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NEAR SHORE WATER QUALITY ASSESSMENT FOR MONITORING COASTAL DEVELOPMENT IMPACTS IN THE BAHAMAS: CASE STUDIES IN SITE-SPECIFIC VARIABILITY.

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ABSTRACT

The Bahamas is a carbonate archipelago made up of many low-laying islands. Although 70% of the national population resides on New Providence, recent development initiatives have focused on encouraging large residential resorts on the Out Islands. All development is coastal, with the beach and ocean view as the intrinsic tourism attraction. Historical and recent alterations and development of the coastal zone pose a threat to near shore marine habitats through disruption of coastal processes. One of the primary changes in coastal environments is the degradation of near shore water quality, altering the suitability of these environments for fishes, invertebrates and marine plants. This degradation can result in decreased abundance of some species, overall loss of biological diversity and can impact long-term recruitment and reproduction cycles of marine organisms. Excess addition of nutrients to near shore waters (termed "eutrophication") has been documented as one of the most serious threats to coral reef resources globally.

A long-term study of near shore water quality conditions throughout The Bahamas was initiated in 2002 through the Coastal Ecology of The Bahamas project. The objective was to better understand the study design and methods to document variability in water quality parameters over tidal cycles and seasonally. The key parameters measured were temperature, salinity, turbidity, dissolved oxygen and sedimentation rates. Our results present an overview of water quality conditions from Great Guana Cay, Abaco. The presentation of water quality parameters in boxplots by month and tidal cycle illustrates natural and anthropogenic variability. Results found water quality is time consuming and resource intensive to evaluate, and thus it can be difficult to collect consistent long-term data sets that are useful for baseline comparisons. However, these are necessary for understanding coastal processes and how nutrients are processed in coastal waters.

INTRODUCTION

Water and the movement of water through the hydrologic cycle are at the heart of coastal ecological system function. Coral reefs and marine plants require specific water quality parameters for normal growth and procreation. Thus, water quality assessment is a critical component of any ecological study for coastal and marine systems and should be included in environmental monitoring programmes for tourism developments.

The term "water quality" is used to describe the collection of physical and chemical characteristics of water that support the functioning of near shore flora and fauna. Water quality *per se* does not mean crystal clear, potable water, but rather the unique combination of physical and chemical parameters that support ecological communities. Water quality can be described as a composite of key components whose characteristics are generally unique amongst marine habitats (Sullivan *et al.* 1995). Five main components of water quality are: 1) temperature and salinity: "master variables" that determine the density of seawater, 2) inorganic nutrients that influence plant growth, 3) pollutants, 4) contaminants such as PCBs and pesticides, and 5) pathogens such as fungi, viruses and bacteria. Most water mass parameters are considered conservative and it must be noted that there are wide-ranging temporal and spatial changes in water quality that are part of an area's natural oceanography and ecological cycle.

There are natural source events in the environment that cause stress and damage to the near shore ecosystem.. For examples, hurricanes that flush excessive sediments into bays and lagoons can cause damage to seagrass meadows or coral reefs. Anthropogenic source activities can cause more extreme or more frequent damage and a system may not be able to recover due to the nature of continuous degradation. Researchers has strive to develop methods for evaluating natural and anthropogenic sources that impact water quality. Lapointe and Matzie (1996) found that a high frequency of daily sampling was necessary to track the effects of episodic rainfall events on water quality. Storm event effects could be detected at considerable distances (12 km) from shore. Thus, "snapshots" should be avoided when interpreting water quality data, as parameters will likely fluctuate between tidal cycles, seasons and years.

The Bahamas covers six degrees of latitude with north to south patterns in climate and rainfall. Thus water quality parameters vary from island to island and extreme weather conditions and unpredictable events also need to be taken into consideration. Water quality studies must be designed to account for spatial and temporal variability, considering differing coastal geomorphology and oceanography. Development impacts need to be evaluated with at least 18 months of baseline studies, followed by assessments during and after construction.

METHODS

Water quality data was collected using both digital and analog machines. A YSI Model 85 water quality monitoring probe was used to collect temperature (degrees Celcius), salinity (parts per thousand (ppt) dissolved oxygen (DO) (mg/L DO). Sedimentation rates were obtained from sediment traps deployed for one to three days. Turbidity was assessed by two methods: 1.) visibility in meters using a Secchi Disk, and 2.) determination of micro-turbidity in Nephloid Turbidity Units (NTUs) with a La Motte nephelometer. NTUs account for the amount of particles suspended in the water. Long term water quality monitoring was accomplished through HACH LABORAOTRIES Hydrolab sensors (Data Sonde 4a and MiniSonde 4a). Sensors were left in place for up to six weeks to monitor temperature, salinity, pH, DO, and Turbidity.

Water quality parameters are reported as box plots. Typically, water quality data are skewed to the left (low concentrations and below detects) resulting in non-normal distributions. This results in an inflated mean value due to high outliers. Therefore, it is more appropriate to use the median as the measure of central tendency (Christian et al. 1991). The box plot is a useful statistic as it shows the median, range, the data distribution and it serves as a graphical, nonparametric Analysis of Variance (ANOVA). A box plot provides a graphical summary of data based on the quartiles which are used to split the data into four groups, each containing 25% of the measurements. The box contains 50% of the data, and the extremes of that box are the 1st and 3rd quartiles. The average value of the data set is the 2nd quartile value and the extremities of these whiskers are the minimum and maximum values of the data. Data analyses were performed by Statistica 6.0 software. Methodologies are explained in full in the document, *Tools and Methods in Coastal Ecology*, (Sealey *et al.* 2006).

RESULTS AND DISCUSSION.

Temperature and salinity are important master variables employed to understand how coastal processes impact water quality. Run-off, ground water seepage and evaporation all work to alter near shore salinity and temperature in the estuarine environment. The basic nature of these changes (scope and range of variability) are part of the dynamic environment that supports coastal species of plants, fish and invertebrates. Temperature is critical because it can influence dissolved oxygen levels, the rate at which algae and aquatic plants photosynthesize, the metabolic rates of aquatic organisms, how aquatic organisms are affected by different pollutants, parasites and pathogens, the solubility of solutes (e.g. calcium carbonate), and it determines the density of seawater. (Figure 1).

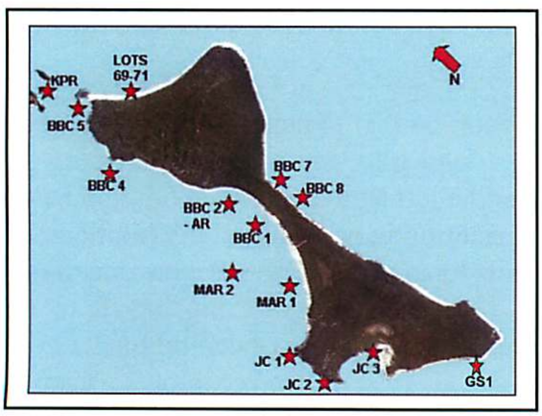

Figure 1: Map of water quality and benthic sampling stations around northern Great Guana Cay. Water quality sampling was carried out primarily in both discrete locations over time, and along transects over space. Water quality information is important to correlate to weather and rainfall conditions, thus the installation of a local weather station helps with the interpretation of variability.

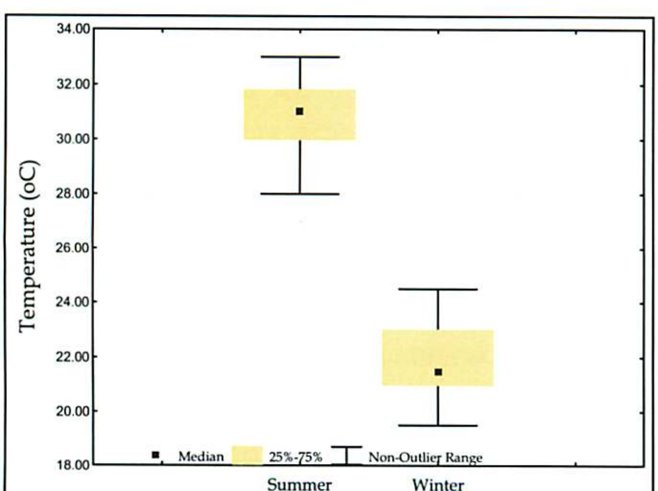

Figure 2. Box plot of summer and winter temperatures. Temperatures differed significantly between January and July-August (2005-2006) for Bakers Bay, Abaco. This particular year, winter temperatures reached a median of 21.5 degrees Celsius. The median temperature can be significantly lower on years with more cold fronts, or cold fronts impacting the northern Bahamas earlier in the winter months. Multi-year monitoring can help characterize the rate of seasonal temperature changes and severe weather events (e.g. high temperatures that may contribute to coral bleaching or extreme cold temperatures leading to fish kills).

Salinity is the total gram weight of dissolved substances (salts) in one kg of seawater and on average seawater has a salinity of 35 parts per thousand grams (ppt). Daily alterations in factors including weather, tidal cycles, and seasons can cause salinity levels to fluctuate (US EPA 2006). Most aquatic organisms function optimally within a narrow range of salinity and when salinity changes to above or below this range, an organism may lose the ability to osmo-regulate and thus become susceptible to biotic pressures such as predation, competition, disease or parasitism. Thus, changing salinity levels can affect the distributions of rooted vegetation (*e.g.* seagrasses) and sessile organisms (Boesch 1977, Alber 2002). In the Bahamas salinity levels can also be influenced by the amount of groundwater seeping into near shore waters and by large incursions of storm-water runoff.

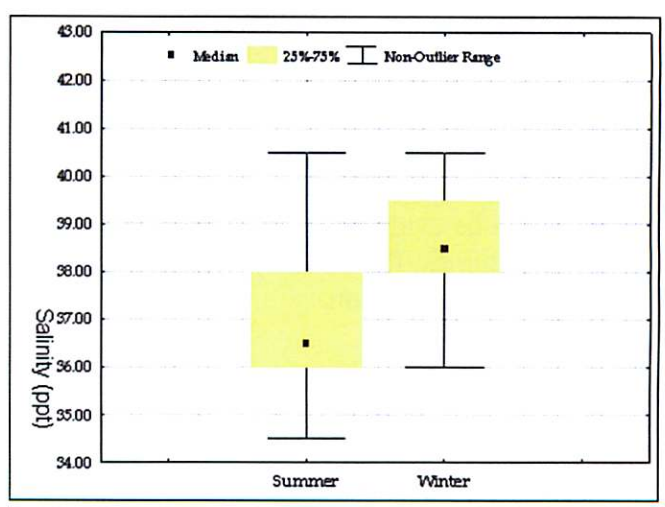

Figure 3 Box plot of summer and winter salinity for near shore environments of northern Great Guana Cay.

Summer salinity levels tend to be lower with acute rainfall events. Salinities differed significantly over seasons, and between years with variability in rainfall events. Coastal Development can drastically impact the coastal ecology of islands with the influx of water from Reverse Osmosis (RO) plants. Increased water usage on an island can alter estuarine environments by increased freshwater inputs.

The principal gases dissolved in seawater are oxygen and nitrogen. Nitrogen is conservative and changes by mixing only; whereas oxygen is not conservative because it's biologically active. The amount of dissolved oxygen (DO) in water controls the distribution of organisms, and serves as an indicator of the Biological Oxygen Demand (BOD). The end result of coastal eutrophication is increased nearshore algal and microbial production, that can drive down DO levels.

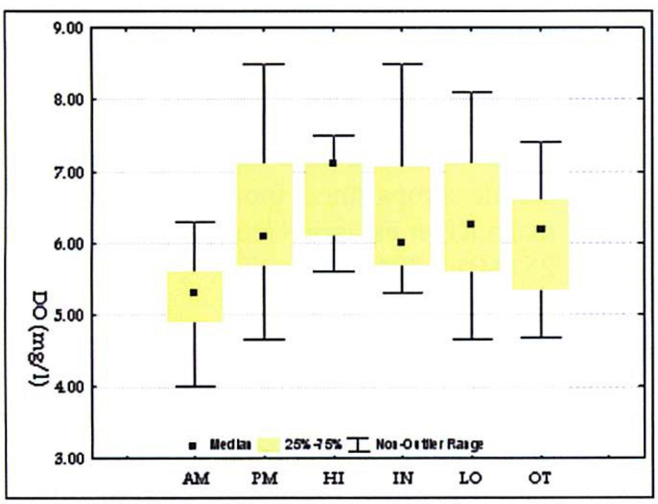

Figure 4. Box plot of dissolved oxygen (mg/l) from July-August 2005. Data are summarized as high tide (HI), incoming (IN), low tide (LO), outgoing (TO) and diurnal (AM and PM).

Turbidity is increased both with the increased concentration of suspended particles, and the increase in phytoplankton and microbial activity in the water column. Increased turbidity reduces the amount of light reaching the sea floor and acute turbidity events can impact the health of both coral reef organisms and seagrasses.

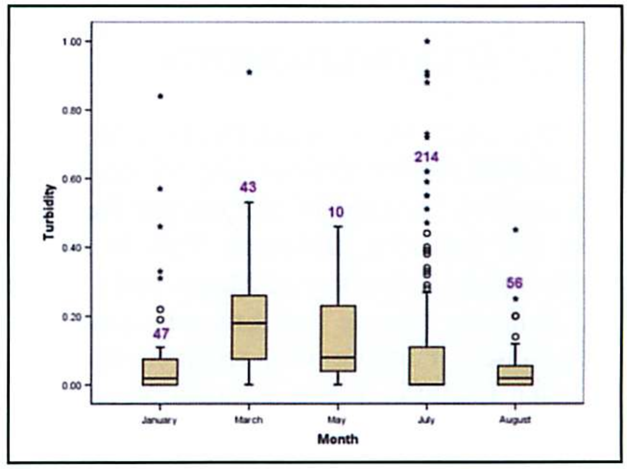

Figure 5. Box plot of turbidity (NTUs) over two years from near shore stations off northern Great Guana Cay. Turbidity events can be caused naturally by storm events and high winds. Human activities such as unmanaged clearing of coastal lands can exacerbate the impacts of storm events. Turbidity data is highly skewed, and the benthos is likely impacted by a few acute events. Monitoring turbidity needs to be long-term, and continuous to accurately characterize the coastal environment.

Water quality parameters are important for interpreting ecological findings and characterizing communities, however, quantifying the direct impacts of coastal development on water quality parameters is not a straightforward process. Changes in water quality parameters due to nutrient loading or land-cover changes may not be as readily detected as changes in biological communities (Sullivan-Sealey 2004). Thus, a mechanism for relating anthropogenic inputs to the health of a system is through the determination of relationships among water quality and biological communities which are sensitive to water quality parameters (Dennison et al 1993). Having information about water quality parameters is key to discerning why there are differences in fish abundances, coral growth, and invertebrate presence from site to site. Long-term monitoring of water quality parameters is an essential component of environmental management of coastal developments.

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