Summary and Comparison of Continuous Sonde Data from the Ogeechee and Savannah River Basins

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Abstract. Continuous sonde data (temperature, pH, dissolved oxygen, and specific conductivity) is important for providing a baseline of parameters that help provide a short-term and long-term perspective of water quality conditions. In this study, we provide a summary of results on the first six months of sonde data from five permanent stations in the Ogeechee River Basin that span from Ogeechee River Mile 162 (ORM 162) to Ogeechee River Mile 27 (ORM 27). We also compare these data to continuous sonde data collected during the same time period from five locations within the Savannah River Basin that span from Savannah River Mile 214 (SRM 214) to Savannah River Mile 27 (SRM 27). Results show significant differences between these two adjacent river basins which likely lead to observed spatial differences in biological species composition and ecosystem processes.

INTRODUCTION

Continuous sonde data is important for providing a physical-chemical record of general water quality conditions over time. Use of the data ranges from instantaneous "sentinel-type" information for water quality protection to multi-year records, which can be used to determine water quality trends over long periods of time. In 2005, Phinizy Center for Water Sciences (formerly Southeastern Natural Sciences Academy) developed a network of water quality monitors to study the limnology of the Savannah River below Thurmond Dam. In its tenth year, that program has been able to provide a long-term dataset for understanding water quality trends for the Savannah River, mostly focused on the reach from Thurmond Dam (SRM 222) to SRM 27, near the I-95 bridge crossing. In 2014, Phinizy Center developed a similar monitoring program in the Ogeechee River Basin as part of a Supplemental Environmental Project. That program spans from ORM 162, near Midville, GA, to ORM 27 near the I-95 bridge. Since the Savannah and Ogeechee Rivers are adjacent basins they share similar climate and the fact that they both cut through the Coastal Plain physiographic province. However, they are distinctly different in that the Savannah River originates in the Blue Ridge and cuts through the Piedmont physiographic provinces (the Ogeechee River begins in the lower Piedmont), has a highly regulated discharge, has a deep water port within the estuary, has two nuclear facilities (Savannah River Site and Plant Vogtle), has been shortened by 40 miles (USACE navigation cuts), and has more permitted discharges compared to the Ogeechee River. The comparison of these two adjacent basins with simultaneous research and continuous monitoring programs will allow for a better understanding of how each of these river systems functions. In this paper we will describe some of the differences in sonde data observed within the first six months from multiple locations within these two adjacent river basins.

METHODS

The Ogeechee River Basin is slightly over 5,500 sq. miles and originates in the lower Piedmont with most of the drainage basin within the Coastal Plain; the river is 294 miles long. The Ogeechee River is one of Georgia's few remaining free-flowing rivers with an average discharge of 2,202 cfs (from available annual data from USGS gage 02202500-near Eden, GA). There are 8 major permitted dischargers within the entire basin (from EPA's Discharge Monitoring Report system).

The Savannah River Basin is nearly 10,600 sq. miles and originates in the Blue Ridge Physiographic Province. The river is well over 300 miles long when accounting for the drainage network that includes the Seneca and Tugaloo Rivers, which combine to form the Savannah River. Flow in the Savannah River is regulated by 7 dams which include 3 hydropower reservoirs for peak power (Thurmond Dam is located at SRM 222), 1 smaller

Temperature(°C)

	SRM 214	ORM 162	SRM 119	ORM 119	SRM 61	ORM 80	SRM 27	ORM 27
Average	18.36	19.27	20.74	20.13	21.50	21.44	20.16	20.51
StDev	2.83	7.20	5.08	6.91	5.43	6.89	6.38	7.33
CV%	15.40	37.39	24.48	34.35	25.25	32.15	31.63	35.75
Count	15168	15168	14855	14855	13597	13597	10717	10717
Max	22.50	28.74	27.55	29.70	28.22	30.73	29.45	31.11
Min	11.81	6.37	10.61	7.30	10.21	7.72	10.45	9.21

Dissolved oxygen(mg/L)

	SRM 214	ORM 162	SRM 119	ORM 119	SRM 61	ORM 80	SRM 27	ORM 27
Average	6.83	7.89	7.55	7.66	7.94	7.35	7.57	5.71
StDev	1.90	1.57	1.00	1.60	0.99	1.48	0.95	1.50
CV%	27.77	19.83	13.25	20.87	12.45	20.12	12.5	26.32
Count	15114	15114	14817	14817	13595	13595	11708	11708
Max	10.74	11.25	9.89	11.5	10.28	11.03	9.49	9.03
Min	4.32	5.68	5.91	4.49	6.59	5.43	4.32	3.66

Specific conductance (μS/sm)

	SRM 214	ORM 162	SRM 119	ORM 119	SRM 61	ORM 80	SRM 27	ORM 27
Average	47.37	72.07	97.89	103.82	97.54	114.36	107.86	531.82
StDev	2.17	4.13	8.23	9.99	8.96	23.36	10.68	842.45
CV%	4.57	5.73	8.40	9.63	9.19	20.42	9.90	158.41
Count	14669	14669	14855	14855	13596	13596	10711	10711
Max	54.00	83.35	123.00	132.30	122.00	166.39	292.00	6961.00
Min	43.00	52.95	77.00	76.70	80.00	40.17	81.00	79.00

pH

	SRM 214	ORM 162	SRM 119	ORM 119	SRM 61	ORM 80	SRM 27	ORM 27
Average	6.27	6.91	6.63	6.98	6.87	6.85	7.02	6.30
StDev	0.29	0.19	0.09	0.29	0.08	0.35	0.24	0.27
CV%	4.59	2.81	1.37	4.20	1.11	5.04	3.38	4.27
Count	15018	15018	14846	14846	12759	12759	11772	11772
Max	6.84	7.22	6.78	7.70	7.10	7.70	7.49	6.96
Min	5.81	6.29	6.32	6.30	6.67	5.33	6.59	5.47

Table 1: Sonde data statistics for Savannah and Ogeechee River sites.

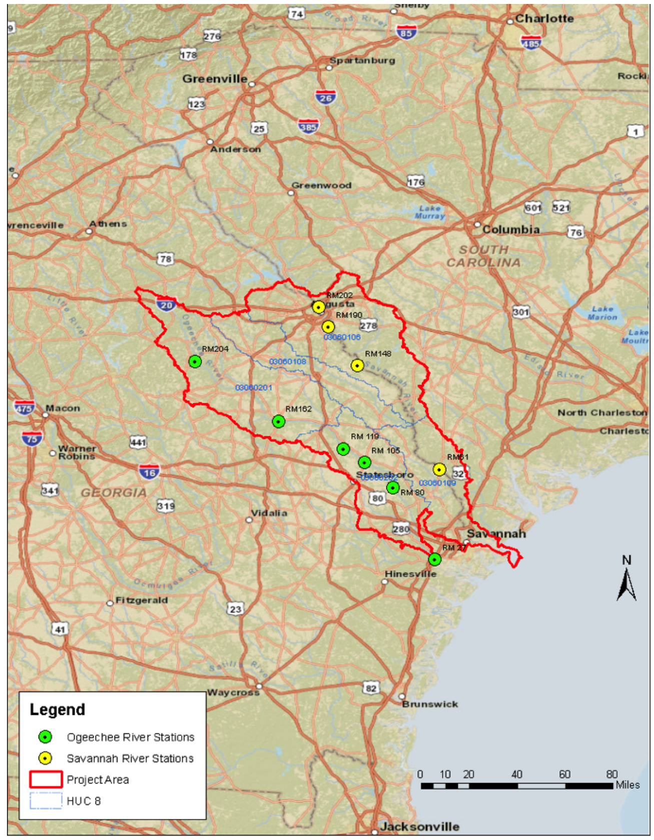

Figure 1: Project area and location of sondes.

hydropower plant that regulates the daily average flow for the river below Thurmond Dam, a diversion dam, and a lock and low-head dam (~SRM 187). The daily average flow for the Savannah River is 11,368 cfs (from available annual data from USGS gage 02198500-near Clyo, GA). There are 31 major permitted dischargers in the Middle and Lower Savannah River Basins (from EPA's Discharge Monitoring Report system).

Phinizy Center's monitoring network for the Savannah River was established in 2005. In 2012, the system was upgraded to a real-time, web-accessible network (http://goo.gl/gyp80z) with 8 sites that span from SRM 214 (six miles below Thurmond Dam) to SRM 27 (near the I-95 bridge). Phinizy Center's Ogeechee River monitoring network was established in 2014 and includes two sites owned by GAEPD; all sites also have real-time, web-enabled data (http://goo.gl/LpPzGK). All sites in both river systems collect data using a YSI water quality sonde which measures water temperature (±0.15°C), pH (±0.2 units), dissolved oxygen (±0.1 mg/L or 1% of reading, whichever is greater; ±1% of reading or 1% air saturation, whichever is greater), and specific conductance (±0.5% plus 0.001 mS/cm) at 15-minute intervals. All sites are maintained at least once per month by Phinizy Center staff; data is post-processed using Aquarius Time Series software.

In this paper, we paired four sites in both basins that were important water quality sites and that were within the same proximate distance upstream from the ocean. In the Savannah River system we chose SRM 214 (eight miles below Thurmond Dam), SRM 119, SRM 61, and SRM 27. In the Ogeechee River system we chose ORM 162 (most upstream site where water flow is constant), ORM 119, ORM 80, and ORM 27 (Fig. 1).

It is usual, for one reason or another, to have some missing data from a deployed sonde dataset. In order to accurately compare statistics between paired sites, we chose to use data that matched the exact date and time from each paired site instead of using the total available record for the paired sites. This matching technique minimizes bias in the data, which could arise from missing data from one of the paired sites. For example, if one month of summer time data were missing from one of the paired sites and present in the other, the statistical analyses would be biased higher for the site with the warmer temperature data. As a result, the number of data points for sites of a given river system differ from site to site but are exactly the same for the paired basin sites. We used Microsoft Excel on post-processed data to develop matched data sets and to develop the descriptive statistics.

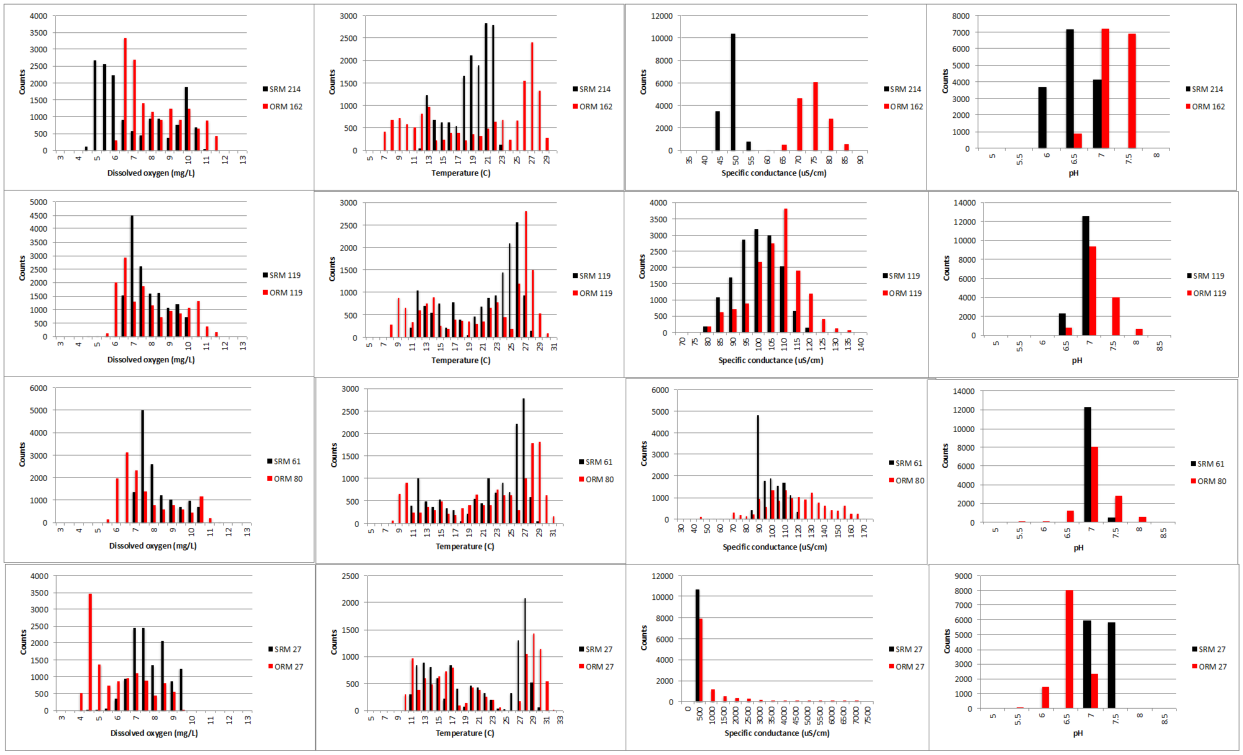

Figure 2: Histograms of dissolved oxygen (column 1), temperature (column 2), specific conductance (column 3), and pH (column 4) data from both the Savannah River Basin (black) and Ogeechee River Basin (red).

RESULTS

Statistics (average, standard deviation (StDev), Coefficient of Variation as a percent (CV%), the number of data points used (count), and minimum (min) and maximum (max) value for the record) from all paired sites is shown in Table 1. In order to develop a better understanding of the spread of the data, we developed histograms for each parameter at each site as well (Fig. 2).

The upper river comparison: Savannah River Mile 214 and Ogeechee River Mile 162. Comparison of the uppermost sites showed, on average, lower values for each parameter in the Savannah River than in the Ogeechee River. The Savannah River had the lowest variability for both temperature and specific conductance but the Ogeechee River had less variable dissolved oxygen and pH at the uppermost sites. The minimum values for each parameter were lowest for the Savannah River except temperature whereas the Savannah River had the highest maximum value for all parameters. Distribution of the data was quite different for all parameters. The Savannah River showed a somewhat bimodal distribution for DO whereas the Ogeechee River showed a somewhat right-skewed distribution, temperature data for the Savannah River were much less distributed compared to a wide temperature range for the Ogeechee River, and both specific conductance and pH showed two distinct ranges with the Savannah River having the lower range for both parameters.

The middle river comparison: Savannah River Miles 119 and 61 versus Ogeechee River Miles 119 and 80. Comparison of the two paired sites within the middle of the study reach showed, on average, that the Savannah River had lower pH and specific conductance at both sites and lower DO at SRM 119 only while the temperature was lower at both sites in the Ogeechee River and had lower DO at the ORM 80 site only. The Savannah River had the lowest variability and the lowest maximum value for all parameters at both paired sites. Minimum values for all parameters at both paired sites was lowest in the Ogeechee River except for specific conductance and pH at the RM 119 site pair where the lowest value was essentially the same in both rivers. Distribution of the data for the two paired sites in the middle of the study reach were more alike than the SRM 214/ORM 162 pair but the spread of the data remained slightly wider for the OR sites than for the SR sites. Data distribution for specific conductance at both paired sites and pH for the RM 119 sites were centered slightly lower for the SR sites than in the OR sites.

The lower river comparison: Savannah River Mile 27 and Ogeechee River Mile 27. Comparison of the lowermost sites showed, on average, lower values for temperature and specific conductance for the Savannah River and lower values for DO and pH for the Ogeechee River. The Savannah River had the lowest variability for all parameters at the paired RM 27 sites. The minimum values were lowest for all parameters for the Ogeechee River while maximum values were lowest for temperature and specific conductance only. Distributions for Ogeechee River DO and pH were slightly wider and to the left of the distribution for the Savannah River while the distribution of temperature was similar for both basins except ORM 27 had slightly more counts at the maximum temperatures than SRM 27. Statistics for specific conductance comparisons between the RM 27 pairing was quite different because the saltwater wedge reaches much further up in the Ogeechee River; all 10,711 measurements taken in the Savannah River were between 0 μS/cm and 500μS/cm whereas 26% of all measurements were $> 500\mu$S/cm in the Ogeechee River.

CONCLUSIONS

As shown, Thurmond Dam has an impact on each of the sonde parameters in the Savannah River relative to the uppermost location in the Ogeechee River; it is generally colder in the summer and warmer in the winter, more dilute, has less DO, has a lower pH, and shows less variability for each parameter. Our preliminary data comparing aquatic insect populations between these two basins indicates that SRM 214 in the Savannah River was dominated mostly (~95%) by collector-gatherers and has no taxa represented by the orders Ephemeroptera, Plecoptera, or Tricoptera (EPT) whereas, the uppermost sampled site in the Ogeechee was mostly shredders (~50%) with only about one-third of the population categorized as collector-gatherers with about 5% of the population as EPT taxa (Mullis et al., 2015). While these findings could be consistent with one or more of the sonde parameters measured, additional research is required to strengthen the causational relationships.

The initial conditions set by Thurmond Dam in the Savannah River seem to leave a lasting "imprint" on the downstream sites for most of the parameters. Dissolved oxygen is one exception, DO starts low in the Savannah as a result of metalimnetic discharges from the reservoir, but increase with downstream direction whereas DO in the Ogeechee starts higher and decreases with downstream direction. It is likely that large organic material fluxes (Flite et al., 2015), and concomitant bacterial respiration, from the estuary in the Ogeechee Basin are responsible for lower DO values at ORM 27 compared to SRM 27. It will be important to continue this research to understand the dynamics of the low DO condition in the Ogeechee River estuary. It will also be important to continue research on the potential impacts of the lasting "imprint" of Thurmond Dam on the aquatic ecosystem below the dam.

We have known that continuous data sets are important for determining short-term and long-term trends in river basins. However, this study has shown that comparison of continuous data sets of adjacent river basins can make these data even more powerful, especially if the river basins share some common elements (i.e. geology, climate, and aquatic species) but differ in others (i.e. managed flows with dams and drainage basin area). Since the physical and chemical environment is so critical for aquatic species survival and fitness, adjacent basin comparisons can give scientists, regulators, managers, and other stakeholders an important baseline of information for guiding river basin management efforts to protect and enhance the riverine ecology and can support more informed regulatory decision-making.

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