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CSREES 406 National Integrated Water Quality Program-Nutrient Science

Utilizing Mississippi River Diversions for Nutrient Management in a Louisiana Coastal Watershed (NUMAN)

PPROGRESS REPORT FOR FY 2003

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Award/Grant Number 2002-51130-01919
Proposal Number: 2002-00561

Date: September 2, 2003

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The main objective of the NUMAN project is to determine the main sources and sinks of N, P, and Si in the Caernarvon watershed, LA, encompassing 1,100 km^2 of fresh, brackish, and saline wetlands, in Louisiana (Fig.1) and examine nutrient removal potential. This project builds on an earlier project called PULSES which was funded by the Water and Watersheds program of EPA-USDA-NSF. The Caernarvon diversion control structure began diverting river water into Breton Sound in 1991 (Fig. 2). In order to measure impacts of the riverine inflow into this estuarine watershed, the project team proposed the following five research questions as research objectives. The project began in August 2002. In coordination with a stakeholder decision-making advisory committee, we manipulated the flow into Breton Sound as pulses ranges from 14 m^3/sec to 114 m^3/sec. The following is the list of the research questions and respective research accomplishments thus far.

Objective 1. What are the sources and magnitude of nutrients entering watersheds and how do these sources and magnitudes vary with watershed size, geographic location, and position within a watershed?

(Accomplishments)
Hydrologic assessment of the Breton Sound Estuary affected by the Caernarvon Freshwater Diversion is being made through both continuous and synoptic measurements of flow at channel and marsh stations. Velocity and stage gages have been established at key locations in major channels downstream of the diversion to evaluate the preferential annual flow routes of water in the upper estuary. These stations make continuous measurements of velocity, stage, and temperature, which we then use to calculate discharge. This information is being incorporated into a model of estuarine hydrodynamics to evaluate the confounding effects of wind speed and direction, the freshwater diversion, and marine influences on the upper estuary circulation and residence time. One person from the research associate pool is dedicated to this aspect of the project. He has begun developing the model and has already been able to establish the effects the diversion has on the estuary water levels. The next step will be to incorporate sea level fluctuations and winds. In addition, we will apply a similar model of a conservative dissolved tracer, salinity, to determine the primary controlling force on salinities in the estuary. During periods when the diversion is operational above the threshold for overland marsh flow, we established temporary stations to characterize this flow. Marsh stations are temporary, because when no overland flow takes place, the marsh becomes dry, or at least has low saturation. Unsaturated conditions are unfavorable for the equipment probes as well as there not being anything to measure. Flow over the marsh has occurred twice under experimental conditions -- each time in the spring during high pulse discharge. We established stations to address to important spatial scales in marsh overland flow: (1) local effects as the flow first enters the marsh; and (2) and more widespread effects on the whole marsh once the water has filled all ponds and interior channels.

During the experimental diversions, we set up a station at the marsh edge that had a 30-m long x 2-m wide flume built perpendicular to the channel edge and parallel to the route of overland flow to evaluate the local effects of overland flow. The flume experiment was established to characterize not only the water flux across the marsh, but also nutrient flux. Inside the flume, we set up 3 marsh velocimeters at different depths to determine velocity gradients within the overland flow. Turbidity probes were set up at the beginning and end of the flume to assess sediment deposition along the flow route. A water level gage was established near the flume to monitor stage through time. These measurements were made in conjunction with nutrient measurements.

In addition to the flume experiments, a grid-system was set up to spatially characterize velocity in the marsh from a eulerian perspective using a hand-held velocimeter during the experimental diversions. This experiment was utilized for regional water movements in the marsh. Using an airboat, we made velocity and current direction measurements at over 50 stations in the marsh during the experimental diversions to characterize flow patterns. These measurements will be incorporated into an overall picture of the general direction and magnitude of flow that occurs during overbank flooding into the marsh. One important question we hope to answer from these experiments is whether overland flow moves into the marsh at one location and out at another, or if the water moves in and out in the same general area. The answer to this question has critical implications for both the estuary water budget and the ability of the marsh to retain nutrients and sediments.

Thus far, we have the following preliminary results. There are four potential sources of nutrients to Breton Sound watershed. The Caernarvon diversion and precipitation are important sources. In addition, pumped storm-water and groundwater are likely to be much less important. The Caernarvon diversion introduces 1 to 3 billion cubic meters of Mississippi River water into the receiving estuary annually. This riverine input contains 2 to 5 million kg of nitrate and 3 to 7 million kg of TN. Rainfall in the region is approximately 1.6 m/yr, or the equivalent of 0.7 billion cubic meters over the upper 440 km^2 of the estuary, introducing approximately 0.55 million kg of nitrate and 0.64 million kg of TN annually to the upper 440 km^2 of the estuary. We use the value of 440 km^2 because it is the area that is most directly affected by the diversion and encompasses about half of the estuary. Approximately 0.1 billion cubic meters is pumped into the estuary, but the nutrient concentration of this water is currently unknown. We have estimated, based on rainfall and storm water pumpage data, that 0.6 million cubic meters of groundwater may pass into the estuary, but again, the nutrient concentration of this water is unknown. These data show that water diverted through the structure and rainfall are the most important sources for the Breton Sound estuary. Pumpage and groundwater are much less important.

Objective 2. What processes control the biogeochemical cycling of nutrients to and through an ecosystem and how do these processes vary over space and time?

(Accomplishments)
Several NUMAN project members are studying the processes influencing the biogeochemical cycling of nutrients in wetland soils and estuarine sediments and how these processes vary over space and through time.

Two spring field campaigns and subsequent non-vegetated sediment core incubations in the laboratory took place in February and March of 2003 during major diversion events. The setup for both experiments was similar. Sediments (18 individual cores) were incubated in a continuous flow-through system with filtered water. The systems was sampled several times after reaching equilibrium. Concentration changes of dissolved inorganic nutrients compared to a control are used to estimate processing rates of the cores.

Four locations with increasing distance from the diversion (Big Mar, Lake Leary West, Lake Leary East, Grand Lake) were tested in triplicate with filtered water from the respective locations. Additionally, Grand Lake sediment was tested with water from the diversion. This setup will allow for comparison of nutrient processing capabilities at local background levels compared to potential rates reached with nutrient rich water from the Mississippi.

During these experiments, we measured dissolved inorganic nutrients which are currently being processed and analyzed. Initial results indicate high nitrate uptake. Our nitrate uptake rates can be compared with direct measurements of denitrification for one experimental run, done in cooperation with Dr. J. Cornwell and M.Owens of the University of Maryland Horn Point Laboratories. Another experiment is currently planned for late summer to test the nutrient processing potential of the soils under more marine conditions when no diversion is running and temperatures are higher.

Vegetated marsh sediments were tested in two ways for their nutrient assimilation potential. At a location close to the diversion, a large-scale flume (4 m* 40 m) with a boardwalk on the side was built. During high pulse diversions in February and March, water overflowed the marsh surface and two major field studies were conducted after the first and second week into the pulse. Water moving in the flume was sampled repeatedly upstream and downstream with ISCO-samplers. Samples for total and dissolved inorganic nutrients and dissolved organic matter were processed and need to be analyzed in the coming months. Nutrient processing potential of the marshes during the spring diversions will be estimated directly from this study of a undisturbed large area of marsh.

In a second set of experiments, vegetated marsh cores were taken this summer (2003) at several locations and incubated in a batch setup with five replicates per location. Cores were incubated with filtered water at background nutrient concentration or with an enrichment treatment of 50 µmol nitrate per liter. Sample analysis for these batch incubation experiments will also be run over the next months.

Objective 3. How do terrestrial, freshwater, and estuarine communities respond to changes in nutrient loads.

(Accomplishments)
We have been evaluating the spatial and temporal patterns of phytoplankton productivity in upper Breton Sound using stable isotopes as tracers. The resulting production and respiration rates will help us to evaluate autotrophy and heterotrophy of the system. Additionally, we have been studying the carbon and nitrogen uptake by shrimp and fish using stable isotopes. Initial results show that phytoplankton loses its Mississippi River signal (high 13C and 15N values) about halfway through the estuary, but higher trophic levels show elevated 13C and 15N (indicative of river input) values even further down-estuary. This discrepancy might be based on a higher degree of nutrient recycling in the mid and lower part of Breton Sound and the longer turn-over rates of higher trophic levels relative to phytoplankton.

Objective 4. What land management activities are responsible for measurable fluxes of nutrients into and out of watersheds and how can these activities be altered to improve the quality of water resources within a watershed?

(Accomplishment)
The primary objective of the modeling effort was to develop and implement a hierarchical suite of models for the Caernarvon watershed. These models will be used to help answer the question that is central to this proposal - "How can the Caernarvon diversion be managed to maximize nutrient removal and marsh productivity, while concurrently minimizing the potential for development of noxious phytoplankton blooms? In order to answer this question, we proposed to examine changes in nitrogen and carbon budgets over different time-scales ranging from several hours to decades.

As a result of a previous collaboration with Drs. Paul Kemp and Hassan Mashriqui, we developed a general framework for the implementation of a 2-D finite-element hydrodynamic model (TABS) in the Caernarvon diversion area. The model has been tested using environmental data collected during the 2001 PULSES project experiment. Predicted flows and salinity distributions generally have shown a good agreement with the measured values. Our current work is concentrated on including nutrient and light in the model, and simulating the temporal and spatial distributions of chlorophyll a.

Objective 5. How do interactions between management actions with competing objectives affect the delivery of nutrients to estuaries and how can management practices be adapted to better control nutrient delivery across an entire watershed?

(Accomplishments)
We have also actively interacted with stakeholders. The Caernarvon Interagency Advisory Committee (CIAC), a legally-constituted stakeholder decision-making committee, approved the pulsed diversion plan and is incorporating our results in their management schemes. The CIAC is composed of oyster, shrimp, and recreational fishers, land-owners, local government representatives, state and federal agency representatives, and scientists. We take part in the annual meeting of the CIAC and we have conducted scientific surveys and detailed interviews with CIAC members. We are presently analyzing this information and preparing a report identifying areas of conflict and potential ways to deal with these conflicts.

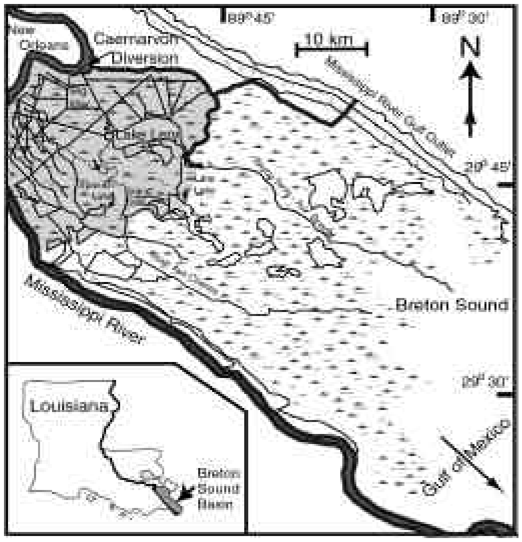

Fig. 1. Breton Sound Basin with main region of estuary influenced by diversion highlighted in gray.

Fig. 2. The Caernarvon diversion structure