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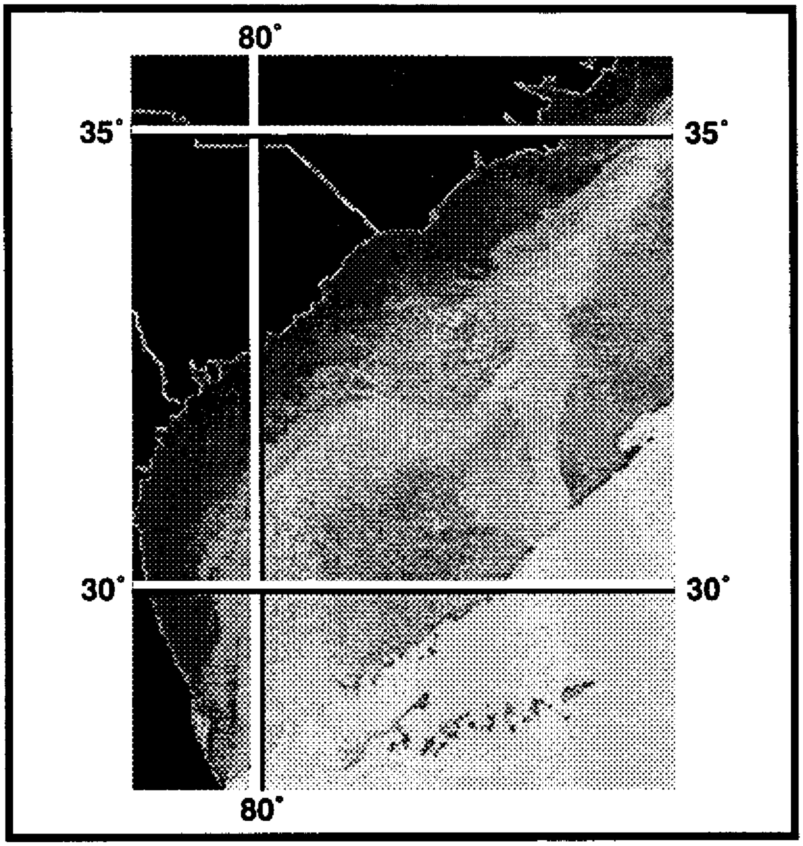
# *The South Atlantic Bight Land Use – Coastal Ecosystem Study (LU-CES)*




## Report of a Planning Workshop

Savannah, Georgia
June 23-24, 1996

*by*
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*on behalf of*
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The LU-CES User/Management Panel
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**The South Atlantic Bight**

# LAND USE - COASTAL ECOSYSTEM STUDY

# (LU-CES)

## REPORT OF A PLANNING WORKSHOP

June 24-25, 1996
Savannah, GA

**Gary S. Kleppel and M. Richard DeVoe, Editors**

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# LAND USE - COASTAL ECOSYSTEM STUDY
# (LU-CES)

## Report of a Planning Workshop

## I. Introduction

### I.A. Workshop Goals and Objectives

This document summarizes the rationale for and results of a workshop on the South Atlantic Bight Land Use-Coastal Ecosystem Study, LU-CES, convened in Savannah, Georgia on June 24-25, 1996 . The goal of the LU-CES, which is funded as part of the NOAA Coastal Ocean Program's Regional Ecosystem Study effort, is to establish a functional understanding of the environmental and socioeconomic trends that characterize the southeastern U.S. coastal region. Further, LU-CES will fill critical information gaps that currently limit the identification of links between population and development trends, and their effects on the region's ecosystems (LU-CES Program Management Team 1995). During the first year of this project, funds will be provided to support a series of issue-driven analyses of existing information that relate to the goal of the program. The results of these State-of-Knowledge studies (SOKs) will be used to guide the development of the research portion of LU-CES.

The workshop focused on making definitive progress toward the preparation of an Announcement of Funding Opportunity for the SOKs. The objectives of the workshop, stated in the planning document, were to:

1. Describe the LU-CES project to the scientific community;
2. Further develop and refine the study objectives and approach;
3. Identify and document major issues and concerns associated with the relationships among population growth, economic development and ecosystem condition in the inner South Atlantic Bight (SAB) region, with the overall goal of maintaining existing environmental quality in the inner SAB system, during the next 20 years.
4. Clarify the concepts embodied in the alternative hypotheses of the LU-CES program.
5. Convert the conceptual framework for LU-CES into a research plan, with specific hypotheses, siting and measurement priorities to be incorporated into an RFP for (issues-based) retrospective analysis.
6. Explore data management and GIS approaches for the program.

Using a model-driven approach, working groups considered a set of questions designed to address these objectives. The results of the working group discussions were summarized both verbally and in writing by the working group leaders, who were selected for their expertise in and contributions to the natural, social and political sciences in the southeastern United States. Together, the working group leaders comprise a multidisciplinary program development group called the LU-CES Coordinating Committee (LCC). The LCC met shortly before and soon after this workshop to consider the conceptual basis from which the workshop report and an Announcement of Funding Opportunity for the SOKs would be generated.

## I.B. Background

### I.B.1. Rationale for LU-CES

Among the coastal regions of the coterminous United States, the portion of the Southeastern Atlantic seaboard between Florida and North Carolina is one of the least developed and least affected by anthropogenic activities. In many other regions of the country, environmental management is typically reactive, centered on remediation of contaminated systems and reclamation of altered habitats. By contrast, it is still possible to employ proactive environmental management and planning in the southeast to minimize the impacts of rapid population growth on ecosystem function and process.

Although the southeastern U.S. presently has one of the smallest coastal populations in the country, the region is expected to experience unprecedented growth in the coming decades. Increases of both residents and visitors are now occurring at the highest rates in the nation. This growth is placing enormous pressure on coastal resources, watersheds and the adjacent coastal ocean. The opportunity for managed growth and science-based decision-making now exists; unfortunately, much of the scientific knowledge needed to make decisions does not. Significant delays in obtaining this information may result in missed opportunities to provide for effective, sustainable coastal development.

The intent of the SAB Land Use-Coastal Ecosystem Study (LU-CES) is to establish a functional understanding of the environmental and socioeconomic trends that characterize the southeastern U.S. coastal region and to fill critical information gaps that currently limit the identification of links between population and development trends, and their effects on the region's ecosystems. We will focus our efforts on the coastal section of the South Atlantic Bight that adjoins the states of Georgia and South Carolina. The data and knowledge that is obtained will be converted into useful information by means of integrative analyses using GIS, statistical tools and conceptual and numerical models. These tools will be developed to quantify linkages and provide practical information to facilitate decision-making on potential linkages and provide practical information on development of coastal resources and ecosystems. Results of these analyses will: (1) allow us to qualitatively predict impacts (by identifying key processes and system interfaces); (2) build conceptual models of linkages between the habitats and ecosystems that form the SAB; and (3) define the spatial scale at which management has the highest probability of minimizing or preventing impacts (local/county, basin/state or region).

Although the coastal population of the southeastern United States is the smallest by region in the country, it is projected to increase by 181 percent (the highest in the country) between 1960 and 2010 (Culliton et al. 1990). Growth at this rate will certainly result in major effects on the natural and social landscapes of the region.

Population density in coastal South Carolina and Georgia are 114 and 130 persons per square mile, respectively, with projections to 134 and 145, respectively, by the year 2010. In the six coastal counties of Georgia, population grew by 20% between 1980 and 1990, and is projected to rise by at least another 20% by the year 2000 to a level of one-half million people. Population in the eight coastal counties of South Carolina is expected to increase by 75 percent by the year 2010 to over one million people. As population increases in these coastal regions, so will the demand for freshwater resources and the need for waste water disposal. Additionally, freshwater surface flows will be altered by urban construction for commercial enterprises, residential housing and accompanying roadway infrastructures.

Although coastal South Carolina and Georgia remain relatively undeveloped compared to the rest of the nation, a large amount of the coastal acreage is owned and/or managed by the federal and state governments. The limited amount of land which is available for private development will receive disproportionate pressures from development interests, which may result in spillover effects on adjacent public lands. For example, in South Carolina, less than ten linear miles of oceanfront remain available for development. As a result, future development will expand the size of popular areas such as Myrtle Beach, Charleston and Hilton Head/Beaufort in South Carolina, and Savannah and Brunswick in Georgia.

From the interior basins to the coastal margins, natural processes and human activities on the land surface in the southeastern United States affect water flow characteristics, their role in the transport and fate of living and non-living materials and the ecological characteristics and integrity of coastal ecosystems. The environmental issues and the management alternatives appropriate for maintaining and restoring system condition is not the same for all spatial and temporal scales and system types.

Inputs of freshwater from rivers, ground water and the atmosphere vary spatially and temporally within the SAB. Small nonriverine estuaries dominate the northern (Little River Inlet to North Inlet, SC) portion of the study region, while large riverine systems dominate the middle and southern portions of the region (North Inlet, SC to St. Mary's Inlet). In addition to changes in the volumes of water delivered to the coastal ocean, correspondingly variable loads of sediment, nutrients (e.g., nitrogen, phosphorus, and silicon), and organic and inorganic pollutants are expected, as well. The inputs of freshwater and materials interact with the coastal ocean to influence processes such as local circulation patterns, sediment accumulation and transport, and marine organism habitat quality and stability.

Material inputs from terrestrial sources of the SAB have varied historically because of past land use practices and recent stabilization. Water inputs have varied because of impoundments (i.e., dams) and demand on aquifers for agricultural irrigation and human consumption. Future demands for water supplies may affect interbasin transfers that could shift large quantities of water from the SAB to the Gulf of Mexico. High coastal turbidity is largely attributable to anthropogenic influences upstream in the watershed, such as deforestation and agricultural practices which began in the eighteenth and nineteenth centuries. Severe alteration of the landscape has led to an increase in riverine sediment load from enhanced soil erosion and in the requirement for regular maintenance dredging in all the region's ports and marinas. The influences of watershed alterations on coastal rivers, estuaries, oceans and organisms are poorly understood, and either little information is available of what is available is limited for developing management strategies for watersheds and coastal environments. Past modifications of the landscape, however, are minor in comparison to the anticipated rate of change that will occur during the next few decades. The development and implementation of a variety of management tools will be necessary for planners and managers to use as they seek to balance population growth and associated development with resource conservation. This is particularly important for industries based on commercially and recreationally important species of fishes and shellfish which, in addition to the added pressures of exploitation by increasing fishing pressure, must also be concerned with impacts from urbanization.

In order to examine how changing patterns of land use and anthropogenic inputs from increasing coastal development will affect habitat quality and living marine resources in the SAB, we need a functional understanding of the processes common to the entire system as well as those that are unique to individual systems. Additionally, a functional understanding of how anthropogenic activities impact coastal resources, scaled to distinct land use units, is required.

As a general conceptual model, the coastal ocean region can be subdivided into distinct generic compartments: (1) tidal rivers and their associated watersheds and landscapes: (2) estuaries and associated marshlands that are directly influenced by each river system; (3) saltwater marshes not influenced by riverine systems; (4) the inner shelf region of the coastal ocean; and (5) mid and outer shelf regions bordered by the Gulf Stream. Defining the functioning of biogeochemical processes within each compartment of the coastal system and the regulation of material exchanges between such compartments will provide information required to plan for sustainable development and management of aquatic and coastal resources that may be stressed as a function of changing land use patterns.

Characterization of the fluxes of materials into, within and through compartments is critical for investigating both natural processes and anthropogenic impacts. Particles (materials) entering the SAB cross a number of compartments as they transit the freshwater environment (via terrestrial sources) through estuaries to the coastal ocean. As salinity gradients are crossed, changes occur in transport mechanisms and in the forms the materials take. Many of the materials discharged into the coastal zone (e.g., nutrients, pesticides, heavy metals, radionuclides and other living and non-living matter) are particle-reactive and thus are intimately associated with fine-grained sediment. These fine particles may cross the fluvial/marsh boundary to accumulate in salt-marsh environments effectively being removed from the system, or they may be only temporarily deposited, ultimately being resuspended and transported downstream or redeposited elsewhere. Particles may cross the sediment/water interface to be buried or regenerated in shelf sediment, or be transported across the shelf-break front to be deposited on the continental slope. The location of the major depositional regions for these fine-grained sediments identifies, by proxy, areas of significant organic carbon and contaminant accumulation. Similarly, coarser particles accumulate near river and estuary mouths, influencing bathymetry and circulation patterns. Complicating these patterns are the alterations by jetties at the mouths of many of the estuaries, which were constructed to stabilize the migration of sediments deposits within navigable waterways. The rates at which these processes and depositional regions remove material from the coastal system is important for predicting and managing loading parameters and carrying capacities for coastal ecosystems. Grain size may also play a major role in determining partitioning, bioavailability and resource impacts.

The interfaces separating these compartments are sites where sedimentary and transport processes also change. Focusing on tidal processes alone, the tidal wave transversing the inner continental shelf into estuaries, up tidal creeks and finally dissipating in the rivers changes its character in a manner that significantly alters the net transport of material. For example, at the interface between estuary and ocean, the abrupt change in tidal current strength causes, to a large extent, deposition on the adjacent shelf. Also, significant alteration in the direction of material transport occurs along small tidal creeks due to the distortion of the tidal wave (Postma 1967). The character and strength of wind-generated and density-driven currents also change at the interfaces between compartments (Blanton et al. 1989a).

Information on these processes has been generated by scientists in the region for more than 40 years (e.g., Atkinson et al. 1985, Miller et al. 1989, Menzel 1993). Unfortunately, in most cases, the analysis and synthesis of extant information is limited by the lack of standardized protocols and processes utilized in the great number and diversity of these typically short-term studies (Davis et al. 1992, Blood et al. 1992). These and other authors (NRC 1989, COBIA 1992, Fulton et al 1993, Steel 1994, NRC 1994) suggest that multi-objective and multidisciplinary investigations into the relationships between land use and the quality of the estuarine/coastal ocean ecosystem remain a critical need.

A significant portion of this information has been incorporated into models to enhance understanding of how the natural coastal system operates, but little has been used to examine the impacts of human activity on specific processes within these systems. As a result, a limitation of existing models is that most are individual process models (e.g., nutrients, sediments, water loading) which are not quantitatively linked to Geographic Information Systems to permit land use-specific applications (although several efforts are now underway on specific estuaries; e.g., through the Charleston Harbor SAMP and the USES program), and those linking abiotic processes (hydrodynamics, sediments, contaminants) are not linked interactively with biotic resource models. It is unlikely, therefore, that these models will be able to generate information on the magnitude and nature of changes to the ecological integrity, living marine resources and/or environmental quality of the system as a result of the exponential growth rate anticipated over the next two decades.

It will be impossible to monitor or study all of these systems from the headwaters to the Gulf Stream on a routine basis. It is critical, therefore, to identify mechanisms and important systemic interfaces on appropriate scales by which the status of the ecosystem can be evaluated and quantitatively linked. We propose to address this dilemma by examining "Compartmental Interfaces" in the system to identify the effects of various land use practices, and the influences of changing land uses, on the physical, chemical and biological processes of the system.

### I.B.2. Goal and Hypotheses

It is assumed in this approach that land use activities which alter stream flows, hydrodynamics and the loading of both natural and man-made materials to these ecosystems, and their resultant impacts on biotic resources and processes, will eventually be reflected in the structure and functioning of ecosystems. This framework stems from recent discussions among members of our research group and in essence seeks to address the spatial and temporal "scale" issue.

Given the characteristics of the natural and human environment of the South Atlantic Bight region, the overall goal of the SAB Land Use-Coastal Ecosystem Study is to:

> **Develop science-based predictive, decision-making models (tools) that integrate changes in land use patterns with effects on hydrodynamics, transport processes and ecosystem function to assist in planning for sustainable coastal land use and resource management.**

This goal is based upon two unifying themes. The first theme postulates that different types and intensities of development will result in different impacts to ecosystems and living marine resources. For instance, as the coastal populations of Georgia and South Carolina continue to grow, with much of the growth reflected by immigrants, the region will see its urbanized areas consist of more seasonal, transient/tourist populations which are increasingly consumptive (requiring highly infrastructured services) with high impact and intensity (e.g., Myrtle Beach, Charleston and Savannah). In outlying areas of the coast, new residents will locate in either retirement communities, which tend to be suburban residential facilities requiring services year-round (e.g., the 8,000 household Sun City development in Bluffton, SC), or gated communities, which require external commercial services and infrastructure (e.g., Hilton Head Island).

One of the most tangible sign of urbanization impacts is the closure of shellfish beds, as this indicates not only areas where human influences may have degraded ecosystem integrity and environmental quality, but also areas where watershed management has not succeeded. More than 30 percent of the shellfish harvesting waters of Georgia, South Carolina and North Carolina are closed due to fecal coliform pollution. Similarly, severe restrictions on fisheries harvest can indicate that living marine resource management has had limited success. Fish advisories due to chemical contamination also serve as indicators of ineffectual environmental management. As these examples illustrate, there is clearly a need to examine the relationship of human activities on ecological integrity of the coastal region taking a distinct and innovative approach. Therefore, we intend to determine what parameters need to be measured, at what scale and at what compartmental interface to assess system status and health. Then, management alternatives to maintain or restore valued system attributes for each of the system components (e.g., tidal creeks, tidal rivers, estuaries, etc.) can be formulated.

The second theme suggests that different types of watershed/coastal ocean systems will respond differently to developmental pressures. For example, the response of different types of watershed/coastal ocean systems (e.g., riverine vs. non-riverine estuaries) may vary significantly in the wake of increasing development pressures. Most important is to define (a) key compartmental interfaces where management can intervene; (b) the type of ecosystem quality indicators appropriate to represent ecosystem condition; (c) the scale of information needs to describe ecosystem condition within each compartment; and (d) the dynamic interactions within and among the compartments. It is not our intent to study every system, but to conduct sufficient regional scale research to develop conceptual, qualitative models to extrapolate to unsampled systems and situations.

Alternate Hypotheses:

1. Increases in coastal population and concomitant economic development have measurable impacts on coastal ecosystem function and living marine resources, which can be predicted by existing or newly generated scientific knowledge and management tools.

2. Population density in the SAB is increasing and will have significant effects on coastal ecosystems and living marine resources through changes in freshwater availability or delivery.

3. The transport, fate and effects of materials from land use practices on coastal ecosystems and living marine resources are driven by changes at compartmental interfaces within the system.

4. "Compartmental Interfaces" exist within the watershed/coastal ocean system of the SAB where effects of human population growth and land use changes are measurable on a variety (spatial, temporal, biotic, and abiotic) of scales.

5. Improved knowledge of the linkages between land use activities in coastal watersheds and the hydrodynamics and functioning of adjacent ecosystems of the SAB will provide the basis for the identification and implementation of sustainable economic development strategies.

### I.B.3. The "LU-CES Model"

The impact of population growth in the southeastern United States on coastal resources will occur in a variety of ways. The LU-CES project will focus on those impacts associated with modification of land use patterns and hydrology (Fig. 1). The conceptual point of convergence between land use and the hydrosystem represents a boundary or interface between systems or compartments. Thus, the effect of upstream, non-point source runoff on biological resources in the estuarine receiving waters is determined at points of contact between the land and the water. The impact is dependent upon the characteristics of the land over and through which the runoff is moving (e.g., is it natural forest, pesticide-treated and fertilized agricultural, suburban landscape or paved city streets?) and on the nature of the receiving waters (e.g., is the runoff

# *LU-CES Conceptual Model*

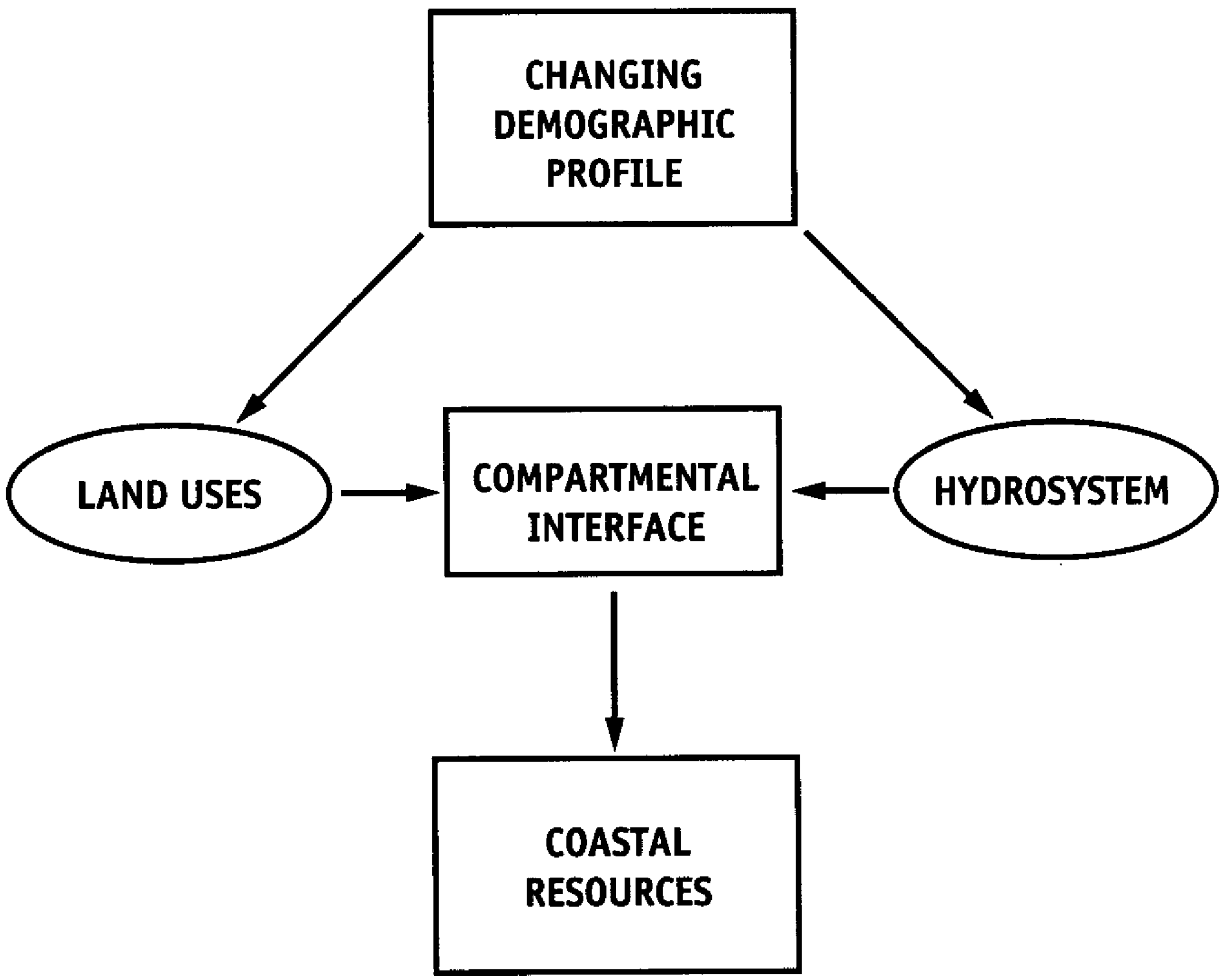


**Figure 1.** The LU-CES conceptual model. The focus of this program is on the impacts that the rapidly changing demographic profile in the Southeastern U.S. will have on coastal living resources as a function of changes in land use patterns and hydrosystem modification, the conveyences of which occurs at a theoretical or compartmental interface.

entering a series of streams and moving to a river and then to the estuary; is it entering the estuary directly; or is it entering via the groundwater system?).

Furthermore, both forcing and effects of changes in coastal resources can be viewed from a variety of perspectives. For instance, one might consider the biological effects of specific land use practices, such as agriculture, on specific receiving systems such as tidal creeks. Similarly, one can examine the same problem from a socioeconomic perspective. Perhaps more revealing is to take a slice across several disciplines. Thus, one can follow an issue from its physical-biological origins to its end point in management and policy. The possibilities within which one can view these issues are, therefore, multidimensional. They can be expressed graphically as a complex block model (Fig. 2) for which the intersections among component blocks can be considered compartmental interfaces (the points at which perspective-based issues and processes converge with the environmental realities of land use and hydrological transport and fate).

### I.B.4. The LU-CES Program

LU-CES was framed conceptually by a Program Management Team during the spring of 1995. The Savannah Workshop of June 1996 was convened to begin implementation of the LU-CES program, the initial phase of which is a series of retrospective State of Knowledge studies. The LCC was organized in early June to provide advice and guidance to the workshop organizers and to begin development of the RFP for the State of Knowledge studies. The LCC consists of a team of faculty from universities in the region with expertise in the natural and social sciences, environmental policy, economics, GIS and data base management (Table 1).

**Table 1. Working groups and LU-CES Coordinating Committee Leaders.**

| | **Land Uses** | **Prospective Hydrosystems** |
|---|---|---|
| **Natural Sciences** | **T. Chandler** | **J. Blanton** |
| **Social Sciences** | **W. Kreisel** | **R. Becker** |
| **Policy & Management** | **L. Osborne** | **J.M. Dean** |
| **GIS/Data Mgt.** | **D. Cowen** | **R. Welch** |

Members of the LCC led the discussions of the working groups and focused the output into summary documents that were used to generate this workshop report and the RFP for the State of Knowledge studies. The LCC met on August 23, 1996, to discuss the results of the workshop and to more clearly define the approach to development of the RFP.

## II. Workshop Approach

### II.A. Agenda

The LU-CES workshop was organized in a traditional workshop format that incorporated introductory remarks, explanation of workshop goals and objectives, and invited presentations

# *LU-CES Multi-Disciplinary Matrix*

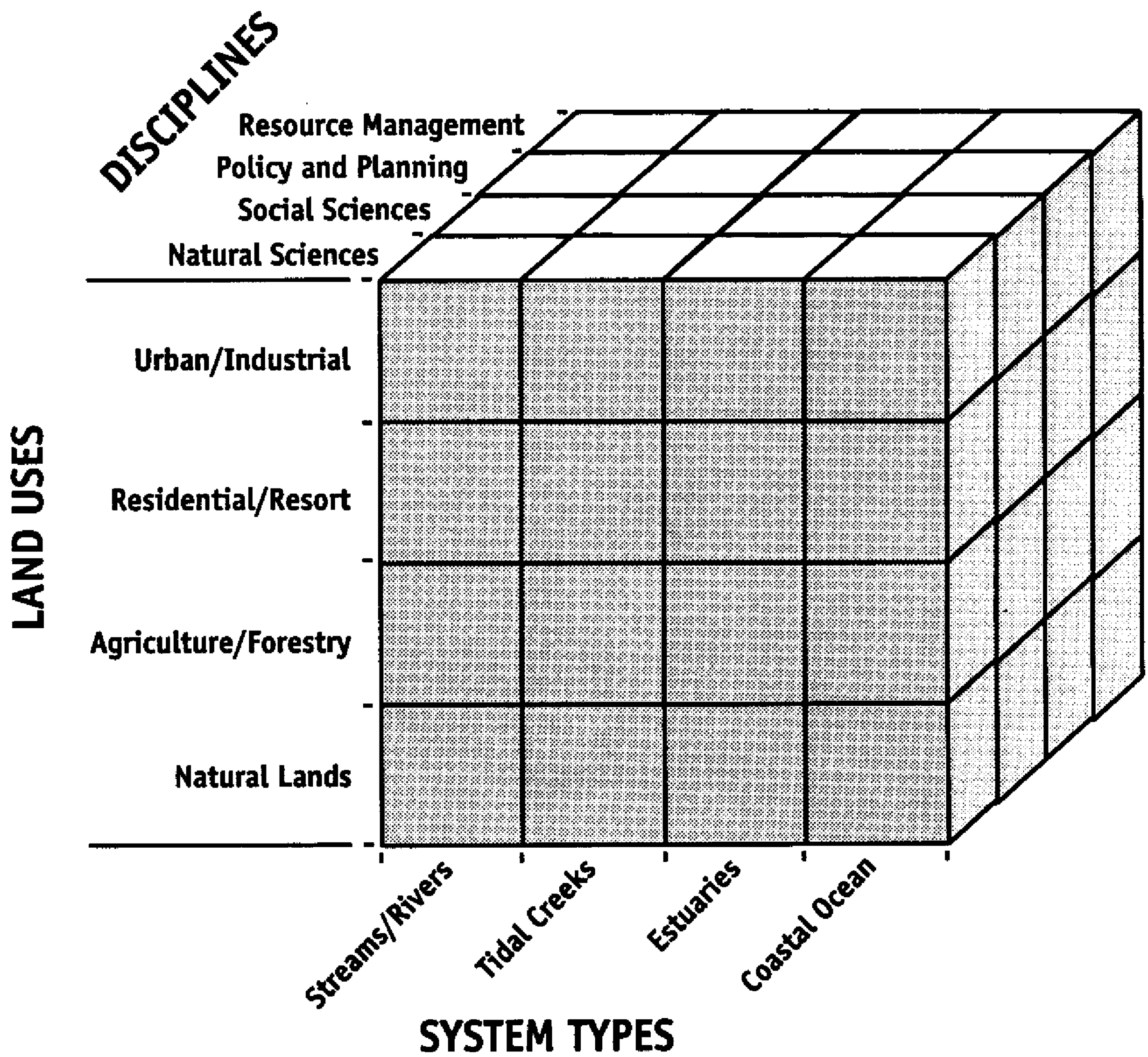


**Figure 2.** Multi-disciplinary matrix of the interactions among LU-CES program components.

in the morning of the first day. (See Appendix 1 for a list of Workshop attendees.) This was followed by working group discussions in the afternoon of Day 1 and on the morning of Day 2. A plenary session was convened after lunch on Day 2 to solicit summaries from the working group leaders (the LCC) and general comments from the participants. A complete agenda is appended to this report (Appendix 2).

### II.B. Plenary Sessions

A sense of the state of available data on the coastal regions of Georgia and South Carolina was provided by presentations during the first day of the meeting. first Plenary was intended to set the context for the workshop. Presentations were made by several senior scientists in the region, including F.J. Vernberg, L. Pomeroy, and E.P. Odum. Additional presentations by F. Holland, G. Scott, P. Verity and D. Porter described the considerable effort in ecosystem analysis currently underway in the southeastern regional coastal zone. Presentations by W. Kriesel and R. Becker described the socio-demographics of the region. A detailed list of presentations and authors is provided in Appendix 2.

The second plenary session provided the first opportunity to summarize what had been discussed in the working groups. It also allowed workshop participants to express ideas, interests and concerns to the community and to the LU-CES program managers.

### II.C. Working Groups

Working groups were used in an unusual manner that was designed to optimize the value of the expertise provided by LCC members as working group leaders while permitting the larger group to provide insight on issues from the two perspectives of both land use and hydrosystems. There were a total of eight working groups. Four of the working groups were focused on the Land Use perspective; four on the Hydrosystems perspective. For each of the two perspectives, there was a group on the Natural Sciences, Social Sciences, Policy and Management, and GIS/Data Management. The distribution of leaders among groups is shown in Table 1.

On Day 1, the participants in each working group considered a list of objectives and questions (Table 2) that characterized the system (land or water) in which they work. They also considered factors associated with changes within these systems. On Day 2, the members of each working group changed perspective, such that those working on Land Uses on Day 1, now took the Hydrosystem perspective. What remained constant were the working group leaders and the questions. Thus, group leaders worked on the same set of questions with two different working groups.

## III. Results

### III.A. Plenary Session I. The State of the Data on Coastal Resources, Processes and Populations

#### III.A.1. Summary

Abstracts from several of the presenters are included in Appendix 2. It was apparent from the presentations that several multi-year data bases exist for the Georgia-South Carolina coastal region. Standard physico-chemical and biotic parameters such as temperature, salinity, sediment characteristic and chlorophyll are widely available in the region. Taxonomic characterizations of the plankton and macrobenthos are available in some areas, as are extensive contaminant distribution data sets. Current research in the region includes: (1) A seven year study of Georgia's rivers as sources of organic and inorganic materials to coastal and estuarine waters as part of the NSF Land Margin Ecosystem Research program (Pomeroy et. al.); (2) An intensive characterization of South Carolina's tidal creeks with a focus on their ecological and economic values and threats to their functional integrity by the SC Department of Natural

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**Table 2. Objectives of the working groups and questions for consideration.**

**The Hydrosystem**

a. Objectives:

i. Identify the components of the hydrosystem of the SAB and its watersheds
ii. Characterize the role that each component plays in transporting materials and affecting processes (e.g., sediment characteristics, the salinity cycle, ecosystems and productivity) in the coastal zone
iii. Identify specific "indicators" (e.g., certain contaminants, certain chemical signals such as DO, BOD, certain organisms or biological process) characteristic of hydrosystem components and processes

b. Topics and Questions for Consideration:

i. Current Status of the Hydrosystem: What are the hydrological features (e.g., rivers, groundwater, runoff, buoyancy-driven flows and tidal currents that influence marine resources at present? Where in the region does each hydro-feature operate? What is the impact of each feature on: (a) defining habitats and important physical structures (e.g., the turbidity maximum) in the coastal zone; (b) maintaining natural cycles (e.g., the salinity cycle, recruitment); and (c) transporting inert (e.g., sediments) and toxic contaminants? Where in the system is the influence of each hydro-feature most apparent? How important is each feature as a characteristic of the total hydrological picture of the region?
ii. Characterization of Parameters: What are the major types of hydrosystem manipulations expected as a result of population growth? (overlap with land use group will be expected) What are the marine resources most likely to be impacted by each type of manipulation? By what mechanism(s) does each hydro-feature convey an impact to marine resources? What processes control and/or affect the nature of the transport and fate functions of the impact? What mechanisms and processes have yet to be understood? At what physical location(s) and time/space scales can each manipulation/process be measured?

**Land Use Practices**

a. Objectives

i. Describe the present and future distributions of land uses [undeveloped (natural), rural/agriculture, residential, industrial/commercial] in the SAB and its watersheds.
ii. Characterize the typical inputs (e.g., sediments, metals, synthetic hydrocarbons) from each land use.

iii. Identify specific "indicators" (e.g., certain contaminants, certain chemical signals such as DO, BOD, certain organisms or biological process) characteristic of each land use.

b. Topics and Questions for Consideration

i. Land uses: What are the current land uses in the watersheds? What are the projected changes in land uses over the next ten years? What are the present input terms (what is put in and how much) from each land use category? What will be the input in the future? What impact do land uses have on the use and distribution of water? (overlap with hydrosystem group will be expected)

ii. Impacts: What are the expected impacts of various land use inputs on the marine system? How will these impacts manifest themselves as a function of different hydrodynamic and geomorphological regimes? Are there "unique" signatures to identify particular land uses and, if so, what are they? What are the time and space scales of impacts on living and non-living resources from various land use activities?

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Resources and cooperating agencies and institutions (Holland et al.) and; (3) The long-term study of a pair of adjacent inlets, one pristine, the other anthropogenically perturbed, as part of the NOAA Coastal Ocean Program's Urbanization and Southeastern Estuaries Study (USES) (Vernberg et al.; Porter et al.). In addition, a considerable data set is available on scales of pulsed variability in the estuaries of the southeast (Verity; Odum).

Extensive demographic data are also available for the coastal regions (Becker). These data provide graphic evidence that population on the coast is increasing, aging and changing socioeconomically and effectively modifying the coastal environment to fit the lifestyle consistent with the emerging demographic profile (Becker and Kriesel).

### III.A.2. Abstracts of Presenters

Submission of an abstract was not a prerequisite for presentation. Not all presenters chose to submit abstracts. The purposes of the presentations was to provide: a sense of regional context, an appreciation for the sort of information that has been and is being collected, and motivation to the group by summarizing some of the environmental and cultural research that has been undertaken to date. It was also expected that at least some data needs would emerge from the review effort. The abstracts are included in Appendix 3.

## III.B. Working Groups

### III.B.1. Summary

In this section we summarize the major findings of the individual working groups. We do not attempt, however, to tie the results from the different groups together; that will be undertaken in the Conclusion (Section IV) of this report. The detailed, original reports of the working group leaders are included in Appendix 4 Working Group Reports. We include these as an appendix because they are not uniformly formatted. We did not provide specific formatting instructions to the group leaders, preferring instead that they write in the style most comfortable for them. In some cases, reports are outlines while in others, they are prose.

In each case, the groups were asked to respond to the action items and questions listed in Table 2. An interesting and unexpected trend developed in the approach of the groups. As we progress through disciplines, from natural to social to policy sciences, and especially as the disciplinary expertise of the working group leadership progresses from the natural to the social sciences, we observe a tendency for the working groups to abandon the format provided by the LU-CES Program Directors, adopting instead, formats more appropriate to the discipline.

### III.B.1.a. Natural Sciences Working Groups Summary

The Natural Sciences Working Groups adhered closely to the Land Use and Hydrosystem formats. The focus of the Land Use groups (T. Chandler, leader) was on the problem of scaling. The space and time scales of detecting impacts, particularly those associated with non-point source contamination by toxins and nutrients resultant from suburbanization and agriculture, need to be appropriate to the likely scales of impact. Frequently, this requires a large spatial-long time scale focus. Critical needs were perceived as: gaining an historical perspective to land use change, assessment of coastal land use genesis, a detailed characterization of nutrient and toxics loadings and identification of useful biological indicators of impacts on living resources.

The Natural Sciences-Hydrosystem groups (J. Blanton, leader) focused on flushing time as a major factor that determines the impact of any substance and activity on coastal resources. The flushing time ($T_f$) is a time scale associated with the ratio of reservoir volume to volume-input rate of a specific material (which can be water, a nutrient, a contaminant or a living particle or population.) Thus,

$$T_f = f(VB/V_i\ t^{-1},\ M), \qquad (1)$$

where VB is the basin volume, $V_i$ is the input volume, t is time (usually days to years) and M is the nature of the material being transported with respect to its ability to pass through the system.

Various natural and human activities are associated with different flushing regimes. Activities associated with growth and development, both along the coast and upstream, alter the flushing characteristics associated with coastal systems as a function of changes to both the flow fields and the volumes of materials loaded. Impacts occur as a result of physiographic modification of the basins, increased removal of ground and surface waters and introduction of exotic species. Modifications of the hydrosystem can be predicted to increase the rate of eutrophication, bacterial levels, levels of water-borne contaminants, the rate of salt water intrusion to surface and ground water systems. These will alter the flow characteristics of freshwater approaching the coast, thus modifying food web-nutrient pathways and resulting in the loss of nursery grounds. These impacts will lead to increased nutrient levels in the estuaries and increases in the relative importance of buoyancy-driven flow as a function of groundwater depletion.

### III.B.1.b. Social Sciences Working Groups Summary

The Social Sciences Working Groups perceived that demographic changes during the coming decades would create a need for tools to measure the impacts of human population growth in the coastal zone and for methods regulating or controlling that growth if impacts are to be minimized. Sociologists who considered these challenges as they relate to land uses (W. Kriesel, leader), recognized that small changes in land use could result in large environmental and socioeconomic impacts. They identified a need to improve cross-disciplinary communication and the development of society-sensitive instruments that will be responsive to the impacts of land use change on resource sustainability. That is, the social and natural sciences communities need to develop, in partnership, tools that allow socioeconomic responses to predicted or detected impacts of land use. This translation will come, in part, through the conversion of state of knowledge information into socioeconomic instruments. The process will involve the public and outreach activities and will both help to create and respond to environmental priorities.

The growth of population along the coast and waterways of the southeastern U.S. is changing the regional demographic profile in striking ways. The new, immigrant population is altering both the land and the hydrosystem. The group that considered the socioeconomic patterns associated with these changes (R. Becker, leader) focused less on the hydrosystem per se, than on demographic issues. This departure from the "prescribed" approach is perceived as healthy. Most environmental alterations are associated with suburbanization and gentrification, and with the production of a recreational relationship with the hydrosystem that is, perhaps, best exemplified by the growth of resort and retirement communities along the coast. The recreational focus in development is, in turn, producing a service-oriented economy. Marina building and recreational fishing and boating are slowly replacing traditional fishery-based coastal economies. The population is aging, increasing in mobility and in general becoming better educated. The new population is wealthier and older than the traditional culture, and it is capable of purchasing second dwellings. Thus, the coming growth is capable of producing a large impact through its own affluence. The perceived response to this potential impact appears to be associated with a combination of growth management tools, education and within the development of an understanding within the management community of the limits that the Public places on acceptable change. The principal information need was for human and resource historical context.

### III.B.1.c. Policy and Management Working Groups Summary

The land use perspective subgroup of the Policy and Management Working Groups (L. Osborne, leader) considered that a broad-scale, multidisciplinary assessment of the resources of the South Atlantic Bight region is needed to document both natural and human resources, including current land use and demographic profiles, to identify components of the system most sensitive to stress and to define research priorities. This approach would be especially useful, it was suggested, to resource managers at the local level. The group indicated that linkage among the natural resources base, economic activity and demographic perspectives is key to the usability of such a summary product. Further, the focus must be dynamic, emphasizing both historical and projected trends in sufficient detail to be applicable to local management needs. As in many discussions, the need is not only, to identify stresses and stressors, but also to understand the scales at which different stressors operate. Further, the working group suggested that the product be developed in three "volumes." The first would be a description of resources. Next would be a ranking of resources to describe the current state of the resource base or the health of the system. Third would be to predict sociological change from an analysis of existing data.

As perceived by the subgroup of the Policy and Management Working Group which focused on the hydrosystem (J.M. Dean, leader), a principal feature of regional population growth and demographic change that changes in upland areas affect coastal resources. Residents in the uplands are less aware of and less concerned with their impacts on the coast than is necessary to ameliorate these impacts. Among the specific problems identified by this group were: (1) altered availability and flows of freshwater resultant from demand and utilization, (2) transport and increased loading of contaminants to coastal regions, (3) increased competition for resources among populations and user groups, (4) need for improved public understanding of the role of science in creating policy.

Alteration of freshwater flows will impact the availability and quality of freshwater to the public. An understanding of the hydrology and resource availability are crucial remediative steps. Studies of allocation systems are needed and educational outreach both to coastal and upland populations on the sensitivity of the hydrosystem are important. Contaminants loading can be regulated by understanding their impacts at the habitat scale, by incorporating cumulative and multiple stressor scenarios into risk assessment models and by other management tools. Competition for resources tends to increase resource variability (especially in fisheries) to alter biodiversity and reduce habitat availability and quality. Remediation includes classification of sensitive resources, such as tidal creeks, development of tool for determining where to put restorative efforts, development of a habitat quality index, adaptive management strategies and a set of benchmarks along which to evaluate the success of management efforts. Finally, the public understanding of the role of science in the development of policy is poor. The feedback loops between the public and the scientific sectors are not well developed. Outreach is clearly required to increase public understanding of science and support for it, to improve communication between science and the public and to reduce conflict especially as regards questions of access to resources.

### III.B.1.d. GIS and Data Management Working Groups Summary

The GIS and Data Management Working Groups produced a sophisticated set of products within the stringent time constraints of the workshop. These groups, perhaps more than the others, were faced with the challenge of modifying the objectives and questions and formulating a framework relevant to the subject area. Land use groups (D. Cowen, leader) focused on data layering, success criteria, user communities and analytical and system characteristics. The most important data layers (and this addresses the question of scale) were perceived as the estuary and the indicators of estuarine water quality, second was population and third and fourth were infrastructure and climate (temperature, precipitation). The most important criterion for success was its value to modeling processes. Second was scientific soundness, followed by its use for early warning. The target users are perceived to be scientists, state and regional managers in that order, and the most important characteristic of the system must be its user orientation. This is followed by (1) the ability of the GIS/data management system to interface to models, (2) data quality assurance, (3) consistency of classification, (4) metadata and (5) analytical functions.

The GIS focus group concerned with the hydrosystem emphasized the expediency of using existing remote sensing and GIS facilities, archived data and off-the-shelf hardware and software. Sensing of resources, remote evaluation of resource quality and identification of stressors (particularly sedimentation and pollutants) were identified as key issues. The question of examination of features and processes at a variety of time/space scales was also of interest. It was suggested that user-oriented, affordable remote sensing and GIS capabilities were crucial. Quality assurance practices and the kinds of data products to be provided must be determined early in the project.

## III.C. Plenary Session II: Comments of Participants

The workshop participants generally recognized the value of this forum and expressed positive sentiments toward the exercise. One participant, however, suggested that nothing new had been put forth. Overall, participants recognized the difficulty of developing a truly multidisciplinary context within LU-CES, though all agreed that such a context is crucial to the project. It was also apparent that LU-CES must be focused and should not seek to solve all the problems associated with the impact of population growth on coastal resources. To this end, additional support will be sought for projects ancillary to LU-CES. Among the themes that recurred through the workshop was the sense that suburbanization and the so-called "hardening" of the landscape represented an important change in the physiography as related to impacts on coastal resources. This trend, however, was also indicative of the general demographic context and correlative with the specific types of changes that differ from the impacts associated with other land uses. Thus, suburbanization implies road paving, single family dwellings, golf courses, marinas and boat docks and infrastructural impacts that are distinct from those observed with other kinds of land uses. There was a clear concern from the group to focus the scope of LU-CES, and to develop creative decisionmaking approaches that will permit planning for sustained productivity twenty years into the future

## IV. Synthesis and Summary

The LU-CES workshop was an initial step toward the type of improved multidisciplinary communication and problem solving that will be required for addressing the LU-CES hypotheses. The working group reports provide strong evidence that while different disciplines see problems in different ways, both the perceptions of the problems and elements of the solutions have certain fundamental contexts that extend across the disciplines. For instance, there is a repeated focus on the importance of scale in identifying and addressing problems. Several reports (e.g., see reports by Chandler and Dean) used the scaling issue to emphasize the implications of how activities occurring hundreds of kilometers upstream may impact coastal and marine resources. The ability to develop data products on the watersheds that have resource management values at the coast is of clear concern to the research community.

Concern with issues involving communication is also evident in the reports. Three needs are recognized. First is the need for information exchange across disciplines. Social scientists, economists and policy analysts need information on environmental sensitivities and impacts (see reports by Kriesel and Osborne). GIS development requires information on indicators. These are critical information needs recognized by natural scientists and environmental managers. Second is the need for user friendliness in data base management and GIS to permit ease of information exchange to the scientific and management communities (see reports by Cowen and Welch). Third is the need for education and outreach. Every working group pointed out the need for outreach. The academic and management communities are committed to a public partnership in LU-CES. The public must understand why the LU-CES program is necessary and what it aims to accomplish in order for the tools that are produced to be effective. LU-CES research products must reach the public sector rapidly and effectively, both to help create a greater public environmental consciousness and to generate support for the idea that science actually does address society's problems.

Another issue that stood out in the working group reports is the relationships between source, fate and effects. Demographics, during the coming few decades, will both reflect the natural land and hydroscapes, and they will modify them. Social and ecological perturbations will be especially extensive and in many cases, related (see reports by Becker and Blanton for some examples). The development of assessment techniques that supersede correlative approaches and mechanistically address issues of toxic contamination, eutrophication, habitat degradation, and exotic species invasions are crucial. But these tools must not function solely on an ecological plane. The results of these measurements must be translatable to cultural impacts in economics and public health. Information must be provided in such a way that it leads to the development of planning instruments and models.

The progress of academe toward multidisciplinary research has been slow, perhaps slower than in other segments of the research community. However, progress has been constant. LU-CES has from its conceptual infancy been a multidisciplinary program. There is however, no consensus on how much data paradigm usable for addressing the LU-CES objectives currently exist. As a first effort in LU-CES it will be necessary to know what information is out there and how well the pieces fit together. While syntheses of some of the data exist, very few attempts have been made at multidisciplinary analyses. It is necessary to determine if relationships between land use and ecosystem condition can be extracted from the data. It is also crucial that the first stages of the project address issues that will be relevant to later stages of the project but with a broader focus than will be possible during the field phase. This will permit the focus to be narrowed and targeted on specific data needs in the later phases of the project. These objectives will be addressed by the State of Knowledge studies.

The LU-CES Coordinating Committee met on August 23, 1996, to review the findings of the workshop. This meeting resulted in initial efforts to identify the general focus of the State of Knowledge RFP. It had been recognized previously, that to be successful, the scope of the LU-CES project must be narrowed. Broadening of focus may be feasible, however, by coordination with other agencies and resources. It was decided, however, that the programmatic boundaries of LU-CES would be the inner South Atlantic Bight, between the Little River Inlet, SC, to the north, and the St. Mary's River, GA, to the south. The targeted natural resource support system will be the tidal creek - salt marsh complex (the TCSM). The estuary and shoreline will form the inner boundaries with the TCSM. Outer boundaries, i.e., interfaces with the larger scale, exist between the estuary and the coastal ocean and will be assessed at the inlets. Interfaces with the watersheds exist at the head of tide, in riverine systems. In non-riverine systems, interfaces with the TCSM occur at the shoreline and at the point of aquifer discharge. A unique boundary exists at the air/water interface.

Fundamental differences exist between ecosystems and their responses to land use patterns with respect to flushing. Examples of estuaries along the continuum from low to high flushing are abundant in the South Carolina Georgia coastal corridor. It is impossible to determine the effect of any single forcing variable on a system without sampling it. Such an effort would exceed the scope of LU-CES. A tractable focus is on land use patterns, on identifying specific, potentially far-field (upstream) land use indicators in the estuaries and TCSM's and on measuring the effects of these land use indicators in the TCSM's. These effects will be determined and measured in human as well as physico-chemical and biological terms. Impacts will need to be expressed both in ecological terms and on the human dimensions of quality of life, economic stability and public health. We note, however, that although we can provide guidance about the priorities and focus of LU-CES, it must be the scientific community that defines the research questions that will be addressed.

The State of Knowledge study effort will address these manifold issues with a thoroughly multidisciplinary approach. They will provide the framework fundamental to future research in LU-CES and they will lead to major and unique syntheses. These will include a symposium at the Southeastern Coastal Ocean Research (SECOR) Conference in 1998 and a summary volume on the state of coastal resources in the South Atlantic Bight to be published in 1999.

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**Appendix 1**

**List of Attendees**

Mr. Tim Adams
SC Forestry Commission

Dr. Marge Aelion
University of S.Carolina

Dr. Meryl Alber
University of Georgia

Dr. Jim Alberts
University of Georgia

Dr. Jeff Allen
Clemson University

Dr. Clark R. Alexander
Skidaway Inst. of Ocean.

Dr. Tony Artuso
University of Charleston

Dr. H. Wayne Beam
OCRM-DHEC

Dr. Barry Beasley
SCDNR-Water Resources

Dr. Brad Bebout
University of Maryland

Dr. Robert Becker
Clemson University

Mr. Chip Berry
SCDNR-Land Resources

Dr. Jack Blanton
Skidaway Inst. of Ocean.

Dr. Ben Blount
University of Georgia

Mr. Robert Boyles
SC Sea Grant Consortium

Dr. Alice Chalmers
University of Georgia

Dr. Tom Chandler
University of S.Carolina

Mr. Mark Corley
SCDNR-Land Resources

Dr. David Cowen
University of S.Carolina

Dr. Wesley Crum
USEPA-Region IV

Dr. Ron Cummings
GA State University

Dr. John M. Dean
University of S.Carolina

Ms. Terry DeMeo
Inst. of Comm & Area Dev.

Mr. Rick DeVoe
SC Sea Grant Consortium

Dr. Giacomo DiTullio
NMFS Chas Lab

Ms. Tonya Edwards
Oral Roberts University

Dr. Mark Fischer
Skidaway Inst. of Ocean.

Dr. Mike Fulton
NMFS-Chas Lab

Dr. Sylvia Galloway
NMFS Chas Lab

Dr. Paul Gayes
Coastal Carolina Univ.

Dr. Matthew Gilligan
Savannah State College

Mr. Karem Hardy
Jackson State University

Dr. Kathy Hatcher
University of Georgia

Dr. Jim Henry
Skidaway Island

Dr. Robert Hodson
University of Georgia

Dr. Fred Holland
SCDNR-Marine Resource

Dr. Verne House
Clemson University

Dr. Jeff Hyland
NOAA Carolinian Province

Dr. Richard A. Jahnke
Skidaway Inst. of Ocean.

Dr. Gary Kleppel
University of S.Carolina

Ms. Elaine Knight
SC Sea Grant Consortium

Ms. Sally Knowles
SCDHEC

Dr. Warren Kriesel
University of Georgia

Dr. John Kucklick
NMFS-Chas Lab

Mr. Dave Kyler
Coastal GA Reg Dev Cntr

Mr. Richard Lacy
SCDNR-Land Resources

Dr. Thomas Leatherman
University of S.Carolina

Dr. Cyndy Lee
Clemson University

Dr. Richard F. Lee
Skidway Inst. of Ocean.

Dr. Alan Lewitus
University of S.Carolina

Mr. Rob Mikell
SCDHEC-OCRM

Ms. Ayana McCoy
Savannah State College

Ms. Simone McWeay
Claflin College

Mr. Cleveland
Ft. Valley College

Dr. Jim Morris
University of S.Carolina

Dr. Eugene Odum
University of Georgia

Ms. Vanessa Olivera
Savannah State College

Dr. Eugene Olmi
SCDNR-Marine Res Div

Dr. Laura Osborne
GA State University

Dr. Steve Pennings
University of Georgia

Dr. Larry Pomeroy
University of Georgia

Dr. Dwayne Porter
University of S.Carolina

Dr. Larry Pugh
NOAA Coastal Ocean

Dr. Mac Rawson
University of Georgia

Ms. Carita Richardson
University of Maryland

Ms. Enerida Rivera
Savannah State College

Mr. Heyward Robinson
Charleston Harbor Project

Dr. Phil Ross
The Citadel

Dr. Mike Saunders
GA Institute of Techn.

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NOAA Coastal Ocean

Mr. Miki Schmidt
NOAA Coastal Service Cntr

Dr. Geoff Scott
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Ms. Susan Shipman
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Ms. Rebecca Shortland
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Dr. Tom Siewicki
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Ms. Shunder Simmons
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Mr. Carl Snell
Georgia Southern University

Ms. Michelle Stevens
S.C. State University

Dr. Stuart Stevens
GA Dept. of Natural Res.

Ms. Antonetta Thompson
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Dr. Bob Van Dolah
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Dr. F. John Vernberg
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Dr. Roy Welch
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Ms. Marlene Wiggins
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Dr. Herb Windom
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**Appendix 2**

## The South Atlantic Bight LU-CES Workshop

**AGENDA**
June 24-25, 1996
Savannah Hyatt Regency

**Monday, June 24, 1996 -** [Verelst/Percival Room]

7:30 am **Workshop Registration** (check-in)

8:15 am **Welcome** (G. Kleppel and M.R. DeVoe)

8:20 am **Introduction:** "NOAA Coastal Ocean Program's Regional Ecosystem Studies" - Don Scavia (Director, NOAA COP)

8:30 am **Keynote Address:** "The Coastal Resources of the SAB: A last chance for America's natural legacy" - F. John Vernberg (Director, Belle W. Baruch Institute, USC)

9:00 am **Foundation Address:** "Population growth, land use and coastal marine resources" - Warren Kriesel (Ag and Applied Economics, UGA) and Bob Becker (Director, Strom Thurmond Institute, Clemson)

9:30 am **Specific Examples and Case Studies:**

9:30 am "Lessons from the tidal creeks" - Fred Holland (Director, Marine Resources Research Institute, SCDNR)

10:00 am "The tributaries and rivers of the inner South Atlantic Bight" - Larry Pomeroy (School of Marine Programs, UGA)

10:30 am **Break**

11:00 am **Specific Examples and Case Studies (cont.):**

11:00 am "Productivity of estuaries: The pulsing paradigm and its implications to demographically induced impacts on resources" - Gene Odum (Institute of Ecology, UGA)

11:30 am "TBA" - Peter Verity (Skidaway Institute of Oceanography)

11:50 am "A myriad of contaminants: Which ones count?" - Geoff Scott, (Chief, Ecotoxicology Section, NMFS-Charleston)

12:10 pm "Linking land use with estuarine impact" - Duane Porter (Belle W. Baruch Institute)

12:30 pm **Lunch** (on your own)

2:00 pm **The SAB LU-CES Model:** "A description of the SAB LU-CES Conceptual Framework" - Gary Kleppel (University of South Carolina) and Rick DeVoe (Interim Director, S.C. Sea Grant Consortium)

2:15 pm **Charge to the Working Groups:** Rick DeVoe and Linda Ketner (President, KSI Corporation)

2:30 pm **Working Group Breakout Sessions*:**

Breakout Group #1 [Waterfront North and South Room] -- The Hydrosystem
Breakout Group #2 [Verelst/Percival/Vernon Room] -- Land Use Practices

4:00 pm **Break**

4:30 pm **Working Group Breakout Sessions** (cont.)

6:00 pm **Adjourn for the day**

6:00 pm **Happy Hour** (and a Half) - [Chatham Room]

7:30 pm **Dinner** (on your own)

8:00 pm **Meeting of the PMT, Users Panel and LCC** - Westbrook Room

**Tuesday, June 25, 1996**

8:15 am **"Re-charge" to the Working Groups** - Verelst/Percival Room

8:30 am **Working Group Breakout Sessions*:**

Breakout Group #1 (Verelst/Percival/Vernon Room) -- Land Use Practices
Breakout Group #2 (Waterfront North and South Room)-- The Hydrosystem

10:00 am **Break**

10:30 am **Working Group Breakout Sessions (cont.)**

12:00 noon **Lunch** (on your own)

1:30 pm **Plenary Session: Working Group Reports** - Verelst/Percival Room

3:00 pm **Adjourn**

3:30 pm **Working Group Leaders (LCC) Meeting** - Verelst/Percival Room (Begin synthesis of workshop results and agree on writing assignments.)

5:00 pm **LU-CES Workshop Ends**

*Each working group is composed of a leader (a LCC member) in each of the following areas: data management and GIS, natural science, social science, policy and management.

## Appendix 3

### Plenary Abstracts

**Assessment of the Impact of Watershed Development on the Nursery Functions of Tidal creek Habitats**. A. F. Holland, G.H.M. Riekerk, S.B. Lerberg, L.E. Zimmerman, and D.M. Sanger, South Carolina Department of Natural Resources, Marine Resources Research Institute and G.I. Scott and M.H. Fulton.

Background Information and Problem Definition: Meandering shallow tidal creeks and the associated intertidal salt marshes are dominant features of Southeastern estuaries and provide nursery habitat for many species of fish, crabs, and shrimp. These shallow tidal creeks are also conduits through which many pollutants enter estuaries with creek sediments serving as a repository for toxic chemicals and other contaminants discharged to estuarine environments.

Objective: In 1994, the South Carolina Marine Resources Research Institute initiated a study, called the Tidal Creek Project (TCP), to develop the information needed to: (1) characterize and define the ecological values of tidal creeks and associated marsh habitats; (2) identify the major pollution threats to tidal creeks associated with human development; (3) assess the cumulative impacts of human development on tidal creek habitats and the living resources that use them as nurseries; and (4) develop environmental quality criteria for sustaining tidal creek nursery functions. This study was funded jointly by the Charleston Harbor Project (1994-1996) and the Marine Recreational Fisheries Advisory Board (1995-1996).

Approach: The general approach was to sample tidal creeks draining relatively pristine, undeveloped watersheds (called reference creeks) and creeks draining highly developed watersheds (called developed creeks) and then determine the similarities and differences in environmental and ecological characteristics between the two types or classes of creeks sampled. Associations between physical, chemical, and ecological characteristics of creeks and the various types of human development and land cover that occurred in each watershed were also evaluated. This sampling approach is generally referred to as the comparative watershed assessment approach. Creeks in the developed watershed class were selected to represent the major types of development that occurs in South Carolina coastal zone including: (1) industrial development, (2) urban development, (3) suburban development, and (4) agriculture. Creeks in the reference class were either predominately forested and/or salt marsh. Watersheds of similar sizes and physical characteristics were evaluated from both the reference and developed classes. The tidal creeks sampled also included representatives of the major salinity zones (brackish water to near full strength sea water) and creek sediment types (sand, mixed, and mud sediments) that exist in the region.

Findings: Salinity was identified as the major factor controlling the distribution and abundance of living resources in shallow tidal creeks. Salinity fluctuated over greater ranges and was generally more variable in creeks with developed watersheds than in reference creeks. The increased variability and extreme fluctuations in the salinity of developed creeks appeared to be related to the "flashier" runoff associated with the increased amount of impervious surface in developed watersheds (e.g., roofs, roads, parking lots). Creeks that were dominated by salt marshes and limited sources of freshwater inputs had relatively stable salinity distributions.

Sediment characteristics were also identified as important environmental factors controlling the distribution of the living resources in shallow tidal creeks. Sediments in developed creeks were generally composed of more sand and had larger site-to-site variation in physical characteristics than reference creeks. The greater sand content and more variable sediment characteristics in creeks located on developed watersheds were probably associated with alterations in erosion and deposition processes associated with watershed development. Creeks in both the reference and developed classes, however, had the range of sediment types sampled.

Dissolved oxygen concentration (DO) is a fundamental requirement for maintaining balanced, indigenous populations of fish, shellfish, and other aquatic biota in shallow tidal creeks. Pollution related decreases in DO is generally considered to be the greatest threat to the environmental quality of estuaries. DO in tidal creeks fluctuated with phase of the moon, time of day, and stage of the tide. DO in both reference and developed creeks frequently did not meet state water quality standards (4 mg/1). The lowest and most stressful DO to living aquatic resources occurred during early morning and night-time low tides. DO in developed creeks was less predictable and had larger amounts of unexplained variance than DO in reference creeks. About 68% of the variance in the DO of reference creeks was associated with natural cycles. Only about 20% of the variance in DO of developed creeks could be attributed to natural cycles. Living resources developed creeks were exposed to stressful low DO more frequently than living resources inhabiting reference creeks. Point-in-time measurements of tidal creek DO does not adequately represent the exposure of living resources to stressful low DO events.

Tidal creek sediments are repositories for pollutants. Trace metal and organic contaminant concentrations in sediments of the upper reaches of developed creeks, particularly those with industrialized watersheds or long histories of human development, were enriched with toxic chemicals to levels known to adversely affect living resources. Enrichment levels ranged from 2-10,000 times the values observed in reference creeks or deeper areas of South Carolina estuaries. Contaminants of particular concern were copper, lead, chromium, polycyclic aromatic hydrocarbons (PAHs), polychlorinated biphenyls (PCBs), and the pesticides of antiquity, including DDT and chlordane. The distribution of contaminants in tidal creeks varied with the type of development and kind of contaminant. For example, PAHs which are mainly derived from street runoff and specific point sources generally had the highest concentrations in sedimentary environments of upper reaches of creeks. Pesticides concentration in suburban watersheds were frequently highest in the salt marsh adjacent to houses.

Sediment bioassays indicated that sediments in the upper reaches of developed creeks, particularly industrialized creeks, were potentially toxic to living resources. Sediment bioassays from reference creeks did not suggest exposure to these sediments resulted in acute or chronic impacts on living resources.

The kind of benthic prey available to fish, crabs, and shrimp using tidal creeks as nurseries varied with salinity and sediment characteristics. Human activities associated with watershed development did not adversely affect the biodiversity of benthic organisms in creeks. Long-term salinity distributions and estuary-wide water quality were more important in controlling biodiversity of benthos in tidal creeks than were the local processes occurring within creeks.

Variation in the abundance of benthic organisms due to natural factors (salinity, sediment characteristics, and location within tidal creeks) was large, accounting for 7 to 84% of the variance in these densities. After accounting for natural sources of variation, both increases and decreases in the abundance of benthic organisms were found; the greatest differences occurred in the upper regions of developed creeks where the amount of benthic biota was generally reduced.

Results of a benthic recruitment experiment demonstrated that benthic resources maintained high population levels in creeks by continually recruiting to bottom sediments over the summer. Salinity, sediment characteristics, location within creeks (upper or lower reaches), and predation by fish and shrimp all had large influences on benthic recruitment success and colonization processes. Predation was a particularly important factor affecting the magnitude of benthic recruitment. After accounting for variation in recruitment due to these natural factors, human alterations of tidal creek watersheds were found to adversely affect the abundance of the numerically dominant benthic organisms that recruited to creeks during the summer. Lower recruitment occurred in developed creeks.

Mummichogs and grass shrimp, the preferred prey of many species of recreationally important fishes, including juvenile red drum, spotted seatrout and flounder were the dominant fish and crustaceans collected in seine samples from tidal creeks during summer. Penaeid shrimp were the dominant recreationally important living resource that were found to use tidal creeks as a nursery. Spot was the most abundant recreationally important juvenile fish that used tidal creeks as a nursery. Much of the variation in the abundance of fish and crustaceans that occurred from creek-to-creek was associated with variation in sediment characteristics and salinity distributions. After accounting for these sources of variation, no differences in abundance of the numerically dominant species of fish and crustaceans and the kinds/diversity of the fish and crustacean assemblage were observed between developed and reference creeks.

Although no differences in abundance of numerically abundant fish were observed between creeks located in developed watersheds and reference creeks, the numerically dominant resident fish (mummichogs) collected from creeks located on developed watersheds generally were characterized by weaker physiological condition (i.e., skinnier). These fishes had blood that was not as vigorous as fish from reference creeks. The differences in the blood vigor between developed and reference creeks was most pronounced in male fish.

Fish and crustaceans in size ranges sought by fishermen were rarely collected from tidal creeks. These biota are apparently not able to tolerate the low DO and other environmental conditions that occur in tidal creeks during summer. Environmental conditions in shallow tidal creeks, reference or developed, during summer will not support populations of larger fish.

We believe the defined alterations to tidal creeks identified above are "early warnings" of more widespread degradation that will occur if the factors that contributed to these problems are not remediated. It is interesting that these are the same symptoms that were identified for Chesapeake Bay in the early to mid 1970s before it became obvious that the living resource populations of the Bay were also declining.

Conclusions and Recommendations: Factors that contribute to low DO in tidal creeks have not been identified or evaluated. Currently, we do not know if the observed alterations to DO dynamics in developed tidal creeks is associated with increased loading of oxygen consuming pollutants, increased loadings of nutrients (nitrogen and phosphorous) that stimulate excessive growth of primary producers, modifications to the hydrodynamics of tidal creeks from development of the watershed, and/or some other unidentified cause. Until the low DO in tidal creeks can be linked to contributing factors, it is unlikely that it can be efficiently remediated should policies be developed that decide to do so. A DO budget for tidal creeks and the associated salt marshes that defines their relative importance as consumers and identifies the major factors controlling low DO conditions need to be developed. This DO budget is a critical step toward the development of DO standards that ensures the nursery functions are sustained as South Carolina's coastal watersheds are developed.

Research on the chronic, sublethal effects of chemical contamination to the health of individual organisms in tidal creeks needs to be conducted. The population of tidal creeks identified and the associated data base that has been developed on environmental conditions provide a research platform for designing and conducting this ecotoxicology research. Priority research topics include evaluation of the effects of contamination on immune systems, genetic adaptations of resident living resources to chronic exposure to high levels of chemical contaminants, bioaccumulation/trophic transfer of contaminants as a means of export, and *in situ* effects of contaminant exposure on survivorship, growth, and production of valued living resources (e.g., juvenile red drum).

**Productivity of Estuaries: The Pulsing Paradigm and Its Implications for Demographically-Induced Impacts on Resources.** Peter G. Verity, Skidaway Institute of Oceanography, 10 Ocean Science Circle, Savannah, GA 31411

The intent of LU-CES is to improve our understanding of the impacts of human population development and land use practices on coastal ecosystems. The program has identified important interfaces where the interaction between scales and processes regulates the flow of energy and materials, and where man's activities may alter these relationships. Most of the mechanisms driving the processes occurring at these interfaces occur at regular, pulsed frequencies. The dominant frequencies associated with the major pulsing parameters appear to be hourly-daily, while subdominant frequencies are primarily seasonal. It is essential to remember that while the forcing functions pulse at different frequencies, (a) the pulse amplitudes vary among organisms, and (b) organisms integrate these varying amplitudes at different frequencies.

In S.E. USA, estuarine waters, annual patterns in plankton and nutrient distributions are dissimilar. Whereas water temperature exhibits a predictable sinusoidal pattern each year, salinity varies dramatically among years depending upon rainfall/runoff. Phosphate follows temperature closely, while nitrate and dissolved organic nitrogen are essentially unpredictable; the pattern for ammonium is in-between. Accordingly, chlorophyll exhibits a pattern with both predictable and stochastic components. If sufficient data (several years) are available, the best predictor of phytoplankton biomass is primarily silicate (and ammonium, secondarily). In contrast, the best predictor of the RATE of biomass production is primarily ammonium (and irradiance, secondarily). These data indicate that the heartbeat of estuarine waters is limited by one parameter, whereas the accumulation of plant mass (= chlorophyll), which is generally used as an indicator of system health, is set by another parameter. Each pulses at different frequencies and predictabilities.

In the surrounding salt marsh, areal primary production is even higher than in the water column, and biomass accumulation is strictly predictable from air temperature. However, the salient process to the overall ecosystem is the exchange between land and water, which is regulated according to two different pulses: tidal inundation, and seasonal export of dead grass during autumn and winter. The latter provides the detritus responsible for much of the unique nature of S.E. ecosystems.

The system also pulses at longer frequencies, which is important in understanding human perturbations and land use patterns. For example, the S.E. has mirrored global temperature increases, but with exaggerated changes. Concurrently, precipitation has risen ca. 10% during the past 100 years. Freshwater runoff has also increased but at twice this rate, perhaps due to decreased evapotranspiration associated with clearing of eastern North America. Inputs of nitrogen and phosphorus to S.E. rivers have also been elevated. Provocatively, silicate concentrations are steady and should decrease as soil eroded by deforestation finds its way to the sea. Thus the N:Si and P:Si rations should increase, perhaps altering the structure and composition of planktonic food webs in estuarine and coastal waters.

The major pulsing function, however, is the tides, which average 2-3m in Georgia and South Carolina waters. Tides regulate particle residence times, erosion/deposition of particles, sediment/water column exchanges, and salt marsh/estuary communication. Tides also exert control over ecosystem productivity, as estuaries with higher tidal ranges contain less chlorophyll per unit nitrogen input, than estuaries with lower tidal ranges. Other datasets, however, show that fisheries yield normalized to primary production is higher in marine coastal waters than in fresh waters, perhaps implying that the additional energy associated with tides is responsible for the enhanced yield of plankton and fish. These conflicting hypotheses indicate that we still lack a fundamental understanding of relationships between biology and physics, which is essential if we ever are to predict impacts of human perturbations.

**Linking Land Use and Associated Anthropogenic Activities to Coastal Ecosystem Health.** D.E. Porter, W. Vernberg, F.J. Vernberg, M. Aelion, T. Chandler, H. McKellar, T. Kawaguchi, D. Edwards, M. Wahl and B. Jones, Belle W. Baruch Institute for Marine Biology and Coastal Research and the School of the Environment, University of South Carolina, Columbia, SC 29208. G. Scott, M. Fulton and T. Siewicki, Southeast Fisheries Science Center, NOAA, NMFS, Charleston, SC 29422.

One of the recognized environmental concerns in the southeastern United States is the rapid development of urban and suburban areas adjacent to estuarine ecosystems. With this growth comes increasing demands on the coastal environment for commercial, industrial, recreational and residential facilities and services. Associated anthropogenic impacts place enormous pressure on coastal ecosystems which may limit their ability to function biologically, chemically and physically. If left unmanaged, these impacts threaten the environmental health and economic vitality of the high-salinity estuaries of the Southeast.

Historically, the dynamic and complex nature of critical estuarine ecosystems inhibited the successful development of effective models for use by coastal zone managers. The complexity and urgency of ecosystem health issues associated with exploding coastal development have led research and management agencies to explore new spatial analytical techniques for monitoring and assessing estuarine health. Advancing technologies of Geographic Information Systems (GIS), Global Positioning Systems (GPS), remote sensing and environmetrics are enabling scientists to develop predictive models of how ecosystems, and their components, respond to natural and developmental pressures. When successfully implemented, these models can provide valid and timely information to assist resource managers with proactive coastal zone management. The utilization of these technologies can be integrated under the umbrella term of Geographic Information Processing (GIP).

In response to these environmental concerns and the identified need for better databases and integrated spatial models supporting sustainable coastal development, a long-term study was initiated in 1990 to define, measure and model the impacts of urbanization on estuaries of the southeastern US. An overall goal of the National Oceanic and Atmospheric Administration (NOAA) funded Urbanization and Southeastern Estuarine Systems (USES) project is the utilization of GIP to assimilate and integrate data and scientific expertise for identifying, assessing and modeling relationships between land use and associated anthropogenic activities and coastal ecosystem health. The primary objectives of this study are 1.) to delineate the impacts of multiple stresses resulting from urbanization on high-salinity estuaries, and 2.) develop models which will provide a scientifically valid basis for land-use management in the coastal zone.

Developed spatial models incorporate land-use patterns and integrated multidisciplinary (bacteriology, chemical contaminants, coastal geography, eutrophication and nutrients, toxicology) approaches. Emphasis has been placed on watershed dynamics, including an examination of land use patterns and the impacts to ecosystem health associated with watershed loadings. By comparing the system responses of a relatively pristine estuary (North Inlet, SC) with those of a developed estuary (Murrells Inlet, SC), a better scientific understanding of the impacts of development is obtained. Results suggest that specific land-use practices within and adjacent to the marsh/upland interface are forcing agents for nonpoint source pollution, water quality degradation and habitat alteration, disrupt and contaminate sediment composition, and influence spatial distribution patterns of natant fauna.

**The Georgia LMER Program** - L. Pomeroy, Institute of Ecology, University of Georgia, Athens, GA 30602

The Georgia LMER program, now in year two of a seven-year study funded by NSF, is concerned with the transport and transformation of inorganic and organic materials carried from land to sea by the five Atlantic coast rivers of Georgia: Savannah, Ogeechee, Altamaha, Satilla, and St. Mary's. The Savannah and Altamaha have drainage basins extending into the upper piedmont, while the drainage basins of the Ogeechee, Satilla, and St. Mary's are wholly or largely on the coastal plain, and these latter and "blackwater" rivers. The St. Mary's drains the Okefenokee Swamp and has exceptionally low pH. Our regions of study are from the inlets to the head of tide, well into the fresh water portions of the rivers (Figure 1). Work in progress includes detailed studies of intertidal areas and flood plains, and GIS approaches to whole drainage basins. Both individual studies of component processes and coordinated cruises which consider many aspects from physics to microbiology are currently under way.

The LMER principal investigators are Merryl Alber (U. Ga. Marine Sci.), Clark Alexander (Skidaway Inst.), J.O. Blanton (Skidaway Inst.), Alice Chalmers (U. Ga Marine Inst.), R.E. Hodson (U. Ga. Marine Sci.), Mary Ann Moran (U. Ga Marine Sci.), L.R. Pomeroy (U. Ga. Institute of Ecology), W.J. Wiebe (U. Ga. Marine Sci.), and R.G. Wiegert (U. Ga. Marine Sci.). Wiegert is lead P.I. and coordinator. In addition to the P.I.'s and their students, Deborah Bronk and Wei-Jun Cai of the U. Ga Marine Science Department have related projects and are utilizing our ship time. We are encouraging additional ancillary research projects to build around the core LMER research.

Phase 1 of the work, now nearing completion, is a series of cruises involving all nine P.I.'s plus students and technicians, in which we are characterizing the five rivers. Measurements include salinity, sediment suspension, flushing rates, concentrations of nitrate, nitrite, ammonium, phosphate, silicate, dissolved oxygen, pH, $pCO_2$, microbial respiratory rates, and bacterial production rates.

Phase 2 of the work consists of more focused observations and experiments on the rivers. Mary Ann Moran's group is working on chemical fingerprinting of the dissolved organic matter in the rivers and transformations of that organic matter as it passes through the lower river and estuary. Wiebe, Pomeroy, Blanton and Wiegert are conducting studies of the transport and transformation of materials by tributary creeks in low salinity and zero salinity regions and have recently completed the first of these on White Oak Creek (Satilla River). Additional work by several of the investigators is planned that will use 16S rRNA probes and $\partial$13C of nucleic acids to define the distribution of populations of micro- and macro-organisms along salinity gradients.

Modeling by Wiegert's group is in progress and will continue throughout. Starting with single-process models, an hierarchical set of nested models is being constructed up to the landscape-watershed level. We expect interaction between modeling and empirical field studies to shape the direction of research in the latter years of the project.

**Chemical Contaminants in the South Atlantic Bight: A Myriad of Contaminants-Which Ones Count?** - Geoffrey I. Scott[1], Michael H. Fulton[1], John Kucklick[1], Tom Siewicki[1], Todd Shearer[2], Fred Holland[3], Tom Chandler[4] and Dwayne Porter [5], [1]NMFS Southeast Fisheries Science Center, Charleston Laboratory; [2] Medical University of South Carolina, Environmental Studies Program, [3]SC Department of Natural Resources, Marine Resources Research Institute; [4]University of South Carolina, School of Public Health; and [5]University of South Carolina, Marine Science Program.

The coastal region of the South Atlantic Bight (SAB) is experiencing major alterations in land use due to the rapid population growth and urbanization of the region. Major sources of chemical contaminants include point source discharges such as industrial/municipal treatment plants and abandoned hazardous waste sites and nonpoint source (NPS) runoff from agriculture and urbanization. Several regional monitoring studies have measured chemical contaminants in surface waters, sediments and biota of the SAB including the Urbanization in Southeast Estuarine (Eco)System (USES) Project, the NOAA National Status and Trend Program, the Environmental Monitoring and Assessment Program (EMAP), the Charleston Harbor Project, and the South Carolina Department of Natural resources Small Tidal Creeks Study.

The USES study evaluated the effects of suburbanization (e.g., roadways, marinas, housing and service industries without industrial discharges) on sediment and biota contaminants levels in Murrells Inlet, a highly urbanized area south of the Myrtle Beach *Grand Strand*, and pristine North Inlet (A NOAA NERRS Site). Results from the USES Study have indicated that the major chemical contaminants in Murrells Inlet was NPS runoff of polycyclic aromatic hydrocarbons (PAHs) from roadways and marinas and chlordane from housing. Other sources of contamination included pollution from septic tanks which caused elevated levels of fecal coliform bacteria in the inner and outer regions of Murrells Inlet and Garden City Beach, respectively. Elevated levels of fecal coliform bacteria were also observed at the inner regions of North Inlet, which were associated with discharges from wildlife populations there. Coliform *finger printing* by API biotyping indicated that fecal coliform sources in Murrells Inlet were dominated by inputs of *E. coli* bacteria where as in North Inlet *E. coli* inputs were greated reduced.

The Charleston Harbor Project study and S.C. Department of Natural Resources's Small Tidal Creek study found that the major sources of chemical contaminants were associated with point source industrial discharges (Cr), abandoned hazardous waste sites (PAHs, Pb, Ni and DDT), and urbanization (PAHs and chlordane). There was a gradient of PAHs pollution in going from small tidal creeks--> rivers ---> harbor regions of Charleston Harbor estuary. Highest levels of contaminants were found in the small tidal creek reaches. The only river system with major contamination sources was the Ashley River as the Wando and Cooper Rivers as well as the lower harbor did not have elevated levels of chemical contaminants. Comparison of sediment contaminants levels with sediment quality guidelines/criteria indicated regions of Charleston Harbor which may contain potentially toxic sediments and included Koppers, Diesel, Shipyard, Vardell and Shem creeks as well as the Ashley River.

Monitoring of nonpoint source agricultural runoff indicated significant runoff of insecticides (azinphosmethyl, endosulfan and fenvalerate) used on vegetable crops occurred which often resulted in fish kills and other impacts (toxicity in field bioassays, brain enzyme AChE inhibition, altered growth, reduced reproduction, increased respiration and reduced NH4 excretion) in fish, crustaceans and mollusc. Impacts were greatest in the headwaters of small tidal creeks draining agricultural areas.

Results of these various monitoring studies in the SAB clearly indicate that chemical contaminants from industrial, urban/suburban, and agricultural sources may cause impacts in estuarine ecosystems. Highest contaminant concentrations and greatest impacts were observed in the headwaters of small tidal creeks which are the true nursery grounds for fish, crustacean and mollusc. Protection and management of NPS runoff loading into these watersheds is essential in protecting habitat quality within the SAB region.

**Appendix 4**

## Working Group Reports

### Natural Sciences

### G.T. Chandler: Land Use Practices Breakout-Group summary -- LUCES 1996

"Land Use Practices" of potential impact to coastal living marine resources occur at square meter (e.g., docks, bulkheads) to square kilometer (e.g., forestry/agriculture) spatial scales, and hours (e.g., pesticide runoff) to decades (e.g., suburbanization, paved surfaces) temporal scales. At the core of the problem of characterizing which land use practices deserve the most attention with regard to greatest potential impact on resources lies the challenge of how to address scale incongruencies. Lee (1993) aptly states "when human responsibility does not match the spatial, temporal or functional scale of natural phenomena, unsustainable use of resources is likely, and it will persist until the mismatch of scales is cured." It will always be difficult to convince people in Greenville or Atlanta that their activities (and responsibilities) will have impacts on coastal resources hundreds of miles away when the available science does not or cannot address such large scales.

In the LUCES workshop, the Natural Scientists "Land Uses" groups (NATSLUGs) reached strong consensus that suburbanization/development, forestry and agriculture pose the greatest threats to SAB living marine resources and their habitats through the processes of non-point source loadings of nutrients AND contaminants (especially pesticides & PAH's), with subsequent negative effects on pelagic and benthic community diversity and abundance. For non-point source loadings, the most obvious scaling challenge is spatial. In contrast to most coastal resource issues such as dredging, bulkheading, loss of wetlands, etc., the sources of eutrophication and contaminant loading to water and sediments often originate far up the watershed, hundreds of miles away, or even outside of the watershed in the case of atmospheric loadings. The NATSLUGs consensus was that the most appropriate spatial scale for loadings assessments was the entire SAB watershed, or large scale sub-sheds -- but the group realized funding limitations could best address loadings at compartmental interfaces such as estuarine creeks to upper tidal front margins. The NATSLUGs also agreed that sediments are the most important repository of contaminant loadings with subsequent impacts on benthos; and phytoplankton/zooplankton abundances/diversities and linkages are the best indicators of eutrophication impacts overall. Temporal scales of land use impacts are particularly difficult to assess and predict because processes such as eutrophication, habitat loss and species loss also occur naturally and episodically. Without knowledge of what living marine resources and habitats were like before anthropogenic inputs of nutrients/contaminants/pathogens reached present levels, it is difficult to gauge how rapidly and to what degree impacted ecosystems will degrade -- or recover following mitigation and restoration.

Having accepted the preceding caveats that the most appropriate spatial and temporal scales to address land use impacts are large and long-term, the NATSLUGs were charged with addressing the more fundamental and pragmatic question of "What land use practices are likely to have the largest impacts on living marine resources and their habitats (LMRH) over the next 10-20 years?" Each NATSLUG member was asked to brainstorm for 15-20 minutes on four subcomponents of this general question: 1) What do you think are the most important land use practices with regard to threats to LMRH? 2) What are the most important effectors of impacts on LMRH arising from these land use practices? 3) What are the most important effects/impacts on LMRH from these effectors? and 4) What are, in your best scientific opinion, the best assessment approaches for characterizing impacts of these various land use practices? Each question was addressed and discussed sequentially, with each NATSLUGs member ranking on a scale of 1 to 5 the importance/utility of each answer (i.e., land use practice, effector, effect and scientific approach) in characterizing land use impacts on LMRH. There were typically 10-20 different responses to each question -- those responses receiving the five highest summary scores for importance are summarized here. Responses sharing the same number were tied in rank importance.

A. Most important land use practices and associated threats to living coastal marine resources and their habitats?

1. Suburbanization/development -- housing & sewage disposal, land-clearing, golf courses, direct coastal habitat modification/destruction (e.g., water diversion -- tidal and fresh water), paved surfaces and automobile use, marinas, and non-point source runoff of pesticides, PAH's, sediments and pathogens. Past, present and future projected scales of development badly needed.
2. Agriculture and Forestry -- NPS runoff of nutrients (esp. nitrogen), pesticides, and eroded sediments. Areal-based loading models available; modifications badly needed for coastal habitat dynamics.

B. Most important effectors of negative impacts on LMRH?

1. NPS loadings of pesticides.
2. NPS loadings of nutrients, especially nitrogen.
3. NPS loadings of PAH's and "paved surface" toxicants.
4. Direct coastal habitat modification -- building, paving, bulkheading, dredging.

C. Most important impacts/effects of land use practices on LMRH?

1. Eutrophication (rates, magnitudes, impacts on community diversity, food web structure).
2. Habitat loss (quantity and quality) -- wetlands and maritime forests (historical, current and projected loss rates and contaminant profiles, esp. sediments).
3. Loss of species abundance and richness -- esp. sublethal population-level effects of contaminants, and habitat/nursery loss.
4. Food web structural simplification (and linkages to fisheries decline).

D. Most scientifically valid/useful tools to characterize land use practices impacts?

1. Chemical fingerprinting of pesticides, PAH's and metals (e.g., fuel combustion products vs. direct fuel spillage, specific pesticides associated with specific agriculture/golf courses/forestry practices, metals associated with specific industrial activities).
2. Fecal coliforms/coprostanol as indicators of sewage, septic tanks and/or animal farm loadings).
3. N:P ratios for nutrient source characterization (e.g., fertilizer, sewage, animal farms).
4. Acute to chronic toxic effects of contaminants and/or eutrophication-induced anoxia on key benthic and pelagic fauna (bioassays to species-abundance/community assessments).

The NATSLUGs were asked informally to discuss critical data needs for assessment of land use practice effects on LMRH. Four critical needs areas were identified: 1) A historical perspective of natural LMRH change in the absence of current land use practice pressures; 2) an assessment of coastal land use genesis in the past, present and future; 3) an assessment/compilation/survey of toxicant (esp. sediments) and nutrient concentrations in SAB coastal watersheds; and 4) identification of useful, sensitive biological indicators/thresholds of response to land use impacts. The critical question of "What are the appropriate time and space scales for impacts on living marine resources and their habitats?" was effectively tabled by the NATSLUGs. All members felt that temporal and spatial scales are driven by the process in question, thus, a general consensus on how many years or how many hectares must be studied to assess land use impacts is logically not achievable for such a complex set of problems. Dr. R. Jahnke (and others) suggested that each process of interest be non-dimensionalized if possible, or, at least, have the scale defined to the most appropriate length to see a process produce an effect or impact. Dr. E. Odum suggested that we "think globally but act locally"; that is if we can come up with an approach that at least works on a small scale, others will adopt the model everywhere.

Reference:
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## Working Group Reports

## Natural Sciences

### J. Blanton: Land Use Practices Breakout-Group summary -- LUCES 1996

#### Introduction

The hydrosystem is defined as a series of reservoirs connected by conduits, both of which are surrounded by land boundaries. Each reservoir may have its own characteristic set of habitats and/or landscapes. In the southeastern United States (SAB), rivers collect material from water sheds of different sizes and with different types of development (forest, urban, agricultural). The rivers transport dissolved and particulate material into an estuary where the throughput time is suddenly altered by tidal currents. This material, if not trapped within the estuary, may be transported to the ocean where its fate is affected not only by tidal currents but by wind stress which induces its own system of cross-shelf and alongshelf currents. The estuaries in the SAB usually consist of a main tributary tidal conduit off of which branches a series of primary, secondary and tertiary tidal creeks, each with its own set of morphological and tidal attributes. The tidal creeks themselves as well as the main tidal river are surrounded by marshes that are alternately wet and dry throughout a tidal cycle. Between these reservoirs (rivers, estuaries, tidal creeks, marshes, ocean) are interfaces where hydrodynamic forces and continuity considerations abruptly change the dynamics governing material transport and fate.

The throughput, flushing, or resident time of a reservoir is a useful (but often misleading concept. When used here, it is defined as a time scale based on the ratio of the volume of a reservoir to the volume input rate of a specified material. Instantaneous and complete mixing throughout the volume is assumed. (This assumption can lead to misuse of the concept.) However, it is a useful number when comparing different reservoirs. To keep jargon at a minimum, we use the term "flushing time" throughout this document.

The natural ability of the reservoirs to flush themselves varies on time scales from hours to years. This natural ability can be altered by flow restrictions such as bridges and causeways that would further decrease flushing rates. Upper reaches of tidal creeks whose beds may be exposed at low water represent one extreme where tidal currents themselves are very small, resulting in tidal excursions that are also small. Fine sediments with low settling velocities settle out carrying to the bed any pollutants adsorbed onto the particles. The flushing time of the sediments of such a system could be years if not decades until some catastrophic natural event or some man-made mitigation procedure removes the material or alters the flushing time by changing the morphology of the reservoir.

At the other extreme are the large tidal rivers which carry the various runoffs from the water sheds. These discharge fresh water into reservoir volumes that are relatively small (neither wide nor deep in an average sense) and flushing times can be as short as a few days. Here, current velocities can be large enough during some portion of ebb and flood tidal currents to resuspend all but the largest particles. Depending upon the temporal changes in the strength of the tidal current over its ebb and flood cycle, these particles may be slowly transported seaward or landward. These temporal changes result in a tidal asymmetry that differs from reservoir to reservoir, and the net effect of the asymmetry on transport of particulate material will also differ depending upon the settling velocity. In a reservoir with a large range of particle sizes and settling velocities, tidal asymmetries may actually sort these sediments in such a way that the fine, slowly settling particles are carried one way while the larger courser particles are carried the other.

Thus the flushing times of the various reservoirs vary from time scales ranging from a few days to years, and the times themselves depend on whether one is considering dissolved or particulate material. Each reservoir has its own water shed which may range from a tidal marsh and its surrounding land to a large piedmont water shed extending into the mountains. One intuitively expects that the larger the drainage basin, the more "global" will be the impact resulting from various manipulations. In other words, while point source impacts are important in small reservoirs with small flushing times, nonpoint source impacts become increasingly important for reservoirs connected to the larger water sheds.

**Potential Impacts and Issues**

The rapid growth in population and resulting alteration in landscape will result in several types of impacts to marine resources, whether they be finfish, crustaceans and mollusks, vegetated wetlands, or water and sediment quality. Activities such as dredging which increase depth, and flow restrictions which reduce flushing, will alter the cycling of material. Increases in discharge of material will result from increased surface runoff. Increased runoff will result in increases in effluent to receiving waters from wastewater treatment plants and increases of other contaminants such as organic and inorganic pesticides, heavy metals and fecal coliform. While man-made changes to flow are small compared to nature, man-made inputs in nutrients can be large. Inputs of nutrients can occur when groundwater is recharged with an extra load of nutrients through increased suburbanization (golf courses, deforestation).

Activities resulting from population growth and urbanization, some of which are listed above, will result in impacts which will largely occur through (1) reservoir alterations at the boundaries (e.g., forest removal and other habitat loss, increase of impervious surfaces through activities such as road paving, and bulkheads), (2) alterations in reservoir depth (i.e. dredging and port development), (3) increased industrial and domestic use of ground water and surface water, and (4) the introduction of exotic species. Taken in concert, the potential impacts in the reservoirs (large tidal rivers or small tidal creeks) include:

- increased eutrophication (even in some tidal creeks which are naturally eutrophic)
- increased levels of fecal coliforms
- increased waterborne contamination from organic/inorganic pollutants
- intrusion of salt into ground water sources
- changes in supply of freshwater to the estuaries and coastal ocean
- alteration of the cycle of nutrients through the food web
- loss of nursery grounds to important fish and shell fish

**Scientific Research Priorities**

The impacts enumerated above will lead to (1) increases in the loading of nutrients and contaminants in water and sediment, and (2) increases in the buoyancy input to estuaries and the inner shelf through the shift of ground water resources to surface discharges. Gaining a scientific understanding of how these increases affect processes in the various reservoirs of the SAB is the thrust of the recommended research program for LUCES. This understanding is to be derived from comparisons of reservoirs with different flushing times (Table 1).

Impacts will differ in each of the types of reservoirs listed in the above table. Development along the periphery of a tidal creek will result in point-source inputs. Residential developments are often found in low-discharge environments such as tidal creeks or the back side of islands facing lagoons, environments that have relatively high flushing times. On the other hand, industrial development is usually focused in high discharge environments where the loading can be non-point source as well as localized discharges.

Table 1. Reservoirs/habitats/landscapes having different flushing times

| **Reservoir** | **High Discharge** | **Low Discharge** |
|---|---|---|
| Tidal creek/marsh | | X |
| Estuary with small coastal plain river | | X |
| Estuary with large piedmont river | X | |
| Coastal ocean | X | |

Coastal plain watersheds usually have different land-use activities than to the piedmont watersheds. The result is that estuaries with high freshwater discharge, like the piedmont rivers, have different material inputs at the head of tide than do the coastal plain river estuaries with comparatively low discharge.

Small tidal creeks with relatively long flushing should be compared to estuaries with large rivers which have short flushing times and, as a result, large carrying capacities. Circulation in the latter may be sensitive to changes in buoyancy input. Circulation in the former will be sensitive to changes in the tidal currents along the creek and over the marsh. What will be the effect of changes in the flushing times of tidal creeks and marshes on the supply of fish and shell fish larvae to these environments?

Reservoirs with different flushing times will allow biogeochemical processes to occur at different rates. This results in different trace element ratios in different reservoirs. Different reservoirs may respond to different nutrient ratios. Large systems may be able to buffer the usual episodic events such as winter storms and respond slowly to varying inputs, whereas the smaller systems may be altered easily by the same episodic events.

We have the least understanding about the interface regions between the various reservoirs. A comparison of findings between adjacent reservoirs will yield considerable insight on processes affecting the transport and fate of material through the interface regions, processes such as component transformations and the import/export of material.

The various scientific issues covered above can be organized into those related to flushing and circulation and those related to biogeochemical cycling. Those related to flushing are covered first. Marine systems with different flushing times can be understood in terms of the processes that maintain the balance of salt. Understanding the salt balance will translate into knowledge of the balance of other conservative materials. This balance is different, not only for systems having different freshwater discharge rates, but for estuaries having a deep (e.g., shipping channel) versus a shallow connection to the ocean (offshore tidal delta). Buoyancy forcing and tidal mixing will be important in the former while tidal mixing assumes a greater importance in the latter.

Understanding the biogeochemical cycling of material has many interlinking components. It requires a knowledge of material transfer processes occurring with flow through porous media.

The substrate(geology) becomes part of the system through erosion, and sediments have the ability to accumulate both nutrients and contaminants. Which ones are released to the environment, how much, and what are their ultimate fates? The carrying capacity of a reservoir is governed by component transformations and import and export of material (related to the salt balance in conservative cases). Are there thresholds and cumulative effects? What are the thresholds above which nutrients will increase the present state of eutrophication? What other thresholds exist for the various reservoirs?

Nutrient loading to the different reservoirs is a particularly important issue. For example, what is the impact of different nutrient ratios on food web response and the state of eutrophication? Closure of shellfish beds is usually the first sign of problems. Eutrophication itself is very difficult to quantify, and it is difficult to identify a baseline. Identifying the best nutrient for study is particularly problematic. Phosphate is a poor indicator in food web studies because it is absorbed by clay. Everything appears to take up nitrogen.

## Most Important Mechanisms Requiring Study

Budget and time constraints required a reduction in the degrees of freedom covered by the many aspects of research covered above. This was accomplished by synthesizing the priorities developed at the Savannah LUCES workshop during which a hierarchy of the most important issues was identified. This reduction is summarized as follows:

1. What mechanisms incorporate contaminants into sediments and biota? What mechanisms release contaminants back to the environment? What processes transform contaminants and increase the contaminant load?

2. How does a given system (reservoir) respond to increased inputs? Is there a threshold response to acute versus chronic inputs? How does the system respond to major storms?

3. How does the system respond to changes in groundwater extraction?

The study of these mechanisms is grouped into the categories of (1) buoyancy dynamics, (2) geochemical and sedimentary dynamics, and (3) state of eutrophication. Buoyancy-driven circulation is directly related to processes that maintain the salt balance and flush the system. Correlations of nutrients and other dissolved material with salinity reveal important information on their balance (input, removal, or conserved) within the system. The nutrient balance is linked to the state of eutrophication. Sediments integrate both the time and space scales of the transport processes as well as the inputs of nutrients and contaminants. Thus sediment quality is just as important as water quality as an indicator of the state of the environment of the various reservoirs.

### *Buoyancy*

Changes of freshwater inputs (surface and groundwater) result in the alternation of an important component of the force that drives estuarine and coastal currents on the continental shelf. This buoyancy-driven component drives the gravitational circulation and is responsible for net transport of material shoreward near bottom and offshore near surface. Ingress of the larval stages of many estuarine-dependent species appears to benefit from the cross-shelf circulation driven by buoyancy. Heavy minerals are imported from the ocean to the estuarine environment by the gravitational circulation.

It is important to locate areas in the hydrosystem where groundwater contributes a significant source of buoyancy and maintains a specific ecological environment. Recent work suggests that groundwater is an important, and overlooked, source of buoyancy to waters of the continental shelf. Hydrodynamic models interfaced to water quality models can offer a means to determine the likely effect of reducing or even terminating this component on the transport and ecology of a system.

Questions to be addressed:

1. How do increases and decreases in buoyancy supply affect the salt balance and flushing time of the system?

2. How are nutrient supplies affected by changes in buoyancy supply?

3. What are the relative inputs of nutrients and other material in surface water versus groundwater?

***Geochemical and Sedimentary Dynamics***

Many contaminants are particle reactive and processes governing their adsorption and desorption onto sediments must be known. Particles may be initially formed in certain environments, such as their first encounter with salt water (usually in a range between 0 and 10 parts per thousand salt). Moreover, increases in particle size and/or settling velocity can occur in regions where turbulent kinetic energy is particularly high, such as tidal rivers of relatively large volume versus small volume peripheral tidal creeks. Thus, major emphasis must be placed on studies of (1) adsorption/desorption processes, and (2) sediment transport and fate. The dynamics of sediment transport are nonlinearly linked to the temporal changes in tidal current strength (at frequencies ranging from quarter-diurnal to semi-monthly) and the range of particle sizes and settling velocities encountered in the various reservoirs. Numerical simulations incorporating all the nonlinearities and feedback mechanisms (some of which are electrochemical) are in their infancy. A minimal effort would consist of studies in reservoirs with contrasting flushing rates (a main river channel versus a small peripheral tidal creek).

Questions to be addressed:

1. How is the tidal wave (height and velocity) modified from the inner shelf, through the estuary, and through final dissipation at the head of tidal creeks?

2. How is larval transport modified by these alterations in the tidal wave?

3. What particles sizes are suspended and deposited in the various reservoirs throughout tidal cycles ranging from semi-diurnal to semi-monthly?

4. How are the sizes sorted in the different reservoirs?

5. What contaminants and biological materials are associated with these particles?

6. How are contaminants absorbed and desorbed on these particles?

7. How are contaminants altered as they flow through porous media?

***State of Eutrophication***

The increased loadings of nutrients will increase the potential of eutrophication. Increased groundwater extractions will be added to normal surface discharges often with an accompanying increase in nutrient concentrations. Some tidal creeks and marshes are naturally eutrophic as revealed by depressed oxygen concentrations relative to saturated values. Because of their small potential for flushing, these environments will be particularly vulnerable to increases in nutrients with high oxygen demands. Fecal coliform and waterborne contaminants will often be transported in with the dissolved material causing increased eutrophication.

Question to be addressed:

1. What are the responses of the various reservoirs to different nutrient ratios?

2. What are the thresholds of input above which eutrophication increases?

3. What reactions occur in flow through porous media that alter nutrient ratios?

It is obvious that most of the questions posed in the three categories are intimately liked. A comparison of the answers to these questions in the different reservoirs identified in Table 1 should yield a rich set of data for better managing the changing land-use patterns in the coastal zone of the southeastern United States.

## Working Group Reports

## Social Sciences

### R. Becker - LUCES 1996

### Implications of Regional Demographic and Social Trends on the Marine Resources of the South Atlantic Bight

In considering demographic trends, the first and foremost to consider is the size of the total population residing in counties within 50 miles of coastal shorelines, with this number reaching 129 million plus by 1988 and no sign of any decline for the future (U.S. Department of Commerce 1990). This then means 53.1% of all the people residing in the United States live in the coastal region. Broken down, this equates to 22.5% in the Atlantic, 12.3% in the Pacific, 12.2% in the Great Lakes, and 6.0% in the Gulf of Mexico regions. To illustrate the extent of the increasing density of these regions, in 1960 there were approximately 199 people per square mile in the coastal regions; by 1980 this figure had risen to 277 people per square mile and is expected to double by the year 2000. In the Atlantic region alone, the change in density during this twenty year period went from 342 people per square mile in 1960 to 451 people per square mile in 1980.

This trend of a larger proportion of the population moving to the coastal regions is expected to continue, particularly in the areas in the South Atlantic Bight. The area between Wilmington, NC and Savannah, GA should experience the greatest growth given the rising popularity of this region for retiree relocation and tourism development. The implications this has for resource management is what impacts the construction, the traffic, the pollution, and social pressures that comes with increased population density will have the regions marine resources.

First, to consider is the environmental problems stemming from an ever increasing population. Among these problems are the conversion and hardening of land surfaces, the loss of even more of the nations wetland, and the degradation of water systems. Along with increasing numbers of people comes increased demands on the available supplies of quality drinking water; what to do with the sewage that is produced; how do you handle the tons and tons of solid waste that is produced; and last, but not least, is the air pollution from car exhaust and industry.

In conjunction with this total population growth, there are additional implications from various compositional changes in this population that need to be addressed. The changing age mix, indicate there will be more people in the older age categories. This can have many implications for the future, for it has already been shown that older people have different wants and desires from younger people, also they have more choices and financial abilities than their younger counterparts. Second, the change in household composition will be even more evident than it is currently. The nuclear family will become an even smaller proportion of the total households in the U.S. On the other hand, single (primarily female) headed households will be an ever increasing proportion of the total household population. There is a similar trend occurring for the single population group. This changing household structure brings with it many implications for the types of recreational activities and vacations that people will take in the future. For instance, these groups will have less money to spend and will be looking for moderate to low cost travel accommodations, restaurants, and amenities. Likewise, their choice of travel destination will likely change in the future, to which they will travel more to areas close to home and when traveling only being away from home for shorter periods of time.

A household component that is increasing is dual income families, with this extra income comes less time for leisure and travel leading to shorter travel trips and places a demand on travel and recreation providers to develop new and innovative methods and opportunities in the future to meet these demands.

Traditional industries (agriculture, fishing) in the coastal regions are being replaced in a larger percent of the workforce by jobs in the retail, service, and construction sectors. In addition, to the changing of the industry structure there are population changes occurring within the laborforce that are important. With the aging of the general population there also is an aging effect for the laborforce. With fewer people in the age groups following the baby boom generation, there will be a need to have people work longer in their working lives to fill the demand for workers. This lessening of the work age population also means there will be a greater dependency in the ration of nonwork population to work age population to pay into social security, Medicare, pension funds, and so on. Placing an even greater burden on a much smaller group to care for the older, much more currently, affluent group. Suggesting that as this group of workers approach retirement age they will have considerably fewer resources provided for them or available to them than their counterparts today.

In the short run with the baby boomers reaching middle age and arriving at points in their lives where perhaps the children are grown, the housing costs are lower and incomes are higher. This group of people are moving toward a "country" renaissance. They long for the image of the all-American small town, for the warm feelings that come from living close to the land. In addition to the feelings for country and folk styles, this group has the financial means, inclination, and from the lack of opportunity for long periods of travel and other indicators mentioned previous this group is purchasing second homes at an ever increasing rate.

On a different note, the proportion of minorities making up the population of the United States will only increase in the years to come.

This rising proportions of minority population will have impacts in a number of areas. First, because their birth rate is considerably higher than the white population, the schools population will include a great deal more minorities than today. This strains the educational resources due to the necessity of upgrading the education currently being achieved by the majority of minority students. This in turn means that if this education is not successful, then there will not be qualified workers to fill the jobs of the future, because of the larger proportion that this group in the younger cohorts they will be the ones found in the available workforce of the future.

A policy implication that stems from the movement of the population to the coastal regions and other demographic projections is the aspect of accessibility. As more and more of the coast becomes developed and primarily in private hands fewer and fewer of the general public will have access to use the beaches and other coastal environments. Additionally, there is the lessening of accessibility to coastal land due to land becoming more scarce, thereby eliminating a greater proportion of the population every year from the opportunity of purchasing that land. Escalating land values from regional population expansion also results in displacement of long-time residents from family held property as all property taxes grow with sales prices.

Another policy implication from these trends are that uses of coastal resources may change and activities such as recreation and tourism will change with the changes in the population. As Murdoc, et al (1991) suggest for fisheries management, the major demographic changes impacting both the characteristics of the clientele served and the social, economic, and political environment in which management occurs.

The characteristics of clients served by fishery agencies are changing. Client populations are growing more slowly than in the past. They are likely to be older and have a larger number and proportion of individuals of minority status. Because rates of participation in fishing for older participants and minority participants differ from those for younger whites who have tended to dominate fisheries clientele in the past, increases in the proportion of the population in older and minority groups are likely to change angler clientele accordingly.

These demographic changes have social and economic implications if major changes do not occur in the relationship between minority status and social and economic resources, many anglers will have fewer resources than was the case previously or may not be able to participate at all. They will require lower access and use fees at a time when agencies are considering increased license fees to support fishery programs.

Another point of reference here is that consumptive resource users (anglers and hunters) have paid the majority of costs for natural resources management previously, approaches that collect revenues from nonconsumptive users (birdwatchers, hikers, nature photographers, etc.) may be required to meet new demands of expanded user groups who are either unable to pay or have been exempted from paying. Regardless of which of these funding alternatives are selected in the future, fisheries and other coastal managers will not be able to ignore the interests and demands of older persons and minorities (Murdock et al 1991).

In looking at South Carolina, in particular, this state shows an impressive increase in population between 1980 and 1990 with a 11.78% increase in total population placing South Carolina 18th of 50 states in total population growth in the last decade. In a recent study completed in the state on boater use, all projects indicate an increase in boater use, all projections indicate an increase in boater use, particularly in the coastal region. In looking at the age structure of the state of South Carolina, the age cohorts between 35 and 54 appear to be one of the fastest growing population segments. It has been shown that this cohort also has a higher participation rate in boating, as well as in the purchase of boats. Suggesting that there should be a continuation to the increasing demand for boating opportunities in the future.

In conclusion, some trends that appear to be rising in the decades to come are more environmental concern, waste disposal problems, more retirement communities, and nursing homes, need for infrastructure rehabilitation, more highway and air traffic congestion, increases in participation in activities such as golf, bicycling, walking, and cross-training, more service sector businesses, needs for child care and eldercare, more flexible work hours and more foreign competition.

**References**

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## Working Group Reports

## Social Sciences

## W. Kriesel - LUCES 1996

Below, I report on the highlights/commonalities from the two groups that I facilitated at our meeting in Savannah. Finally, I will give my own impressions of the tasks facing the LUCES group.

As a point of introduction, I think that the participants at my sessions were impressed with the importance of the research topics being considered by LUCES, and the high potential for society to greatly benefit from LUCES research results. They were all aware that preventing further environmental degradation is highly desirable, and that future developmental pressures in our region are unavoidable. Both of the groups were highly motivated and they gave us their best effort.

<u>Highlight 1</u>:

Limiting environmental impacts may mean limiting how people can use their private property. As the presentation by Dr. Vernberg illustrated, seemingly innocuous land changes such as altering the plant cover around homes in sensitive areas can have tremendous ecological impacts. If land use controls are needed to obtain the LUCES objective of "no further degradation," then we need to know everything possible about land use policy. At a broader level, research should define the entire spectrum of available policy instruments and, for each one, address:

- What effect does each have?
- What are costs and benefits of each?
- What institutions are needed to implement the policies?
- What are their information/educational needs?
- Are the Florida water districts something to copy?

<u>Highlight 2</u>:

We are dealing with environmental impacts that have probably been researched, but we aren't aware of the results. Therefore, we need a state of knowledge report on unit resource impacts for a unit change in each coastal use category. As an example, suppose we knew the unit resource impact of a recreational boat. Then, if we knew the demand for boats by new residents, and the value (non-market) of impacted coastal resources, then we would have much of the information needed to estimate costs and benefits from alternative boating policies.

A similar situation holds for forest land use, residential land use, agriculture, etc. With information about all of the activities that would need regulation, then a set of optimal policies can be proposed.

<u>Highlight 3</u>

Both groups were concerned about the public's involvement at the grass-roots level, in the early, middle and later stages of the research. In retrospect, I think that this was on everyone's mind because they were sensitive to the fact that this project will call for environmental preservation on a very large scale that will affect many people's lives. Thus, public inputs at all stages will help to gain their acceptance of the research results and the methods of preservation.

Therefore, we need to know how the public's input can best be obtained. With other projects of this type, how has grass roots involvement been fostered?

Regarding dissemination of the research results, what is the best public education strategy? We could use GIS/visualization techniques to demonstrate "what if" scenarios to the public, i.e., "what if" the current development trend continues and "what if" another approach is taken.

One participant suggested that the residents should be regarded as a coastal resource with an integral role in our research. Finally, we must be sensitive to the plight of poor people in this region. How will they react to our anti-development predilection that may block out employment opportunities for them and their families?

Highlight 4:

We need to inventory the state of knowledge in:

- Demographic projection - how many more people can we expect here?
- Predicting land use change
- Institutions and policies for land use control
- Off-the-shelf models of how land use changes impact resources
- Community-based programs that set environmental priorities.

My Own Impressions

I think that the LUCES objective of "no further degradation" is a great one, but one of our basic problems is how do we get people to act in more environmentally-friendly ways? In the 26 years since the first Earth Day, each successful environmental protection program has to address this problem. The LUCES objective will have to address the problem also. One obvious method is by the command and control approach, and in our case it will involve new laws that control land use. However, in the current political climate I don't think that any legislature will pass significant new restrictions on the use of private property.

As an example of the current climate, the US Congress is currently considering HR 2275 and S 768 to reauthorize the Endangered Species Act. They would require full compensation of a landowner for diminutions in the value of any portion of his by 20 percent or more due to actions under the ESA. The action agency would pay compensation from its current budget. Note that unless an agency wanted to lay off its employee, it would not enforce the ESA. I do not believe that this move to radically strengthen private property rights is motivated solely by Endangered Species, but it is more a result of the public's growing mistrust of government at all levels.

A second approach would involve a less intrusive system of financial incentives for landowners to use their land in eco-friendly ways. For example, Georgia's Conservation Use Assessment gives a reduction in property tax if you agree to keep your land in its current use for ten years. This sounds nice, but research has shown that in areas where the profit from land use conversion is great, then a tax subsidy is needed to prevent conversion. Needless to say, the ordinary taxpayer dislikes subsidizing others.

Another approach is the public policy education approach suggested by Richard Barrows of UW-Madison. The approach works at the grassroots level and involves Universities, including the Cooperative Extension Service. Here, the research results are presented to the public with the message that "if you do X, then Y will result." Early education about new and controversial laws and policies is vital. The approach is very Jeffersonian in its faith in the abilities of an educated electorate, something I'm not so sure about.

Doubtless, there are other approaches that I'm ignorant of. But unless someone can suggest better ideas, I'd like to see elements of the financial incentives and the policy education approach written into the RFP at some stage. I feel that this is necessary if we wish to make it clear to the project sponsors that the project's outcome will do more than provide extra funding for some faculty.

**Working Group Reports**

**Policy and Management**

**J.M. Dean - LUCES 1996**

**Statement of the Problem: Population growth will result in the following changes in coastal ecosystems.**

The basic situation is that fundamental and underlying activities and actions is that decisions that affect the coast are and will continue to be made elsewhere. However, there will be little awareness and knowledge of the implications and outcomes of those actions in Greenville, SC and Hiawasee, GA. The jurisdictional roles and individual actions are a function of local political processes and therefore be driven by perceptions of short term advantages and gains.

(1) Problem:

Altered flows in freshwater as a result of demand and utilization by different user groups.

Outcome:

(a) Availability to different user groups for allocation (industry, agriculture, residential, recreational).
(b) Variation in quality and quantity.

Management Needs:

(a) Predictive capability of resource availability.
(b) Allocation process that is fair, equitable and transparent.
(c) Education of user groups at the coast and removed from coast.

(2) Problem:

Transport and availability of contaminants

Outcome:

(a) Distribution to sites removed from origin.

Management Needs:

(a) Establishment of contaminant criteria of traditional and new general chemicals to establish policy and regulation.

(1) For water, sediments (both physical and chemical).
(2) Must be done at the habitat scale (not just local and for individual species).

(b) Risk assessment and management tools.
(c) Cumulative impact index.
(d) Multiple stress index.

(3) Problem:

Competition for resources by user groups (commercial fishing, recreational fishing, development, conservation and environmental activists)

Outcome:

(a) Lack of knowledge of causes of inter and intra-annual variation in fishery resources for recreational and commercial utilization.
(b) Changes in biodiversity
(c) Loss of habitat for resources:

(1) change in nursery functions.
(2) alterations in predator prey relationships.
(3) conflicts on protection of endangered species.

(d) Pull up the gangplank syndrome.

Management Needs:

(a) A classification system for tidal creeks such as exists for freshwater systems, (stream order, hydrogeomorphology, Index of Biotic Integrity) that must be descriptive and prescriptive.
(b) Tools for "triage ecology," (where to put effort to get the best return).
(c) Habitat quality index.
(d) Benchmarks for management to measure outcomes of actions.
(e) Civic science (adaptive management).

(4) Problem:

The need for an understanding and necessity for political reality. There are fundamental questions of the credibility of the science that is used for policy development, regulations, implementation and enforcement.

Outcome:

(a) the public perception of the quality of the science has great variability and the public does not understand risk and uncertainty.
(b) There is a consistent lack of feedback to the scientific community about the credibility of the science.
(c) There is a lack of understanding in the scientific community about:

(1) the political process,
(2) the regulatory process,
(3) the data needed and used in the process (the scale the problem dictates, and providing information at the scale it is applied),
(4) who provides the data (advocatory and non-advocatory roles, who says it and how it is said),
(5) the critical need to check the "so-what" linkage.

Management Needs:

(a) Aggressive outreach program for education of all user groups (specifically including the scientific community).

(b) Development of public support.
(c) Tools for communication of science information to local decision makers.
(d) Development of process to reduce conflict in the public and private sectors about the access to and use of the resources.

## Working Group Reports

## Policy and Management

### L. Osborne - LUCES 1996

This report summarizes the major issues that were identified by the two breakout sessions discussing the policy and management concerns for land use practices and their effects upon coastal ecosystems. I begin with a general discussion of the most pervasive theme across both groups. Following this discussion, I report a summary of the major issues identified and discussed among each breakout group.

My interpretation of the charge to these breakout groups was to help identify the needs/questions that should be considered during the preparation of the first year's RFP -- with an eye toward what that first year could produce to then develop a five-year extensive study. Most likely as a result of my focus upon this goal, one overall theme developed in both breakout groups: that an assessment of the current state of the South Atlantic Bight was needed -- in sufficient detail to be informative at several different levels of "scale." This assessment obviously would have as a major component a quantification of the current resource (i.e., "what's there and how much of it do we have?"). In addition, owing to the diverse background of the participants in these markets, a consensus was that any assessment would also include in a substantial way economic, demographic, legal, political, and dynamic considerations. Both breakout groups considered each of these factors equally important in understanding how land use changes are occurring, why they are occurring, and predict in what ways they will continue to occur. Without a complete characterization of the forces in play, as well as the ecosystems they affect, it was the consensus that one cannot know where to focus attentions and limited financial resources to produce the best information and policy options relevant to the SAB.

Both breakout groups focused on two potential benefits from this type of assessment of the SAB. First, in the short term, any compilation of ecological, economic, and demographic factors affecting the SAB would be useful information that could easily be disseminated to local resource managers who may not have easy access to information on areas not directly under their control. Secondly, and importantly, a comprehensive understanding of the current state of the SAB is needed to inform the participants who will determine the agenda for the following four years of the LUCES project. A clear research agenda for a four-year project cannot be developed without an adequate understanding of what the most severely stressed resources are (or are going to be), which are in need of policy intervention. The group participants felt a comprehensive, multi-disciplinary summary of the SAB was needed in order to begin to define the research priorities. The breakout groups hoped that in developing a comprehensive study of the current state of the SAB, a general goal such as "preserving the SAB" would be set aside in lieu of more specific agendas that focus on a few key resources, resource-types, land uses, or land-use-types (or combinations thereof) which would be identified as the priority areas that could be effectively addressed in a comprehensive four year study. While the information generated from such a research agenda might not be directly relevant to all policy makers, the breakout groups felt it could generate very valuable insights for the managers of a few key resources. This was thought to be a better alternative than to try to provide too general a research agenda which produces information that has too little cohesion across studies and translates into generalities that are not feasible to apply at the local or even regional level.

Other issues identified by each breakout group are discussed below and are presented by order of the breakout group.

## I. Summary: Group 1

Two major points summarize the issues Group 1 focused upon.

1. For the first year of the LUCES program, a useful product for local resource managers would be a complete characterization of current and projected land-uses and demographic patterns.

It is crucial that such a characterization have the following traits:

-A focus upon the link between the resource base (which also requires documenting the resource base and its changes) and the economic and demographic development
-A dynamic component: Historical and projected trends
-Sufficient detail: county-level reporting

Group 1 members felt such a product would be useful for two reasons. First, local managers would benefit from a detailed characterization of their own areas as well as surrounding areas that appears in one document. Secondly, as the relevant parties reconvene to identify the priority areas for the remainder of the LUCES project life, this type of summary document would be useful to help prioritize research goals.

2. Upon disseminating information described in (1.), it is then desirable to identify priority areas. To successfully do this, the LUCES project members must also focus upon the economic and political factors that lead to changes in land-uses. In general, the feeling was that with a limited budget, the more the research agenda accommodates the economic and political realities of the relevant study areas, the more likely this research will be able to be disseminated to and ultimately useful for the local policy makers and resource managers.

Some questions that are pertinent to the above two goals are:

-What are the ecosystems that are most threatened and what part of that ecosystem is the major recipient of the stressor (which may then have a myriad of effects on other members of the ecosystem)?
-With the stressed resource identified, what scale should the research be aimed at so it produces a product congruent with the scale at which policies to ameliorate the problems are available.
-What are the sources of the major stressor to these most threatened ecosystems?
-What are the alternatives for the policy makers, resource managers, and local citizens for dealing with the source?

An important product from this research should summarize the existing policy tools that have been applied to resource issues in similar areas, report their effectiveness, suggest alternatives, all with a focus upon the feasibility of implementing such a policy given the local economic and political institutions.

## II. Summary: Group 2

Group 2 developed three issues to focus upon. These issues may be presented as goals for three companion documents that could be prepared in the first year of the LUCES project.

While there is some overlap with Group 1's priorities, all concerns are presented below for completeness

1. The first document would complete and "indexation" and would need to establish "what is there" in the SAB, both in terms of environs and human impacts. This index should be prepared at several different levels of scale. Economic, demographic, and political quantification are also very important components of this overall index of the SAB region. It is important to have a clear understanding of who the current users are, where they are from, and land-use changes they are associated with. Examples of the types of questions the participants thought the synthesis should focus upon are: who owns the land? what are the landowner rights? and what are the political and legal institutions that control the resources?

2. The companion to the quantification described in (1.) would conduct comparisons of the relevant regions, ecosystems, and/or resources and "rank" the current state of each of these. Although the metric by which the rankings would be conducted was left unclear, some notion of "how healthy is the resource (region or ecosystem)?" and "How does the resource's health impact on the health of other resources, the economic base, or the cultural health of the relevant region?" was the implied metric. This ranking would be useful to local managers as a comparative tool for describing their resource bases to relevant parties.

3. The third companion piece would speculate on how these relative rankings are expected to change over time as land use changes over time. The group recognized that predictive models may be outside the scope of the first year project, however, they felt it important enough to begin development as early as possible. The models should have the ability to predict changes in demographic and economic factors that are the root of land use changes and then use this information to predict the changes in the coastal resources.

The combination of these summaries would provide enough information, it was thought, to help develop the following questions for later research:

- How can future growth be managed to reduce stressors that result from growth?
- How can boundaries (political/economic/ecological) be "overcome" so effective management practices may be implemented?

A few miscellaneous issues that received some attention by breakout Group 2 were:

- The development of a comparative analysis of past land-use policies/regulations and their effectiveness in reducing the impacts of land use on coastal ecosystems.
- Preparation of a syntheses focusing on zoning laws (a major tool of local policy makers), the commonalities across communities, how they are influenced by outside forces, and how have they been effective in reducing the impacts of land use on coastal ecosystems.
- What will be the mechanisms that are in place to translate information and data produced by the LUCES project to a format that is usable by local or regional managers?

## Working Group Reports

## Data Management/GIS

## R. Welch - LUCES 1996

Introduction

The LU-CES project is based on an understanding of: 1) land use/land cover changes within the watershed of the coastal South Atlantic Bight (SAB); 2) the impact of changes on marine resources of the SAB; and 3) future predictions of population growth, land use/land cover changes and marine ecosystem health. Remote sensing and geographic information systems (GIS) are recognized as essential components of this project. They can be used to assess land use/cover changes, monitor current conditions, organize large volumes of spatial data, perform spatial analysis, link with existing process models, and predict future developments. As a key ingredient to the success of the LU-CES project, substantial time/effort must be given to planning GIS database development, spatial data management, hardware/software configurations, protocols and accuracy requirements. In order to minimize the costs for image data, computer resources and personnel, the following suggestions may be appropriate:

(1) utilize existing remote sensing/GIS facilities with digital data processing capabilities;
(2) make use of archived image data maintained by government agencies such as the U.S. Geological Survey and National Oceanic and Atmospheric Administration (NOAA); and
(3) specify use of off-the-shelf software/hardware and database management systems, and minimize software development.

Day 1:

During the breakout session on Day 1 of the LU-CES Workshop, the Data Management/GIS - Hydrosystems Working Group focused on the topics outlined in the Planning Document. Initial discussions concerned the use of a GIS approach to study hydrologic features influencing the current status of marine resources. Major inputs or data layers that should be included in a database for GIS analysis and modeling of the hydrosystem included:

(1) Land use/cover;
(2) ground/surface water;
(3) water quality;
(4) marsh productivity;
(5) sediment/pollutant transport;
(6) remotely sensed image data;
(7) census data; and
(8) field monitoring measurements.

The effects of population growth on hydrosystem manipulations were discussed and itemized, as were the marine resources most likely to be impacted by each manipulation (Table 1).

Sediment and pollutant in the river systems were identified as the most important mechanisms by which hydrologic features impact marine resources. The physical location and time/space scales for which each of the manipulations can be studied ranged from sample point measurements taken at regular time intervals (e.g., hourly, daily, monthly) to large areas (e.g., watersheds, headwaters, regions) assessed for land use change at intervals of one to ten years.

**Table 1.**

| Hydrosystem Manipulations | Impacts on Marine Resources |
|---|---|
| Land use/cover change (e.g., deforestation, wetland alteration) | Decreased marsh productivity |
| Increase impervious surfaces and pollution runoff | Loss of commercial and recreational fisheries and shell fish industry |
| Groundwater withdrawal and surface water diversion (with saltwater intrusion) | Loss of freshwater reservoirs |
| Contamination of groundwater | Loss of water quality |
| Flow diversion and channelization (with increased potential for flooding) | Increased non point source pollution input to coastal areas, increased sedimentation |
| Increased recreational demands | Increased recreational resource development<br>Possible effects on scenic value, tourism and property values |

Finally, the Working Group members ranked the hydrologic parameters in order of their importance for study the effects of increased population growth on coastal marine resources. Land use/land cover was identified as the most critical information layer for the LU-CES project. The parameters, their data source and ranked score are listed below in Table 2.

Day 2:

On the second day of the Workshop, it was decided that the most productive discussion should center on the requirements of a GIS digital database to address the objectives of the LU-CES project. A matrix was constructed that listed data sources, data types, spatial and temporal resolution of the data, study area, estimated data volume and length of data records. This matrix summarizes the discussions of the Data Management/GIS - Hydrosphere Working Groups over the two-day workshop and more clearly defines the requirements of a GIS database containing information on land use/land cover changes, ground and surface water supply, water quality, marsh productivity and transport.

In a summary session, it was agreed that user-oriented, affordable remote sensing/GIS systems must be defined in the early stages of the project. Consideration must be given to data formats, map coordinate systems, classification techniques, accuracy standards, data transfer mechanisms and output products.

**Table 2**

| Parameter | Data Source | Ranked Score |
| --- | --- | --- |
| Land use/land cover change | Remote sensing image data & census information | 17 |
| Ground/surface water alteration | Ground monitoring | 12 |
| Water quality | Remotely sensed image data showing turbidity, ground-based samples | 11 |
| Marsh productivity | Remotely sensed image data, field samples | 8 |
| Transport | Ground measurements | 7 |
| Commercial/recreational fisheries | Field surveys | 7 |
| Property value/recreational use | Field surveys | 3 |

## Working Group Reports

## Data Management/GIS

## D.J. Cowen - LUCES 1996

### Overview

The goal LU-CES project is to:

> Develop a science-based predictive, decision-making models (tools) that integrate changes in land use patterns with effects on hydrodynamics, transport processes and ecosystem function to assist in planning for sustainable coastal land use and resource management.

This suggests that GIS will be the basis for the entire project. GIS is a computer based technology that will enable users to measure, map, monitor, model and manage the land use information for the LUCES study area. It is clear that the GIS must be able to capture, store, analyze, and display both current and historical land use within the SAB. The land use data base will be huge. The ultimate size will be a function of the final boundaries of the study area, the resolution of the data, the data structure and the number of time slices. The maintenance of the data will become a sizable data management task. The GIS must be carefully designed to meet the needs of the ultimate users. Since the users will be widely distributed it probably will be necessary to distribute the data on CD-ROM and build simple user tools for the basic functions. It will be important to agree on a common hardware and software configuration and develop a good set of documentation and a training program.

From a technical perspective the LU-CES project requires a close coupling of a process model with a standard GIS. This is a very difficult problem computationally and means that it is difficult to put into the hands of the public policy people who have a minimum of computer knowledge. Therefore, efforts will have to be focused on simplistic ways to visualize the scientific data. The feeling of the group was that the primary function of the GIS was to support good scientific results that can be credible. For example, when a public policy maker wants to make a land use change at a location a system should be able to respond with the likely outcome. This type of analysis is extremely difficult. All we ever know is how land uses have changed over time. Predictions about the future are just educated guesses. The goal of GIS will be to make sure that the best available historic data is in a system that can be responsive to the request. In order to accomplish this will require a set of consistent protocols to follow when collecting data for the entire region. This means that South Carolina and Georgia will have to agree on a number of substantive issues. In order to achieve some of the results we will have to rely on remotely sensed data to get a regional perspective.

The key factors are predictive tools, process models, and decision support systems. This is a spatial decision support system (SDSS). A successful SDSS will have a good graphical user interface that will enable the decision maker to effectively use it. We have decided that it will be a science oriented system. The goal would be to develop a system that is so reliable that the decision maker would not want to ignore it.

It must be remembered that computer systems must be precise. A GIS can only retrieve the data that are entered. We need to determine the data base components of the system. This includes the boundaries of the study area, the resolution of data and time framework. For example, there is a big difference between the needs of a biologist studying the dynamics of an estuary and the data inputs to a water shed model for the Savannah River Basin. In the one case we might need 10 centimeter contour data and in the other case we might have difficulty handling 30 meter satellite data. This is not really a GIS problem but rather a data definition one. GIS can only capture digital representations of existing maps and other inputs. If there is no source material a GIS is not going to make it up. Their appears to be a misunderstanding of whether the GIS is the starting point or the final product. It is important that the requirements for the data base be determined at the start and that users are educated about the expected output and capabilities.

The system has to be user oriented and scientifically sound. It will be judged on how well it helps people make decisions.

- Need consistent land use classification
- Need multiple scales
- Public access would be desirable
- It must be cost effective

There is little money for data collection, therefore, we will have to utilize existing data resources from the two states as well as Federal organizations such as the NOAA Coastal Services. It will be important to determine whether the NOAA C-CAP protocol is applicable or the Environmental Sensitivity Maps.

**Basic Assumptions for the GIS Component**

(1) The tool should have sufficient resolution to assist local government zoning decisions.

(2) There are not sufficient resources to collect new high resolution data.

(3) The system will be built on the existing GIS data such as the 1:24,000 USGS digital line graphs that have been created for most of SC.

(4) The system must include a remote sensing component such as SPOT 20 meter multi-spectral data of LANDSAT 30 meter Thematic Mapper Data.

(5) Land use changes are a direct result of population pressures (permanent and visitors) therefore, there is a need for census and other demographic indicators - motor vehicle registrations, utilities etc.

(6) Data must be created and distributed according to Federal guidelines; therefore, there must be FGDC metadata to accompany each layer.

(7) All data should be accessible through a data clearinghouse that is linked to the Internet.

(8) Boundaries should be precisely defined and replicable. There is a need to determine whether the study area is going to be based on administrative polygons (i.e., counties) or geomorphological such as drainage basins.

(9) The land use classification must have mutually exclusive and exhaustive categories.

(10) Once the limits of the study area are determined then it will be important to create "wall to wall" coverages of for each data layer.

(11) There should be data definition committees established for each layer to insure that agreement is built into the front end.