the canal is controlled by the head difference between the aquifer and the canal. Structures at the northern and southern ends of the canal are used to discharge water from the canal, lowering the canal stage and increasing the discharge rate from the aquifer into the canal. A layer of fine sediments (at the bottom of the canal), measured to be at least 2 feet thick, retards seepage into the canal from the underlying aquifer. Thus, based on the head differences between the aquifer and the canal and the confining sediments at the bottom of the canal, most of the seepage into the canal appears to be from the uppermost part of the aquifer on the western side of the canal through the side of the canal.

South Florida Ecosystem Database Development

By

Jo Anne Stapleton[1], Herta Bell[1], Roy Sonenshein[2], and Scott Pendygraft[3]

The South Florida Ecosystem Restoration Program is an intergovernmental effort to reestablish and maintain the fragile environment of South Florida. Many significant changes have occurred in the South Florida area in the past 100 years as a result of increased human activity and subsequent water control efforts. One element of the restoration effort is the development of a firm scientific basis for resource decision making. The USGS began its own program, called the South Florida Ecosystem Program (SFEP), in fiscal year 1995 for the purpose of gathering hydrologic, cartographic, geologic, and biologic data that relate to the mainland of South Florida, Florida Bay, and the Florida Keys and Reef ecosystems. The USGS is developing a distributed spatial database as part of the SFEP; this database will be used for storing and maintaining metadata and geospatial data sets produced by participating Federal, State, regional, and local agencies. Preexisting data sets relevant to the restoration effort also will be included. The database development project consists of four parts: (1) a metadata database, (2) a geospatial database, (3) a web site summarizing the USGS SFEP and providing access to data and metadata, and (4) a graphical interface to the data using a geographic information system (GIS). A significant goal of this project is to provide continuing access to metadata and data for researchers in South Florida after the USGS has completed the SFEP.

Metadata (data about data) provide information that can be used to evaluate data sets for usefulness in current research projects. Metadata can also be used to document research projects and so reduce or avoid duplication of effort. Executive Order 12906, "Coordinating Geographic Data Acquisition and Access: The National Spatial Data Infrastructure," mandates that all federally produced data will be documented using the Federal Geographic Data Committee (FGDC) June 4, 1994, standard for metadata. A method of generating compliant metadata records has been devised using a combination of word processing and preparser software before validation with a metadata parser. The FGDC-compliant records are indexed for searching using Z39.50 compatible software.

The geospatial database will rely on a relational database management system (RDBMS). All data being collected by the USGS as part of the SFEP will be included in the database, either in data tables in the RDBMS or as related files. The top layer of the database provides the relational structure that allows RDBMS retrievals. This part of the database will consist of indexed station and data type tables. These tables will allow researchers to use standard structured query language to query the database by station attributes and data type. An interface is being developed that will allow querying and retrieval of the data through the web site. Data sets stored at an easily accessible location will allow researchers to locate and exchange information. Relevant data provided by non-USGS researchers will be included in the database in the appropriate format.

As part of the mechanism for public dissemination of the metadata and data, a web site is maintained on a server at the USGS Center for Coastal Geology in St. Petersburg, Fla. More than 25 fact sheets describing USGS South Florida research projects are available on the web site at http://sflwww.er.usgs.gov. Links to related sites maintained by the USGS and other agencies are included.

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More than 100 metadata records for research on the South Florida ecosystem, including Florida Bay and the Everglades, are available for searching on the web site. Metadata records will be added for new research projects, for historical data sets relevant to the restoration effort, and for data contributed by other Federal, State, regional, and local researchers. The metadata records have elements to show either an online link or instructions on how to contact the person who has the data.

The graphical interface is being developed to provide an additional tool for helping researchers to obtain data from the database. The graphical interface consists of a menu-driven system using ARC/INFO GIS software to view and query the database. Map graphic tools (menus) allow the user to pan and zoom to a geographic area of interest, select map layers to be displayed, identify map attribute information, and select and view data collection sites by location and attribute. These attributes will include station name, station identification number, parameters of data being collected, frequency of collection, and period of record. The data sets associated with the selected sites can then be retrieved from the RDBMS.

Temporal and Spatial Change in Coastal Ecosystems Using Remote Sensing: Example with Florida Bay Emphasizing AVHRR

By

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Florida Bay has undergone dramatic changes in recent years. Following seagrass die-offs in the late 1980's, both algal blooms and high turbidity (from resuspended sediments) have become common in the Bay. Monitoring programs are documenting the system to describe current conditions and changes that may occur because of alteration to the Everglades and Florida Keys. We are monitoring the Bay using satellite imagery, in particular imagery from the AVHRR (advanced very high resolution radiometer), in order to provide details on sea surface temperature and water reflectance (the latter indicating light attenuation or sediment loads during turbid conditions). During the summer, when this extremely shallow bay is relatively clear, the reflectance information also provides bottom albedo information that may correspond to patterns in bottom habitat. In addition, daily processing of AVHRR data provides imagery suitable for the planning of monitoring cruises. Using AVHRR data starting July 1985, we have developed a time series consisting of over 700 usable scenes, and we anticipate extending the time series back to 1982. Comparisons with field data have provided relationships with light attenuation, Secchi depth, total suspended solids, and nephelometric turbidity. The time series data set provides monthly and seasonal mean conditions, showing the seasonal change in turbidity resulting from high winds associated with winter cold fronts. Over the 11 years studied, Florida Bay has shown a complex pattern of changes in water clarity, with spatial variations in the Bay being identified by looking at mean winter (December to March) conditions. Areas of high turbidity appear consistently in the northeast and western bay. Areas of clear water may have expanded in the southwest bay, and contracted in the central bay. The integration of AVHRR data with Landsat data may provide additional insights into the Bay in the 1970's and early 1980's.

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Determining Freshwater Discharge Through Coastal Structures in Southeastern Florida

By

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Coastal structures along canals in eastern Dade, Broward, and Palm Beach Counties, Florida, are used to maintain higher water levels upstream, preventing saltwater intrusion into the Biscayne aquifer. Higher surface-water levels induce higher ground-water levels, which prevent saltwater movement inland through the aquifer. Excess stormwater is also drained through these coastal structures. These freshwater discharges not only affect the amount of water available to the wetland areas and for water supply in the lower east coast, but also affect the biota in Biscayne Bay and the Intracoastal Waterway.

Quantifying these freshwater discharges to the east coast is an important component in computation of accurate water budgets for the inland and wetland areas, calibration and use of regional water-management models, and computation of nutrient loadings to Biscayne Bay, the Intracoastal Waterway, and associated water bodies. The U.S. Geological Survey began a study in 1994 to measure freshwater flows through coastal structures in southeastern Florida and to develop discharge-coefficient ratings for these coastal structures. Flows through the 16 coastal structures in Dade County, the 7 coastal structures in Broward County, and the 3 coastal structures in Palm Beach County are presently computed by theoretical discharge-coefficient ratings developed from scale modeling and theoretical flow coefficients, whose accuracies for specific sites are unknown. To create more accurate discharge-coefficient ratings for the coastal structures, field flow measurements were taken with an Acoustic Doppler Current Profiler at each coastal structure under a variety of structure operations. The Acoustic Doppler Current Profiler is capable of measuring low velocities and rapidly varying flow patterns that occur at the coastal structures. These field measurements were used to develop computed discharge-coefficient ratings for the coastal structures under different flow regimes: submerged orifice flow, submerged weir flow, free orifice flow, and free weir flow. The computed-coefficient ratings were compared to the theoretical-coefficient ratings for each coastal structure.

The theoretical- and computed-coefficient ratings for submerged orifice flow were similar at structures G-56, S-13, S-22, S-25B, S-26, S-27, S-28, and S-123, but were remarkably different at structures G-57, S-20F, and S-21. The theoretical- and computed-coefficient ratings for submerged weir flow were similar at structures G-57, G-93, S-20F, S-27, S-29, S-33, and S-123; however, significant differences were apparent at structures S-20, S-20G, S-21, S-21A, S-25B, S-28, S-36, and S-37A. The closest match to the theoretical-coefficient rating for the submerged orifice- and submerged weir-flow regimes was at structure S-33 in Broward County and structure S-123 in Dade County; the worst match was at structure S-21 in Dade County and structure S-36 in Broward County. Discharge-coefficient ratings for the free orifice- and free weir-flow regimes were determined at the three coastal structures (S-40, S-41, and S-155) in Palm Beach County. The theoretical- and computed-coefficient ratings for free orifice and free weir flows were similar at these structures. Some differences between the theoretical- and computed-coefficient ratings for the four flow regimes could be better defined with more data because the ratings were based on 30 or fewer points. This study shows the usefulness of the Acoustic Doppler Current Profiler in rating these coastal structures and the value of discharge-coefficient ratings developed from field measurements in evaluating the accuracy of the theoretical discharge-coefficient ratings.

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Geologic Framework of the Surficial Aquifer System in Southwest Florida

By

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Restoration of the wetland ecosystem of south Florida requires restoration of the natural hydrologic system. In this regard, land and water managers in south Florida are dependent on computer models that simulate both the natural hydrologic system and the added engineering structures. However, because insufficient hydrologic data exist for southwest Florida, current hydrologic models, such as the South Florida Water Management Model and the Natural System Model, do not cover the entire ecosystem area. The purpose of this project is to acquire subsurface geologic and hydrologic data in southwest Florida that will extend current ground-water models to the southwest coast, thereby expanding the utility of these models for land and water management (Weedman, 1996). We have completed coring and logging of seventeen holes through the surficial aquifer system in southwest Florida and can now begin to expand and refine our understanding of the geologic framework of the surficial aquifer system across south Florida.

We drilled seven continuous cores in FY96 in western Collier County (Weedman and others, 1997) and ten cores in FY 97 in the Big Cypress National Preserve; each core is approximately 60 m deep. The cores are being examined for mineralogy, composition, texture, structures, and fossils to determine lithology, alteration, porosity, and age of the aquifer rocks, and to construct a depositional model that will aid in the extrapolation of subsurface data from each site. Stratigraphic units are being correlated between coreholes and their lithologic and hydrologic properties estimated where core data are absent. Permeability tests have been run on selected lithified core samples and integrated with hydrologic and geophysical logs to estimate hydraulic conductivity of each lithofacies. Geophysical logs (natural gamma ray, caliper, induction, temperature, neutron, flowmeter, televiewer) are run soon after holes are drilled. While core analyses are in progress, several preliminary conclusions can be drawn and integrated with the geophysical data (Paillet and Weedman, 1996; Hite and others, 1997; Paillet, 1997).

The study area in southwestern Florida (Collier and Monroe Counties) can be divided roughly into two regions that fall to the east and west of State Route 29, respectively, and are bounded to the north by I-75 and to the south by the Tamiami Trail and the Loop Road. The greatest variability in both the surficial aquifer system and the subsurface sedimentology and diagenesis is from west to east, rather than north to south; however, there are regional depositional patterns that apply to the entire study area. In most cores there is a densely cemented "caprock" about 1 m thick near the surface, which is underlain, in the west, by a lithified carbonate unit and, in the east, by an unconsolidated carbonate unit, both of which contain increasing amounts of quartz sand with depth. Below the carbonate unit is an unconsolidated siliciclastic (that is, containing primarily quartz sand, silt, and clay) unit. In some cases the siliciclastic unit has a tightly cemented zone tens of centimeters thick at the lithologic boundary with the carbonate sediment, which may form a local confining zone where it is present. In the central and eastern part of Collier County, the siliciclastic unit is quite thick (>90 m). It is a poorly sorted (fine to pebble)

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unconsolidated, marine sand interbedded with an olive gray silty clay. Preliminary data indicate that this unit is not very permeable, despite its coarse component, especially when compared to the upper carbonate unit. Below the siliciclastic unit, in the western part of the study area, is a mottled dolomitized limestone; in the central part of the study area there is a dolomitized unconsolidated sand at about the same depth as the dolomite on the west; to the east, there is quartz sand and interbedded olive gray silty clay to the bottom of the cores, at depths of about 60 m.

The most porous and permeable zones of the surficial aquifer system, all across the study area, appear to be in the upper 15 m, with transmissivities that appear to be higher in the west than in the east. Those zones typically are the highly leached, but lithified, carbonate units, primarily found in the western part of the study area. Preliminary isotopic and paleontologic data, from the western part of the study area, indicate that the upper aquifer is primarily Pliocene, and that the Miocene-Pliocene boundary occurs within the siliciclastic unit. The occurrence of mixed-age fauna in the siliciclastic units suggests reworking of sediments at some horizons.

In the west, the surficial aquifer system is compartmentalized into aquifers that are successively more saline with depth, either by thin (< 1 m) horizons of tighly cemented carbonates and sandstone, or by thicker (> 3 m) zones of poorly sorted siliciclastics. In contrast, in eastern Collier County, virtually all ground water in the upper 60 m of the aquifer system is fresh, and lithification is rare in both the carbonates and the siliciclastics. While the base of the surficial aquifer system over the study area is assumed to be an olive gray, dolomitic silty clay, we did not encounter that lithofacies within the upper 60 m of the system in the western part of the study area; however, it was encountered within 12 m of the surface in the east, where it typically acts as a confining zone.

The next phase of this study is to develop a depositional model to correlate corehole sites, to install monitor wells in selected coreholes at depths of interest, and to design aquifer tests to quantify the transmissivities of the major rock and sediment types in the surficial aquifer system.

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Inorganic Nutrient Fluxes in Mangrove Communities Along the West Coast of Everglades National Park: Effects of Hurricane Andrew

By

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Following Hurricane Andrew, a study was undertaken to examine the effect which the catastrophic damage had on the sediment biogeochemistry of the mangrove forests along the west coast of Florida. It was postulated that the large increase of forest litter and dead roots to the sediment system, combined with the removal of many or all live mangrove trees, would dramatically reduce the interstitial water nutrient pools and ultimately affect the particulate concentrations. Eleven primary sampling sites were chosen for study. These represented a broad spatial area and encompassed damage classes of from near complete destruction to areas of no damage at all (controls). The sites were within three tidal river systems of Everglades National Park: the Shark, Broad and Lostmans. Over a 3-year period, we sampled each site multiple times to determine sediment porewater concentrations of ammonium, nitrate, phosphate and silicate. Particulate nitrogen and phosphorus concentrations were also measured at all sites in winter and summer. Additionally, sediment concentrations of 19 elements (Al, As, B, Ba, Ca, Cd, Co, Cr, Cu, Fe, K, Mg, Mn, Na, Ni, P, Pb, Si, Sr & Zn) were measured at 19 sites during winter and summer. Our goal was to have as an extensive site and sampling system as possible to examine differences between sites, seasons and degree of damage from the hurricane.

The major results can be summarized as follows. There is evidence for an effect due to storm damage at two sites: North and South Highland Beach. Both of these sites had higher porewater total nitrogen, ammonium, silicate and lower particulate C:N ratios than all other sites. These two sites also suffered the most catastrophic damage from Hurricane Andrew of all the sites studied. Tree mortality was 100 percent at South Highland Beach and 95 percent at North Highland Beach. Intra-site variation in porewater nutrient concentrations was high, and thus at all other sites hurricane damage affects could not be discerned. Differences between the two Highland Beach sites and all others were maintained over the entire sampling period.

No differences were noted across seasons, although clear differences were observed spatially. The most landward sites in all three river systems had higher percentages of particulate carbon and nitrogen and higher N:P ratios than all other sites. There were also differences in the patterns of elemental concentrations between rivers. In the Lostmans River, 14 of 19 elements increased from river mouth to upstream, whereas five showed no trend. Along the Broad River three elements increased moving upstream and six decreased with 10 having no trend. On the Shark, five elements increased going upstream and seven decreased. This suggests that the Lostmans River has a very different hydrodynamics regime than the Shark and Broad Rivers and demonstrates the spatial variation within the region.

Finally the results indicate that the sediment biogeochemical regime in this system is only loosely connected with plant processes; only major, catastrophic damage affects sediment characteristics.

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Vegetational Changes in South Florida Over the Last Two Millenia

By

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Terrestrial ecosystems of south Florida have undergone numerous human disturbances, ranging from alteration of hydroperiod, fire history, and drainage patterns by water control structures to expansion of agricultural activity to the introduction of exotic species. Over historical time, striking changes in the ecosystem have been documented, and these changes have been attributed to various human activities. However, the natural variability of the ecosystem is unknown and must be determined to assess the true impact of human activity on the modern ecosystem. To document historical changes and to establish the baseline level of variability in the historic Everglades, the project "Ecosystem History: Terrestrial and Freshwater Ecosystems of southern Florida" is analyzing biotic components from cores and surface samples collected throughout the region. These components include pollen and other organic-walled microfossils, peat composition, molluscs, and foraminifers, and these data are integrated with geochronologic data to form a comprehensive picture of the timing and extent of ecosystem changes in the south Florida region.

Shallow cores and surface samples have been collected at numerous sites in the Water Conservation Areas, Big Cypress National Preserve, and Everglades National Park, with highest sampling density in the Taylor Slough region. To accurately interpret vegetational composition from down-core pollen assemblages, it is critical to correlate modern pollen assemblages with standing vegetation and develop an understanding of how over- or underrepresented a taxon is in the pollen record. Surface samples of peats have been collected at 42 sites selected to maximize areal coverage and diversity of vegetational types in a database of pollen abundance in modern sediments. This database is used to identify the closest modern analogs for down-core assemblages, improving the accuracy of interpretation of past vegetational composition from the pollen record. Initial results show good general correlation between pollen and vegetational composition and provide evidence on which plants are greatly overrepresented in the pollen record (such as amaranths) and which ones are underrepresented relative to their abundance in the standing vegetation (such as cattail).

Seven cores, four from the Taylor Slough/Buttonwood Embankment region, two from Water Conservation Area 2A, and one from Big Cypress National Preserve, have been analyzed to date. All show fluctuation in the abundance of different types of marsh and slough vegetation over the "prehistoric" part of the record, reflecting natural changes in hydroperiod, fire regime, and other environmental parameters. A core collected at site MC1 along Mud Creek (near Joe Bay) consists of alternate layers of marl and peat deposited over the last 2,050 years. Pollen assemblages were dominated by *Cladium* (sawgrass) pollen from the base of the core to at least 800 BP. Most of these sediments are marls, and the presence of *Spirogyra* zygospores and fresh- water molluscs prior to 800 BP indicate that they are fresh-water marls. In sediments deposited after 800 BP, foraminifers and molluscs characteristic of brackish water are present, and *Spirogyra* zygospores are sparse to absent, indicating a salinity increase that is consistent with sea-level rise. Over the last 150 years, pollen of *Myrica* (wax myrtle),

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Rhizophora (red mangrove), *Avicennia* (black mangrove), *Quercus* (oak), and the Asteraceae (daisy family) are more abundant than at any previous time, but little variation occurs within that time interval, and the site appears to have been relatively insulated from anthropogenic changes.

Cores collected at site TC2 along Taylor Creek also show dominance by sawgrass pollen from about 2,000 years ago until the mid- to late 1800's. Some variation is seen in the relative abundances of sawgrass, cattail, Polygonaceae (knotweed family), and Asteraceae through this time, but, in general, the assemblage varies little in the lower three-quarters of the core. The vegetational response to environmental changes between 1900 and 1960 is greater than at the Mud Creek site; by 1960, the abundance of sawgrass pollen dropped to lower levels than seen elsewhere in the core, and tree pollen increased in abundance. The loss of sawgrass appears to be correlated with hydrologic alterations to the area; such alterations include construction of the Tamiami Trail (1915-1928) with the resulting changes to sheet flow patterns and construction of canal and levee system throughout the region in the 1950's and 1960's. Two other cores, one collected downstream from TC2, and another one collected in the middle of Taylor Slough, show similar patterns to these cores. Of the 35 additional cores collected in this area, several will be selected to form transects along and across Taylor Slough; their flora and fauna will be analyzed for biotic components to establish regional patterns of biotic response to environmental perturbations in the Taylor Slough area.

Cores also have been collected in Big Cypress National Preserve, Everglades National Park, and the Water Conservation Areas to provide a more regional picture of biotic changes over time. In Big Cypress National Preserve, one core from a cypress strand has been analyzed and illustrates a fairly stable vegetational history. Logging in the early part of the century is documented by a great decrease in abundance of cypress pollen; that decrease and the subsequent recovery are the only notable changes in pollen assemblages from the site.

Two cores collected along a nutrient gradient in WCA 2A illustrate the affect of proximity to a canal and a nutrient source on vegetational composition. Both cores date back about 2,000 years and document similar fluctuations in marsh vegetation until the early 1900's. The core in the nutrient-affected site close to the Hillsboro Canal shows a doubling in abundance of pollen of the Chenopodiaceae/ Amaranthaceae (pigweed/amaranth families) in the early 1900's, when construction of the Hillsboro Canal began, as well as a tenfold increase in cattail pollen beginning in the 1960's. Neither of these changes occur in the core from the "pristine" site.

Continuing analysis of other cores from the historic Everglades will provide a regional overview of both naturally occurring floral and faunal changes and those resulting from human activity in the region. Integration of this information with similar data from Biscayne Bay and Florida Bay is helping reconstruct the ecosystem history of the entire south Florida system and document the impacts of various natural and anthropogenic changes on the ecosystem.

Uranium and Uranium Isotopes as Tracers of Nutrient Addition in Everglades Peat

By

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Drainage water from agricultural areas south of Lake Okeechobee is the suspected carrier of excess phosphorous (P) to portions of the Everglades of South Florida. The addition of fertilizer-derived P to Everglades peat can be assessed through the monitoring of fertilizer-derived uranium (U). Phosphate fertilizer typically contains 20-200 ppm U that correlates with P content and that originates from the mined phosphate rock. Uranium in fertilizer has a distinctive 234U/238U alpha activity ratio (AR) of 1.00±0.05, that is inherited from the mined phosphate rock. These characteristics provide a distinctive U signature of fertilizer that is potentially traceable in low-U environments such as Everglades peat.

Efficient uptake of U by peat is documented in the geologic literature and was confirmed for Everglades peat by mixing peat with a simulated surface water doped with added U. The peat extracted 90 percent of the added U. In contrast, samples of agricultural soil and sugar cane char extracted only 20 to 30 percent of the added U. These results are qualitatively consistent with a natural system in which upland agricultural areas act as sources for U and peat acts as a sink for U.

A preliminary investigation of the distribution and concentration of U in Everglades peat involved collection of six peat cores from areas known to be variably impacted by excess P. The collection was designed to investigate the distribution with depth and the lateral dispersion of U from the Hillsboro canal in Water Conservation Area 2A (WCA-2A; 3 cores), to investigate a U profile in the Everglades Nutrient Removal Area (ENR; 1 core), and to sample U profiles at probable background sites in WCA-3A and WCA -1A (1 core each).

Cores were sampled at 1 or 2 cm intervals over the upper 30 cm, and some cores were sampled at 5 cm intervals to greater depth. The bulk U content of air-dried peat was determined by a neutron activation technique with a precision of 5 to 10 percent (RSD) and a detection limit of 0.2 ppm. Selected peat samples from a variety of depths were leached over a period of 24 hours with a solution of 0.1 M $NaHCO_3$ to extract easily-exchangeable U. The 234U/238U ratio of the leachate was determined by thermal ionization mass spectrometry, and the AR was calculated from this mass-based ratio. The technique has an analytical precision of better than 0.3 percent at the concentration levels encountered. The fraction of easily-exchangeable U in this low ash (<15 wt. percent) peat is a complex function of the age, granularity and organic chemistry of the dried peat. Leachable fractions ranged from 40 to 85 percent and showed no consistent relation to total U content.

The entire peat core closest to the Hillsboro canal (0.3 km from the canal) and a surface sediment collected from a distributary canal contained anomalous concentrations of U in excess of 1.0 ppm. The AR of extracts from three selected depth intervals in the core and the sediment sample ranged from 0.97 to 1.03; within the narrow range that is permissive of a possible fertilizer origin. In contrast, peat samples from an unimpacted site in WCA-1A contained <0.2 ppm U and had AR values of 1.10 to 1.22 in their exchangeable fraction. These latter AR values are distinctly outside the narrow range of AR for fertilizer, but are well within the larger range of 0.9 to 3.0 that is typical for most surface and ground water.

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Two cores more distant from the Hillsboro canal (3.5 km and 8.3 km) also had anomalous U concentrations of >1.0 and >0.5 ppm respectively, and enrichment was confined to increasingly shallow surface horizons of <10 cm and <7 cm. The AR of extracts from three enriched samples was 1.03, 1.04 and 1.13, compared to values from deeper samples of 1.15, 1.19 and 1.22. The upper 36 cm of the core at ENR (cell 1, site 102) contained >0.4 ppm U, with values greater than 1.0 ppm confined to the upper 6 cm. The AR of two extracts was 1.02 (2-4 cm) and 1.04 (20-22 cm). A deeper horizon at 60-65 cm contained <0.2 ppm U and had an AR of 1.14. A peat core from a background site in WCA-3A showed a puzzling trend of enrichment of U with depth, suggestive of sorptive uptake from upwelling ground water. Uranium concentrations were <0.2 ppm at the surface and increased to 1.0 ppm at 30 cm depth. The AR of three extracts from this core ranged from 1.05 to 1.08.

Additional measurements of U and U isotopes in profiles from fertilized and unfertilized organic-rich soils south of Lake Okeechobee were performed to search for evidence of fertilizer-added U. Evidence of U enrichment in an historically fertilized field was confounded by similar, but more variable, background values of U in nearby unfertilized soil (0.2-0.9 ppm). Uranium concentrations in the upper 15 cm of the fertilized soil are relatively homogeneous with depth, consistent with periodic tillage. A strong positive correlation of U with ash content distinguished the fertilized soil from the nearby unfertilized soil, and this may indicate some association of U with insoluble constituents of fertilizer or other soil additives/fertilizer fillers. Isotopic evidence for fertilizer addition to the cultivated soil was also equivocal because the AR values of extracts from the fertilized soil and unfertilized soil were not significantly different (AR=1.03 to 1.05), and did not show sufficient contrast with AR values of fertilizer.

Hillsboro canal water collected in 8/96 near Belglade, Florida, carried a large component of agricultural drainage and had a U concentration of 0.3 ppb and an AR of 0.99, which is permissive of a fertilizer source. Additional water samples will be collected to investigate areal and temporal variability of AR in canal water and in surface water and ground water in ENR and WCA-2A. Future studies of peat cores should focus on further documenting a consistent relationship between high U content, fertilizer-like AR, and impact by nutrients, and contrasting this with data from unimpacted background sites.