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Development Of Water Pollution Early Warning System For Oyster Harvesting Areas

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DEVELOPMENT OF WATER POLLUTION EARLY WARNING SYSTEM FOR OYSTER HARVESTING AREAS

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The objective of this study is to develop a **Pollution Early Warning System (PEWS)** for efficient management of water quality in oyster harvesting areas. To that end, this paper presents a web-enabled, user-friendly **PEWS** for managing water quality in oyster harvesting areas along Louisiana Gulf Coast, USA. The **PEWS** consists of (1) an Integrated Space-Ground Sensing System (ISGSS) gathering data for environmental factors influencing water quality, (2) an Artificial Neural Network (ANN) model for predicting the level of fecal coliform bacteria, and (3) a web-enabled, user-friendly Geographic Information System (GIS) platform for issuing water pollution advisories and managing oyster harvesting waters. The ISGSS (data acquisition system) collects near real-time environmental data from various sources, including NASA MODIS Terra and Aqua satellites and in-situ sensing stations managed by the USGS and the NOAA. The ANN model is developed using the ANN program in MATLAB Toolbox. The ANN model involves a total of 6 independent environmental variables, including rainfall, tide, wind, salinity, temperature, and weather type along with 8 different combinations of the independent variables. The ANN model is constructed and tested using environmental and bacteriological data collected monthly from 2001 – 2011 by Louisiana Molluscan Shellfish Program at seven oyster harvesting areas in Louisiana Coast, USA. The ANN model is capable of explaining about 77% of variation in fecal coliform levels for model training data and 44% for independent data. The web-based GIS platform is developed using ArcView GIS and ArcIMS. The web-based GIS system can be employed for mapping fecal coliform levels, predicted by the ANN model, and potential risks of norovirus outbreaks in oyster harvesting waters. The **PEWS** is able to inform decision-makers of potential risks of fecal pollution and virus outbreak on a daily basis, greatly reducing the risk of contaminated oysters to human health.

INTRODUCTION

The U.S. National Shellfish Sanitation Program (NSSP)—a cooperative program between the U.S. Food and Drug Administration (FDA), state regulatory agencies, the Interstate Shellfish Sanitation Conference, and the shellfish industry, requires shellfish producing states to monitor shellfish harvesting waters to determine that they are safe before harvesting is permitted (FDA 2011). The primary bacteriological indicator generally used for determining water pollution and shellfish contamination is fecal coliform. Due to high costs involved in field sampling and

laboratory analysis of fecal coliform, water samples are commonly taken from each oyster growing area and analyzed on a monthly basis. The main problem with the current water quality monitoring and management practice is that the level of fecal coliforms may change significantly between two consecutive sampling times (one month). Decision on opening or closing oyster growing areas based on the monthly sampling can lead to unnecessary harvest water closures, causing unwarranted loss of valuable economic resources, when water quality is actually good in most time periods or to permit harvesting when conditions present an unacceptable level of risk. People eating the oysters harvested at the peak contamination time during two sampling times may be infected with viruses or bacteria and get sick.

The primary objective of this study is to develop a **Pollution Early Warning System (PEWS)** for predicting fecal coliform levels in oyster harvesting waters on a daily basis and issuing oyster contamination alert when the predicted fecal coliform level in a specific oyster harvesting area exceeds water quality standard.

MATERIAL AND METHODS

The **PEWS** consists of (1) an Integrated Space-Ground Sensing System (ISGSS) gathering data for environmental factors influencing the level of fecal coliform bacteria in oyster growing waters, (2) an Artificial Neural Network (ANN) model for predicting the level of fecal coliform bacteria, and (3) a web-enabled, user-friendly Geographic Information System (GIS) platform for issuing water pollution alerts and managing oyster harvesting waters.

Integration of space-borne remote sensing and ground-based in-situ sensing data
Ground-based in-situ sensing data for water temperature, salinity, and tide are available daily for 13/30 oyster growing areas in Louisiana Coast, USA from USGS website (http://maps.waterdata.usgs.gov/mapper/index.html). Additional daily data, needed in the PEWS for rainfall, wind, and weather type, are also available online (http://weather.lsuagcenter.com). The in-situ sensing data are just available for thirteen oyster growing areas among the total of thirty oyster growing areas in Louisiana Coast. In order to obtain model input data for the remaining seventeen areas, NASA satellite remote sensing data are employed. The space-borne remote sensing system utilizes NASA MODIS Terra and Aqua data for temperature and the Tropical Rainfall Measuring Mission (TRMM) data. The Terra spacecraft crosses the equator at 10:30 AM local time, and the Aqua spacecraft crosses at 1:30 PM local time, thereby potentially providing two views of a given area each day.

Development of artificial neural network (ANN) model
The artificial neural network (ANN) in MATLAB Toolbox is utilized to develop a model for prediction of the level of fecal coliform bacteria in oyster growing waters. Input variables involved in the model include rainfall, tide, wind, salinity, temperature, and weather type. Seven years of sampling data for fecal coliform levels, collected in 2001 – 2008 by the Molluscan Shellfish Program of Louisiana Department of Health and Hospitals, are used to construct the ANN model. In the model development the input data are split into three data groups for training (Group-1: 60%), validation (Group-2: 20%), and testing (Group-3: 20%). Additional three years of data collected in 2009 – 2011 are used to test the performance of the ANN model independently.

Construction of GIS platform

A web-enabled GIS (Geographic Information System) platform is constructed using ArcView GIS and ArcIMS (Deng et al. 2014). The web-enabled GIS system is designed for shellfish managers to display the classification and reclassification of oyster growing areas based on both measured and model predicted fecal coliform levels in oyster growing waters. The oyster growing areas, where the levels of fecal coliform bacteria exceed water quality standards, are highlighted with red color while the areas meeting water quality standards are indicated with blue color, as shown in Figure 1.
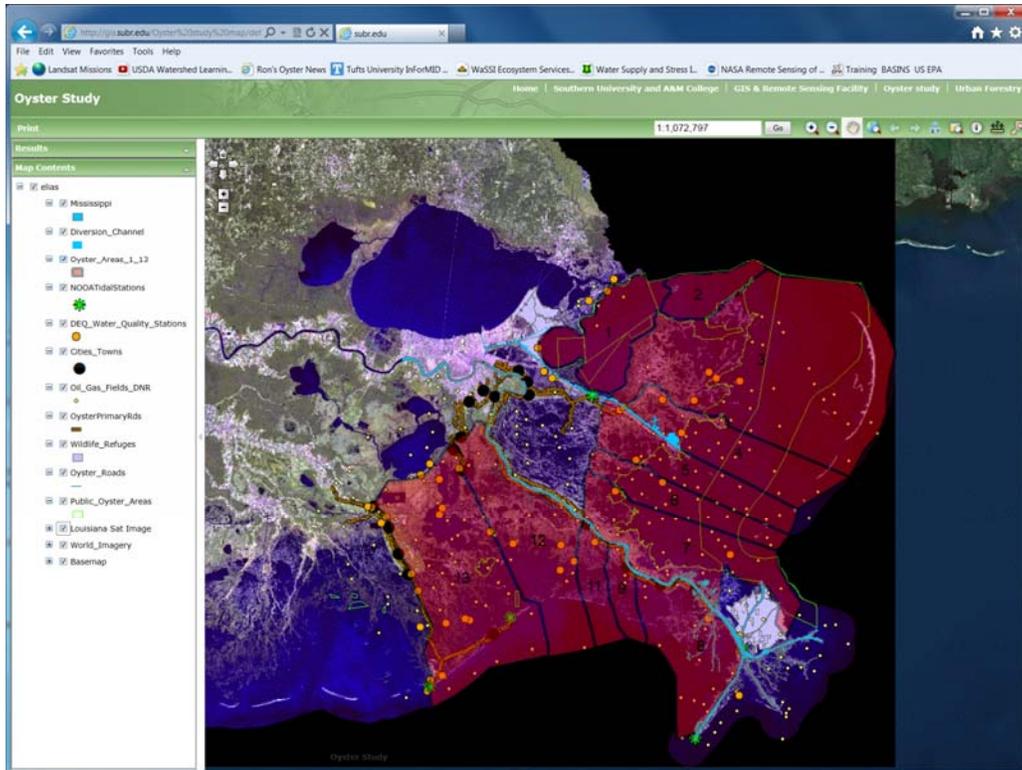

Figure 1. Web-enabled GIS interface showing various GIS layers constructed for the oyster growing areas with red color indicating closure and blue color indicating that the area is open for harvesting

RESULTS AND DISCUSSION

Figure 2 shows a comparison between the log-transformed fecal coliform (Ln(FC)) levels predicted using the ANN model and observed in 2005 – 2008 in the oyster growing areas 1 – 7 (Figure 1). It can be seen from the figure that the ANN model is capable of predicting the overall variation trend in observed fecal coliform levels. The linear correlation coefficient (R) between the model predictions and the observed data is 0.7738, indicating a good performance of the ANN model. It means that the ANN model could be utilized to make daily predictions of the level of fecal coliform bacteria in oyster growing areas, greatly reducing the cost involved in conventional field sampling and laboratory analysis of water samples. In addition, the daily prediction of fecal coliform levels can also help oyster monitoring programs make more

informed decisions on closing contaminated oyster growing waters, greatly reducing the human exposure to contaminated oysters and avoiding unnecessary oyster harvesting water closures.
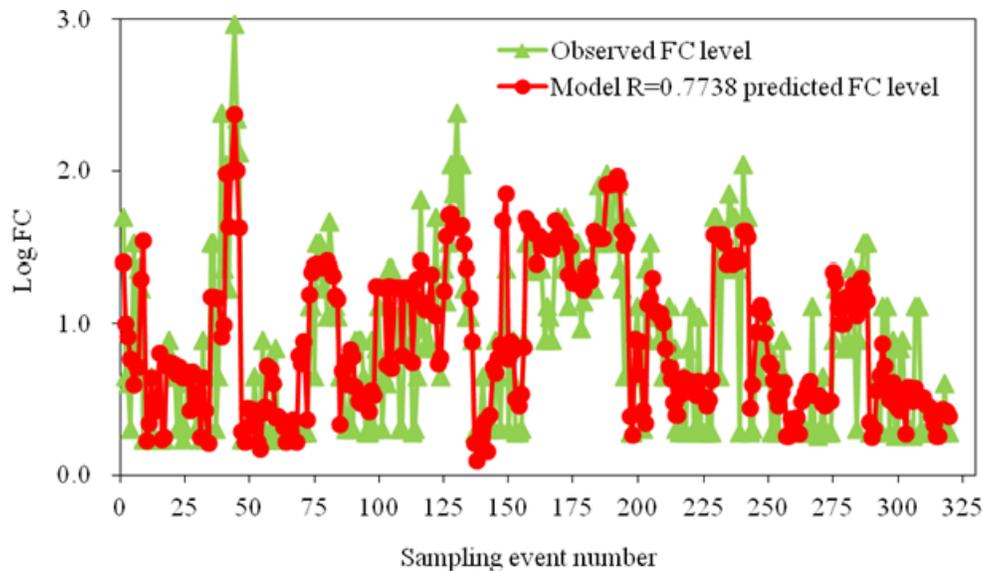

Figure 2. Comparison between the ANN model predicted and observed Ln(FC) levels

CONCLUSIONS

The following conclusions can be drawn from this study:

 (1) The Pollution Early Warning System (PEWS) could be utilized to make daily predictions of the level of fecal coliform bacteria in oyster growing areas, greatly reducing the cost involved in conventional field sampling and laboratory analysis of water samples.
 (2) The PEWS can help oyster monitoring programs make more informed decisions on closing contaminated oyster growing waters, reducing the human exposure to contaminated oysters and avoiding unnecessary oyster harvesting water closures.

REFERENCES

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