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HOLLOW CREEK WATER QUALITY MONITORING RESULTS (SEPTEMBER 2012 TO AUGUST 2014)

By
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Abstract

Over the past eight years, a team of volunteers monitored water quality at locations on Hollow Creek in Aiken County, SC. This report presents data obtained from September 2012 to August 2014. Previous reports summarized results for November 2006 to August 2012. 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 102 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 observed rose dramatically in 2014 after low numbers observed from 2010 to 2013. This change probably occurred in response to increased rainfall amounts in 2013-14.

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.

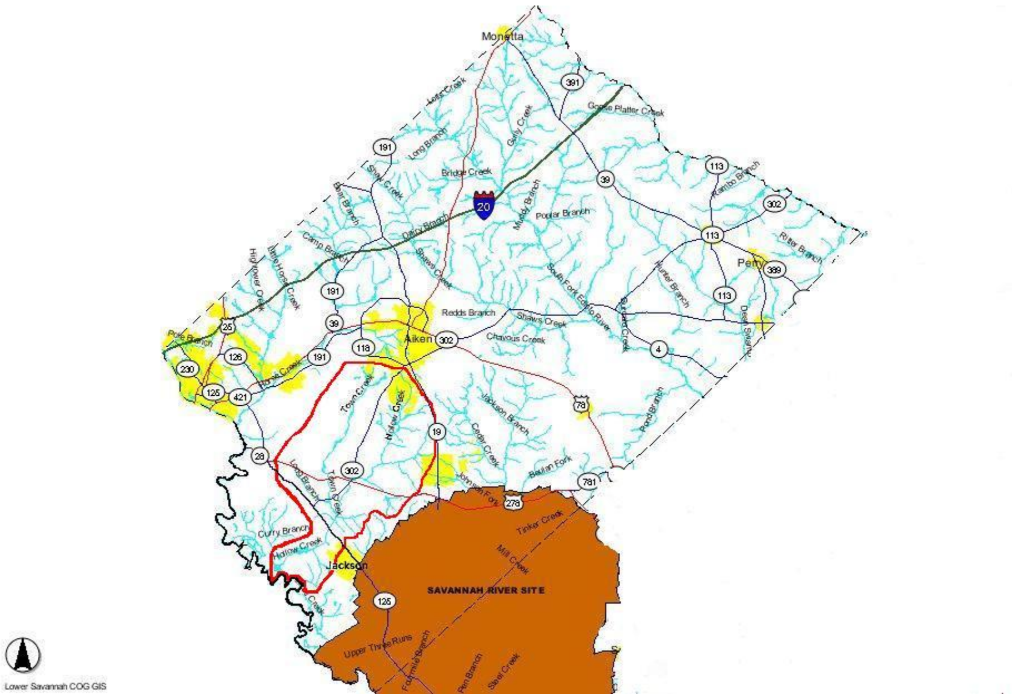

FIGURE 1. Map of Aiken County showing the Hollow Creek watershed, circled in red.

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". Three previous reports summarized data obtained between 2006 and 2012 (Ref. 2).

Sampling Locations

The three monitoring sites used in 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.

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). At least two GAAS-trained and qualified monitors participated in each monitoring event. Appendix B contains detailed descriptions of the equipment and methods.

Results and Discussion

Two years of 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 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 II lists results of chemical monitoring from September 2012 to August 2014. Tables III and IV list results from biological monitoring during the same period. Table V lists the results of amphibian monitoring from September 2012 to December 2014.

Chemical Monitoring

Figure 2 shows the dissolved oxygen concentrations found between September 2012 and August 2014. In the stream samples taken at HC-1 and HC-2, the concentration varied between 6.4 and 11.0 mg/L. This range is very similar to the range found during the first six 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.

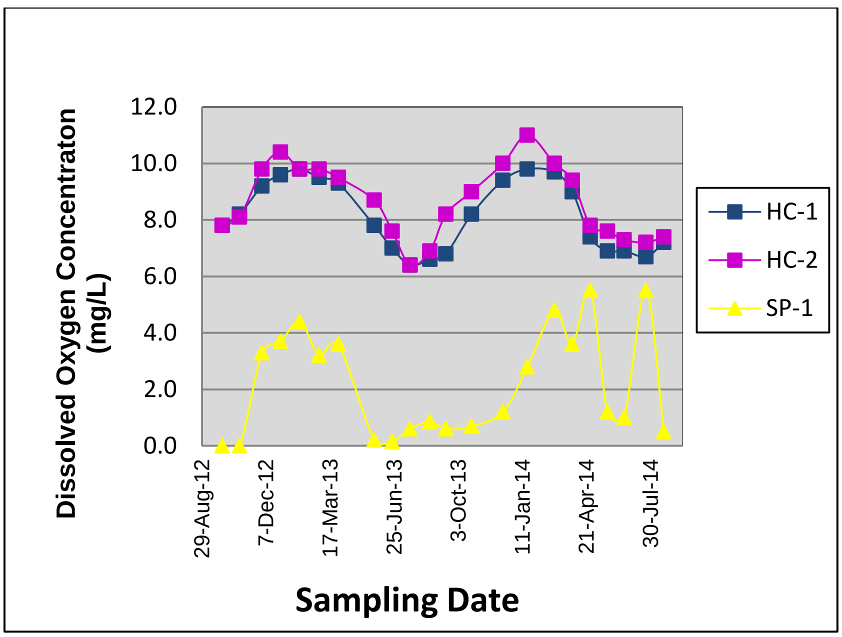

FIGURE 2. Dissolved oxygen concentrations

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 8.1 mg/L and varied from 6.4 to 9.8 mg/L, whereas HC-2 averaged 8.6 mg/L and varied from 6.4 to 11.0 mg/L. In 18 of 22 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 (14 of 22 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 75 to 95% with little difference between the two points. HC-1 averaged 85% and HC-2 averaged 88% over the two year period, almost exactly the same as the previous two year period (86% and 88%, see Ref. 2c).

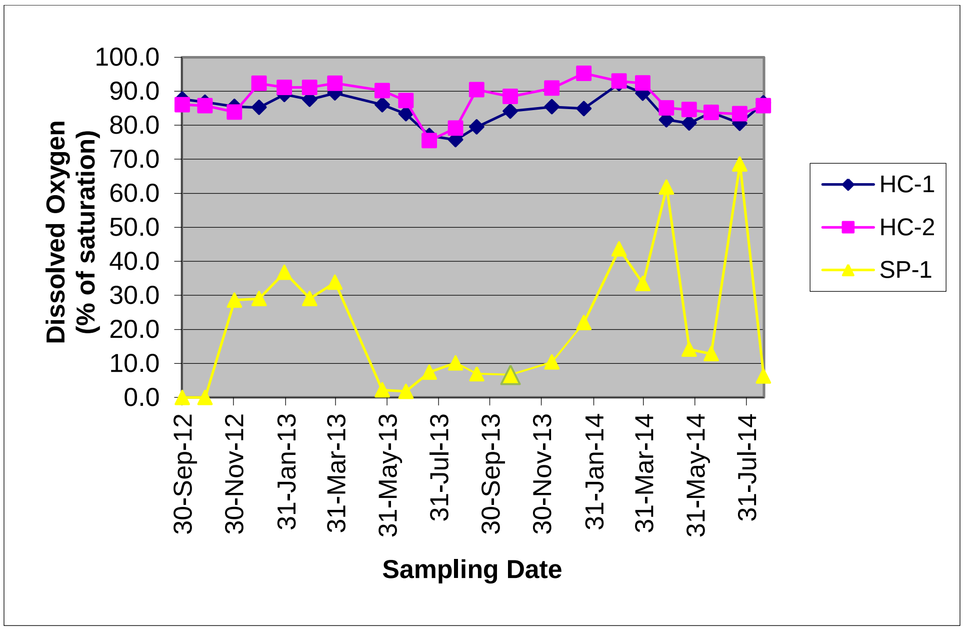

FIGURE 3. Dissolved Oxygen Concentrations as Percentage of Saturation

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 0 and 70%, with an average of 21%. The low values likely occur because of the slow flow rate and oftentimes almost stagnant conditions at the stork pond inlet.

The stream pH at HC-1 and HC-2 equaled 6.0 in 39 of 44 measurements. A pH value of 5.5 was obtained four times and 6.5 was obtained once. The non-6.0 readings occurred at both sampling points and showed no consistent trends. This pH range is consistent with the slightly tannic nature of the stream and is intermediate between values of 3.5 for slow moving, black-water rivers and 6.0 to 8.0 for fast-moving mountain streams. The pH at the stork ponds was slightly lower at 5.5 in 20 of 22 measurements. The other two measurements were 5.8 and 6.0. The stork pond pH has been consistently 0.5 pH units lower than the stream since a fire event occurred near the pond in December 2007.

Chemical pollutants (nitrate, ammonia, and phosphate) in the main stream were low and below levels of concern. Nitrate was always $\leq$ 0.2 mg N/L, compared to the EPA drinking water standard of <10 mg N/L. Nitrate levels at the stork pond inlet (SP-1) were below the detection limit in 100% of the samples. Ammonia concentrations were $\leq$ 0.3 mg N/L at all times at all sampling points. Phosphate was never detected in the stream or in the stork pond inlet (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.

The stream 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 7 of 44 samples, with the highest value of only 0.1 mL/L. This frequency is a slight increase over previous years and may be related to recent rain events. Normally, the stream was clear to the bottom or approximately 1 meter, as shown in the Secchi disk results. Only one measurement was made when the stream was not clear to the bottom.

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 disturbance during sampling. The water level can be very low, particularly in the late fall and winter, such that removing samples stirs up solids from the bottom. However, Secchi disk depths less than the depth of the available water occurred in 18 of 22 sampling events. The transparent depth varied between 15 and 55 cm and averaged 33 cm in the 18 events. This is a significant decrease since we began monitoring this location and it is due to a recent change in a local farm. 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. This change was unclear in our previous report because water levels in the stork pond were extremely low due to the drought and rarely deep enough to produce a “not-on-bottom” measurement.

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 37 to 86 µS/cm at SP-1. 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>Biological Monitoring</u>

Biological monitoring occurred quarterly between November 2012 and August 2014. Only the two stream sites (HC-1 and HC-2) were sampled. Table III lists the macro-invertebrates that were found which count toward the GAAS diversity rating. Table IV lists additional animals that were found but do not count in the GAAS rating. Table III 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). Both sites scored either

Good or Excellent in all sampling events. Average scores at the two sites were similar: 21.8 pts at HC-1 and 23.4 points at HC-2. The average at HC-2 is slightly lower than the 25.5 point average for the previous two years (Ref. 2c). We do not believe the changes are significant.

Amphibian monitoring

Amphibian monitoring began at HC-1 in January 2010 and has continued through the period covered by this report. Inspection of the tubes for treefrogs and the coverboards for salamanders generally occurred whenever chemical/physical monitoring was performed. The GAAS frog monitoring protocol focuses on six treefrog species: *Hyla cinerea* (green treefrog), *H. squirella* (squirrel treefrog), *H. chrysoscellis* (Cope's gray treefrog), *H. femoralis* (pine woods treefrog), *H. gratiosa* (barking treefrog), and *H. avivoca* (bird-voiced treefrog). Only frogs found in the tubes were counted, although other frogs were observed in the area.

A sharp 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). Also, between 2010 and 2013, the only frog species found in the tubes was *H. cinerea*. In 2014, we found two new species, *H. squirella* and *H. femoralis* (Table V).

We attribute the increase in the number of frogs observed to the increased rainfall in 2013. The higher rainfall in 2013 resulted in more adult frogs in 2014. Table 1 lists the local annual rainfall amounts, the number of frogs observed, and the calculated frog occupancy rates in the tubes. Average to above average rainfall occurred in 2008-09. This was followed by very significant drought years in 2010 to 2012. In 2013, the region emerged from the drought with a year of above average rainfall. The changes in occupancy rates appear to follow this trend, but delayed a year. If this is true, we may see a decline in the frog count in 2015 since rainfall in 2014 was below normal again.

TABLE I. 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	16	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

*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.

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 vicinity of the stream at HC-1. One southern two-lined salamander was found under a coverboard (2 ft x 2 ft) placed about 30 yards away from the creek bank in 2010. In addition, two salamander efts have been captured in the D-net samples taken from the creek at HC-1 during the interval covered by this report (Table V). The close proximity of the coverboards to the stream bed at HC- may explain the lack of salamander observations, with adult salamanders choosing to reside farther from the stream bed.

Fish Monitoring

In 2013-14 we have identified five new fish species in Hollow Creek, bringing our total to 15 species observed between 2006 and 2014. Although fish are not included in the GAAS evaluation system, we have recorded those that we found. Table VI lists the species and the number of individuals we have found between September 2012 and August 2014.

Summary

The Stream Stompers have collected over eight 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. This program will continue in 2015 using funding from the Augusta-Aiken Audubon Society and collaborative funding from National Audubon and Audubon South Carolina.

Acknowledgements

We appreciate the funding for our monitoring program that we received from National Audubon, Audubon South Carolina, and the Augusta-Aiken Audubon Society. We thank Tara Muenz and Allison Hughes (Georgia Department of Natural Resources, Environmental Protection Division, GAAS) for training and helpful discussions of our observations. We thank Ruth Mead (Phinizy Center for Water Sciences) for training the team members in Physical/Chemical Monitoring and Biological monitoring. We also thank Tony & Tanya Strickland and David & Yvonne Kling for allowing access to Hollow Creek through their property.

References

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Table II. Results of Chemical Monitoring

	Temperature (ºC) Air			**Temperature (ºC) 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												
09/30/12	20	20	20	21	20	19.5	7.8	7.8	0.0	6.0	6.0	5.5
10/27/12	20	19	21	18	18	16	8.2	8.1	0.0	6.0	6.0	5.5
12/01/12	18	16	17.5	12	8.5	9	9.2	9.8	3.3	6.0	6.0	5.5
12/30/12	8	7	6.5	10	10	5	9.6	10.4	3.7	5.5	6.0	5.5
01/29/13	21	14	13	11	12	7.5	9.8	9.8	4.4	6.0	6.0	5.5
02/28/13	11	12	16.5	11.5	12	11	9.5	9.8	3.2	6.0	6.0	5.5
03/30/13	14.5	14	14	13.5	14	12.5	9.3	9.5	3.6	6.0	6.0	5.5
4/13	No samples taken this month.											
05/25/13	17	16	20	20	17	19.5	7.8	8.7	0.2	6.0	6.0	5.5
06/22/13	26	24	25.5	24	22	24	7.0	7.6	0.2	6.0	6.0	5.5
07/20/13	27	25	26	24.5	23.5	26	6.4	6.4	0.6	6.0	6.0	5.5
08/20/13	23.5	24	25	22	22	24	6.6	6.9	0.9	5.5	5.5	5.5
09/14/13	24	20	21	23	20	22.5	6.8	8.2	0.6	6.5	6.0	5.5
10/24/13	9.5	11	7	16.5	14.5	13	8.2	9.0	0.7	6.0	6.0	5.5
11/13	No samples taken this month.											
12/12/13	8.5	10.5	12	11	11	9	9.4	10.0	1.2	6.0	6.0	5.5
01/19/14	13	11.5	15	9	9.9	5	9.8	11.0	2.8	6.0	6.0	5.5
03/02/14	19	17	14	13	12	11	9.7	10.0	4.8	6.0	6.0	5.5
03/30/14	18	13.5	13.5	15	14.5	12	9.0	9.4	3.6	6.0	5.5	5.8
04/27/14	24	23	24	20	19.5	21	7.4	7.8	5.5	6.0	6.0	5.5
05/24/14	24	22	25	23	20.5	23.5	6.9	7.6	1.2	6.0	6.0	6.0
06/19/14	30	33.5	30	25	22	28	6.9	7.3	1.0	6.0	6.5	5.5
07/23/14	25.5	26	26.5	24.5	22.5	26.5	6.7	7.2	5.5	6.0	6.0	5.5
08/20/14	37	30.5	31	24.5	22.5	27	7.2	7.4	0.5	6.0	6.0	5.5

TABLE II. 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									
09/30/12	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
10/27/12	0.10	0.11	0.00	0.00	0.00	0.00	0.00	0.00	0.00
12/01/12	0.10	0.15	0.00	0.10	0.10	0.20	0.00	0.00	0.00
12/30/12	0.08	0.10	0.00	0.20	0.20	0.30	0.00	0.00	0.00
01/29/13	0.07	0.04	0.00	0.10	0.10	0.20	0.00	0.00	0.00
02/28/13	0.04	0.01	0.00	0.10	0.10	0.20	0.00	0.00	0.00
03/30/13	0.08	0.10	0.00	0.00	0.00	0.00	0.00	0.00	0.00
4/13	No samples taken this month.								
05/25/13	0.09	0.08	0.00	0.00	0.00	0.00	0.00	0.00	0.00
06/22/13	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
07/20/13	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
08/20/13	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
09/14/13	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
10/24/13	0.12	0.11	0.00	0.00	0.00	0.40	0.00	0.00	0.00
11/13	No samples taken this month.								
12/12/13	0.08	0.06	0.00	0.00	0.00	0.30	0.00	0.00	0.00
01/19/14	0.12	0.10	0.00	0.00	0.00	0.40	0.00	0.00	0.00
03/02/14	0.15	0.00	0.00	0.00	0.00	0.10	0.00	0.00	0.00
03/30/14	0.00	0.08	0.00	0.10	0.00	0.00	0.00	0.00	0.00
04/27/14	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
05/24/14	0.00	0.09	0.00	0.00	0.00	0.00	0.00	0.00	0.00
06/19/14	0.00	0.09	0.00	0.00	0.10	0.00	0.00	0.00	0.00
07/23/14	0.00	0.06	0.00	0.00	0.00	0.40	0.00	0.00	0.00
08/20/14	0.08	0.08	0.00	0.00	0.00	0.00	0.00	0.00	0.00

TABLE II. Results of Chemical Monitoring (continued)

	Settleable Solids (mL/L)			**Secchi Disk (cm)**			**Conductivity (µS/cm)**			**Stream Depth***
Location	HC-1	HC-2	SP-1	HC-1	HC-2	SP-1	HC-1	HC-2	SP-1	
Date										
09/30/12	Trace	Trace	Trace	68	82	44(nob)	15	15	66	2 ft 3 in
10/27/12	Trace	Trace	1.3	122	114	38	14	14	86	2 ft 1 in
12/01/12	Trace	Trace	Trace	120	129	39	16	15	46	2 ft 4 in
12/30/12	Trace	Trace	Trace	122	121	20(nob)	16	16	74	2 ft 11 in
01/29/13	Trace	Trace	Trace	118	124	52	14	14	44	2 ft 3.5 in
02/28/13	Trace	Trace	Trace	129	120	54(nob)	17	17	54	3 ft 5.5 in
03/30/13	Trace	Trace	Trace	117	119	31(nob)	17	16	53	2 ft 5 in
4/13	No samples taken this month.									
05/25/13	Trace	Trace	0.3	115	100	38.0(nob)	16	14	52	2 ft 3.5 in
06/22/13	Trace	0.1	5.2	86	97	20(nob)	19	17	44	2 ft 9 in
07/20/13	Trace	0.1	0.3	76	116	19(nob)	20	19	37	2 ft 11.5 in
08/20/13	Trace	Trace	Trace	119	108(nob)	44(nob)	20	18	50	3 ft 6.0 in
09/14/13	Trace	0.0	0.6	85	80	35(nob)	16	14	60	2 ft 3.0 in
10/24/13	Trace	0.0	0.15	96	138	34(nob)	15	14	54	2 ft 3.0 in
11/13	No samples taken this month.									
12/12/13	Trace	Trace	Trace	112	113	44(nob)	16	16	62	2 ft 10 in
01/19/14	Trace	Trace	Trace	124	91	27(nob)	16	16	42	2 ft 10 in
03/02/14	Trace	Trace	Trace	132	134	38(nob)	17	15	45	3 ft 0 in
03/30/14	Trace	Trace	Trace	132	132	63	17	15	44	2 ft 11.5 in
04/27/14	Trace	0.1	0.1	123	132	31(nob)	18	17	42	2 ft 11.5 in
05/24/14	Trace	Trace	1	112	117	40(nob)	17	15	59	2 ft 7 in
06/19/14	Trace	Trace	0.1	107	143	34(nob)	16	14	68	2 ft 5 in
07/23/14	Trace	0.1	0.4	112	126	15(nob)	20	16	60	3 ft 0 in
08/20/14	Trace	0.1	0.2	122	153	35(nob)	16	15	54	2 ft 4 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

Table III. Results of Biological Monitoring

Date	November 2012		February 2013		May 2013		August 2013		November 2013		February 2014		May 2014		August 2014	
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	Excel. 24	Excel. 23	Good 20	Excel. 25	Excel. 23	Excel. 26	Good 17	Good 20	Good 18	Excel. 24	Good 21	Good 18	Excel. 26	Excel. 25	Excel. 25	Excel. 26
Sensitive																
Stonefly	1	7	10	6	1	5	3			4	2	5	6	10	2	2
Mayfly	27	32	35	20	28	17	21	10	4	15	19	6	34	18	13	23
Water penny																3
Riffle beetle	3	5	3	0	6	16	11	5	1	1	1	1	4	6	16	13
Caddisfly	11	23	19	20	16	6	15	2	6	35	28	35	5	127	10	30
Gilled Snail	3	0	0	1			1		1	9			1	3	1	1
Somewhat sensitive																
Common net spin. caddisfly	14	12	17	4	12	17	6	9	6	4	7	0	10	6	6	17
Dobsonfly/fishfliy/ alderfly	0	1							2					1	1	
Dragonfly/damselfly	16	7	13	5	22	7	3	2	2	5	7	3	6	1	8	9
Crayfish	0	1		3	1			3		3			2		1	1
Cranefly												1				
Aquatic sow bug				1		5										
Scud			2	1												
Clam/mussel	1	0			1	2					1		7			
Tolerant																
Midge fly	43	17	39	9	31	48	16	3	5	8	36	6	16	37	5	12
Blackfly	1	9	3	3	1	5				7	5	1	9	9	4	1
Lunged snail														1		
Aquatic worm	1	3		10	5	8			1	2	5	0	15	56		
Leech																

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 IV. Other Animals Found (excluding fish)

Date	November 2012		February 2013		May 2013		August 2013		November 2013		February 2014		May 2014		August 2014	
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
Planaria	1			1				1							1	
Annelid worm(terrestrial)														1		
Daphnids	1															
Copepods				1												
Shrimp	1	5	1	1	1	1	4			3	1	1			1	10
Water mite	16	7	4	9	6	18	4			6	1	3	1	8	8	23
Mosquito larva	4	3	1	1	6	2				1			1		3	1
Waterboatman		1		2					1							
Whirlgig beetle		1	5		1				8				1			2
Water Scavenger beetle		4				1						1				
Diving beetle(adult)						1										
Water scorpion (adult)	1													1		1
Beetles (other)							1	1								3
Salamander eft		2			1	1						1	1			

Table V. Amphibian Monitoring Results

	Frog Occupancy											
Tube	**1A**	**1B**	**2A**	**2B**	**3A**	**3B**	**4A**	**4B**	**5A**	**5B**	**6A**	**6B**
Date												
9/30/12	0	0	0	0	0	0	0	0	0	0	0	0
10/27/12	0	0	0	0	0	0	0	0	0	0	0	0
12/1/12	0	0	0	0	0	0	0	0	0	0	0	0
1/29/13	0	0	0	0	0	0	0	0	0	0	0	0
2/28/13	0	0	0	0	0	0	0	0	0	0	0	0
3/30/13	0	0	0	0	0	0	0	0	0	0	0	0
4/01/13	Did not monitor this month.											
5/25/13	1 H.cin.	0	0	0	0	0	0	0	0	0	0	0
6/22/13	0	0	0	0	0	0	0	0	0	0	0	0
7/20/13	0	0	0	0	0	0	0	0	0	0	0	0
8/20/13	0	0	0	0	0	0	0	0	0	0	0	0
9/14/13	Did not monitor this month.											
10/24/13	0	0	0	0	0	0	0	0	0	0	0	0
11/01/13	Did not monitor this month.											
12/12/13	0	0	0	0	0	0	1 H.cin.	0	1 H.cin.	0	0	0
1/19/14	0	0	0	0	0	0	0	0	0	0	0	0
3/2/14	0	0	0	0	0	0	1 H.cin.	0	1 H.cin.	1 anole	0	0
3/30/14	0	0	0	0	0	0	1 H.cin.	0	1 H.cin.	0	0	0
4/28/14	0	0	0	0	0	0	0	0	1 H.cin.	0	0	0
5/24/14	0	0	0	1 H.sq.	0	0	0	0	0	1 H.cin.	0	0
6/19/14	0	0	0	0	0	0	0	0	0	0	0	0
7/23/14	0	0	0	1 H.cin.	0	1H.fem.	0	0	0	0	0	0
8/17/14	0	1 H.cin.	0	0	1H.fem.	0	0	0	0	0	0	1H.fem.
9/20/14	0	3 H.sq.	0	0	0	0	0	0	0	0	0	1 H.cin.
10/21/14	1 H.sq.	2 H.cin.	0	2 H.cin.	1H.fem.	1H.fem.	2 H.cin.	0	2 H.cin.	1 H.cin.	1 H.cin.	0
11/20/14	0	2 H.cin.	0	2 H.cin.	1H.fem.	1H.fem.	3 H.cin.	1 H.cin.	2 H.cin.	0	0	2 H.cin.
12/27/14	0	1 H.cin.	0	2 H.cin.	0	0	0	0	2 H.cin.	0	0	2 H.cin.

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

TABLE VI. Fish Monitoring Results

Fish Species	**Common Name**	**Number of Fish Found (by date and locations)**							
		5/17 2013	5/18 2013	8/16 2013	11/2 2013	2/22 2014	2/23 2014	8/16 2014	8/17 2014
		HC-2	HC-1	HC-2	HC-2	HC-2	HC-1	HC-2	HC-1
Etheostoma fricksium	Savannah darter			1					
Hybognathus regius	E. silvery minnow		1			1			
Leponys macrochirus	Bluegill					1			
Micropterus salmoides	Large-mouth bass			1			1		
Notropis cummingsae	Dusky shiner				1			1	
Noturus insignis	Marginated mad tom		1						1
Noturus leptacanthus	Speckled mad tom		1	2				1	1
Sampling method:*		D-net, VM	Fish trap	D-net, WD	D-net, SB	D-net, VM	D-net, VM	NR	NR

*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	1-10
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.

APPENDIX B
Experimental Methods

Physical/Chemical Methods.
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 84 μS/cm KCl/NaCl standard (Oakion #23757), 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 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).

Distribution

1. Barbara Thomas, Audubon South Carolina, Harleyville, SC
2. Lynn Tennefoss, Audubon Chapter Services, Missoula, MT
3. Norm Brunswig, c/o Audubon South Carolina, Harleyville, SC
4. Paul Koehler, Audubon Silver Bluff Center and Sanctuary, Jackson, SC
5. Seirisse Baker, Georgia Department of Natural Resources, Environmental Protection Division, Atlanta, GA
6. Tonya Bonitatibus, Savannah Riverkeeper, Augusta, GA
7. Frank Carl, c/o Savannah Riverkeeper, Augusta, GA
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