

AN ASSESSMENT OF SOUTH CAROLINA WATERS

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Abstract. South Carolina's coast is one of the fastest growing regions in the United States, prompting concern for the potential effects of coastal development on estuarine eutrophication that can lead to an increase in harmful algal blooms. One of the primary consequences is an increase in algal biomass that results in degradation of the coastal environment. A coastal survey program was developed to monitor water quality and phytoplankton community structure along the SC coast using fixed sampling sites that includes a monthly monitoring effort of 18-20 fixed sites providing the same spatial coverage of other programs (ie. NERRS and SCECAP) that already exist, but help to further expand their assessments by providing temporal coverage as well. The main intent of the coastal survey is to monitor dynamics of the phytoplankton community spatially and temporally and monitor for harmful and nuisance algae in the coastal waters of South Carolina. Also, regular monitoring allows us to understand anthropogenic impacts on estuarine water quality within the context of natural environmental variability. Fixed sampling sites were chosen because it allows for easy access to the sites, the ability for other interested parties to sample the same sites, and the opportunity to utilize volunteers as a tool for outreach. The data gathered during this research program will be used to determine water quality and generate a water quality index. We utilized the same indicators as the United States Environmental Protection Agency (USEPA) 2004 National Coastal Condition Report (NCCR). Other parameters collected were pH, temperature, salinity and phytoplankton composition. By using these published thresholds, we will be able to classify each sampling site as good, fair and poor. It should be noted that the water quality score can only be used as an indicator of the conditions at the site at the time of sampling. However, by sampling the same site regularly, we should be able to see trends and therefore make some broader statements of these systems. Phytoplankton assemblages seen within the coastal survey are generally dominated by a mixed diatom community. However, harmful species are routinely present in some portion of sites sampled each month.

When comparing the individual Southeast water quality indicators in the 2004 EPA NCCR report to the current Coastal Survey data, dissolved oxygen, chlorophyll *a*, dissolved inorganic nitrogen and phosphorous appear to be more degraded. Through this effort, we will help develop more effective management practices for water quality and HABs.

INTRODUCTION

The southeast coastal region is one of the fastest growing regions in the United States and the coastal region of South Carolina's population is expected to increase by 50% within twenty years (Blood and Smith 1996). With the increased population it would be expected that the land use would be increasingly urban and as urban expansion increases along South Carolina's coast, point and non-point source runoff will become a problem and could affect water quality to the estuaries and other receiving water bodies. With the increased input of nutrients into the coastal waters there can be increased algal growth and low dissolved oxygen leading to eutrophic conditions (Bricker et al 2007). Monitoring programs such as the National Estuarine Research Reserves (NERR), Urbanization and Southeastern Estuarine Systems (USES), South Carolina Estuarine and Coastal Assessment Program (SCECAP) and others have greatly expanded our knowledge of South Carolina waters. However, such programs require significant financial resources and staff. There exists to our knowledge, only one volunteer monitoring program in South Carolina; The Waccamaw River Volunteer Monitoring Project. While such programs are new to South Carolina, in other states they have become an important part of the statewide monitoring efforts. The Alliance Citizen Monitoring program in the Chesapeake Bay region has been sampling since 1985. Because such programs are of need in South Carolina, a pilot sampling program was initiated that obtain water quality measurements identified by the EPA's National Coastal Condition Report (2007) and general

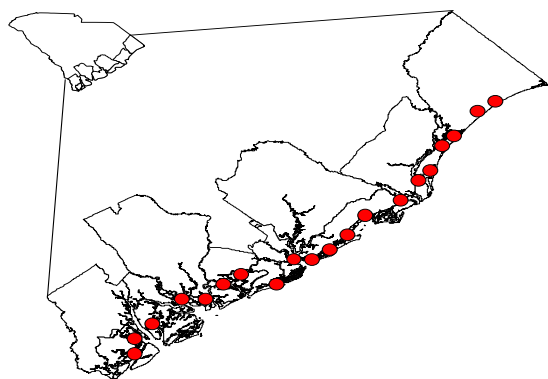


Figure 1 Spatial distribution of sampling sites for the Coastal Survey Monitoring Program

phytoplankton composition. This pilot program has demonstrated that while basic in its design and approach, it still has the ability to produce valuable data that can help inform resource managers, community municipalities and their citizens.

MATERIALS AND METHODS

Samples were collected monthly (when able) from 18-20 coastal sites along the coast of South Carolina (Fig. 1). Duplicate samples were collected during mid-day at low tide (± 2 h) in 1-l high-density polyethylene bottles from ~ 0.5 m below the surface. Prior to sampling, the bottles were washed in 10% HCL and rinsed six times with de-ionized water. Samples were kept in a cooler at ambient temperature, transported to the laboratory and processed within 4 h. Salinity, temperature, and dissolved oxygen concentration were measured at the time of sample collection using field YSI meters (YSI 85). Water clarity was determined by using a secci disk. Chlorophyll *a* samples were collected by vacuum filtration of samples onto GF/F glass fiber filters at 5 psi. One ml of saturated magnesium bicarbonate was added, and then the filters were frozen at -20°C until laboratory analysis. Chl *a* was extracted from the filters using 90% acetone according to the freeze-thaw method of Glover and Morris (1979). Fluorescence was measured using a TurnerTM 10-au fluorometer. Dissolved nutrients were analyzed after filtering through pre-combusted (450°C for 24 h) GF/F glass fiber filters. Ammonium (NH_4^+), nitrate/nitrite ($\text{NO}_3^-/\text{NO}_2^-$) and orthophosphate (PO_4^{3-}) were determined using a Lachat Quickchem 8000TM auto-analyzer according to the wet chemical methods of Grasshoff (1983), Johnson and Petty (1983), and Zimmerman and Keefe (1991). Dissolved inorganic nitrogen (DIN) was

determined as the sum of NH_4^+ and $\text{NO}_3^-/\text{NO}_2^-$, and dissolved inorganic phosphorus (DIP) as PO_4^{3-} . Water samples were screened for dominant algal species within 24 hours of collection (Shuler and Hayes, this proceeding). Samples for Dissolved inorganic nitrogen (DIN) dissolved inorganic phosphorus (DIP), dissolved oxygen and chlorophyll *a* were categorized by their concentration and classified as good, fair or poor, following the NCCR scheme. Water clarity was ranked and categorized by using the guidelines of the EPA (2002). The indicators and their scores are used to calculate and rank the Water Quality Index

RESULTS

The water quality index covering the entire sampling period indicates that when compared to either NCCR report, South Carolina is overwhelmingly “fair” while the former reports indicate that the South Eastern coastal condition, which includes South Carolina, is “good” to “fair” (Figure 2). The coastal survey also indicates that there is an increase in those sites that scored as “poor”. Elevated chlorophyll *a* and DIP values were the primary reason for the increase in the “poor” category. The relative dominance of NH_4^+ vs. $\text{NO}_3^-/\text{NO}_2^-$ as inorganic N source varied, with annual mean concentration of $\text{NH}_4^+ > \text{NO}_3^-/\text{NO}_2^-$ in the survey (Table 1) while the mean annual molar nitrogen to phosphorus ratio was close to the Redfield ratio of 16. Chlorophyll *a* values averaged greater than 10 mg/L with 24 % of the samples considered “poor” and 61% being “fair”. Nutrient and chlorophyll *a* did not correlate well with salinity, nor did DIN correlate with DIP indicating that the source for DIP was different than that of DIN (data not shown).

Table 1 Summary statistics for all nutrient and chlorophyll *a* data from the 2007-2008 coastal survey.

	NH_4 (μm)	NO_3+NO_4 (μm)	PO_4 (μm)	Chl <i>a</i> (μm)
Mean.	5.53	2.73	1.53	10.75
Std. dev.	5.51	5.18	1.20	15.59
Min.	0.04	0.00	0.11	0.55
Max.	65.40	36.00	7.75	178.10
Sample #	478	482	484	484

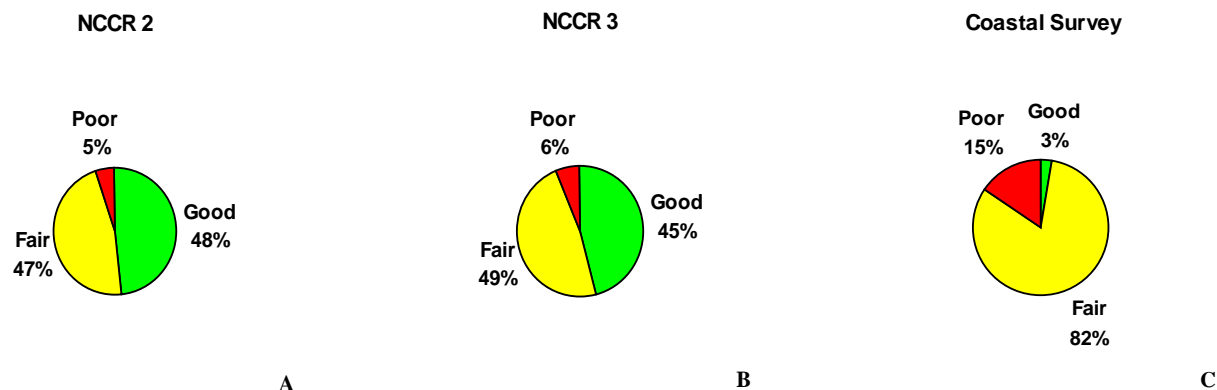


Figure 2 Water quality index data for the National Coastal Condition Report II (2001) (A), National Coastal Condition Report III (in review 2007) (B) and the data from the 2007-2008 coastal survey (C).

DISCUSSION

The coastal survey served as a way to determine if such a program was feasible, requiring nominal time and effort. It turns out that if adequately supported by state institutions, such a program is feasible. The coastal survey came about because of a need to get a broad spatial-temporal sampling coverage along the South Carolina coast. The primary interest was to assess phytoplankton composition and determine the seasonal distribution of the mixotrophic and harmful algal species. Utilizing EPA water quality standards would help to classify what sites are considered impaired and to see if there is a relationship between phytoplankton community structure and nutrient availability. The coastal survey data clearly indicate that the coastal waters that were sampled are more impaired when compared to the Southeastern condition in the NCCR II and III reports. There are several possible reasons for this. First, the NCCR data was primarily in the summer to fall periods while the coastal survey was over one whole season. Both covered the period of when the most obvious symptoms of eutrophication occur, but the latter considers seasonal conditions. NCCR II and NCCR III utilized data from 1997 to 2000 and 2001 to 2002 respectively while coastal survey covered from May 2007 to June 2008. Second, the NCCR data included data from upper North Carolina down to the southern tip of Florida while the data in this paper are from coastal South Carolina exclusively. It should be noted that most of the “good” ratings given to specific sites in the NCCR regional studies were overwhelmingly in North Carolina. When we look only at the South Carolina portion of the NCCR maps, South Carolina had mostly “fair” and “poor” ratings, which is consistent with what we saw in the coastal survey. Lastly, the predominance of harmful

algae along the coast year round is interesting because it is thought that South Carolina coastal waters are regional studies were overwhelmingly in North Carolina. When we look only at the South Carolina portion of the NCCR maps, South Carolina had mostly “fair” and “poor” ratings, which is consistent with what we saw in the coastal survey. Lastly, the predominance of harmful algae along the coast year round is interesting because it is thought that South Carolina coastal waters are relatively pristine and well flushed (Lewitus and Holland, 2003). Trying to establish water quality standards is incredibly difficult. South Carolina is still in the process of establishing numerical nutrient and chlorophyll *a* ranges for estuarine and coastal waters. Once such criteria are established then it will be easier to truly track impacted waters and begin to address the causes by engaging the EPA and SCDHEC. A problem arises with the selection of what nutrients need criteria. TN and TP are typically used because they indicate total loading into a system, however, if chlorophyll *a* is to be a major indicator of poor water quality and eutrophication, then those nutrients most likely to be utilized by phytoplankton (DIN and DIP) should also have criteria. According to Bricker et al. (2007), DON and DOP should be included as well because they can be an important form of usable N and P derived from many sources (e.g. atmospheric deposition, runoff from rain and irrigation events, phytoplankton DON release, N₂ fixation, microbial regeneration).

CONCLUSIONS and RECOMENDATIONS

Coastal South Carolinas waters are in “fair” to “poor” condition and the year around presence of harmful algae

should be viewed with caution. The coastal survey model worked well and would be greatly enhanced by the use of citizen scientists. The overall costs would be much lower than having full time scientists and the army of volunteers could do the work necessary to cover such large expanses of our coastline. One such case is the Casco Bay Estuary Partnership in Maine. They have been successful in sampling for more than twelve years and there data was used to help develop the Casco Bay Water Quality Health Index (Bricker et al, 2007). Coastal Carolina University's Waccamaw Watershed Academy (WWA) supported by the Center for Marine and Wetland Studies (CMWS) has been sampling along the Waccamaw River using citizen scientists for more than two years to address water quality and the overall health of the watershed. In 2001 the South Carolina Phytoplankton Monitoring Network was established. That program uses citizen scientists to monitor our coastal waters for harmful algae. It is obvious that using volunteers that have been properly trained can be a valuable tool and South Carolina is defiantly trailing other states in this area.

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