SYNOPSIS

Project Number: 2005PR20B (extended to FY2006) Start: 03/01/2004
End: 12/31/2006

Title: Monitoring Nutrients Content in the San Juan Bay Estuary using Hyperspectral Remote Sensing

Investigators: Gilbes, Fernando

Focus Categories: Nutrients, Nitrate Contamination, Non-Point Pollution

Congressional District: N/A

Descriptors: N/A

Problem and Research Objectives:

Several point and non-point sources pollution have been identified in the San Juan Bay National Estuary (SJBNE) and represent a potential threat to the site in maintaining its environmental balance and protection of the local surviving species. During 1994 and 1995, the United States Geological Survey (USGS), in cooperation with the United States Environmental Protection Agency (EPA), and the Puerto Rico Environmental Quality Board (EQB), conducted water and sediments sampling survey on the SJBNE. While on certain section of the SJBNE the conditions have improved, there are still degraded conditions at the Caño Martin Peña and SJL, the results of the survey reflected presence of toxic sediments deposited in the above surface water systems. Furthermore, anoxic and abiotic conditions persisted at both systems caused by stagnant water conditions with virtually no mixing during daily ocean tides events.

Monitoring of water pollution with satellite imaging will provide important information related to the nutrients loadings along the SJBNES. Remote sensing techniques are appropriate due to the complexity of the reserve's ecosystem particularly because of the larger mangrove population. This study will suggest the use of hyperspectral imaging as a nutrients pollution monitoring tool in tropical estuaries. The Hyperion hyperspectral sensor has the capability to define spectral profiles in the visible and near infrared bands where nitrates and total phosphorus are suspected to reflect. Field reflectance validation will be required to co-relate the satellite measurements with true nutrients reflected water quality characteristics at the deeper SJL sections, based on field sampling results. Finally, a mathematical algorithm will be developed from a separate research to extract nitrates or phosphorus information from the satellite image based on reflectance characteristics. This data will be used to determine nitrates and phosphorus concentration in the lagoon waters. A water quality model will be used to validate the spectral results with predicted nutrients concentrations inside the SJL.

Methodology:

A. Satellite Sensor

The Hyperion Hyperspectral Instrument (HIS), which was developed by the National Aeronautics and Space Administration (NASA) and installed at NASA's EO-1 satellite, provides a high spatial resolution of 30 meters ranging from the ultraviolet to the infrared spectral bands (operating between the 0.4 to 2.5 μm bands). The HIS also has a high spectral resolution as it provides high radiometric accuracy in 220 spectral bands. Such variety in spectral bands is necessary to identify different vegetation species present inside a small area such as the SJBNES, particularly swamp lands (NASA, 2002), distinguish between the bay's bottom bed and brushes, and identify planted areas. Other sensor alternatives, such as Thematic Mapper (installed in the Landsat 7 satellite), have been considered. However, most of the available sensors have much lower spatial and spectral resolutions not useful for the SJBNES study due to the site's small area.

B. Image Processing

The ENVI 4.0 version software, developed by Research Systems, is used to process and classify the SJBNES images used in this study. ENVI provides needed geometric correction, terrain analysis, radar analysis, raster and vector Geographic Information System (GIS) capabilities. The ENVI 4.0 was purchased by the Geology Department at the University of Puerto Rico's Mayagüez Campus (RUM) where a significant amount of the study activities are completed. Several HIS images were purchased to the USGS, with passes taken without presence of clouds.

1. Field Data Processing

All terrain and water resources data have been obtained from available sources, such as the United States Environmental Protection Agency (USEPA), the United States Geological Survey (USGS), the United States Department of Agriculture's Natural Resource Conservation Service (NRCS), the National Oceanic and Atmospheric Administration (NOAA), the Puerto Rico Department of Environmental and Natural Resources (PRDENR), the Puerto Rico Environmental Quality Board (PREQB), and others. All satellite imaging has been obtained from NASA and NOAA, and others.

Field data have been converted to ENVI format for processing. Maps are digitized into GIS formats using digitizing tables available at UPRM. These digital data will be directly included as a separate file for processing by ENVI.

2. Image Data Processing

Data obtained from the images are used to define (and correct for) parameters such as:

1. Vegetation indices
2. Surface albedo
3. Atmospheric radiation
4. Land surface radiation

Data obtained from the field will be used to correct for parameters, such as:

1. Radiance
2. Reflectance

C. Water quality samples (QA/QC protocols)

Approximately forty (40) field nitrates and total phosphorus water quality samples have been obtained from the San José lagoon to validate the results from the Hyperion co-related reflectance data. Grab samples for both parameters were collected from a location grid previously defined in accordance with depth restrictions. Due to the high water turbidity the samples were obtained at a depth not exceeding 6-inches from the water surface. Strict Quality Assurance/Quality Control (QA/QC) procedures were followed in accordance with the U.S. Environmental Protection Agency (EPA) established protocols. Samples handling was evidenced with the use of chain-of-custody documentation, which details: sample number, date, time, type, container information, site name, arrival temperature, and delivery receipt signatures. Five-hundred (500) milliliter polyethylene, uncolored bottles were used with sulfuric acid (H_2SO_4) as the preservative with a pH less than 2. All samples were preserved at a temperature not to exceed 4°C. Sample analyses methods EPA 353.2, for Nitrate as Nitrogen, and EPA 365.3, for total phosphorus were performed by EQ Lab, a private environmental quality laboratory, in charge of conducting the analyses.

D. Algorithm Development

The image(s) evaluation activities will be concurrently undertaken with *in-situ* sampling of the bay's waters for nitrates or total phosphorus, with locations identified by a field grid. Such locations will be at the San José lagoon Based on the above data, an algorithm for nutrients concentration will be defined using nitrates or total phosphorus as a leading indicator. The field sampling will be accomplished to test and validate the developed algorithm, which will be developed through a separate research. Since the lagoon is excessively polluted with phosphorus the algorithm may be developed to provide total phosphorus concentrations uniformly distributed throughout the lagoon. However, there are certain limitations in the use of total phosphorus as an indicator. Organic phosphorus is one of the leading components in the sediments of an eutrophicated surface water body. While the intent of the algorithm is to develop a nutrients pollution control management tool, it may provide misleading results as excessive organic phosphorus may influence the spectral map final results without necessarily identifying point and non-point pollution sources. In order to overcome such restriction a water quality model will be used to predict overall total phosphorus concentrations throughout the lagoon with corrections accounting for the organic phosphorus content within the sediments. Another disadvantage may be the inability of the sensor to adequately obtain reflectance characteristics from the water column, particularly if turbidity conditions prevail during most part of the year. Thus, surface concentrations will only be used for purposes of this research. However, and since the algorithm is intended to provide nutrients concentrations from suspected or unknown pollution sources, spectral characteristics of the water column may not be affecting such purposes.

Principal Findings and Significance:

The USGS collected the first Hyperion image during June 22, 2005 (Figure 1a). Field data was not collected during that day because the field radiometer was not working properly. A second Hyperion image was collected during August 7, 2005 (Figure 1b). Field data was collected that day in 38 stations of San Jose Lagoon (Figure 2). Nutrients concentration was measured and the results are shown in Figure 3. In September the USGS changed the frequency of the satellite overpass on the study region, which significantly reduced all imaging activities until October. The spectral data to be obtained from the second image (which was sufficiently clear for the sampling area) will be used to compare the spectral and sampling data to be obtained from the selected image. At the time of the preparation of this report we are still waiting for the USGS to provide us with the next satellite overpass date in order to perform the second field sampling campaign.

Additional field samplings were carried out during days of satellite overpasses. The field reflectance measurements and the nutrients are being processed and analyzed in order to compare them with the Hyperion images. The Hyperion image collected during February 24 of 2006 is being received and we are now performing the atmospheric correction using the software called Atmospheric COrrection Now (ACORN). This initial step will produce a corrected image with reflectance values that will be compared with the field data. The same image has been explored using ENVI.

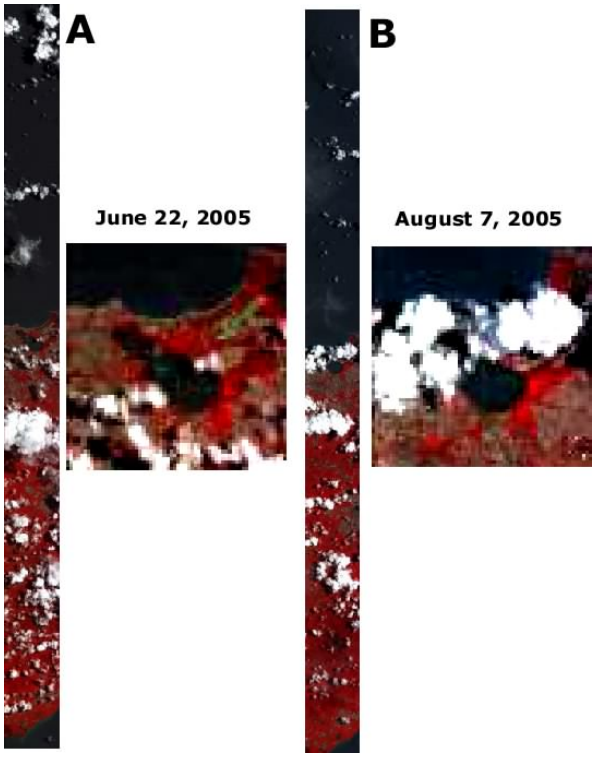

Figure 1: Examples of Hyperion Images collected over the San Jose Lagoon.

Figure 2: Study area and sampling stations in San Jose Lagoon.

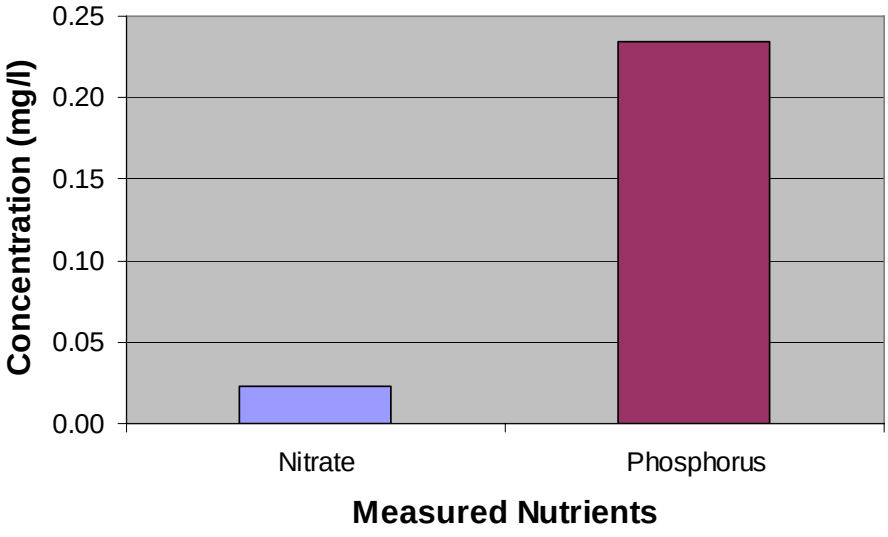

Figure 3: Mean Concentration of nutrients measured in 38 stations.

Publications

No publications were completed during the year as a result of work funded under Section 104 during the current budget period.

TRAINING ACCOMPLISMENTS

List all students participating in Section 104 projects.

Field of study	Academic Level				Total
	Undergraduate	MS	Ph.D.	Post Ph.D.	
Chemistry					
Engineering:					
Agricultural					
Civil			Luis Campos		1
Chemistry					
Computer					
Electrical					
Industrial					
Mechanical					
Geology					
Hydrology					
Agronomy					
Biology					
Ecology					
Fisheries, Wildlife, and Forestry					
Computer Science					
Economics					
Geography					
Law					
Resources Planning					
Social Sciences					
Business Administration					
Other (specify)					
Totals			1		