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HOLLOW CREEK WATER QUALITY MONITORING RESULTS (SEPTEMBER 2014 TO AUGUST 2016)

By

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Abstract

During the past ten years, a team of volunteers monitored water quality at locations on Hollow Creek in Aiken County, SC. This report presents data obtained from September 2014 to August 2016. Previous reports summarized results for November 2006 to August 2014. Monitoring included measuring chemical and physical properties of the water and benthic macroinvertebrate biodiversity of the stream habitat. In addition, amphibian monitoring began in January 2010 and fish monitoring in 2012. A total of 91 sampling events took place during the two years covered by this report. The sampling results show consistently good water quality in Hollow Creek. Dissolved oxygen content in the creek was high, the pH was in the range expected for a slightly tannic stream, chemical pollutants were low or absent, turbidity was low, and biological diversity ranged from good to excellent. The number of frogs decreased in 2016 after peaking in 2015. The water diverted from Hollow Creek for the stork ponds was sampled twice for *E. coli* near hog pens adjacent to the diversion canal. *E. coli* levels were below levels of concern.

Introduction

Hollow Creek drains approximately 89 squares miles of Aiken County located between the towns of Aiken, Beech Island, Jackson, and New Ellenton (Figure 1.) The creek passes through the Silver Bluff Audubon Center and Sanctuary, a recognized Important Bird Area (IBA), and provides water to ponds used in a feeding program for threatened wood storks (*Mycteria americana*). The creek eventually drains to the Savannah River from which various communities downstream take their drinking water. Although most of the watershed is rural, significant development is underway, particularly urban development on the south side of the city of Aiken. Farming, residential and commercial development in the drainage basin may affect the water quality. Thus, parties interested in maintaining good water quality in this stream include the local residents, the Silver Bluff Audubon Center and Sanctuary, South Carolina Department of Health and Environmental Control, the Savannah Riverkeeper, and Georgia Adopt-A-Stream (GAAS). In 2006, concerned members of the Augusta-Aiken Audubon chapter, staff of the Silver Bluff Audubon Center and Sanctuary, and local residents formed a volunteer group to monitor the water quality of their stream. Monitoring includes both chemical and physical measurements performed monthly, amphibian counts performed monthly, and benthic macroinvertebrate counts performed quarterly. Monitoring allows assessment of current water quality and provides baseline data to gauge the effects of future development.

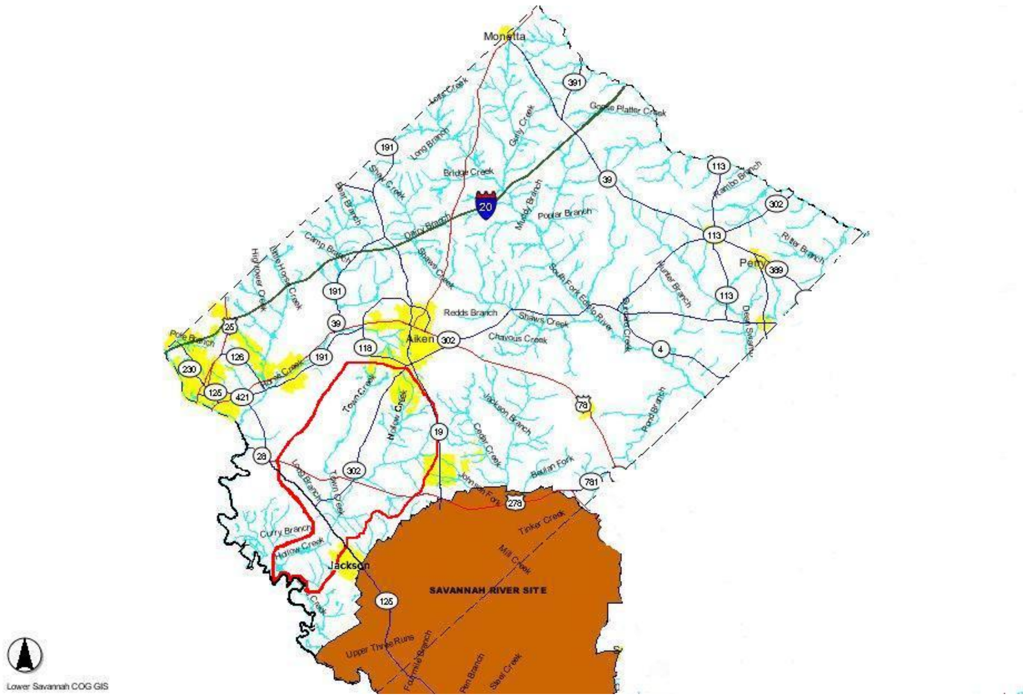

FIGURE 1. Map of Aiken County showing the Hollow Creek watershed, circled in red.

The Hollow Creek stream monitoring effort forms part of the Georgia Adopt-A-Stream program. The volunteers received GAAS training, including annual retraining, and follow GAAS sampling and data collection protocols. The results from sampling the main stream of Hollow Creek are entered in the GAAS database and are available on-line (Ref.1). The team's identification number is AAS-G-1087 and its name is "AAAS Stream Stompers". Four previous reports summarized data obtained between 2006 and 2014 (Ref. 2).

Sampling Locations

The three monitoring sites used in the majority of this study are located within Aiken County, SC, on or near the Silver Bluff Audubon Center and Sanctuary, Jackson, SC. See Appendix A for the locations, site names, photographs of each site, and description of the habitat. Two additional sites were sampled for bacteria counting in March, 2016. The samples came from the diversion canal that brings water from Hollow Creek to the Silver Bluff Audubon stork ponds. See Appendix A for details of these locations

Procedures

Georgia Adopt-A-Stream (GAAS) provided the monitoring procedures. These are accessible through the GAAS website (Ref. 1) or through their publications (Ref. 3, 7-8). At least two GAAS-trained and qualified monitors participated in each monitoring event. Appendix B contains descriptions of the equipment and methods.

Results and Discussion

The latest two years of sampling results show consistently good water quality in Hollow Creek with few differences from the previous eight years. Dissolved oxygen content in the creek was high, the pH was in the range expected for a slightly tannic stream, chemical pollutants were low or absent, turbidity was low, and biological diversity was good to excellent (by the GAAS criteria). The water diverted from the stream and which flows into the stork ponds (sampled at SP-1) shows greater variation in pH and was significantly lower in dissolved oxygen. Table I lists results of chemical monitoring from September 2014 to August 2016. Tables II and III list results from biological monitoring, Table IV lists the results of amphibian monitoring, and Table V lists the results of fish monitoring during the same period.

Chemical Monitoring

Figure 2 shows the dissolved oxygen concentrations found between September 2014 and August 2016. In the stream samples taken at HC-1 and HC-2, the concentration varied between 5.9 and 10.7 mg/L, essentially unchanged from results during the first eight years of monitoring (5.9 to 12 mg/L) (Ref.2). A concentration of 5 to 6 mg/L provides adequate oxygen for most aquatic life forms. As shown in the graph, the oxygen concentration varies seasonally due to temperature changes, being higher in the cold winter months and lower in the hot summer months. Oxygen in the water feeding the stork ponds (SP-1) is lower than in the stream and varies considerably, but it also tends to be higher in winter and lower in summer.

Consistent differences in dissolved oxygen concentrations occur between the two stream sampling points with HC-1 showing slightly lower oxygen levels. The average oxygen concentration at HC-1 was 8.0 mg/L and varied from 6.0 to 10.5 mg/L, whereas HC-2

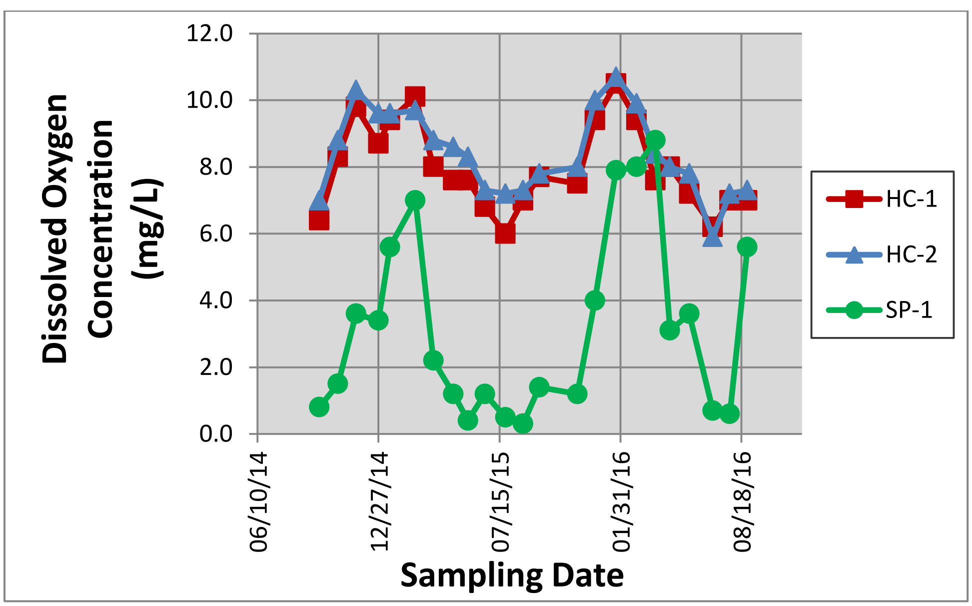

FIGURE 2. Dissolved oxygen concentrations

averaged 8.4 mg/L and varied from 5.9 to 10.7 mg/L. In 20 of 23 sampling events, the oxygen level at HC-1 was lower than at HC-2. The differences are small and are mostly attributable to water temperature. Water temperature is expected to rise slightly during the day due to solar heating. We have consistently sampled HC-1 later in the day and the water temperature is normally warmer than at HC-1 (20 of 23 events). Since oxygen solubility decreases as the water temperature increases, one would expect oxygen levels at HC-1 to average slightly lower than at HC-2.

The temperature dependence of oxygen concentration can be removed by calculating the oxygen concentrations as a percentage of the saturation limit. Figure 3 shows the same data recalculated as "% of saturation" based on the saturation limit of pure water at the temperatures of the samples (Ref. 3). At HC-1 and HC-2 dissolved oxygen (as % of saturation) ranged from 70 to 90% with little difference between the two points. HC-1 averaged 83% (±5%) and HC-2 averaged 85% (±4%) over the two year period, slightly lower than during the previous two year period (85% and 88%, see Ref. 2d).

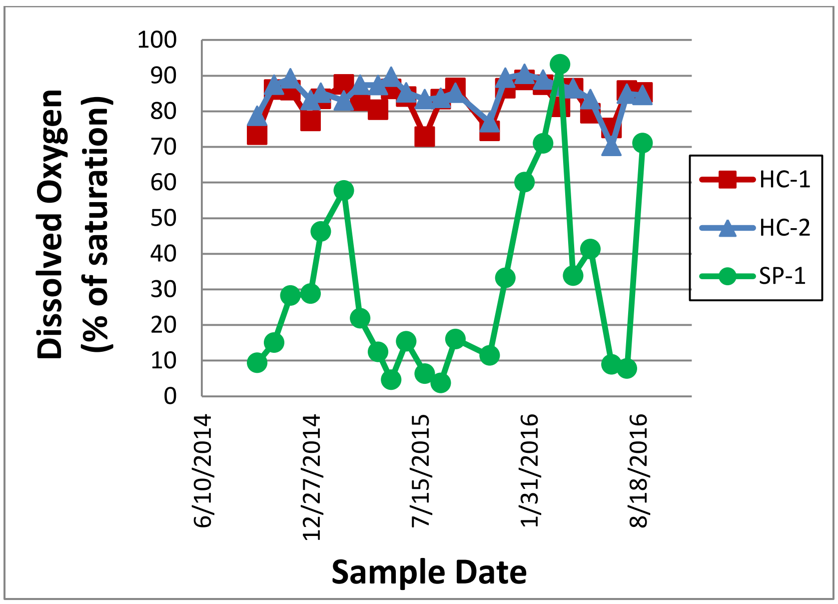

FIGURE 3. Dissolved Oxygen Concentrations as Percentage of Saturation

Dissolved oxygen content at the stork pond inlet varied erratically and was usually much lower than the main stream. The percentage of saturation varied between 4 and 93%, with an average of 30%. The low values likely occur because of slow flow rates, and, at times, stagnant conditions at the stork pond inlet. The presence of floating plants, algae, and debris in the vicinity of the sampling point also add to the variability in DO.

Figure 4 shows the stream pH measurements at HC-1, HC-2, and SP-1. HC-1 and HC-2 were quite similar, varying between 5.5 and 7.0 and averaging 6.0 ±0.4 (HC-1) and 5.9±0.4 (HC-2). This pH range is consistent with the slightly tannic nature of the stream and is closer to the expected range for a fast-moving mountain stream (6.0 to 8.0) rather

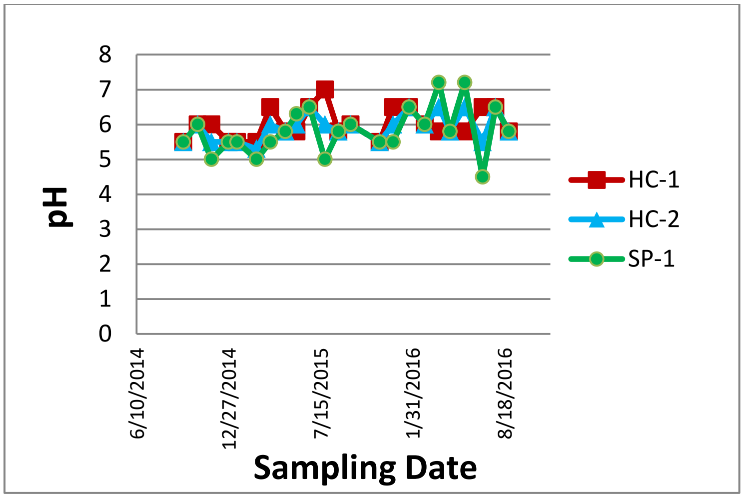

FIGURE 4. Results of pH measurements at HC-1, HC-2, and SP-1.

than a slow-moving black-water river (as low as 3.5). The average pH at the stork ponds was 5.7±0.7, slightly lower than the stream and with greater variability. The stork pond pH has been consistently lower than the stream since a fire event occurred near the pond in December 2007, but the effect appears to be diminishing.

In the main stream (HC-1 and HC-2), chemical pollutants (nitrate, ammonia, and phosphate) were low and below levels of concern. Nitrate was always ≤ 0.2 mg N/L, compared to the EPA drinking water standard of <10 mg N/L. Ammonia concentrations above detection limit were found only three times (out of 46 samples) in the main stream. Phosphate was never detected in the stream (detection limit equaled 0.2 mg PO_4/L). Levels of phosphate above 0.3 mg/L can stimulate plant growth sufficiently to surpass natural eutrophication rates and lead to oxygen depletion.

In the stork ponds (at SP-1), nitrate and phosphate were never detected. Ammonia was detected in the range 0.1 to 1.0 mg N/L during eight of 23 sampling events. This is about the same frequency and amount of ammonia found in the previous two years. Two conditions have changed in the past year that could affect ammonia levels. A local farmer now grazes cattle in a new pasture that drains into the stork pond, and beavers have been active in the pond. These sources have apparently not degraded the water quality detectably by our methods.

The stream (HC-1 and HC-2) did not contain significant amounts of settleable solids (by Imhoff cone) or exhibit significant turbidity (by Secchi disk). Settleable solids at HC-1 and HC-2 were detected above trace levels (<0.1 mL/L) in only six of 46 samples, with the highest value of only 0.1 mL/L. This frequency is the same as found during the previous two years (seven of 44 samples). Turbidity (by Secchi disk) was low, with the stream clear to the bottom at the deepest place we could locate (0.6 to 1.5 meters) Three measurements were made when the stream was not clear to the bottom. In July 2016, settleable solids and turbidity were both non-trace for both sampling points. This was likely caused by three inches of rain recorded in the drainage basin during the two days before sampling occurred.

The suspended solids and clarity of the water at the stork pond sampling point is poor compared to the main stream. Settleable solids exceeded trace levels at the stork pond inlet about half of the time, but this is attributed to stagnant (no flow) conditions coupled with the disturbance caused during sampling. However, Secchi disk depths less than the depth of the available water occurred in 19 of 24 sampling events. The transparent depth varied between 9 and 50 cm. This continues a trend observed in the previous two years and is due to a change in an adjacent farm field. A wooded field that drains into the stork pond was cleared and converted to a pasture. The water in the pond has been turbid since the clearing occurred and the turbidity can be observed to arise from an intermittent stream that drains the pasture and flows into the stork pond.

Conductivity proved quite low, indicating very low concentrations of dissolved ions. The conductivity is typical for a soft water natural stream. Raw sewage, and, if close to the coast, salt water intrusion, can cause very high conductivity (>500 µS/cm). Measured conductivity ranged from 14 to 20 µS/cm in the stream, and 32 to 100 µS/cm at SP-1. This is unchanged from the previous two years. The higher conductivity at SP-1 does not appear to correlate with the turbidity changes, since it has been relatively constant since the start of our conductivity measurements in 2008.

<u>Macroinvertebrate Counts</u>
Biological monitoring occurred quarterly between February 2007 and August 2016. Only the two stream sites (HC-1 and HC-2) were sampled. Data for November 2014 to November 2016 are reported here for the first time and data for February 2007 to August 2014 can be found in the references (Ref. 2). At the back of this report, Table II lists the macro- invertebrates that were found which count toward the GAAS diversity rating. Table III lists additional animals that were found but do not count in the GAAS rating. Table II also shows the GAAS score and the corresponding diversity descriptor: Poor (<11 pts.), Fair (11-16 pts.), Good (17-22 pts.), and Excellent (>22 pts). During the past two years, both sites scored either Good or Excellent in all sampling events. This result parallels the previous eight years of monitoring.

The following discussion summarizes information for all ten years of our monitoring. Table VI and Figure 5 compare the GAAS scores for the two sampling sites.

TABLE VI. Summary of Macroinvertebrate Counting Results

	GAAS Score	
Year(s)	**HC-1**	**HC-2**
2015-16	21.2	23.2
2013-14	21.4	23.8
2007-16	21.6±3.1	24.5±3.1
Highest score	25	31
Lowest score	15	18

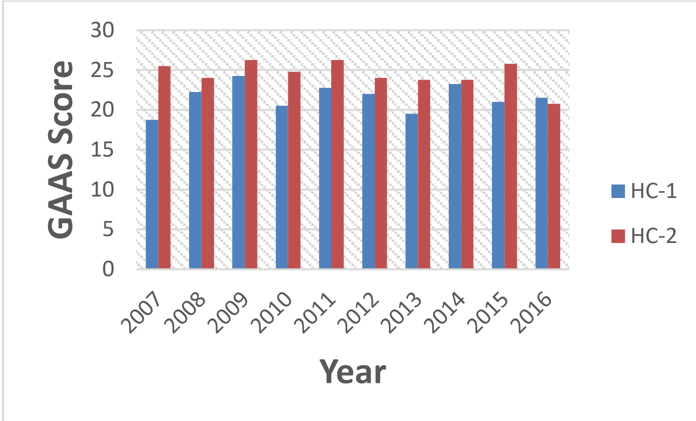

FIGURE 5. Annual average GAAS scores for HC-1 and HC-2 for 2007 to 2016.

Over the ten year period, HC-2 usually scored slightly better than HC-1. This is shown by the average over ten years (Table VI), by each yearly (Figure 5) or bi-yearly set (Table VI) of averages (except for 2016), and by the record high and low at each site (Table VI). There is no apparent trend upward or downward at either location (Figure 5). The greater diversity at HC-2 may be caused by greater sunlight at stream level due to less canopy coverage, compared to HC-1.

We see little variation in the GAAS scores based on the sampling month (Table VII). August produced the highest monthly average (at HC-2), but also the lowest monthly average (at HC-1). The seasonal averages are consistently higher at HC-2 over HC-1.

TABLE VII. Seasonal Variation in GAAS Scores (averages for 2007-2016)

	Sampling Month			
	February	**May**	**August**	**November**
HC-1	20.8	23.2	20.6	21.7
HC-2	23.2	24.6	25.6	24.5

During the ten years of macroinvertebrate counts, we have recorded 13,441 individuals. HC-1 accounted for 38% and HC-2 accounted for 62% of the total. The five most numerous insects (by GAAS scoring categories) are listed in Table VIII. Caddisfly larvae are easily the most numerous insect found. The distribution by season varies with the insect category. Many categories are low in the August sampling, but some, such as common net-spinning caddisflies, peak in August. Although not listed in the table, riffle beetles (eighth ranked in total abundance) peak in August (54%).

Seasonal variations occur in the total number of animals found at the GAAS scores, but the two sampling sites differ in their trends (see Table IX). The most animals are found in May (4213), followed by November (3476). February (2913) and August (2839) have

TABLE VIII. Top Five Insects by Total Number of Individuals Recorded (2007-2016)

Rank	Insect	Total	Percentage of Total by Season			
			February	May	August	November
1	Caddisfly larvae	4034	17	33	17	33
2	Mayfly larvae	2607	25	31	16	28
3	Midge fly larvae	1714	34	30	15	22
4	Common net-spinning caddisfly larvae	1039	18	26	40	16
5	Stonefly larvae	703	42	31	7	20

TABLE IX. Seasonal Variation in Numbers of Individuals Observed (2007-2016)

	Sampling Month			
	February	**May**	**August**	**November**
Total individuals	2913	4213	2839	3476
HC-1	1332	1294	1308	1209
HC-2	1581	2919	1531	2267

approximately equal numbers, but are significantly lower than May and November. At HC-1, we have counted approximately the same number of individuals in each season. However, at HC-2, May sampling is particularly high and November is moderately high.

<u>Amphibian monitoring</u>

A three-year decline in frog occupancy observed between 2010 to 2013 dramatically reversed in 2014 when we found 50 frogs during the year (Note: This includes data for September through December, 2014). High numbers of frogs continued to occur through 2015, but declined severely in 2016.

In our report for 2013-14, we attributed the increase in the number of frogs observed in 2014 to the increased rainfall in 2013. Table X lists the local annual rainfall amounts, the number of frogs observed, and the calculated frog occupancy rates in the tubes through August, 2016. It now appears the excess rain in 2013 increased frog populations in 2014 *and* in 2015. However, the subsequent low-rain year (2014) has again lowered the frog population.

No salamanders have been found under the GAAS coverboards during the five years of monitoring. This does not mean that there are no salamanders in the stream. Several salamander efts were captured in the D-net samples taken from the creek during the interval covered by this report (Table IV). Eight efts were caught in D-nets, one at HC-1 and seven at HC-2.

TABLE X. Precipitation and Frog Observations for 2008-2014

Year	Rainfall (inches)*	Rainfall (deviation from average, in inches)	Total Number of frogs found in the year	Frog Occupancy Rate (%)**
2009	50.6	+ 6.1		
2010	28.6	-15.9	14	7.8
2011	29.4	-15.1	12	7.7
2012	36.1	- 8.4	1	0.7
2013	55.5	+11.0	3	3.1
2014	36.4	-8.1	50	34.7
2015	47.4	+2.9	49	37.1
2016	38.2	-6.3	17	17.7

*Local annual rainfall totals measured at Bush Field in Augusta, GA (Ref.4).
**Occupancy rate equals the total number of frogs observed in tubes in the year, divided by the number of tubes inspected during the year, times 100.This corrects for changes in the number of monthly inspections that were conducted in each year.

<u>Fish Monitoring</u>
Although fish are not included in the GAAS evaluation system, we have recorded those that we captured in our D-nets when taking macroinvertebrate samples. Table V lists the species and the number of individuals we found between September 2014 and August 2016. In 2014-16, we captured fewer fish (6 individuals/4 species) than in the previous two years (15 individuals/7 species). The decrease is likely due more to our irregular sampling than to a decline in the fish population. One new fish species, *Fundulis chrysotus* (golden topminnow), was found at HC-2 in November of 2015, bringing our total to 16 species observed between 2006 and 2016.

In addition to catching fish in our D-net samples, occasionally we set up fish traps at HC-1. Although we set traps twice (November, 2014, and August, 2015), we did not catch fish either time.

<u>Bacteria Monitoring</u>
On two dates in March 2016, team members took water samples for E. coli monitoring. The samples came from SP-1 and from two points along the diversion canal upstream of SP-1 (and downstream of HC-2). One sampling point was above and one was below the location of hog pens on property adjacent to Silver Bluff Audubon. The hog pens drain into the diversion canal and have the potential to pollute the water going into the Audubon stork ponds. The second sampling (3/29/16) occurred two days after a 1.1 inch rain event. Table XI lists the results of the tests.

TABLE XI. Results of Bacteria Counts

	***E. coli* count (CFU/100mL)**		
Sampling location	**AP**	**BP**	**SP-1**
Date			
3/15/2016	200	100	0
3/29/2016	500	167	0

Bacteria colony counts are reported in units of "CFU" (colony forming units) per 100 mL of sample. Our results ranged from 0 to 500 CFU/100 mL. GAAS training suggests action is warranted when *E.coli* bacteria counts exceed 1000 CFU/100 mL.

Summary

The Stream Stompers have collected ten years of water quality data at locations on Hollow Creek in Aiken County, SC. Measurements of chemical and physical properties of the water and benthic macroinvertebrate biodiversity of the stream habitat show that Hollow Creek currently has good water quality. The data provide a baseline to monitor changes in water quality as Aiken County develops. We plan to continue this program in 2017 using funding from the Augusta-Aiken Audubon Society.

Acknowledgements

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Table I. Results of Chemical Monitoring

	Temperature (deg C) Air			Temperature (deg C) Water			Dissolved Oxygen (mg/L)			pH		
Location	HC-1	HC-2	SP-1	HC-1	HC-2	SP-1	HC-1	HC-2	SP-1	HC-1	HC-2	SP-1
Date												
09/20/14	22.0	22.0	23.0	22.0	21.0	23.0	6.4	7.0	0.8	5.5	5.5	5.5
10/21/14	18.0	16.0	15.0	17.0	15.0	15.5	8.3	8.8	1.5	6.0	6.0	6.0
11/20/14	13.0	13.0	9.5	9.5	9.0	5.0	9.8	10.3	3.6	6.0	5.5	5.0
12/27/14	14.0	12.0	11.0	10.0	9.0	8.0	8.7	9.6	3.4	5.5	5.5	5.5
01/25/15	9.0	5.0	5.0	10.0	10.0	7.0	9.4	9.6	5.6	5.5	5.5	5.5
02/26/15	6.0	7.0	8.0	9.0	8.5	7.0	10.1	9.7	7.0	5.5	5.3	5.0
03/28/15	12.0	10.0	11.5	17.0	15.0	15.0	8.0	8.8	2.2	6.5	6.0	5.5
04/30/15	23.0	16.5	26.5	18.0	16.0	17.0	7.6	8.6	1.2	5.8	5.8	5.8
05/24/15	22.0	20.0	25.0	21.5	19.0	22.0	7.6	8.3	0.4	5.8	6.0	6.3
06/21/15	37.0	25.5	34.0	26.0	23.0	28.0	6.8	7.3	1.2	6.5	6.5	6.5
07/25/15	25.0	24.0	21.5	25.0	22.5	27.5	6.0	7.2	0.5	7.0	6.0	5.0
08/23/15	25.5	24.0	25.0	24.0	22.0	26.5	7.0	7.3	0.3	5.8	5.8	5.8
09/19/15	23.0	21.0	25.0	21.0	19.5	22.0	7.7	7.8	1.4	6.0	6.0	6.0
10/31/15	no data											
11/21/15	11.0	11.0	14.0	15.0	13.5	13.0	7.5	8.0	1.2	5.5	5.5	5.5
12/20/15	11.5	8.0	7.3	11.5	10.3	7.3	9.4	10.0	4.0	6.5	6.0	5.5
01/24/16	5.0	1.0	3.0	8.0	8.0	3.8	10.5	10.7	7.9	6.5	6.5	6.5
02/27/16	4.0	7.0	5.0	12.0	10.5	10.0	9.4	9.9	8.0	6.0	6.0	6.0
03/29/16	17.5	20.5	17.0	18.5	17.0	18.0	7.6	8.4	8.8	5.8	6.5	7.2
04/22/16	20.0	20.0	22.0	19.0	19.0	19.5	8.0	8.0	3.1	5.8	5.8	5.8
05/24/16	21.0	19.0	24.0	20.0	18.5	22.0	7.2	7.8	3.6	5.8	6.5	7.2
07/02/16	29.5	27.0	29.0	25.0	24.0	27.5	6.2	5.9	0.7	6.5	5.5	4.5
07/30/16	27.0	25.5	27.0	25.5	23.5	28.5	7.0	7.2	0.6	6.5	6.5	6.5
08/28/16	28.0	27.0	31.5	24.8	22.5	27.5	7.0	7.3	5.6	5.8	5.8	5.8

TABLE I. Results of Chemical Monitoring (continued)

	Nitrate Ion (mg N/L)			Ammonia (mg N/L)			Phosphate (mg PO4/L)		
Location	HC-1	HC-2	SP-1	HC-1	HC-2	SP-1	HC-1	HC-2	SP-1
Date									
09/20/14	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
10/21/14	0.10	0.20	0.00	0.00	0.00	0.00	0.00	0.00	0.00
11/20/14	0.10	0.10	0.00	0.00	0.00	0.00	0.00	0.00	0.00
12/27/14	0.00	0.10	0.00	0.00	0.00	0.20	0.00	0.00	0.00
01/25/15	0.09	0.06	0.00	0.00	0.00	0.20	0.00	0.00	0.00
02/26/15	0.08	0.05	0.00	0.00	0.10	0.20	0.00	0.00	0.00
03/28/15	0.02	0.08	0.00	0.00	0.00	0.20	0.00	0.00	0.00
04/30/15	0.09	0.06	0.00	0.00	0.00	0.00	0.00	0.00	0.00
05/24/15	0.08	0.10	0.00	0.00	0.00	0.00	0.00	0.00	0.00
06/21/15	0.02	0.10	0.00	0.00	0.00	0.10	0.00	0.00	0.00
07/25/15	0.08	0.05	0.00	0.04	0.00	0.00	0.00	0.00	0.00
08/23/15	0.08	0.10	0.00	0.20	0.00	0.00	0.00	0.00	0.00
09/19/15	0.10	0.16	0.00	0.00	0.00	1.00	0.00	0.00	0.00
10/31/15	No samples taken this month.								
11/21/15	0.00	0.00	0.00	0.00	0.00	0.10	0.00	0.00	0.00
12/20/15	0.10	0.19	0.00	0.00	0.00	0.00	0.00	0.00	0.00
01/24/16	0.14	0.16	0.00	0.00	0.00	0.00	0.00	0.00	0.00
02/27/16	0.06	0.04	0.00	0.00	0.00	0.35	0.00	0.00	0.00
03/29/16	0.04	0.07	0.00	0.00	0.00	0.00	0.00	0.00	0.00
04/22/16	0.08	0.09	0.00	0.00	0.00	0.00	0.00	0.00	0.00
05/24/16	0.09	0.10	0.00	0.00	0.00	0.00	0.00	0.00	0.00
07/02/16	0.08	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00
07/30/16	0.10	0.10	0.00	0.00	0.00	0.00	0.00	0.00	0.00
08/28/16	0.10	0.10	0.00	0.00	0.00	0.00	0.00	0.00	0.00

TABLE I. Results of Chemical Monitoring (continued)

	Settleable Solids (mL/L)			Secchi Disk (cm)			Conductivity (micros)			Stream Depth*
Location	HC-1	HC-2	SP-1	HC-1	HC-2	SP-1	HC-1	HC-2	SP-1	
Date										
09/20/14	Trace	Trace	Trace	84	119	42(nob)	20	19	52	3 ft 4 in
10/21/14	Trace	Trace	0.45	109	126	9(nob)	14	14	47	2 ft 3.5 in
11/20/14	Trace	Trace	Trace	128	139	20(nob)	14	14	44	2 ft 9 in
12/27/14	Trace	Trace	Trace	106(nob)	106	50(nob)	20	16	32	3 ft 11 in
01/25/15	Trace	Trace	Trace	128	136	32(nob)	16	15	44	3 ft 7 in
02/26/15	Trace	Trace	Trace	120	95	18(nob)	16	16	39	3 ft 11 in
03/28/15	Trace	Trace	Trace	100	146	48(nob)	19	17	48	2 ft 11 in
04/30/15	Trace	Trace	0.5	125	122	26(nob)	18	16	58	2 ft 10 in
05/24/15	Trace	Trace	0.2	61	80	33(nob)	16	15	58	2 ft 3 in.
06/21/15	Trace	Trace	Trace	61	77	19(nob)	17	16	62	2 ft 1 in.
07/25/15	Trace	0.1	0.1	93	112	12(nob)	17	16	68	2 ft 1 in.
08/23/15	Trace	0.1	2.4	117	119	12(nob)	18	17	71	2 ft 4 in.
09/19/15	Trace	Trace	10	61	127	8(nob)	17	17	100	2 ft 1.5 in
10/31/15	No samples taken this month.									
11/21/15	Trace	Trace	0.2	125	87	16(nob)	20	20	66	3 ft 8 in.
12/20/15	Trace	Trace	Trace	116	114	24.5(NOB)	17	16	52	2 ft 10 in.
01/24/16	Trace	Trace	Trace	98	101	48	18	18	44	3 ft 0 in
02/27/16	Trace	Trace	Trace	111	121	46(nob)	17	16	42	3 ft 1 in
03/29/16	Trace	0.1	NM	115	119	24(nob)	19	18	48	2 ft 11 in
04/22/16	Trace	Trace	0.15	117	140	32(nob)	17	17	42	2 ft 6 in
05/24/16	Trace	0.1	0.3	114	128	31	17	17	55	2 ft 6.5 in
07/02/16	0.1	0.1	Trace	88(nob)	56(nob)	24	19	24	58	2 ft 10 in
07/30/16	Trace	Trace	0.1	73	94	36(nob)	18	18	60	2 ft 3 in
08/28/16	Trace	Trace	1.25	99	87	17	18	17	62	2 ft 1.5 in

* Measured at the bridge adjacent to the stork ponds.
Notes: "Trace" indicates settled solids were visible but the amount was too small to quantify (i.e., <0.1 mL). "nob" indicates the Secchi disk was not on the stream bottom when the disk markings became unreadable. In most cases, the stream was transparent to the deepest point accessible. "NM" indicates no measurement was made.

Table II. Results of Biological Monitoring

Date	November 2014		February 2015		May 2015		August 2015		November 2015		February 2016		May 2016		August 2016	
Location	HC-1	HC-2	HC-1	HC-2	HC-1	HC-2	HC-1	HC-2	HC-1	HC-2	HC-1	HC-2	HC-1	HC-2	HC-1	HC-2
GAAS Score	Good 21	Excel. 26	Excel. 25	Excel. 25	Good 20	Excel. 26	Good 20	Excel. 27	Good 19	Excel. 25	Good 19	Good 22	Excel. 23	Good 21	Good 20	Good 20
Sensitive																
Stonefly	2	5	4	20	0	33	2	6	1	10	11	19	3	14	1	2
Mayfly	24	42	41	33	17	88	19	14	43	108	47	92	37	35	22	33
Water penny																
Riffle beetle	1	2	2	2	1	18	8	9		2	3	6	4	9	9	13
Caddisfly	23	30	65	50	4	81	47	6	36	23	14	24	11	28	11	36
Gilled Snail		2	2	2		7		14		1						
Somewhat sensitive																
Common net spin. caddisfly	5	3	9	9	6	9	3	6	2	6	29	6	6	5	18	8
Dobsonfly/fishfliy/ alderfly		1	5	0		8		2		1						
Dragonfly/damselfly	14	10	7	6	14	13	13	7	5	6	4	7	8	12	5	5
Crayfish	2	1	0	1	4	4	2	1	2	5		1	1	2	1	1
Cranefly								1	1							
Aquatic sow bug												1				
Scud																
Clam/mussel				3	1								1			
Tolerant																
Midge fly	5	4	10	57	13	12	10	11	8	13	47	46	6	5	4	8
Blackfly		2	3	0	1	6			1	11	3	2	4	2	2	12
Lunged snail			1													
Aquatic worm	1	7	1	6	2	7	3	4			1		1	2		
Leech	1															

Note: The GAAS score is calculated by adding 3 points for each of the "Sensitive" families found, 2 points for each of the "Somewhat sensitive" families, and 1 point for each of the "Tolerant" families. The three categories differ in their dissolved oxygen requirements, with the "Sensitive" category requiring the most oxygen.

TABLE III. Other Animals Found (excluding adult fish)

Date	November 2014		February 2015		May 2015		August 2015		November 2015		February 2016		May 2016		August 2016	
Location	**HC-1**	**HC-2**	**HC-1**	**HC-2**	**HC-1**	**HC-2**	**HC-1**	**HC-2**	**HC-1**	**HC-2**	**HC-1**	**HC-2**	**HC-1**	**HC-2**	**HC-1**	**HC-2**
Bryozoan												1				
Planaria			1			1		1								1
Annelid worm(terrestrial)		1												1		
Daphnids	1															
Copepods				1												
Shrimp	3	4		3	5	4	4		1	5		4		1	1	3
Water mite	7	4		6	11	33	1	7	5	5	6	5	2	2	1	15
Mosquito pupae				1	1	4			2	4					3	
Waterboatman		2		2					1						3	
Whirlgig beetle				1								3	1		2	1
Water Scavenger beetle													1			
Diving beetle(adult)						1										
Water scorpion (adult)	1													1		1
Beetles (other)		1														
Soldier fly larva											1				1	
Dance fly larva																
Aquatic moth larva		1														
Salamander eft				2										2	1	3
Tadpole					1											
Fish larva													2			

Table IV. Amphibian Monitoring Results

	Frog Occupancy											
Tube	**1A**	**1B**	**2A**	**2B**	**3A**	**3B**	**4A**	**4B**	**5A**	**5B**	**6A**	**6B**
Date												
09/20/14	0	3 H.sq.	0	0	0	0	0	0	0	0	0	1H.cin.
10/21/14	1H.sq.	2H.cin.	0	2H.cin.	1H.fem.	1H.fem	2H.cin.	0	2H.cin.	1H.cin.	1H.cin.	0
11/20/14	0	2H.cin.	0	2H.cin.	1H.fem.	1H.fem	3H.cin.	1H.cin.	2H.cin.	0	0	2H.cin.
12/27/14	0	1H.cin.	0	2H.cin.	0	0	0	0	2H.cin.	0	0	2H.cin.
01/25/15	0	1H.cin.	0	2H.cin.	0	0	0	0	0	0	0	0
02/26/15	0	1H.cin.	0	2H.cin.	0	0	0	1H.cin.	1H.cin.	1H.cin	0	1H.cin.
03/28/15	0											
04/30/15	0	0	2H.cin.	0	0	1H.cin. 1H.fem.	0	0	0	1H.cin	0	0
05/24/15	0	0	1H.cin.	1H.cin.	1H.fem.	0	0	0	2H.cin.	1H.cin	0	0
06/21/15	0	0	1H.cin.	0	0	0	0	0	1H.cin.	0	0	0
07/25/15	0	0	0	0	0	1H.fem	1H.cin.	0	0	0	0	0
08/23/15	0											
09/19/15	0	0	0	0	0	1H.fem	0	0	0	0	0	0
11/21/15	0											
12/20/15	0	0	0	1H.cin.	0	0	1H.cin.	0	0	0	0	0
01/24/16	0	0	3H.cin.	2H.cin.	2H.fem.	0	2H.cin.	0	0	1 anole	0	1 anole
02/27/16	0	0	0	0	0	0	0	0	0	0	0	0
03/29/16	0	0	1H.cin.	1H.cin.	0	2H.fem.	0	0	0	0	0	0
04/22/16	0	0	1H.cin.	1H.cin.	0	0	0	1H.fem.	0	0	0	0
05/24/16	0	0	0	0	0	0	0	0	0	0	0	0
06/07/16	0	0	0	1H.sq	0	0	0	0	0	0	0	0
07/30/16	0	0	0	0	0	0	0	0	0	0	0	0
08/28/16	0	0	0	0	0	0	0	0	0	0	0	0

Note: H.cin. = *Hyla cinerea* (green treefrog); H.sq. = *Hyla squirella* (squirrel treefrog); and H.fem. = *Hyla femoralis* (pine woods treefrog).

TABLE V. Fish Monitoring Results

Fish Species	**Common Name**	**Number of Fish Found (by date and locations)**		
		11/23 2014	11/15 2015	8/14 2016
		HC-1	HC-2	HC-2
Leponys macrochirus	Bluegill	1		
Notropis cummingsae	Dusky shiner		2	
Noturus hudsonium	Spot-tailed shiner			2
Fundulis chrysotus	Golden topminnow		1	
Sampling method:*		NR	NR	D-net, VM,WD

*VM=vegetative margin sample, WD=woody debris sample, SB=sandy bottom sample, and NR=sample type not recorded.

APPENDIX A
Monitoring Sites

TABLE A1. Sampling Points

Identifier	HC-1	HC-2	SP-1
GPS coordinates	N 33˚ 20.073′ W 81˚ 51.205′	N 33˚ 20.605′ W 81˚ 49.336′	N 33˚ 20.317′ W 81˚ 50.377′
Location	within the Silver Bluff sanctuary	on private land at the Hwy-5 bridge over Hollow Creek	within the Silver Bluff sanctuary
Description	Hollow Creek downstream from stork ponds	Hollow Creek upstream from stork ponds	inlet to upper stork pond (this water is diverted from Hollow Creek)
Habitat	mixed hardwood/pine lowland	mixed hardwood/pine lowland	reedy marsh
Flowrate est. (cfs)	50-100	50-100	0-10
GAAS site identifier	AAS-S-953	AAS-S-954	

(a)

(b)

(c)

FIGURE A1. Views of the three sampling points during high water . a) HC-1, b) HC-2, c) SP-1.

TABLE A2. Bacterial Monitoring Sites

Identifier	AP	BP
GPS coordinates	N 33° 20.465′ W 81° 50.000′	N 33° 20.382′ W 81° 50.149′
Location	within the Silver Bluff sanctuary	within the Silver Bluff sanctuary
Description	diversion canal upstream from stork ponds and upstream from the pig sties	diversion canal upstream from stork ponds and downstream from the pig sties
Habitat	mixed hardwood/pine lowland	mixed hardwood/pine lowland
Flowrate est. (cfs)	0-10	0-10

(a)

(b)

FIGURE A2. Views of the two additional sampling points for bacterial monitoring.
a) AP (upstream of pigs) (Note: farm equipment in background on adjacent farm property.
b) BP (downstream of pigs) (Note: pig sties are visible in the background; drainage pipe inlet visible at lower left).

APPENDIX B
Experimental Methods

<u>Physical/Chemical Methods.</u>
Air and water temperatures were measured using alcohol-in-glass general purpose thermometers, 0-50 ºC, purchased from Ben Meadows Co., Janesville, WI (Catalogue #8JB-111052) or similar models.

Dissolved oxygen was measured using a field test kit purchased from the LaMotte Company, Chestertown, MD (Catalogue #5860). The kit uses the Winkler method (Ref. 5) for oxygen concentrations in the range 0-15 ppm. In this method, dissolved oxygen reacts with Mn(II) in base to form Mn(IV), followed by reduction of the Mn(IV) with I^- to form I_3^-. The I_3^- is titrated with sodium thiosulfate in the presence of starch to detect the endpoint (loss of blue color).

Nitrate was measured using a test kit purchased from Hach Company, Loveland, CO (Hach Nitrate Kit, Model N1-14, Catalogue #14161-00). The procedure measures the sum of nitrate and nitrite concentrations in the range 0-10 mg/L. Sample preparation includes first reducing nitrate to nitrite with cadmium metal, followed by reaction with sulfanilic acid to form a diazonium salt, followed by reaction of the diazonium salt with chromatropic acid to form a pink colored compound. The concentration is determined by comparison of the sample color to a color wheel.

Ammonia was measured using a test kit purchased from Hach Company, Loveland, CO (Hach Ammonia Kit, Model N1-SA, Catalogue #24287-00). The test kit measures the sum of ammonium ion and aqueous ammonia concentrations in the range 0 to 2.5 mgN/L (0-3.0 mg NH_3/L). The method is based on the hypochlorite oxidation of ammonia to chloramine, followed by reaction of chloramine with salicylate to form 5-aminosalicylate, followed by the nitroprusside catalyzed reaction of 5-aminosalycilate to indosalicylate. The blue indosalicylate concentration is determined by comparison of the sample to a color wheel.

Phosphate ion was measured using a test kit purchased from Hach Company, Loveland, CO (Hach Ortho Phosphate Kit, Model 10-19, Cat. No. 2248-00). The kit measures phosphate concentrations in the range 0-50 mg/L. The test instructions suggest a lower limit of 0.06 mg/L, although the color wheel does not allow eyeball estimates below 0.2 mg/L of phosphate. The method is based on the reaction of phosphate with molybdate in acid to form a phosphomolybdate complex that is reduced using ascorbic acid to a molybdenum blue complex. The concentration is determined by comparison of the blue solution to a color wheel.

Conductivity was measured using a Hanna Instruments Model DiST WP hand-held conductivity meter with temperature compensation. The instrument was calibrated using distilled water (0 μS/cm) and an 1413 μS/cm KCl/NaCl standard (Oakion #23759), purchased from Ben Meadows, Jamesville, WI.

Imhoff cones were used to measure settleable solids. Samples (1.0 L) were allowed to settle for 45 minutes before measuring the volume of the settled solids. The quantification limit was approximately 0.1 mL solids/ L sample. If settled solids were visible but less than 0.1 mL in volume, the result was recorded as "trace".

A 20-cm diameter Secchi disk and wooden meter stick were used to measure the turbidity of the stream. In most cases, the water was transparent to the maximum depth of the stream. The maximum depth varied between 10 and 150 cm.

Biodiversity Assessment

Biologic diversity was assessed through macroinvertebrate counting using the protocol of the Georgia Adopt-A-Stream (Ref. 3). The stream was sampled quarterly within the reach of the center (approximately 85-90 yards upstream and 85-90 yards downstream of the center). Samples were taken using 1-ft wide, D-frame sampling nets over a distance of 1 foot (i.e., 1 ft^2 area). Seven samples were obtained from the vegetative margins of the stream, 4 samples from woody debris, and 3 samples from sandy bottom areas. Samples of each type were combined, transported to an indoor laboratory, and processed. Processing included placing an aliquot of the sample in a shallow tray followed by a thorough search for macro- invertebrates. Individual animals were then identified and counted. Generally, the macroinvertebrates were identified to the class or order using the Georgia Adopt-A-Stream "Aquatic Macroinvertebrate Field Guide for Georgia's Streams" (Ref. 3) with additional help from field guides to North American freshwater invertebrates (Ref. 6). A bio-diversity rating (Excellent, Good, Fair, or Poor) was assigned based on the GAAS protocol that assigns values to sensitive (3 points), somewhat sensitive (2 points), or tolerant (1 point) organisms. Sensitivity is based largely on tolerance to low levels of dissolved oxygen. The number of individuals in each category was recorded but did not affect the diversity score. All organisms found were recorded, regardless of whether or not they were part of the GAAS scoring system. At the culmination of the counting, all animals were returned to the stream.

Amphibian Monitoring

Amphibian monitoring followed the protocols of the Georgia Adopt-A-Stream (Ref. 7). Twelve 4-inch diameter PVC pipes, each about 3 feet long, were camouflaged with brown and green spray paint. The pipes were driven about 6 inches into the ground in pairs, approximately equally spaced within the reach of HC-1 (about every 35 yards apart). One pipe in each pair was placed approximately 1 foot from the stream edge and the other was placed 3 feet farther from the stream. Adjacent to each of the pipes, a 1-ft square wooden coverboard was placed on the ground. Approximately once a month, the inside of the pipes were checked for treefrogs and the underside of the coverboards were checked for salamanders. The amphibians were identified using the field guide provided by GAAS (Ref. 7).

Bacterial Monitoring

Bacterial monitoring followed the protocol of the Georgia Adopt-A-Stream (Ref.8). Stream samples were taken in Whirl-pak® bags (Cole Parmer #EW-06499-80). One-mL aliquots were transferred to 3M Petrifilm™ *E. coli*/Coliform Count Plates (Nelson-Jameson, Marshfield, WI) using a calibrated 1-mL pipette (Cole-Parmer, Vernon Hills, IL, #EW21600-06). The plates were incubated at 35±1ºC for 24±1 hr in a Genesis Model 1588 Hova-Bator incubator (GQF Manufacturing Co., Savannah, GA). The temperature of the incubator was monitored with a Traceable® Big-Digit Memory Thermometer (VWR, Suwanee, GA, #61161-324).

Distribution

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