HOLLOW CREEK WATER QUALITY MONITORING RESULTS (SEPTEMBER 2016 TO AUGUST 2018)

By
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Abstract

During the past twelve years, a team of volunteers monitored water quality at locations on Hollow Creek in Aiken County, SC. This report presents data obtained from September 2016 to August 2018. Previous reports summarized results for November 2006 to August 2016. Monitoring included measuring chemical and physical properties of the water and benthic macroinvertebrate biodiversity of the stream habitat. A total of 99 sampling events occurred 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 was rated “good” or “excellent” (with the exception of one “fair” rating). The frog occupancy rate increased slightly in 2017 (compared to 2016), and decreased in 2018. Three new fish species were observed, bringing the species total to nineteen.

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.

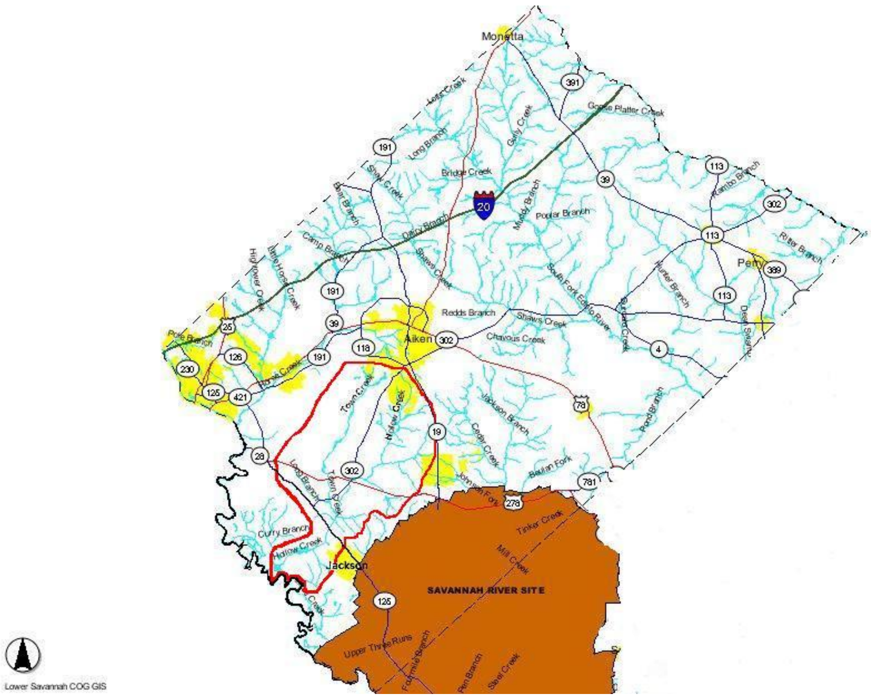

FIGURE 1. Map of Aiken County showing the Hollow Creek watershed, circled in red.

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". Five previous reports summarized data obtained between 2006 and 2016 (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. 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 fair to excellent as rated 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 2016 to August 2018. 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 (DO) concentrations found between September 2016 and August 2018. In the stream samples taken at HC-1 and HC-2, the concentration varied between 5.4 and 11.4 mg/L, essentially unchanged from results during the first ten 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 DO 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.

Slightly lower DO concentrations continue to be seen at HC-1 compared to 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. Since oxygen solubility decreases as the water temperature increases, one would expect DO levels at HC-1 to average slightly lower than at HC-2. The average DO at HC-1 equaled 7.8 mg/L, compared to 8.1 mg/L at HC-2, an average difference of 0.3 mg/L. The differences in water temperature accounts for 0.2 mg/L of the 0.3 mg/L.

The temperature dependence of DO concentration can be removed by calculating the DO 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 66 to 96% with little difference between the two points. HC-1 averaged 83% (±5%) and HC-2 averaged 84% (±4%) over the two year period, virtually the same as during the previous two year period (83% and 85%, see Ref. 2e).

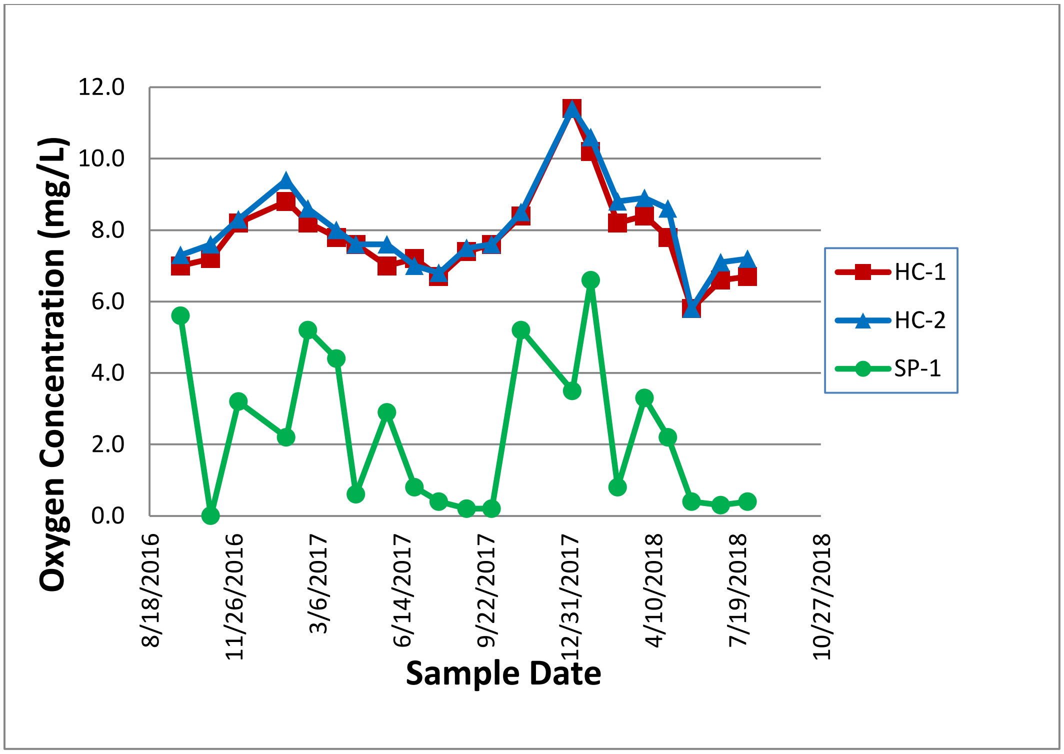

FIGURE 2. Dissolved oxygen concentrations

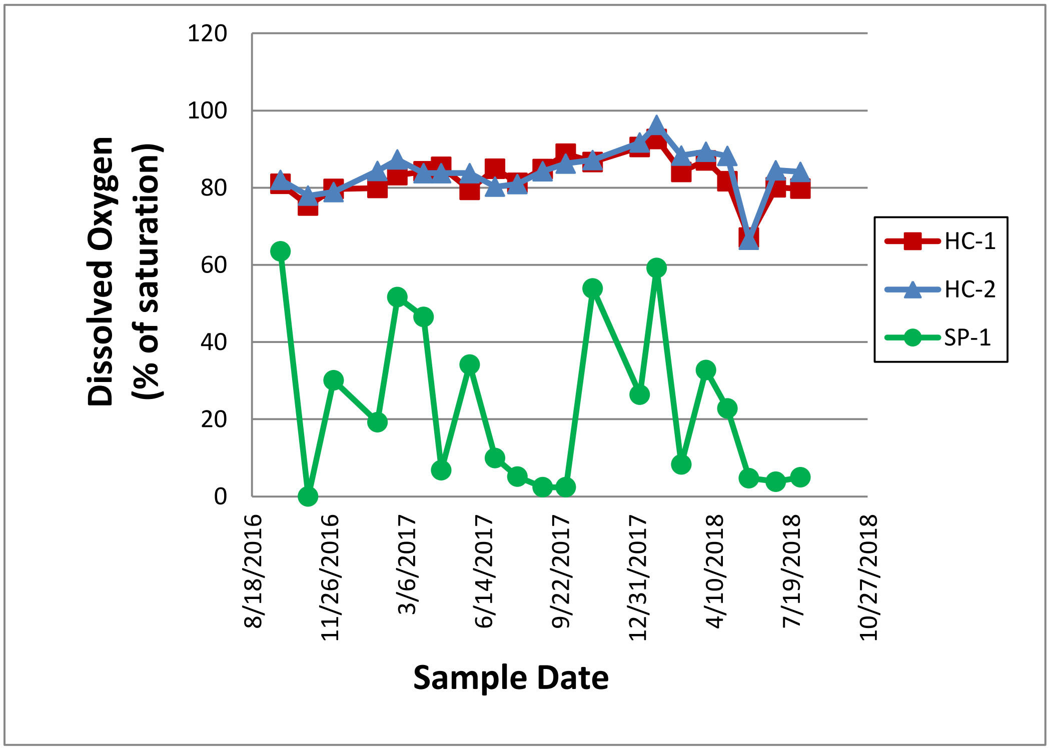

FIGURE 3. Dissolved Oxygen Concentrations as Percentage of Saturation

Dissolved oxygen content at the stork pond outlet varied erratically and was usually much lower than the main stream. The percentage of saturation varied between 0 and 64%, with an average of 23%. The low values likely occur because of slow flow rates, and, at times, stagnant conditions at the stork pond outlet. The presence of floating plants, algae, and debris in the vicinity of the sampling point also add to the variability in DO. There does not appear to be a trend between the two-year data sets.

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 5.8 and 6.5 and averaging 6.1 ±0.3 at both HC-1 and 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 than a slow-moving black-water river (as low as 3.5). The average pH at the stork ponds was 5.9±0.4, 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 continues to diminish. In the period 2014-16, it averaged 5.7±0.7 (Ref. 2e).

In the main stream (HC-1 and HC-2), chemical pollutants (nitrate, ammonia, and phosphate) were low and below levels of concern. Nitrate was ≤ 0.2 mg N/L, with the exception of September 2016, when a value of 0.7 mg N/L was found at HC-1 (but not HC-2, upstream). The unusually high value did not occur again prior or subsequent to that date, so no action was taken. All of these values are significantly below the EPA drinking water standard of <10 mg N/L.

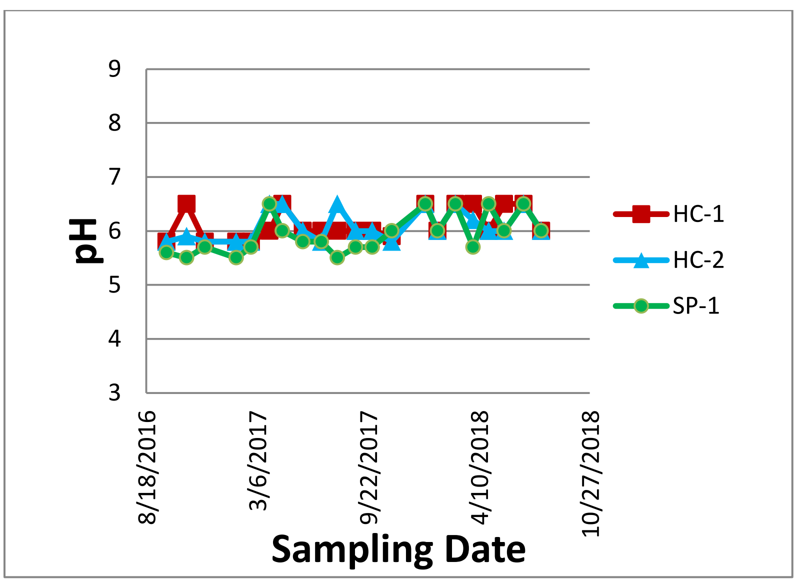

FIGURE 4. Results of pH measurements at HC-1, HC-2, and SP-1.

An ammonia concentration above our detection limit was found only once in the main stream of Hollow Creek (0.2 mg N/L, on 12/02/16). This is a lower rate of incidence than observed in previous two-year periods when ammonia was detected in 8 to 18 samples in a two-year period. Phosphate was never detected in the stream (detection limit approximately 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 was never detected, probably because of slow flow and removal by the plants in the wetlands at that location. Ammonia was detected in the range 0.1 to 1.6 mg N/L in five of 23 samples. The frequency of detection has decreased over the past ten years (see Table VI).

TABLE VI. Frequency and Range of Ammonia at the Stork Pond (SP-1)

Time Period	No. of samples with ammonia	Total number of samples	Conc. Range (mg N/L)
2006-08	11	19	0.1 to 1.0
2008-10	18	23	0.1 to 1.0
2010-12	13	24	0.1 to 0.3
2012-14	9	22	0.1 to 0.4
2014-16	8	23	0.1 to 1.0
2016-18	5	20	0.1 to 1.6

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 not detected above trace levels (<0.1 mL/L) during this two year period, except in one case (June 2017). This is less often than previously when five to seven samples during a two-year period showed amounts above the detection limit. Turbidity (by Secchi disk) was low, with the stream clear to the bottom at the deepest place we could locate (0.8 to 1.3 meters) in all but one sample. The high Secchi disk reading occurred at the same time as the high settleable solids reading (June 2017). The stream level was low and no recent thunderstorms could account for the turbidity.

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 in eight of twenty samples. Secchi disk depths less than the depth of the available water occurred in 18 of 20 sampling events. The transparency depth varied between 13 and 58 cm. This continues a trend observed previously 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 16 to 22 μS/cm in the stream, and 44 to 87 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.

Macroinvertebrate Counts

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 2016 to August 2018 are reported here for the first time. 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 but one sampling event (HC-1, August 2017) when a rating of Fair was obtained. Fair scores at HC-1 occurred twice previously (Feb. 2010 and Feb. 2007). Comparing two year periods, we see a slow decrease in the average scores over the past six years (see Table VII.). Both sampling points appear to be decreasing over the past 8 to 10 years. The decline is small and may just be a statistical fluke, but it bears watching in the future.

TABLE VII. Average Scores for Macroinvertebrate Counts by 2-Year Periods

Time Period	Avg. 2-yr score	HC-1 Average	HC-2 Average
2006-08	22.7	20.6	24.9
2008-10	23.8	22.2	25.2
2010-12	23.8	22.0	25.5
2012-14	22.6	21.8	23.4
2014-16	22.4	20.9	24.0
2016-18	22.1	20.5	23.8

Amphibian monitoring

A three-year decline in frog occupancy observed between 2010 to 2013 dramatically reversed in 2014 when we found 50 frogs during the year. High frogs counts continued in 2015, but declined severely in 2016. In 2017 and 2018, the frog counts again increased (relative to 2016), as did the rainfall totals.

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 VIII lists the local annual rainfall amounts, the number of frogs observed, and the calculated frog occupancy rates in the tubes through August, 2016. The correlation between rain and frog counts appears to continue in 2017-18. Judging from the 2018 rainfall total, an increase in frog count is expected in 2019.

TABLE VIII. Precipitation and Frog Observations for 2008-2018

Year	Rainfall (inches)[1]	Rainfall (deviation from average, in inches)	Total Number of frogs found in the year	Frog Occupancy Rate (%)[2]
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	2.8
2014	36.4	-8.1	50	34.7
2015	47.4	+2.9	49	37.1
2016	38.5	-6.1	20	15.2
2017	45.0	+0.5	23	17.4
2018[3]	54.8	+10.3	15	20.8

[1]Local annual rainfall totals measured at Bush Field in Augusta, GA (Ref.4).
[2]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.
[3]Frog data through September 30. Rainfall data through December 30.

No salamanders have been found under the GAAS coverboards during the past eight years of monitoring. In the past two years, two ring-necked snakes (*Diadophis punctatus*) were found. The lack of amphibian sightings does not mean that there are no salamanders in the stream. Eight salamander efts were caught in D-nets, one at HC-1 and seven at HC-2, during the interval covered by this report (Table III).

<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 found between September 2016 and August 2018. In 2016-18, we captured about the same number of fish as in the previous two years (6 individuals/4 species), but fewer than in the period 2012-14 (15 individuals/7 species). The low numbers are likely due more to our irregular sampling than to a decline in the fish population. Occasional attempts using fish traps produced no catch. Three new fish species were found during the reporting period, bringing our total to 19 species observed between 2006 and 2018. The new species are: *Leponys cyanellus* (Green sunfish), *Leponys marginatus* (Dollar sunfish), and *Gambusia afinis* (Mosquitofish).

Summary

The Stream Stompers have collected twelve 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 2019 using funding from the Augusta-Aiken Audubon Society.

Acknowledgements

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References

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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												
09/24/16	24.5	21.0	24.0	22.5	21.0	21.5	7.0	7.3	5.6	5.8	5.8	5.6
10/30/16	23.0	20.0	24.0	17.5	16.5	18.0	7.2	7.6	0.0	6.5	5.9	5.5
12/02/16	11.5	11.5	14.5	14.0	13.0	12.5	8.2	8.3	3.2	5.8	5.8	5.7
12/xx/16	Did not sample.											
01/28/17	8.0	6.0	8.0	11.0	10.5	9.5	8.8	9.4	2.2	5.8	5.8	5.5
02/23/17	23.5	17.5	19.5	16.0	16.0	15.0	8.2	8.6	5.2	5.8	5.8	5.7
03/29/17	18.0	15.0	15.0	19.0	17.5	18.0	7.8	8.0	4.4	6.0	6.5	6.5
04/21/17	23.5	23.5	23.0	21.0	20.0	21.5	7.6	7.6	0.6	6.5	6.5	6.0
05/28/17	23.0	27.5	27.0	21.5	20.0	23.5	7.0	7.6	2.9	6.0	6.0	5.8
06/30/17	24.0	23.5	25.0	23.5	22.0	26.5	7.2	7.0	0.8	6.0	5.8	5.8
07/29/17	26.0	25.5	30.0	25.0	24.0	28.0	6.7	6.8	0.4	6.0	6.5	5.5
08/31/17	24.0	25.0	25.0	22.0	21.0	24.0	7.4	7.5	0.2	6.0	6.0	5.7
09/30/17	21.0	20.5	24.0	23.0	21.5	24.0	7.6	7.6	0.2	6.0	6.0	5.7
11/04/17	16.0	19.0	18.5	16.8	16.5	17.0	8.4	8.5	5.2	5.9	5.8	6.0
11/xx/17	Did not sample.											
01/04/18	-0.5	0.0	1.0	5.5	6.0	3.5	11.4	11.4	3.5	6.5	6.5	6.5
01/26/18	15.0	17.0	19.0	11.0	11.0	10.5	10.2	10.6	6.6	6.0	6.0	6.0
02/27/18	15.0	12.5	12.0	16.5	15.5	17.0	8.2	8.8	0.8	6.5	6.5	6.5
03/31/18	15.0	14.0	14.0	17.0	15.5	15.0	8.4	8.9	3.3	6.5	6.2	5.7
04/28/18	15.5	15.0	15.0	17.5	16.5	17.0	7.8	8.6	2.2	6.0	6.0	6.5
05/26/18	24.0	24.0	25.5	22.5	22.0	24.0	5.8	5.8	0.4	6.5	6.0	6.0
06/30/18	27.0	25.0	29.0	25.0	24.0	28.0	6.6	7.1	0.3	6.5	6.5	6.5
08/01/18	24.5	24.0	28.0	24.0	23.0	26.0	6.7	7.2	0.4	6.0	6.0	6.0
8/xx/18	Did not sample.											

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									
09/24/16	0.70	0.16	0.00	0.00	0.00	1.60	0.00	0.00	0.00
10/30/16	0.10	0.11	0.00	0.00	0.00	0.00	0.00	0.00	0.00
12/02/16	0.10	0.08	0.00	0.00	0.20	0.00	0.00	0.00	0.00
12/xx/16	Did not sample.								
01/28/17	0.20	0.40	0.00	0.00	0.00	0.40	0.00	0.00	0.00
02/23/17	0.10	0.11	0.00	0.00	0.00	0.00	0.00	0.00	0.00
03/29/17	0.06	0.10	0.00	0.00	0.00	0.00	0.00	0.00	0.00
04/21/17	0.10	0.06	0.00	0.00	0.00	0.00	0.00	0.00	0.00
05/28/17	0.08	0.00	0.00	0.00	0.00	0.10	0.00	0.00	0.00
06/30/17	0.05	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
07/29/17	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
08/31/17	0.05	0.05	0.00	0.00	0.00	0.00	0.00	0.00	0.00
09/30/17	0.04	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
11/04/17	0.09	0.05	0.00	0.00	0.00	0.00	0.00	0.00	0.00
11/xx/17	Did not sample.								
01/04/18	0.07	0.05	0.00	0.00	0.00	0.20	0.00	0.00	0.00
01/26/18	0.05	0.07	0.00	0.00	0.00	0.00	0.00	0.00	0.00
02/27/18	0.05	0.05	0.00	0.00	0.00	0.20	0.00	0.00	0.00
03/31/18	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
04/28/18	0.06	0.08	0.00	0.00	0.00	0.00	0.00	0.00	0.00
05/26/18	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
06/30/18	0.00	0.06	0.00	0.00	0.00	0.00	0.00	0.00	0.00
08/01/18	0.05	0.13	0.00	0.00	0.00	0.00	0.00	0.00	0.00
8/xx/18	Did not sample.								

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										
09/24/16	Trace	Trace	0.15	89	92	21(nob)	18	18	87	2 ft 4 in
10/30/16	Trace	Trace	0.4	106	87	22(nob)	17	17	62	2 ft 4 in
12/02/16	Trace	Trace	Trace	115	101	24(nob)	18	18	53	2 ft 10 in
12/xx/16	Did not sample.									
01/28/17	Trace	Trace	Trace	110	110	34(nob)	20	20	44	3 ft 6 in
02/23/17	Trace	Trace	Trace	110	102	48(nob)	20	19	50	2 ft 10.5 in
03/29/17	Trace	Trace	Trace	93	101	38(nob)	19	18	46	2 ft 8.5 in
04/21/17	Trace	Trace	Trace	112	107	41	19	19	54	2 ft 7 in
05/28/17	Trace	Trace	0.1	116	120	26(nob)	20	20	52	2 ft 7 in
06/30/17	Trace	0.25	0.1	93	78(nob)	17(nob)	17	19	50	2 ft 5 in
07/29/17	Trace	Trace	Trace	106	109	14(nob)	21	20	63	2 ft 7.5 in
08/31/17	Trace	Trace	50(algae)	111	106	15(nob)	17	18	54	3 ft 3.5 in
09/30/17	Trace	Trace	1.0	103	127	24(nob)	18	18	63	2 ft 4 in
11/04/17	Trace	Trace	Trace	108	110	50	18	17	61	2 ft 6 in
11/xx/17	Did not sample.									
01/04/18	Trace	Trace	Trace	109	140	58(nob)	16	18	70	2 ft 9 in
01/26/18	Trace	Trace	Trace	129	120	58(nob)	17	16	66	2 ft 8 in
02/27/18	Trace	Trace	Trace	114	113	13(nob)	20	18	76	2 ft 7.5 in
03/31/18	Trace	Trace	Trace	123	118	30(nob)	18	17	63	2 ft 8 in
04/28/18	Trace	Trace	Trace	118	110	26(nob)	20	19	60	2 ft 8 in
05/26/18	Trace	Trace	0.2	84	105	30(nob)	21	22	54	3 ft 8 in
06/30/18	Trace	Trace	0.15	127	127	26(nob)	21	20	64	2 ft 8 in
08/01/18	Trace	Trace	Trace	114	123	40(nob)	19	20	50	2 ft 8 in
8/xx/18	Did not sample.									

* 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 2016		February 2017		May 2017		August 2017		November 2017		February 2018		May 2018		August 2018	
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	Good 20	Good 20	Excel. 23	Good 20	Good 21	Fair 14	Excel. 27	Excel. 24	Excel. 29	Good 22	Excel. 26	Good 17	Excel. 24	Excel. 23	Good 20
Sensitive																
Stonefly	4	6	5	14	3	19		2	2	10	2	4		19	1	
Mayfly	45	54	153	37	78	58	32	28	109	169	80	76	50	76	8	42
Water penny																
Riffle beetle			2	14	11	7	10	4		3	6	3		8	8	6
Aquatic snipe fly										1						
Caddisfly	10	7	21	12	28	167	16	44	17	7	8	4	9	18	11	10
Gilled Snail								3	7	5	1	16				11
Somewhat sensitive																
Common net spin. caddisfly	1	5	19	3	57	41	14	8	8		8	4	1	7	8	1
Dobsonfly/fishfliy/ alderfly								3		1				1	1	
Dragonfly/damselfly	11	7	5	7	12	12	19	9	10	8	7	20	7	10	36	17
Crayfish	2		1	2	1	1		10	4	3	3	5	6	1	9	3
Cranefly	2											1				
Aquatic sow bug	4	1							1							
Scud	7	1		2									1			
Clam/mussel									2	5				1	2	
Tolerant																
Midge fly	6	43	14	36	11	22	6	6	45	28	14	35	27	79	10	9
Blackfly		4	0	4	13	9		3		2		6	3			
Lunged snail	1															
Aquatic worm	2	1	3	29		1		3	1	1		6	3	4		2
Leech								3						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 2016		February 2017		May 2017		August 2017		November 2017		February 2018		May 2018		August 2018	
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				35							4					
Planaria					4						1					1
Annelid worm(terrestrial)																
Daphnids																
Copepods																
Shrimp	1	2		9	7	5	7	5	5	1	4	8	5	2		5
Water mite		3	1	13	5	5	3	11	1	2	3	12	1	1	4	6
Mosquito pupae	1	7	1	3	1		1	1	1	1	3		2	11		4
Waterboatman					1					1	1				2	
Whirlgig beetle					3		1								2	
Water Scavenger beetle		2		1										1		
Diving beetle(adult)																
Water scorpion (adult)																
Beetles (other)								1								
Soldier fly larva																
Dance fly larva																
Aquatic moth larva													3	1	2	3
Salamander eft		3				2	1	1		1						
Tadpole															2	
Fish larva											1		1	1		

Table IV. Amphibian Monitoring Results

	Frog Occupancy											
Tube	**1A**	**1B**	**2A**	**2B**	**3A**	**3B**	**4A**	**4B**	**5A**	**5B**	**6A**	**6B**
Date												
09/24/16	0	0	0	0	0	0	0	0	0	0	0	0
10/30/16	0	0	0	1H.sq.	0	0	0	1H.cin.	0	0	0	1H.cin.
12/02/16	0	0	0	0	0.	0	0	0	0	0	0	0
12/xx/16	DNM											
01/28/17	0	0	0	0	1H.fem.	1H.cin.	0	1H.cin.	0	0	0	1H.cin.
02/23/17	0	0	0	1 anole	1H.cin.	1H.fem.	0	1H.cin.	1H.cin.	1 anole	0	0
03/29/17	1H.cin.	0	0	1H.cin.	0	1Hcin. 1H.fem.	0	0	0	0	0	0
04/21/17	0	0	0	0	0	1H.fem.	0	0	1H.cin.	0	0	1H.cin.
05/28/17	0	0	1 H.sq.	0	0	0	0	0	1H.cin.	1H.cin	0	0
06/30/17	0	0	0	0	0	0	0	0	0	0	0	0
08/01/17	0	0	0	1H.cin.	0	0	0	0	0	0	0	0
08/31/17	0	0	0	0	0	0	0.	0	0	0	0	0
09/30/17	0	0	0	0	0	0	0	0	0	0	0	1H.cin.
11/04/17	0	0	0	1H.cin.	0	0	0	0	0	2H.cin.	0	0
11/xx/17	DNM											
01/04/18	0	0	0	1H.cin.	0	0	0	0	1H.cin.	3H.cin.	0	0
01/26/18	0	0	0	0	0	0	0	0	0	2H.cin.	0	0
02/27/18	0	0	3H.cin.	1H.cin.	0	0	1H.cin.	0	1H.cin.	2H.cin.	0	1H.cin.
03/31/18	0	0	0	1H.sq.	0	0	1H.cin.	0	1H.cin.	1H.cin.	1H.cin.	1H.cin.
04/28/18	0	0	1H.cin.	0	0	0	0	0	0	1H.cin.	0	0
05/30/18	DNM											
06/30/18	0	0	0	0	0	0	0	0	0	0	0	0
08/01/18	0	0	0	1H.sq.	0	0	0	0	0	0	0	0
08/xx/18	DNM											

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)**					
		2/26 2017	5/21 2017	12/1 2017	2/24 2018	2/25 2018	5/20 2018
		HC-1	HC-2	HC-1	HC-1	HC-2	HC-2
Leponys cyanellus	Green sunfish	1*					1
Percia nigrifasciata	Black-banded darter		1				
Noturus insignis	Margined madtom			1	1		
Leponys marginatus	Dollar sunfish					1*	
Microterus salmoides	Large-mouth bass						1
Gambusia afinis	Mosquitofish						1*
Sampling method:*		WD D-net	WD D-net	NR	NR	VM D-net	VM D-net

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

**New species not previously reported in Ref. 2.

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.

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 a 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).