WATER QUALITY STATUS OF GEORGIA ESTUARIES AND COASTAL WATERS USING RECOMMENDED INDICATORS

Merryl Alber and Joan E. Sheldon

AUTHORS: Dept. of Marine Sciences, University of Georgia, Athens, GA 30602.
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Abstract. Water quality is a concern in many estuaries, and the U.S. EPA has mandated the development of numeric nutrient criteria to assess the status of U.S. coastal waters. We have proposed a suite of seven indicators that are intended to help classify and understand the causes of water quality degradation in Georgia by covering the progression of eutrophication from nutrient over-enrichment to algal overgrowth (if present) to enhanced microbial respiration and hypoxia. Of these, we are able to assess four indicators coastwide using data collected by GA DNR CRD during 2003-2006. pH status was assessed using ΔpH, the deviation from the expected pH according to the sample salinity and estuary type (alluvial/tidewater, blackwater, alkaline blackwater). Annual median pH deviations were classified as good at almost all sites in all years, whereas annual minimum pH deviations often ranged into the fair and poor categories. pH status generally improved from 2004 to 2006. Annual median dissolved oxygen (DO) was mainly good to fair, while annual minimum DO was mainly fair to poor, with sites classified as poor occurring sporadically along the coast. DO status generally improved from 2003 to 2006. Annual median dissolved inorganic nitrogen status was mostly fair coastwide in all years, with the few sites classified as poor concentrated in the Altamaha River estuary. Annual median total dissolved phosphorus was fair coastwide during the study period. The generally poorer water quality in 2003 compared to later years may have been due to conditions related to high rainfall after a severe drought.

INTRODUCTION

Georgia coastal waters are home to commercially and recreationally important species such as fish, shrimp, crabs and oysters as well as the smaller organisms on which they feed. They are also important areas for nutrient cycling and the treatment of waste and runoff. The condition of our coastal waters affects fishing and shellfishing as well as other human uses of the coast, such as boating and swimming.

The Coastal Resources Division (CRD) of the Georgia Dept. of Natural Resources (GA DNR) has collected water quality data in support of a variety of programs. We recently compiled these observations into an integrated database and analyzed it for long-term and seasonal trends (Sheldon and Alber 2010). As a part of that effort, we proposed a set of seven indicators and recommended criteria intended to help classify and understand the causes of water quality degradation in Georgia. These indicators, which are described in a companion GWRC paper (Sheldon and Alber 2011) that also details how the criteria were selected, are pH, dissolved oxygen, nitrogen, phosphorus, chlorophyll *a*, transparency, and biochemical oxygen demand (BOD), along with some basic ancillary data (water temperature, salinity, specific conductance).

In this paper we use the CRD data to assess the status of Georgia estuaries and coastal waters according to the criteria recommended for each of these indicators. At the present time we do not have data to assess chlorophyll *a* and BOD, and the turbidity data collected by CRD are not directly relatable to the recommended transparency criteria. This paper therefore only describes the status of the remaining four parameters. It is our hope that assessments of all seven of these indicators will be conducted on a regular basis moving forward in order to provide ongoing information on the status of Georgia's estuarine and coastal waters.

METHODS

The data used in this evaluation were collected by four GA DNR CRD water quality monitoring programs: the Shellfish Sanitation program monitors shellfish harvesting areas; the Sound program measures water quality in Georgia's sounds; the River program measures water quality in the lower reaches of the Ogeechee, Altamaha and St. Marys rivers; and the Beach program monitors recreational beaches (Fig. 1). Sampling frequency is generally monthly at River and Sound sites, bimonthly at Shellfish sites, and weekly to quarterly at Beach sites depending on each site's usage classification. Below we describe the data that were used to evaluate water quality status and the criteria used for each proposed indicator. For information on analytical methods and the full suite of measurements available for each program, see Sheldon and Alber 2010. The status evaluations described here are based on calendar years using criteria to ensure sufficient sampling frequency and distribution throughout each year at each site. Where annual minimum or maximum values

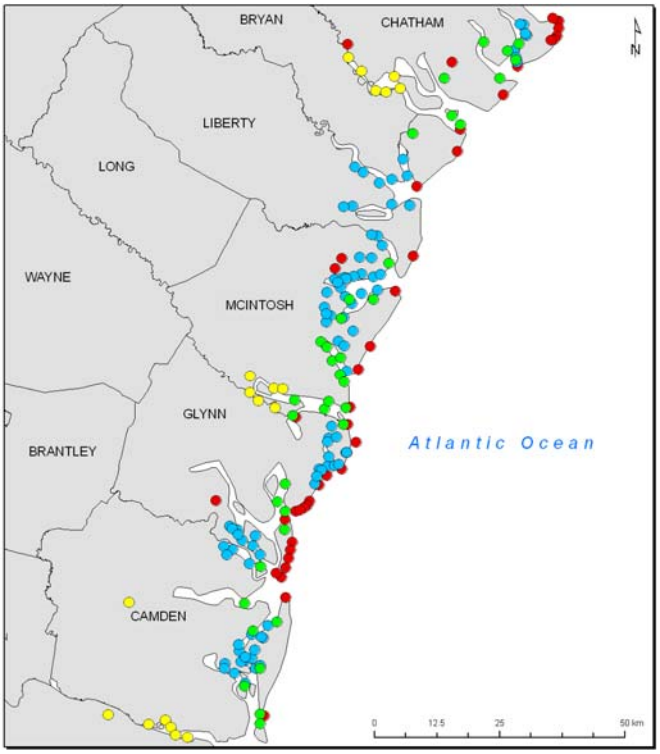


Figure 1. Sites monitored by four water quality monitoring programs conducted by GA DNR CRD along the GA coast: Beach Water Quality Monitoring (red); River Nutrient Monitoring (yellow); Sound Nutrient Monitoring (green); Shellfish Sanitation Program (blue).

are reported, they denote the lowest (or highest) value reported in a given year.

pH

pH is measured by all four programs. pH was assessed using ΔpH, the deviation from the expected pH according to the sample salinity and estuary type (blackwater, alkaline blackwater, and alluvial/tidewater; see Sheldon and Alber 2011). Deviations of less than 0.5 pH unit were considered "good", those between 0.5 and 1 were considered "fair", and those greater than 1 were considered "poor." Both the annual minimum (most extreme negative) and annual median ΔpH values from 2004-2008 were evaluated for each site.

Dissolved Oxygen

Dissolved oxygen (DO) is measured by all four programs. DO values greater than 5.5 mg L^{-1} were considered "good", those between 3 and 5.5 mg L^{-1} were considered "fair", and those lower than 3 mg L^{-1} were considered "poor." Both annual minimum and annual median DO values from 2000-2008 were evaluated for each site.

Phosphorus

Total dissolved phosphorus (TDP) is measured at River, Sound, and Shellfish sites. TDP concentrations lower than 0.01 mg L^{-1} were considered "good", those between 0.01 and 0.1 mg L^{-1} were considered "fair", and those greater than 0.1 mg L^{-1} were considered "poor." Annual median values from 2002-2006 were evaluated for each site.

Nitrogen

The indicator criteria were developed to evaluate total dissolved nitrogen (TDN). However, CRD has so far measured only dissolved inorganic nitrogen (DIN), which is the sum of the component measurements of ammonia, nitrite, and nitrate. In order to have at least a rough estimate of the nitrogen status of Georgia coastal waters, we assumed that DIN is approximately 25% of TDN in Georgia coastal waters and we compared DIN to criteria representing 0.25 times the recommended TDN criteria. We therefore considered DIN concentrations lower than 0.025 mg L^{-1} "good", those between 0.025 and 0.25 mg L^{-1} "fair", and those greater than 0.25 mg L^{-1} "poor." DIN components are measured at River, Sound, and Shellfish sites. Annual median values from 2002-2006 were evaluated for each site.

RESULTS

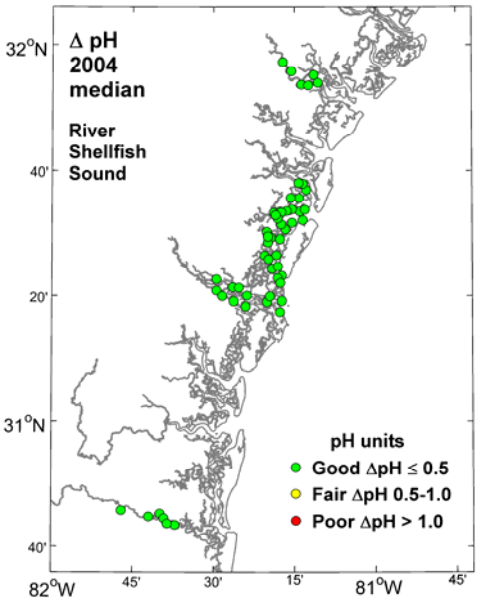
The discussion below focuses primarily on 2003 and 2006. 2003, which was characterized by high rainfall after a drought, was the first year when there were enough observations for most parameters to classify their status. 2006, which was a dry year, is the most recent year with data available from all programs. However, the full report (Sheldon and Alber 2010) includes annual status maps of each parameter for all years when data were sufficient.

pH

pH status based on annual median pH deviations was good at all sites in all years except for two sites in 2006 (Fig. 2). In contrast, annual minimum pH deviations often ranged into the fair and poor categories. During 2004 ten sites, mostly in the Ogeechee and St. Marys rivers, were classified as poor in terms of their minimum pH. pH conditions were generally better coastwide in 2006, with no sites classified as poor (Fig. 3).

Dissolved Oxygen

Annual median DO was generally good to fair, with no sites having poor annual median DO in any year. Median DO was markedly poorer coastwide in 2003 than in other years, with only 13 sites (out of 125) classified as good (Fig. 4). These were mostly in Altamaha and Doboy



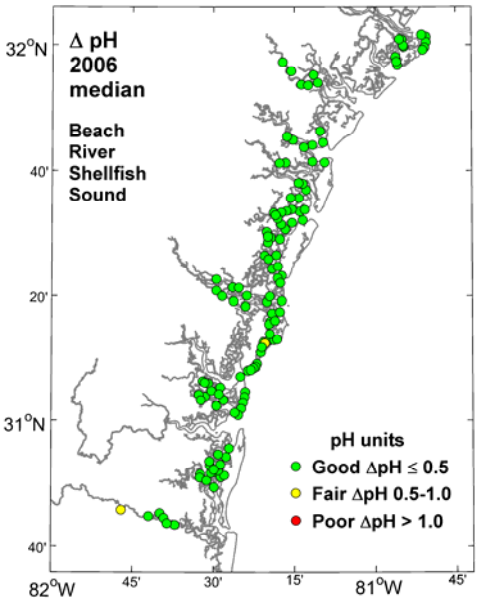
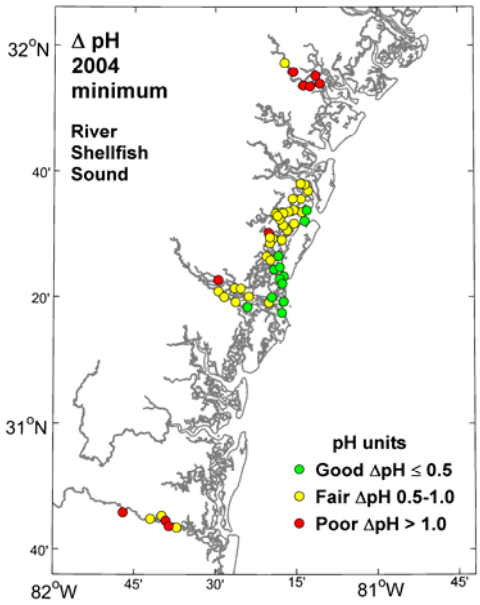


Figure 2. Annual median pH deviation status at sites sampled by GA DNR CRD during 2004 and 2006 for programs noted on maps.



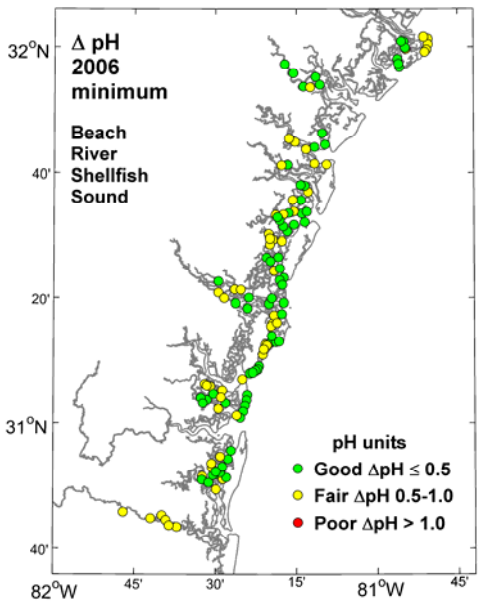


Figure 3. Annual minimum pH deviation status at sites sampled by GA DNR CRD during 2004 and 2006 for programs noted on maps.

sounds. Median DO was considerably better in 2006 than in other years, with all but three sites classified as good (and these three sites had DO concentrations at the upper end of the fair range). Annual minimum DO was generally fair to poor. Sites classified as poor were not consistently concentrated in specific locations, but rather occurred sporadically along the coast. Minimum DO was markedly poorer in 2003 than in other years, with 65% (81 of 125) of the sites classified as poor and the remaining 35% classified as fair (Fig. 5). These proportions improved in later years, with 12% of sites classified as poor and 87% classified as fair in 2006.

Phosphorus

Annual median TDP was fair at all sites throughout the study period (not shown).

Nitrogen

An average of 92% of sites from the three programs were classified as fair between 2003 and 2006. Sites classified as poor were located in the Altamaha River (Fig. 6). Only a few sites sporadically showed good annual status.

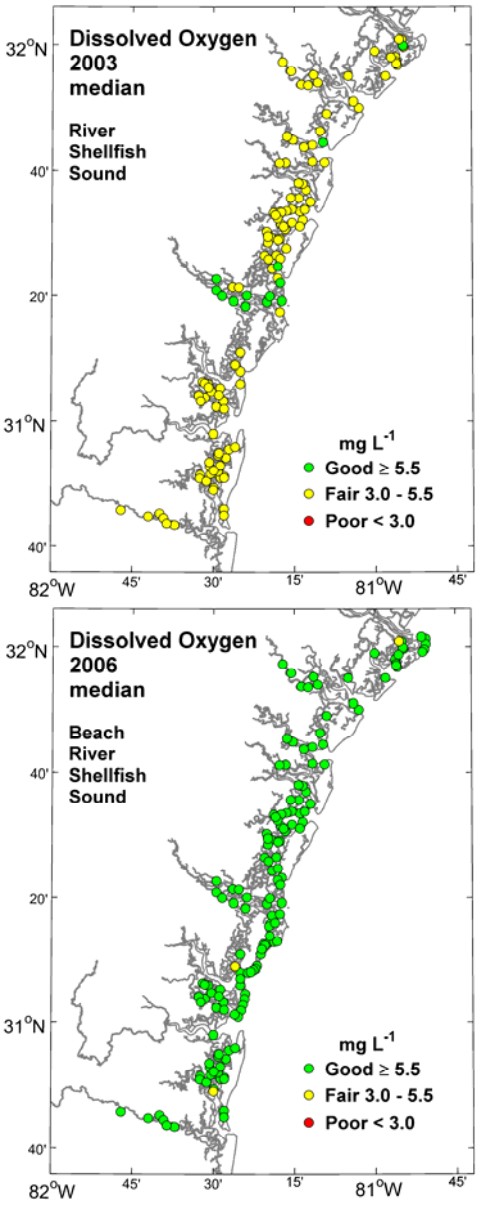


Figure 4. Annual median dissolved oxygen status at sites sampled by GA DNR CRD during 2003 and 2006 for programs noted on maps.

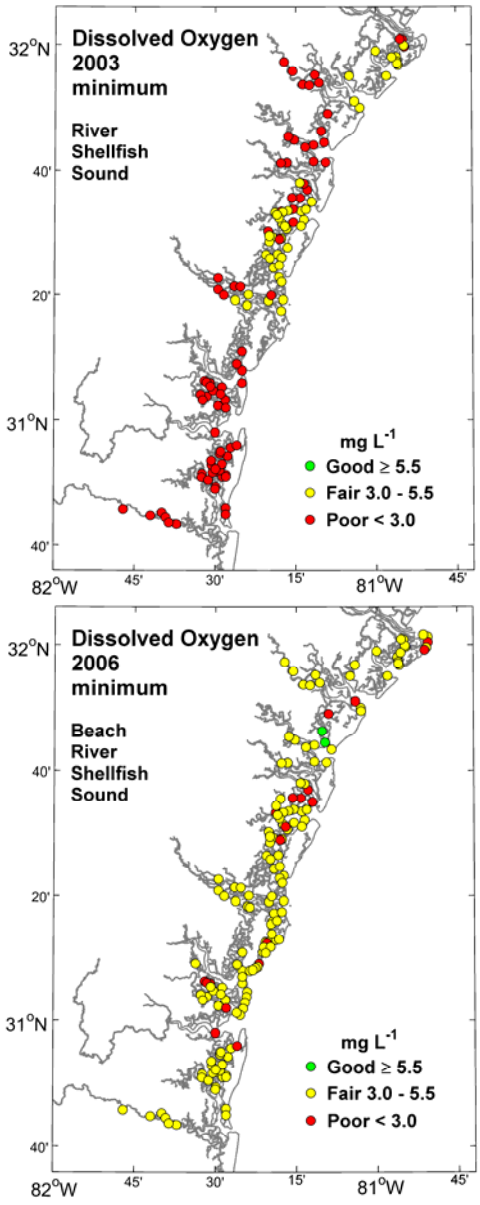


Figure 5. Annual minimum dissolved oxygen status at sites sampled by GA DNR CRD during 2003 and 2006 for programs noted on maps.

Multiple Criteria

Another way to evaluate status is to examine individual sites to determine if a site ranked as poor in more than one category or year. In 2003 annual minimum DO was classified as poor at 81 sites. Of these only sites in the Altamaha River were also classified as poor in terms of DIN. In 2004 there were two sites in the St. Marys River that were classified as poor in terms of both their annual minimum pH and DO, and one site in the Altamaha River classified as poor for minimum pH and median DIN. This was similar to 2005, when two sites in the St. Marys River and one in St. Andrew Sound were classified as poor in terms of minimum pH and DO (note that only one of the St. Marys sites had also shown two poor measurements in 2004). In 2006 no sites were classified as poor in more than one category. This suggests that poor water quality was sporadic, with no locations standing out in particular.

The differences in numbers of poor status sites between years can also be evaluated. 2003 had numerous sites classified as poor in terms of minimum DO, with most other observations (median DO, DIN, and TDP) classified as fair. This improved in 2004, with minimum DO improving to fair and median DO improving to good at most sites. 2005 and 2006 were similar to 2004 in terms of DO, but there was improvement in pH. These results

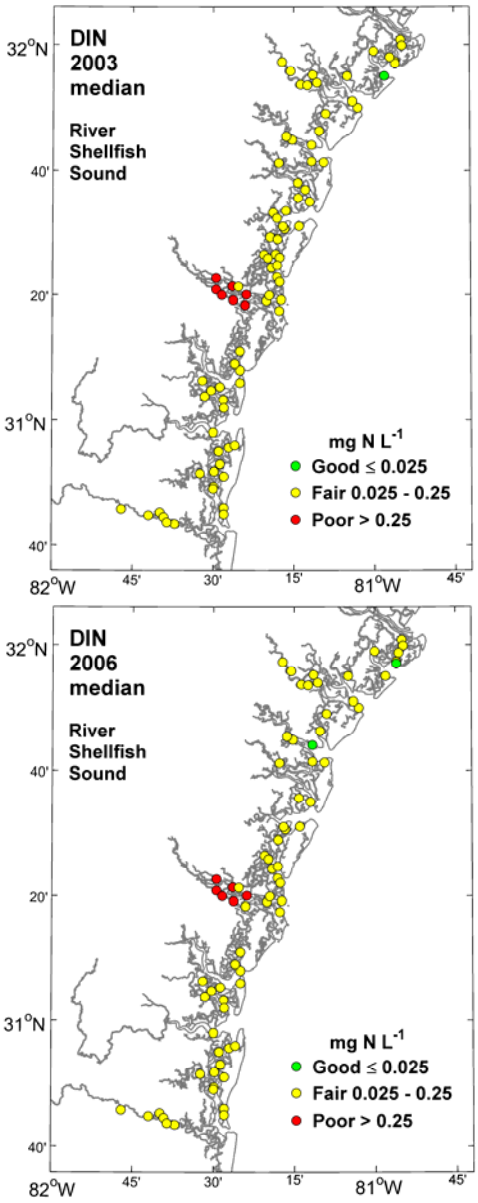


Figure 6. Annual median nitrogen status (using DIN) at sites sampled by GA DNR CRD during 2003 and 2006 for programs noted on maps.

will need to be extended to be able to say anything definitive about long-term trends, but they suggest that water quality was poorer in 2003 compared to later years.

DISCUSSION

The results presented here represent an initial evaluation of the status of Georgia coastal and estuarine waters. Our analyses indicate that the status of individual sites can vary, with some areas being classified as poor one year and good the next. Note that a designation of "fair" or "poor" is not necessarily a result of human activities, as natural processes can determine an area's status. Regardless of their cause, however, these classifications can still indicate potential problems.

GA DNR CRD now has a growing record of water quality data for the Georgia coast. It is critical that this continue, both to identify areas of potential concern and to evaluate trends over time..

The proposed indicators used in this assessment were recently submitted to GA DNR CRD for their consideration. If these indicators were to be adopted, the following changes to the state's monitoring programs would be required:

- CRD currently measures DO, pH and ancillary data (salinity, conductivity and water temperature). These should be continued on a regular basis.
- CRD currently measures inorganic nitrogen (DIN) and both inorganic and total dissolved phosphorus. We recommend that CRD instead measure both total dissolved (TDN, TDP) and particulate (PN, PP) material, and then use this information to calculate total nitrogen (TN = TDN + PN) and phosphorus (TP = TDP + PP).
- CRD currently measures nephelometric turbidity, but objective criteria for this are not available and the data are not comparable to measures of transparency. We recommend that CRD switch to a measure of transparency, such as % light transmission or Secchi depth, to facilitate comparison with other studies and compliance with likely EPA requirements.
- Chlorophyll *a* and 5-day BOD, which are not currently being measured, should be added to the monitoring programs. Chlorophyll is a critical response variable that can be use to evaluate whether algal biomass increases in response to nutrients. 5-day BOD will provide information on the availability of organic matter to microbes, which is another potential pathway to eutrophication (see Sheldon and Alber 2010, 2011).

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