South Carolina Water Resources Research Institute

Annual Technical Report

FY 1999

Introduction

Research Program

Basic Project Information

Basic Project Information	
Category	**Data**
Title	Assessment of Conditions and Public Attitudes Concerning Marine Sanitation of the Lakes Encompassed by the Savannah River Watershed Region:colon; Policy Projections for the Future
Project Number	C-01
Start Date	03/01/1999
End Date	02/28/2000
Research Category	Social Sciences
Focus Category #1	Water Quality
Focus Category #2	Management and Planning
Focus Category #3	Recreation
Lead Institution	Clemson University

Principal Investigators

Principal Investigators			
Name	**Title During Project Period**	**Affiliated Organization**	**Order**
Kenneth F. Backman	Assistant Professor	Clemson University (PRTM)	01
Sheila J. Backman	Professor	Clemson University (PRTM)	02

Problem and Research Objectives

Due to the population growth in the region comprising the Savannah River Watershed and counties adjacent to this area, two questions arise: how will this growth and its impacts affect water quality and how will it affect the management of these waters? Using and extending the results and insights gained in a study on the Clean Water Act in the State of Illinois, the current study deals with the determination and extent that sewage discharge by recreational vessels may have as a substantial contribution to regional degradation of water quality in the lakes comprising the Savannah River Watershed Area (Lakes Jocassee, Keowee, Hartwell, Russell and Thurmond). Discharge of treated or untreated sewage from boats may degrade water quality by introducing microbial pathogens into the environment and locally increasing biological oxygen demand. These conditions can negatively impact natural resources, contaminate potable water sources, affect recreational fisheries and tourism causing economic problems through such actions as requiring closure of recreational tourism facilities. This research is useful to the South Carolina Department of Health and Environmental Control which is attempting to develop a plan to control dumping of waste into lakes. The same information would be useful to the Georgia Department of Natural Resources Environmental Protection Division and the United States Corps of Engineers (who control Lake Hartwell). An additional beneficiary of this data would be the committees of the Savannah River Basin Watershed Management Project which is being sponsored by the US Environmental Protection Agency. All these agencies can use this data to fill information gaps on use, extent of public perception and attitudes on water quality and use and concentrations of recreational boaters on the lakes in the study region of South Carolina and Georgia. Statement of the Results, Benefits, and/or Information: The study will provide information on the location, use, and types of existing pumpout stations and waste reception facilities. It will provide information to determine needs and potential locations for additional pumpout stations and waste reception facilities along the lakes in the study area. Additionally, the study will assess the size, distribution and aggregate characteristics of human populations important to the understanding of types of demands likely to be placed on management and planning in the coming decades. Using GIS, the study will identify areas of concentrated use of the lakes and suggest alternative means of dealing with waste and sanitation problems in a lake environment. It will identify an approach to educate and inform recreational boat users and operators of marinas and other sites where boats congregate of the environmental value and use of pumpout stations and waste reception facilities. In addition to the survey and GIS mapping, an informational brochure will be prepared for distribution on the environmental value and to promote understanding of and compliance with the federal, state, and local laws and regulations by recreational boaters and boat access operators concerning discharge of untreated human waste from recreational vessels. In 1992 the Congress of the United States of America passed the Clean Vessel Act (Wicks 1994). This act required each coastal state to conduct a survey of recreational boaters to determine the number and location of pump-out stations and waste reception facilities (dump stations). In 1998 in South Carolina the issue of recreational boaters dumping waste into its lakes became a public issue (Anderson Independent February 14, 1998). Concerns were being expressed about the current practice of dumping treated waste into the lakes of South Carolina and ways to ensure that these lakes continue to be as clean and safe as they have always been historically. The current proposal deals with the determinant that sewage discharged by recreational vessels may be a substantial contributor to regional degradation of water quality in the lakes comprising the Savannah River Watershed Area (Lakes Jocassee, Keowee, Hartwell, Russell and Thurmond). Discharge of sewage from boats may degrade water quality by introducing microbial pathogens into the environment and locally increasing biological oxygen demand, particularly in poorly flushed water bodies. These conditions may negatively impact natural resources, contaminate potable water sources, and cause economic problems through such actions as requiring closure of recreational and tourism facilities. The changes in rates of population

growth as well as in the characteristics of the participant population have been major determinants of the rapid growth in recreational activity in the past decades and created the context from which many of our conclusions regarding participation in recreation and tourism activities have been derived (Clawson 1985; Murdock et al 1990). Particularly, in areas where rapid increases in population have occurred, simultaneous increases in recreation activity has also tended to occur. This study will assess the population growth in and adjacent to the Savannah River Basin Region, to show the size, distribution and aggregate characteristics of the human population of the region. The demographic changes occurring in this region have social, economic and managerial implications for water resource managers. The shoreline of the study area includes hundreds of miles within the states of South Carolina and Georgia. The adjacent areas include a number of large population centers (Atlanta, GA; Greenville, SC; Charlotte, NC); the largest discrete unit is the Atlanta Metropolitan Region with a population of nearly one million people. Recreational boating in the study area of South Carolina and Georgia is a growing activity due to the large nearby population, an increasing number of immigrant retiree population, a popular sport fishery and a series of large and aesthetically attractive lakes. The burgeoning recreational boating industry includes a larger and diverse recreational vessel that contains portable toilets or type III marine sanitation devices. The number of these boats using these lakes is not determined nor the number using concentration areas. Similarly, the number and location of pump-out stations and waste reception facilities are not known nor is their relationship to concentration areas of recreational boats. Due to the recreational and tourism economic value of these lakes in South Carolina and Georgia, efforts must be made to ensure degradation of its water quality does not occur. As water quality of these lakes can be degraded by human waste discharged from recreational vessels, the potential for discharge from recreational boats and locations where discharge is most probable and most concentrated must be determined. This information is required to determine the need for additional pump-out stations and waste reception facilities. In addition to determining the need for additional facilities is a need for an educational process to be developed to provide awareness of the environmental benefits of the facilities and their locations. The level and type of education needed can only be determined after determining the existing attitudes and knowledge of boaters and marina operators of existing laws, regulations related to discharge of waste from recreational boats and benefits of pump-out facilities. The four primary objectives of this project are: 1. (a) To determine and map the number, location and condition of pump-out stations and waste reception facilities used by recreational boats and other types of lake visitors that are using the lakes comprising the Savannah River Watershed Region in South Carolina and Georgia. (b) To assess and map the population growth as well as characteristics of the population involved in recreational and tourist us of the lakes comprising the Savannah River Watershed Region. 2. To determine the number of recreational vessels with type III marine sanitation devices or portable toilets that utilize these lakes in South Carolina and Georgia and the areas where they congregate. 3. To identify and map optimal locations for construction or renovation of pump-out stations and waste reception facilities needed to ensure that an adequate number are reasonably available for recreational vessels using these lakes. 4. To develop information and education literature on the value and use of pump-out stations and waste reception facilities for recreational boaters who use the lakes in the Savannah River Watershed Region.

Methodology

METHODS This project will include three components. The first will be the survey conducted by the Strom Thurmond Institute (STI) at Clemson University in consultation with the South Carolina Department of Health and Environmental Control (SCDHEC). The second component of the study is the identification and mapping of existing pumpout stations and waste reception facilities for recreational boaters who use the study lakes. Also, in this mapping phase current population and project populations of lake users will be completed. The second phase of the study will include using

geographic information systems (GIS) capabilities to spatially identify optimal location or upgrading of waste disposal facilities on the study lakes. The third component of the study will include development, design, printing and distribution of a brochure designed from the results of the first two phases of the study. THE SURVEY The survey will utilize two methods: a questionnaire evaluating boaters and marina operators' existing attitudes and knowledge of existing laws, regulations related to discharge of waste from recreational boats and benefits of such facilities. Data also will be collected on demographic characteristics to be used in a cohort-component projection model and user segmentation analysis. The questionnaire also will include questions on types of boats, uses of each study lake, demographics of boaters, views on the experience of recreational boating on the study lakes, water quality and sanitation, sanitary equipment and preferred alternatives to traditional marine sanitation devices for use by recreational boaters. The questionnaire will be assessed by the STI research team, SCDHEC, US Army Corps of Engineers and some of their counterparts in Georgia for relevance, reliability, validity, content and completeness of the questions. The questionnaire then will be pretested with a group of boaters and marina personnel. The data collection procedure for marina personnel and other visitor types will be to have these questionnaires completed in a personal interview process. All public and private marina facilities will be approached to participate in the survey. The data collection method for the boaters will use the Dillman Total Design (1978) mail survey technique where an advanced-notice letter is sent to all members of the selected sample. A second contact will be made about a week after the advance-notice letter which will include a personalized cover letter, questionnaire and stamped return envelope. Third, a postcard follow up will be mailed to all members of the sample about a week after the questionnaire. Fourth, for all members of the sample who have not responded by the third or fourth week, a new personalized cover letter, questionnaire, and stamped return envelope will be sent. Finally, a follow up is sent to those who still have not responded. Using this survey procedure should yield a 60 percent or higher response rate in a specialized population such as recreational boaters (Salant & Dillman 1994). The sample for the boaters mail survey will be obtained from a central database on boat registrations from the South Carolina Department of Natural Resources and the Georgia Department of Natural Resources. Data on registered boats will be obtained for South Carolina and Georgia counties adjacent to the lakes in the study and from counties that are part of the metropolitan areas close to the lakes in the study. A stratified sampling method will be used in the selection of participants in the study using the following formula: boats 16 feet and under in length, boats 17-25 feet, boats 26-40 feet, and boats over 40 feet. These strata were derived from an EPA assessment that is described in the technical guidelines for the Clean Vessel Act (Federal Register Volume 58, No. 115, pages 33447-33457). In this the EPA suggested 20 percent of boats 16-26 feet have portable toilets, 50 percent of boats 26-40 feet have holding tanks, and 100 percent of boats 40+ feet have holding tanks. The size of the boater's mail survey was selected using Fleiss' (1973) Statistical Methods for Rates and Proportions which suggests that with a population size in both South Carolina and Georgia of approximately 50,000 in each, a sample of 400 from each state would more than ensure a sample size for 95 percent confidence level and a margin of error of plus or minus 2.5 percent. THE MAPPING Mapping, location identification, and types of pumpout stations and waste reception facilities used by recreational boaters on Lakes Jocassee, Keowee, Hartwell, Russell and Thurmond will be done with the assistance of SCDHEC and Georgia Department of Natural Resources Environmental Protection Division (GAEPD). According to the SCDHEC department the number of pumpout stations includes: Lake # Lake Jocassee none Lake Keowee 2 Lake Hartwell 3 or 4 Lake Russell none Lake Thurmond 2 or 3 These numbers should be the total number of pumpout stations on these lakes either in South Carolina or Georgia. The global positioning system (GPS) technology will be used to locate and map the precise location of existing facilities and to tag pertinent ancillary data to those locations. This data will be added to existing map data for each of the lakes in the study. In addition, the data collected from the surveys of marinas and recreational boaters will be input to the geographic information system (GIS). This data will be analyzed by relating vessel location concentrations and boater needs to existing infrastructure (roads, electrical lines, water lines, sewer lines, etc.) in order to model optimal site locations where pumpout stations or

some other waste disposal system could be located in relation to boater needs, wants and concentration areas of use. The projections of the water-based recreation and tourism population will be accomplished using a cohort-component population projection model employing age, sex, race/ethnicity population detail and rates of participation in different activities. The projection population participation method used in this study will be very similar to that used by Murdock, Backman, Ditton, Hoque and Ellis (1992 a&b). This project will utilize the Strom Thurmond Institute Spatial Analysis Laboratory (SAL). The SAL is a fully functioning geographic information systems (GIS) and remote sensing /image analysis laboratory. The Institute has the facilities, expertise and experience to perform many types of spatial analysis tasks as well as project planning and management. Past project experience includes: construction, maintenance, and analysis of vector and raster GIS database; gap analysis in Central America; change detection and assessment through satellite image analysis; timber stand assessment and management; facility planning and placement; subpixel image analysis; land use classification and accuracy assessment through image analysis; international project coordination; global positioning systems; aerial photograph interpretation; map production; interfacing GIS with the world wide web. THE BROCHURE Taking information gleaned from the first two components of this study, a brochure will be designed that will inform the recreational boaters about relevant laws, regulations and environmental factors concerning waste from boats. It will provide information about available pumpout stations and waste reception facilities on the study lakes. The brochure will include information and educational literature on the value and use of waste facilities and identify alternatives to traditional marine sanitation devices. RELATED RESEARCH The South Carolina Department of Health and Environmental Control and the United States Army Corps of Engineers are aware of a need for information that would be provided by the study being proposed regarding pumpout stations and waste reception facilities on lakes such as Jocassee, Keowee, Hartwell, Russell and Thurmond. Currently, SCDHEC has developed a new plan to ban recreational boats from dumping waste into Lake Murray and eventually other lakes in the state. But, SCDHEC officials state that this plan and any ban is years from taking effect. The issue of enforcement also has been raised and foreseen as a problem (Anderson Independent-Mail 1998; personal conversation 1998). Related to this, the US Army Corps of Engineers has banned recreational boaters from dumping in Lake Hartwell, the second most used Corp of Engineers controlled lake in the United States. But, the problem still remains: how does a heavily used lake such as Hartwell meet the need for pumpout and waste reception facilities with only 3 or 4 such facilities for a lake with over 900 miles of shoreline?

Principal Findings and Significance

The project, after numerous delays due to University accounting problems, is now progressing well. But, to enable the research team time to complete the project the ending date for the needs to be pushed back to June 30, 1999 from February 29, 2000. Also, as you suggested in personal conversation, the project is concentration more on the survey of boat owners/users of the lakes and reducing the "identification and mapping of optimal locations for construction or renovation of pump-out stations and waste reception facilities needed" on the lakes included in the study area. Due to recent work by the South Carolina Department of Health and Environmental Control (DHEC) and their report titled" report on Process of Selecting Lakes for Possible Designation as No Discharge Zones (NDZ's) for Marine Toilets," dated December 1998. So to date, the project team has been in the process of collecting current review of the literature on public attitudes and perceptions of marine sanitation in fresh water lakes. The team also has made site visits to the field to observe existing facilities and assess boat usage and locations for data collection sites. The team has begun development and pretesting of a questionnaire to be utilized in the mail survey portion of the project. Additionally, a mail list of current registered boaters in the ten county area adjacent to the study lakes has been purchases from the South Carolina Department of Natural resources. This list will be used as the sampling frame from which the

survey sample for the project will be drawn. An additional mail list is in the acquisition process from which the State of Georgia's boaters will be surveyed. The questionnaire to be utilized to assess marina operators both public and private is being developed and pretested also. Data collection should begin in January 2000 allowing for sufficient data collection time, time for analysis of the data and preparation of the final report and maps to complete the project.

Descriptors

Marine sanitation, waste disposal, water quality management, lakes, boating, planning, watershed management recreation.

Articles in Refereed Scientific Journals

None

Book Chapters

None

Dissertations

None

Water Resources Research Institute Reports

None

Conference Proceedings

None

Other Publications

None

Basic Project Information

Basic Project Information	
Category	**Data**
Title	Reestablishment of an Estuarine Marsh and Waterway after Causeway Removal
Project Number	C-02
Start Date	03/01/1999
End Date	02/28/2000
Research Category	Climate and Hydrologic Processes
Focus Category #1	Water Quality
Focus Category #2	Hydrogeochemistry
Focus Category #3	Models

Focus Category #3	Models
Lead Institution	Other

Principal Investigators

Principal Investigators			
Name	**Title During Project Period**	**Affiliated Organization**	**Order**
Mary Carla Curran	Assistant Professor	University of South Carolina at Beaufort	01
Randall E. Cross	Assistant Professor	University of South Carolina at Beaufort	02
Earl J. Hayter	Associate Professor	Clemson University	03

Problem and Research Objectives

The U.S. Geological Survey has identified "Aquatic and Environmental Protection" as one of its research priorities. Specifically, this priority area states "research needs in this area include studies of wetlands, swamps and marshes, fish and other biota, and the quality of life." The goal of the proposed study is within this research priority area. The goal of the proposed project is to study the ecological and geomorphological effects caused by the reduction in length of dirt causeways (accompanying bridge replacement) over a tidal waterway (Cowan Creek) and marsh in Beaufort County, South Carolina. Specific objectives to accomplish the stated goal include: 1) studying the effects of the bridge/causeway changes on tidal- and wind-induced circulation through Cowan Creek and the resulting geomorphological changes in the creek and adjacent tidal marshes; 2) evaluating the change in the nektonic community in the creek and tidal marshes in terms of species composition, density, and size distributions; 3) determining whether the percentage of parasitized grass shrimp changes after the changes to the causeways; 4) monitoring the benthic meiofaunal community in the area by collecting sediment cores; and 5) monitoring several surface water quality parameters to allow an assessment of changes associated with the altered hydraulics in Cowan Creek. Based on previous research, the following changes are predicted to occur in Cowan Creek and the adjacent marshes after completion of the new bridge: 1) increases in water flow and sediment transport rates; 2) change in sediment composition; 3) change in marsh geomorphology and size (i.e., surface area); 4) change in habitat utilization by nekton; and 5) change in various water quality parameters. It is also anticipated that the increase in bridge deck elevation and length, and the potential increase in water depth under the bridge will make this creek a viable transportation route between Port Royal and St. Helena Sounds, thus restoring it to its historic importance. These changes would also enhance recreational usage and enable fisherman to catch the species known to exist there at present (Curran, unpub. data). Some of this work will be directly comparable to the extensive survey conducted in a similar habitat in northern South Carolina (Ogburn et al. 1988). Our study will result in a better understanding of how causeways alter flow in tidal creeks and the concomitant change in sediment transport, water quality, sediment composition of marsh habitat, and nekton utilization of estuarine habitats. Beaufort County, which consists almost entirely of low-lying barrier islands, is one of the fastest growing counties in the country. With the increase in human population and concomitant coastal development, roads are being widened, new bridges are being constructed, and existing bridges are being replaced. In particular, the Route 21 bridge over Cowan Creek, near Beaufort, South Carolina is going to be replaced within the next two years. Construction of bridges over wide inland waterways, such as Cowan Creek, have historically involved the construction of dirt causeways (i.e., elongated highway embankments) to reduce the length, and therefore the cost of the bridge. Causeways have been shown to reduce the circulation through waterways in that they act as restrictions to flow, and thus greatly decrease the hydraulic efficiency of the waterway (Lee et al. 1994). The reduced flow often results in the deposition

of sediments and organic detritus, which, over time, leads to the formation of marshes. For example, the tidal marshes adjacent to Cowan Creek are approximately 2,000 ft wide. Historic French and English nautical charts (circa 1780) show that the width of the waterway has been reduced from 2,000 ft to its present day width of approximately 80 ft. This proposal raises an interesting philosophical argument. Is the "restoration" of this estuary to its historical state desirable, if this indeed does occur, if it will most likely result in the reduction of marsh habitat and perhaps alter the community of organisms that utilize the marsh and adjacent estuarine habitat? Cowan Creek is a tidal waterway that connects St. Helena Sound and the Beaufort River. The mean tidal range at the Route 21 bridge is 7.1 ft, whereas the spring tidal range varies from 9.5 to 11 ft. The South Carolina Department of Transportation (SCDOT) is initiating work that will eventually reduce the lengths of the two dirt embankments across Cowan Creek by 425 percent and replace the existing 120 ft bridge with a new 510 ft bridge. Our proposed study will document the changes in the flow regime, tidal marsh geomorphology, utilization of marsh habitat by nekton, and water quality that will occur with the replacement of the existing bridge over Cowan Creek. This study would be unique because it would address the impact of the removal (not addition) of a man-made structure (i.e., dirt causeways). We predict that the following changes will occur in Cowan Creek and the adjacent marshes after completion of the bridge replacement: 1) an increase in water flow and sediment transport rates; 2) a change in sediment composition; 3) a change in marsh geomorphology and size (i.e., surface area); 4) a change in habitat utilization by nekton; and 5) a change in various water quality parameters. It is also anticipated that the increase in bridge deck elevation and potential increase in water depth will make this creek a viable transportation route between Port Royal and St. Helena Sounds, thus restoring it to its historic importance. These changes would also enhance recreational usage and enable fisherman to catch the species known to exist there at present (Curran, in prep.). Some of this work will be directly comparable to the extensive survey conducted in a similar habitat in northern South Carolina (Ogburn et al. 1988). Our request to continue this research this summer is crucial because work on bridge replacement is scheduled to be completed in 2000. The South Carolina Sea Grant Consortium (SCSGC) has approved funding ($7,000) to assist in the pre-construction study in 1999. The on-going two-year study is a continuation of the work previously funded by the South Carolina Water Resources Center. At present, no obvious changes to the marsh or Cowan Creek have occurred (see attached Progress Report). The proposed research is part of a broader-scale interest in the estuaries of Beaufort County. We will be able to integrate the results of the proposed study with those collected from our study sites on Pritchards Island. In particular, we are currently monitoring the changes in abundance of juvenile fishes in two connected marsh creeks. Additionally at this site, a study of larval and juvenile nekton utilization of a developing overwash impacted barrier island marsh (containing sandy sediments) with an adjacent established marsh (containing natural mud sediments) indicated that juvenile nekton use of marsh habitat at similar tidal elevations is markedly different (Cross, in prep). These differences may be related to differences in benthic metazoan food resources available in the different sediment types (Cross, in prep). Other information concerning the importance of sediment associated factors to nekton utilization of intertidal marshes may be found from studies of artificially created marshes in the early stages of development which contain sediments with a large sand component. Comparisons of these marshes to established, natural marshes have demonstrated reduced densities of juvenile Fundulus and harpacticoid copepods in the created marshes (Moy and Levin 1991), both of which are important food sources. Numbers of commercial species may also decrease. We anticipate a change in sediment composition over time at Cowan Creek due to altered hydrology and system morphology. Thus, accumulating evidence suggests that differences in sediment composition can alter nekton utilization of marsh habitats and benthic metazoan food resources upon which they feed. In summary, this research will result in a better understanding of how causeways alter flow in tidal creeks and the concomitant change in sediment transport, water quality, availability and sediment composition of marsh habitat, and nekton utilization of estuarine habitats. The goal of this project is to continue a multi-year study of the ecological and morphological effects caused by the reduction in length of the Highway 21 dirt causeways over Cowan

Creek. Specific objectives to accomplish the stated goal of the herein proposed study are: a. to study the effects of the bridge/causeway changes on tidal- and wind-induced circulation through Cowan Creek and the resulting morphologic changes in the creek and adjacent tidal marshes. Changes in morphology will be determined by a GIS using pre- and post-construction surveys. b. to evaluate the change in the nektonic community in the creek and tidal marshes in terms of species composition and density; c. to determine whether the percentage of parasitized grass shrimp changes after removal of the causeways; d. to continue monitoring the benthic meiofaunal community in the area by collecting sediment cores; e. to monitor several surface water quality parameters to allow an assessment of changes associated with altered hydrology. Parameters measured will include: concentrations of ammonia, reactive phosphorus, and dissolved oxygen, turbidity, suspended sediments, suspended particulate organic matter, temperature and salinity.

Methodology

The methodology proposed to accomplish the stated objectives are described next. The first three tasks are components of the remaining ones. a. Measure the tides in the Beaufort River and St. Helena Sound at the entrances to Cowan Creek -The USGS has installed a stage and conductance recorder in the Beaufort River across from the entrance to Cowan Creek as a component of a study to determine Total Daily Maximum Loads (TMDLs) in the Beaufort River. The Beaufort-Jasper Water Authority is funding this study. Thus, we will have access to these data. Another stage and conductance recorder, to be paid for using funds from the SCSGC project, was installed by the USGS in St. Helena Sound near the entrance to Cowan Creek. b. Perform a limited survey of the creek and marsh to determine the bathymetry and geometry of this system — Using survey equipment (either a survey grade GPS unit or a total station), the elevations of at least 50 locations throughout the marsh along Cowan Creek will be surveyed to determine the variation in the marsh surface elevation. In addition, the bathymetry of the creek will be determined using a boat and fathometer. c. Monitor the changes in the morphology of the creek and marsh, particularly in proximity to the bridge, during and following construction of the new bridge — This will be performed bi-monthly using the previously described surveying techniques. d. Model the circulation and sediment transport in Cowan Creek using the HSCTM-2D hydrodynamic and sediment transport model (Hayter et al. 1998). The purpose of this modeling effort is to predict the increase in hydraulic efficiency of the creek and the decrease in marsh surface area that we propose will occur after bridge replacement. The measured tides and conductances at the two entrances of Cowan Creek, along with the measured wind field at the nearby University of South Carolina Beaufort campus and the U.S. Marine Corp Base on Parris Island, will be used as the boundary conditions to predict the tide- and wind-induced circulation through this waterway system. Current measurements at several locations throughout the creek over the course of a spring tidal cycle will be used to calibrate the hydrodynamic model. In addition, the predicted change in tide- and wind-induced circulation will be correlated to the monitored change in marine species composition and density to determine the effect of the current regime on the marsh and creek habitat. e. Utilize the GIS capabilities that will be available at Spring Island (through collaboration with the Low Country Institute) and USC Beaufort to make our data available over the Web. f. Evaluate the change in sediment composition in the creek system and on the marsh by two different methods. Sediment cores will be collected at a variety of locations and transported to the lab, dried, weighed and sorted through a series of sieves to determine % sediment fraction. Additionally, the fractions of sand, silt, and clay will be determined in sediments using the American Society for Testing and Materials procedure D422. Organic matter content will also be determined by combustion. g. Evaluate changes in the sediment deposition rates and composition of transported sediments in the creek system and marsh by deploying sediment traps at selected locations where changes in hydrological flow rate are expected to occur. These sediment samples will be treated as described above in the previous description (f). h. Perform seining to evaluate the change in species

composition and density. We will use pit traps on the intertidal marsh to determine larval and nekton use of these habitats. A 10-ft seine net will be used at low tide to assess species composition, and the numbers and sizes of fishes. Length frequency distributions will be constructed in order to identify the size classes that are most abundant in this area. Based on 1998 data (Curran, in prep.) we anticipate a seasonal change in species composition and size. i. Determine the parasitism rate of shrimp by collecting and measuring individuals in three replicate seine hauls and counting the number of parasitized and unparasitized shrimp. j. Survey the number of major meiofaunal groups by collecting sediment cores in a variety of areas of the creek bed. We will sample the top three centimeters of sediment using a 2-cm syringe. Two replicate cores will be taken. Samples will be preserved and stained in a 15% buffered formalin/rose bengal solution for examination under stereomicroscope at 20X. Animals will be enumerated and categorized into the taxonomic groups: nematodes, copepods, ostracods, polychaetes, and oligochaetes. k. Various water quality parameters of surface water will be determined. Ammonia and reactive phosphorus concentrations will be measured with a spectrophotometer. Turbidity will be measured on site with a nephelometer. Particulate organic matter will be measured following filtration and combustion on glass fiber filters. Dissolved oxygen will be measured on site with a portable dissolved oxygen meter. Salinity will be determined with a refractometer. Replicate samples for the above water quality parameters will be collected from the study site every other week from May through August and every other month from September through April. Samples will be filtered, transported to the lab at USCB, and analyzed on the same day of collection or preserved for analysis if samples cannot be analyzed on the same day. Periodically, samples will be collected from water draining the marshes and will be compared with flooding water samples. To the best of the investigators' knowledge, this study will be unique because it will address the impact of the removal (not addition) of a man-made structure (i.e., dirt causeways) on estuarine waterways and adjacent wetlands. Related research previously conducted by the investigators at the proposed study site includes: a. We have already completed the first year of our study. We have therefore assessed the state of the marsh system before any alterations have occurred (see attached Progress Report). b. The PIs have already constructed a 200-m long elevated walkway within 500 m of the bridge to enable access to the marsh with minimal disturbance in the area most likely to be affected by the altered hydrodynamics. Members of the local community assisted in the construction because of their continued interest in our current baseline study of the marsh. c. Drs. Curran and Cross have already approached the Beaufort County Council to obtain their approval for the study of this marsh system impacted by coastal development. Beaufort County is one of the first counties in South Carolina to develop a comprehensive coastal land use plan. We have strong support from the local politicians, concerned citizens whom have allowed us access to the marsh through their property, and the Beaufort Marine Institute which has volunteered use of their teenagers to help sample and build necessary structures. d. Drs. Curran, Cross and Hayter conducted a reconnaissance level study of Cowan Creek during a new moon spring tide on July 23 and 24, 1998. This study included measuring currents at several locations in Cowan Creek. e. Dr. Curran has conducted additional weekly sampling in 1998 to determine the species composition and size distribution of fishes using this area. R. Cross and M.C. Curran have also evaluated the composition of the major meiofauna taxa in undisturbed sediments as well as those disturbed by the construction of sting ray pits. Additionally, in 1998, M.C. Curran has noted the degree of parasitism by an isopod crustacean on grass shrimp, a major food source of fishes. f. Dr. Cross has conducted baseline studies of marsh utilization by larval and juvenile nekton. g. Dr. Cross has conducted baseline water quality and sediment studies that involved three undergraduate students and one student from the Governor's School of Math and Science. In addition to the baseline studies several experiments were conducted at the study site including small scale nutrient dynamics in ray feeding pits, effects of fiddler crab feeding activities on benthic meiobenthos and microalgae, and characterization of sediments at the study site.

Principal Findings and Significance

Summary of Work Conducted on Marsh Utilization by Nekton and Water Quality and Sediments 1999. Funding from SCRWI for 1999 allowed the collection of baseline data prior to bridge construction and removal of the causeway. The following is a brief description of work conducted by R. Cross during from June through mid-August 1999. The elevated walkway over the marsh was finished and the tidal elevation along the walkway was determined. Pit traps were installed into the marsh surface at four locations along the elevated walkway. The pit traps were used to sample larval and juvenile nekton that naturally utilize shallow pools of water on the intertidal marsh during low tide periods. Samples were also collected within 24 hrs of samples collected at the study site at a similar site (same tidal elevation) on Pritchards Island. It is hoped that the Pritchards Island site may be suitable as a control site in a BACI (Before-After-Control-Intervention) experimental design for differences in marsh utilization by nekton. Samples were highly variable in numbers of individuals but samples were numerically dominated by two species: mummichog (Fundulus heteroclitus) and grass shrimp (Palaemonetes pugio). The following surface water quality parameters were determined weekly at mid-ebb and mid-flood tide stages at the study site creek: NH3, PO4, DO, turbidity, salinity, and temperature. Nutrient concentrations were determined spectrophotometrically. Dissolved oxygen concentrations were measured with a dissolved oxygen meter and turbidity measured with a nephelometer. Salinity was measured with a refractometer and temperature recorded with a temperature sensor. Duplicate water samples were collected at each sample time. There appears to be a consistent trend of greater NH3, PO4, and turbidity in mid-flood water. Sediment particle size analyses were conducted for both creek bed and marsh areas at the study site in July. These analyses were performed using the ASTM particle size analysis for soils method D422 using a soil hydrometer to measure particle settling rates. A sediment trap was installed in the creek bed and a characterization of settled sediments was made. Organic content of creek bed and marsh sediments was also determined using the combustion method. The benthic meiofauna community was also characterized using sediment core samples from the creek bed at the study site. The sediments were sieved to obtain the meiofauna and then stained and preserved. Preserved samples were examined under stereomicroscopes and enumerated into the following taxonomic categories and stages: nematodes, copepods, copepod nauplii, ostracods, oligochaetes, and polychaetes. Samples were numerically dominated by nematodes. Ostracods were second in importance, followed by copepods. Related research was conducted on ray feeding pits which are numerous at the study site. Water retained within the feeding pits at low tide was analyzed for nutrient concentrations (NH3 and PO4). Water in newly formed pits was compared to that in older pits and differences were found. In addition, short time scale nutrient dynamics were examined and changes in nutrients were evident over 15 min intervals. Summary of nekton in Cowan Creek, St. Helena's Island. The results of the nekton study indicate that there is variability in the abundance of fish in Cowan Creek during the summer of 1999. Peak abundance (1627 individuals) occurred near the end of the season (8/19/99); a total of 24 species were collected throughout the summer. The dominant species were, in order of numerical abundance, silversides, mummichogs, and anchovies. We collected over 1000 silversides on two occasions. We collected over 500 mummichogs on three occasions, and over 100 anchovies on one occasion. Based on our consistent collection of several species, including those mentioned above as well as mojarra, pipefish, and members of the drum family, we conclude that this area is an important habitat for juveniles of these species. Furthermore, results from 1998 also indicate that this small tidal creek is consistently important for these commercially important or forage fishes; we collected 2166 fishes on 8/12/98, and had over 200 specimens collected on nine different dates. Therefore, despite the limited flow of the creek, and the warm temperatures (reaching 39oC), this creek provides valuable habitat for juvenile fishes that themselves are important commercial species or provide food for commercially important species. We anticipate continuing our survey of this area in 2000 to determine whether this trend of habitat use remains after bridge construction potentially increases creek flow. We also determined the number of grass shrimp parasitized by an isopod crustacean. The percent

parasitism ranged from 0.5-9.2% per sampling date. The mean rate of parasitism for the season was 4.5%. This is very similar to the overall value of 3.4% from the 1998 study. As grass shrimp are a staple food item for many of the juvenile fishes that utilize the estuary, it is important to determine if the parasitism rate changes in 2000 after the causeways are removed. This is because these parasites may reduce both shrimp growth and fecundity. The specific objective being addressed by E. Hayter is the following: 1) studying the effects of the bridge/causeway changes on tidal- and wind-induced circulation through Cowan Creek and the resulting morphological changes in the creek and adjacent tidal marshes. The tasks performed in Year 1 to partially accomplish this objective are discussed below. 1. Measure the tides at both ends of Cowan Creek - The USGS has been operating a stage and conductance recorder in the Beaufort River across from the entrance to Cowan Creek as a component of a study to determine Total Daily Maximum Loads (TMDLs) in the river. Another stage and conductance recorder was installed by the USGS in August near the St. Helena Sound entrance to Cowan Creek. This second gage was paid for by the one-year seed-level project funded by the South Carolina Sea Grant Consortium. Funds from the proposed project will be used to pay for continued operation of both gages for an additional 12 months. These synoptic tide and conductance records are needed to serve as boundary conditions for the hydrodynamic and salt transport model being established for Cowan Creek. 2. Perform a survey of Cowan creek and tidal marsh — The elevations of at least 50 locations along the marsh in proximity to the Route 21 bridge were surveyed to determine the variation in the marsh surface elevation. In addition, the bathymetry of the creek was surveyed by the USGS at 11 selected cross-sections. One cross-section was at the bridge, five were south of the bridge, and the remaining five were north of the bridge. These studies were funded by Year 1 funds. 3. Construct a Digital Elevation Model (DEM) of Cowan Creek — The USGS was contracted to construct a DEM of Cowan Creek. The DEM was then imported into a pre-processor for the HSCTM-2D model and used to construct the finite element grid for Cowan Creek. 4. Model the circulation and sediment transport in Cowan Creek using the HSCTM-2D hydrodynamic and sediment transport model (Hayter et al. 1998). The purpose of this modeling effort is to predict the increase in hydraulic efficiency of the creek and the decrease in marsh surface area that we hypothesize will occur after bridge replacement. The input files, including the finite element grid developed for Cowan Creek, have been created, and initial runs of the hydrodynamic module in HSCTM-2D have been made to debug the input files. The measured tides and conductances at the two entrances of Cowan Creek, the measured wind field at the nearby U.S. Marine Corp Base on Parris Island, and the suspended sediment concentrations to be measured in Year 2 are being used as the boundary conditions. Current measurements to be made in Year 2 at several locations along the creek over a spring tidal cycle will be used to calibrate the hydrodynamic model. Similar measurements will be performed during a neap tidal cycle to partially validate the hydrodynamic model.

Descriptors

Marshes, ecosystems, estuaries, fish ecology, water quality monitoring geochemistry, sedimentation, model studies

Articles in Refereed Scientific Journals

None

Book Chapters

None

Dissertations

None

Water Resources Research Institute Reports

None

Conference Proceedings

None

Other Publications

Information Transfer Program

Basic Project Information

Basic Project Information	
Category	**Data**
Title	Assessment of Conditions and Public Attitudes Concerning Marine Sanitation of the Lakes Encompassed by the Savannah River Watershed Region:colon;colon; Policy Projections for the Future
Description	
Start Date	03/01/1999
End Date	02/28/2000
Type	Publications
Lead Institution	Clemson University

Principal Investigators

Principal Investigators			
Name	**Title During Project Period**	**Affiliated Organization**	**Order**
Kenneth F. Backman	Assistant Professor	Clemson University	01
Sheila J. Backman	Professor	Clemson University	02

Problem and Research Objectives

In 1992 the Congress of the United States of America passed the Clean Vessel Act (Wicks 1994). This act required each coastal state to conduct a survey of recreational boaters to determine the number and location of pump-out stations and waste reception facilities (dump stations). In 1998 in South Carolina the issue of recreational boaters dumping waste into its lakes became a public issue (Anderson Independent February 14, 1998). Concerns were being expressed about the current practice of dumping

treated waste into the lakes of South Carolina and ways to ensure that these lakes continue to be as clean and safe as they have always been historically. The current proposal deals with the determinant that sewage discharged by recreational vessels may be a substantial contributor to regional degradation of water quality in the lakes comprising the Savannah River Watershed Area (Lakes Jocassee, Keowee, Hartwell, Russell and Thurmond). Discharge of sewage from boats may degrade water quality by introducing microbial pathogens into the environment and locally increasing biological oxygen demand, particularly in poorly flushed water bodies. These conditions may negatively impact natural resources, contaminate potable water sources, and cause economic problems through such actions as requiring closure of recreational and tourism facilities. The changes in rates of population growth as well as in the characteristics of the participant population have been major determinants of the rapid growth in recreational activity in the past decades and created the context from which many of our conclusions regarding participation in recreation and tourism activities have been derived (Clawson 1985; Murdock et al 1990). Particularly, in areas where rapid increases in population have occurred, simultaneous increases in recreation activity has also tended to occur. This study will assess the population growth in and adjacent to the Savannah River Basin Region, to show the size, distribution and aggregate characteristics of the human population of the region. The demographic changes occurring in this region have social, economic and managerial implications for water resource managers. The shoreline of the study area includes hundreds of miles within the states of South Carolina and Georgia. The adjacent areas include a number of large population centers (Atlanta, GA; Greenville, SC; Charlotte, NC); the largest discrete unit is the Atlanta Metropolitan Region with a population of nearly one million people. Recreational boating in the study area of South Carolina and Georgia is a growing activity due to the large nearby population, an increasing number of immigrant retiree population, a popular sport fishery and a series of large and aesthetically attractive lakes. The burgeoning recreational boating industry includes a larger and diverse recreational vessel that contains portable toilets or type III marine sanitation devices. The number of these boats using these lakes is not determined nor the number using concentration areas. Similarly, the number and location of pump-out stations and waste reception facilities are not known nor is their relationship to concentration areas of recreational boats. Due to the recreational and tourism economic value of these lakes in South Carolina and Georgia, efforts must be made to ensure degradation of its water quality does not occur. As water quality of these lakes can be degraded by human waste discharged from recreational vessels, the potential for discharge from recreational boats and locations where discharge is most probable and most concentrated must be determined. This information is required to determine the need for additional pump-out stations and waste reception facilities. In addition to determining the need for additional facilities is a need for an educational process to be developed to provide awareness of the environmental benefits of the facilities and their locations. The level and type of education needed can only be determined after determining the existing attitudes and knowledge of boaters and marina operators of existing laws, regulations related to discharge of waste from recreational boats and benefits of pump-out facilities. The four primary objectives of this project are: 1. (a) To determine and map the number, location and condition of pump-out stations and waste reception facilities used by recreational boats and other types of lake visitors that are using the lakes comprising the Savannah River Watershed Region in South Carolina and Georgia. (b) To assess and map the population growth as well as characteristics of the population involved in recreational and tourist us of the lakes comprising the Savannah River Watershed Region. 2. To determine the number of recreational vessels with type III marine sanitation devices or portable toilets that utilize these lakes in South Carolina and Georgia and the areas where they congregate. 3. To identify and map optimal locations for construction or renovation of pump-out stations and waste reception facilities needed to ensure that an adequate number are reasonably available for recreational vessels using these lakes. 4. To develop information and education literature on the value and use of pump-out stations and waste reception facilities for recreational boaters who use the lakes in the Savannah River Watershed Region.

Methodology

METHODS This project will include three components. The first will be the survey conducted by the Strom Thurmond Institute (STI) at Clemson University in consultation with the South Carolina Department of Health and Environmental Control (SCDHEC). The second component of the study is the identification and mapping of existing pumpout stations and waste reception facilities for recreational boaters who use the study lakes. Also, in this mapping phase current population and project populations of lake users will be completed. The second phase of the study will include using geographic information systems (GIS) capabilities to spatially identify optimal location or upgrading of waste disposal facilities on the study lakes. The third component of the study will include development, design, printing and distribution of a brochure designed from the results of the first two phases of the study. THE SURVEY The survey will utilize two methods: a questionnaire evaluating boaters and marina operators' existing attitudes and knowledge of existing laws, regulations related to discharge of waste from recreational boats and benefits of such facilities. Data also will be collected on demographic characteristics to be used in a cohort-component projection model and user segmentation analysis. The questionnaire also will include questions on types of boats, uses of each study lake, demographics of boaters, views on the experience of recreational boating on the study lakes, water quality and sanitation, sanitary equipment and preferred alternatives to traditional marine sanitation devices for use by recreational boaters. The questionnaire will be assessed by the STI research team, SCDHEC, US Army Corps of Engineers and some of their counterparts in Georgia for relevance, reliability, validity, content and completeness of the questions. The questionnaire then will be pretested with a group of boaters and marina personnel. The data collection procedure for marina personnel and other visitor types will be to have these questionnaires completed in a personal interview process. All public and private marina facilities will be approached to participate in the survey. The data collection method for the boaters will use the Dillman Total Design (1978) mail survey technique where an advanced-notice letter is sent to all members of the selected sample. A second contact will be made about a week after the advance-notice letter which will include a personalized cover letter, questionnaire and stamped return envelope. Third, a postcard follow up will be mailed to all members of the sample about a week after the questionnaire. Fourth, for all members of the sample who have not responded by the third or fourth week, a new personalized cover letter, questionnaire, and stamped return envelope will be sent. Finally, a follow up is sent to those who still have not responded. Using this survey procedure should yield a 60 percent or higher response rate in a specialized population such as recreational boaters (Salant & Dillman 1994). The sample for the boaters mail survey will be obtained from a central database on boat registrations from the South Carolina Department of Natural Resources and the Georgia Department of Natural Resources. Data on registered boats will be obtained for South Carolina and Georgia counties adjacent to the lakes in the study and from counties that are part of the metropolitan areas close to the lakes in the study. A stratified sampling method will be used in the selection of participants in the study using the following formula: boats 16 feet and under in length, boats 17-25 feet, boats 26-40 feet, and boats over 40 feet. These strata were derived from an EPA assessment that is described in the technical guidelines for the Clean Vessel Act (Federal Register Volume 58, No. 115, pages 33447-33457). In this, the EPA suggested 20 percent of boats 16-26 feet have portable toilets, 50 percent of boats 26-40 feet have holding tanks, and 100 percent of boats 40+ feet have holding tanks. The size of the boater's mail survey was selected using Fleiss' (1973) Statistical Methods for Rates and Proportions which suggests that with a population size in both South Carolina and Georgia of approximately 50,000 in each, a sample of 400 from each state would more than ensure a sample size for 95 percent confidence level and a margin of error of plus or minus 2.5 percent. THE MAPPING Mapping, location identification, and types of pumpout stations and waste reception facilities used by recreational boaters on Lakes Jocassee, Keowee, Hartwell, Russell and Thurmond will be done with the assistance of SCDHEC and

Georgia Department of Natural Resources Environmental Protection Division (GAEPD). According to the SCDHEC department the number of pumpout stations includes: Lake # Lake Jocassee none Lake Keowee 2 Lake Hartwell 3 or 4 Lake Russell none Lake Thurmond 2 or 3 These numbers should be the total number of pumpout stations on these lakes either in South Carolina or Georgia. The global positioning system (GPS) technology will be used to locate and map the precise location of existing facilities and to tag pertinent ancillary data to those locations. This data will be added to existing map data for each of the lakes in the study. In addition, the data collected from the surveys of marinas and recreational boaters will be input to the geographic information system (GIS). This data will be analyzed by relating vessel location concentrations and boater needs to existing infrastructure (roads, electrical lines, water lines, sewer lines, etc.) in order to model optimal site locations where pumpout stations or some other waste disposal system could be located in relation to boater needs, wants and concentration areas of use. The projections of the water-based recreation and tourism population will be accomplished using a cohort-component population projection model employing age, sex, race/ethnicity population detail and rates of participation in different activities. The projection population participation method used in this study will be very similar to that used by Murdock, Backman, Ditton, Hoque and Ellis (1992 a&b). This project will utilize the Strom Thurmond Institute Spatial Analysis Laboratory (SAL). The SAL is a fully functioning geographic information systems (GIS) and remote sensing /image analysis laboratory. The Institute has the facilities, expertise and experience to perform many types of spatial analysis tasks as well as project planning and management. Past project experience includes: construction, maintenance, and analysis of vector and raster GIS database; gap analysis in Central America; change detection and assessment through satellite image analysis; timber stand assessment and management; facility planning and placement; subpixel image analysis; land use classification and accuracy assessment through image analysis; international project coordination; global positioning systems; aerial photograph interpretation; map production; interfacing GIS with the world wide web. THE BROCHURE Taking information gleaned from the first two components of this study, a brochure will be designed that will inform the recreational boaters about relevant laws, regulations and environmental factors concerning waste from boats. It will provide information about available pumpout stations and waste reception facilities on the study lakes. The brochure will include information and educational literature on the value and use of waste facilities and identify alternatives to traditional marine sanitation devices.

Principal Findings and Significance

The project, after numerous delays due to University accounting problems, is now progressing well. But, to enable the research team time to complete the project the ending date needs to be pushed back to June 30, 1999 from February 29, 2000. Also, as you suggested in personal conversation, the project is concentrated more on the survey of boat owners/users of the lakes and reducing the "identification and mapping of optimal locations for construction or renovation of pump-out stations and waste reception facilities needed" on the lakes included in the study area due to recent work by the South Carolina Department of Health and Environmental Control (DHEC) and their report titled" Report on Process of Selecting Lakes for Possible Designation as No Discharge Zones (NDZ's) for Marine Toilets," dated December 1998. So to date, the project team has been in the process of collecting current review of the literature on public attitudes and perceptions of marine sanitation in fresh water lakes. The team also has made site visits to the field to observe existing facilities and assess boat usage and locations for data collection sites. The team has begun development and pretesting of a questionnaire to be utilized in the mail survey portion of the project. Additionally, a mail list of current registered boaters in the ten county area adjacent to the study lakes has been purchases from the South Carolina Department of Natural resources. This list will be used as the sampling frame from which the survey sample for the project will be drawn. An additional mail list is in the acquisition process from

which the State of Georgia's boaters will be surveyed. The questionnaire to be utilized to assess marina operators both public and private is being developed and pretested also. Data collection should begin in January 2000 allowing for sufficient data collection time, time for analysis of the data and preparation of the final report and maps to complete the project. The study will provide information on the location and relative use and types of existing pumpout stations and waste reception facilities. In addition, potential locations of new or upgraded facilities will be provided. It will identify an approach to educate and inform recreational boat users and operators of marinas and other sites where boats congregate, of the environmental value and use of waste facilities. An additional audience for the information provided by this study are the committees involved in the Savannah River Basin Watershed Project (SRBWP). This project was initiated by the US Environmental Protection Agency Region 4 Office. The stated vision of the SRBWP is "to management comprehensively the Savannah River basin to conserve, restore, enhance, and protect its ecosystems, especially aquatic ecosystems, in a way that allows the balancing of multiple uses" (SRBWP report, 1995). The lakes included in this study are all part of this ecosystem, and currently, the data that this project would provide would assist in filling a number of information gaps in the ongoing management effort of this watershed area. An information brochure will be prepared for distribution on the environmental value, location and use of these types of waste facilities. Because no simple, easy-to-read or easily dispersed literature exists to provide information to recreational boaters on the value of these types of facilities, the brochure will be designed such that it can be distributed to the boating public, or others interested in this issue, and will be placed at readily accessible points such as marinas, tourist information centers, Corp of Engineer offices, or state health departments. In addition, the brochure will be placed on the world wide web at the Strom Thurmond Institute site. Links to relevant sites will be developed.

Articles in Refereed Scientific Journals

None

Book Chapters

None

Dissertations

None

Water Resources Research Institute Reports

None

Conference Proceedings

None

Other Publications

None

Basic Project Information

Basic Project Information	
Category	**Data**
Title	Reestablishment of an Estuarine Marsh and Waterway after Causeway Removal
Description	
Start Date	03/01/1999
End Date	02/28/2000
Type	Publications
Lead Institution	Other

Principal Investigators

Principal Investigators			
Name	**Title During Project Period**	**Affiliated Organization**	**Order**
Mary Carla Curran	Assistant Professor	Other	01
Randall E. Cross	Assistant Professor	Other	02
Earl J. Hayter	Associate Professor	Clemson University	03

Problem and Research Objectives

The U.S. Geological Survey has identified "Aquatic and Environmental Protection" as one of its research priorities. Specifically, this priority area states "research needs in this area include studies of wetlands, swamps and marshes, fish and other biota, and the quality of life." The goal of the proposed study is within this research priority area. The goal of the proposed project is to study the ecological and geomorphological effects caused by the reduction in length of dirt causeways (accompanying bridge replacement) over a tidal waterway (Cowan Creek) and marsh in Beaufort County, South Carolina. Specific objectives to accomplish the stated goal include: 1) studying the effects of the bridge/causeway changes on tidal- and wind-induced circulation through Cowan Creek and the resulting geomorphological changes in the creek and adjacent tidal marshes; 2) evaluating the change in the nektonic community in the creek and tidal marshes in terms of species composition, density, and size distributions; 3) determining whether the percentage of parasitized grass shrimp changes after the changes to the causeways; 4) monitoring the benthic meiofaunal community in the area by collecting sediment cores; and 5) monitoring several surface water quality parameters to allow an assessment of changes associated with the altered hydraulics in Cowan Creek. Based on previous research, the following changes are predicted to occur in Cowan Creek and the adjacent marshes after completion of the new bridge: 1) increases in water flow and sediment transport rates; 2) change in sediment composition; 3) change in marsh geomorphology and size (i.e., surface area); 4) change in habitat utilization by nekton; and 5) change in various water quality parameters. It is also anticipated that the increase in bridge deck elevation and length, and the potential increase in water depth under the bridge will make this creek a viable transportation route between Port Royal and St. Helena Sounds, thus restoring it to its historic importance. These changes would also enhance recreational usage and enable fisherman to catch the species known to exist there at present (Curran, unpub. data). Some of this work will be directly comparable to the extensive survey conducted in a similar habitat in northern South Carolina (Ogburn et al. 1988). Our study will result in a better understanding of how causeways alter

flow in tidal creeks and the concomitant change in sediment transport, water quality, sediment composition of marsh habitat, and nekton utilization of estuarine habitats. Beaufort County, which consists almost entirely of low-lying barrier islands, is one of the fastest growing counties in the country. With the increase in human population and concomitant coastal development, roads are being widened, new bridges are being constructed, and existing bridges are being replaced. In particular, the Route 21 bridge over Cowan Creek, near Beaufort, South Carolina is going to be replaced within the next two years. Construction of bridges over wide inland waterways, such as Cowan Creek, have historically involved the construction of dirt causeways (i.e., elongated highway embankments) to reduce the length, and therefore the cost of the bridge. Causeways have been shown to reduce the circulation through waterways in that they act as restrictions to flow, and thus greatly decrease the hydraulic efficiency of the waterway (Lee et al. 1994). The reduced flow often results in the deposition of sediments and organic detritus, which, over time, leads to the formation of marshes. For example, the tidal marshes adjacent to Cowan Creek are approximately 2,000 ft wide. Historic French and English nautical charts (circa 1780) show that the width of the waterway has been reduced from 2,000 ft to its present day width of approximately 80 ft. This proposal raises an interesting philosophical argument. Is the "restoration" of this estuary to its historical state desirable, if this indeed does occur, if it will most likely result in the reduction of marsh habitat and perhaps alter the community of organisms that utilize the marsh and adjacent estuarine habitat? Cowan Creek is a tidal waterway that connects St. Helena Sound and the Beaufort River. The mean tidal range at the Route 21 bridge is 7.1 ft, whereas the spring tidal range varies from 9.5 to 11 ft. The South Carolina Department of Transportation (SCDOT) is initiating work that will eventually reduce the lengths of the two dirt embankments across Cowan Creek by 425 percent and replace the existing 120 ft bridge with a new 510 ft bridge. Our proposed study will document the changes in the flow regime, tidal marsh geomorphology, utilization of marsh habitat by nekton, and water quality that will occur with the replacement of the existing bridge over Cowan Creek. This study would be unique because it would address the impact of the removal (not addition) of a man-made structure (i.e., dirt causeways). We predict that the following changes will occur in Cowan Creek and the adjacent marshes after completion of the bridge replacement: 1) an increase in water flow and sediment transport rates; 2) a change in sediment composition; 3) a change in marsh geomorphology and size (i.e., surface area); 4) a change in habitat utilization by nekton; and 5) a change in various water quality parameters. It is also anticipated that the increase in bridge deck elevation and potential increase in water depth will make this creek a viable transportation route between Port Royal and St. Helena Sounds, thus restoring it to its historic importance. These changes would also enhance recreational usage and enable fisherman to catch the species known to exist there at present (Curran, in prep.). Some of this work will be directly comparable to the extensive survey conducted in a similar habitat in northern South Carolina (Ogburn et al. 1988). Our request to continue this research this summer is crucial because work on bridge replacement is scheduled to be completed in 2000. The South Carolina Sea Grant Consortium (SCSGC) has approved funding ($7,000) to assist in the pre-construction study in 1999. The on-going two-year study is a continuation of the work previously funded by the South Carolina Water Resources Center. At present, no obvious changes to the marsh or Cowan Creek have occurred (see attached Progress Report). The proposed research is part of a broader-scale interest in the estuaries of Beaufort County. We will be able to integrate the results of the proposed study with those collected from our study sites on Pritchards Island. In particular, we are currently monitoring the changes in abundance of juvenile fishes in two connected marsh creeks. Additionally at this site, a study of larval and juvenile nekton utilization of a developing overwash impacted barrier island marsh (containing sandy sediments) with an adjacent established marsh (containing natural mud sediments) indicated that juvenile nekton use of marsh habitat at similar tidal elevations is markedly different (Cross, in prep). These differences may be related to differences in benthic metazoan food resources available in the different sediment types (Cross, in prep). Other information concerning the importance of sediment associated factors to nekton utilization of intertidal marshes may be found from studies of artificially created marshes in the early stages of development

which contain sediments with a large sand component. Comparisons of these marshes to established, natural marshes have demonstrated reduced densities of juvenile Fundulus and harpacticoid copepods in the created marshes (Moy and Levin 1991), both of which are important food sources. Numbers of commercial species may also decrease. We anticipate a change in sediment composition over time at Cowan Creek due to altered hydrology and system morphology. Thus, accumulating evidence suggests that differences in sediment composition can alter nekton utilization of marsh habitats and benthic metazoan food resources upon which they feed. In summary, this research will result in a better understanding of how causeways alter flow in tidal creeks and the concomitant change in sediment transport, water quality, availability and sediment composition of marsh habitat, and nekton utilization of estuarine habitats. The goal of this project is to continue a multi-year study of the ecological and morphological effects caused by the reduction in length of the Highway 21 dirt causeways over Cowan Creek. Specific objectives to accomplish the stated goal of the herein proposed study are: a. to study the effects of the bridge/causeway changes on tidal- and wind-induced circulation through Cowan Creek and the resulting morphologic changes in the creek and adjacent tidal marshes. Changes in morphology will be determined by a GIS using pre- and post-construction surveys. b. to evaluate the change in the nektonic community in the creek and tidal marshes in terms of species composition and density; c. to determine whether the percentage of parasitized grass shrimp changes after removal of the causeways; d. to continue monitoring the benthic meiofaunal community in the area by collecting sediment cores; e. to determine the amount of oyster spat settlement on the oyster beds in the creek; f. to monitor several surface water quality parameters to allow an assessment of changes associated with altered hydrology. Parameters measured will include: concentrations of ammonia, reactive phosphorus, and dissolved oxygen, turbidity, suspended sediments, suspended particulate organic matter, temperature and salinity.

Methodology

See attachment for progress report. The methodology proposed to accomplish the stated objectives are described next. The first three tasks are components of the remaining ones. a. Measure the tides in the Beaufort River and St. Helena Sound at the entrances to Cowan Creek -The USGS has installed a stage and conductance recorder in the Beaufort River across from the entrance to Cowan Creek as a component of a study to determine Total Daily Maximum Loads (TMDLs) in the Beaufort River. The Beaufort-Jasper Water Authority is funding this study. Thus, we will have access to these data. Another stage and conductance recorder, to be paid for using funds from the SCSGC project, was installed by the USGS in St. Helena Sound near the entrance to Cowan Creek. b. Perform a limited survey of the creek and marsh to determine the bathymetry and geometry of this system — Using survey equipment (either a survey grade GPS unit or a total station), the elevations of at least 50 locations throughout the marsh along Cowan Creek will be surveyed to determine the variation in the marsh surface elevation. In addition, the bathymetry of the creek will be determined using a boat and fathometer. c. Monitor the changes in the morphology of the creek and marsh, particularly in proximity to the bridge, during and following construction of the new bridge — This will be performed bi-monthly using the previously described surveying techniques. d. Model the circulation and sediment transport in Cowan Creek using the HSCTM-2D hydrodynamic and sediment transport model (Hayter et al. 1998). The purpose of this modeling effort is to predict the increase in hydraulic efficiency of the creek and the decrease in marsh surface area that we propose will occur after bridge replacement. The measured tides and conductances at the two entrances of Cowan Creek, along with the measured wind field at the nearby University of South Carolina Beaufort campus and the U.S. Marine Corp Base on Parris Island, will be used as the boundary conditions to predict the tide- and wind-induced circulation through this waterway system. Current measurements at several locations throughout the creek over the course of a spring tidal cycle will be used to calibrate the hydrodynamic model. In addition, the predicted change in tide- and wind-induced circulation will be correlated to the monitored change in marine species composition and

density to determine the effect of the current regime on the marsh and creek habitat. e. Utilize the GIS capabilities that will be available at Spring Island (through collaboration with the Low Country Institute) and USC Beaufort to make our data available over the Web. f. Evaluate the change in sediment composition in the creek system and on the marsh by two different methods. Sediment cores will be collected at a variety of locations and transported to the lab, dried, weighed and sorted through a series of sieves to determine % sediment fraction. Additionally, the fractions of sand, silt, and clay will be determined in sediments using the American Society for Testing and Materials procedure D422. Organic matter content will also be determined by combustion. g. Evaluate changes in the sediment deposition rates and composition of transported sediments in the creek system and marsh by deploying sediment traps at selected locations where changes in hydrological flow rate are expected to occur. These sediment samples will be treated as described above in the previous description (f). h. Perform seining to evaluate the change in species composition and density. We will use pit traps on the intertidal marsh to determine larval and nekton use of these habitats. A 10-ft seine net will be used at low tide to assess species composition, and the numbers and sizes of fishes. Length frequency distributions will be constructed in order to identify the size classes that are most abundant in this area. Based on 1998 data (Curran, in prep.) we anticipate a seasonal change in species composition and size. i. Determine the parasitism rate of shrimp by collecting and measuring individuals in three replicate seine hauls and counting the number of parasitized and unparasitized shrimp. j. Survey the number of major meiofaunal groups by collecting sediment cores in a variety of areas of the creek bed. We will sample the top three centimeters of sediment using a 2-cm syringe. Two replicate cores will be taken. Samples will be preserved and stained in a 15% buffered formalin/rose bengal solution for examination under stereomicroscope at 20X. Animals will be enumerated and categorized into the taxonomic groups: nematodes, copepods, ostracods, polychaetes, and oligochaetes. k. Various water quality parameters of surface water will be determined. Ammonia and reactive phosphorus concentrations will be measured with a spectrophotometer. Turbidity will be measured on site with a nephelometer. Particulate organic matter will be measured following filtration and combustion on glass fiber filters. Dissolved oxygen will be measured on site with a portable dissolved oxygen meter. Salinity will be determined with a refractometer. Replicate samples for the above water quality parameters will be collected from the study site every other week from May through August and every other month from September through April. Samples will be filtered, transported to the lab at USCB, and analyzed on the same day of collection or preserved for analysis if samples cannot be analyzed on the same day. Periodically, samples will be collected from water draining the marshes and will be compared with flooding water samples.

Principal Findings and Significance

Summary of Work Conducted on Marsh Utilization by Nekton and Water Quality and Sediments 1999. Funding from SCRWI for 1999 allowed the collection of baseline data prior to bridge construction and removal of the causeway. The following is a brief description of work conducted by R. Cross during from June through mid-August 1999. The elevated walkway over the marsh was finished and the tidal elevation along the walkway was determined. Pit traps were installed into the marsh surface at four locations along the elevated walkway. The pit traps were used to sample larval and juvenile nekton that naturally utilize shallow pools of water on the intertidal marsh during low tide periods. Samples were also collected within 24 hrs of samples collected at the study site at a similar site (same tidal elevation) on Pritchards Island. It is hoped that the Pritchards Island site may be suitable as a control site in a BACI (Before-After-Control-Intervention) experimental design for differences in marsh utilization by nekton. Samples were highly variable in numbers of individuals but samples were numerically dominated by two species: mummichog (Fundulus heteroclitus) and grass shrimp (Palaemonetes pugio). The following surface water quality parameters were determined weekly at mid-ebb and mid-flood tide stages at the study site creek: NH3, PO4, DO, turbidity, salinity, and temperature. Nutrient

concentrations were determined spectrophotometrically. Dissolved oxygen concentrations were measured with a dissolved oxygen meter and turbidity measured with a nephelometer. Salinity was measured with a refractometer and temperature recorded with a temperature sensor. Duplicate water samples were collected at each sample time. There appears to be a consistent trend of greater NH3, PO4, and turbidity in mid-flood water. Sediment particle size analyses were conducted for both creek bed and marsh areas at the study site in July. These analyses were performed using the ASTM particle size analysis for soils method D422 using a soil hydrometer to measure particle settling rates. A sediment trap was installed in the creek bed and a characterization of settled sediments was made. Organic content of creek bed and marsh sediments was also determined using the combustion method. The benthic meiofauna community was also characterized using sediment core samples from the creek bed at the study site. The sediments were sieved to obtain the meiofauna and then stained and preserved. Preserved samples were examined under stereomicroscopes and enumerated into the following taxonomic categories and stages: nematodes, copepods, copepod nauplii, ostracods, oligochaetes, and polychaetes. Samples were numerically dominated by nematodes. Ostracods were second in importance, followed by copepods. Related research was conducted on ray feeding pits which are numerous at the study site. Water retained within the feeding pits at low tide was analyzed for nutrient concentrations (NH3 and PO4). Water in newly formed pits was compared to that in older pits and differences were found. In addition, short time scale nutrient dynamics were examined and changes in nutrients were evident over 15 min intervals. Summary of nekton in Cowan Creek, St. Helena's Island. The results of the nekton study indicate that there is variability in the abundance of fish in Cowan Creek during the summer of 1999. Peak abundance (1627 individuals) occurred near the end of the season (8/19/99); a total of 24 species were collected throughout the summer. The dominant species were, in order of numerical abundance, silversides, mummichogs, and anchovies. We collected over 1000 silversides on two occasions. We collected over 500 mummichogs on three occasions, and over 100 anchovies on one occasion. Based on our consistent collection of several species, including those mentioned above as well as mojarra, pipefish, and members of the drum family, we conclude that this area is an important habitat for juveniles of these species. Furthermore, results from 1998 also indicate that this small tidal creek is consistently important for these commercially important or forage fishes; we collected 2166 fishes on 8/12/98, and had over 200 specimens collected on nine different dates. Therefore, despite the limited flow of the creek, and the warm temperatures (reaching 39oC), this creek provides valuable habitat for juvenile fishes that themselves are important commercial species or provide food for commercially important species. We anticipate continuing our survey of this area in 2000 to determine whether this trend of habitat use remains after bridge construction potentially increases creek flow. We also determined the number of grass shrimp parasitized by an isopod crustacean. The percent parasitism ranged from 0.5-9.2% per sampling date. The mean rate of parasitism for the season was 4.5%. This is very similar to the overall value of 3.4% from the 1998 study. As grass shrimp are a staple food item for many of the juvenile fishes that utilize the estuary, it is important to determine if the parasitism rate changes in 2000 after the causeways are removed. This is because these parasites may reduce both shrimp growth and fecundity. The specific objective being addressed by E. Hayter is the following: 1) studying the effects of the bridge/causeway changes on tidal- and wind-induced circulation through Cowan Creek and the resulting morphological changes in the creek and adjacent tidal marshes. The tasks performed in Year 1 to partially accomplish this objective are discussed below. 1. Measure the tides at both ends of Cowan Creek - The USGS has been operating a stage and conductance recorder in the Beaufort River across from the entrance to Cowan Creek as a component of a study to determine Total Daily Maximum Loads (TMDLs) in the river. Another stage and conductance recorder was installed by the USGS in August near the St. Helena Sound entrance to Cowan Creek. This second gage was paid for by the one-year seed-level project funded by the South Carolina Sea Grant Consortium. Funds from the proposed project will be used to pay for continued operation of both gages for an additional 12 months. These synoptic tide and conductance records are needed to serve as boundary conditions for the hydrodynamic and salt transport model being established for Cowan Creek.

2. Perform a survey of Cowan creek and tidal marsh — The elevations of at least 50 locations along the marsh in proximity to the Route 21 bridge were surveyed to determine the variation in the marsh surface elevation. In addition, the bathymetry of the creek was surveyed by the USGS at 11 selected cross-sections. One cross-section was at the bridge, five were south of the bridge, and the remaining five were north of the bridge. These studies were funded by Year 1 funds. 3. Construct a Digital Elevation Model (DEM) of Cowan Creek — The USGS was contracted to construct a DEM of Cowan Creek. The DEM was then imported into a pre-processor for the HSCTM-2D model and used to construct the finite element grid for Cowan Creek. 4. Model the circulation and sediment transport in Cowan Creek using the HSCTM-2D hydrodynamic and sediment transport model (Hayter et al. 1998). The purpose of this modeling effort is to predict the increase in hydraulic efficiency of the creek and the decrease in marsh surface area that we hypothesize will occur after bridge replacement. The input files, including the finite element grid developed for Cowan Creek, have been created, and initial runs of the hydrodynamic module in HSCTM-2D have been made to debug the input files. The measured tides and conductances at the two entrances of Cowan Creek, the measured wind field at the nearby U.S. Marine Corp Base on Parris Island, and the suspended sediment concentrations to be measured in Year 2 are being used as the boundary conditions. Current measurements to be made in Year 2 at several locations along the creek over a spring tidal cycle will be used to calibrate the hydrodynamic model. Similar measurements will be performed during a neap tidal cycle to partially validate the hydrodynamic model. Information related to this project will be made available both locally, nationally, and internationally. We will be working very closely with local concerned citizens who are interested in local environmental issues and this project in particular. We have already met with county government members and they have collectively indicated interest in the project. The local television and newspapers will be updated periodically on the progress and findings of the project. M.C. Curran has already been filmed by the local public TV station (WJWJ) during her first year of research. The university community will benefit from information presented during faculty and student seminars. M.C. Curran designed an upper-level field biology course geared around sampling this creek in the fall of 1999. We determined fish and meiofauna abundances in the same manner described herein. It is anticipated that students will present the results at a future meeting. We intend to continue this project in some form for several years and will incorporate many aspects of this project into laboratory and lecture sections of our courses in biology, environmental science, and marine science. Student participation will provide hands-on learning experiences in a real world situation and give a sense of continuity from one year to another. The USC Beaufort Student Environmental Awareness Club, which we advise, is active in environmental education of the community and will play a key role in disseminating information to the general public through activities associated with Earth Day, the Water Festival, the Shrimp Festival, and other community centered events. The faculty and students participating in the project will expand the scope of disseminated information to a national and international scale through poster sessions and talks given at regional and national scientific meetings (e.g., Estuarine Research Federation, Southeastern Estuarine Research Society, Benthic Ecology Meeting). Specifically, we will promote the dissemination and application of the results of the research in the following ways: a. Place the results of our GIS study on the Web so that scientists, teachers, and concerned citizens can observe how the marsh system will change after the removal of earthen causeways. We will coordinate this effort with the Low Country Institute, which is conducting a watershed survey of Spring Island and will be supplying us with GIS facilities and expertise. We will work with the Low Country Institute to help educate school teachers about GIS and Web-based instruction so that they can access our information and use it in conjunction with the Spring Island program as part of their science curriculum. We will also incorporate our GIS information into our science courses at USC Beaufort. As many of our students are education majors and/or parents, we will reach a broad audience by incorporating this into our curriculum. We will be working with several local scientists regarding our GIS program in the Beaufort County area. Several of us have undergone GIS training in a manner, which will enable us to train other scientists and teachers in the area. Our

previous discussions with the Low Country Institute have revolved around outreach programs that involve the scientific community and local citizens in water quality education. This collaboration between USC Beaufort and the Low Country Institute will facilitate a more in-depth study of our site on St. Helena and the watershed on Spring Island. b. We have involved a South Carolina Governor's School student in our summer research. This was one of the first opportunities that USC Beaufort has had to interact with some of the best high school students in the state. This student participated in research related to the overall goal of the project to understand effects on water chemistry and larval/juvenile nekton ecology that is necessary to our overall understanding of this system. This student was required to complete a paper and present the information to their entire school body. We anticipate that the research will be presented at a regional meeting such as the Southeastern Estuarine Research Society (SEERS). c. We have funds to involve approximately 4 USC Beaufort undergraduate students. Some of these students may choose to expand a particular aspect of our research for an independent study project. Some of these students have already attended a SEERS meeting and would be capable of presenting work at an upcoming meeting. d. All of the PIs will be presenting their research at national meetings and publishing their work in appropriate journals. R. Cross and M.C. Curran have already presented results at SEERS. R. Cross and M.C. Curran have a manuscript accepted (upon revision) to Estuarine, Coastal, and Shelf Science.

Articles in Refereed Scientific Journals

None

Book Chapters

None

Dissertations

None

Water Resources Research Institute Reports

None

Conference Proceedings

None

Other Publications

None

USGS Internship Program

Student Support

Student Support					
Category	**Section 104 Base Grant**	**Section 104 RCGP Award**	**NIWR-USGS Internship**	**Supplemental Awards**	**Total**
Undergraduate	N/A	N/A	N/A	7	$4800
Masters	1	N/A	N/A	1	$6200
Ph.D.	1	N/A	N/A	N/A	$3400
Post-Doc.	N/A	N/A	N/A	N/A	N/A
Total	2	N/A	N/A	8	$14,400

Awards & Achievements

Publications from Prior Projects

Articles in Refereed Scientific Journals

Book Chapters

Dissertations

Water Resources Research Institute Reports

Conference Proceedings

Other Publications