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Florida Big Bend Coastal Research Workshop

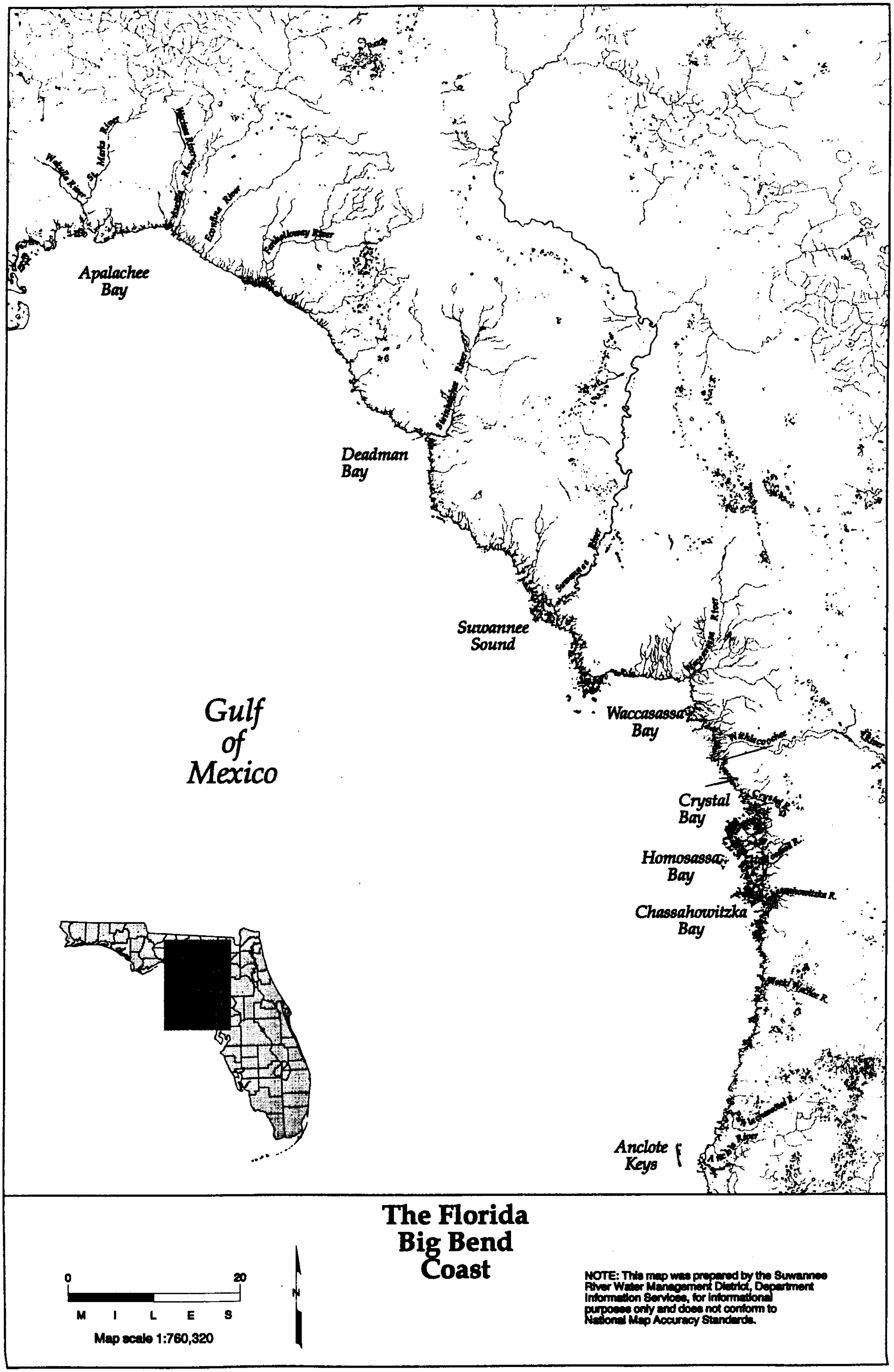
TOWARD A SCIENTIFIC BASIS FOR ECOSYSTEM MANAGEMENT

William J. Lindberg - Editor

PROCEEDINGS OF A MEETING HELD:

MAY 7-8, 1997

STEINHATCHEE, FLORIDA



Wakulla River
St. Marks River
Econfina River
Fenholloway River
Apalachee Bay
Steinhatchee River
Deadman Bay
Suwannee River
Suwannee Sound
Gulf of Mexico
Waccasassa Bay
Withlacoochee
Crystal Bay
Crystal R.
Homosassa Bay
Chassahowitzka R.
Chassahowitzka Bay
Weeki Wachee R.
Anclote River
Anclote Keys
The Florida Big Bend Coast
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NOTE: This map was prepared by the Suwannee River Water Management District, Department Information Services, for informational purposes only and does not conform to National Map Accuracy Standards.

Florida Big Bend Coastal Research Workshop

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PREFACE

The Florida Big Bend, which stretches roughly from Anclote Key to St. Marks along the Gulf of Mexico coast, is widely recognized as a pristine natural area in comparison to other coastal regions of Florida or, for that matter, the southeastern United States. Its relatively undeveloped character is evidenced by the several sanctuaries and preserves designated by state and federal resource agencies (e.g., the St. Marks Wildlife Refuge, the Big Bend Seagrass Preserve, the Lower Suwannee National Wildlife Sanctuary, and the St. Martins Marsh Aquatic Preserve Complex). Historically, the economy of this traditionally rural area has been based on abundant natural resources, particularly commercial fisheries and timber. The economic viability of commercial fishing, however, changed as a consequence of the Florida Net Ban Amendment of 1995, with some commercial fishers turning to alternatives such as clam culture. Over the past decade, business leaders in this six-county region began promoting the Big Bend as Florida's Nature Coast, with an emphasis on eco-tourism and recreational fishing. Population growth and associated development have been occurring in the region's most southern counties (i.e., Pasco and Citrus), and strong interests exist for economic development in the region's more rural counties to the north (i.e., Levy, Dixie, and Taylor). The challenge is inevitable; development will increase pressures on naturally productive ecosystems that must continue to function as the foundation for this region's economy.

The simultaneous needs for economic development *and* sustainable natural resources have been recognized, and State policy now mandates ecosystem management. The Nature Coast Ecosystem Management Area (EMA), established in 1996, exists largely through cooperative efforts of the Suwannee River Water Management District (SRWMD), the Florida Department of Environmental Protection (DEP), and the University of Florida's Department of Fisheries and Aquatic Sciences. Mr. David Fisk, Assistant Executive Director of SRWMD, provided the leadership for this initiative. The Nature Coast EMA includes the coastal plains of Levy, Dixie and Taylor Counties, and was the first EMA in Florida to also explicitly include the adjacent coastal ocean. Similarly, the DEP, with cooperation from other entities, established the Springs Coast Ecosystem Management Area to include the southern counties of the Big Bend. To the scientists involved in the process of establishing these EMAs, it became abundantly clear that a scientific basis for ecosystem management in the Big Bend did not yet exist, but was essential for the needs of this region.

Ecosystem management is very much in its infancy. Individual success stories are accumulating, but in many respects the jury is still out as to whether this policy will actually be more effective than natural resource policies of the past. For the ideal and potential of ecosystem management to be realized, the research community must have an objective voice. The inaugural Florida Big Bend Coastal Research Workshop was a forum for that voice, an opportunity for scientists from various disciplines and institutions to recognize their common ground. The intended audience was primarily active scientists with past and present research activity in the Big Bend, although other interested researchers and resource managers were certainly welcome to attend.

The Florida Big Bend Coastal Research Workshop had two primary objectives:

1. To define the state of scientific knowledge specific to the Big Bend by asking past and present investigators: to report research results and current activities in the region, and to identify from their individual perspectives the most obvious gaps in knowledge, the desirable links to related research, and the priority research needs for the region.

2. To foster the coordination of current research efforts, the integration of research results, and collaborations among investigators toward a more holistic scientific understanding of this relatively pristine and productive coastal system.

This two-day workshop was convened on May 7-8, 1997 with an overflow capacity of 70 people in attendance. The format was intended to stimulate collegial interactions among participants so that new dialogues would continue into the future. Mr. Ernie Barnett, Director of Ecosystem Planning and Coordination for the Florida Department of Environmental Protection, opened the workshop with an overview of ecosystem management and examples of its successful application. Invited speakers then gave 25-minute oral presentations over the next day-and-a-half. Topics ranged from regional geology, hydrology, and physical oceanography, as the template for biological and human systems, through wetland, estuarine, and coastal ocean biological systems, to the social and economic character of the region. On the evening of Day One, more than 15 scientific posters related to these topics were presented in conjunction with a social held prior to dinner. On the afternoon of Day Two, workshop participants discussed each topic in an open forum and then Drs. Larry Crowder and Bill Herrnkind, workshop rapporteurs, gave their summary comments and recommendations.

Speakers and presenters of posters were asked to submit abstracts or brief (1-3 pages) research summaries for this proceedings. For the convenience of the participants, no particular format was required. The purpose here is simply to convey the scope of research done in the Big Bend.

To a large degree, success of this first workshop can be attributed to its venue and timing. The Steinhatchee Landing resort at Steinhatchee, Florida was ideal for our workshop objectives. The Landing's colloquial setting provided a relaxed, collegial atmosphere. Mr. Dean Fowler, proprietor of The Landing, and his staff served attendees in the best southern tradition. The outdoor breaks, lunches, and evening social on the banks of the Steinhatchee River, and springtime strolls across this campus, gave ample opportunity for informal and spontaneous discussions. Screened verandas of individual cottages then hosted many after-hours conversations among participants. A more suitable place and time for bringing people together would be difficult to imagine.

Credit for the workshop purpose, organization, and scope belongs to the Organizing Committee members named on page **viii**. Credit for the implementation of that vision belongs to the invited speakers, the presenters of posters, the rapporteurs, and attendees – all of whom were active participants. Credit for making this first workshop possible belongs to the several sponsors, acknowledged on page **viii**, who provided both financial and in-kind support. The Florida Big Bend Coastal Research Workshop was a truly cooperative effort among individuals, institutions, and agencies. Such cooperation must continue and expand for the challenges before us to be met.

William J. Lindberg
June 6, 1997

The Florida Big Bend Coastal Research Workshop

May 7-8, 1997 - Steinhatchee, Florida

Workshop Sponsors

Florida Sea Grant College Program
Suwannee River Water Management District
U.S.Geological Survey, Florida Caribbean Science Center
University of Florida, Department of Fisheries and Aquatic Sciences

Organizing Committee

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Ken Sulak, U.S. Geological Survey, Florida Caribbean Science Center
Fred Vose, Florida Department of Environmental Protection, Cedar Key Laboratory

An Overview of The Big Bend Ecosystem

Robert Mattson[1]

The area of interest for this Workshop is geologically a carbonate platform developed over the last 25 - 30 million years, overlain by sandy sediment or organic peat of recent origin (within the last 100,000 years). The region has been submerged by higher sea levels several times during the Pleistocene epoch ($\leq$ 2 million years ago), as indicated by six relict marine terraces found in the region. The area has been physiographically classified as the "Big Bend Drowned Karst" region of the Gulf of Mexico coastline (1,2). Characteristics of this coastal region include "Rugged shoreline, rocky bottoms, very wide shallows area, clear water, extensive seagrass beds and marshes, high fish production, extensive oyster bars."(2)

The region has been described as a low or "zero-energy" coastline. The broad shallow submerged shelf off the coast (up to 160 km wide), coupled with prevailing storm winds from the north and east and the small fetch of the Gulf of Mexico, results in low wave and wind energy effects on the shoreline(3, 4). The area has also been described as a "sediment-starved" coast (5). The 15 rivers that drain to the region all carry very low sediment loads. Juxtaposed with this low wave energy environment is the generally higher tidal range along this coast, compared to other areas on the Florida Gulf Coast. Tide range at the Suwannee River mouth is about 1 meter, with a maximum during spring tides of about 1.2 m. This coastal region may also be characterized as an "estuarine realm"; a coastal area bounded by the sea on one side and freshwater inflow on the other side.

Fifteen river systems drain to the coast (see map on the inside front cover). The two largest, in terms of freshwater discharge, are the Suwannee River (mean annual flow 298.5 m^3/sec) and the Withlacoochee River (mean annual flow 40.8 m^3/sec). Flow and water quality characteristics of most of the rivers on this coast are affected by groundwater inflow from an extensive regional aquifer; the Floridan Aquifer System. Rivers in the northern portion of the region (roughly from Levy County, northward) exhibit peak flows in February-April. Rivers in the southern portion of the region exhibit August-September peak flow periods. All rivers in the region are very low gradient systems with primarily sand-bed channels, although many have outcrops of rocky bottom where they incise into the limestones of the Floridan aquifer.

The major intertidal ecosystem in the region is coastal marsh. Most of these marshes are dominated by black rush, *Juncus roemerianus* (5, 6). Associate plant species include, but are not limited to, smooth and marsh hay cordgrass (*Spartina alterniflora* and *S. patens*), saltwort (*Batis maritima*), glassworts (*Salicornia* spp.), and several other salt-tolerant taxa. Near the mouths of the major rivers (particularly the Suwannee), the coastal marshes include brackish and freshwater plants such as bulrushes (*Scirpus* spp.), sawgrass (*Cladium jamaicense*), giant reed (*Phragmites communis*) and big cordgrass (*Spartina cynosuroides*). The Cedar Key area, in Levy County, represents the northernmost limit of distribution of mangroves on the Florida Gulf coast, with scattered patches of freeze-stunted, scrubby mangrove (black mangrove; *Avicennia germinans*) occurring in protected areas. Small patches of mangrove are found in the counties to the south (Citrus, Hernando and Pasco), although coastal marshes are the major intertidal community in terms of areal coverage.

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[1] Information about the participants can be found in the *Directory of Workshop Participants* located at the end of this report.

Landward of the coastal marshes, a major forested wetland community type is hydric hammock (7). The Big Bend encompasses some of the most extensive areas of hydric hammock in Florida; major areas are found in the Gulf Hammock area in Levy County and the Tide Swamp area in Taylor County. These forested wetlands are characterized by periods of short but possibly deep inundation, and may be flooded several times during the course of a year. Species richness in the tree canopy may be among the highest in Florida forested wetlands, with 20 or more tree taxa typically found. Along the river corridors, river floodplains are vegetated with various types of bottomland hardwood swamp communities (8), including baldcypress-water tupelo, oak-hickory, and mixed forests with various evergreen and deciduous hardwoods. Most of the remaining areas along the coast appear to have been historically covered by various pine-dominated forests, ranging from wet and mesic pine flatwoods (dominated by pond pine, *Pinus serotina*, or slash pine, *Pinus elliotii*) to well draining sand hill ecosystems dominated by a canopy of long-leaf pine (*Pinus palustris*) (5). On relict dune ridges, xeric communities of sand pine scrub, xeric hammock (in inland regions), or maritime hammock (along the coast) may occur (5).

Major nearshore subtidal structural habitats include seagrass beds and oyster bars. The Big Bend encompasses the second largest seagrass area in the eastern Gulf of Mexico (9), covering an area of about 3,000 km^2. Five species of vascular plants are found in these beds: widgeon grass (*Ruppia maritima*), found in brackish areas around the river mouths; shoal grass (*Halodule wrightii*); turtle grass (*Thalassia testudinum*); manatee grass (*Syringodium filiforme*); and Engelmann's grass (*Halophila engelmannii*). A diverse assemblage of benthic macroalgae are often interspersed in these submerged aquatic beds, primarily representatives from the order Siphonales. Oyster reefs dominated by eastern oyster (*Crassostrea virginica*) are found around the river mouths, and provide refuge and forage habitat for large number of invertebrates and fishes. Oyster reefs also provide a harvestable economic resource in areas where water quality is sufficiently good.

Offshore regions include areas of deep seagrass beds (primarily dominated by *H. engelmannii*) and "hardbottom". These are natural rock outcrops which may support a live-bottom community comprised of sponges, soft corals (octocorallia) and other reef-associated invertebrates. Groupers, sea basses, grunts and other fishes occur around these habitats and are an important recreational and commercial fishery resource. Artificial reefs have been placed in these areas to provide additional hard-bottom habitat. Recent research has indicated that these structures can provide important habitat for juvenile reef fishes in addition to simply attracting fish (10).

Major human land uses in the Big Bend region include commercial forestry (producing fiber and wood), agriculture (row crop, dairy, beef, and poultry production, with some citrus in the southern portion of the area), and moderate levels of urban development (11). The highest level of urban/suburban development is in the southern portion of the region in Citrus, Hernando and Pasco counties and the inland counties of Alachua, Marion and Sumter. Industry includes tourism, forest products (pulp and sawmill facilities; primarily in Taylor and Dixie Counties), power generation (Citrus County), boat manufacturing (in Lafayette, Alachua and Citrus counties), commercial fishing (in all of the coastal counties), rock mining (most of the coastal counties) and trucking. The two major port facilities in the region are on the St. Mark's River, where oil barges and tankers are docked to offload petroleum products, and the Florida Power Corporation generating complex near Crystal River, which imports coal and fuel oil via barge. The coastal communities usually have a maintained navigation channel to permit access for recreational and small commercial boats. Major highway corridors in the region include U. S. Highways 19, 41 and 301 and Interstates 75 and 10.

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Physical Oceanography, Hydrology and Geology

SEDIMENTARY PROCESSES, GEOMORPHIC VARIABILITY, AND GEOLOGIC EVOLUTION OF FLORIDA'S BIG BEND COAST

Albert C. Hine, Daniel F. Belknap, Joan G. Hutton, Eric B. Osking, and Mark W. Evans*[2]

A major portion of Florida's Gulf of Mexico coastline is a siliciclastic, sand-starved, low-wave-energy system dominated by marshes that face the open sea. Because of its location at the center of an enormous (350,000 km^2), flooded, broad, flat, ancient carbonate platform, this coastline can be viewed as the margin of an incipient epicontinental sea.

Within a 65-km sector along this 300-km-long, open-marine marsh coast, four distinctly different morphological sectors have been identified: 1) berm-ridge marsh shoreline, 2) marsh peninsula shoreline, 3) marsh archipelago shoreline, and 4) shelf embayment shoreline. The underlying Paleogene limestone bedrock topography results from karstification and dissolution processes. This antecedent topography and the distribution of actively discharging freshwater springs affect sedimentary processes, facies, and stratigraphic units. The morphology and processes within the four coastal sectors vary as a function of a northerly decrease in the thickness of relict Pleistocene quartz-sand cover and an increase in the complexity and relief of the underlying bedrock topography.

Each of the four coastal sectors has a unique distribution of sedimentary products. In addition, each has responded differently to rising sea level - a process that continues to control the spatial distribution of organisms and sediments. However, the sedimentary lithosomes in all four coastal sectors share a similar fate during landward shoreline translation. Within the inner continental shelf, very little of the marsh stratigraphy or large oyster bioherms is preserved. Only those sediments that have accumulated within bedrock depressions or sinkholes have the best chance for long-term retention. Thus a condensed stratigraphic section is produced.

Since only thin and discontinuous sediment accumulations are preserved, the relief and texture of the bedrock surface due to chemical etching and bioerosion must also be used as clues to the recognition of similar coastal systems in ancient settings.

* From: Journal of Sedimentary Petrology, v. 58, p. 567-579

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[2] Information about the participants can be found in the *Directory of Workshop Participants* at the end of this report.

Hydrogeology of the Coastal Big Bend Portion of the Suwannee River Water Management District

Ron Ceryak and Frank Rupert[3]

The coastal Big Bend region is situated over a structurally positive subsurface feature named the Ocala Platform. Tertiary carbonate rocks lap onto and over this structure, locally forming a shallow Floridan aquifer system covered by a veneer of undifferentiated quaternary sands and clayey sands. The topography is characterized as a low, gently-seaward-sloping karst plain which is part of the Gulf Coastal Lowlands geomorphic zone. Land surface elevations near the coast are generally less than 25 feet above mean sea level (msl). At least 90% of the area within 10 miles of the coast is flood-prone.

The Floridan aquifer system is the sole aquifer present in the coastal portion of the District. In Taylor and southern Jefferson counties, the Oligocene Suwannee Limestone comprises the upper rock unit of the Floridan aquifer system. In Dixie and Levy counties, the Eocene Ocala Limestone is the upper unit. The upper surface of the limestone varies from approximately sea level to about 20 feet above msl 10 to 15 miles inland. Near the mouth of the Suwannee River, the top of rock is locally depressed as much as 30 feet below msl.

The District maintains groundwater level and groundwater quality monitoring networks. The density of wells in the groundwater levels monitoring network is about one well per Township and these wells are measured monthly. Within 15 miles of the coast, the water table in the Floridan aquifer system is generally less than ten feet below land surface except in the areas of extensive dunal sands. In this same area, the total fluctuation of the water table is 5 to 6 feet, while the average annual fluctuation is about 3 feet. In this unconfined portion of the Floridan aquifer system the groundwater level fluctuation is directly and immediately related to rainfall. Groundwater flow is toward the coast and this coastal zone is also a discharge area from the aquifer to the Gulf of Mexico. Deep, as well as shallow, flow paths converge near the coastline. Saltwater/freshwater interface conditions are presumed to be natural as there are no major pumping centers on this coast to create cones of depression.

The density of wells in the groundwater quality monitoring network is also about one well per Township. These wells are sampled every 3 years. However, in the past, these wells have been sampled monthly for up to 5 years to determine the temporal variability of the groundwater chemistry. The parameters that appear to be influenced by seawater are sodium, chloride and total dissolved solids (TDS). Sodium has the only Primary Drinking Water Standard among the three. The Maximum Concentration Level for sodium in drinking water is 160 mg/L. This value was exceeded in only one monitor well in Taylor County. On average, the values within a few miles of the coast are 25 mg/L or less. Chloride has a Secondary Drinking Water Standard of 250 mg/L. Only two coastal wells in Taylor County exceed this value and within a few miles of the coast the groundwater has 10 mg/L or less of chloride. TDS has a Secondary Drinking Water Standard of 500 mg/L. Groundwater along the Taylor County coast exceeds this value for a mile or two inland. Values of 300 mg/L or greater occur for about ten miles inland around the Steinhatchee and Aucilla river valleys. All of these conditions appear to be natural.

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[3] Information about the participants can be found in the *Directory of Workshop Participants* at the end of this report.

OBSERVATIONS AND MODELING OF THE WEST FLORIDA CONTINENTAL SHELF CIRCULATION

Robert H. Weisberg[4,5]

An understanding of the West Florida coastal zone requires an understanding of shelf-wide circulation. Recognizing the need for measurements and the systematic application of models, the Department of Marine Science, University of South Florida, in cooperation with the USGS Center for Coastal Geology, initiated a study in 1993 on the West Florida continental shelf circulation that continues through the present time. This shelf circulation study has expanded under MMS support to include partners from the Florida State University and the Scripps Institution of Oceanography. This presentation at the Florida Big Bend Coastal Research Workshop will highlight the work in progress, provide a case study of upwelling along Florida's west coast and offer some speculations on how the circulation may impact the biological resources of the Big Bend region.

The USE initiative set out to combine in-situ measurements, remotely sensed sea surface temperature imagery and numerical circulation modeling toward achieving the following objectives:

1) Develop a description of the seasonally varying circulation over the west Florida continental shelf.

2) Develop an improved understanding of how the various forcing functions: tides; synoptic weather systems; and surface, coastal, and offshore buoyancy fluxes affect the West Florida shelf circulation.

3) Determine how these processes, in combination, affect both the along- and across-shelf transports of material properties.

4) Determine the relative importance of the surface fluxes and the coastal ocean dynamics in the distribution of water properties on the west Florida shelf, particularly during the seasonal transitions.

5) Relate these physical oceanographic findings to questions of geological, biological and chemical importance.

Accomplishments to Date Include:

1) Deployment of a pilot mooring at mid-shelf to initiate a long time series and test mooring behavior.

2) Deployment of a trans-shelf array of moorings from the near shore to the shelf break.

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[4] Information about the participants can be found in the *Directory of Workshop Participants* at the end of this report.

[5] This article has been edited to fit the format of this report.

3) Development of a numerical circulation model of the West Florida continental shelf for use in Eulerian and Lagrangian studies of the large scale shelf circulation and smaller, regional scale studies.

4) Collected satellite SST images for interpretation relative to the moored and shipboard measurements and interact with SEAWIFS investigators once ocean color data become available.

5) Deployed a near shore array of moorings off Sarasota FL.

6) Collected hydrographic data on mooring deployment cruises.

7) Long-term currents monitored at mid-shelf

Related Projects

1) MMS supported in-situ measurements of currents using moored current meters under the direction of Dr. W. Sturges, Department of Oceanography, Florida State University.

2) MMS supported in-situ measurements of currents using surface drifters under the direction of Dr. P. Niiler, Scripps Institution of Oceanography.

3) MMS supported circulation modeling under the direction of Dr. Y. Hsueh, Department of Oceanography, Florida State University.

Note that the measurements of the related projects 1 and 2 covered a one year period beginning in February 1996. Limited moored measurements remain in collaboration with the USF work. Related project 3 is in the second year of a four year effort and is also collaborative with USF. Dr. Hsueh has implemented the Bryan and Cox MOM code.

Implications for the Big Bend Region

The Big Bend region of Florida's west coast, by virtue of its geometry relative the continental shelf, shows many unique circulation features, both on seasonal and synoptic time scales. For the same geometrical reasons, it is also a region that experiences relatively large storm surge. It also has relatively large sources of fresh water. Given the recent in situ measurements and model experiments, we can now begin to draw physically reasonable hypotheses on material property transports that may be of relevance to the rich assortment of biological processes known to be important within this region.

Appendix: Publications and Reports

Publications:

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Weisberg, R. H., B. Black and Z. Li and H. Yang (1997a). A case study of upwelling along the west Florida coast. (in preparation)

Data Reports:

Weisberg, R. H., B. D. Black, J. C. Donovan and R. D. Cole (1996). The west-central Florida shelf hydrography and circulation study: a report on data collected using a surface moored acoustic doppler current profiler, October 1993-January 1995. DMS-USF tech. rep., Jan. 1996

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HYDRODYNAMIC & ECOLOGICAL PROCESSES IN THE SUWANNEE RIVER COASTAL & ESTUARINE ECOSYSTEM

Y. Peter Sheng[6]

Introduction

This paper presents three research topics related to the Suwannee River Coastal & Estuarine Ecosystem. The ecosystem includes the Suwannee Regional Reef System (SRRS) (see Lindberg, this proceeding) which has shown significant increase in gag population in the past seven years. Suwannee River is the primary source of freshwater in this region.

A Preliminary Study on the Hydrodynamics in the SRRS

The first research topic deals with a preliminary study on the hydrodynamics in the Suwannee Regional Reef System (SRRS) sponsored by Florida Sea Grant through a DNR project (Sheng 1992). The study consisted of a two-month measurement of currents, waves, and water level at two locations in the vicinity of a reef structure at the southern end of the SRRS during February-March 1992. The results indicated that the near-bottom currents are definitely affected by the presence of the reef structure, while the waves are not significantly affected by the reef structure. Moreover, waves during the study period were found to be quite strong, with wave height up to 1-2 meters. Based on model simulation, it was found that sediments at the reef site could be resuspended during the study period. This suggests that sediment nutrients could be released into the water column during episodic events which occur quite frequently in the area. During the same time period, a field study in Tampa Bay (Sheng et al. 1993) showed clearly that resuspension of sediments and nutrients took place.

A Study on the Effects of Hydrodynamics on Baitfish Abundance

The second research topic deals with the effects of hydrodynamic processes on the phytoplankton and baitfish abundance at the SRRS. Performance of the SRRS has been found to be very successful during the past 5-6 years. Hence it is important to understand what enhanced the performance of artificial fishery reefs in SRRS. The project, which started in January 1997, aims to measure concurrently the hydrodynamics, sediment and nutrient concentrations, and fish abundance at the SRRS reefs. From the data to be collected in the summer of 1997 by Sheng, Phlips, and Lindberg, we will examine the relationships among the various hydrodynamic, sediment, nutrient, and fishery parameters to establish the possible causes for enhanced fish population.

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[6] Information about the participants can be found in the *Directory of Workshop Participants* at the end of this report.

A Regional Ecosystem Model for Impact Assessment

The third research topic deals with a recommended framework for a regional ecosystem model of the Suwannee River Coastal & Estuarine Ecosystem. Recent measurements by Lindberg found that the freshwater plume from the Suwannee River could reach the southern end of the SRRS, thus suggesting the important role of Suwannee River plume in delivering sediments and nutrients to support the SRSS. Due to increasing demand for freshwater in the Southwest Florida, it has been suggested that freshwater be withdrawn from the Suwannee River and transported to SW Florida via pipeline. To make a scientifically sound decision on freshwater removal, it is essential to fully understand the potential effects of freshwater removal on the Suwannee River Coastal & Estuarine Ecosystem. The model will link up various component models for hydrodynamic processes, sediment transport processes, nutrient processes, light attenuation, sea grass and marsh grass growths, and fish population dynamics. The model domain should include the Suwannee River Coastal and Estuarine Ecosystem and may be extended to included more GOM (Gulf of Mexico) water, as an existing three-dimensional circulation model by Sheng has been applied to the entire Western Florida Shelf. After careful calibration and verification of each component model, the overall integrated model can be used to assess the impacts of human actions (e.g., freshwater withdrawal) on the ecosystem. Such studies have been accomplished in some Florida ecosystems. For example, Sheng et al (1995) developed a coupled hydrodynamics-water quality-seagrass model for Roberts Bay and used the model to determine the response of water quality and seagrass biomass to nitrogen load reduction. Sheng (1997) has developed a similar three-dimensional fine-resolution model of the Indian River Lagoon and the offshore water. After the model is calibrated and validated with hydrodynamic, sediment, water quality, light, and seagrass data, the model will be used to determine Pollutant Load Reduction Goals for various watersheds of Indian River Lagoon.

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POSTER PRESENTATIONS

Quantification of Short and Long Term Accretion and Subsidence in Big Bend Coastal Wetlands, Florida

Hendrickson, J. C., Donoghue, J. F., Highley, A. B., Hoenstine, R. H., Ladner, L. J., Cahoon, D. R.[7]

Net elevation and accretion of the marsh surface have been quantified along Florida's Big Bend Coast in an attempt to determine the response of Florida's Gulf of Mexico coastal wetlands to rising sea level. Florida's coastal wetlands are essential economically, ecologically, and geologically to our state's well-being. Coastal salt marshes are nursery grounds for commercially important finfish, shellfish, and crustaceans. They act as sediment traps and also protect the coast from potentially damaging storms. Sea level rise of as much as 2 mm/yr. along the Gulf threatens to destroy these valuable resources. It is important to learn more about the nature and magnitude of this threat.

A cooperative agreement between the United States Geological Survey and the Florida Geological Survey, along with Florida State University has made it possible to make highly accurate measurements of net accretion and elevation changes within the coastal fringing salt marshes using a combination of measurement techniques. These data provide a quantitative basis for assessing the threat of rising sea level to Florida's coastal wetlands.

A variety of methods are used to measure marsh elevation, net vertical accretion, erosion, and compaction in the intertidal *Juncus Roemerianus* marsh of the Florida Big Bend coast. Two different types of Sediment Erosion Tables (SET) will be employed. First, a deep SET will be used to measure total elevation changes within the complete section of sediments that overlie the limestone in the study area. A shallow SET will be used to measure accretion/erosion within only the upper fifty centimeters of the *Juncus* marsh. Comparison between these two different SET measurements will provide information on compaction of the marsh sediments and on where it occurs within the sediment column.

Cryogenic cores are taken in addition to the SET data. The amount of sediments that have accumulated over a measured period of time can be quantified through cryogenic coring. These data complement the SET data and give information on absolute sediment accretion and erosion. Comparison between the SET data and the cryogenic core data give insight into the degree to which the various factors contribute to elevation changes within the marsh.

Lead-210 dating of sediment cores taken adjacent to SET stations (both intertidal and subtidal) quantify the average sedimentation rates in the area over the past century. Comparisons between the accretion data and the lead-210 data reveal the relation between current sedimentation and average sedimentation for the past century.

Using lead-210 alone, it is not possible to account for the compression of sediments in the marsh subsurface due to autocompaction of the organic-rich sediments. The shallow and deep SET measurements, in combination with the lead-210 data and the accretion data from the cryogenic cores allow for the measurement of sedimentation while providing a measure of sediment compaction.

Tide gauge records taken from stations at Cedar Key and Pensacola, Florida provide data on the average rate of local relative sea level rise for the Big Bend coast. Relative sea level rise data are ultimately compared to a value for sediment accumulation for each of the coastal fringing marshes in the study. Conclusions are then drawn addressing the original question of whether these coastal fringing

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[7] Information about the participants can be found in the *Directory of Workshop Participants* at the end of this report.

Juncus marshes are keeping pace with the local rise in sea level. This allows for predictions to be made concerning the relative health of Florida's coastal wetlands today and in the future.

The elevation data shows that the coastal wetlands of the Florida Big Bend are generally healthy and are not being destroyed by current sea level rise. It should be noted that the data in the study are short term values that are being compared to longer term values like sea level rise and average sedimentation rates determined using lead-210 dating. Continuation of the study will allow for the data set to lengthen and comparisons with the long term variables to be more meaningful.

Storm of the Century Makes Contribution to a Sediment-Starved Coastal Marsh

A.C. Hine, W.C. Quigley and P.R. Stumf[8]

On March 12-13, 1993, the passage of a severe extratropical storm, popularly referred to as the "Storm of the Century," resulted in the deposition of a storm-suspended sediments along Florida's west-central coastline. In Waccasassa Bay, surge waters near 3 m in height inundated the coast and transported resuspended, near-shore sediments onto the open-marine marshes rimming the embayment. The thickness of the resulting storm deposit reached 12 cm on the levees and up to 2 cm on the marsh surface, and visible sedimentation occurred several hundred meters from the creek banks into the marsh interior. The tan to gray storm layer was composed of mixed clays, silt to very fine sand-sized quartz, and marine biogenic sediments, all similar to those of the underlying marsh sediments.

Despite the evidence for severe storm conditions, this event was characterized further by the absence of shoreline erosion along the marsh coast. This condition contrasts with sandy coasts, where strong storms often result in shoreline erosion. As compared to sandy shorelines, the stability of this marsh-fronted coast is enhanced by the cohesive nature of the fine-grained marsh muds, baffling by the marsh-grass canopy, and sediment binding by plant root matrices. Locally, the Waccasassa Bay coastal system has developed under sediment-poor, sand-starved, and low-energy conditions, and large-scale storm events may be an important component in sediment-transport processes and marsh-surface accumulation. The response of the Waccasassa Bay system to this event offers a different view of storm-related shoreline effects and, in particular, the role that storms may play in long-term shoreline stability.

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[8] Information about the participants can be found in the *Directory of Workshop Participants* at the end of this report.

Holocene Stratigraphic Evolution of a Riverine Siliciclastic Coastline Overlaying and Eocenve Karst Limestone Platform: Suwannee River Marsh System, West-Central Florida

Eric E. Wright, Albert C. Hine, Lynn A. Leonard, and Steven L. Goodbred, Jr.[9]

Florida's sediment-starved Big Bend coast is typified by low-energy, open-marine marsh systems fringing spring-fed embayments. The Suwannee River represents the only major point source of sediment along this coastline. Originating in southern Georgia and entering the Gulf of Mexico at the center of the Big Bend coast, the partially spring-fed Suwannee River follows a narrow incised valley and produces a small river-dominated delta. Dominating the development of the nearshore regions, the Suwannee River fresh-water point source has allowed for the growth of ubiquitous oyster reefs and associated oyster biohermal basins.

Sixty-four vibracores and approximately 225 track-line kilometers of side-scan, high-resolution seismic and bathymetric data have been collected across the region, mainly in the nearshore but also up to 25 km offshore. The stratigraphy of the Big Bend coast is composed of thin, discontinuous siliciclastic sequence overlying the gently sloping karstic Florida limestone platform. In the Suwannee region, this siliciclastic sediment cover thins to exposed limestone at 7 m depth (15 km offshore). Away from the narrow river valley, the wide (3 km) marshes are accreting over freshwater swamps, Pleistocene eolian and riverine sands, and exposed Eocene limestone.

Core data reveal that the Holocene transgressive sequence was generated as marshes were submerged and replaced by a shallow marine setting. Offshore, barrier/shoal sand, tidal flat, nearshore muddy sand and oyster bioherm facies are recognized. River channel infill is composed of shell and coral fragments. Radiocarbon dates indicate that sea-level rise slowed at 4,000 ka and allowed salt marsh deposits and offshore oyster bioherms to build vertically. Sands ultimately filled the incised river valley producing the Suwannee's small siliciclastic delta.

This study indicates that Holocene deposition along the Big Bend coast has switched from transgressive to vertical accretion. As sea level has advanced over the karst limestone peneplain, a thin Holocene record is deposited with greater preservation potential in karst limestone lows and in the narrow Suwannee River valley.

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[9] Information about the participants can be found in the *Directory of Workshop Participants* at the end of this report.

CATION EXCHANGE CAPACITY AND NORMALIZATION OF TRACE METAL CONCENTRATIONS IN SEDIMENTS OF THE STEINHATCHEE RIVER ESTUARY, NORTH-CENTRAL FLORIDA.

Trimble, C. A., Ragland, P. C., Donoghue, J. F., Hoenstine, R. W., and Highley, A. B.[10]

The Steinhatchee River Estuary is a small relatively pristine bay located on the northwest Florida Gulf of Mexico coast. Sedimentary accretion rates within the system vary 1.4-4.1mm/yr based on Pb-210. Samples collected from 31 location, representing four sedimentary lithofacies, were analyzed for major and trace element content (ICP-AES), texture, total organic matter, clay mineralogy, and cation exchange capacity. Cation exchange capacity was determined by calcium exchange and weighing of excess salts. Two ICP extraction methods were evaluated: partial, aqua- regia digestion and total, hydrofluoric acid digestion.

The chemical and physical factors affecting the ability of a sediment to concentrate trace metals introduce uncertainty in distinguishing anthropogenic from naturally-occurring concentrations of many metals. The standard practice of normalization of metal concentrations assumes a linear relationship between either geochemical or sedimentological characteristics and the metal. The following standard methods were evaluated: granulometric normalization of metal concentrations against total weight percent fines; geochemical normalization against the reference elements (Al, Fe, and C); and normalization to sediment organic matter content. A new geochemical method, normalization against cation exchange capacity (CEC) was compared with accepted procedures.

The best correlations were found when trace metals were normalized with respect to Al. Aqua-regia partial leach was found to be as reliable, for most metals, as HF-total digestion. Normalized data indicated little evidence of significant contamination in this system. Exceptions included lead levels, which appeared to be significantly elevated in a few areas of the salt marsh. Mercury values were also elevated with respect to the expected trends in three locations. Potassium and phosphorous also appeared slightly elevated in several of the marsh sample. This may be due to the presence of nutrient loading from local communities, or application of these elements in fertilizers.

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[10] Information about the participants can be found in the *Directory of Workshop Participants* at the end of this report.

DEVELOPMENT AND USE OF SEDIMENT ASSESSMENT TECHNIQUES IN FLORIDA

Thomas L. Seal[11]

Introduction

In the areas of environmental protection, the issue of sediment contamination is not given as much attention as water quality, mainly because state and federal agencies do not have legally enforceable criteria for sediments. However, it appears that regulating the water column alone does not protect the entire aquatic ecosystem in many cases. For example, measurements of contaminants in the water column can show that concentrations are within state water quality standards, while concurrent measurement of the sediment reveals the site as contaminated. Nationwide, there has been an increased recognition of the role sediments play in maintaining healthy aquatic ecosystems. In addition to providing important habitats for organisms, sediments play a role in the fate of virtually all environmental contaminants. Sediments link chemical and biological processes in benthic communities by providing essential habitat for spawning, incubation, and other biological processes. Direct contact with or ingestion of contaminated sediments may affect the health and behavior (feeding/burrowing) of benthic organisms. As contaminants accumulate in these organisms, subsequent bioconcentration may occur if the contaminants are transferred to consumer organisms such as fish, birds, and humans. Elevated levels of contaminants have been observed in fish and wildlife from many locations of the country, and concern over the risk of consuming seafood and fish has increased public awareness of the issues of coastal pollution. Of equal importance is the issue of contaminants affecting the structure of coastal ecosystems for all species, not just the commercial species.

On both the national and state level, development of sediment regulatory criteria has been a slow process, in part because scientific experts do not agree on a method for sediment criteria development. The Florida Department of Environmental Protection (FDEP) is presently assessing the issue of sediment contamination and attempting to decide what is the best course of action. Discussion of this topic is prompted in part because Florida's coastal areas are expecting population growth rates of over 30 percent in the next 20 years. This growth will likely result in increased discharges of contaminants and nutrients into coastal systems despite pollution control efforts by state and local governments. For Florida, protection of coastal ecosystems is paramount because of the impact on the ecological as well as economic health of the State.

Recognizing the need to answer sediment contamination questions <u>today</u>, FDEP developed two tools to assist in the area of sediment management, that is, until criteria can be developed. To assess sediment quality with respect to biological effects, FDEP published numerical Sediment Quality Assessment Guidelines (SQAGs). The SQAGs identify sediment concentrations ranges predicted to coincide with minimal-, possible-, and probable-biological effects. SQAGs currently exist for 34 contaminants, ranging from metals to organic

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[11] Information about the participants can be found in the *Directory of Workshop Participants* at the end of this report.

contaminants. To identify sediments contaminated with metals such as lead and zinc, FDEP developed a statistical tool based on normalization of metal concentrations to a reference element (aluminum). The metal to aluminum tool, as it is commonly described, does not predict biological effects; however, when used in tandem with the SQAGs, it provides guidance for identifying contaminated sediment management priorities.

The Problem

Recent sediment chemical measurements indicate that contaminants are present at elevated levels in a number of coastal areas of Florida (Seal *et al.*, 1994). Florida freshwater and coastal waters receive metals and organic contaminants from a variety of sources, including natural contributions from rivers and streams, direct discharges of treated effluent from sewage treatment facilities, industrial and mining point sources, and non-point sources such as urban stormwater runoff, agricultural runoff, and atmospheric deposition. While sediment data provide information on the nature and extent of contamination, they do not provide direct measurement of adverse biological effects or indicate potential for such effects. Biological effects-based sediment testing can answer this question, but the expense and complexity of such tests prohibits most managers from evaluating sites for potential problems. Recognizing this deficit, the FDEP sediment management group decided that sediment evaluation tools were needed to evaluate the potential for biological effects associated with sediment-sorbed contaminants.

Sediment Metal Data Interpretation

With respect to metals contamination, all metals are naturally occurring. Therefore, sediment monitoring programs must distinguish between what may be present in the environment naturally versus what has been added by human (anthropogenic) activities. Metals enter surface waters during weathering of minerals that contain these elements. Air deposition is another pathway for metals to enter aquatic systems. To distinguish anthropogenic enrichment from natural metal concentrations in sediments, a mathematical method known as normalization is used. Normalization is simply defined as a method where constant natural chemical relationships are detected and used as a basis for comparison. The normalization method has been used in other parts of the country with favorable results (Goldberg *et al.* 1979; Trefry *et al.* 1985; Windom *et al.*, 1989; Loring 1991). Hanson and Evans (1991) published a trace metal enrichment aluminum normalization model based on a NOAA coastal sediment database of sites in the Atlantic and Gulf of Mexico coastal areas. Similar approaches using iron as a normalizing element were developed by Trefry and Presley (1976) to evaluate metal concentrations in sediments from the Gulf of Mexico and by Zdanowicz (1991) to evaluate anthropogenic metal enrichment by offshore dumping of contaminated sediment and sewage sludge.

The metal-to-aluminum normalization method, described in the FDEP publication *A Guide to the Interpretation of Metal Concentrations in Estuarine Sediments*, was based on a "clean" background sediment database. Over 100 sites were selected throughout the state for inclusion in the clean database, based upon their remoteness from known anthropogenic metal sources. At these sites, sediment metal concentrations correlate positively with aluminum concentrations. Eight metals (As, Cd, Cr, Cu, Hg, Pb, Ni, and Zn) were tested to determine their relationship to aluminum. Based on the relationships between seven of the eight metals (excluding mercury) and aluminum, the FDEP developed a graphical tool to assess trace metal contamination in a sediment sample. Simply put, as aluminum concentrations in clean sediments increase, all metal concentrations increase. Mercury does not significantly covary with aluminum concentrations in the clean data set. To quantify the amount of mercury contamination, the maximum concentration of mercury observed in the clean data set, $0.21\ Tg \cdot g^{-1}$ (210 ppb), was selected to represent the background value for natural mercury concentrations.

Least squares regression analysis, using aluminum concentration as the independent variable (X axis) and the concentration of the other metal as the dependent variable (Y axis), was employed to calculate the best fit regression line. Next, 95 percent prediction limits were calculated and drawn parallel to the regression line to define a field of naturally occurring metal values. If a metal concentration falls above the upper 95 percent limit, the sample is designated as enriched in that metal. The enrichment factor, defined as the ratio of the measured metal concentration to its maximum expected concentration in natural sediments, is used to compare different geologic regions of the state with a single evaluation tool.

The metal to aluminum tool requires use of a total digestion technique of the sediment, which employs hydrofluoric (HF), nitric (HNO_3), and a strong oxidizing acid. Total digestion of the sample is necessary because repeated studies have shown that aluminum recovery is low with other digestion procedures. Most commercial labs do not conduct total digestion procedures. Laboratory procedures in quality assurance plans and contract scope of work documents should contain a total digestion requirement. Question the laboratory manager to ensure standard reference materials are analyzed (e.g., NIST-SRM 1646 estuarine sediment standard or the NIST-SRM 2704 Buffalo River standard) to insure accuracy of data from your own samples. The use of reference materials provides the only means of judging analytical accuracy because it allows assessment of digestion efficiency as well as instrument calibration. Intercalibration laboratory exercises (Loring and Rantala, 1988; Schropp, 1992) illustrate the variability of sediment data from different analytical laboratories when there has not been an attempt to run analyses with total digestion procedures.

Florida Sediment Quality Assessment Guidelines

To identify a procedure for deriving sediment quality assessment guidelines (SQAGs), the major approaches used in other jurisdictions to derive sediment quality guidelines were evaluated in the context of Florida's requirements. The results of this analysis indicated that the approach used by the National Status and Trends Program, a research arm of the National Oceanic and Atmospheric Administration (NOAA), would provide a basis for addressing Florida's immediate need for reliable SQAGs (MacDonald 1994). Using this strategy, data derived from a wide variety of sediment biological evaluation methods were assembled and evaluated to derive SQAGs for 34 priority contaminants in Florida coastal waters, including metals, polynuclear aromatic hydrocarbons (PAHs), pesticides, and polychlorinated biphenyls (PCBs). As more sediment toxicity studies are completed in the future, more guidelines can be calculated, and any existing guidelines can be refined. The numerical SQAGs define three ranges of concentrations for each contaminant: a probable-effects range; a possible-effects range; and a minimal-effects range. Contaminant concentration ranges were considered to be more effective assessment tools than single numerical guideline values. The SQAGs are published in a four volume set which is available from FDEP upon request.

The SQAGs should be applied with care and in concert with other assessment tools, such as the FDEP metal-to-aluminum interpretive tool and various bioassessment techniques. After screening sediment chemistry data, priorities can be established with respect to sediment quality management. They should not be used in lieu of water quality criteria, as waste cleanup targets, or as stand-alone sediment quality criteria. In addition to the guidelines themselves, there is some follow-up actions needed in this area of environmental protection. Recent results of Florida sediment toxicity studies should be used to increase the number of substances covered by the SQAGs and strengthen their applicability and defensibility. Since 1991, FDEP and NOAA staff have conducted a series of sediment toxicity surveys in Florida estuarine systems (Tampa Bay, Pensacola Bay, Choctawhatchee Bay, St. Andrew Bay, Apalachicola Bay, and Biscayne Bay). The results of these assessments have and will be published by NOAA over the next few years.

Conclusion

It is apparent that to move to the next step of sediment criteria development and department rulemaking would be premature at this point, especially since EPA does not yet have any national sediment criteria. However, the issue of sediment contamination periodically resurfaces. For example, the issue of protection of benthic habitats has been a topic of discussion in recent FDEP staff meetings concerning a proposed change in state water quality standards for certain trace metals. Development of criteria for sediment contaminants has been a slow process, on both the national and the state level. In 1994, the United States Environmental Protection Agency (EPA) released, in draft form, five criteria for sediment contaminants based on an equilibrium partitioning approach. All five are organic compounds (two pesticides and three PAHs). The EPA has encountered various levels of resistance to this method of criteria development from a number of agencies, ranging from the Army Corps of Engineers to FDEP. The process of setting national sediment standards will be long and difficult, as attested by the fact that EPA has been examining this issue for over six years. To briefly summarize, the Department's position is that the five EPA criteria, as they stand, would not be protective of organisms that utilize sediments.

An important step in this area of environmental protection is to confirm with additional field studies the Florida SQAGs. Since the SQAGs are derived from a database that contains sediment bioassay data, the more organisms, and life stages of these organisms, that are studied, the greater the level of confidence that can be placed on Florida's sediment quality assessment guidelines.

COASTAL RIVERS AND WETLANDS

SOILS, CARBON, AND SULFUR DYNAMICS OF FLORIDA BIG BEND COASTAL WETLANDS

Y.P. Hsieh and C.L. Coultas [12]

A. Soils

The wetland Ecology Program at FAMU was started in 1967. The first research project was carried out by Dr. C.L. Coultas and students in the soil science program. Earlier studies consist of morphological, physical and chemical characteristics of the tidal marsh soils, vegetated with *Juncus roemerianus*, in Wakulla County, Florida. Upon receipt of more funding, we expanded the soil studies to include all of the Big Bend, and the Apalachicola Delta southward to Pasco County. We also studied productivity of the marsh plants and related this to certain soil characteristics.

We have found seven Great Groups of soils in the inter-tidal marshes: Sulfaquents, Sulfihemists, Psammaquents, Medisaprists, Haplaquods and Ochraqualfs. To illustrate the relationship among four Great Groups of soils, position and vegetation, two transects in the area of Dallus Creek in Taylor County can serve as examples. As in much of the Big Bend, the tidal amplitude in the area of Dallus Creek is about 1 m. The usual zonation, except in areas with high fresh-water input, the lowest positions are occupied with *Spartina alterniflora* follow by a large area of *Juncus roemerianus* (low and middle marshes) and often a "salt barren", which marks the mean high tide level. Above the salt barren is another band of *J. roemerianus* (high marsh) before reaching the forested uplands. On both transects at Dallus Creek, Sulfaquents occur at the lowest elevations. On one transect, *J. roemerianus* occurs from the sea to the uplands with Psammaquents in middle marsh and Haplaquods (drowned upland soils) in high marsh. On another, *S. alterniflora* occupies a large area primarily on Sulfaquents, but extending up to a tree island where the soils are Haplaquods.

The soils along these transects are near neutral in pH but become more acidic upon drying. This is especially true with the Sulfaquent where upon drying, pH drops from 6.3 to 3.1 in the A_{12} horizon. Electrical conductivity is primarily in the range of 30 to 60 mmhos/cm. The Sulfaquent has the highest conductance and the conductance decreases with depth in all soils. Total S ranges from a high of 6.79% (by wt.) in the Sulfaquent to 0.05% in the Haplaquod. Cation exchange capacity (CEC) is highest in the Sulfaquent (26 to 76 meq/100g in the A horizon). Calcium is the predominant cation in all soils. Total N and C are highest in the Sulfaquent. Nitrogen ranges from 0.49% in the lower A horizon to 1.17% in the A_{11} and organic C ranges form 11.6 to 16.1% in the A horizon. The Psammaquent and Haplaquod are composed primarily of sand while the Sulfaquent contains relatively high levels of clay in the a horizon grading to sand with depth.

Tidal marsh soils have many properties in common. They are wet, saline, near neutral in pH, highly base saturated, and have a relatively high N, OC, S content especially in the low marshes. Soils can be divided into two groups depending on their elevations, drowned upland soils in the high marshes and recently deposited soils in the low marshes.

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[12] Information about the participants can be found in the *Directory of Workshop Participants* at the end of this report.

B. Carbon and Sulfur Dynamics

Our research efforts have been focus on dynamics of carbon and sulfur cycles in recent years. Following are results of some of our current studies:

1. The bomb "^{14}C" method for carbon cycle dynamics: A new tool for the study of ecosystem carbon dynamics was developed (Hsieh, 1992a; 1993; 1996a). Turnover times of most ecologically significant carbon pools are less than a few decades which can not be determined by the traditional carbon dating method. We developed the bomb "^{14}C" signature method which takes the advantage of the bomb "^{14}C" in the atmosphere since 1956 to trace some important carbon pools in soils and sediments. The method is much simpler and versatile in the study of carbon dynamics in wetlands.

2. Net above ground primary productivity (NAPP) of coastal marshes: Uncertainty of NAPP in coastal marshes has been a problem of carbon and nutrient cycling study in coastal marshes. We have developed a simple and objective method to study NAPP (Hsieh, 1996b). The results of our study confirm that NAPP generally increases from landward (high marshes) to seaward (low marshes). The NAPP of high marshes are generally underestimated by other methods because the higher rates of marsh plant turnover.

3. Net below ground primary productivity (NBPP) of coastal marshes: We just started to tackle this problem (If you think study NAPP is difficult, try NBPP.) First, we have developed a dissolved organic carbon (DOC) method for the determination of living roots in marshes (Hsieh, 1992b). Second we use the bomb "^{14}C" signature method to determine the turnover time of dead roots. By knowing the turnover time and the size of dead roots, we can calculate the NBPP and the associated carbon and nutrient cycling. NBPP probably is more important than NAPP in driving carbon, sulfur and nutrient cycles in coastal wetlands.

4. C, N and P sequestration in coastal salt marshes: Formation of coastal wetlands resulted in sequestration of organic carbon and nitrogen in sediments. Phosphorus, on the other hand, has not been sequestered.

5. Net primary production (NPP), soil organic matter (SOM) formation and Dynamics of C, N and P cycles: SOM in a coastal marsh is the result of a feedback relationship between NPP input and SOM decomposition (Hsieh and Weber, 1984). Simulation modeling of an Apalachicola sawgrass marshes indicate that the carbon, nitrogen and phosphorus would reach an equilibrium in 30-50, 40-60 and 60-80 y, respectively, if landscape is relatively stable during the period of time (Hsieh, 1988).

6. Sulfate reduction in tidal marshes: Dissimilatory sulfate reduction is a major biogeochemical process in a coastal marsh. Sulfate is being used as an electron acceptor in the respiration of the sulfate reducing bacteria. Probably 60-90% of the organic carbon in a tidal marsh is oxidized by sulfate reduction. We study the effects of marsh vegetation on the sulfate reduction rates, accumulation and oxidation of sulfate reduction end products in tidal marshes (Hsiehand Yang, 1997). The accumulation of pyrite, i.e., the end product of sulfate reduction in marshes, in the tidal marshes of Florida is limited due to the lack of iron source of the sediments. We developed diffusion methods for the separation and determination of reduced sulfur species in sediment (Hsieh, 1989; Hsieh and Shieh, 1997).

7. Sulfate reduction and trace metal retention in coastal wetlands: The direct product of dissimilatory sulfate reduction, i.e., hydrogen sulfide, can form insoluble metal sulfides when trace elements are available. Sediments of coastal marshes, therefore, may preserve records of trace metal pollution in the past. Sediments of coastal marshes may also serve as a media to sequester trace metals in the polluted coastal waters. We have initiate studies to investigate those effects. Preliminary data suggest that salt marsh does retain trace metals. Different trace metals have quite different behavior in the formation of metal sulfide in salt marshes.

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WHAT MAKES BIG BEND SALT MARSHES UNIQUE?

Clay L. Montague[13]

The Big Bend coast (Wakulla to Pasco Counties), which accounts for only 17% of Florida's coastline, has 41% of Florida's intertidal marsh. This marsh is unusually heavily dominated by *Juncus roemerianus* (black needlerush) rather than *Spartina alterniflora* (smooth cordgrass), which dominates U.S. East coast salt marshes. In addition, the region is the northern-most limit of mangroves. Unlike the rest of Florida's coast, the Big Bend region is very undeveloped. Most research on marsh production, functions, and relationships with adjacent land and water, however, has been done on East coast marshes. How do Big Bend marshes compare? Why should they be similar? Can results from marshes elsewhere be sufficient for decisions that affect marshes and the economy? Characteristics of the Big Bend which make salt marshes there unique are:

- Very flat topo-bathymetric slope and a relatively large tidal range creates a vast intertidal area.
- Long, shallow shelf and the parabolic bend amplifies and focuses the small tidal range of the open Gulf to 75 cm, or so.
- Average 4-5 days per year below freezing is right at the biogeographic limit of mangroves.
- Little wave energy, so marshes extend to open water.
- Wide shallow shelf allows frequent strong winds to affect water level, increasing the range by perhaps 25 cm, but also causing irregular flooding. Irregular flooding may lead to dominance by *Juncus roemerianus* instead of *Spartina alterniflora*.
- Karst topography on land, with probable groundwater seepage through the intertidal zone; moderate river discharge (500 m^3/s, 40% of the Panhandle flow), but river discharge spreads widely alongshore directly into the Gulf, rather than behind a series of barrier islands.
- Groundwater and surface water discharge make the intertidal water fresher than in any other region of Florida's coast. Lower salinity may favor *Juncus roemerianus*.
- Sediment is in short supply. Rivers carry little sediment (109,000 tonnes per year, less than 10% of the Panhandle sediment discharge). Sediment in Big Bend marshes is mostly organic, incompletely decomposed, marsh detritus. Major storms can transfer fine shelf sediments to marshes, but without a supply of sediment, the coastal band of marshes will move inland as sea level rises and become narrower as the band approaches steeper slopes near higher ground.
- The Big Bend counties are the least populated and least economically developed coastal counties in Florida (Table 1), and this is unlikely to change because of so little high ground.

Conclusion: the unique Big Bend marshes are a consequence of a singular combination of geomorphology, climate, and river discharge. Nearly flat topography allows a large intertidal zone, and accounts for higher tides, wind driven water levels, reduced waves and surf, and low economic development. The bend itself amplifies tides. The number of days below freezing is just at the tolerance limit of mangroves. Surface- and groundwater discharge maintains relatively low salinity in the

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[13] Information about the participants can be found in the *Directory of Workshop Participants* at the end of this report.

intertidal zone, favoring certain species over more common dominants in other places. How do these differences affect the what is known of the functions and values of estuarine marshes?

Needed Research: The unique band of *Juncus roemerianus* marshes in the Big Bend may be maintained by irregular flooding and groundwater seepage. Both factors have been proposed, but not tested as determinants of the dominant marsh plant. *Juncus roemerianus* marshes have received little attention in the literature compared to the *Spartina alterniflora* dominated marshes of the eastern seaboard. The functional similarity can be challenged, so long term protection of these areas would benefit from studies of: a) use of marsh creeks by juvenile fish and invertebrates of commercial and recreational value; b) energy flow, especially the transfer of production to fish, birds, and invertebrates that feed in marsh creeks; c) removal of nitrate from groundwater seepage through the intertidal zone before it reaches the water over seagrass beds; d) exchange of nitrogen, phosphorus, and organic carbon with adjacent waters; and e) reduction of storm surge and erosion.

Table 1. Although Florida's coastal development far outweighs inland development, the Big Bend region (Wakulla to Pasco Counties) is quite the opposite. Compare the percentages given below to the first one (land area).

Statistic	Coastal / Florida (%)	Big Bend / Coastal (%)
Land area	57	19
Defense department expenditures	73	2
Commercial & industrial waste discharge	74	12
Pleasure boats	74	7
Tourism industry employees	75	3
Value added by manufacturing	77	3
Population	77	6
Total personal income	80	3
Mosquito control funds	85	10
Commercial boats	86	12
Municipal waste discharge	87	2
Coastline Length		17
Intertidal marsh and mangrove		17
Intertidal marsh		41

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RIVER DRAINAGES AND THEIR CHARACTERISTICS

Robert A. Mattson , Michael S. Flannery[14]

Fifteen major stream drainages convey freshwater to the Big Bend/Springs Coast region. In the Big Bend, these are the St. Mark's, Aucilla, Econfina, Fenholloway, Steinhatchee, Suwannee and Waccasassa rivers and Spring Warrior Creek. Along the Springs Coast the principal drainages are the Withlacoochee, Crystal, Homosassa, Chassahowitzka, Weeki Wachee, Pithlachascotteeand Anclote rivers. The Suwannee is the largest drainage system in the Big Bend (drainage area over 25,000 km^2; mean annual flow 298.5 m^3/sec) and the Withlacoochee is the largest drainage on the springs coast (drainage area about 5,320 km^2; mean annual flow 40.8 m^3/sec). Seasonal flow characteristics differ north and south of the Waccasassa River, along a "Climatic River Basin Divide". Streams of the Big Bend north of the divide exhibit peak flows during February-April and low flows in May-June and October-November. Streams south of the divide along the Springs Coast exhibit peak flows during August-October and low flows in May-June. These flow characteristics derive from seasonal changes in rainfall and evapotranspiration.

The hydrologic, chemical and ecological characteristics of streams in the region are heavily influenced by the underlying geology. The larger streams of the Big Bend derive much of their flow from surfacewater runoff during periods of higher rainfall. The channels of all these streams intercept the potentiometric surface of the underlying Floridan Aquifer System as they approach the coast, receiving some or a major portion of their base flow from the aquifer. For example, the annual 90% exceedence flow of the Suwannee River is 136.4 m^3/sec which equates to about 57% of its 50% exceedence flow (238.6 m^3/sec). Some stream systems along the Springs Coast derive almost no flow from surface runoff and are fed entirely by groundwater inflow from the Floridan Aquifer via large springs, such as the Crystal, Homosassa, Chassahowitzka and Weeki Wachee rivers. These rivers flow through a sediment-poor karst terrain characterized by widespread coastal wetlands overlaying a broad limestone shelf.

The Withlacoochee River (the northernmost major stream on the Springs Coast) is similar to the Big Bend streams, in that it receives flow from both groundwater discharge and surfacewater runoff. The Rainbow Springs/River complex contributes an average of 20.6 m^3/sec to the Withlacoochee about 39 km upstream from its mouth. Downstream of Rainbow River, the physical characteristics of the Withlacoochee have been affected by Lake Rousseau, a 16.8 km^2 impoundment constructed in the early 1900's for hydroelectric power. In the 1960's it was was intended for this reservoir to be a component of the Cross Florida Barge Canal (now decommissioned) and a 13.4 km stretch of the canal was excavated between Lake Rousseau and the Gulf of Mexico. Prior to 1970, all water discharged from Lake Rousseau flowed to the 18 km channel of the lower Withlacoochee. Since that time, high flows from the reservoir, equivalent to 36% of its total outflow, are diverted down the barge canal.

In the middle of the Springs Coast four unique spring-fed river systems flow to the Gulf: the Crystal, Homosassa, Chassahowitzka, and Weeki Wachee rivers. These are all very short, and with the exception of the Weeki Wachee, tidal water level fluctuations occur at the headwater springs. Estimated average flows range from 4 m^3/sec for the Chassahowitzka River to 27.8 m^3/sec for the Crystal River. These rivers and smaller isolated springs create a large estuarine zone along the springs coast. Although various flow estimates have been made in the past, flow measurements in these rivers are generally difficult because of

[14] Information about the participants can be found in the *Directory of Workshop Participants* at the end of this report.

the tidal nature of the rivers and their braided coastal channels. Improved flow estimates are a major management priority for these rivers, as trends in freshwater flows could potentially result from climatic cycles or increased groundwater development in the region.

In both the Big Bend and Springs Coast, a major management issue involves the determination of minimum flow regulations that establish withdrawal quantities that can be obtained from these streams without causing significant ecological harm. Several minimum flows studies have been conducted in the region, while other important studies are presently underway or are being scheduled for the near future. Minimum flow studies can be quite broad in scope and account for physical, chemical and biological processes in both freshwater and estuarine regions.

Many of the stream systems in the region have been mistakenly classified as "blackwater" streams, principally due to the high levels of color exhibited during higher flows. Although many of these streams, particularly from the Withlacoochee River northward, always exhibit some color, chemically, most are more similar to "calcareous" or spring influenced streams because of inflow of groundwater from the Floridan and also because the channels lie embedded within the underlying limestones of the region. Conductivities of the Big Bend streams average between 189 and 352.8 micromhos/cm; pH levels are circumneutral to alkaline (≥ 7), indicating a high degree of influence of mineralized groundwater inflow on surfacewater chemistry. Although they receive very little surface water inflows, the salt content of waters flowing from many of the springs in the Crystal, Homosassa, and Chassahowitzka river systems can vary between wet and dry seasons as the transition zone between brackish and fresh waters in the Floridan aquifer migrates seasonally in response to changing groundwater levels. Since excessive groundwater withdrawals could cause this transition zone to move inland, a management concern involves potential increases in the salinity of water flowing from these springs that could jeopardize freshwater communities presently limited to short river reaches near the headwater springs.

The groundwater influence on the water quality of the Big Bend/Springs Coast drainages is manifested through the estuarine portions of these rivers into the Gulf. Compared to estuaries dominated by large rivers with substantial sediment loads, estuaries associated with these rivers are generally characterized by high water clarity and low levels of turbidity. In turn, much of the biological production in these systems is associated with benthic environments, particularly submersed plant communities. The "Big Bend" seagrass ecosystem (which encompasses 3,000 km^2 in the entire region) is the second largest area of seagrass in the eastern Gulf of Mexico. A management issue identified in recent years has been increasing trends in nutrient concentrations in the springs dishcharging to many of the rivers, particularly nitrate nitrogen. Concerns have been raised that increasing nutrients are contributing to increased algal growth and reduced water clarity that may be impacting submersed plant communities. Nitrogen sources in the groundwater basins of the rivers are being identified to develop watershed management strategies to address this issue. Also, because the river corridors are attractive to waterfront development, the localized effects of stormwater runoff and septic tank leachate are major concerns.

The lower reaches of all streams are characterized by extensive floodplain areas with forested wetlands. Many of these may be flooded annually during high flows, and thus the streams and downstream estuarine areas may be regarded as highly "interactive" with these floodplains, which provide dissolved and particulate material used in riverine and estuarine food webs and serve as seasonally available aquatic habitat. Because the topography of this coast is so flat, increasing sea levels, or excessive water withdrawals for human use, may result in increased salinity intrusion, which would affect freshwater wetland and floodplain plant communities associated with the region's rivers.

Important stream habitats include woody debris (snags), which has been shown to be important loci for biodiversity and secondary production in southeastern coastal plain streams. The spring-fed stream systems are characterized by beds of submersed aquatic vegetation, which have been shown to provide important habitat and sources of primary production. A major management concern in rivers of the springs coast is the increase in exotic plants, particularly *Hydrilla verticillata*. This aquatic weed has replaced native plants, particularly eelgrass (*Vallisneria americana*), in many of the spring-fed rivers. *Hydrilla* experiences large natural changes in seasonal biomass, and periodic die-offs of *Hydrilla* can result from increased salinity caused by storm tides from the Gulf. Also, because of the problems it poses to fishing and recreation, *Hydrilla* infestations are often controlled with herbicides. As a result, nutrient fluxes associated with *Hydrilla* populations may be much greater than with the more stable *Vallisneria*, contributing to nutrient releases and impacts to water quality.

Riverine benthic algal communities consist of macrophytic green and blue-green algae and periphyton communities of diatoms, green algae, and blue-green algae. Reported increases in filamentous blue-green algae (e.g. *Lyngbya* sp.) in many of the spring-fed rivers is a management concern. This suggested increase is difficult to quantify, and it is not clear whether this may be a natural phenomenon, a result of increasing nutrient loading to the rivers, or nutrient turnover caused by changes in aquatic plant communities. Benthic invertebrate communities consist primarily of aquatic insects, molluscs and crustaceans, with the latter two groups being numerically more dominant in the more spring influenced streams. Fish communities in most streams are characterized by sunfishes (*Lepomis* spp.), bass (*Micropterus* spp.), bullhead catfishes (Ictaluridae) and minnows (Cyprinidae).

Land cover in the northern portion of the region consists primarily of agriculture (14.8 %), commercial forestry (30.3%) and wetlands (26.7 %), with low amounts of urban development and industrialization. In the southern portion of the area, land cover consists primarily of agriculture, wetlands and residential development . This area is somewhat more urbanized, with residential and commercial development concentrated along the U.S. 19, U.S. 41, U.S. 27, and Interstate 75 corridors.

POSTER PRESENTATIONS

Determination of Long-Term Change in the Big Bend Tidal Wetlands: Landscape-Scale Ecosystem Evaluation with Satellite Imagery

Ellen A. Raabe and Richard P. Stumpf [15]

The U.S. Geological Survey, St. Petersburg, FL, is conducting research on long-term change in wetlands along the Gulf of Mexico and the southeastern U.S. coast. The investigation will determine historical change, and identify the significance of changes during the past 20 years, since satellite imagery has become available. The project will match these changes with known factors such as sea level change, sedimentation, and human impacts. A landscape evolution model will be applied to evaluate the current understanding of critical ecosystem processes. The model will assess change and vulnerability of coastal environments in respect to the various processes. The study complements the work being conducted by other agencies including NBS, NOAA, and FWS.

Specifically, the project focuses on the physical and geological factors of the Big Bend intertidal zone, including but not limited to sea level rise, storm surge, sediment supply, climate, and human alterations. The time series of satellite imagery will help identify ecosystem response to and recovery from various processes and their significance in producing long-term change. The investigation is conducted at a regional level, including the whole of the Big Bend intertidal marshes. The use of satellite imagery permits the additional examination of changes to the adjoining uplands during the same time period.

The spatial and temporal scales of the project are broad, including the Big Bend estuary and uplands, and including, at a minimum, the last 20 years, extending further back with historic maps, and field cores. Field sites include St. Marks NWR and Waccasassa State Preserve. Data on water level, sedimentation-erosion tables (SET's), and cores will be collected at the field sites, complementing already existing data. Patterns and aerial extent of change will be documented from NOAA T-sheets, photography and satellite imagery. Elevation, current sedimentation, climate and sea level variations will be included with core records on sedimentation and peat. We will model the response of the wetlands to the changes using the existing understanding of wetlands response to the underlying processes. We will also evaluate the model for the potential to identify wetlands that are vulnerable to decline or loss.

The results of a preliminary study document indicate a variety of disturbance regimes including fire, storm surge, sea level, climate, erosion, and development accompanied by observations of response to and recovery from these disturbances (Raabe and Stumpf, 1997). Many of the events are cyclic in nature, creating a mosaic of habitats superimposed on the underlying geology within the current hydrologic regime (Raabe and Stumpf, 1996). Both tidal and fresh water flow play a major role in the dynamics of the ecosystem. It is critical to note the location of the Big Bend tidal marshes in relation to the surface of the Floridan Aquifer. Sea level for the region is increasing an average of 1.4 mm/year and accretion rates may be as high as 2 mm/year in some areas. A measure of biomass, a vegetation index, is used to identify areas which have significantly changed in the quality and quantity of cover. The vegetation index change gives a preliminary look at areas which may be vulnerable to long or short-term stresses. The current project, with an extended time series and an historic review, will allow the separation of those cycles which truly do operate on a short-term scenario, and those disturbance regimes which induce long-term change. Long-term change may be due to the magnitude of individual

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events, but more likely will be attributable to cumulative effects and the vulnerability of a particular area due to factors such as underlying geology, the local elevation gradient, and fresh water supply. We document the essential processes at work in the intertidal environment, resistance to and recovery from disturbances, and the system's adaptability to long-term changes in the environment.

Sustainable management of the Big Bend will require a landscape-scale perspective. At the terrestrial/marine boundary, the Big Bend may be considered one large estuary, 250 km across from Pasco County to Franklin County. Within this framework is a backdrop of sea-level change, in decadel cycles ranging to 10 cm variations. To fully comprehend the ecosystem and to develop sustainable management strategies, the region must be viewed as a whole unit. Changes observed in one area may be precursors to changes which will occur elsewhere. A model of landscape level processes and patterns coupled with a long-term view of the tidal wetlands can provide future trajectories based on known and projected disturbance regimes. Although complex, and to some extent incompletely understood, the interactions of the various disturbance patterns will be identified at the ecosystem level set in a time frame exceeding the length of ordinary field research. The spatial and temporal coverage provided will serve as the basis for a regional ecosystem perspective.

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SEA- LEVEL RISE AND COASTAL FOREST RETREAT AT WACCASASSA BAY, FLORIDA

***Kimberlyn Williams*[16]**

Studies of forest zonation and stand dynamics along a gradient of tidal flooding frequency at Turtle Creek, Waccasassa Bay, Florida, revealed that forest retreat in this area is a multi-step process, with the regeneration of different tree species failing at different tidal flooding frequencies. This pattern results in the formation of relict stands of some species within healthy, regenerating stands of other species. In the stands studied, *Sabal palmetto* (cabbage palm) was the most tolerant of tidal flooding, followed by *Juniperus virginiana* var. *silicicola* (southern red cedar), *Quercus virginiana* (live oak), then *Celtis laevigata* (sugarberry or hackberry). In stands that flooded only during storm surges, healthy stands of many other tree species occurred.

Failure of regeneration, while associated with high frequency of tidal flooding, did not appear to be associated with lowered soil redox potential (flooding stress) or high densities of halophytic species. In this forest, a hydric hammock or wetland hardwood forest, many species can cope with periodic flooding. Exposure to salt, rather than flooding stress or interference from encroaching marsh vegetation seemed the most likely cause of regeneration failure in the face of sea-level rise. Greenhouse studies supported this contention: the pattern of relative seedling salt-tolerance among species was largely consistent with the order in which regeneration failed in the field. Because of the role of salt in forest retreat, factors that influence the salinity of floodwaters (e.g., freshwater outflow) and factors that influence the extent to which salts concentrate in soils (e.g., rainfall patterns), may affect the rate at which tree species are eliminated from stands exposed to rising seas.

The rapidity with which a tree species is eliminated from a stand following regeneration failure may depend on factors such as the inherent longevity of the tree, salt-tolerance of the mature tree, and susceptibility of the mature tree to storm damage. For *Sabal palmetto*, regeneration appeared to cease several decades before mature trees were eliminated from the site. The "Storm of the Century" in 1993, caused mortality among mature southern red cedars in several stands, with little effect on other species. The storm reduced seedling establishment during 1993, but this reduction in regeneration appeared temporary. The permanent effect of the storm on southern red cedar stands was to hasten the elimination of the species from stands that were already effectively dead (not regenerating). Because the length of time between regeneration failure and mature tree death may be long and variable, studies linking the timing of canopy-tree decline to sea-level rise should be viewed with caution. Dying stands of mature *Sabal palmetto* observed along the coast represent only the last stages in sea-level induced forest decline, with regeneration having ceased decades before, and the regeneration of other species having ceased long before that.

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[16] Information about the participants can be found in the *Directory of Workshop Participants* at the end of this report.

Estuarine Systems

PLANKTON COMMUNITY STRUCTURE AND DYNAMICS IN THE SUWANNEE RIVER ESTUARY

Edward J. Phlips and Erin L. Bledsoe[17]

The aquatic habitats of the Big Bend area of Florida have long been recognized as highly productive, diverse and relatively unimpacted by anthropogenic forces. Burgeoning development of Florida's coastal environment will unquestionably impact water quality in the Big Bend area. One of the focal points of this impact may be the Suwannee River and the coastal estuary associated with it. Development along the Suwannee River has accelerated over the past decade and new proposals have been forwarded for the diversion of Suwannee River water to satisfy the needs of the large metropolitan areas along the Southwest coast of Florida.

In 1996 we began initial efforts to establish baseline data for key water quality parameters and the structure, distribution and variability of primary producers in the Suwannee River and the coastal environment most directly impacted by the outflow of the river. The focus of our current effort is the plankton community. Beyond describing the structure of this community we are concerned with determining the factors that control productivity and biomass.

Results and Discussion

This initial study included determination of selected physical and chemical characteristics along a transect from the Suwannee river to the Gulf of Mexico (Fig. 1). Water samples were collected for analysis of composition and abundance of plankton and to evaluate nutrient limitation for phytoplankton growth. Sampling began in the fall of 1996.

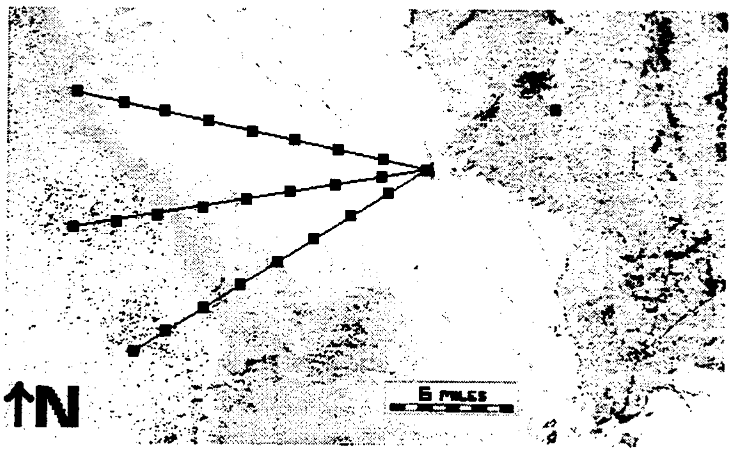

Figure 1. Coastline image of the Suwannee River estuary.

[17] Information about the participants can be found in the *Directory of Workshop Participants* at the end of this report.

This report only includes results for sampling sites along the central transect shown in Figure 1.

Physical parameters - Light transparency and color were measured at two mile intervals along the central transect from the Suwannee River to the Gulf of Mexico (Fig. 1). The penetration of light through water is influenced by color, tripton and phytoplankton abundance and measured by Secchi depth or light extinction coefficients (K_t). Light transparency in the river was low. One of the major contributors to light attenuation in the river was color, which reached levels greater than 200 Pt Co units. Water transparency increased along the transect into the Gulf of Mexico as indicated by higher Secchi depths and lower K_t values.

Chemical parameters - Total nitrogen (mg/L), phosphorus (mg/L) and silica (mg/L) were measured at the surface and bottom along the same transect. All nutrients were generally higher in the river than offshore. Surface waters typically had greater concentrations than bottom samples, possibly indicating a freshwater lens. Nitrate/nitrite (mg/L) and soluble reactive phosphorus levels decreased significantly from the river to the offshore stations. Ammonium (mg/L) was found at detectable levels only in the estuary (1-3 miles from shore).

Biological communities - The structure and abundance of bacteria (<2um), picoplankton (>2um), phytoplankton (>5um) and zooplankton were determined along the transect. Total chlorophyll (ug/L) was used as an overall estimate of the phytoplankton biomass. Biomass peaks occurred three miles offshore on October 31, 1996 and seven miles offshore on November 18, 1996. Continuous offshore winds may have contributed to the displacement of the phytoplankton bloom on the later date. In the river and offshore of the peak biomass region, plankton abundance dropped off considerably.

The phytoplankton community along the transect consisted of diatoms, green algae, blue-greens and dinoflagellates. Based on light microscopy, green algae (Chryptophyceae) were frequently dominant on a numeric basis (i.e., cells/ml). Fluorescence microscopy indicated that picoplanktonic cyanobacteria were also numerically abundant. Diatoms, while less numerically abundant, were much larger in size and therefore should dominant on a biomass basis. We are currently converting the numeric data into biovolumetric distributions. The estuary and the Gulf of Mexico samples contained many large diatoms (e.g. *Rhizosolenia spp.).*

The zooplankton were examined at three stations. The river samples consisted mainly of protozoans and rotifers. In the estuary and at marine stations typical classes of marine zooplankton were identified (e.g. Copepods). Two other important families detected were the Larvacea and Doliolida. These organisms are successful grazers characterized by high filtering rates and can influence "top down" selective pressures.

Nutrient limitation bioassays - Primary production in aquatic ecosystems is directly dependent on the availability of essential growth-limiting factors, principally nutrients and light. The character and quantity of nutrient and light supplies also impact the structure and dynamics of primary producer communities. Nutrient addition bioassays were conducted with samples from riverine, estuarine and marine stations to evaluate the nutrient limiting status of the region. Nitrogen (N), phosphorus (P), silica (Si) and trace metals were added to the water and phytoplankton growth was measured fluorometrically. The riverine samples were not nutrient limited for the dates sampled. The estuary was N limited on Oct. 31, 1996 and N limited on Nov. 18, 1996 after three days. The marine station displayed N and P co-limitation for both days.

Conclusions

The results of this research provide a preliminary view of spatial and temporal patterns in basic water quality parameters and the structure of primary producer communities. This type of information forms the basis for establishing the characteristics of the aquatic environment that sustain other biological resources of the Big Bend area, including shellfish and fish populations.

During the fall sampling reported here, phytoplankton standing crops were greatest in the estuarine region of the transect. As nutrients are transported from the river into the Gulf of Mexico, there is an area of sufficient light and nutrient availability for phytoplankton to bloom. The location of this region of peak production is dependent upon river flow, wind and tidal mixing, as well as, N and P limitation offshore and light and/or flushing rates in the river.

The near term goal of this research initiative is to determine seasonal, interannual and spatial patterns of plankton structure and dynamics in the Suwannee River and its estuary. We are currently focusing on the roles of nutrients and light availability in the limitation of phytoplankton standing crops. The longer term goal is to describe the processes that control primary production and standing crops in this region.

THE MOVEMENT OF NITROGEN IN COASTAL RIVERS AND ESTUARINE SYSTEMS: USING STABLE ISOTOPES AS *IN SITU* TRACERS

Thomas K. Frazer[18]

Estuarine systems are characterized by well-defined spatial gradients in chemical and physical properties. Spatial gradients in nutrient concentrations, particularly of nitrate and/or ammonium, are often apparent and occur as a result of physical mixing processes and also because of uptake and assimilation by phytoplankton and other autotrophs, e.g., attached macroalgae, seagrasses and/or epiphytic microalgae. Isotopic fractionation associated with the uptake and assimilation of nitrate and/or ammonium can, in theory, lead to spatial gradients in the stable nitrogen isotope composition of the residual pool of dissolved inorganic nitrogen that will be reflected also in the isotopic composition of nitrogen sequestered in particulate form. In essence, stable nitrogen isotopes can serve as *in situ* tracers of nitrogen as it moves through an estuarine system. In the Big Bend Region of Florida, there is concern over increased nutrient loads to the estuaries of several spring fed coastal rivers. Natural abundance measurements of stable nitrogen isotopes can likely be used to investigate the dynamics of nitrogen within many of these coastal systems and also to help determine the fate of the increased nitrate.

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[18] Information about the participants can be found in the *Directory of Workshop Participants* at the end of this report.

FISHERIES-INDEPENDENT MONITORING IN THE CEDAR KEYS AREA AND SUWANNEE SOUND

Frederic E. Vose[19]

The Florida Department of Environmental Protection (FDEP) established a field station in Cedar Key, Florida, in September 1995. In 1996, the Fisheries-Independent Monitoring (FIM) team began to monitor young-of-the-year (YOY) fishes and selected invertebrates, as well as to test different types of gear to determine the type most effective for capturing pre-recruit finfish. Researchers used 6-m otter trawls and 21-m center bag seines to sample YOY from June to December 1996 at randomly chosen stations in the study area. A total of 66,499 fishes and selected decapods (genera *Penaeus*, *Menippe*, *Callinectes*) were collected from 307 stations. Catches of economically valuable species (EVS) comprised a small percentage of the total and were somewhat dependent on gear type, although sampling effort was not the same for each gear because of differences in gear usability within the highly variable habitats found in the study area. Seines deployed rapidly by staff in boats along the shoreline (boat sets) collected 565 individuals of EVS (n=31) and were dominated by sand seatrout (*Cynoscion arenarius*). Trawl collections (n=138) accounted for 1773 individuals of EVS, also dominated by sand seatrout. Seines pulled by hand in open water (offshore sets) and along shorelines (beach sets) collected 3072 individuals in 138 hauls and were dominated by spot *(Leiostomus xanthurus*). Gear testing of 183-m haul seines is underway during 1997; this type of gear captures larger-bodied fishes that are pre-recruits to the recreational and commercial fisheries. Information gathered about the abundance and life history of these fishes can be used by those making important fisheries-management decisions. Trial use of 183-m purse seines to evaluate habitats in water depths (1-3 m) not readily studied with current gears is underway in other areas of Florida and is planned for the Cedar Key area in mid-1997.

In addition to conducting the fisheries monitoring just described, FDEP has recently begun a cooperative effort with the University of Florida to collect water samples that are analyzed for selected water-quality parameters. This supplementary sampling began in April 1996, and complements the water-quality data already gathered in regular fisheries monitoring (e.g., dissolved oxygen, temperature, salinity, conductivity, pH, and secchi depth). One goal defined by the Nature Coast Ecosystem Management Initiative was to establish water quality monitoring thereby providing baseline data on total chlorophyll, total nitrogen, and total phosphorus within the Cedar Key/ Suwannee Sound area. In the 1996 samples analyzed to date, total chlorophyll ranged from 0.3 to 81.0 mg m^{-3}, with an overall mean/sd of 11.0 +/- 9.9 (n=336). Total nitrogen ranged from 0.13 to 1.34 mg l^{-1}, with a mean/sd of 0.54 +/- 0.27 (n=194). Total phosphorus ranged from 0.007 to 0.2 mg l^{-1}, with a mean/sd of 0.06 +/- 0.05 (n=89). GIS (Geographic Information System) is being used to graphically depict these data and FIM data from the Cedar Key area.

Acknowledgments: This project was supported in part under funding from the Department of Interior, U.S. Fish and Wildlife Service, Federal Aid for Sportfish Restoration Project # F-43 and under funding from sales of Florida Recreational Fishing Licenses. Cindy Cooksey, Mark DeHaven, Wendy Leavens,

[19] Information about the participants can be found in the *Directory of Workshop Participants* at the end of this report.

Joe Malbrough and Bryan Summerlin are thanked for their dedication in field sampling and data analysis.

LIFE HISTORY OF THE GULF STURGEON IN THE SUWANNEE/BIG BEND ECOSYSTEM

Kenneth J. Sulak and James P. Clugston[20]

The Gulf sturgeon, *Acipenser oxyrinchus desotoi*, is an anadromous species inhabiting the Gulf of Mexico and Gulf Coast rivers from Louisiana to Florida. The Suwannee River is the stronghold of this threatened species, supporting the largest population of the species. The species in Florida has been protected from all fishing due to state and federal regulations put in place in 1984 and 1991. Knowledge critical to conservation and restoration of this species is being developed by our research group, particularly information on location of spawning sites, timing of spawning events, habitat requirements for eggs, larvae and early juveniles, population size and length frequency composition, and location of overwintering grounds. Our research of recent years has focused on four fundamental questions:

1) Where do Gulf sturgeon spawn and what habitat parameters are essential to spawning site determination?

2) Where do young-of-the-year Gulf sturgeon spend their first year of life, and in what habitats are they found?

3) How many sturgeon comprise the Suwannee River population, how is that population structured, and how has it changed over time?

4) Where do fall emigrating sturgeon overwinter?

We investigated these life history aspects in the Suwannee River, Suwannee Sound, and the adjacent nearshore marine waters of the Big Bend. The Suwannee River is one of the few un-impounded, relatively unimpacted rivers used by the anadromous Gulf sturgeon.

Egg collection with substrate buffer pad samplers over four years identified a spawning site 215 km upstream from the Suwannee River mouth. Eggs were deposited only on the side of the river characterized by numerous eddies, including a persistent major eddy with reverse bottom current (locally flowing upstream at 11-42 cm s^{-1}). Eddy fields are important determinants of egg deposition sites. The egg deposition substrate consisted of a 2-4 m depth bedrock platform of eroded limestone overlain by a 0-10 cm deep layer of clean fine sand, and densely populated with elliptical, randomly spaced, 4-10 cm diameter calcium carbonate pebbles. The spawning site, the first to be described for the species in any river, lies 15 km below the Cody Scarp. Differential water chemistry (due to differential sources: surface runoff vs spring ground-water) above and below the scarp may determine the upstream boundary of suitable conditions for embryonic development. Physical parameters bracketing spawning were: depth 2-4 m, conductivity ca 50-110 µS, dissolved oxygen >6.0 mg L^{-1}. Calcium ion concentration and

[20] Information about the participants can be found in the *Directory of Workshop Participants* at the end of this report.

pH may also be important factors. We hypothesized a second site for rkm 209 where substrate and current appeared appropriate; eggs were subsequently collected at this site in 1997.

Spawning in 1995, 1996, and 1997 began 4-7 days after the March new moon, with water temperature above 17.0 °C, and extended for 10-11 days as discrete events involving individual females. Spawning may resume on the next new moon, if temperature remains below 21-22°C. Spawning occurs every year at rkm 215, perhaps only during high water years at rkm 209. It is probably restricted to the upper Suwannee River, below the Cody Scarp. Spawning grounds are very small (<10,000 m^2), eggs are contagiously distributed, suggesting very localized deposition (not broadcast). Estimates of total eggs deposited for individual days approximate the fecundity of an individual female.

Some mature fish appear to immigrate too late to accomplish spring spawning at suitably low temperatures. Fall capture of females laden with large black eggs and males with flowing sperm suggest the possibility of fall spawning prior to annual emigration to the Gulf of Mexico. This inference is reinforced by the occurrence in our river samples of two batches of juveniles, six months out of phase with regard to size-at-age.

Multi-gear sampling throughout the river has resulted in the capture/observation of 36 riverine young-of-the-year (YOY) (<450 mm TL), including the smallest Gulf sturgeon ever captured (82-149 mm TL). Developing YOY were found from km 12 to km 237, primarily on sand shoals along open straight stretches of the river in tannic mainstem river water. Contrary to earlier speculation, no particular association of YOY with natural springs appears to occur. Our capture data suggest that young fish remain in natal fresh water habitat for at least the first 6-10 months of life, attaining a length of 350-450 mm TL. Their initial downstream migration to the estuarine river mouth occurs in January/February, separate from the main October-November migration of larger fish. Age 1-5 juveniles overwinter at the river mouth and in the adjacent nearshore estuary. Fish >1000 mm TL are absent from the river mouth over winter, until initiation of the spring immigration in mid to late February. These larger Gulf sturgeon move offshore (in depths >10m) in December to as yet undetermined foraging grounds in the Gulf of Mexico. Archival data-loggers fitted to offshore migrators may ultimately reveal the locations of offshore winter foraging areas.

Fall net census of the emigrating sub-adult/adult population in 1995 revealed a strongly bi-modal size-frequency. The main population mode centered upon 1450-1500 mm TL (ca 10-12 year old adults), with a subsidiary modes at 700-950 mm (ca 3-8 year old juveniles/subadults. A major valley centered upon 1000-1100 mm TL (subadults from 1984-1990 year classes). The secondary peak displays strong recruitment to the population of 1991-1993 year class juveniles, following recruitment failure in earlier years (valley). It appears that the species has made a very strong response to protection of spawning adults in terms of spawning success and juvenile recruitment. This trend appears to be continuing, based on our evidence of successful spawning in the Suwannee River in 1995-1997. By the years 1999-2000, the large influx of juveniles recruited to the population beginning in 1991 will begin to substantially bolster the ranks of reproductive adults. The post-protection size/age structure of the Suwannee River population as displayed by the 1995 census is dramatically different from its structure in 1973 (Huff, 1975). In 1973, the commercially fished Gulf sturgeon population had a unimodal length frequency distribution, centered on 1300 mm TL. The population was comprised almost entirely of age 5-11 subadults, with very few reproductive size adults (age 12 and older), and very few juveniles (under age 5). Remaining in this perilous status until cessation of commercial fishing in 1984, it is not surprising that success of reproduction and juvenile recruitment through 1990 was minimal. At present, the Suwannee River population of Gulf sturgeon appears to be making a strong natural recovery on its own, despite a fairly limited number of large spawning adults in the population. Stocking with hatchery reared fingerlings seems ill-advised and cost-ineffective relative to simple protection of adults and spawning grounds. Also ill-advised, at this critical early point in population recovery, is the removal of spawning adults to serve as hatchery broodstock for commercial aquaculture.

Splendor in the Grass: Intimate Associations of Habitat and Fishery Abundance.

Christopher C. Koenig and Felicia C. Coleman [21]

The majority of our research in seagrass habitat of west Florida has focused on the development of recruitment forecasting models for several economically important estuary-dependent reef fish species. We have initially focused on the most tractable of reef species--gag grouper--but other reef species with similar life history characteristics-- gray snapper, lane snapper, and black seabass--are also being studied. Gag is also the most important of these species in terms of landings, and there has been recent concern about loss of reproductive potential of this species through a reduction in the proportion of males and loss of spawning aggregations.

Gag spawn on offshore reefs in February and March and offspring recruit to seagrass habitat in April and May. Linear growth in the seagrass habitat of west Florida averages about 0.8 mm/day, but declines from August through early October, at which time fish migrate to shallow reefs. Liver hypertrophy during slowed growth indicates a reallocation of food resources and probably confers on gag a hedge against the uncertainty of finding offshore food and cover. Although seagrass is not the only estuarine habitat occupied by this species, it appears to be the dominant habitat.

Our initial effort in developing a recruitment model was to determine absolute density (numbers per unit area) of gag in seagrass. Absolute densities were determined using the Jolly-Seber mark and recapture method for open populations. We did concurrent standardized trawl sampling in the area of each mark and recapture site and divided apparent density (captures per unit area) by absolute density. This gave us an estimate of sampling efficiency. The effects of fish size and habitat condition on sampling efficiency were minimal.

Absolute abundance was calculated for the sampling region by multiplying seagrass area by average absolute density. In the area of St. George Sound, where this study was conducted in 1991, the seagrass coverage was 15 square kilometers. Juvenile gag density was about 500 per hectare, or about 1 per 20 square meters. The absolute abundance for the area was 750,000 juveniles. Extending this value to the entire Big Bend seagrass habitat (ca. 3,000 sq. km) gives a theoretical abundance of 150,000,000.

While we know that survival in the seagrass habitat is high (Jolly-Seber and CPUE regression), at less than 0.5% mortality per day, we know little about survival after egress from the seagrass habitat. There are likely to be density-dependent factors and fishery-related factors that increase mortality rates for abundant year classes. For example, in 1993 we recorded a very high year class in north Florida seagrass beds (nearly 1000 per hectare in St. George Sound). In 1996 this year class was captured by the fishery as legal and undersized catch. The 1993 year class comprised 96% of the undersized catch and 40% of the total catch taken from water depths greater than 50 meters. Survival of released fish from these depths is low so the net effect of high capture rates was to diminish the beneficial effects of a fortuitous year class.

A preliminary comparison of the time series of the juvenile abundance in north Florida with the age structure of the catch indicates good concordance, that is, year classes with high abundance were reflected in the age structure as the year class pulses through the fishery leading us to begin developing a

[21] Information about the participants can be found in the *Directory of Workshop Participants* at the end of this report.

model relating abundance to future stock size. However, the time series of juvenile abundance and adult fishery data must be extended over a longer time period before the model can be fully developed.

The work that we are doing relates directly to the Big Bend seagrass habitat. This is an enormous, relatively pristine system. Thus juvenile reef fish recruitment to this system must considered. However, we are limited in our determination of this for the Big Bend because accurate habitat maps do not exist. We suggest that several types of research should be of high priority for the Big Bend seagrass system: (1) habitat mapping, (2) habitat characterization, (3) studies of ecosystem function and interaction with other systems, and (4) criteria should be developed for a system of no-take reserves based on the seagrass habitat maps and characterization.

POSTER PRESENTATION

Biogeochemical Indicators of Trophic Status in a Relatively Undisturbed Shallow Water Estuary

L.K. Dixon and E.D. Estevez[22],[23]

ABSTRACT

Shallow water environments offshore of the Chassahowitzka River, west-central Florida, were sampled for submerged aquatic vegetation and water quality to establish baseline estuarine conditions in a relatively unstudied national wildlife refuge, and to identify indicators of trophic status. All field work was conducted during the spring dry season to characterize conditions accompanying minimal freshwater inflow. Chassahowitzka Bay is a large, shallow (<2 m), exposed mosaic of saltmarshes, seagrass beds, and algal assemblages growing on an extensive karst limestone shelf. Algal and/or seagrass cover was nearly continuous with moderate densities. Drift algae, followed by *Caulerpa paspaloides* were the most common species. The water column during the study was well mixed and nutrients, chlorophyll, and trophic state indices were low, indicating "Good" water quality overall. Dinoflagellates formed a relatively constant proportion of the phytoplankton community. Algal growth was nitrogen limited and nitrate contributed by the Chassahowitzka Springs was rapidly removed from the water column within the Chassahowitzka River. The northern region apparently received a higher nutrient loading than the southern region, as indicated by a trophic state index.

METHODS

Study Area: The study area was the near coastal waters of the Chassahowitzka National Wildlife Refuge, outside of the mouths of the Chassahowitzka and Homosassa Rivers. Randomized stations within 30 polygons were sampled for submerged aquatic vegetation (SAV), and a subset of 20 stations sampled for water chemistry during May 1996. Five stations were also sampled for water chemistry in the Chassahowitzka River.

Water Quality: Water quality samplings consisted of early morning and late afternoon *in situ* measurements of physical parameters at all 30 stations, with samples for nutrients, chlorophyll, and phytoplankton collected at 20 stations during the morning sampling. Sampling and analyses were under Mote Marine Laboratory's Florida Department of Environmental Protection-approved Comprehensive Quality Assurance Plan.

SAV Surveys: Cover and abundance of SAV were measured using a rapid-survey technique (Braun-Blanquet, 1932), assigning a cover-abundance value for each taxon or group for each of four 0.25 m^2 quadrats per station.

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[22] Information about the participants can be found in the *Directory of Workshop Participants* at the end of this report.

[23] This article has been edited to fit the format of this report.

RESULTS

Riverine Morphology and Vegetation: Numerous vents are associated with the Chassahowitzka headsprings and discharges consist of waters of widely varying conductivities. Floating mats of senescent vegetation and *Typha sp.* were at the most upstream stations, but the mainstem was clear and fast-moving. Tidal changes in water elevation, but no reversing flows, were observed at this site (Station R1). At the eastern boundary of the Refuge (Station R2), floating algae mats, *Myriophyllum brasiliense*, and *Hydrilla verticillata* were very dense. Reversing tidal flows were observed. By Station R3, *Cladium jamaicensis* lined the river, while *Juncus* dominated the higher marsh. *Ruppia maritima* was present in the river. At Station R4, *Ruppia* growth was luxuriant. The remaining coastal stations were within and offshore of a dense archipelago of *Juncus* islands, with relatively shallow, clear waters.

Water Quality - Physical Parameters: The coastal and riverine waters were well mixed with minimal stratification. Some coastal areas recorded lower salinity values at depth and may indicate a region of groundwater discharge. Based on conductivity, spring discharge quality may vary with tide stage. Conductivities in the southern portion of the study area are comparable with areas influenced directly by the Homosassa and Chassahowitzka Rivers, implying other freshwater discharges in the southern region. Dissolved oxygen values exhibited typical diurnal swings with mean morning values of 4.8 mg L^{-1} (64% saturation) and afternoon values averaging near 8.9 mg L^{-1} (128% saturation). Two coastal area stations were below instantaneous criteria of 4.0 mg L^{-1} during the morning sampling.

Water Quality - Nutrients and Phytoplankton: Nutrient concentrations were low. All but one total phosphorus value were below detection limits (<0.05 mg L^{-1}). For ortho-phosphorus, 13 of the 20 coastal stations were below detection limits (<0.005 mg/l). The highest ammonium-nitrogen concentrations (0.027 mg L^{-1}) were observed at the head of the river (Stations R1 and R2) but ammonium-nitrogen was not detected in discharge from the main spring.

Nitrate-nitrite-nitrogen concentrations were notable both in the main spring and at Station R1 (near 0.400 mg L^{-1} NO_{2+3}-N) but were rapidly assimilated. Water column nitrogen is halved by Station R2 to approximately 0.2 mg L^{-1}, almost all in the organic form and subsequently increases downstream with increasing conductivity. This spatial pattern may represent some combination of nitrogen fixation and export of organic nitrogen from the extensive marshes. Inorganic nitrogen to inorganic phosphorus ratios (IN:IP, mg:mg), were generally less than 7, indicating nitrogen-limitation. For riverine and coastal stations, dinoflagellates formed a relatively constant proportion of the phytoplankton population.

Water Quality - Trophic State Index: Trophic state indices (TSI) (Hand et al., 1988) were calculated from limiting nutrients and chlorophyll. TSI values at all stations were less than 50, therefore considered "Good". Spatial patterns of TSI, however, indicate higher values (40-49) in the northern Mason Creek-Homosassa Bay area. Conductivity values, however, were comparable between the northern and southern regions indicating comparable freshwater influence. The higher TSI in the northern region imply that nutrient loadings may be greater in this area, perhaps attributable to the relative development and to failed septic systems as referenced in older literature (FLDE, 1988,1989; Hand *et al.*, 1988).

Submerged Aquatic Vegetation: Of the 30 polygons identified for sampling, vegetation was found at all but one of the primary sites. A variety of drift algal species was also observed in almost half of all quadrats. The drift algae were surveyed as a single category of miscellaneous rhodophyta. *Ruppia* was common and dense in tidal creeks, but was seldom recorded in quadrats.

Braun-Blanquet estimates of frequency, abundance, and density of the following species within the coastal vegetated regions off of the Chassahowitzka National Wildlife Refuge.

Species	Frequency (%)	Abundance (B-B)	Density (B-B)
Caulerpa paspaloides	38	4.00	1.50
Acetabularia crenulata	31	1.72	0.53
Halodule wrightii	18	3.82	0.70
Thalassia testudinum	18	3.16	0.58
Batophora oersted	18	0.68	0.13
Caulerpa prolifera	13	2.63	0.33
Penicillus capitatus	8	1.87	0.16
Ruppia maritima	5	3.08	0.15
Sargassum spp.	5	0.17	0.01
Udotea flabellum	3	0.08	0.003
Halimeda incrassata	3	0.50	0.01
Caulerpa ashmeadi i	1	2.00	0.02
Miscellaneous Rhodophyta	49	3.37	1.66
Unvegetated	3	5.00	0.13

SUMMARY

During this dry season survey (May 1996), the Chassahowitzka was a well mixed and relatively oligotrophic estuary with trophic state calculations indicating that water quality was in the "Good" range. In all, the Chassahowitzka region can be termed very clean. Inorganic nitrogen supplied to the head of the river by the main spring is quickly removed by the extensive biomass in the river. Algal growth in most of the coastal area appears slightly nitrogen limited. Distribution of phytoplankton between dinoflagellate and non-dinoflagellate species was relatively uniform across the study area. Geographic patterns of trophic state indices indicate that the northern portion of the study area, near the Homosassa River, received higher nutrient loadings but comparable amounts of freshwater.

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SUITABILITY OF FLORIDA WATERS TO INVASION BY THE ZEBRA MUSSEL, *DREISSENA POLYMORPHA*

Don Hayward and Ernest D. Estevez[24]

Recent dispersal of the zebra mussel, *Dreissena polymorpha* (Pallas, 1771), throughout North America invites an assessment of its additional potential spread. Florida, a state with numerous inland and coastal waters, presently is not inhabited by zebra mussels. To assess the suitability of Florida waters for zebra mussel habitation, existing literature on mussel requirements was compared to water quality data for seven parameters– temperature, pH, calcium content, dissolved oxygen, salinity, transparency, and substratum. Habitat suitability indices (HSI) were defined for each parameter. Literature supported definition of life-cycle rather than age or size-dependent HSI. As a proportion of each parameter's range, more temperature values were reported optimal (HSI = 1.0) than for pH or transparency.

Each parameter value present in 281,780 data records from 9,028 unique sampling locations was assigned a suitability value. Parameter-wise habitat suitability was dominated by low (<0.5) values, signifying that the majority of specific parameter conditions in Florida waters are not particularly favorable for zebra mussels. No perfectly unsuitable (0.0) temperature HSI values were computed. In descending order of frequency, perfectly unsuitable HSI values were computed for Secchi depth, calcium, pH, salinity, and dissolved oxygen. Approximately 0.7% of all HSI values computed for state waters were perfectly unsuitable for zebra mussels.

Site specific and regional composite HSI values were calculated. Composite HSI values were calculated for each sample at each site, and the median of the sample HSI values was selected as representative of that site. Sites with median HSI values over 0.5 were found in every region of the state.

U.S. Geological Survey Hydrologic Units (HU) were used as the basis for regional aggregation. Values from the 10th (least suitable), 50th (median suitability), and 90th (most suitable) percentiles were selected for each variable at each site, and a parameter-specific HSI was computed for each variable and percentile level, for each of 51 HU in Florida. Parameter-specific HSI were combined to produce 153 composite HSI model values. Composite HU-specific scores were sorted into low (below 30th percentile), intermediate (30-70th percentile), and high (above 70th percentile) ranges to depict HU with low, moderate, and high suitabilities for zebra mussels, respectively. Florida's hydrologic units tend to have low aggregate HSI values. Median HU-wise HSI was 0.18, meaning that half of state HU values were close to unsuitable conditions.

Uniformly low-suitability HU in all HSI domains included several north Florida systems: Perdido River, Blackwater River, Choctawhatchee Bay, Oklockonee River, St. Marks River, and St. Marys River—commonly acidic, soft-water systems. The 90th percentile value, 0.54, means that only 10% of HU-wise HSI values were in the upper range of possible HSI scores. These HU fall generally in the Lower St. Johns River, Lower Suwannee River and Big Bend streams, and southwest Florida regions. The St. Johns and Suwannee River systems receive significant contributions of mineralized ground-waters, whereas the southwest peninsula HU head in or near the Polk uplands, containing the phosphate-rich Bone Valley geological formation.

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[24] Information about the participants can be found in the *Directory of Workshop Participants* at the end of this report.

HU-level aggregations fail to distinguish local cases of potential importance for zebra mussel management, such as springs. Several categories of Florida springs present conditions favorable for zebra mussels. An aggregate HSI value computed for six representative springs of first magnitude, using all but two parameters (dissolved oxygen, sediment size), ranged from 0.45 to 0.88, the latter value being significantly greater than any HU-wise HSI value calculated from Florida data.

Overall suitability of Florida waters for zebra mussel success was shown to be relatively low, spatially heterogenous, and potentially great in specific systems smaller in scale than the hydrologic unit. We conclude that susceptibility of Florida waters to zebra mussels is neither remote nor absolute, and we underscore this assessment by stating that it: 1) is based on mussel requirements as known from their study in temperate climates, and 2) makes no assumption regarding the capacity of zebra mussels to accommodate Florida conditions through physiological acclimation or genetic adaptation. We also note that our results do not represent a risk assessment, i.e., the relative chance that mussels will be introduced to a system. Risk assessments employ estimates of vector density and intensity, which we have not attempted.

Four lines of application are recommended: risk assessment, monitoring, education, and research. A risk assessment would best proceed by identifying waters receiving the greatest recreational or commercial vessel traffic. A state-wide monitoring program for zebra mussels would be premature, but monitoring should be considered as a priority upon the appearance of mussels in headwater streams of adjacent states. At the present time, a state-wide monitoring program would be expensive and possibly ineffective. Educational programs hold the most promise for prevention of zebra mussel introductions to Florida, and their early detection if established. Research opportunities specifically addressing Florida's vulnerability to zebra mussels are several, and include studies to scope the full range of acclimation, acclimatization, and adaptation potentials of zebra mussels to state water quality conditions; control methods particular to a Florida setting; and natural predation of zebra mussels.

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EFFECTS OF SEASONAL AND PHYSICOCHEMICAL FACTORS ON FISH POPULATIONS OF ALLIGATOR PASS, SUWANNEE RIVER, FLORIDA

V. Kyle Adicks and Charles E. Cichra[25]

Fish populations of Alligator Pass were sampled approximately bimonthly at low tide by seine. Physicochemical parameters including temperature and salinity were measured at times of sampling. The pass was dominated by freshwater at low tide throughout the study. Only 18 of 186 samples were taken in salinities above 5 o/oo. Salinity followed no obvious seasonal pattern, but low tide values from this study were much lower than high tide values of previous works. Temperature followed a typical seasonal pattern.

A total of 47 species of fish were sampled in Alligator Pass. The fish community was dominated numerically by the bay anchovy, *Anchoa mitchilli*, which accounted for nearly 79 percent of the total catch, although they appeared in high numbers only on certain dates. Pinfish, *Lagadon rhomboides*, inland silversides, *Menidia berrylina*, spot, *Leiostomus xanthurus*, and silver perch, *Bairdiella crysoura* were the only other species accounting for more than 1 percent of total catch. A significant difference was found between total abundance of all species at salinities above and below 5 o/oo. A significant but weak effect of stations grouped by location on total abundance of all species was found. Species richness followed a seasonal trend, increasing through the spring and early summer, and decreasing in the fall. No significant relationships were found between species richness and stations grouped by location or salinity. Few relationships were found between abundance of various species on a given date and salinity or location within the pass. With the exception of the bay anchovy, the dominant species seem to appear in the area in high numbers as small juveniles, and decrease in number as they increase in size over time, indicating that life history of individual species is a key factor in their abundances over time.

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[25] Information about the participants can be found in the *Directory of Workshop Participants* at the end of this report.

STATUS OF BAY SCALLOP (*ARGOPECTEN IRRADIANS CONCENTRICUS*) POPULATIONS IN FLORIDA, USA, WATERS.

W. S. Arnold, D. C. Marelli, M. Harrison, W. White, P. Hoffman, K. Hagner, M. Parker, J. Guenthner[26]

Introduction

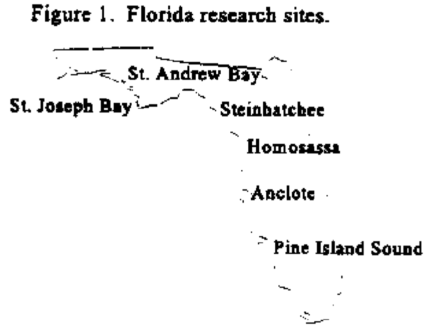
Bay scallops have been a popular and economically important constituent of the marine landscape in Florida for centuries, as evidenced by their widespread distribution and abundance in the shell middens of prehistoric Indians throughout Florida's Gulf of Mexico region. However, in recent decades a clear trend of decline, in both the distributional range and the abundance of the animal, has been observed. Commercial fishery landings of scallops decreased substantially in the 1960's and 70's and are now essentially non-existent. Similarly, the recreational fishery has been in decline since the early 1960's; once popular fishing sites such as Pine Island Sound, Tampa Bay, and the Anclote estuary now yield few scallops and only the waters around Steinhatchee and Port St. Joe remain productive.

Preliminary research conducted by scientists at the Florida Department of Environmental Protection during the early 1990's provided the first comprehensive evidence of the bay scallop decline. That information was used by the Florida Marine Fisheries Commission, the state's regulatory body for marine fisheries, to place a complete moratorium on commercial fishing and to severely restrict the recreational pursuit of this desirable species. The moratorium is temporary, however, and has been implemented to protect the most stressed scallop populations while a restoration strategy is devised. We have been assigned the task of describing the Florida bay scallop fishery and in devising a strategy for restoration.

Materials and Methods

We conduct SCUBA diver surveys to describe the distribution patterns and quantify the abundance of bay scallops at a variety of sites throughout the Florida Gulf of Mexico coast. Surveys are effected at each of 20 stations at each of six sites (Fig. 1); two divers swim the length of a 300 meter transect, with one diver on each side of the transect line counting all scallops within 1 meter of the line. Total survey coverage is 600 m^2 at each station or 12,000 m^2 at each site. Surveys are conducted during June of each year at all selected sites (Pine Island Sound, Anclote, Homosassa, Steinhatchee, St. Joseph Bay, St. Andrew Bay) and again during fall (September-October) at a selected subset of sites. The June survey estimates abundance prior to the recreational fishing season (July-August) and the fall survey provides post-season estimates. Additionally, comparisons are made between sites open and closed to fishing. Resultant data are compared both among and within sites over time to provide first-ever estimates of natural fluctuations in abundance of bay scallops in Florida.

Figure 1. Florida research sites.



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In conjunction with the adult surveys at Anclote, Homosassa and Steinhatchee, we also monitor patterns of recruitment to artificial spat collectors. Collectors are constructed of plastic mesh panels encased within a loose-mesh citrus bag, are anchored to the bottom with a cement construction block, and are identified at the surface with a small float. Spat collectors are deployed and recovered on a six-week schedule; two sets of traps are deployed on a three-week overlapping schedule to preclude missing any settlement that may occur just prior to recovery of a trap set. Collectors are returned to the laboratory where all identifiable scallop recruits are counted. Resultant data are compared with patterns of adult distribution and with temperature-salinity patterns recorded every two hours using a bottom-mounted data logger.

Results and Discussion

Adult abundance differs substantially among research sites distributed along the Florida Gulf of Mexico coast. Areas such as Pine Island Sound and Homosassa generally support fewer than 1 scallop per 600 m^2, whereas abundance of scallops in Steinhatchee and St. Joseph Bay typically exceeds 100 scallop per 600 m^2. At Anclote, scallop abundance is generally low, but localized areas are characterized by densities similar to that observed in the high-density Steinhatchee and St. Joseph Bay areas. However, within each site densities have remained remarkably stable during our three-year study (5 years in Homosassa). We surmise that either: 1) site-specific features maintain scallop density at a stable level over time, or 2) the duration of our sampling is shorter than that required to detect substantial temporal fluctuations in bay scallop abundance. Based upon the life-history of the animal, the more likely explanation is (2). We intend to continue sampling with the goal of experiencing a major population fluctuation at one or more sites to determine if fluctuations are contemporaneous among sites and to describe physical or biological factors that may correlate with those fluctuations.

Recruitment of bay scallops to artificial collectors appears to be positively correlated to adult abundance at each site. Recruitment is generally very low in Homosassa, very high in Steinhatchee, and extremely variable in Anclote. However, a reliable spawner-recruit model cannot be developed from the available data. Similarly, we have not discerned a close relationship between recruitment and temperature-salinity patterns. Recruitment monitoring continues, and again we hope to experience a substantial population fluctuation; such an event may provide important insights into the relationship between larval supply and adult abundance.

The results of our ongoing studies will provide an important baseline against which bay scallop restoration efforts in Florida can be compared. In conjunction with other institutions, we are devising a plan to supplement natural bay scallop stocks with cultured individuals. Prior to initiating that costly and difficult process, we need to know the relationship among extant Florida bay scallop stocks and we need to know if limited larval supply is responsible for some or all of the population collapses recorded for Florida waters. If larval supply is not the primary factor limiting adult population abundance, then restorative efforts may be ineffective.

SHELF AND COASTAL OCEAN SYSTEMS

Factors Influencing the Timing and Magnitude of Settlement of Reeffish Recruiting to Seagrass Meadows along the West Florida Shelf

C. B. Grimes, Gary Fitzhugh, C. C. Koenig, and F. C. Coleman[27]

A number of commercially and recreationally important reeffish species share the common life history characteristics of offshore spawning and transport of larvae inshore to settle in seagrass meadows throughout the Big Bend where they spend an obligatory nursery phase before recruiting to adult stocks offshore. Among these fishes are both winter and summer spawners, gag, *Mycteroperca microlepis*, and grey snapper, *Lutjanus griseus*, respectively, being good examples. The NMFS Panama City Laboratory and the cooperative Florida State University Institute for Fishery Resource Ecology are engaged in studies designed to lead to forecasting recruitment to the fisheries by understanding how stock characteristics and environmental factors regulate settlement to seagrass habitats along the West Florida Shelf (WFS). Gag spawn in February and March in a defined area west of the Florida Middle Grounds, and larvae are transported inshore to settle in seagrass meadows 30 - 50 days later. Juveniles remain in the seagrass nursery areas until October or November when they recruit to adult stocks offshore.

Spawning and settlement dates hind-cast from microstructure of lapillae reveal distinct sptial and temporal patterns for young gag along the WFS. Both spawning and settlement are 10 to 14 days later in the northern (Panhandle) region than in southwest Florida; settlement is relatively consistent in southwest Florida; but highly variable in the northern region.

We propose four mechanisms that may influence the timing and magnitude of settlement: (1) a latitudinal gradient in spawning along the WFS (i.e., spawning occurs earlier in the south than in the north; (2) limitation of settlement by seagrass habitat availability due to the annual cycle of seagrass die-back and regeneration; (3) changes in the main direction of larval transport due to the seasonal shift in the wind field from the winter to spring pattern; and (4) the temporal and spatial match/mismatch between the production cycles on the WFS and spawning and larval production.

Comparison of the temporal distribution of spawning derived from ovarian histology of spawning females to otolith-derived spawning dates of settled juveniles in the northern region shows that spawning occurred February to mid-April while surviving juveniles were spawned mid-March to mid-April. This result leads us to discount the importance of this mechanism.

We are sampling presettlement juveniles in the norther region with channel nets to determine if the arrival dates of newly arriving settlers preceeds otolith-derived settlement dates of settled juveniles. This result would suggest that the larval supply preceeded spring regeneration of seagrass habitat suitable for settlement, thus supporting the importance of the habitat limitation mechanism.

Trajectories of satellite-tracked surface drifters support a strong role for the transport mechanism. They reveal seasonally changing surface circulation on the WFS that would result in high settlement in the south and low settlement in the north early in the spawning season followed by high settlement in the north and low in the south during the latter portion of the spawning season.

The so called "Green River" is an interannually persistent area of high primary production on the WFS that coincides temporally and spatially with gag spawning west of the Florida Middle Grounds. It

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is likely that this production initiates a trophic cascade that supports feeding, growth, and survival of gag larvae during the pre-settlement phase of their life history. The temporal and spatial match/mismatch between the Green River and gag spawning and larval production may also influence the timing and magnitude of settlement.

THE SUWANNEE REGIONAL REEF PROGRAM: PROCESSES AFFECTING REEF FISH DISTRIBUTION AND ABUNDANCE ON THE SHALLOW CONTINENTAL SHELF

William J. Lindberg[28]

The Suwannee Regional Reef Program involves a large-scale experimental approach toward understanding how reef habitat functions ecologically on the shallow continental shelf. Our practical goal is to help resolve the Attraction-Production Issue for artificial reefs (see Fisheries, 22(4), April 1997). Our scientific goals are to test basic ecological theory, and to relate the productivity of reef fishery species to behavioral, community, and ecosystem processes (e.g., habitat selection, species interactions, regional productivity, forcing functions like river outflow and fishing). As part of this program, we have a responsibility to recommend artificial reef siting and design criteria consistent with sustainable fisheries, and to educate people about what is known scientifically regarding artificial reefs, natural processes, and sustainable fisheries in an ecosystem context.

Description of the Suwannee Regional Reef System:

The Suwannee Regional Reef System consists of 22 reef sites along the 13m depth contour bracketing the mouth of the Suwannee River approximately 25-30 km offshore. The percent cover of natural hard-bottom habitat near these reef sites ranges from 0 to 33%, and rocky outcrops higher than 50 cm are not found in the vicinity. Each site has 6 patch reefs arranged in a hexagon and spaced at either 25, 75, or 225 m apart. Each patch reef has either 4 or 16 prefabricated concrete cubes (89 cm3) with horizontal 55-gallon drums as central cavities; all patch reefs on a site are the same size. Our core experiment has 4 replicates for each of the 4 combinations of patch reef spacing and size (i.e., 4 & 16 cubes x 25 & 225 m spacing); the remaining sites are earmarked for intrusive experimental manipulations. Other investigators have tested reef size, but this is the first experimental system in which reef spacing has also been included in order to test habitat patchiness per se.

The General 3-Step Hypothesis That Initiated This Program:

Our previous research in the Big Bend led to a general hypothesis best expressed in three parts: (1) We assume that reef structure provides motile species refuge from predation, and perhaps currents. (2) Reef-dwelling species that forage off-reef on sand-dwelling benthic prey are expected to create a gradient of prey depletion around their refuge, resulting in a negative feedback to the reef dwellers' energy budgets, residency times, and local abundances. (3) The patchiness of reef habitat is expected to affect the degree of prey depletion and the intensity of negative feedback, such that smaller, more widely spaced patch reefs may be more favorable to such reef residents than are larger, more closely spaced patch reefs. We termed this the "resource mosaic hypothesis" as a specific extension of density-dependent habitat selection theory in behavioral ecology. Results from the initial phase of the Suwannee Regional Reef Program led to a broadening of this general hypothesis to also include

[28] Information about the participants can be found in the *Directory of Workshop Participants* at the end of this report.

coupling by gag grouper to pelagic baitfish, with presumably less prey depletion and negative feedback than expected exclusively from benthic prey.

Research Findings to Date:

Initial Project (1991-1995) Sponsored by DEP

As expected for fishes that shelter at reefs and forage over sand, the black sea bass, white grunt, cubbyu, and gray triggerfish were all significantly more abundant on patch reefs spaced at 225 m than at 25 m. Adult tomtate and sheepshead, which also shelter at reefs and forage over sand, were not affected by reef spacing. Adult tomtate, however, were more abundant in summers on 16-cube patch reefs where juvenile tomtate had previously recruited in great swarms, while sheepshead were abundant only in winter spawning aggregations at 16-cube patch reefs.

As expected for the small fishes very closely associated with reef surfaces, the seaweed blenny and belted sandfish were significantly more abundant on 16-cube patch reefs than on 4-cube reefs. The seaweed blenny was unaffected by patch reef spacing, but the belted sandfish was more abundant at 25 m than at 225 m spacings.

Total fish abundance and biomass was significantly greater on 16-cube reefs than on 4-cube reefs, but the four-fold difference in material yielded only a two- to three-fold difference in fish numbers.

Reef age affected abundance patterns of fishes among reef treatments but in an unexpected way. Gag increased significantly in abundance over the first five years, and the rate of increase was greater on 16-cube reefs than on 4-cube reefs. The increase in gag corresponded in both time and reef type to an increase in summer baitfish abundance. By the fifth summer, gag abundance at 16- cube x 225 m reefs averaged almost 400 fish per site (rank order of gag abundance: 16 x 225 > 16 x 25 > 4 x 25 = 4 x 225) and gag accounted for almost 42% of total fish biomass across all reefs. As abundances of gag increased, however, abundances of black sea bass and adult tomtate decreased from several hundreds per reef site to virtually none, with a concurrent loss of reef treatment effects for these species.

With respect to sand-dwelling macro-invertebrates, the densities of suspension feeders and burrowers within 75 m of reef structure were reduced relative to non-reef control areas. Suspension feeders and surface burrowers, in particular, were significantly affected by reef treatments, but the patterns of those effects are too complex for simple interpretation (i.e., apparently involving several direct and indirect effects).

Current Project (1995-1998) Sponsored by DEP and NMFS/MARFIN

The residency "half life" of juvenile to adult gag that have been tagged on Suwannee Regional Reefs is approximately 8 months, and as expected, the rank order of residency times among reef treatments corresponds to the rank order of gag abundance.

Gag move among patch reefs on a site infrequently (0-2 movements per week when sampled at 24 hr intervals), and move significantly less at 225 m reef distances than at 75 or 25 m spacings. Resightings of ultrasonically tagged fish suggest that gag stay at or return to a home patch reef.

An autumnal pulse of immigration by young-of-the-year gag was not obvious during the fall of 1995, but an increased of 18-30 cm gag has been observed in the fall of 1996.

A synchronous emigration of reproductive size classes was not obvious during late fall 1995, although the lowest average numbers in the largest size classes (i.e., 60-69 cm, 70-79 cm, and 80-89 cm) occurred in November (Dec. and Jan. sampling was missed). June 1996 also showed an increase in the largest size classes compared to prior months.

For previously unfished reefs, patch size significantly affected gag relative weights, with fish on 4-cube patch reefs 8% heavier, on average, than fish from 16-cube patches or natural rock.

Data pertinent to hypotheses regarding somatic growth, condition, and fishing effects will be gathered in the fall of 1997.

Conclusions and Inferences from Results to Date:

The resource mosaic hypothesis survived its initial test. However, because of unexpectedly high gag densities, the original hypothesis was broadened to include coupling to pelagic as well as benthic prey. These two sources for off-reef prey are expected to differ in their degrees of local prey depletion and density-dependent effects on reef fish. One can safely assume that gag residency is long enough and movements localized enough for reef treatment effects to appear as differences in growth and condition. Ours are the first experimental results to document enhanced biological production by artificial reefs.

Autumnal immigration by young-of-the-year gag directly onto Suwannee Regional Reefs may depend on year class strength. A highly synchronous emigration during late fall by gag of reproductive sizes has not been obvious; gag in these size classes can overwinter on Suwannee Regional Reefs. A hint of late spring returns of large fish is not yet conclusive.

We now have a much better, but far from thorough understanding of how warm-temperate reefs function ecologically. While the resource mosaic hypothesis remains viable, others have been disproven. High densities of fish at artificial reefs are not simply a behavioral artifact (Carr and Hixon, Fisheries 22:28-33) and are not dependent on primary and secondary production associated with the reef itself (Bohnsack et al., unpublished data). Reef structure provides refuge from predation (e.g., Hixon and Beets, Ecol. Mongr. 63:77-101, Herrnkind, Butler and Hunt, Fisheries 22:24-27), yet trophic linkages to off-reef prey must be important to the production of fishes from reef habitat.

Remaining Research Priorities:

- Direct comparisons of growth rates and condition (e.g., relative weights) between reef fish (e.g., gag) occupying Suwannee Regional Reefs and natural hard-bottom habitat of the region.
- Quantify relationships of reef fish abundance (e.g., gag) with pelagic production (primary, secondary and tertiary) and hydrodynamic processes across spatial and temporal scales.
- Characterize and quantify significant pathways of energy flow and material transport in coastal ecosystems using the Suwannee Regional Reefs and contemporary ecological techniques.
- Test the hypothesis that reef fish production (e.g., gag) is tied to the seasonal transport of tertiary production from inshore habitats (e.g., seagrass).
- Experimentally manipulate gag densities on replicate patch reefs for a direct test of density-dependence in residency times, growth rates, and condition; fish densities and these measures are expected to re-equilibrate over time.
- Experimentally manipulate reef cavity volume for a direct test of refuge control on gag densities and reef fish community structure.

- Develop quantitative models of fish abundance and production derived from the research to date and a coupling to regional productivity and ecosystem processes.
- Continue visual fish counts on the Suwannee Regional Reefs, thereby extending the 6-year time- series of offshore fisheries independent monitoring in order to:
    - Determine if reef fish assemblages attain equilibrium or climax conditions;
    - Distinguish trends in reef fish abundance from natural cycles and variability;
    - Relate reef fish abundance to inshore fisheries independent monitoring;
    - Identify temporal patterns of abundance indicative of species interactions;
    - Validate quantitative models of reef fish abundance (see above).
- Answer the very practical questions, "At what level of fishing pressure does the harvest from a reef equal or exceed the fish production attributable to that reef?" and "To what extent can that equilibrium point be shifted to maximize sustainable fish production in a managed ecosystem?"

POSTER PRESENTATIONS

Comparative Age, Growth, and Stock Structure of Sheepshead (*Archosargus probatocephalus*) (*Sparidae*) Subspecies in the Gulf of Mexico and South Atlantic States

Debra J. Murie, Brian W. Bowen, And Jynessa Dutka-Gianelli[29]

Sheepshead (*Archosargus probatocephalus*) (*Sparidae*) occurs in coastal waters from Nova Scotia to Brazil (Caldwell 1965), and is widespread in the southeastern United States and Gulf of Mexico (Jennings 1985). At present, there are two morphologically-recognized subspecies of sheepshead in the North Atlantic Ocean and Gulf of Mexico: 1) *Archosargus probatocephalus oviceps*, ranging from St. Marks, Florida, west to Campeche Bank; and 2) *A. p. probatocephalus*, ranging from Cedar Key, Florida, south to the Florida Keys and then north in the Atlantic to Nova Scotia, Canada (Caldwell 1965). A third subspecies, *A. p. aries*, occurs in the South Atlantic Ocean, ranging from Central America south to Brazil (Caldwell 1965, Menezes and Figueiredo 1980). These subspecies have been distinguished by a variety of meristic characteristics, including: number of vertical body bars, number of lateral line scales, number of gill rakers on the lower limb of the first gill arch, and the number of spines and rays of the dorsal fin (Caldwell 1965).

From a fisheries perspective, it is essential to determine if sheepshead form two or more stocks that need individual management, especially in areas in the Gulf of Mexico where their geographical ranges potentially overlap. In general, total landings of sheepshead have increased in the commercial fishery (1956-1995) and in the recreational fishery (1981- 1995) in coastal waters of Florida. Overall, the recreational harvest of sheepshead in Florida is 2-5 fold greater than the commercial harvest (Data from NMFS 1997). Fishery management plans and regulations for sheepshead are imperative at current and estimated future harvesting rates.

Uncertainty in the subspecific stock structure of sheepshead also complicates the interpretation of basic biological data necessary for fisheries management. For example, complete age and growth models for male and female sheepshead are known only for fish occurring off Louisiana (Beckman et al. 1991), presumably *A. p. oviceps*. Limited age-at-length data is also available for sheepshead off North Carolina on the Atlantic coast (Schwartz 1990), presumably *A. p. probatocephalus*. At present, however, sheepshead from the Atlantic coast and from the Gulf of Mexico are viewed biologically as if they are one species representing one stock, without regard to subspecific status and geographical ranges. To date, age and growth of sheepshead from coastal waters of Florida has not been reported.

We have initiated research in the age and growth of sheepshead in relation to their subspecific stock structure in the Gulf of Mexico and the South Atlantic States, with special emphasis on the stock that occurs in the northeast Gulf of Mexico (Big Bend), where putative subspecies overlap. Specifically, we propose to:

1. Resolve subspecific stock structure in sheepshead using mitochondrial DNA (mtDNA) and morphometric/meristic analyses: a) to determine if evolutionary partitions within sheepshead are concordant with morphologically-identified subspecies; and b) to characterize mtDNA and

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morphometric/meristic variation of sheepshead throughout the Gulf of Mexico and South Atlantic States to define management units (stocks).

2. Model the sex-specific age, growth, and sexual maturity of sheepshead from the northeastern Gulf (Big Bend) and southeastern Atlantic coasts of Florida using comparative aging methods (otoliths, dorsal fin-rays, and scales). This includes: a) establishing comparative aging criteria; b) validating the age determination methods using marginal-increment analysis and chemical (oxytetracycline and calcein) tagging; and c) assessing the different aging methods for feasibility in production- style aging for stock assessments.

3. Compare age and growth models of sheepshead from the Gulf coast of Florida and Atlantic coast of Florida (this study), to sheepshead aged in Louisiana (Beckman et al.1991) and North Carolina (Schwartz 1990), to test the null hypothesis that the age and growth of sheepshead does not differ significantly throughout its U.S. range.

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Feeding Ecology and Morphology of Three Sea Basses (Pisces:Serranidae) in the Northeastern Gulf of Mexico

Douglas C. Weaver[30]

Introduction

Groupers and other sea basses (family Serranidae) are of great value to recreational, commercial and artisanal fisheries worldwide (Heemstra and Randall, 1993). As large carnivores, groupers are top predators in marine ecosystems, and are considered important in energy flow in reef communities as well as population dynamics of their prey. However, few detailed studies of feeding ecology of groupers exist, particularly size-related shifts in diet and overlap with co-occurring species.

Gag (*Mycteroperca microlepis*) and red grouper (*Epinephelus morio*) are abundant throughout the northeastern Gulf of Mexico. Gag are often the dominant predators on high profile reefs in the eastern Gulf and the southeastern United States, and are found at much higher local densities than red grouper. Black sea bass (*Centropristis striata*) occurs on reefs throughout the year, and forms dense aggregations on high profile reefs during winter months in the northeastern Gulf, presumably to spawn. Trophic relations within and among these species, particularly the prey base required to support dense aggregations of gag, have not been studied.

Ojectives were to describe dietary shifts in gag, including size at piscivory, proportion of pelagic and other off-reef dwelling prey, and seasonal changes in dietary composition. Dietary patterns were compared with red grouper and black sea bass, and morphology of the oral jaws examined to identify possible adaptions for capture of fishes and other evasive prey.

Methods

Live bottom reefs (water depths 11-14m) located approximately 25 and 30 km southwest of Cedar Key, FL were sampled during summer and winter months from July 1994 to September 1995. Groupers were collected primarily by spearing while using SCUBA from approximately 0900-1300 hours; black sea bass were collected by hook and line with cut squid, and ingested bait later discarded. Specimens were packed in wet ice upon return to the boat, and returned to the laboratory.

Each fish was measured (standard length (SL)), and stomach contents removed by dissection. Individual prey items were counted, weighed, and identified to the lowest possible taxon (typically family). Prey items were pooled by family (members considered ecological equivalents), and the percent of the Index of Relative Importance (%IRI), calculated as an average of relative mass (M), frequency of occurrence (F), and relative abundance (N), using the formula IRI=(N+M)F for pooled prey items in each size class examined.

Oral jaws (premaxillae and mandibles) were dissected from a size series of each species, and dentition patterns examined. Tooth counts were made for each jaw, and tooth lengths taken at seven positions for gag and red grouper. Comparisons of tooth lengths were made by analysis of covariance (ANCOVA), to determine signicant differences.

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Seasonal differences in diet of gag was analyzed by pooling fishes collected from April through September "summer", and November through March "winter". This designation was based on the observed presence/absence of schooling, pelagic species, families Clupeidae, Carangidae, and Engraulidae ("baitfishes") during collections.

Results

A total of 251 gag, 191 red grouper and 186 black sea bass were collected during this study. The diet of gag at all sizes was dominated by fishes, and displayed a shift from wrasses (f. Labridae) and other reef-associated species as small juveniles to grunts (f. Haemulidae) and baitfishes in larger size classes. Baitfishes constituted over half of the diet in large juvenile gag, while making up a smaller portion of the diet in medium juveniles and adults (6% in both size classes). Invertebrate prey shifted from small palaeomonid shrimps to penaeids, and ultimately portunid crabs. In contrast, diets of red grouper and black sea bass were dominated by benthic, reef-associated crustaceans (namely majid crabs) and fishes (wrasses in both species, toadfish in adult red grouper) . Both species exhibited an increased inclusion of fishes in the diet, although limited to a lower proportion than gag (3% to 17% in black sea bass, 5% to 66% among four size classes of red grouper. Baitfishes, common in larger gag, were absent from the diet of red grouper and black sea bass.

Dentition patterns among the three species ranges from relatively few, large teeth in gag to high numbers of small, cardiform teeth in black sea bass. ANCOVA analyses of tooth length among gag and red grouper revealed significantly larger teeth in gag at the top canine, bottom canine, top inner depressible, and top fused tooth positions.

The gag displayed marked differences in diet with season. Baitfishes were absent from stomach contents in winter fishes, and grunts (and to a lesser extent, porgies (f. Sparidae)) dominated the diets of the three largest size classes. Fish prey of small juveniles included wrasses and basslets (f. Serranidae). Invertebrates were of increased importance during summer months in all size classes of gag.

Discussion

Diets of gag indicate divergence from patterns displayed by red grouper and black sea bass. The ability of gag to exploit fishes and other evasive prey at small body sizes likely contributes to their success on live bottom reefs by avoiding density-dependent limitations of prey resources. Similar dietary patterns and foraging behavior have been described for other Mycteroperca spp. in the Caribbean (Randall, 1967) and the Gulf of California (Hobson, 1968). Dietary data suggest that gag forage in pelagic habitats in summer months, and likely off-reef sandy habitats throughout the year. Although grunts are reef-associated by day, they are reported to undergo nocturnal migrations away from reefs to feed (Burke, 1995, and references therein). The common occurrence of porgies and portunid crabs, both associated with soft-bottom habitats, in stomach contents suggests off-reef foraging behavior in large gag. These prey taxa also occurred in the diet of red grouper, but were of much lower importance. The abilityof gag to capture prey in pelagic and open sand environments is likely supported by a number of behavioral and morphological adaptions, including enlarged dentition. Future research will focus on interspecific ability in capture of evasive prey and patterns of foraging behavior as causal factors in observed differences in the feeding ecology of these species.

Acknowledgements

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SPATIAL PATTERNS OF GROUPER (PISCES: SERRANIDAE) OCCUPYING EXPERIMENTAL PATCH REEFS

L. Kellogg, B. Kiel, J. Loftin, J. Hale, A. Heck, and W. Lindberg[31]

Introduction

Gag, *Mycteroperca microlepis*, and red grouper, *Epinephelus morio*, are the two most common groupers in the northeast Gulf of Mexico and often co-occur on discrete hard bottom natural or artificial patch reefs, but few data are available on how long these fishes remain on reefs or on how they move or are distributed among differently spaced patch reefs. The Suwannee Regional Reef System (SRRS) provides an ideal opportunity to answer these questions. SRRS reefs are located approximately 24 km offshore at a depth of 13 meters. Reefs are arranged in hexagons with individual patches composed of either 4 or 16 cubes placed at 25, 75, or 225 meter distances.

Methods

We analyzed visual survey data among patches within reefs (from SCUBA divers between 1991-96) in a large scale artificial reef complex, the Suwannee Regional Reef System (SRRS), specifically to test if gag or red grouper were distributed randomly among patches within reefs (alternatives are even or aggregated distributions). Gag distributions were assessed from means of reef log-likelihood ratios computed for each reef survey (G test, =0.05); specific differences were tested by ANOVA after a square root transformation (=0.05). Red grouper distributions were assessed by comparing the observed number of reefs with 2 red groupers on a patch to the simulated probability of those occurrences given the observed reef abundances (=0.05).

We also surgically implanted gag with ultrasonic tags (n=61) then telemetrically monitored over 22 months (1995 to present) to determine residence times and patch-to-patch movements. Residency times and movement were analyzed by Kruskal-Wallis tests for tied ranks (=0.05).

Results

Survey data showed that gag frequently occurred at high numbers (83% of surveys documented >10/reef, to a maximum of 498), while red groupers were always in low numbers (maximum of 10/reef). Gag generally were aggregated on patches within reefs (P=0.04) with a trend from random to non-random distributions over years. Gag were usually aggregated on patches in summer but not in winter (summer-winter contrast, P=0.03; G test for summer, P=0.02; G test for winter, P=0.10). Gag were also aggregated on 225 m reefs but not on 25 m reefs (size contrast of P=0.03; G test for 225 m

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reefs, P=0.02; for 25 m reefs, P=0.09). Gag distributions did not differ between large and small patch reefs (P=0.73).

In contrast, red grouper were more evenly distributed among patches than expected by chance alone (P <0.001), with no apparent seasonal (summer vs. winter) or reef treatment effects (4 vs. 16 cube or 25 vs. 225 m combinations).

Telemetry data from gag to date indicate a mean residence time on reefs of ca. 8 months (max. of 21 months). In a pilot study of tagged gags (n=20) residency was 28% longer on 225 m reefs, compared to 25 m reefs, but current tagging results indicate smaller differences (8.5% higher residence at 225 m sites). Patch-to-patch movements were relatively infrequent and similar between patches spaced at 25 and 75 m. No movements were recorded between patches spaced at 225 m or between reef sites (separated by ca. 2 km). At present 70% of tagged fish are no longer on the Suwannee Regional reefs. Of these, 8 were reported by fishermen from distances up to 68 km away.

Conclusions

- Gag aggregated (e.g. not distributed randomly) on certain patch reefs within a reef site, and their tendency to aggregate increased over years.
- Gag aggregated in the summer but not in the winter. Gag also aggregated on reefs with 225 m between patches but generally not on patch reefs spaced at 25 m.
- Red grouper were evenly distributed among patch reefs both seasonally and by reef treatments (4 cube vs. 16 cube patches and 25 vs. 225 m spacing).
- Average gag residence times were relatively long on reefs arrays (ca. 8 months), with a maximum to date of 21 months.
- Gag move between closely-spaced patch reefs (e.g. 25 and 75 m reefs), but do not move, or do so rarely between widely-spaced patch reefs (i.e. 225 m).

Inferences and Hypotheses

Seasonal distributions of gag may be related to distributions of preferred prey (e.g. in summer when schooling prey are more available gag may aggregate on patches with the highest prey density).

The combination of increased levels of aggregation in recent years of our study, relatively low rates of movement, and higher probabilities of aggregation on patches at 225 m reefs suggests that: 1) similar cues associated with patches such as prey levels, habitat complexity, etc., may lead to aggregated distributions or, 2) gag may estimate habitat quality by the number of conspecifics (i.e. high gag density may be associated with increased prey capture rates, reduced predation, or reduced intraspecific competition).

Red grouper are generally spaced evenly among patches regardless of season or reef treatment. These results are consistent with the hypothesis of territoriality. We hypothesize that red grouper are territorial when the resulting increased access to preferred prey offsets the costs associated with territoriality. The even distribution of red grouper among patches suggests that behavioral interactions may predictably influence their distribution and abundance among habitats.

Relatively long residence times and short distance movements indicate that gag rely on locally available resources. Gag are expected to have small home ranges and may home after experimental displacement. In addition, the distributional data of gag suggest that home ranges may differ seasonally

HARD-BOTTOM HABITAT NEAR SUWANNEE REGIONAL REEFS: QUANTITATIVE DESCRIPTION AND RELATIONSHIP TO FISH ABUNDANCE

James L. Loftin, Jason A. Hale, Alan C. Heck, Kenneth M. Portier, and William J. Lindberg [32]

Introduction

Artificial reefs are traditionally created in areas where natural hard bottom is scarce. As a consequence, there is a paucity of information addressing effects of nearby natural hard-bottom habitat on the abundance of fish associated with artificial reefs.

The Suwannee Regional Reef System is a series of replicated artificial reefs located in the northeastern Gulf of Mexico. Although reef sites were originally chosen to avoid hard- bottom areas, the abundance and distribution of limestone outcrop in the region made complete avoidance impossible. As a result, identical artificial reefs are now located in areas containing various amount of emergent natural reef. This allowed quantification of the relationships between the amount of emergent hard-bottom habitat surrounding artificial reefs and the abundance of fish associated with those reefs.

Methods

Sixteen artificial reef sites were examined in this study. Each site contains an array of six patch reefs constructed from concrete cubes. Transects were extended 75 meters from each patch reef, and point intercepts were sampled along each transect line at 0.5 meter intervals. The percent of sampling points contacting hard-bottom habitat was then calculated for each site.

Fish were counted on patch reefs during a 15 minute interval by a single roving diver, and were identified to species when possible. Counts were performed during winter and summer, 1991 - 1995.

Percent hard-bottom cover was used as a covariate in an analysis of fish data using a series of mixed linear models with computations performed using PROC MIXED in PC - SAS version 6.11.

Habitat Description

Patchy limestone outcroppings covered 7.6% of the total area surveyed. Only 21% of the surveyed rock exceeded 10 centimeters in height, with none higher than 50 centimeters. Most of the hard bottom was fragmented rather than contiguous, with 80% of all rocks one meter wide or less. Only 7% of all rocks were greater than two meters across, with the largest continuous span measured at 12.5 meters.

Hard bottom was not uniformly distributed among reef sites, nor among the patch reefs within sites. The hard-bottom habitat cover ranged from 0 - 33% among sites, and was greatest around the northern sites. Within sites, the number of patch reefs with hard-bottom habitat in the transect area varied from zero to six, and the cover for individual transects ranged from 0 - 63%.

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[32] Information about the participants can be found in the *Directory of Workshop Participants* at the end of this report.

Relationship to Fish Abundance

Eighty-six species were found during nine survey seasons on the 16 artificial reefs. Most were too rare to be incorporated in models used for analysis. Twenty-nine species were tested for an association between abundance and the amount of hard-bottom habitat.

The abundance of eleven species increased significantly with an increase in surrounding hard-bottom cover. These include many sport fish species commonly found on these artificial reefs.

Three species showed a significant negative association. Some may have a negative interaction with gag, the dominant predator on the reefs.

Fifteen species had no significant relationship with the surrounding rock. These include pelagic species as well as many small species which probably do not venture far from the artificial structure.

Discussion

The response of artificial reef fishes to nearby hard-bottom habitats may vary with species, size and behavior, as well as habitat type and distribution. The low relief rock near Suwannee Regional Reefs may provide additional food for artificial reef fishes, while harboring few natural predators. Results from this study may not represent conditions for the entire shallow continental shelf off Florida, because study sites were chosen to avoid natural hard bottom.

Higher abundances of fish on artificial reefs do not necessarily mean improved fitness of the fish present. Additional research relating surrounding hard-bottom cover to fish survival, growth and fecundity is required to test this hypothesis. Possible effects of large concentrations of fishes on adjacent hard-bottom communities also needs to be examined.

ECONOMICS AND COASTAL COMMUNITIES

INDICATORS OF ECONOMIC VALUE AND ACTIVITY IN THE FLORIDA BIG BEND REGION

Chuck Adams[33]

The Big Bend region of Florida has often been described as economically undiversified. As such, a region might be characterized by low population densities, a natural resource or agricultural dominated business sector, low government expenditures per capita, small tax base, high levels of unemployment, and a small economic multiplier effect. If so, the region may be much more vulnerable to changes in regulations and/or policy that directly effects local industry. Although this hypothesis will not be directly tested for the Big Bend, data will be presented that provides an overview of the diversity and relative magnitude of economic activities found within the seven- county region.

During 1990-1995 period, the population of Florida increased by 9.4%, of which 78% was attributable to net immigration. These values are exceeded by all counties in the Big Bend region, with the exception of Taylor County, where population increased by 7.1 percent. Wakulla County exhibited the greatest rate of increase in population during the same period, increasing by 19.7%. The 1996 unemployment rate for Florida (5.1%) was exceeded by Taylor, Dixie and Citrus, with Wakulla, Jefferson, and Levy Counties posting unemployment rates less than the state average. All counties in the region indicated a net decrease in unemployment during the 1991-1996 period, with Hernando County and Jefferson indicating the largest and smallest changes, respectively. Of total employment in the region, wholesale/retail, construction/manufacturing, transportation/communication, and agriculture/forestry/fisheries specifically accounted for 35.3%, 18.4%, 6.3%, and 2.7%, respectively. The Citrus- Hernando County region was much more dependent on wholesale/retail than the remaining counties, where construction and manufacturing are of greater relative importance.

As expected, taxable sales within the region are low relative to other regions of the state. Citrus and Hernando Counties ranked 32 and 33 among all other counties. However, the Florida Price Index (approximate cost of goods purchased) for the seven counties indicated low values relative to other regions of Florida. For example, Levy, Citrus, and Dixie ranked 63, 54, and 51, respectively, among all Florida counties. Also surprising are the disparity of government revenue expenditures per capita with the region. For example, Dixie County ranked 6, while Jefferson, Taylor, and Levy ranked 48, 47, and 43, respectively, among all Florida counties.

Per capita income within the Big Bend region is low relative to other regions in Florida. Dixie County ranked 66 ($11,648) among 67 counties, while Levy, Jefferson, Taylor, Wakulla, Hernando and Citrus Counties ranked 58, 54, 40, 38, 37, and 36 ($16,623), respectively. No county exceeded the 1994 Florida average per capita income ($21,767). Within the seven-county region, most earned incomes are associated with the wholesale/retail industry sectors. However, when excluding the more urban Citrus and Hernando Counties, most incomes are associated with construction and manufacturing. Less than 5% of reported earned incomes are associated with agricultural, forestry, and fisheries within the region. The incomes associated with forestry are unknown, but likely substantial. The region including Jefferson, Taylor, Dixie and Levy Counties accounts for over 20% of the total mean board feet and cords of soft and hard woods for all of Florida.

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The Big Bend region has 66 marinas, 1971 wet slips, 1,430 dry slips and 156 boat ramps. These are found within both fresh and saltwater environments. During the 1995-1996 period, there were over 28,000 recreational boats registered in the region. Of these, 15,624 were less than 16 feet in length. Approximately 12,000 were between 16 and 26 feet in length. The greatest growth in sheer number of registrations is seen in the latter category. Between 1991 and 1996, the number of registered recreational vessels in this category has increased 20%. The number of saltwater recreational fishing licenses has also increased during the 1991-1996 period. There were over 35,000 and 30,000 resident and non-resident licenses, respectively, sold during the 1995-1996 fiscal year. This represents a 20 percent change from sales in 1991. The greatest percentage increase in sales is associated with the northern counties in the region, where non-resident sales exceed resident sales.

There are approximately 2,400 commercial vessels registered in the Big Bend region. The largest component of the fleet is located in Citrus County (913) and Wakulla County (406). During the 1991-1996 period, the number of commercial vessel registrations has declined by 15 percent for the entire region. The Big Bend region is an important source of several high-valued finfish and shellfish species. The region produces 44%, 86% 29% and 39% of the grunt, sea bass, blue crab, and bait shrimp on a statewide basis. During 1994, 6.3 million and 6.8 million pounds of finfish and shellfish, respectively, were landed within the seven- county region. However, finfish landings declined to 2.3 million pounds in 1996, while shellfish landings increased to 9.6 million pounds. The increased importance of shellfish may be a result of the Amendment 3, which banned the use of entangling nets in state waters. Such nets were the primary means for harvesting the nearshore species found in the region. The region accounts for 5% and 11% of the total statewide finfish and shellfish landings, respectively. The leading producer of both finfish and shellfish within the region is Citrus County. Also located within the region are a number of businesses directly associated with the production and distribution of seafood products. There are about 1,400 saltwater product license holders and 320 wholesale/retail seafood dealers. The number of saltwater product license holders had declined 15% since the implementation of Amendment 3.

Social Issues in Ecosystem Management: The Case of Inshore Commercial Net Fishing

Suzanna Smith[34,35]

According to experts in ecosystem management, humans are imbedded in the ecological landscape and must be addressed in defining and implementing ecosystem management (Christensen et al., 1996; Grumbine, 1994). Despite the professed importance of social concerns in ecosystem management, however, the biologists writing on this topic tend to emphasize the scientific aspects of ecosystem management while underestimating the political and social issues in the management process (Grumbine, 1994). In this program, we have an opportunity to think more critically about how humans fit with Florida's natural systems.

This paper provides more information about human populations and activities in the Big Bend region, based on data collected from commercial seafood producers in that area. The results are based on interviews conducted between 1991 and 1993 with 95 married couples with children in 10 coastal communities including 34 couples in the Big Bend. At least one adult was involved in commercial net fishing in state waters.

Who Are These Families and What Do They Do?

The average age of the Big Bend sample was 38, 36 for women and 39 for men. They had lived in their communities for an average of 30 years (women 25, men 34 years) compared to 26 years for the rest of the sample. On average, women had lived in the community for 25 years and men for 34 years. Families had a long history of involvement in the industry: 85% of Big Bend men came from a fishing family compared to 67% of men in other parts of the state (this approaches significance at the .06 level). Men had been earning a living from fishing for 21 years, suggesting that they had started fishing commercially when they were around 18.

In short, the sample of Big Bend families was characterized by a long personal and family history of commercial seafood production. These men, who were approaching middle age, had spent all of their adult lives in the industry and in most cases were second generation fishers. They and their wives had strong attachments to the community.

Couples (n=28) indicated that 71% of their household income was derived from commercial fishing. Yet, changes in regulations, increased coastal development, habitat loss and increased number of recreational fishers had made it more difficult to make a living. Sixty-seven percent (n=14 of 34) reported a decrease in pounds landed. About a third (32%, n=11) reported that they had decreased the number of areas where they fished. However, about one-third were spending more time in fishing to

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[34] Information about the participants can be found in the *Directory of Workshop Participants* at the end of this report.

[35] Support for the research reported here was provided by the National Oceanic and Atmosphere Administration, Office of Sea Grant, U.S. Department of Commerce, Grant No. R/LR-E-14. The author appreciates the assistance of Michael Jepson, Cultural Anthropologist, South Atlantic Fishery Management Council, with the preparation of this paper.

make up for the reduced income. About one-third (n=11) of the Big Bend group had increased their effort toward other species, usually for some combination of mackerel and jacks.

In addition to being financially dependent on the resource, families were also psychologically tied to marine fisheries. They were very satisfied with most aspects of their work including their independence and the worthwhileness of their job. When we asked fishers if would stay in fishing or go into some other occupation if they had a choice, 79% (n=27) said that they would stay in fishing. If they had their lives to do over again, 79% (n=27) would go into commercial seafood production.

A major impact of these changes in operations was a reduced income: 62% reported that their income from fishing had decreased. Half of the families had lowered their food costs, and reduced or eliminated their health insurance or health care; nearly two-thirds (62%, n=20) had increased their use of loans and credit.

Most (62%, n=20) had become more dependent on non- fishing income. Forty-one percent of fishermen (n=14 of 34) worked part time in activities such as construction. The vast majority of women--almost 80%--were working in non-fishing jobs, primarily as waitresses and clerks.

Commercial Fishers and Ecosystem Management

We gathered some quantitative and qualitative information about fishers' views of marine fisheries regulations and management. Virtually everyone in the study felt that the increase in marine fisheries regulations had hurt their ability to make a living from fishing but also felt that some regulations were needed in order to conserve the resource.

Nevertheless, these families were limited by their human capital and by social structural forces in the Big Bend region. Not only were there are fewer job opportunities in the rural communities along the coast, but with less than a high school education (x=11.64 years for women and 11 years for men), these men and women were usually not eligible for the limited number of better paying jobs.

Fishers were not optimistic about the future and did not want to pass on the business to the next generation. When asked if they wanted their children to go into the commercial industry, 79% (n=23 of 29) of the men and 89% of the women said "no". There was no future in it, it was too hard a life, and they wanted a better life for their children. For themselves, they promised to hang in until the "bitter end." Most speculated that they eventually would be regulated out of business.

In every region of the state, fishers claimed that they knew quite a bit about the resource but that their knowledge was not considered in regulatory or policy decisions. They requested that decision-makers spend some time fishing with them and getting to know their communities so that they could make better informed decisions. Currently, marine resource decisions are based on public hearings, but there are numerous problems with the process (Smith & Jepson, 1994). If we are going to be serious about ecosystem management, we must ask whether the public hearing process fulfills its objective of gathering useful information in natural resource use from stakeholders and whether all stakeholders are brought into the information gathering process in a meaningful way (Christensen, et al., 1996).

One of the principles of ecosystem management is to sustain viable communities and jobs while also sustaining the ecosystem. This brings people to the decision making table as a resource to be valued and protected as well as natural systems. If Florida had been using an ecosystem model in the late 1980s and early 1990s, perhaps the human impacts of regulatory changes would have been considered more in regulatory decisions.

Furthermore, managers and academicians might have responded to the proposed net ban if ecosystem management were the operational paradigm. An ecosystem model suggests that scientific information would have been provided to the public from governmental agencies and universities so that the public could have been better informed before voting. In addition, the net ban has probably done considerable damage to human systems. Entire fishing communities have lost their economic base. Some couples have divorced because they have not been able to cope with the job loss, financial stress, and the psychological burden of unemployment. We have probably lost a way of life, not only for many families but also a fundamental part of Florida's history and culture. These unintended consequences of the net ban are really at odds with the basic principles of ecosystem management.

Now, as we recover from the net ban and an ecosystem management plan is in place, what is our role now in sustaining the human communities as they proceed through this transformation? I do not have the answers to this question but I hope that I have offered some points of discussion about the human dimensions of the ecosystem in the Big Bend region.

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POSTER PRESENTATIONS

Springs Coast Ecosystem Management Area Initiatives

Kent Edwards[36]

Abstract

The Florida Department of Environmental Protection (DEP) has undertaken an initiative to change the basic way that it functions. This initiative, called Ecosystem Management, seeks to have DEP activities guided by the knowledge that the environment is an interconnected system. A disruption in one portion of the ecosystem may have unforeseen and far-reaching effects. Humans are a part of the ecosystem but we must plan activities so that the integrity of the ecosystem is not diminished. The Springs Coast Ecosystem Management Area (SCEMA) , which covers the coastal areas of Pasco, Hernando, and Citrus counties, is one of 24 EMA's designated by the DEP. The SCEMA approach, seeks to implement ecosystem management through activities including governmental coordination, citizens outreach, education, critical habitat preservation, land management, research, and application of growth management and planning resources. Specific activities of committees and proposed projects will be detailed.

The SCEMA Citizens Committee Mission Statement

A few specific areas of concern have been identified, and the actual verbage is set for adoption at the next meeting, May 19, 1997. The proposed Mission Statement follows.

The SCEMA Citizens Committee is committed to being informed about all significant environmental issues affecting the area. Monthly meetings will be held, including open discussion , and a scientific presentation on a selected topic of interest.

Any factor causing environmental degradation is of concern, and is appropriate for the committee's attention, but some issues of special concern include:

1. Spring and River Flows, Lake and Groundwater Levels
2. Water Quality, with Special Attention to Nitrate-Related Issues
3. Balancing Quality of Life and Growth Impacts

The committee will seek to create a communication network for private citizens. A portion of the committee meeting will be set aside for other environmentally-active citizens groups to distribute information. Time will also be set aside for citizens to ask questions, voice their opinions, and request information related to environmental issues.

The Florida Department of Environmental Protection (DEP) will help to organize and facilitate the committee. DEP is committed to supplying the committee with any available information that is requested.

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[36] Information about the participants can be found in the *Directory of Workshop Participants* at the end of this report.

The SCEMA Citizens Committee gives citizens the opportunity to talk one on one with governmental and private environmental professionals. This meeting provides a forum for citizens to ask questions and obtain detailed information, pertaining to Florida's environment.

A presentation is given at each meeting on an environmental topic of interest, suggested by the citizens. To date presentations have included:
George Craciun, DEP - The Permitting Review Process for FDOT Projects
Scott Stevens, SWFWMD - Overview of the SWIM and CSWM Programs
Mark Barcelo, SWFWMD - Spring Flows and General Hydrology
Kathy Liles, DEP - Environmental Issues of Spring Hill, A Residents Perspective

The presentation scheduled for the next meeting:

Kelly Dixon, Mote Marine Laboratory - Historical Water Quality Overview, and Recommendations for Future Study

The SCEMA Citizens Committee, meets every fourth Monday of the Month, at the Hernando County Commissioners Office Boardroom, From 6:00 PM- 8:00 PM.

The SCEMA Management Committee

The SCEMA Management Committee (MC) has the main responsibility for designing the ecosystem management initiative. The MC will seek input from all stakeholders, including citizens, in order to keep a perspective that is representative of the community. The membership of the MC is made up of major public, private, government, industry and individual interests in the EMA. With this diverse membership, there is a comprehensive understanding of environmental issues and the differing perspectives on these issues. MC members are encouraged to coordinate and communicate actively in their every day work, as an effective and timely communication network is essential to the ecosystem management approach.

The SCEMA Management Committee is developing an Action Plan that will guide activities for the next two years. It is important to have this plan in place, because there is so much work to be done, it would be easy to get off track. We are committed to developing a program that will help maintain the economic and environmental viability of the area. The Plan is still in preparation but the main "themes" or chapters are:

Land Management
Growth Management, Economics, and Sustainable Growth
Public Communication and Outreach
Water
Habitat and Species Protection
Funding Resources
References

By design the plan will be brief, using other informational sources, such as planning documents and research publications, to describe issues. The main focus of this document will be a short description of projects designed to address the 'theme'. The description will include resources needed for the project to proceed, and the net environmental benefit.

SCEMA MC Action Plan Projects-Proposed

- Research collaboration between Preserved Lands and Universities
- College credit for students working in parks
- Coordinate environmental monitoring programs of all governmental agencies
- DEP research targeted to obtain information base for regulations
- Link existing researchers with appropriate regulatory programs
- National Estuarine Research Reserve designation for St. Martin's Marsh Aquatic Preserve
- Sharing of resources between all state governmental agencies
- Integration of planning and regulatory activities
- Coordinated land acquisition by public & private conservation groups
- Educational programs in secondary schools and colleges
- Identification and acquisition of grants and other funding sources
- Drainage and habitat restoration projects
- Encourage public stewardship: recycling, xeriscaping, knowledge of specific environmental issues
- Best Management Practices in industry
- Information-Based Decision Making
- Communication Network of Environmental Professionals

SCEMA Management Committee Membership

St. Martin's Marsh Aquatic Preserve
Audubon Society
University of Florida
University of South Florida
City Of Crystal River
Gulf Islands State GEOPark
Citrus County Government
Pasco County Government
Hernando County Government
Florida Crushed Stone
Florida Department of Education
Florida Power Company
Florida Department of Environmental Protection
Southwest Florida Water Management District
Withlacoochee Regional Planning Council
Florida Department of Community Affairs
Homosassa Springs State Wildlife Park
Tampa Bay Regional Planning Council
United States Fish and Wildlife Service

SCEMA Citizens Committee Chairman

United States Army Corp of Engineers
United States Geological Survey
Florida Division of Forestry

SYNTHESIS AND INTEGRATION

NO MORE EXCUSES: A RAPPORTEUR'S REPORT

W.F. Herrnkind[37]

I preface my comments by calling attention to the fact that I have resided in Florida for the past thirty-five years, most of it in the panhandle where I have enjoyed its marvelous natural coast. Elsewhere, many of the state's eco-environmental problems came to crisis over that time, each sounding the alarm for regional management for the long-term, based on sound knowledge of natural processes but in full recognition of a continuous population onslaught. Nearly always, it has been too little, too late. Whether we are capable of restoring the Everglades or Florida Bay or Tampa Bay remains to be seen. What matters here is that the Big Bend Gulf coast and adjacent waters offer the last, but perhaps best, opportunity to integrate increasing numbers of people, their interests, activities and impacts while sustaining the essential natural condition. I view this challenge as both scientist and citizen.

What information and what level of understanding is needed? The collectively broad and occasionally deep coverage of the region's natural history provided at this meeting suggested the scope and type of information applicable to its management. Especially clear was the recognized dynamic biotic and physical linkages among the region's defining features including the drainages, springs, rivers, estuaries, marshes, benthos, and offshore Gulf of Mexico. Of these, the least information was given on the nearshore benthos. For that reason it bears brief discussion here.

The entire coast is dominated by extensive seagrass meadows, soft sediments and frequent, intermittent small estuaries bounded mostly by marshes and the gradually deepening Gulf. The vegetated nearshore, estuaries and salt marshes represent interacting biotopes supporting an extremely productive and diverse fauna, and are essential to the successful life cycle and sustained population of ecologically as well as economically important species. While the above is well known generally, the specifics of this region's habitats and organisms have not yet been adequately ascertained. Seagrass meadows also host seasonally extensive benthic algae which, when combined together, probably play a major role in nutrient cycling -- potentially a concern should the amount of nutrient transport by the rivers and springs change markedly in the future. Benthic invertebrates additionally provide the basis for local fisheries, including scallops, oysters, blue crabs, stone crabs and bait shrimp. The burgeoning clam grow-out industry as well as the other fisheries require pristine conditions to serve human consumption. For all these reasons, the regional benthos and its connections to the system will need more attention.

Everyone attending likely lists hydrology in their top three priority topics. The Nature Coast is one elongated estuary fed by freshwater over the ground and through the ground. The biotic systems must adjust and respond to both the flow rate and chemical character of all those watercourses, as we well learned. What is also apparent is the certainty that these conditions, particularly nutrient load, are the ones that will be increasingly and swiftly impacted by human activities. Getting a handle on the dynamics of the present, lightly impacted conditions and establishing how and why the system operates the way it does seems paramount. The Nature Coast may not be in danger of being irreparably altered by cheek-to-jowl high rise condos, but it is very vulnerable to problems local watershed by local

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watershed. One trusts that this can be avoided by effective, well informed management because impact is on the horizon and is coming soon.

The last point forces this natural scientist to recognize that understanding the ecosystem as it is now will only serve a limited service if it immediately goes awry, even though we may be able to pinpoint causes. What managers and researchers need is to anticipate as precisely as possible the type, location, and rate of high impact human activities. This must be provided by the social scientist. It will be essential for them to perform research that seeks and accomplishes prediction (a goal of first rate science) with which to set priorities. This should be done up front so the best estimates can be used to focus efforts where they are most needed. It will not be good enough to only track events or to do post hoc analyses which, in hindsight, blame natural scientist for not providing the right information and managers for overlooking key social, economic and political factors.

Finally, who will guide the research and analysis that will produce the necessary knowledge for the ecosystem managers? The idea is to encourage essential, high quality science. My own lengthy research experience in Florida Bay convinces me that it is wise to promote the creation of a competent and ethical interagency working group of researchers/mangers to continually assess information needs, set priorities, and facilitate support. It is best that perspective also be drawn from respected scientists without vested interest in the research enterprise at hand. However, unlike Florida Bay, all this should be done now, before rather than after massive, unprecedented systemic disturbances!

As a Floridian, I have to hope that this time the management effort will be successful. No more excuses.

ECOSYSTEM MANAGEMENT: BOLDLY GOING WHERE FEW MANAGERS HAVE GONE BEFORE

Larry B. Crowder[38]

As an outsider, who knows little about Florida's Big Bend region, I was impressed by the breadth of knowledge of the region exhibited at the workshop. I was also surprised and pleased by the enthusiasm expressed by participants for interaction among disciplines to protect and conserve the "Nature Coast". Such an interdisciplinary gathering usually fails to materialize for most ecological systems before the post-mortem. The meeting usually emphasizes a hand-wringing discussion of 'restoration' or 'rehabilitation', rather than protection, sustainable development or ecosystem management. Florida has plenty of experience with the former (e.g., Kissimmee River, the Everglades, Florida Bay), but much less with the latter.

Fifteen years ago, I arrived in the Southeast U.S. having worked to enhance our understanding of Great Lakes food webs, which had been dramatically altered by over-harvesting of fish, exotic species invasions, and habitat modification. In my early studies of North Carolina estuaries, I was shocked to find how little was known about these systems compared to the knowledge base available to mangers in the Great Lakes. Why had so little research been done to understand the structure and function of North Carolina's estuarine ecosystems? I concluded that one thing we lacked, that the Great Lakes had, was a first class ecological crisis. In order to secure a public investment in research to support management of ecological systems, these systems often have to first become highly degraded. In North Carolina, recent increases in algal blooms, low oxygen, toxic algae and fish kills have captured the public's attention--and have generated some support to understand the linkages between the land use in the rapidly developing coastal zone and the health of our coastal ecosystem. One hopes this trend toward attending only to crises can be avoided in the Big Bend region of Florida.

If Ecosystem Management Is the Answer--what Is the Question?

Ecosystem management has many laudable goals, but it will not be achieved without carefully considering specific objectives of management. These management objectives will have to address both the integrity and function of the coastal watersheds. Because local culture and human activities play a central role in both the economic and ecological systems of the region, all stakeholders will have to be involved in determining these specific objectives. Management plans developed by managers alone or by mangers and scientist are often doomed from the outset. Based on the program at the meeting, much more thought has been given to the natural science than the social science of the region. This will have to be remedied if ecosystem management is to become a realistic management policy. The development of an interagency program management committee and active citizen involvement will be critical to your long-term success. The reason management objectives must be carefully focused is that ecosystems include many processes and components which could be evaluated and measured--but we can't measure (or model) them all! I have encountered some anxious fisheries managers who are now embracing ecosystem management, having failed to manage fisheries effectively at the population level. I have bad

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news -- ecosystem management isn't going to be easier or cheaper so we have to engage in it thoughtfully and critically.

Linkages

Successful ecosystem management will depend upon making linkages between system components and management cultures that previously have been treated independently. In addition to linking the ecosystem to the human dimension, one must link land use to water quality, or health of coastal ecosystems. Historically, different scientists and mangers are involved in land use planning, managing water quality, managing fisheries, or conserving endangered species. They manage components of the coastal ecosystem according to their own objectives and legislative requirements. But they are managing components of the same ecosystem! The developers of the Nature Coast Ecosystem Management Area are to be congratulated for including the shelf ecosystem in their thinking. If I recall, it was Sir Isaac Newton who first explained that water runs downhill-- but many landscape planners apparently missed physics. Experience suggests that integrating physical and biological sciences at appropriate scales will be difficult, but try linking human institutions if you are looking for the ultimate challenge!

One pitfall for many environmental managers is to relate degradation of particular environmental features (e.g. reef fish populations) to one cause (e.g. over fishing or habitat loss or pollution). The search for the one limiting factor often leads to a blame game that can produce management paralysis. Fishers blame polluters, who blame developers, who blame fishers. And they all blame managers for not regulating the activities of "those other guys"! If we have learned anything from the past 20 years of ecosystem research, it is that ecosystems are complex and rife with multiple causation. Thomas Chamberlain's (1890) "The method of multiple working hypotheses" is a classic paper that is as important today as when it was first published over a century ago. I also recommend Hilborn and Mangel (1977) for current thinking on confronting multiple hypotheses with data and deciding which hypothesis or hypotheses are most (or least) likely to explain the observed dynamics of the system.

Because I am an ecologist interested in food webs, I couldn't help noticing that speakers often emphasized human interactions with the coastal ecosystem, but key food web components were missing from the discussion. Humans remove water from the aquifers and return it to the hydrological systems amended with nutrients and other pollutants. Humans also remove shellfish, and finfish, from the coastal ecosystem. While there were concerns about nutrients negatively impacting fisheries, the intermediary links were often more implicit than explicit. Nutrient loading influences primary producers, which include phytoplankton, epiphytic and epibenthic algae, as well as seagrass and macroalgae. Some of this additional productivity may enter the "macro" food web, but much of it may end up being processed by the microbes, leading to increases respiration and low oxygen. Nutrient loading can also lead to shifts in species composition or losses of some of the primary producers. Because seagrass and macroalgae provide critical habitat for many resource species, as well as species of concern, the indirect effects of nutrient loading on seagrass/macroalgal habitat are an important concern. Benthic algae play a previously under-appreciated role in food webs of shallow marine ecosystems, like the one off your coast. In part because there are agencies responsible for water quality and fisheries, both the bottom and the top of the food web get some attention. What is critical, but missing, are the intermediate players in the web--the grazers. In this case, the marine benthos may play a crucial role in transferring primary productivity up the web to the top consumers-- some of which humans are interested in continuing to consume. Clams and oysters also can play a very important role in converting phytoplankton productivity to harvestable resource. Their absence can also exacerbate water quality problems as more of the plankton productivity makes its way directly into the microbial pathway.

The Challenge

This workshop was the first of what I hope will be many interdisciplinary and interagency meetings in support of ecosystem management of the Big Bend region. You have a unique opportunity to be proactive and develop a region of Florida wisely from its natural condition to an ecosystem that continues to provide appropriate services and amenities. It is a difficult challenge scientifically, institutionally, and socially. But it is an enviable challenge because you are not beginning with a coastal ecosystem already highly altered by human activity. You can preserve ecosystem integrity and develop the "Nature Coast" sustainably, but you should expect to encounter resistance. I wish you the best in your new enterprise and I look forward to visiting the Nature Coast again to see how you have done.

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ORGANIZING COMMITTEE RECOMMENDATIONS

By all accounts, this inaugural workshop was successful because it met a real need for communication among scientists with varied research interests in the Big Bend region. Future Florida Big Bend Coastal Research Workshops should occur at intervals of at least two years, and preferably three, so that results from new research can be reported. In the meantime, we strongly encourage individuals to take personal initiative and responsibility to organize working groups of a collaborative, interdisciplinary nature. So many of these opportunities were apparent at the Steinhatchee workshop that we will not attempt to enumerate them here.

Although we emphasize the need for communication among scientists to remain the focus for future research workshops, we also recognize the need for and importance of comparable workshops for resource managers and decision-makers, as well as for citizen interest groups and the general public. While the intended audiences and program content would differ among these three broad types of workshops, an integration of their salient points can be accomplished through appropriately structured management teams for the Nature Coast and Springs Coast Ecosystem Management Areas (EMA). We recommend that the coordinators of each EMA explore how this approach might be facilitated.

In preparing for each type of workshop, careful consideration should be given to the venue and program structure. The intent is to facilitate communication, both formal and informal. Formal presentations can communicate information and stimulate subsequent conversations. However, informal communication fosters understanding and trust among people, even when they don't necessarily agree on a particular issue. That understanding becomes the springboard for synergism and eventual solutions to real-world problems. As demonstrated at The Steinhatchee Landing, a relaxed setting that maximizes the opportunity for spontaneous, informal discussions will magnify the benefits from genuinely stimulating formal presentations.

Careful consideration should also be given to the choice of workshop rapporteurs, who are charged with capturing the essence of the workshop, synthesizing it in an appropriate context, and providing their best professional guidance. The Organizing Committee, as a whole, wants to acknowledge and thank Drs. Larry B. Crowder and William F. Herrnkind for their substantial service as rapporteurs. Their reports eloquently express recommendations endorsed by our committee. We encourage you to read and re-read their essays, and pay particular attention to what each rapporteur says about:

- Explicit management objectives, public participation, and effective management teams;
- Predictive social science to help focus ecological research and management efforts;
- Hydrologic and circulation models that link river outflows and the distribution of freshwater and nutrient loads through open estuaries to the coastal ocean;
- Continued bottom-up and top-down research associated with water management and fisheries approaches to ecosystem processes, respectively, but with an emphasis on intermediate levels of food webs and the linkages between primary and fisheries production.
- The unique opportunity for research and management in the Big Bend before a major ecological crisis hits, tempered by the fact that, historically, necessary funding has always followed rather than anticipated such crises.

We have had good counsel. Stewardship is clearly the shared responsibility of everyone with interests in the Florida Big Bend.

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