Summary Report
New Hampshire National Coastal Assessment
2002-2005

A final report to the United States Environmental Protection Agency,
Office of Research and Development, Atlantic Ecology Division

Submitted by

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Introduction

The National Coastal Assessment program provides a necessary complement to the existing monitoring programs in coastal New Hampshire. The dual purposes for this project are (1) to fill some of the monitoring gaps currently not targeted through routine monitoring by the State of NH, UNH and others, and (2) to develop state infrastructure and capacity for long-term estuarine monitoring and data analysis. The U.S. Environmental Protection Agency (EPA) supported a four year (2002-2005) monitoring effort through seed funding and training. NHDES, in partnership with UNH/JEL, took advantage of this assistance to create the capacity for periodic monitoring and reporting on the health of the estuarine systems.

The NCA monitoring program employs a probabilistic design using ecological response indicators, along with diagnostic indicators. The probabilistic survey allows data managers to extrapolate to all estuarine resources with measured confidence limits. No pre-existing monitoring stations from other monitoring programs are used, since none fit the requirements of randomness.

The base program suite of analyses conducted at each station includes the following EPA recommended parameters:

1. Water Physiochemistry (temperature, salinity, pH, dissolved oxygen, water clarity)
2. Water Quality (nitrogen, phosphorus and silica species; total suspended solids, chlorophyll-*a*)
3. Sediment Quality (toxic contaminants, sediment toxicity, total organic carbon, grain size)
4. Tissue contaminants (toxic contaminant concentrations)
5. Habitat (occurrence of submerged aquatic vegetation, macroalgae, others)
6. Living Resources (finfish abundance)

The data obtained from the monitoring program can be used to make statements about the condition of estuarine resources on a state level. The data collected by New Hampshire will also be included in the analyses performed at the regional and national levels by EPA.

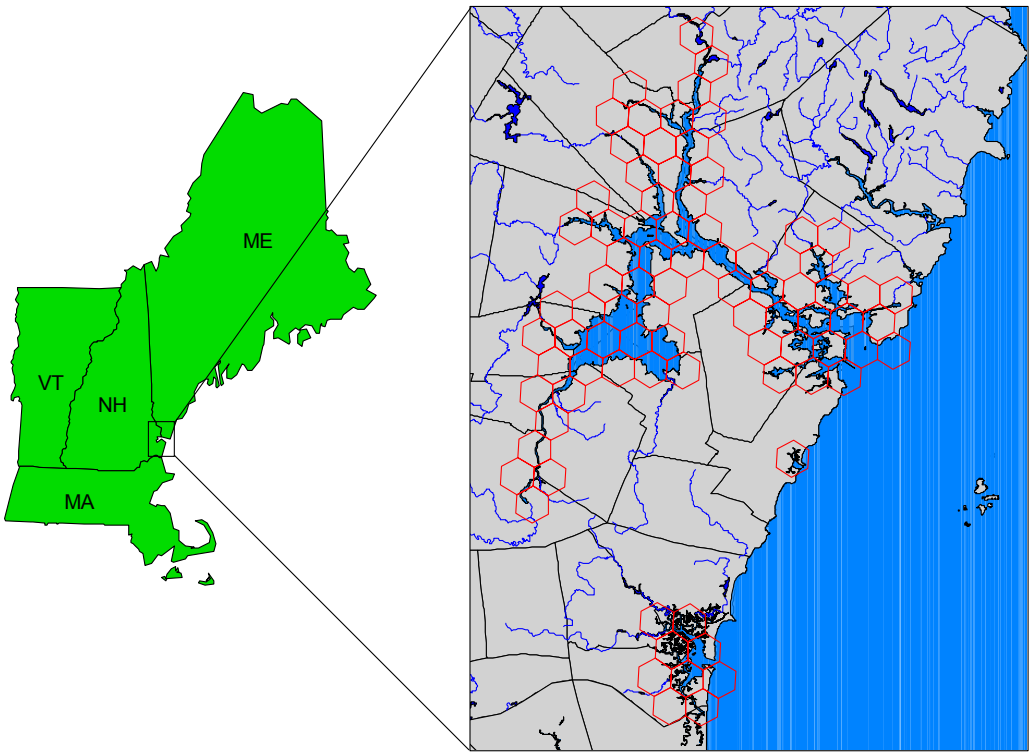
The objectives for this report are to:

- Summarize study design and methods for the 2002-2005 dataset
- Compare the results for water indicators from 2002-2003 to 2004-2005
- Review annual trends for the 2002-2005 period

Methods

The National Coastal Assessment study design for the sampling years 2002-2005 was a stratified random probabilistic survey of all estuarine waters in the Great Bay Estuary and the Hampton/Seabrook Estuary. This resource was overlain by a grid of 82 equal area hexagons covering 56.3 square kilometers of estuarine waters in New Hampshire and Maine. Each hexagon spanned 322 hectares.

National Coastal Assessment Study Area, 2002-2005



The resource was surveyed by monitoring water quality, sediment quality, benthic community indicators, and fish at a randomly chosen location in each hexagon during the index period of July 1 through September 30. Within each hexagon, three random sampling locations in the estuarine resource were generated using ArcInfo software. The first random point was designated the "A" site. The second and third random points were designated the "B" and "C" sites, respectively. Field teams from UNH visited the A sites in each hexagon. If the crew was unable to collect a sample at the A site, the crew went to the B site. If the B site was also unsuitable, the sample was collected from the C site.

During the four year period, field crews collected two rounds of water samples from each hexagon. The first round of samples was collected in 2002 and 2003 (81 of 82 stations sampled). The second round was collected in 2004 and 2005 (80 of 82 stations sampled). One quarter of the stations were sampled for sediment during each year. By the end of the four year period, 80 of the 82 hexagons were successfully sampled for sediments. Samples were missed due to difficult field conditions or unsuitable substrate. Fish trawls were attempted at 81 of the 82 hexagons unless the station was located in Maine waters where trawling was prohibited. For the 2002-2003 period, 37 of the trawls were successfully completed and 18 fish tissue samples were collected. In 2004-2005, 38 of the trawls were successfully completed and 19 fish tissue samples were collected. The field crews followed nationally standardized protocols for sample collection (EPA, 2004).

The survey data from all of the hexagons were aggregated to generate estimates of the percent of the whole resource meeting certain criteria (Appendices A and B). The Horvitz-Thompson Estimator Method for a continuous resource with a known subpopulation size and equal

weighting was used (see Methods 1 and 10 in EPA, 1996). Confidence intervals on the estimates were generated for the 95% percentile for binomial population per guidance from EPA. For annual box plots (Appendix C), a cumulative distribution function was generated for all the results for each year, which was weighted by the probabilistic design factors for each hexagon. The 5^{th}, 25^{th}, 50^{th}, 75^{th}, and 95^{th} percentiles were taken from the cumulative distribution function and used to generate the box plots. All the measurements for a parameter taken during a station visit were averaged (e.g., top and bottom water samples). For results reported as below detection limits, the method detection limit was assumed to be the value. The water parameters that were analyzed for this report were: water temperature, salinity, pH, dissolved oxygen, nitrate+nitrite, orthophosphate, silica, chlorophyll-a, total suspended solids, enterococci, *E. coli*, and fecal coliforms. Sediment data and fish tissue data were not included in this report because these results were still being quality assured by EPA.

Water data from the 2002-2005 seasons were quality assured by EPA and NHDES. Quality assurance checks and modifications to the original datafiles are documented in annual QA memos. The final datasets for water quality and sediment quality have been imported to the NHDES Environmental Measurement Database and the EPA STORET database. Data can be downloaded from the NHDES Environmental Measurement Database at: http://www.des.state.nh.us/OneStop/Environmental_Monitoring_Query.aspx. (query data for "National Coastal Assessment Probability Based Monitoring" under the Project Name field). Additional datasets and metadata are available from the EPA at: http://www.epa.gov/emap/nca/html/regions/northeast.html

Results and Discussion

The following discussion refers to summary results (maps, pie charts) for the 2002-2003 design and the 2004-2005 design, as well as trend plots for the 2002-2005 period. These results are presented in Appendix A, Appendix B and Appendix C, respectively.

During the summer index period, NH's estuaries stratify into distinct areas with different water temperature. At some stations in Portsmouth, Little and Hampton harbors, the temperature matched the Gulf of Maine offshore waters (≤15 degC). The lower Piscataqua River, Rye Harbor and some stations in Hampton, Little and Portsmouth harbors exhibited higher temperatures (15-20 degC). Finally, the upper Piscataqua River, Great Bay, Little Bay and tributaries had the highest temperatures (>20 degC) of the system. There was no apparent trend in the temperature distribution in NH's estuaries from 2002 to 2005.

The geographic distribution of salinity was similar to that for water temperature. The salinities in Hampton, Rye, Little and Portsmouth harbors were equivalent to offshore waters (>30 ppt). Lower salinities (25-30 ppt) were observed in the lower Piscataqua River, Great and Little bays and the Bellamy River. The lowest salinities (<25 ppt) were measured in the upper Piscataqua, Squamscott, Lamprey, Oyster and the Cocheco rivers. In general, the salinity of the bay was lower in 2004-2005 than in 2002-2003. The percent of estuarine area with greater than 30 ppt salinity was 38% in 2002-2003 and only 11% in 2004-2005. The trend plots show a strong decrease in salinity over the four year period. Annual freshwater discharge to the estuary increased from drought conditions in 2002 to above average in 2005. The probabilistic sampling during the summer season was able to detect this hydrologic shift.

There were no distinct geographic patterns for pH, except that the lowest range (<7.5) was typically observed in the Squamscott and Salmon Falls rivers. There was a distinct decrease in the

overall average pH from 2002-2003 to 2004-2005, possibly related to lower salinities/fresher water. In 2002-2003, only 1.9% of the estuary had pH values below 7.5. In 2004-2005, this percentage had increased to 20.9%. The trend plot indicates that the biggest decrease in pH occurred between 2004 and 2005.

Dissolved oxygen in New Hampshire estuarine waters meets State water quality standards in 99% of the estuarine area. In 2002-2003, only two measurements less than 5 mg/L were recorded, one in the upper reaches of the Squamscott River and the other in Spinney Creek. Previous results have shown DO to be low in the Squamscott River and Spinney Creek, which is a relatively shallow salt pond that experiences occasional episodes of low DO. All of the DO observations in 2004-2005 were greater than 5 mg/L. In general, the estuary was more oxygenated in 2004-2005 as compared to 2002-2003. The percent of the estuary with DO concentrations greater than 8 mg/L was 32.2% in 2002-2003 and 61.8% in 2004-2005. However, the trend plot does not indicate a strong temporal change.

NHDES has not established criteria for nitrogen and phosphorus in estuaries. However, EPA used 0.1 and 0.5 mg/L as the cut points between good, fair, and poor water quality for dissolved inorganic nitrogen (DIN) in the National Coastal Condition Report II (EPA, 2004b). The data presented in this report only include nitrate and nitrite, but not ammonium which is also part of DIN. Despite this, if these cut points are applied to the nitrate/nitrite data from NH's estuaries, 86 to 95% of the nitrate/nitrite concentrations were <0.1 mg/L. The highest concentrations were consistently located in the upstream reaches of the tidal rivers. There was no apparent trend in the nitrite/nitrate distribution from 2002-2005.

The EPA cut points for dissolved inorganic phosphorus (DIP) in the National Coastal Condition Report II (EPA, 2004b) were 0.01 and 0.05 mg/L. Applying these cut points to data from NH's estuaries, 79% of the DIP concentrations fell in the middle range. However, the DIP concentrations were greater than 0.05 mg/L for 21% of the estuary in 2002-2003 and only 6.2% of the estuary in 2004-2005. The high DIP values were all in the Great Bay Estuary, in the Bellamy, Oyster, Lamprey and Squamscott rivers and at stations close to the shoreline of Great and Little bays. The lowest DIP concentrations were located in the upstream areas of the tidal rivers – the opposite pattern as was observed for nitrate/nitrite. The trend plots indicate decreasing concentrations of DIP over time.

Dissolved silica levels were highest in the upper reaches of the tidal rivers, which is consistent with the a land-based source for this element. Sites with elevated silica concentrations tended to coincide with the sites with the highest levels of chlorophyll *a*. There was no change in the distribution of silica concentration from 2002 through 2005.

The majority of chlorophyll-*a* concentrations in the estuary were below 5 ug/L, 92% in 2002-2003 and 84% in 2004-2005. In the shallow tributaries to Great Bay, the Upper Piscataqua River and Spruce Creek, the concentrations tended to be higher, between 5 and 20 ug/L. Concentrations greater than the NHDES assessment criterion of 20 ug/L occurred in the Squamscott River, Lamprey River, Cocheco River, at the mouth of Pickering Brook and in Sturgeon Creek. The estuarine area with greater than 20 ug/L of chlorophyll-a was 2% in 2002-2003 and 1% in 2004-2005. The trend plot did not indicate any change in the chlorophyll-a distribution from 2002-2005.

The concentrations of total suspended solids (TSS) were lower in 2004-2005 than in 2002-2003. The percent of the estuary with concentrations below 10 mg/L increased from 30.4% in 2002-2003 to 72.4% in 2004-2005. Similarly, the percent of the estuary with concentrations greater

than 50 mg/L decreased from 11.7% in 2002-2003 to 1.7% in 2004-2005. Elevated TSS concentrations were spread throughout the estuary: the Squamscott River, Great Bay and Little Bay, and Back Channel. TSS can be influenced by resuspension of sediments on windy days, which may explain the elevated levels in Great and Little bay stations. The trend plot indicates a decrease in the median concentrations and the variability of TSS over the 2002-2005 period.

There are standards for concentrations of bacterial indicators in surface waters set by the State of New Hampshire. The strongest signal was observed for the fecal coliforms indicator. The concentrations of fecal coliforms were higher than 43 cts/100ml (one of the shellfish harvesting standards) in 1.2% of the estuary in 2002-2003 and 13.2% of the estuary in 2004-2005. The elevated concentrations occurred in the tidal rivers and Portsmouth Harbor. The increase in concentrations and the pattern of elevated levels are all indicative of increased stormwater loads of bacteria associated with increased rainfall. As demonstrated with the salinity measurements, the estuary received higher annual stream flows during the 2004-2005 period than during the 2002-2003 period. Enterococcus and *E. coli* concentrations were typically less than their State standards and did not change much over time. Violations of the standards for these indicators occurred in less than 4% of the estuary.

Conclusions and Recommendations

The switch from drought conditions in 2002-2003 to above average precipitation in 2004-2005 resulted in significant changes in several water quality parameters from one period to the next. The salinity in the bay decreased from 2002-2003 to 2004-2005 and fecal coliform bacteria concentrations increased. Both of these trends would be expected given the increase in stream flow and stormwater runoff.

The concentrations of dissolved inorganic phosphorus and total suspended solids both decreased from the 2002-2003 period to the 2004-2005 period. It is not clear whether these changes were related to the increasing stream flow or some other factor.

The water quality changes in the system demonstrate the need to repeat PBM sampling annually to obtain a baseline distribution that is not affected by regional hydrologic patterns. Therefore, PBM sampling for water (at least) should continue in NH's estuaries.

References

EPA (1996) EMAP Statistical Methods Manual. U.S. Environmental Protection Agency, Office of Research and Development, National Health and Environmental Effects Research Laboratory, Corvallis OR. May 1996.

EPA (2004) Coastal 2000, Northeast Component, Field Operations Manual. EPA/620/R-00/002. U.S. Environmental Protection Agency, Office of Research and Development, Washington DC. Revised 2004.

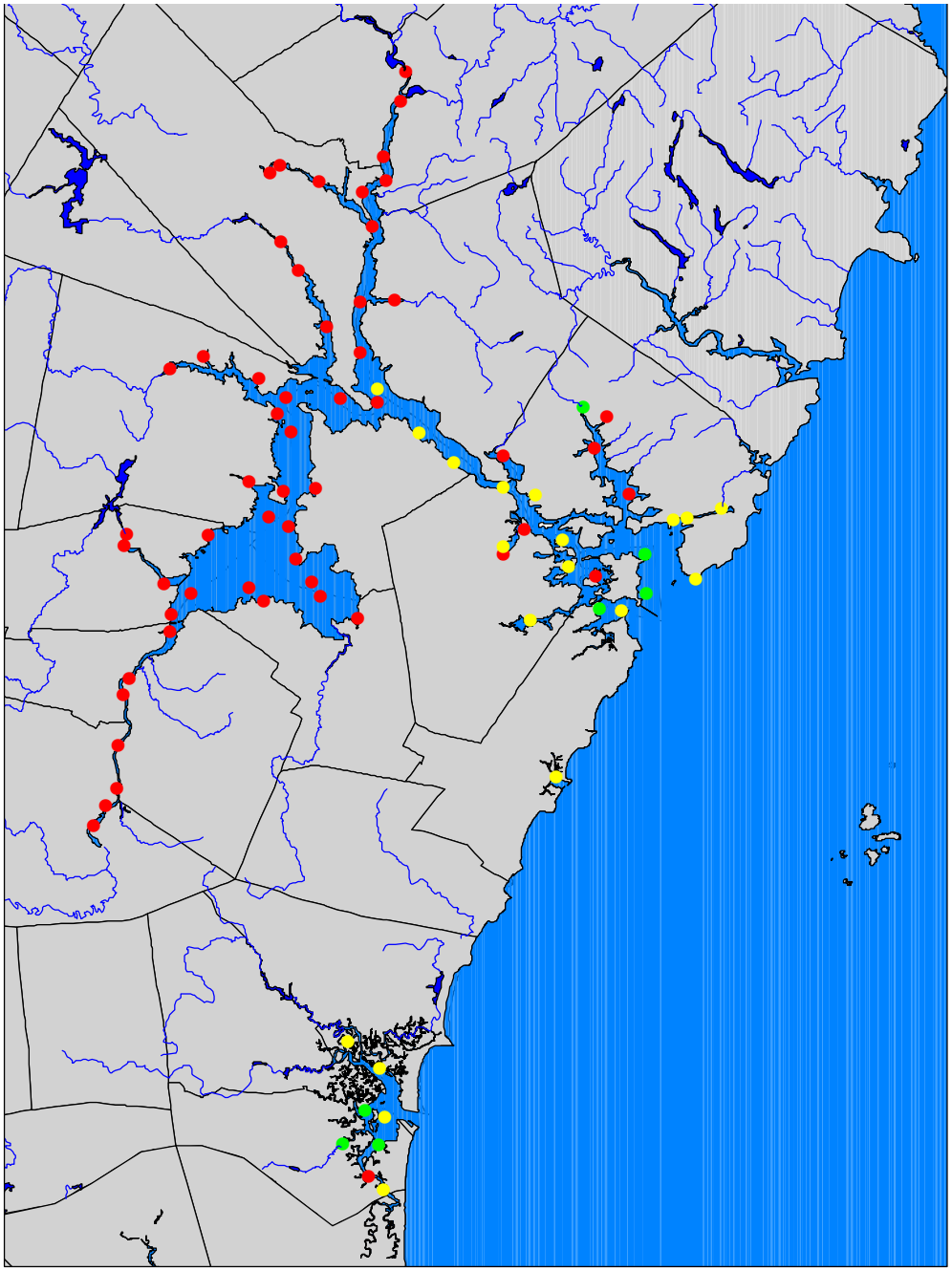
Appendices

A – Maps and summary statistics for water quality indicators, 2002-2003
B – Maps and summary statistics for water quality indicators, 2004-2005
C – Annual trend plots, 2002-2005

Appendix A

National Coastal Assessment Water Quality Indicators

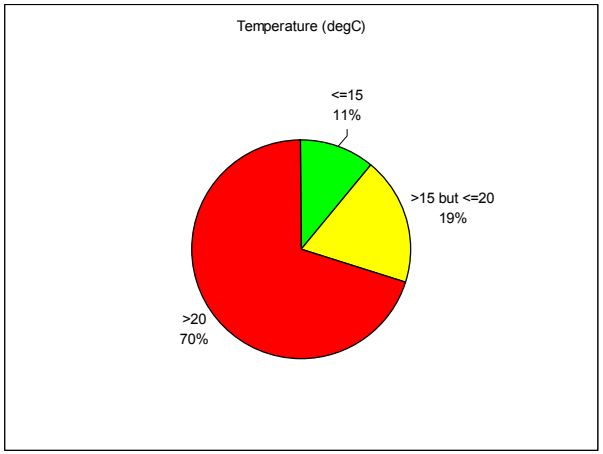
2002-2003



Temperature

Temperature (degC)

Concentration	% of Estuarine Area	Error (+/-)
<=15	11.1%	6.8%
>15 but <=20	18.8%	8.5%
>20	70.1%	10.0%



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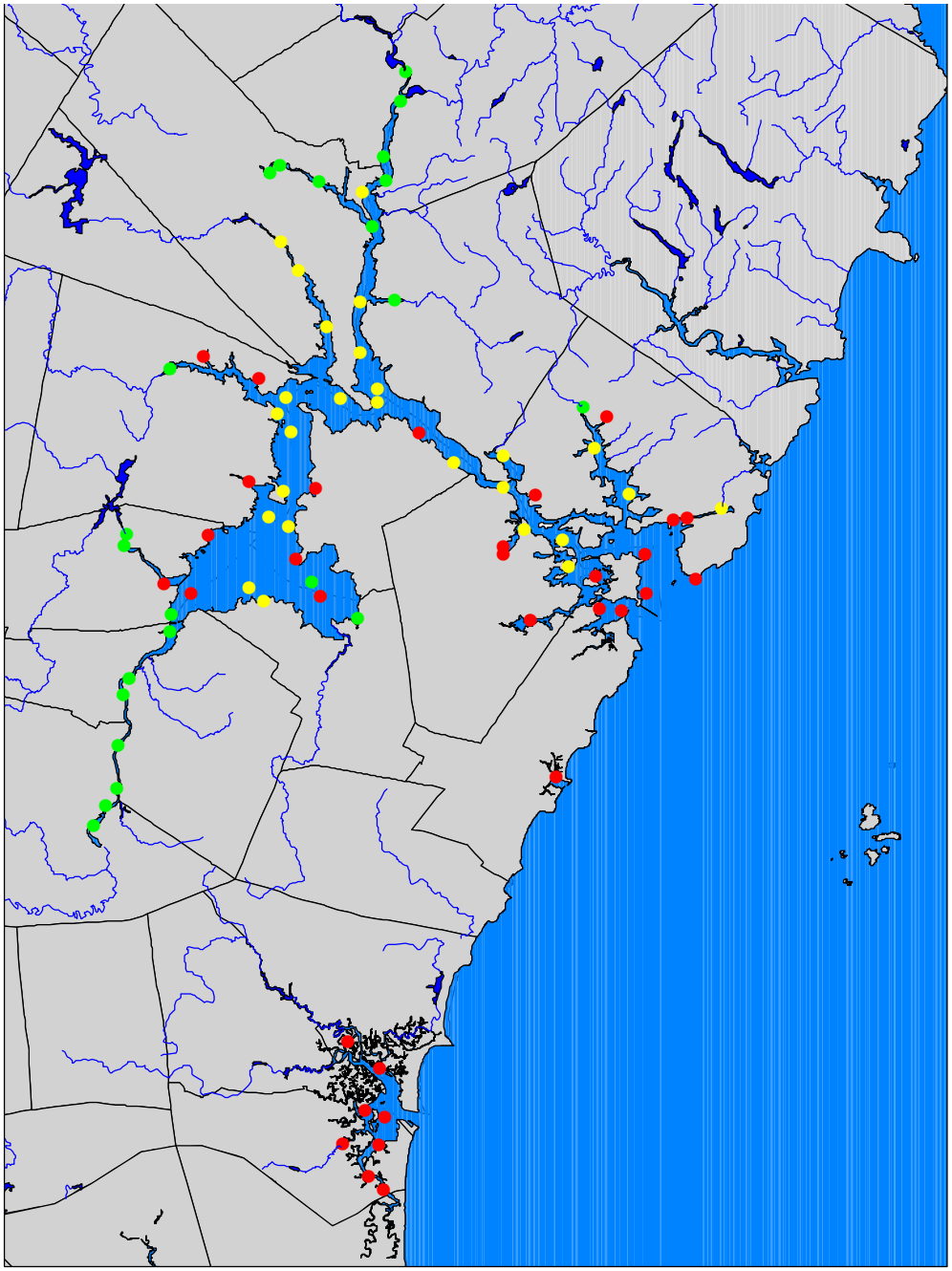
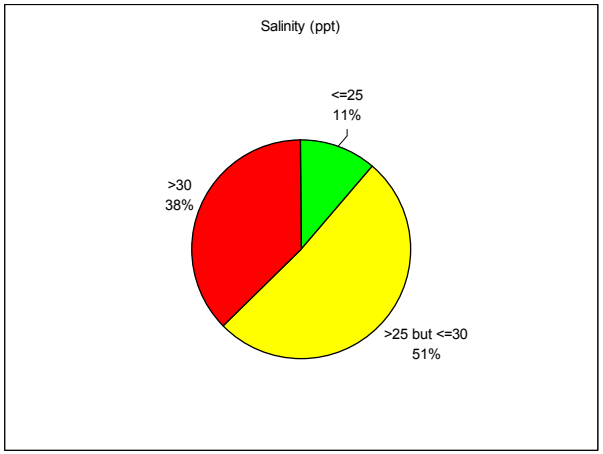


Salinity

Salinity (ppt)

Concentration	% of Estuarine Area	Error (+/-)
<=25	11.3%	6.9%
>25 but <=30	51.1%	10.9%
>30	37.6%	10.5%



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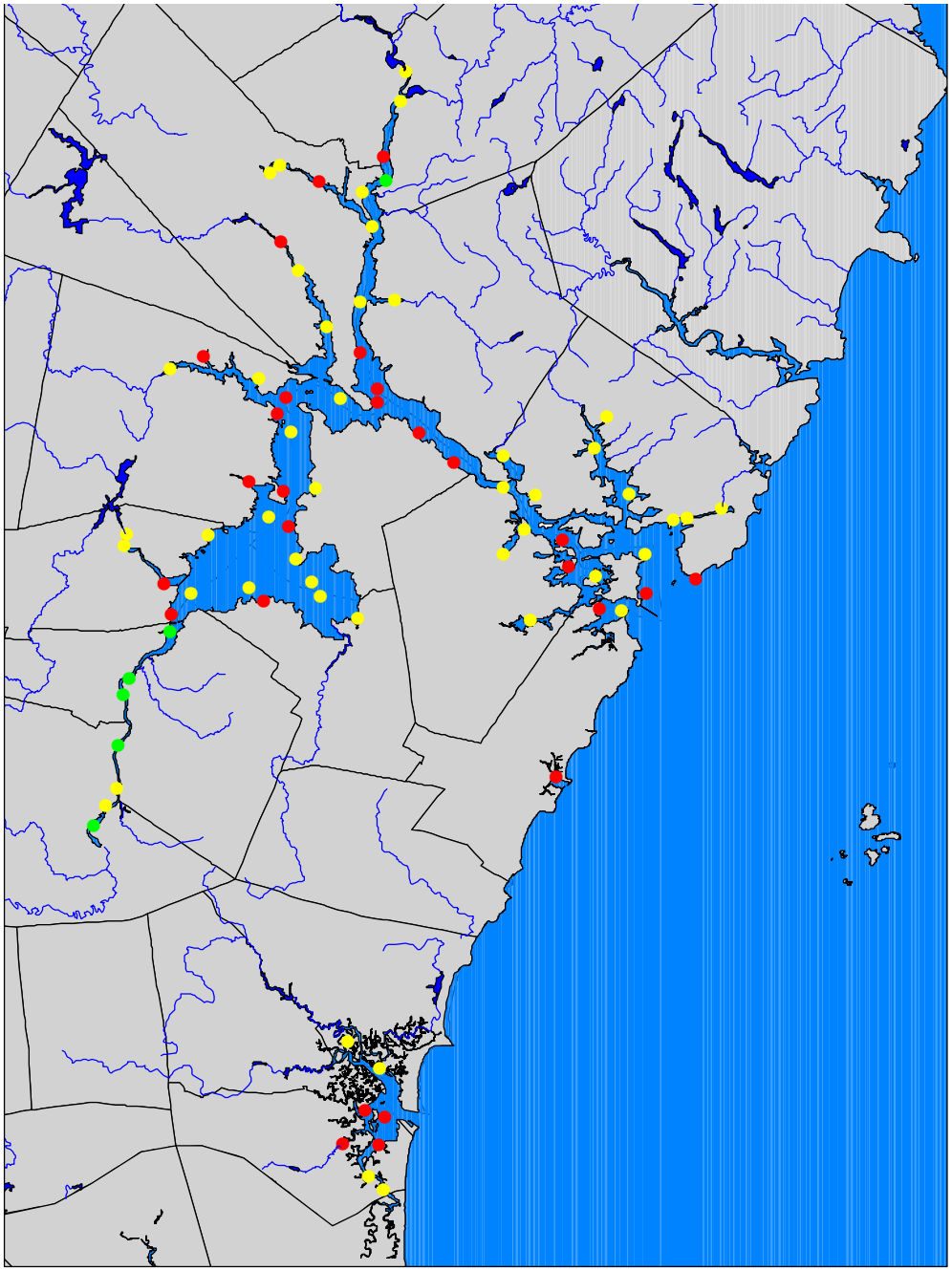
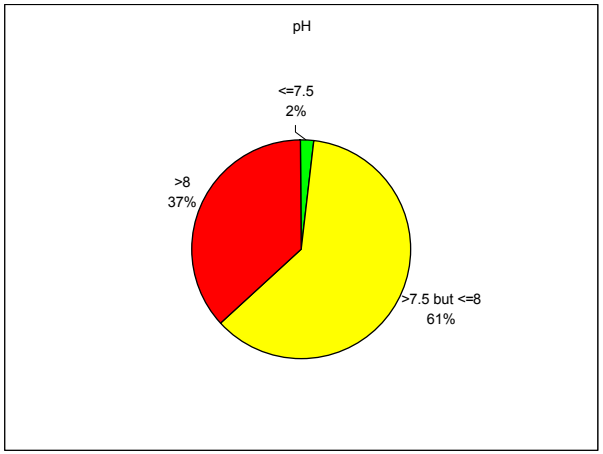


pH

pH

Concentration	% of Estuarine Area	Error (+/-)
<=7.5	1.9%	3.0%
>7.5 but <=8	61.3%	10.7%
>8	36.9%	10.6%



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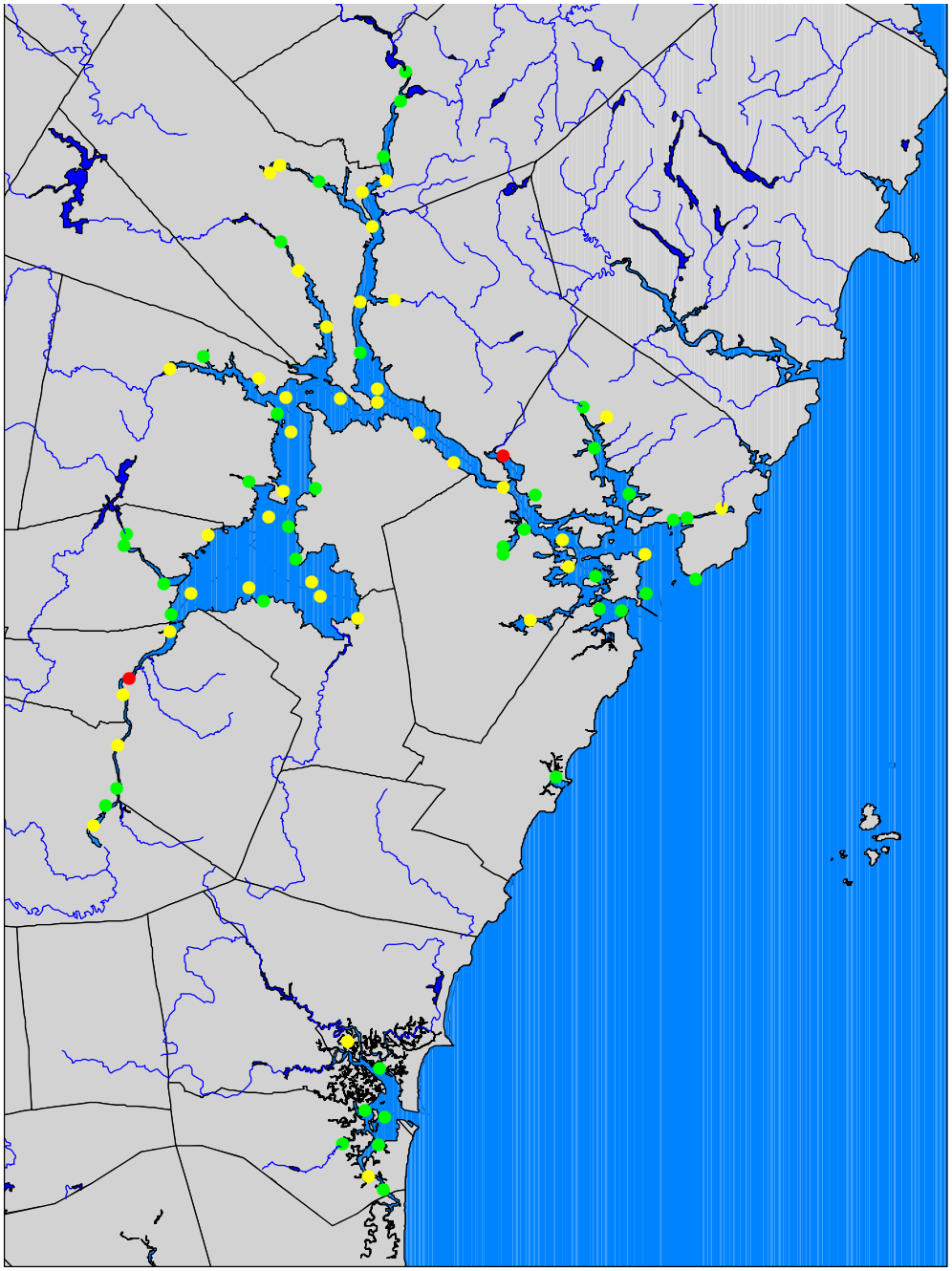
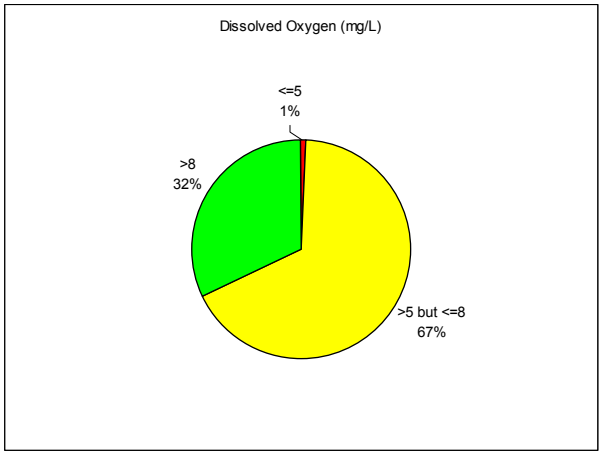


Dissolved Oxygen

Dissolved Oxygen (mg/L)

Concentration	% of Estuarine Area	Error (+/-)
<=5	0.9%	2.0%
>5 but <=8	67.0%	10.2%
>8	32.2%	10.2%



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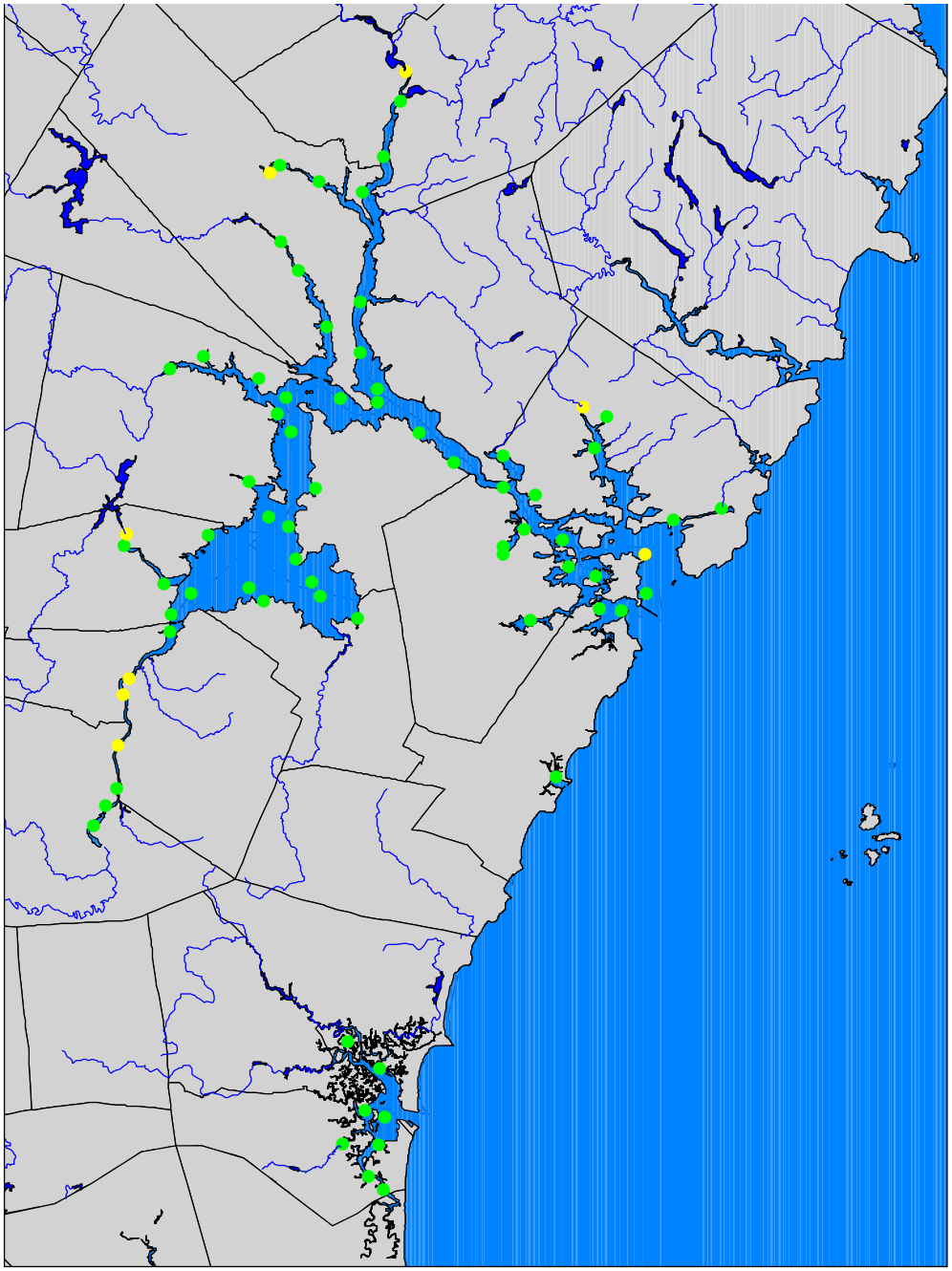
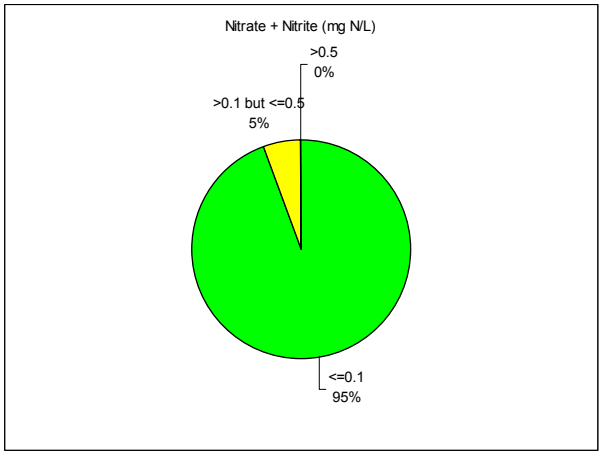


Nitrate + Nitrite

Nitrate + Nitrite (mg N/L)

Concentration	% of Estuarine Area	Error (+/-)
<=0.1	94.5%	5.2%
>0.1 but <=0.5	5.5%	5.2%
>0.5	0.0%	0.0%



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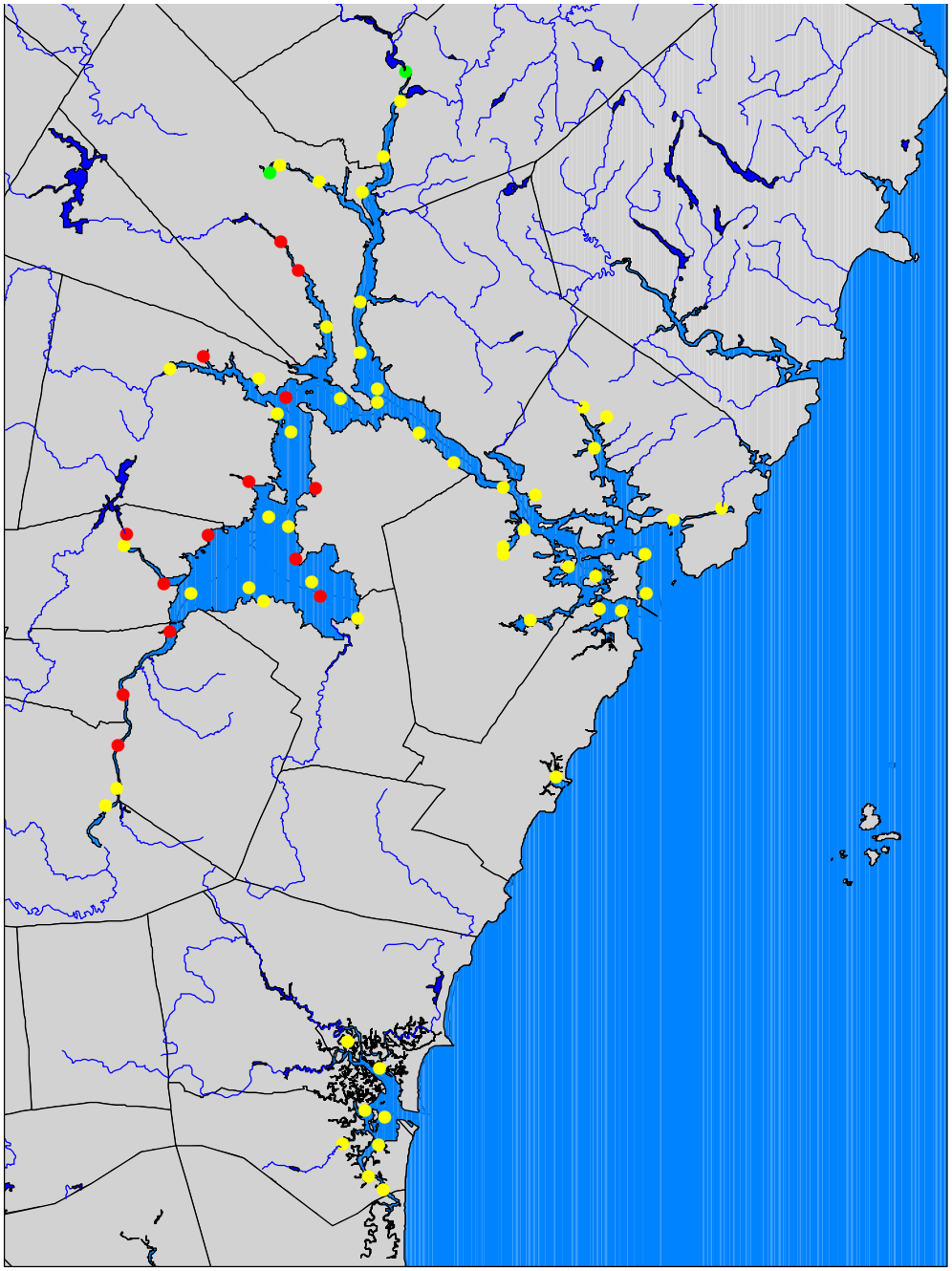
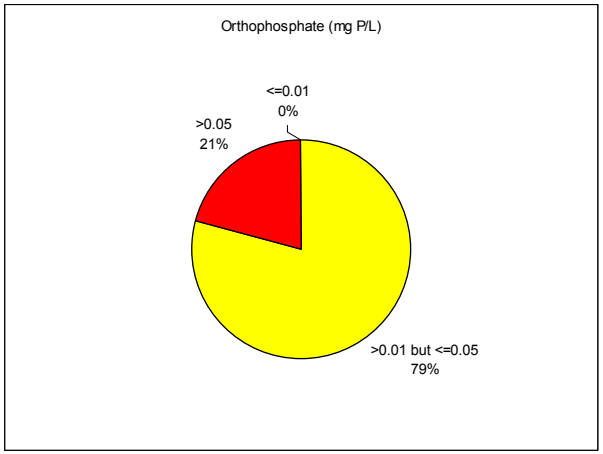


Ortho-Phosphate

Orthophosphate (mg P/L)

Concentration	% of Estuarine Area	Error (+/-)
<=0.01	0.1%	0.7%
>0.01 but <=0.05	79.2%	9.3%
>0.05	20.7%	9.3%



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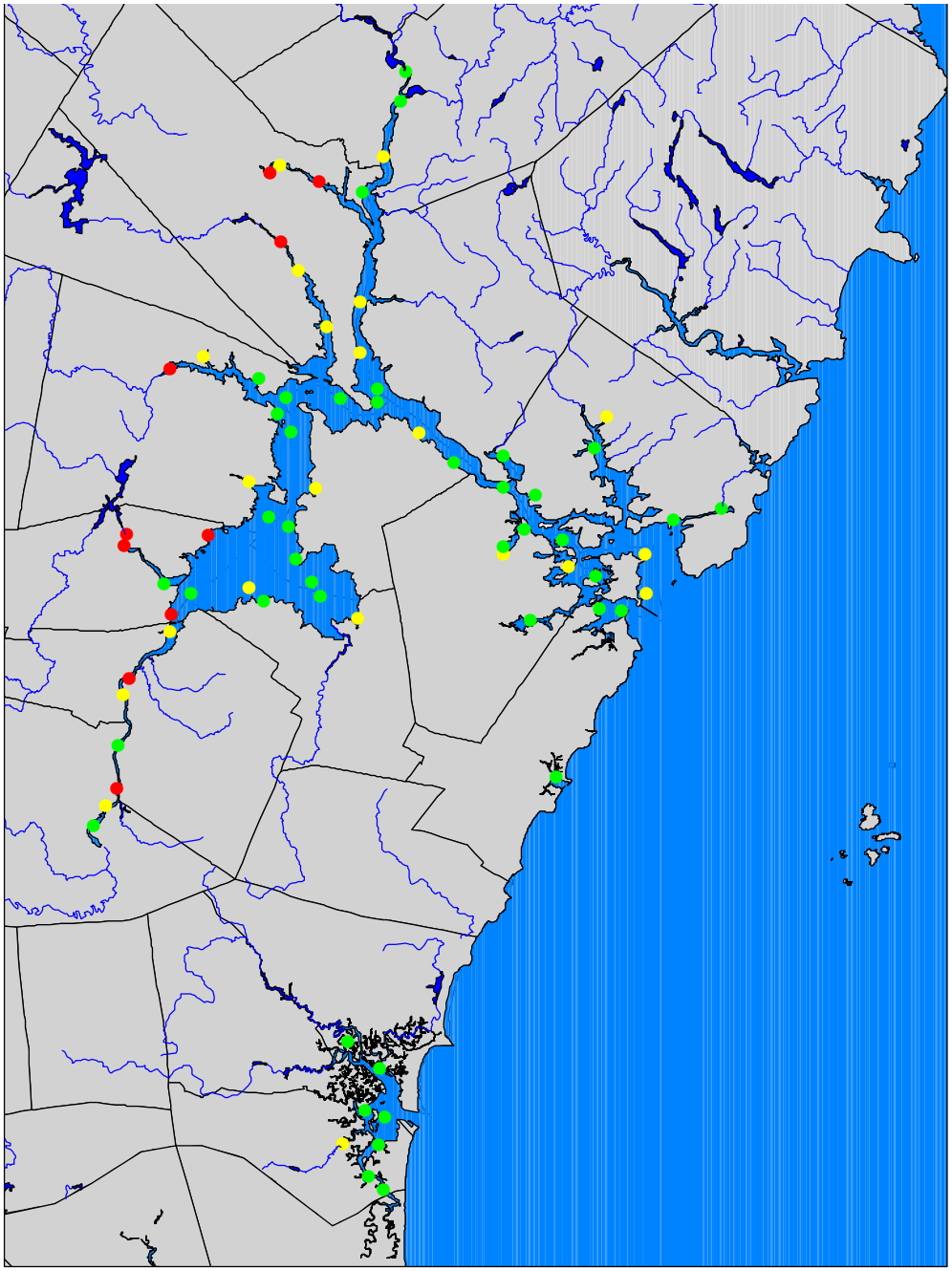
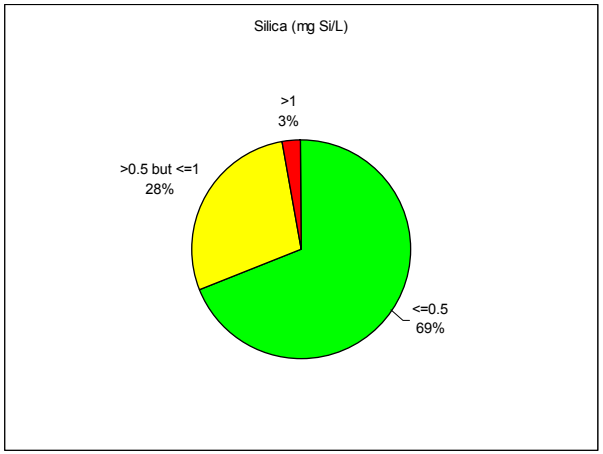


Dissolved Silica

Silica (mg Si/L)

Concentration	% of Estuarine Area	Error (+/-)
<=0.5	69.0%	10.5%
>0.5 but <=1	28.2%	10.3%
>1	2.8%	3.8%



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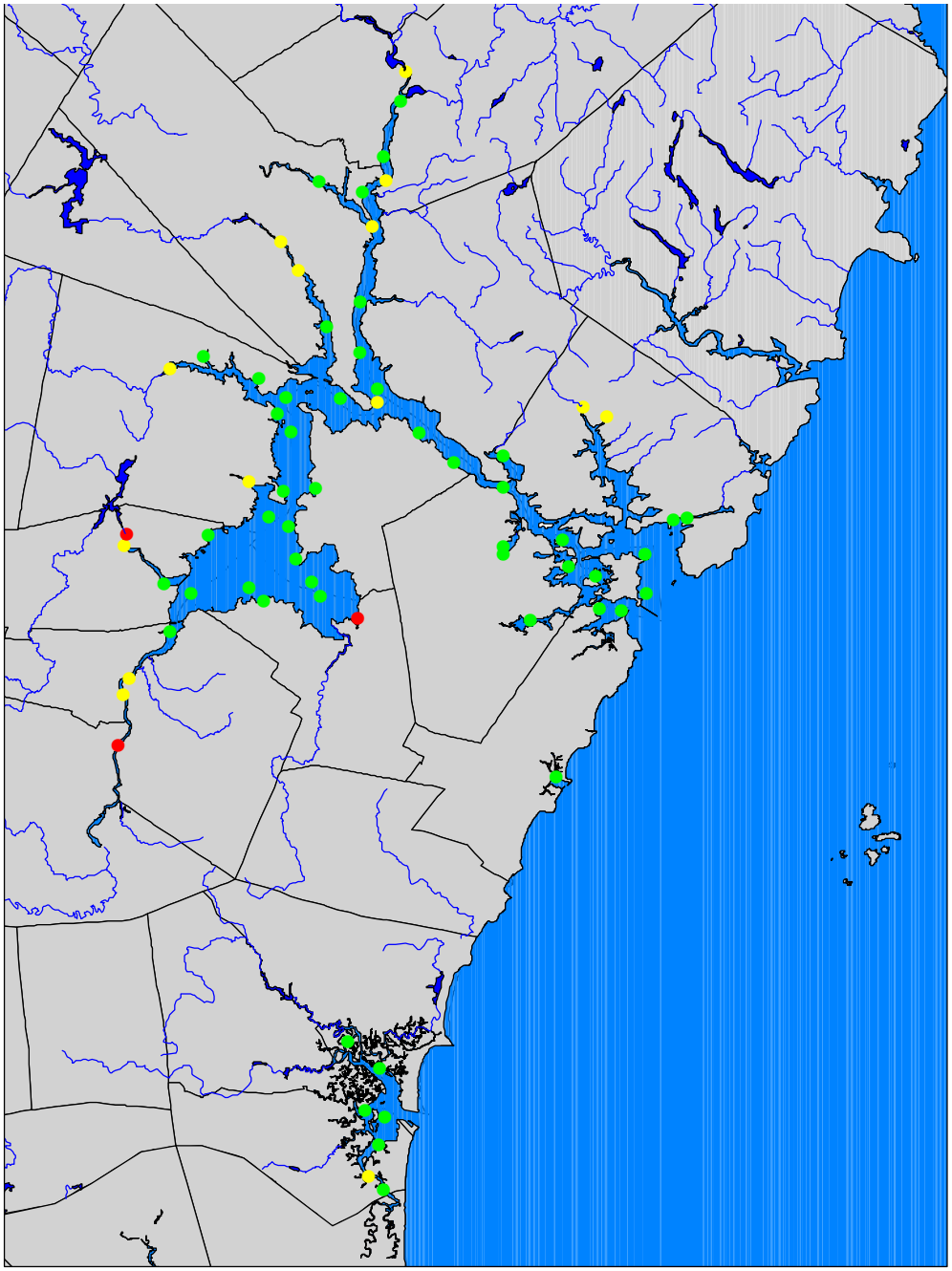
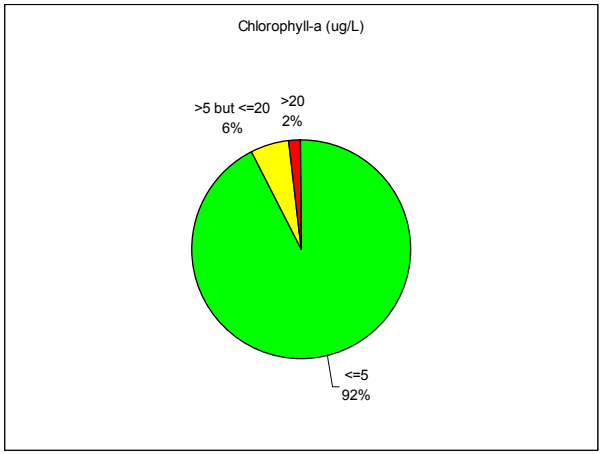


Chlorophyll-a

Chlorophyll-a (ug/L)

Concentration	% of Estuarine Area	Error (+/-)
<=5	92.4%	6.3%
>5 but <=20	5.9%	5.6%
>20	1.8%	3.1%



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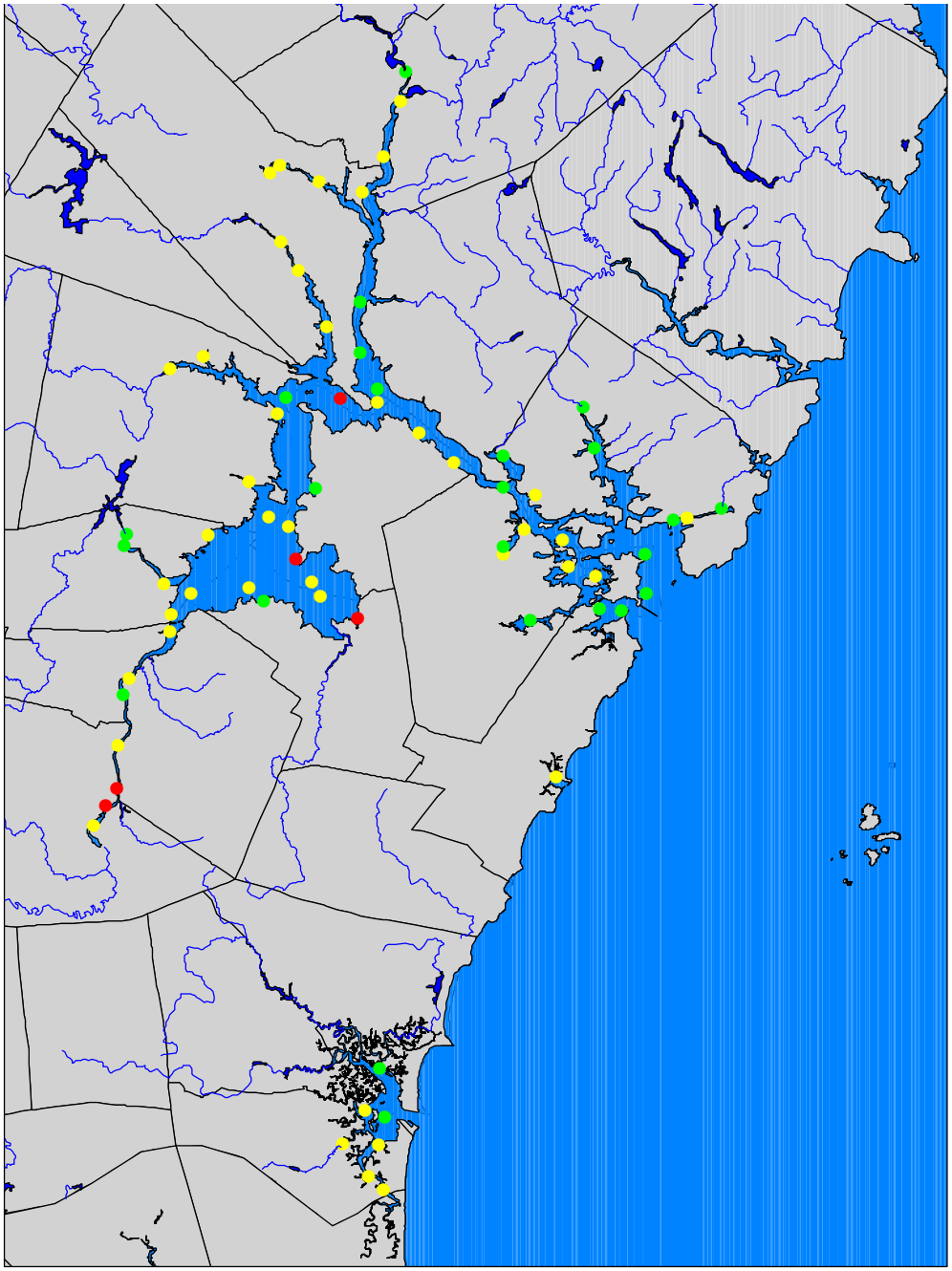
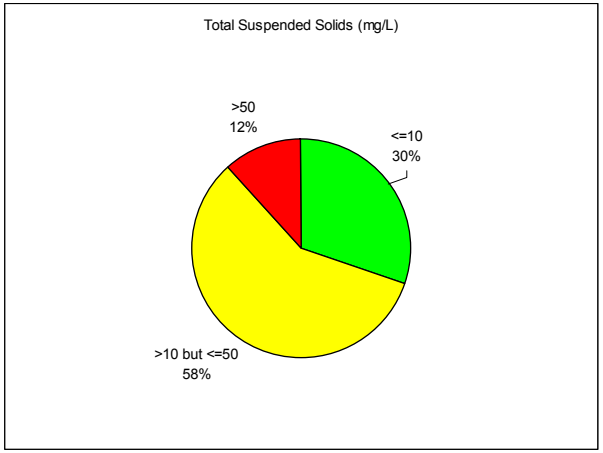


Total Suspended Solids

Total Suspended Solids (mg/L)

Concentration	% of Estuarine Area	Error (+/-)
<=10	30.4%	10.7%
>10 but <=50	58.0%	11.5%
>50	11.7%	7.5%



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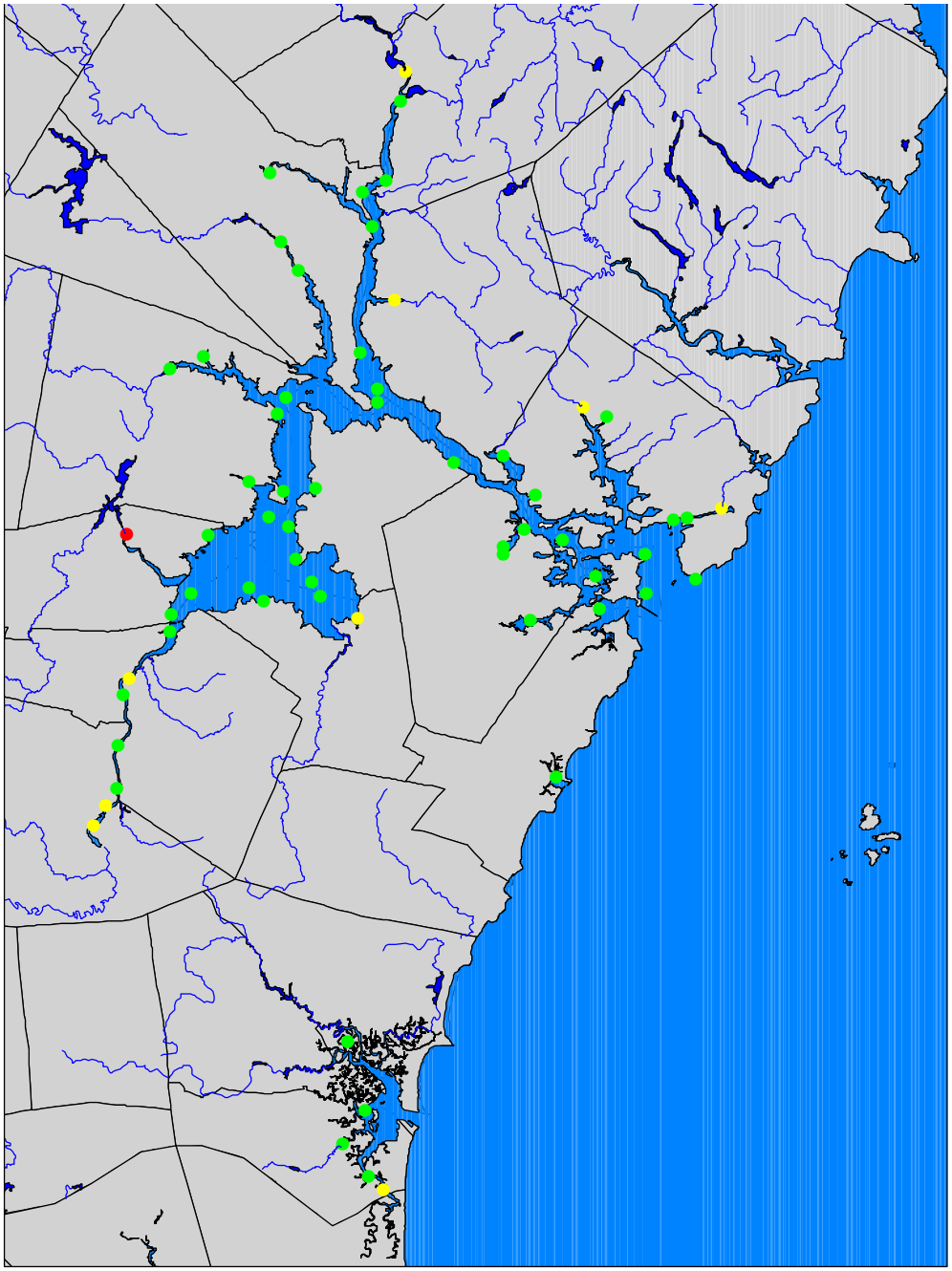
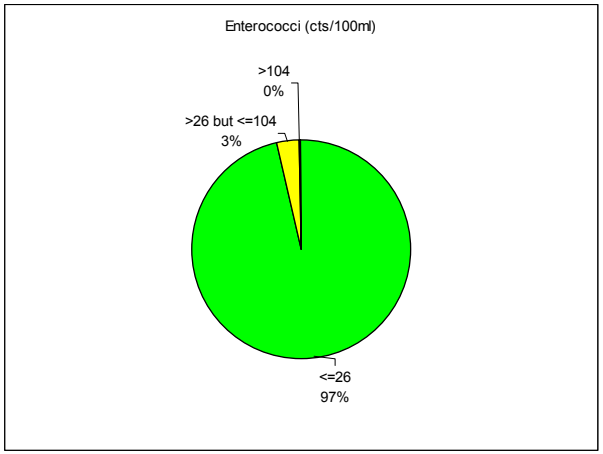


Enterococci

Enterococci (cts/100ml)

Concentration	% of Estuarine Area	Error (+/-)
<=26	96.5%	4.6%
>26 but <=104	3.2%	4.3%
>104	0.3%	1.4%



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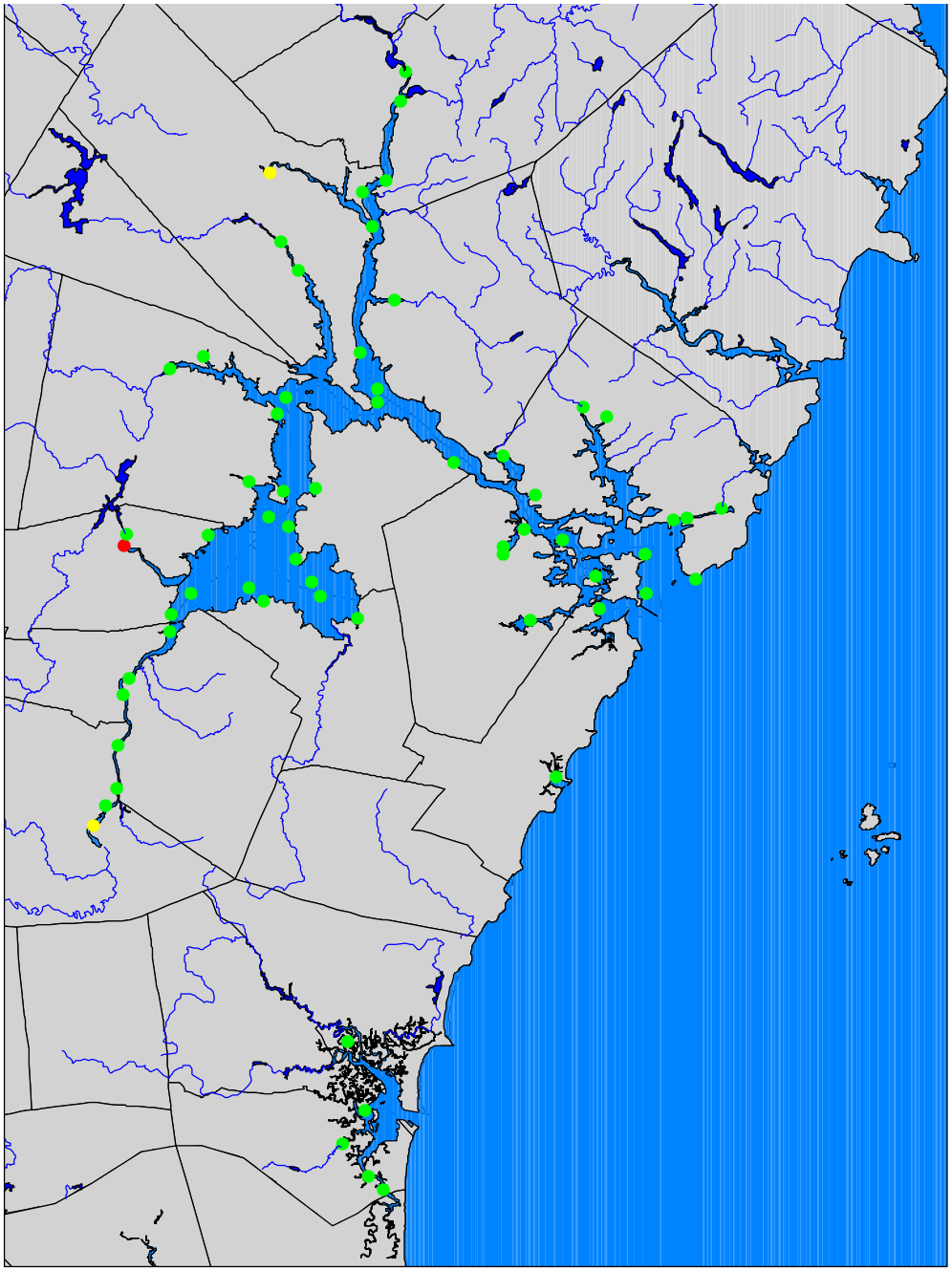
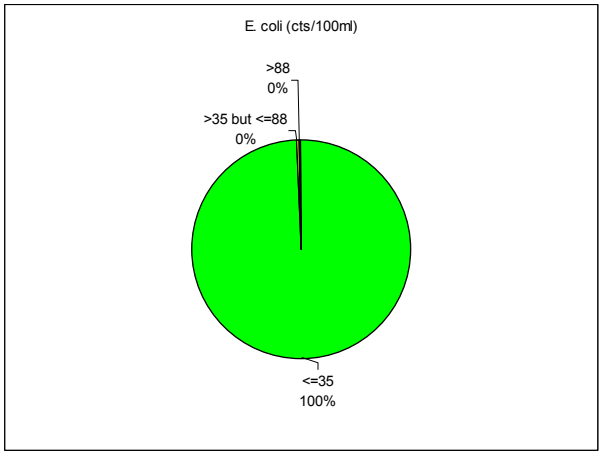


E. coli

E. coli (cts/100ml)

Concentration	% of Estuarine Area	Error (+/-)
<=35	99.3%	2.0%
>35 but <=88	0.4%	1.5%
>88	0.3%	1.4%



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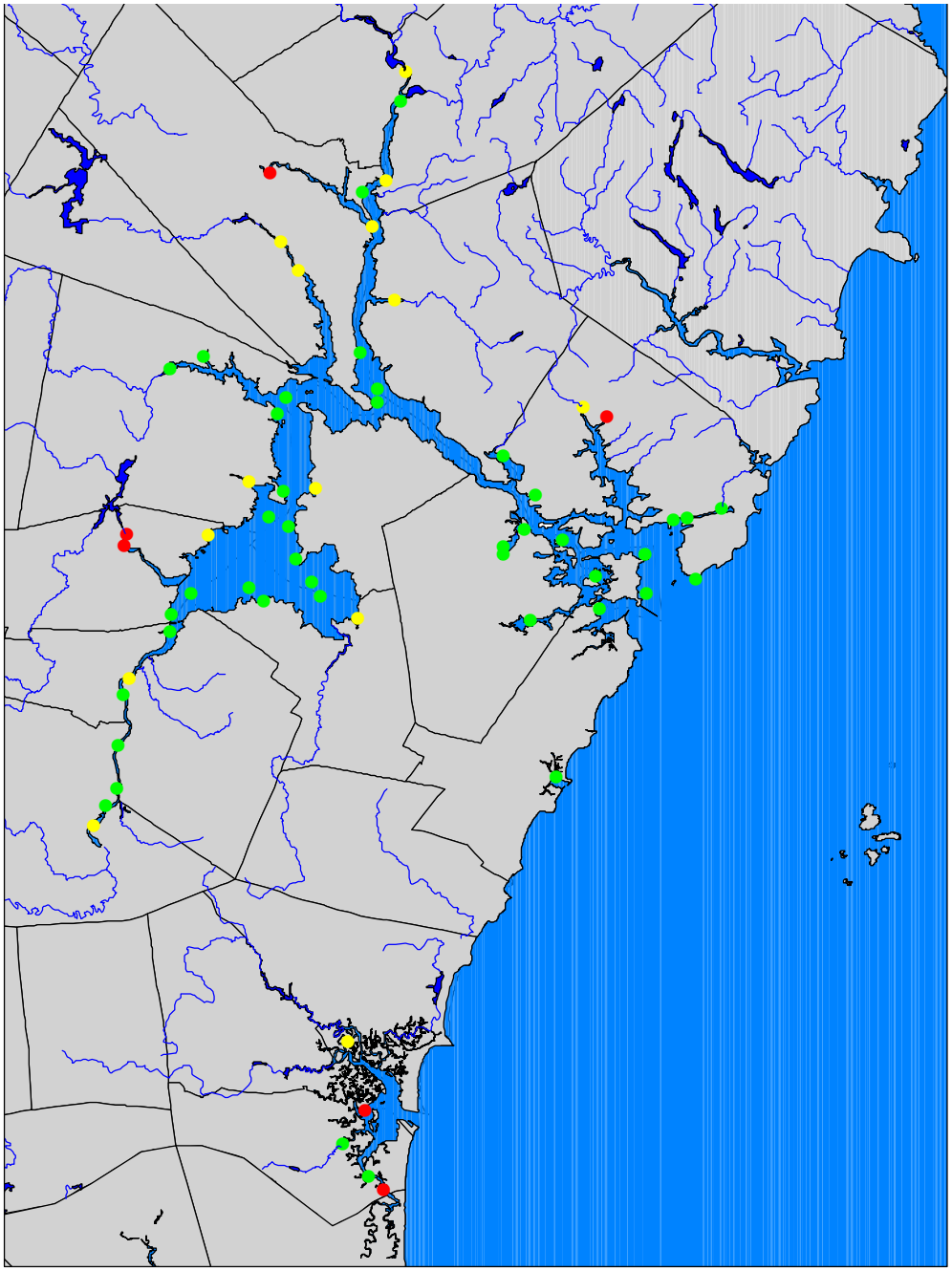
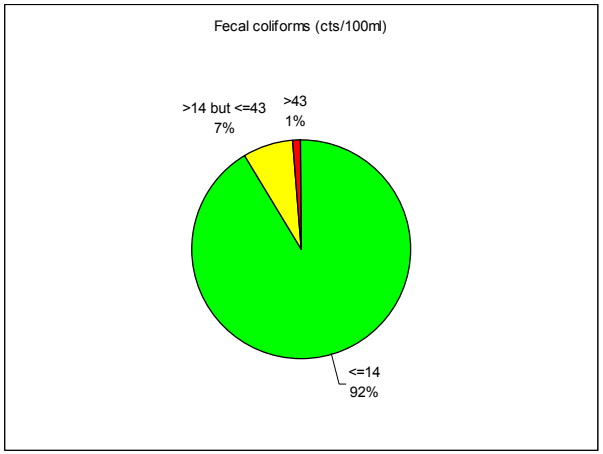


Fecal Coliforms

Fecal coliforms (cts/100ml)

Concentration	% of Estuarine Area	Error (+/-)
<=14	91.3%	7.0%
>14 but <=43	7.5%	6.5%
>43	1.2%	2.8%



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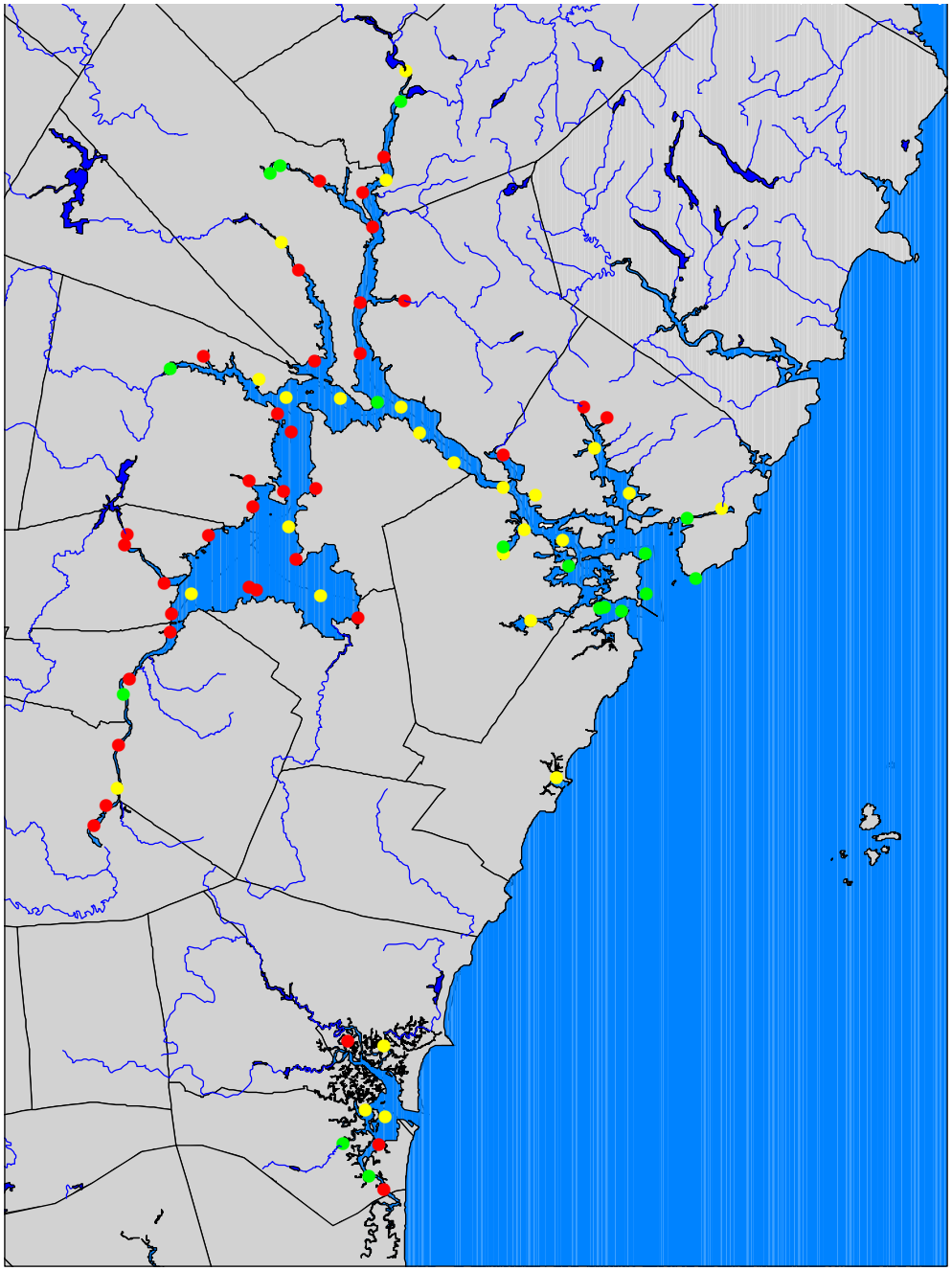
Appendix B

National Coastal Assessment Water Quality Indicators

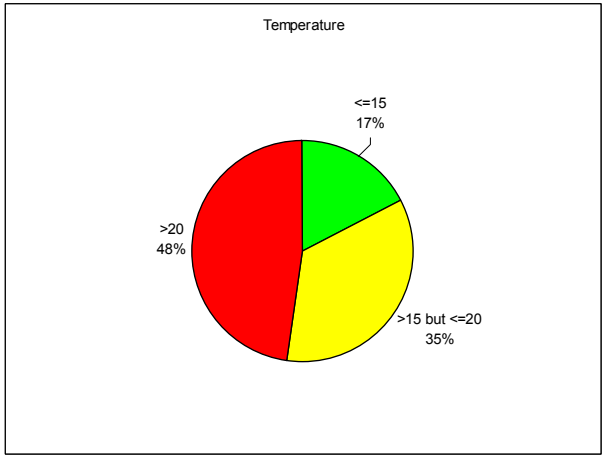
2004-2005



Temperature

Temperature (degC)

Concentration	% of Estuarine Area	Error (+/-)
<=15	17.4%	8.3%
>15 but <=20	34.9%	10.4%
>20	47.7%	10.9%



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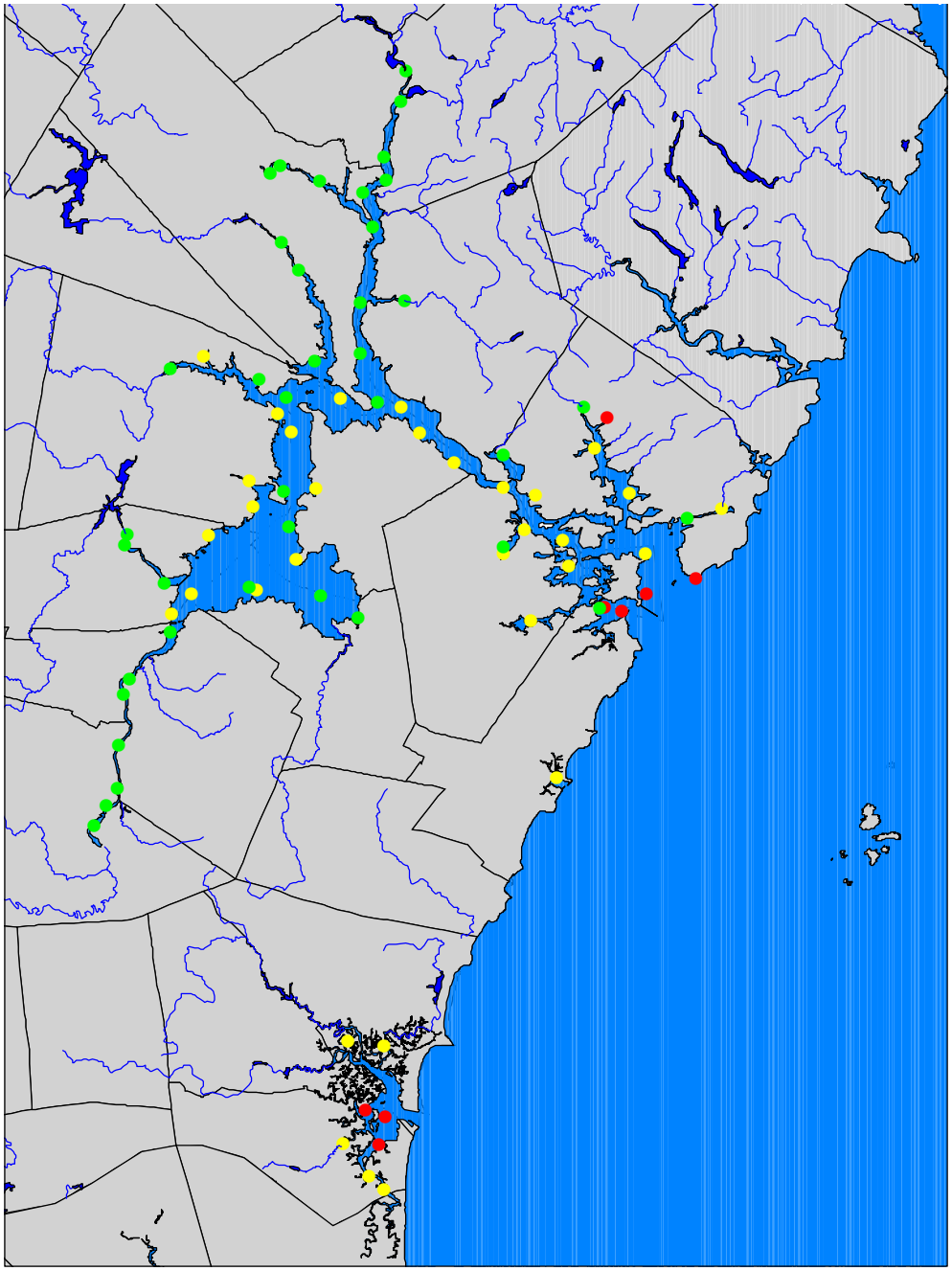
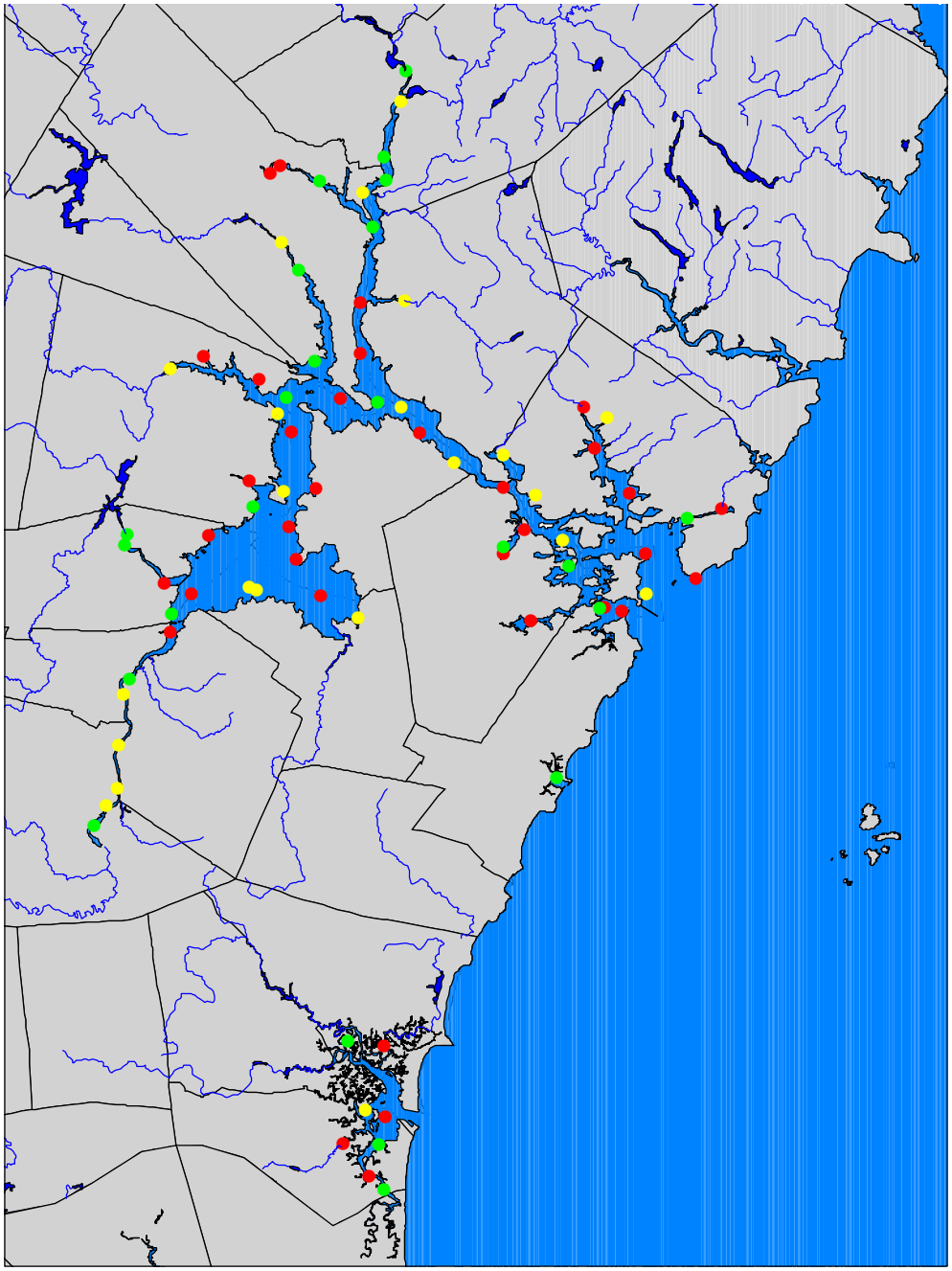


Salinity

Salinity (ppt)

Concentration	% of Estuarine Area	Error (+/-)
<=25	37.0%	10.6%
>25 but <=30	52.3%	10.9%
>30	10.8%	6.8%

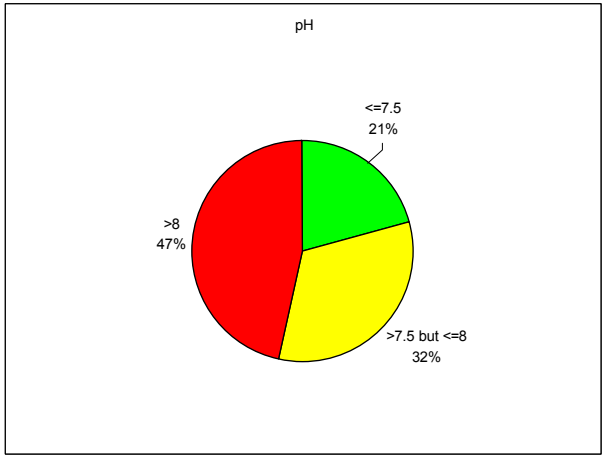
Notes:



pH

pH

Concentration	% of Estuarine Area	Error (+/-)
<=7.5	20.9%	8.9%
>7.5 but <=8	32.4%	10.3%
>8	46.7%	10.9%



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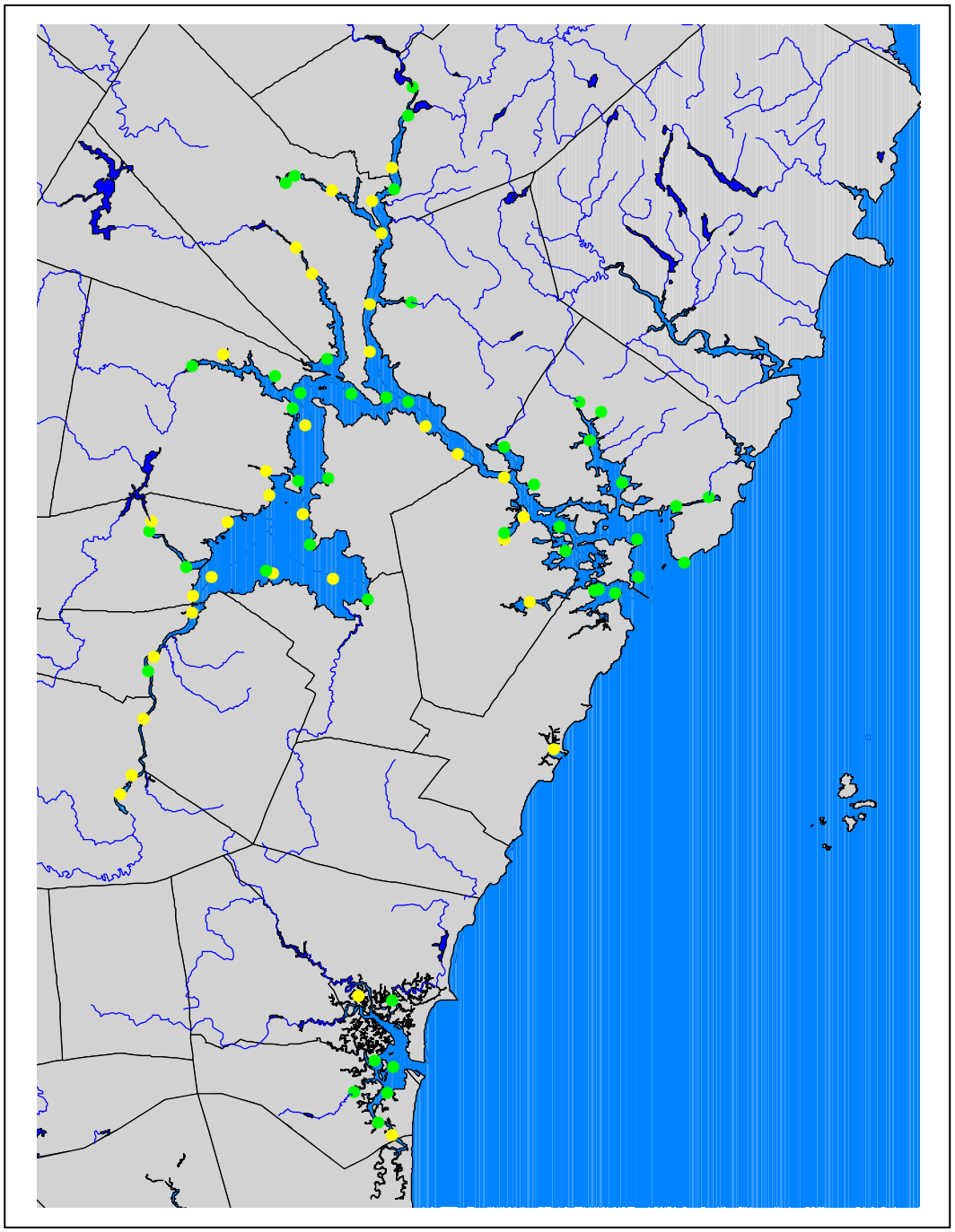
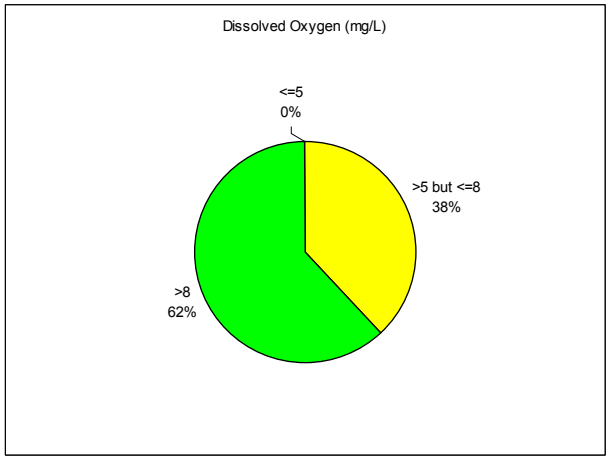


Dissolved Oxygen

Dissolved Oxygen (mg/L)

Concentration	% of Estuarine Area	Error (+/-)
<=5	0.0%	0.0%
>5 but <=8	38.2%	10.6%
>8	61.8%	10.6%



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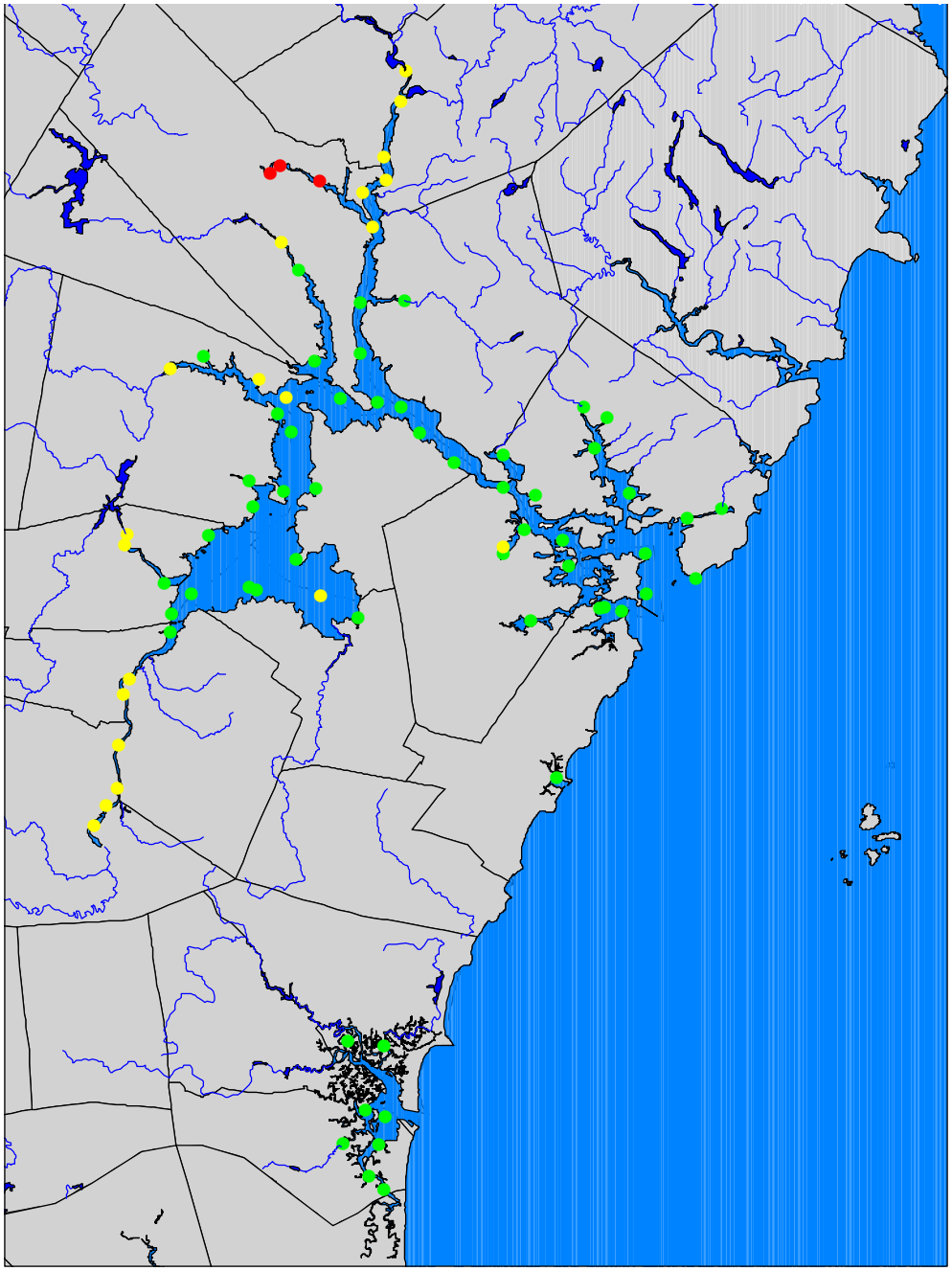
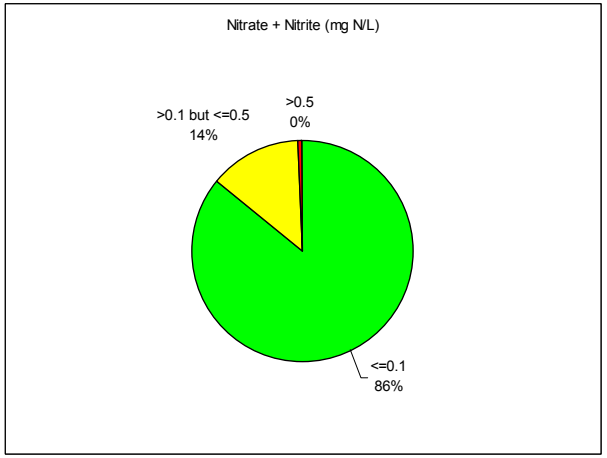


Nitrate + Nitrite

Nitrate + Nitrite (mg N/L)

Concentration	% of Estuarine Area	Error (+/-)
<=0.1	85.9%	7.7%
>0.1 but <=0.5	13.6%	7.6%
>0.5	0.4%	1.4%



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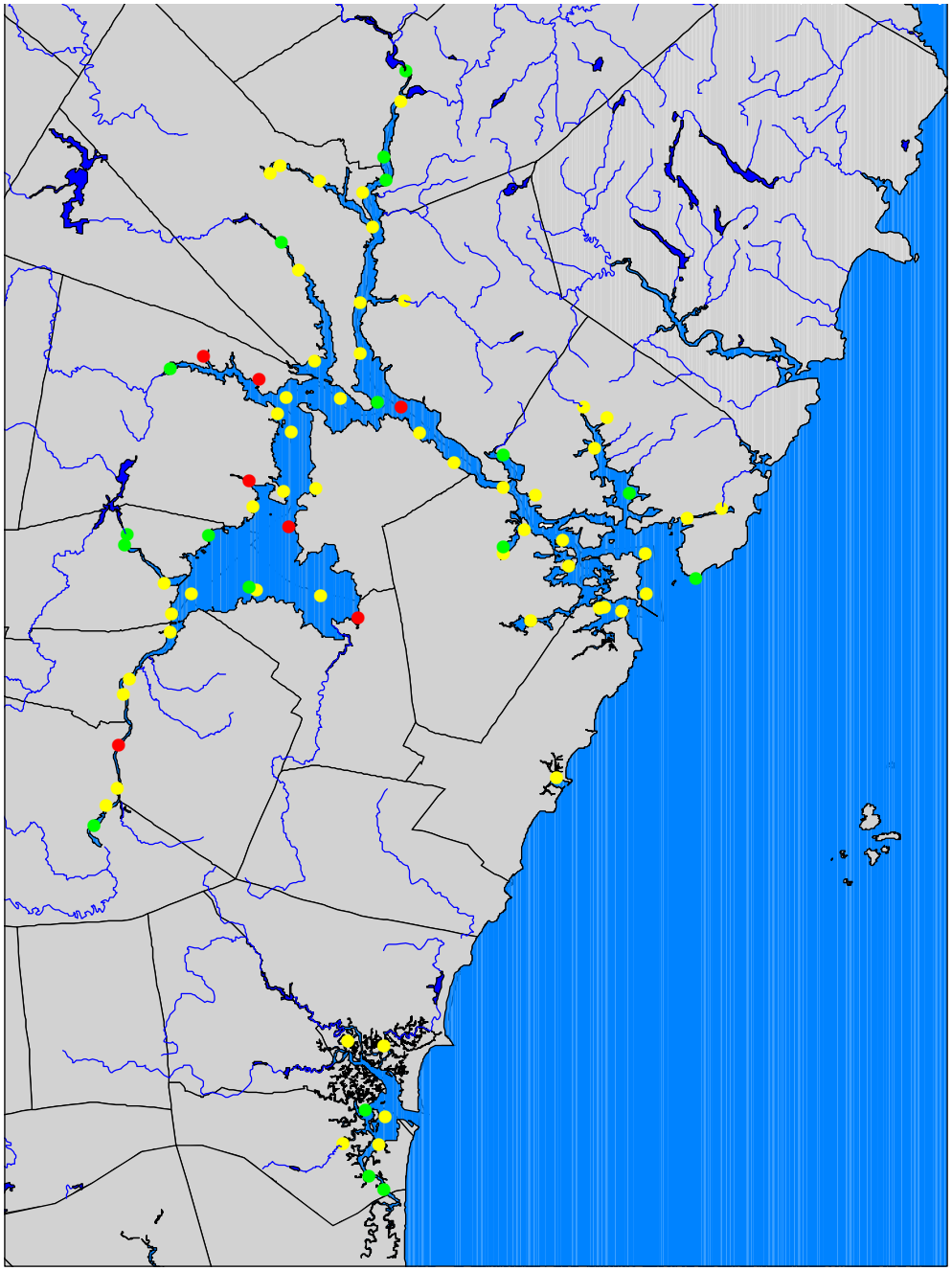
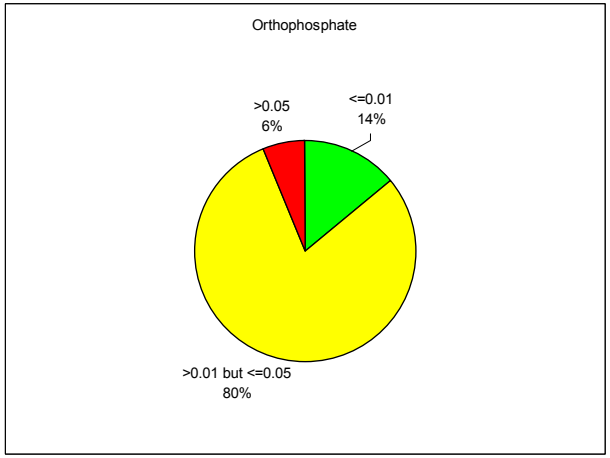


Ortho-phosphate

Orthophosphate (mg P/L)

Concentration	% of Estuarine Area	Error (+/-)
<=0.01	14.3%	7.7%
>0.01 but <=0.05	79.5%	8.9%
>0.05	6.2%	5.3%



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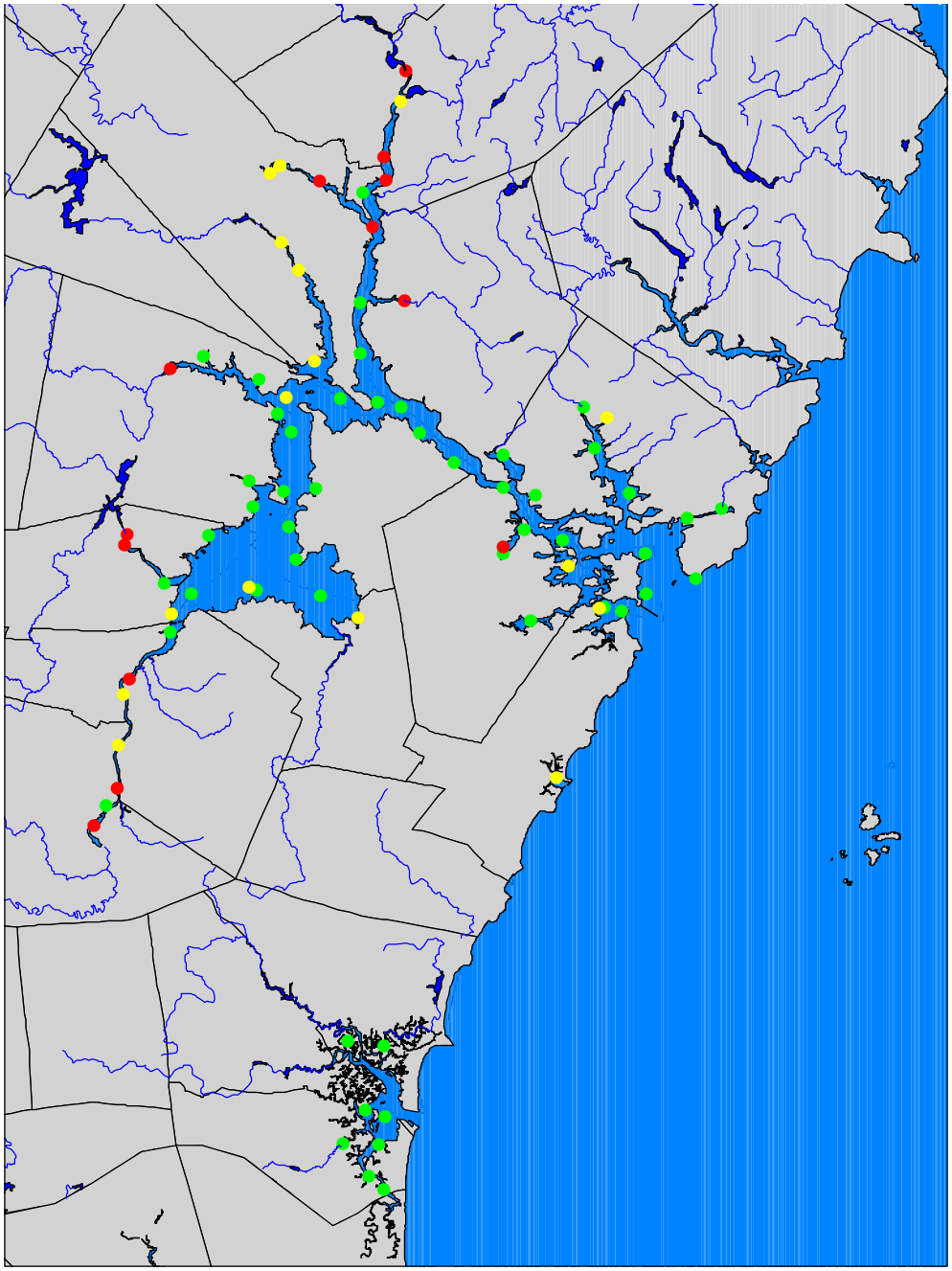
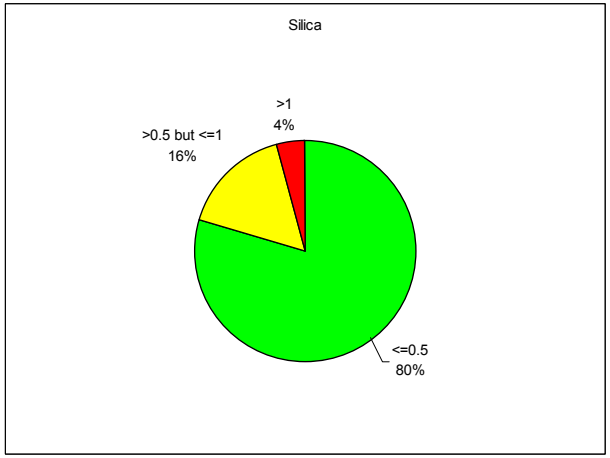


Dissolved Silica

Silica (mg Si/L)

Concentration	% of Estuarine Area	Error (+/-)
<=0.5	79.4%	8.9%
>0.5 but <=1	16.3%	8.1%
>1	4.3%	4.4%



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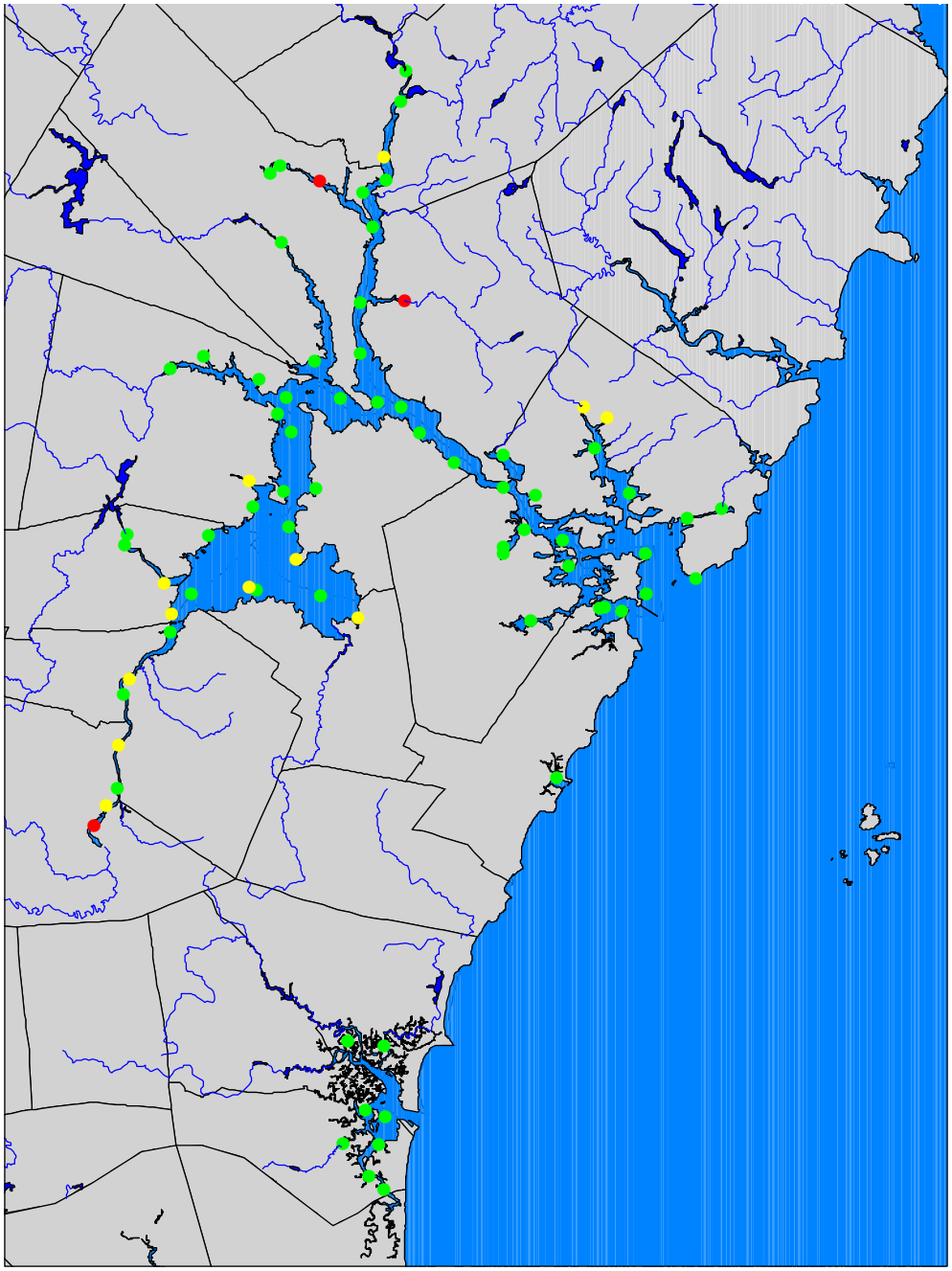
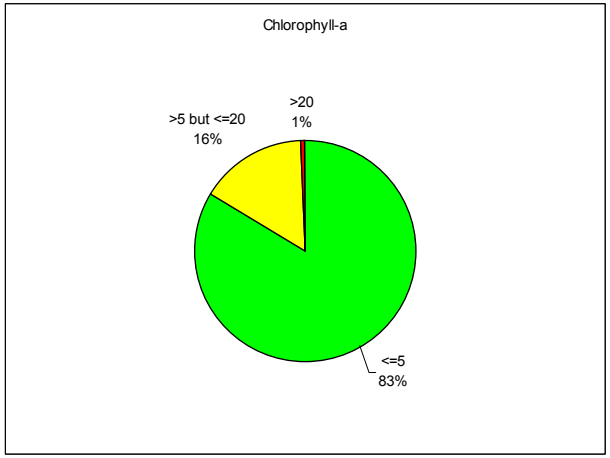


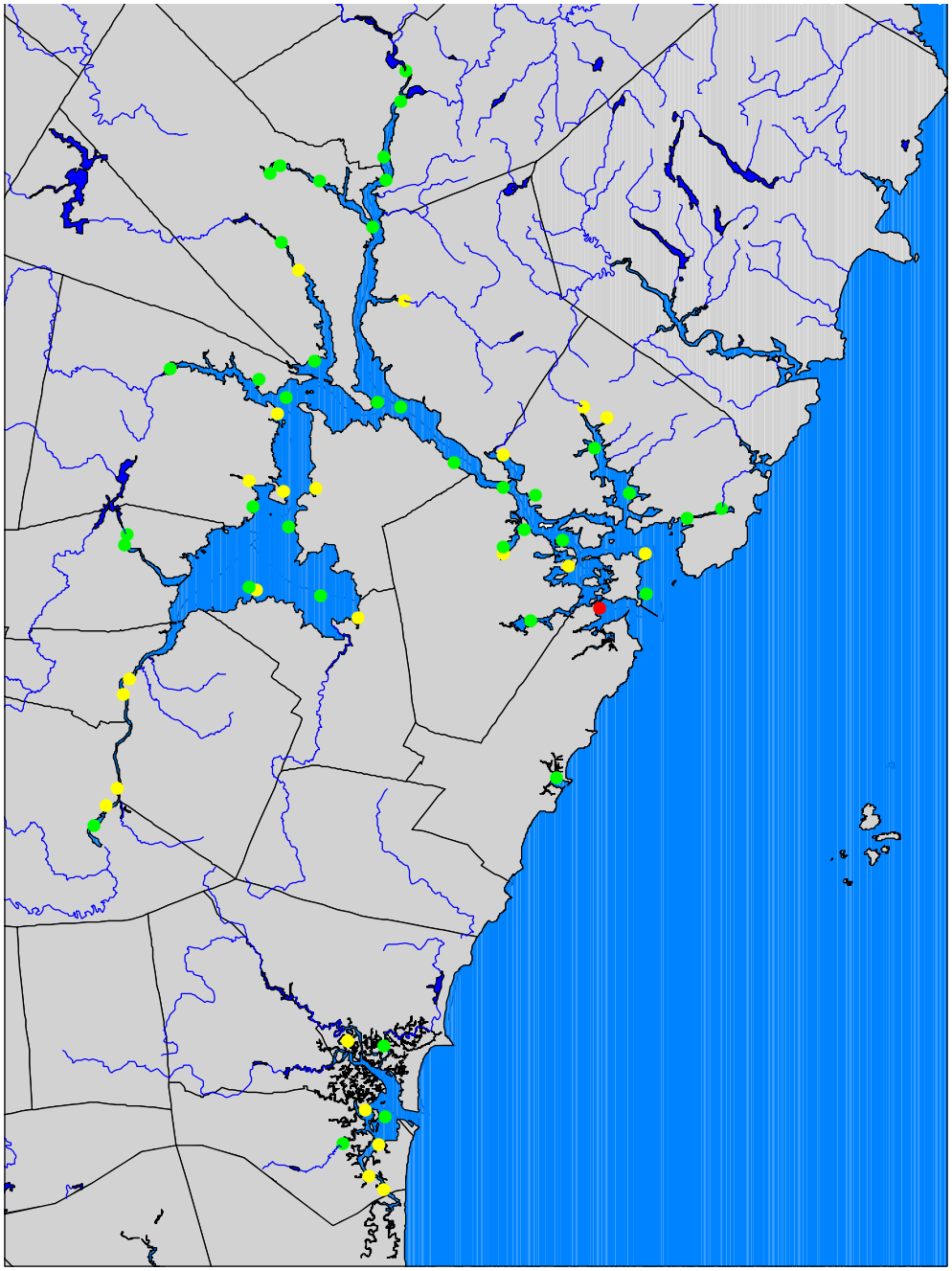
Chlorophyll-a

Chlorophyll-a (ug/L)

Concentration	% of Estuarine Area	Error (+/-)
<=5	83.5%	8.2%
>5 but <=20	15.9%	8.1%
>20	0.6%	1.7%



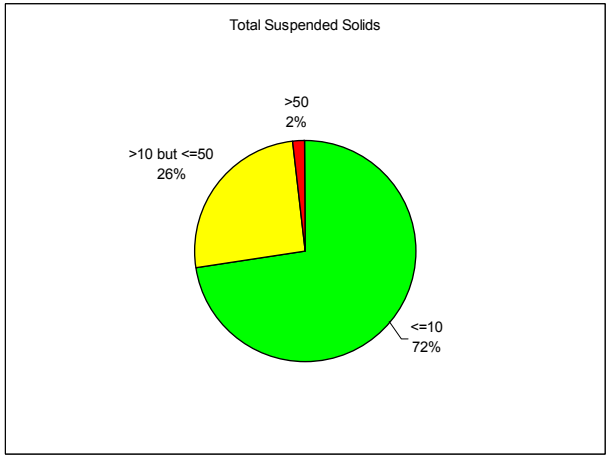
Notes:



Total Suspended Soilds

Total Suspended Solids (mg/L)

Concentration	% of Estuarine Area	Error (+/-)
<=10	72.4%	11.0%
>10 but <=50	25.9%	10.8%
>50	1.7%	3.2%



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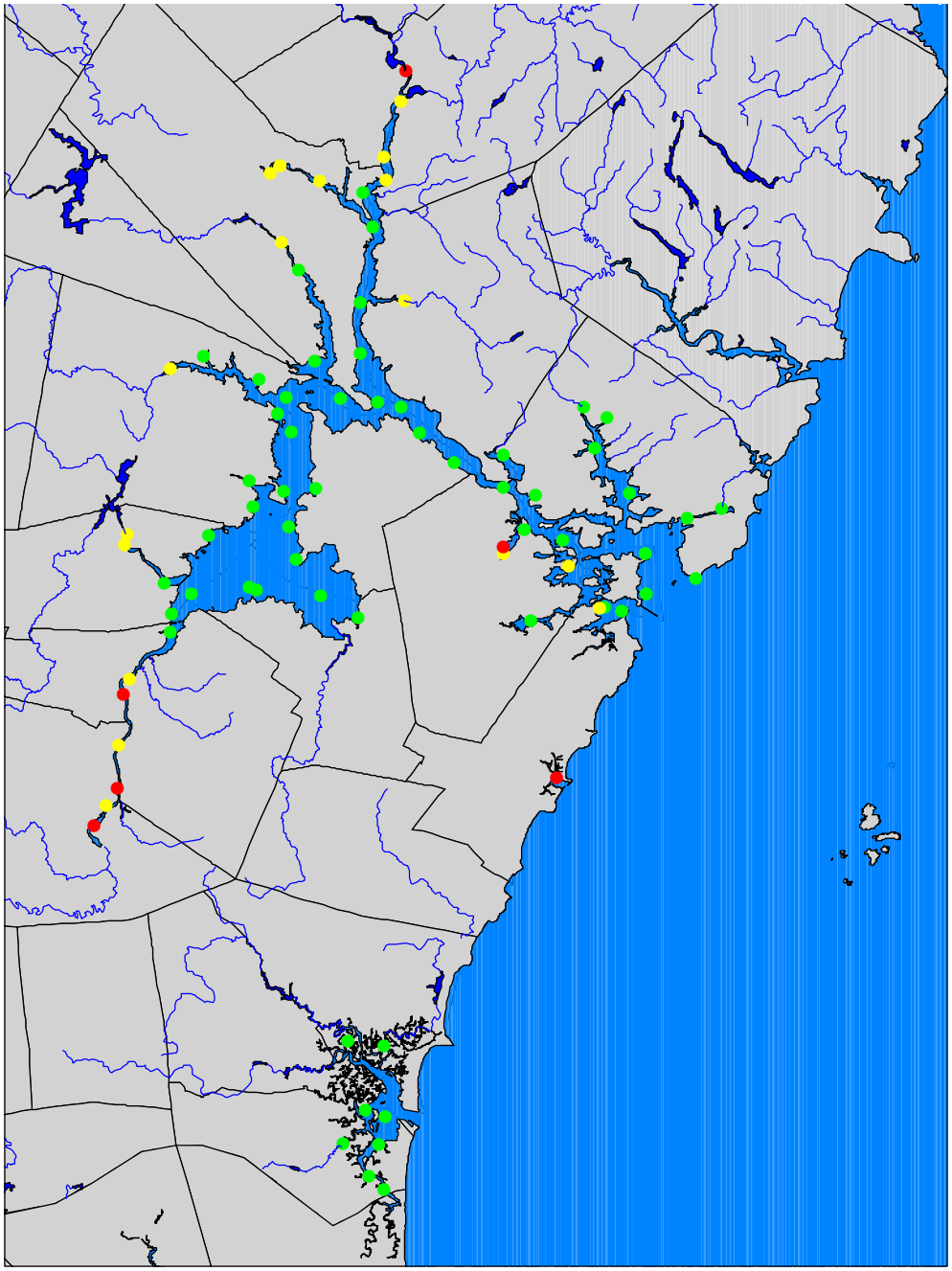
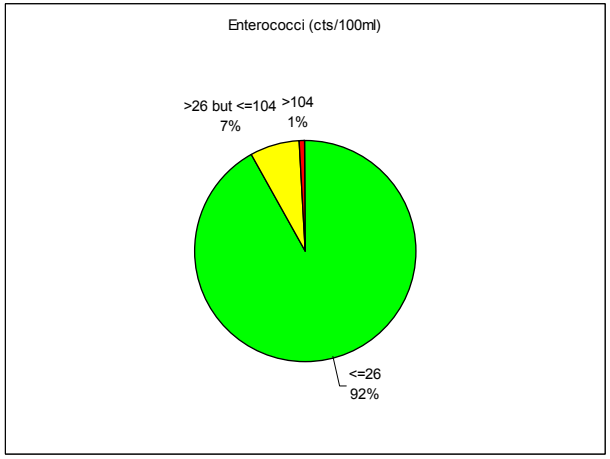


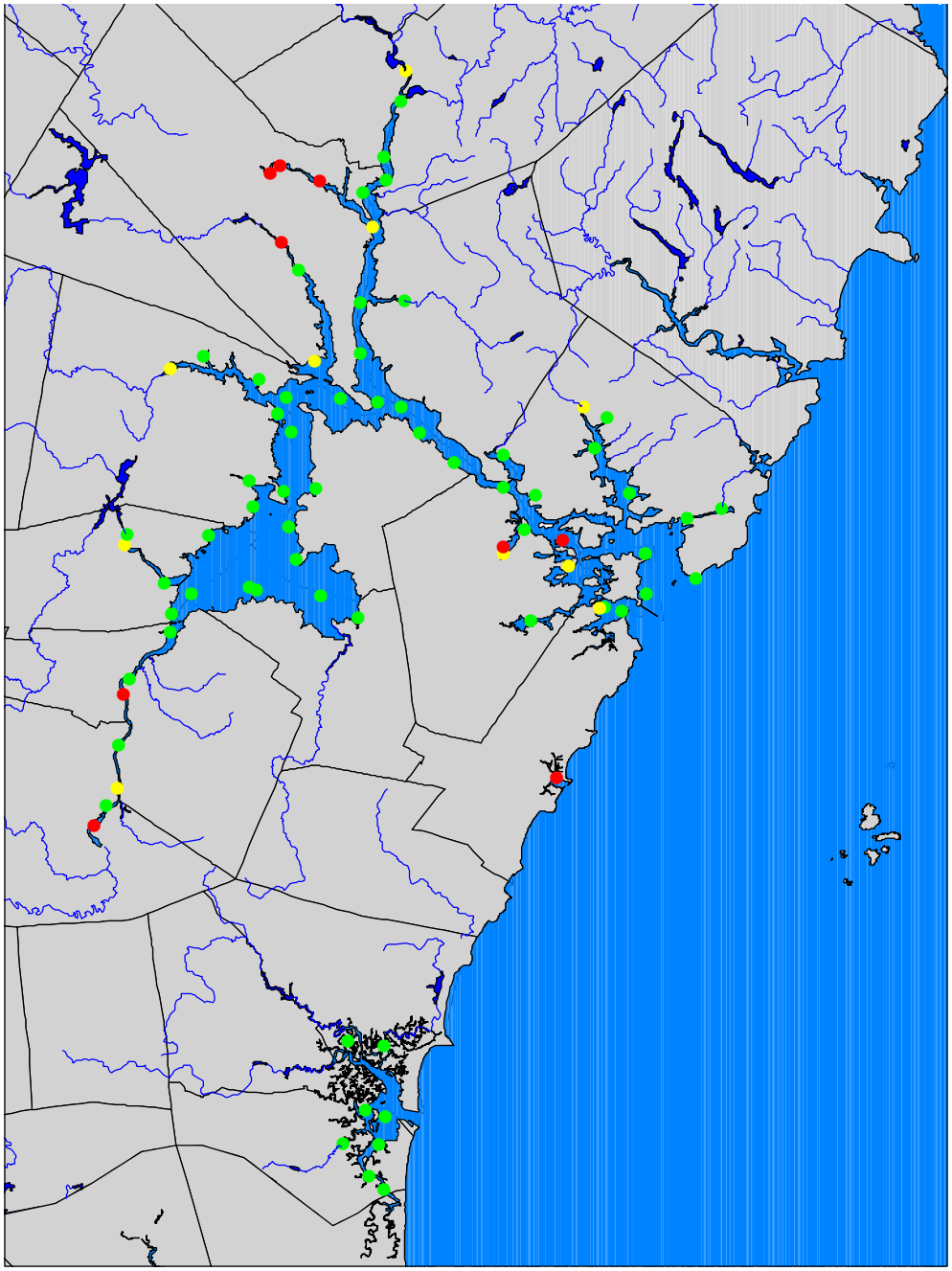
Enterococci

Enterococci (cts/100ml)

Concentration	% of Estuarine Area	Error (+/-)
<=26	91.9%	6.0%
>26 but <=104	7.1%	5.6%
>104	0.9%	2.1%



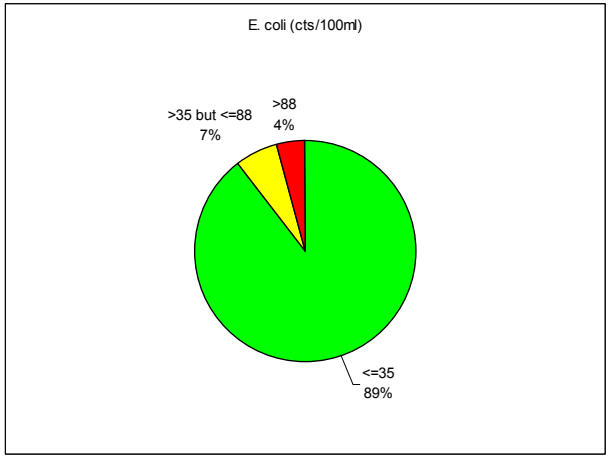
Notes:



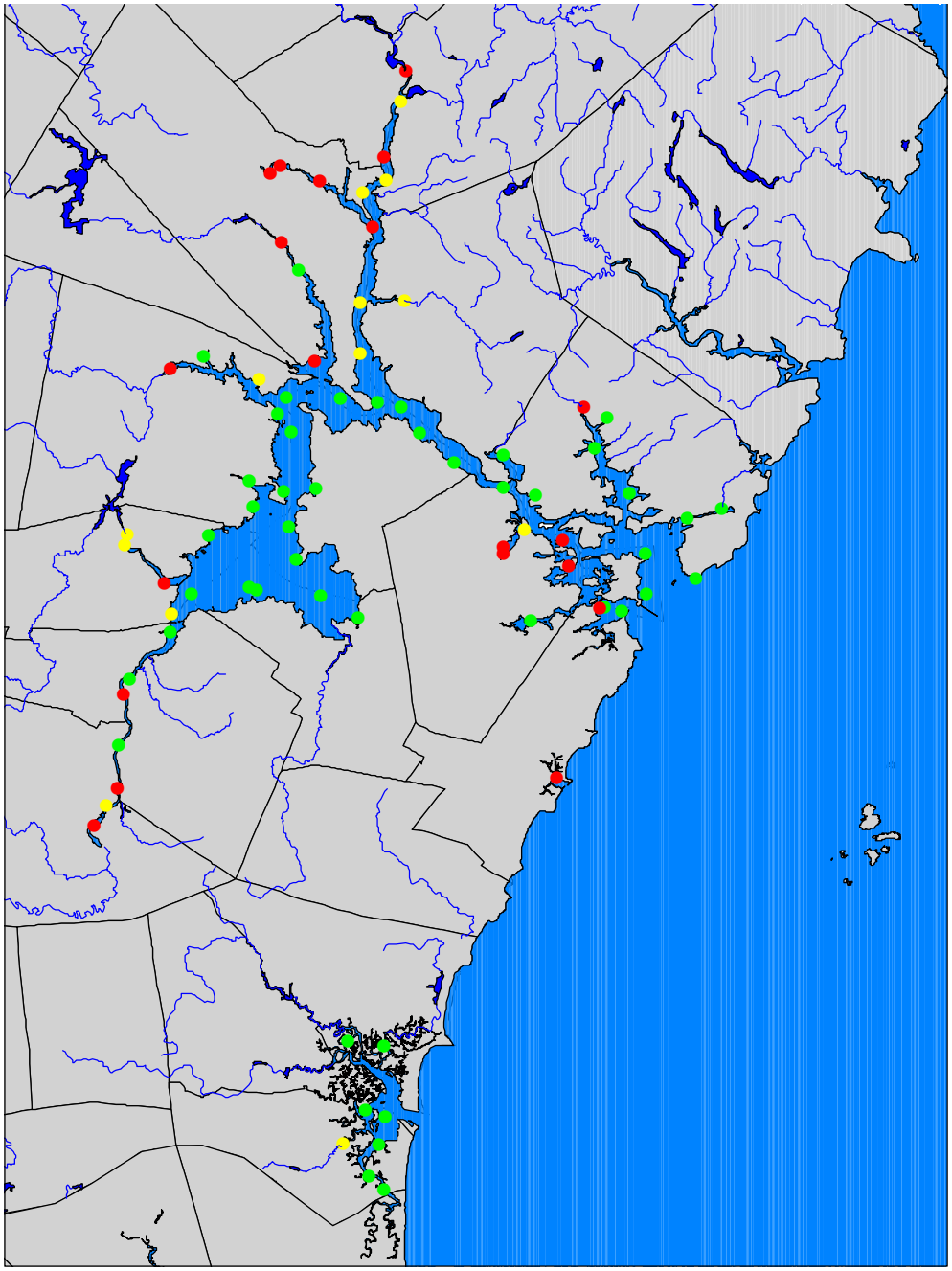
E. coli

E. coli (cts/100ml)

Concentration	% of Estuarine Area	Error (+/-)
<=35	89.3%	6.8%
>35 but <=88	6.6%	5.5%
>88	4.0%	4.3%



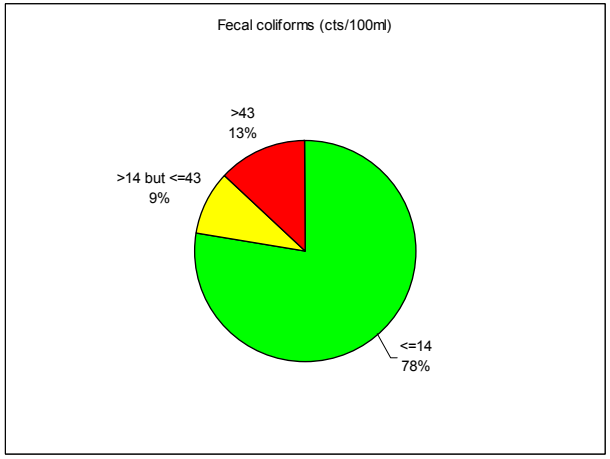
Notes:



Fecal Coliforms

Fecal coliforms (cts/100ml)

Concentration	% of Estuarine Area	Error (+/-)
<=14	77.4%	9.2%
>14 but <=43	9.4%	6.4%
>43	13.2%	7.4%



Notes:

Appendix C – Annual Trend Plots 2002-2005

Figure 1: Temperature (deg C)

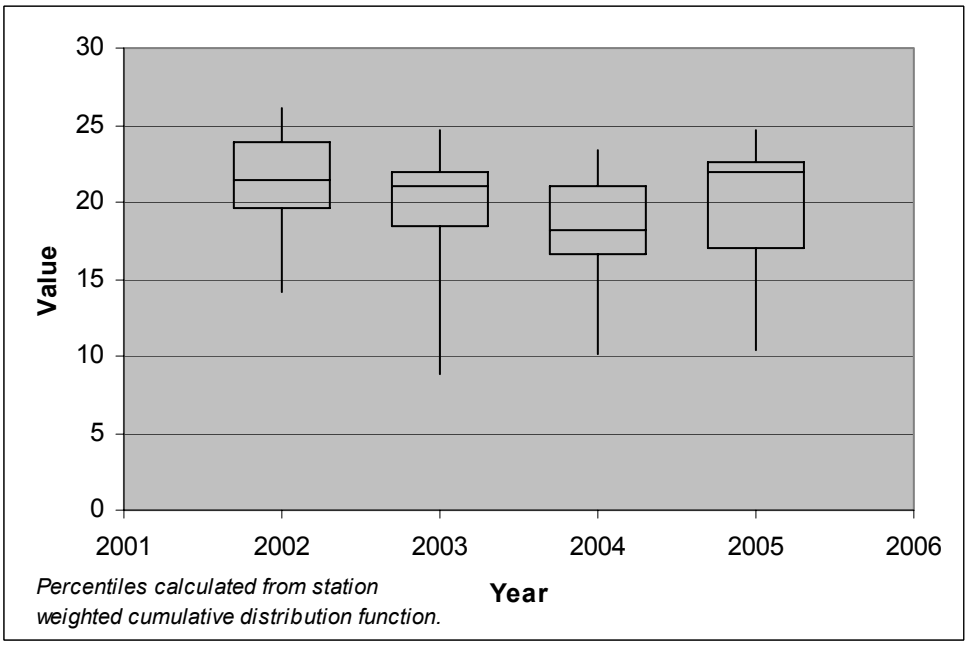


Figure 2: Salinity (ppt)

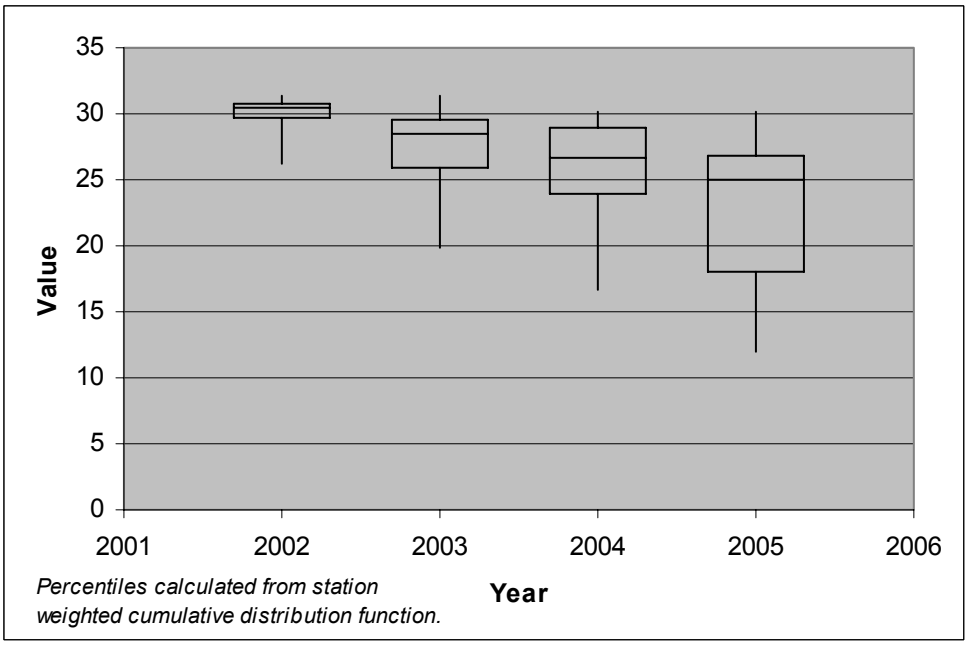


Figure 3: pH

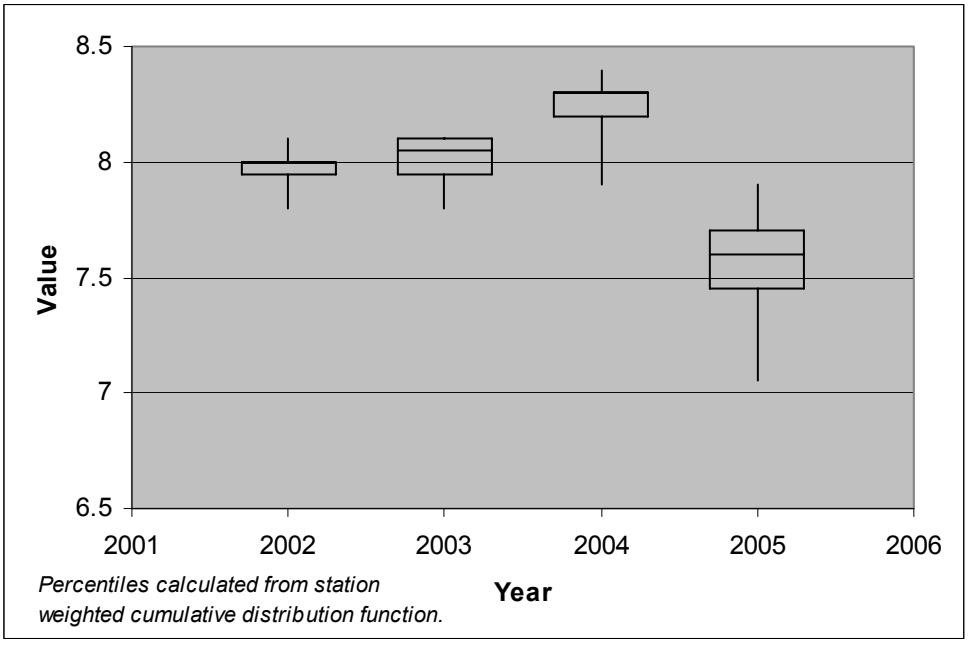


Figure 4: Dissolved Oxygen (mg/L)

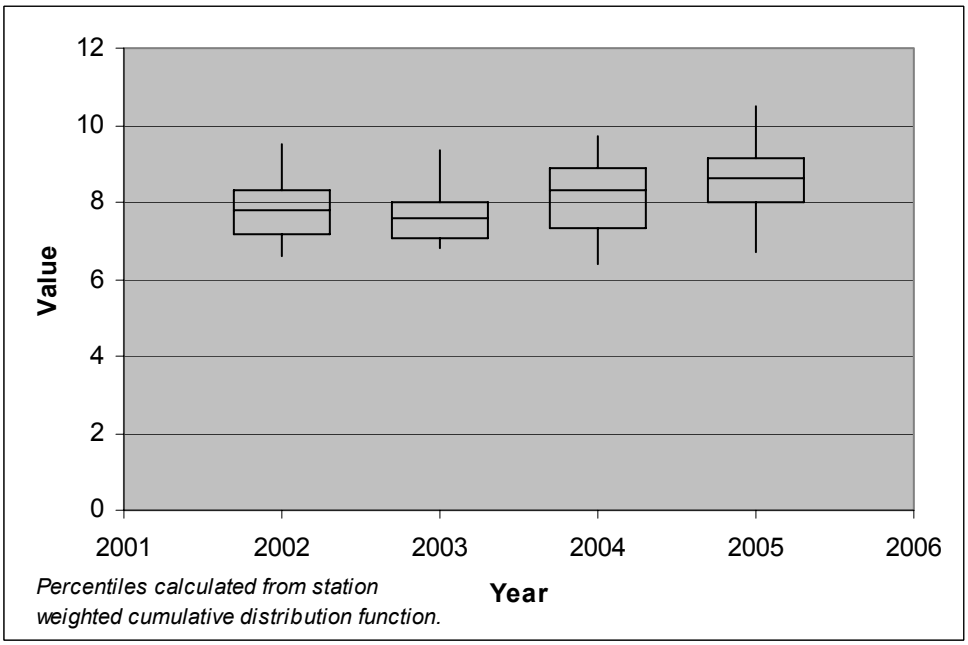


Figure 5: Nitrate + Nitrite (mg N/L)

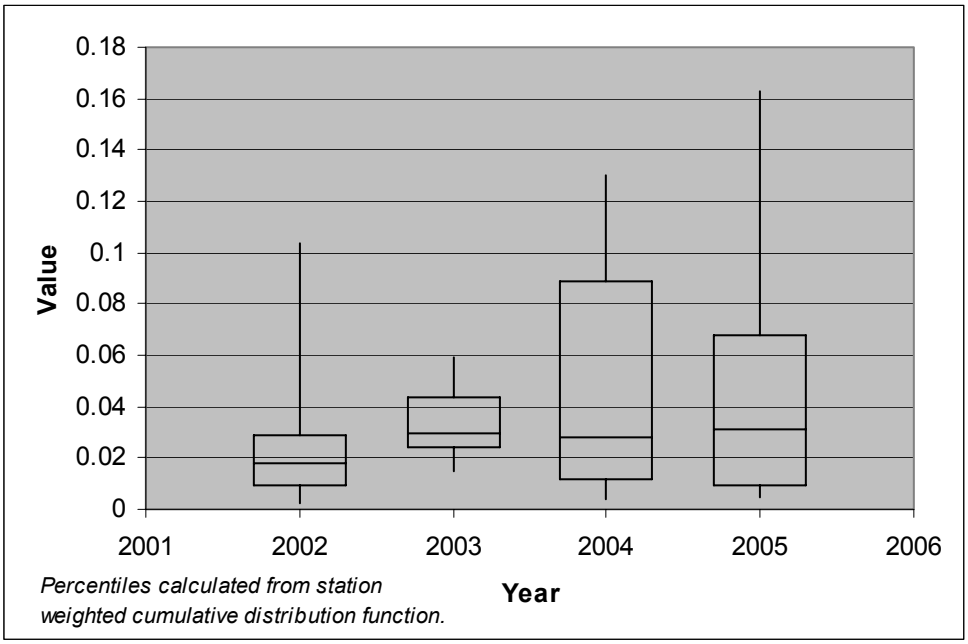


Figure 6: Orthophosphate (mg P/L)

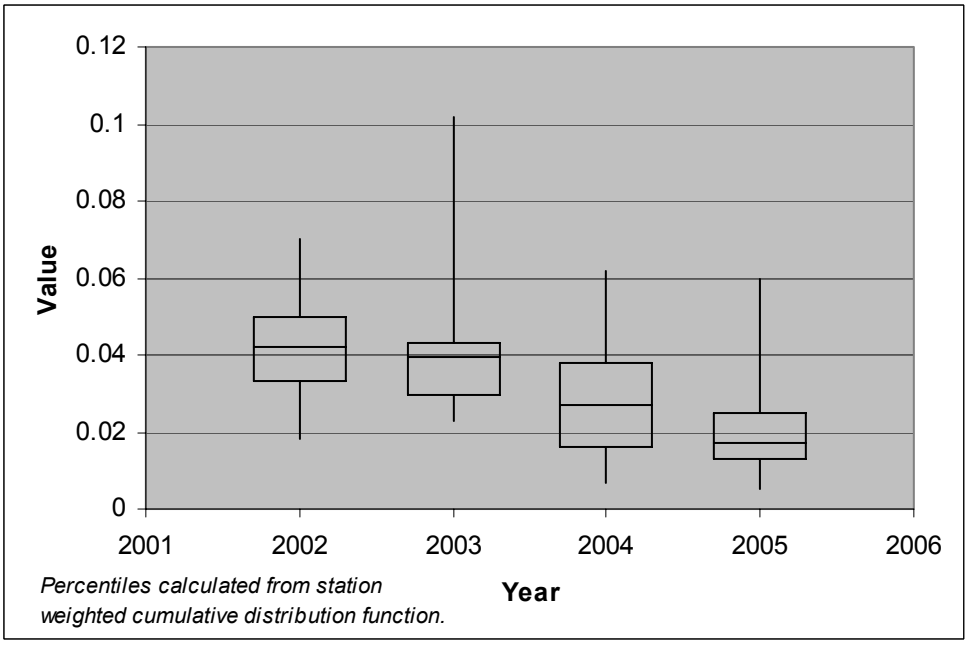


Figure 7: Silica (mg Si/L)

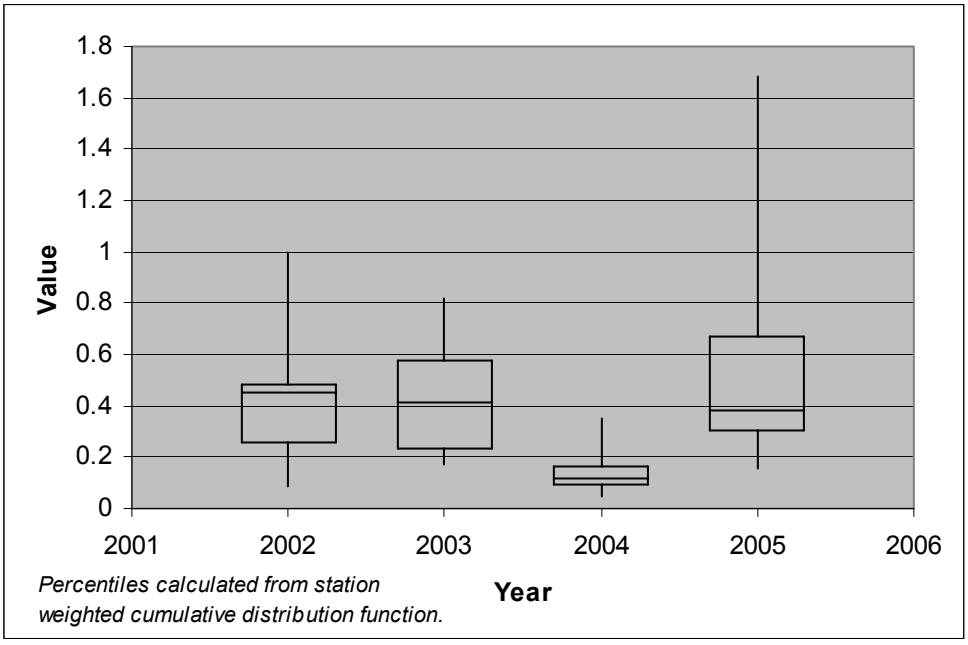


Figure 8: Chlorophyll-a (ug/L)

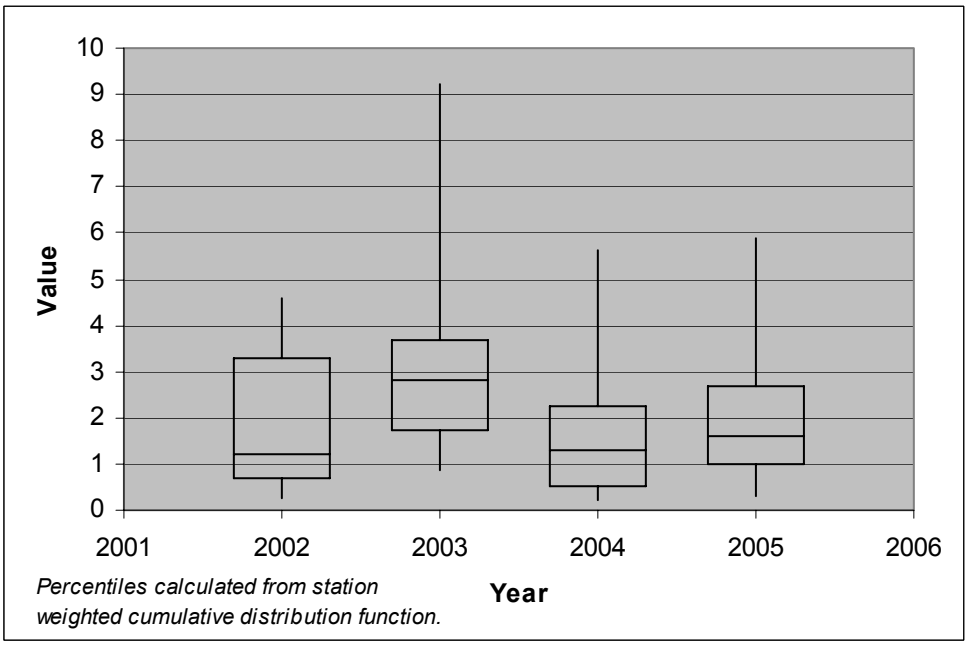


Figure 9: Total Suspended Solids (mg/L)

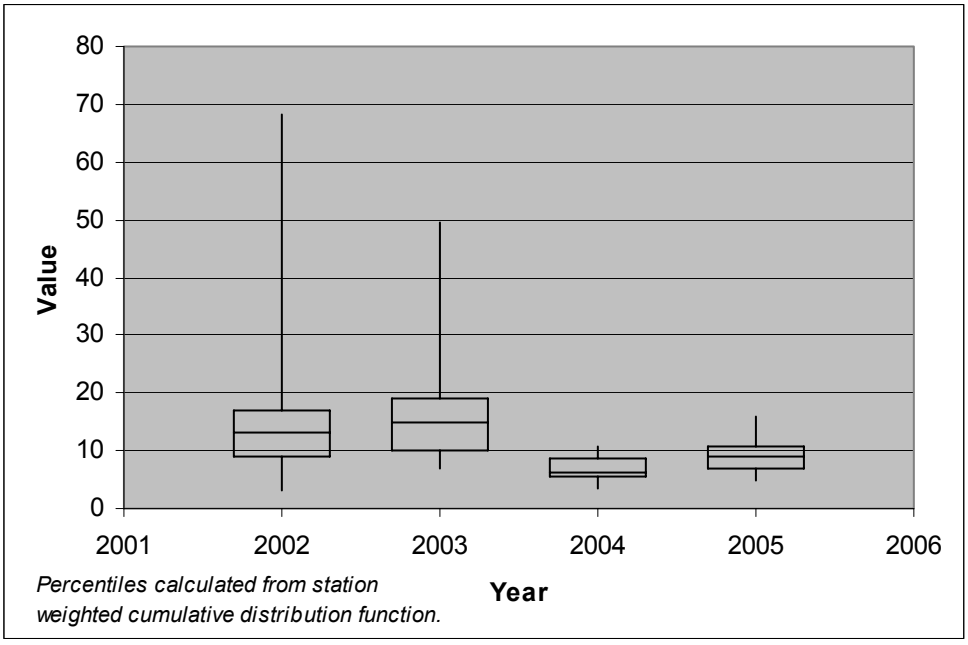


Figure 10: Enterococcus (cts/100ml)

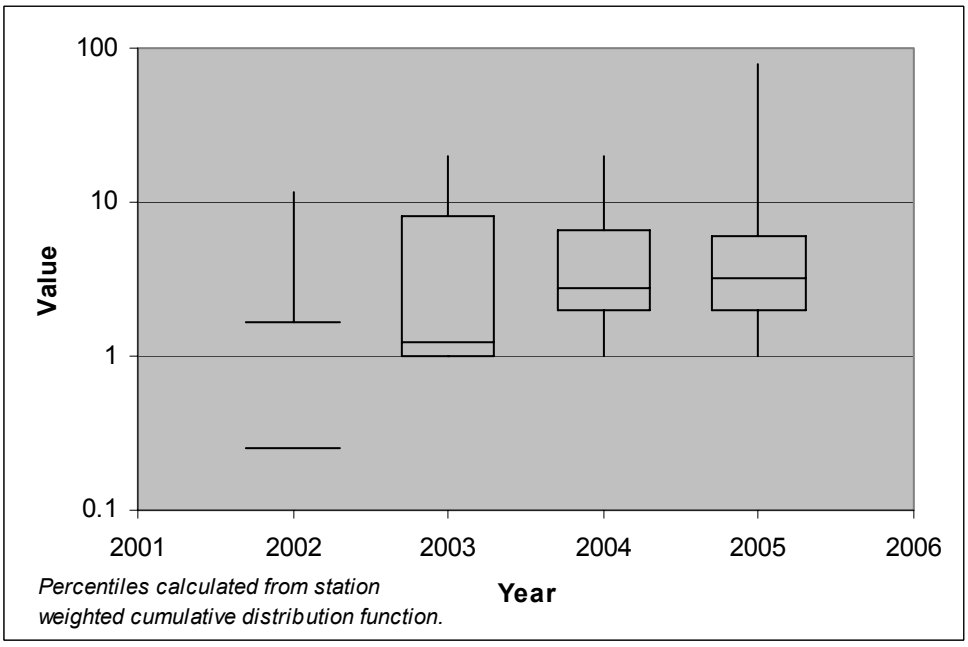


Figure 11: E. coli (cts/100 ml)

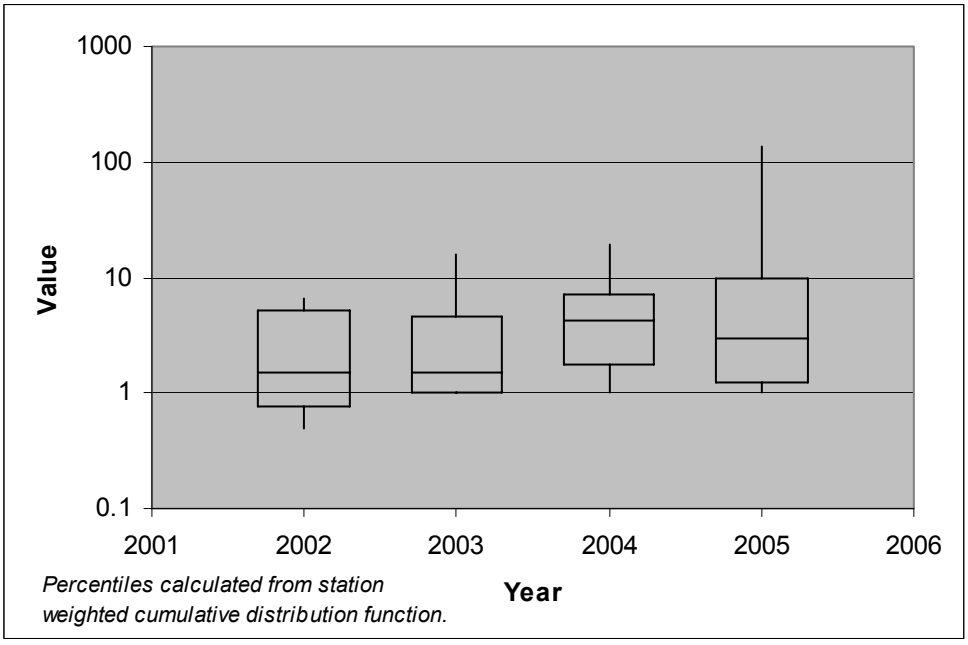


Figure 12: Fecal Coliforms (cts/100 ml)