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SYNOPTIC BIOLOGICAL SURVEY OF 14 SPRING-RUN STREAMS IN NORTH AND CENTRAL FLORIDA

III. MACROINVERTEBRATES OF SUBMERGED AQUATIC VEGETATION COMMUNITIES

by

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EXECUTIVE SUMMARY

As part of a broader initiative to better understand, manage, and restore the springs of the St. Johns River, a short-term, synoptic biological study of 14 springs and their spring-run streams was undertaken by the St. Johns River Water Management District in 2015. This study quantitatively sampled physical-chemical (physicochemical) characteristics and biological measures in these spring-run streams, including submerged macrophyte cover and dry weight; macro- and epiphytic algal cover, dry weight and ash-free dry weight; and vegetation-associated macroinvertebrate community richness, density, diversity, and biological characteristics. The submerged aquatic vegetation community (SAV – both macrophytes and algae) was a major focus of this study due to its prevalence in spring-run streams and because of the changes observed in this community in a number of springs over the past 50 years: a shift from a macrophyte-dominated to an algae-dominated community. This report presents the SAV-associated macroinvertebrate community data and analyses from the springs synoptic sampling effort. Submerged macrophyte data and macro- and epiphytic algal data were presented in previous reports (Mattson et al. 2019; Mattson et al. 2021).

Six sampling events were conducted in 2015 to measure physicochemical conditions (stream physical characteristics and *in situ* water quality). The spring-run streams and their headsprings exhibited a wide range of physicochemical characteristics, including channel width and depth, canopy cover, discharge, base water chemistry, and nutrient concentrations. Spring discharges ranged from small second magnitude springs (Juniper) to some of the largest first magnitude spring groups in Florida (Silver, Rainbow). Base water chemistry (concentration of dissolved solids such as calcium, chloride, etc. as measured by conductivity) ranged from near softwater, low ion springs (Juniper) to salt springs (Silver Glen). Nutrient concentrations (based on existing data, not collected in this study) also varied, from systems with low concentrations of nitrogen and phosphorus, indicating natural background water quality conditions (Juniper, Alexander), to systems with elevated concentrations of one or both nutrients (Silver, Wekiva, Rainbow).

Benthic macroinvertebrates associated with SAV habitats were sampled in all 14 spring-run streams during two sampling events, in spring and fall of 2015. Macrophyte habitat and macroalgal habitat were sampled separately to compare the macroinvertebrate communities of the two habitats. A total of 230 taxa of macroinvertebrates were collected in macrophyte habitat and 136 total taxa in macroalgal habitat. In both habitats, chironomid midges, annelids (worms and leeches) and trichopterans (caddisflies) were the major groups in terms of total number of taxa. In both habitats, higher total taxa richness was seen in the spring sampling season. Higher mean taxa richness was generally seen in the spring in macrophyte habitat while mean richness was similar between spring and fall in macroalgal habitat.

No clear patterns in mean taxa richness, Shannon-Weiner diversity, or Margalef's Species Richness were seen; these three measures of overall diversity varied spatially and temporally. Abundance was measured in two ways, as density based on the area of the sampler used (#

individuals/m^2) and density relative to the plant biomass in the sample (# individuals/g plant biomass). Like the diversity measures, no clear spatial patterns in mean abundance for either measure were seen (among the sampling transects and streams sampled). However, in general mean abundance was lower in the fall sampling event at many sampling transects.

Multivariate analysis comparing the macroinvertebrate data with physical-chemical data indicated that conductivity, dissolved oxygen (DO), pH, water depth and current velocity were the main environmental drivers influencing macroinvertebrate community structure. Higher taxa richness and abundance were associated with higher plant biomass in macrophyte habitat, while in macroalgal habitat, higher abundance but lower taxa richness were associated with higher plant biomass.

Macroinvertebrate communities in the two habitats were different with macrophyte habitat generally supporting higher total and mean taxa richness than macroalgal habitat. Multivariate analysis indicated that overall invertebrate community structure in the two habitats was different, a result seen in other comparisons of these two habitats in Florida spring-run streams. Other community differences included substantially higher relative abundance of the collector-gatherer functional feeding group in macroalgal habitat and higher relative abundance of the clinger life habit mode in the aquatic insects of macrophyte habitat.

Comparisons of the data collected in this study with those collected in prior macroinvertebrate surveys in these spring-run streams were complicated by differences in sampling equipment used to sample invertebrates, differences in stations sampled, and taxonomic issues (i.e., level of identification effort and nomenclature changes over time). Results were mixed and generally inconclusive, indicating the need to use a standardized method over time at similar locations and in similar habitats.

Snails are a diverse and abundant component of the benthic macroinvertebrate community in Florida springs and spring-run streams. Anecdotal and limited quantitative data suggest declines in populations of the common spring snail *Pleurocera floridensis* over time, but again, very limited data exist to make more definitive conclusions. The snail population in Volusia Blue Spring, however, appears to have little changed over the period 2007–2020 and monitoring of snail populations in spring-run streams may be a cost-effective surrogate to evaluate the condition of the general spring-run stream benthic macroinvertebrate community.

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INTRODUCTION

The karst geology of Florida is the basis for the existence of perhaps the densest concentration of springs in the world (Florida Springs Task Force 2000). These aquatic resources have long captivated explorers, visitors, artists and scientists, ranging from Ponce de Leon's mythological search for the "fountain of youth" to the writer Marjory Stoneman Douglas' description of Florida springs as "bowls of liquid light." In Florida, there are two main types of springs; seep springs, which originate from shallow aquifers, and vent springs which originate from deeper aquifers that are partially confined, resulting in groundwater that is under artesian pressure (Copeland 2003). Of the 1,089 individual springs currently mapped in Florida, most are fed by artesian flow from the Floridan Aquifer System, a large regional aquifer system that underlies all of Florida and parts of South Carolina, Georgia, and Alabama. Some Florida springs, particularly those in the Suwannee River Basin, reverse flow and are known as estavelles (Copeland 2003). When the rivers partially fed by these springs flood, the pressure from the overlying surface water exceeds the groundwater pressure head, and the springs reverse flow and take in surface (river) water.

Florida springs have long been classified by Meinzer's system of spring discharge, which is expressed in cubic feet per second (cfs) or a lesser unit of discharge as volume/unit time (Scott et al. 2004). First magnitude springs are the largest, with a mean annual discharge of greater than 100 cfs (64.6 million gallons/day). Second magnitude springs discharge between 10 and 100 cfs, and third magnitude springs discharge between 1 and 10 cfs. The system goes down to eighth magnitude springs with a discharge of <1 pint/minute (200 gal/day). Florida has 33 first magnitude springs and spring groups (groups of spring vents that collectively discharge water and are in close proximity).

Springs are also classified by the composition of the ions and minerals dissolved in the spring water (Woodruff 1993, Slack and Rosenau 1979). Seep springs fed by shallow surficial aquifers are mostly softwater springs with very low concentrations of dissolved solids. Most vent springs discharge water containing dissolved calcium bicarbonate and other ions. This water is considered "hard" and originates from the carbonate rocks that comprise the Floridan Aquifer System. Some springs are a mixed or salt-water quality type, with higher concentrations of chloride and other dissolved solids. These are found in the St. Johns River valley and along the Gulf coast from Taylor County south to Hernando County. The existence of highly mineralized saline groundwater in the aquifer contributing to these springs is related to the depth of the water source in the aquifer and proximity to the coast. In the St. Johns River Valley, the saline groundwater is relict seawater left behind in the aquifer during periods of higher sea level in the Pleistocene Epoch. Along the Gulf Coast, however, this is due to recharge of saline water from the adjacent Gulf of Mexico.

The water discharged from Florida's springs historically had extremely low concentrations of nitrogen compounds, particularly nitrate-nitrite as nitrogen (NOx-N). Background concentrations are generally 0.05-0.1 mg/L, due to a lack of natural sources other than atmospheric deposition (Scott et al. 2004). Background phosphorus concentrations (as total phosphorus, TP) have been moderate in some springs (0.04-0.06 mg/L) due to the existence of natural phosphate deposits in some geologic formations in portions of Florida (Scott et al. 2004). In general, spring ecosystems are adapted to naturally low nutrient concentrations and may become impaired when these are increased (Brown et al. 2008).

Many Florida springs give rise to lotic (flowing water) ecosystems known as spring-run streams. The exceptionally clear water in these streams allows for the proliferation of dense beds of submerged aquatic vegetation (SAV). The SAV habitat (which includes submerged macrophytes and associated algal communities) found in spring-run streams are a major source of primary production, provide habitat for diverse macroinvertebrate and fish communities and provide food sources for freshwater turtles and the endangered Florida Manatee, *Trichechus manatus latirostris* (Odum 1957a, Walsh et al. 2009, Walsh and Williams 2003). The springs also provide a warm water winter refuge habitat for manatee populations. Many springs are also inhabited by endemic species, including certain species in the snail family Hydrobiidae ("silt snails") which are found nowhere else in the world (Thompson 1968). Similarly, the submerged cave systems associated with many springs support one or more species of cave crayfish (mostly species of the genus *Procambarus*) which may only be associated with that particular spring cave system (Franz et al. 1994).

Florida's springs have been subjected to many of the same pressures which have affected other aquatic ecosystems in the state, primarily degradation of water quality and alterations in hydrology (Copeland et al. 2009). Groundwater quantity and quality are both affected by human activities that occur in the highly vulnerable karst areas of Florida. Many springs are discharging water with increased concentrations of nitrate. Nitrogen loading to the landscape in these springsheds comes from agricultural and urban development (MACTEC 2010, Katz et al. 1999). Increased nitrate concentration is one factor that may be contributing to ecological changes in these springs (Stevenson et al. 2007). In addition, many springs in Florida are exhibiting reduced discharge, leading to decreases in current velocity (Kaplan et al. 2017; King 2014). These changes in hydrology are the cumulative result of multiple factors, including changes in rainfall, drainage alteration, and groundwater withdrawals (Copeland et al. 2009). Florida's burgeoning human population, which now exceeds 20 million residents, is placing increasing demands on the state's groundwater resources, and spring ecosystems appear to be exhibiting responses to these demands.

PURPOSE AND OBJECTIVES

This study was conducted as part of a broader management initiative begun by the St. Johns River Water Management District (SJRWMD or the District) in 2013. Called the Springs Protection Initiative (SPI), the effort involved a combination of scientific studies and identification of projects to implement which, 1) reduce nutrient loading (particularly nitrogen) to the landscape of springsheds, and/or, 2) reduce groundwater withdrawal/ pumping. These projects were selected based on a combination of existing data and best professional judgement. As part of the science component of the SPI, District scientists determined that a broad field study of the biology of multiple springs and their spring-run streams was needed. The data from this study would be useful to investigate patterns in vegetation communities and selected elements of the faunal communities and their relationships with physicochemical conditions.

A major focus of the SPI science component (SPIS) was to better understand the drivers (physical, chemical, and/or biological) which exert the greatest influence on the primary producer community structure (the submerged macrophyte and algal communities) in spring-run streams (Reddy et al. 2017). This was prompted by the observation in many of these streams of the proliferation of large mats of “nuisance” benthic algae, which either replaced the macrophytes, and/or substantially increased epiphytic algal biomass on the macrophyte leaves. Hypotheses advanced to explain these biological shifts include increased nitrate concentrations and loads discharged from the springs (Scott et al. 2004, Mattson et al. 2006, Stevenson et al. 2007), decreased spring flows resulting in reduced current velocity (King 2014, Kaplan et al. 2017), and reductions in algal grazer populations, possibly due to lower dissolved oxygen (DO) concentrations in the spring discharge (Heffernan et al. 2010, Liebowitz et al. 2014). Of broader note, Hudon et al. (2014) reported that proliferation of nuisance benthic algae, particularly the filamentous cyanobacterium *Lyngbya wollei* (now called *Microseira wollei*), appeared to be a growing phenomenon in freshwater ecosystems worldwide.

The specific objectives of this study were:

- Select a range of springs and their spring-run streams in which to conduct concurrent quantitative biological and physicochemical sampling
- Quantitatively sample macrophytes and algae to assess current ecological conditions; include quantitative sampling of one or more major groups of fauna
- Evaluate similarities and differences within and among the spring-run streams, both spatially and temporally

These data will form a baseline dataset for comparison with future sampling efforts, and to compare with similar biological data collected in prior studies of Florida spring-run streams.

DESCRIPTIONS OF SPRING-RUN STREAMS

In 2015, SJRWMD employed Amec Foster Wheeler (now WSP USA) to conduct an intensive, synoptic (short-term) biological survey in 14 spring-run streams in north and central Florida (Figure 1). Seven of these were in the St. Johns River Basin (northeast and east central Florida): Alexander Springs Creek, Volusia Blue Spring Run, Juniper Creek, Rock Springs Run, Silver River, Silver Glen Spring Run, and Wekiva River. Three spring-run streams were in west central Florida: Rainbow River, Gum Slough, and Weeki Wachee River. Four streams were in north Florida: Manatee Spring Run, Ichetucknee River, Wacissa River, and Wakulla River. These 14 streams were selected because all had a long term ($\geq$10 years) record of discharge and water chemistry. They were also chosen based on the personal knowledge of the senior author in consultation with other SJRWMD scientists, scientists with other water management districts and the Florida Department of Environmental Protection (FDEP). Brief descriptions of each spring-run stream and its headspring(s) are provided below. A

Figure 1. Map of the region showing the locations of the 14 study streams. Red lines show county boundaries.

summary of some physicochemical characteristics of each headspring (and data sources) is presented in Table 1.

Alexander Spring Creek. Originates at Alexander Spring, a first magnitude spring located in the Ocala National Forest in Lake County. Mean annual flow of Alexander Spring is 102 cfs (Appendix A) and the flow originates from a single main vent. The groundwater contributing area, or springshed (after Copeland 2003), is approximately 151.52 km^2 (Walsh et al. 2009). The spring-run stream flows 19.1 km from the headspring to the mainstem of the St. Johns River, the confluence with the river located near Lake Dexter. Alexander Spring base water quality has been characterized as a mixed spring (Woodruff 1993), with moderately high levels of dissolved ions and salts. Nutrient concentrations (nitrate-nitrite nitrogen, NOx-N, and total phosphorus, TP) in Alexander Spring are low and reflective of background conditions (<0.1 mg/L NOx-N and <0.06 mg/L TP). Human use of the recreational area at the headspring is high, particularly in the summer, but attendance figures (number of persons/day) were not available. Much of Alexander Spring Creek below the County Road (CR) 445 bridge is open to motorized boat traffic, but it is not heavily used due to very shallow depths. Use of the creek by canoes and kayaks is moderate.

Blue Spring Run. Originates at Volusia Blue Spring (called this because of the common use of this spring name throughout the state), located in Blue Spring State Park in Volusia County. Volusia Blue Spring is a first magnitude spring, with a mean annual flow of 144 cfs (Appendix A), although mean annual flow is historically reported as 162 cfs (Scott et al. 2004). Spring flow and stage in the spring run are heavily influenced by backwater from the adjacent St. Johns River. The flow originates from a single main vent in the spring pool. The springshed area is approximately 270.09 km^2 (Shoemaker et al. 2004). The spring run flows 0.67 km to the mainstem of the St. Johns River. Volusia Blue Spring is characterized as a salt spring (Woodruff 1993), with high levels of dissolved sodium, chloride, and other ions. The source of these is relict seawater in a groundwater zone beneath the St. Johns River corridor (Stringfield and Cooper 1951; J. Stewart, SJRWMD, pers. comm.). Nitrate concentrations in Volusia Blue Spring are elevated relative to background conditions (currently averaging 0.6-0.8 mg/L NOx-N). TP concentrations are slightly higher than background (averaging 0.07 mg/L P). Recreational use of the park is high, with an average annual attendance of 589,941 in 2016-17[1]. The spring run is closed to motorized boat traffic. Canoes and kayaks are permitted in the run during certain hours. The entire run and headspring are closed to all human use between November and March to permit manatee use as a warm water refuge.

Juniper Creek. Originates at Juniper Spring in the Ocala National Forest in Marion County. Juniper Spring is a second magnitude spring, with a mean annual flow of 11 cfs (Appendix A). The flow originates from a single main vent and possibly one or more minor vents in the spring

1 – Attendance figures from this and subsequent descriptions are from: https://floridadep.gov/sites/default/files/Economic%20Impact%20Assessment%202016-2017.pdf

Table 1. Selected physicochemical characteristics of the headsprings of the 14 spring-run streams surveyed in this study. Data sources are indicated at bottom of the table. Period of record varies by spring and may not be current data. ND = not determined.

	Alexander	Blue	Juniper	Rock	Silver	Silver Glen	Wekiva
Mean Discharge[1] (cfs)	102	144	11	54	722	101	62
Total Length of Run (km)	19.1	0.7	16.3	14.5	8.5	1.1	25.5
Springshed area[1] (km^2)	151.5	270.1	ND	43.5	2,238	ND	81.8
Conductivity[2] (mean; µmhos/cm)	1,109	1,676	115	261	464	1,815	338
Total Dissolved Solids[2] (mean; mg/L)	593	914	66	148	273	1002	193
pH[2] (mean; units)	7.88	7.37	8.46	7.64	7.20	7.74	7.39
Alkalinity[2] (mean; mg/L as CaCO3)	86	144	47	97	198	69	129
Sodium[3] (total, mean; mg/L)	122	167	2.30	4.80	5.92	238	10.20
Chloride[2] (mean; mg/L)	252	379	5	9	11	437	16
Dissolved Oxygen[2] (mean; mg/L)	1.58	0.47	6.51	0.91	1.91	2.94	0.75
Total Phosphorus[4] (mean; unfiltered mg/L)	0.05	0.07	0.03	0.09	0.04	0.03	0.12
Orthophosphate[2] (mean; mg/L)	0.05	0.07	0.03	0.08	0.04	0.03	0.12
Nitrate-Nitrite N[2] (mean; mg/L)	0.04	0.51	0.10	1.29	1.14	0.06	1.00

1 – Appendix A or sources cited in text;
2 – Di and Mattson, unpublished report using data collected 2009-2013;
3 – from Scott et al. 2004 (single value sampled 2001 or 2002);
4 – calculated from data provided by SWFWMD (Rainbow, Gum, Weeki Wachee), SRWMD (Manatee, Ichetucknee, Wacissa), NWFWMD (Wakulla) and SJRWMD data (Alexander, Blue, Juniper, Rock, Silver, Silver Glen, Wekiwa)

Table 1. Continued.

	Rainbow	Gum	Weeki Wachee	Manatee	Ichetucknee	Wacissa	Wakulla
Mean Discharge[1] (cfs)	687	81	171	181	326	439	417
Total Length of Run (km)	9.7	8.0	12.1	0.4	8.8	21.7	14.5
Springshed area[1] (km^2)	1,904	ND	622	ND	960	ND	5,180**
Conductivity[3] (µmhos/cm)	161	318	320	430	319	326	328
Total Dissolved Solids[3] (mg/L)	89	175	176	268	183	184	183
pH[3] (units)	7.95	7.57	7.70	7.04	7.91	7.40	7.20
Alkalinity[3] (mg/L as CaCO3)	67	129	147	198	154	163	146
Sodium[3] (total or unfiltered; mg/L)	2.33	3.40	3.78	3.78	2.12	2.94	4.99
Chloride[3] (total or unfiltered; mg/L)	3.9	6.0	6.7	7.2	3.6	5.1	7.8
Dissolved Oxygen[3] (mg/L)	6.61	1.81	1.30	1.60	3.52	0.90	2.39
Total Phosphorus[4] (mean; unfiltered mg/L)	0.03	0.03	0.01	0.03	0.03	0.04	0.03
Orthophosphate[4] (mg/L)	0.03	0.03	0.01	0.03	0.02	0.05	0.03
Nitrate-Nitrite N[4] (mg/L)	1.70	1.50	0.90	2.00	0.76	0.30	0.50

** - includes springshed area of Wakulla Spring, Spring Creek Spring group, and St. Marks River Rise

1 – Appendix A or sources cited in text;
2 – Di and Mattson, unpublished report using data collected 2009-2013;
3 – from Scott et al. 2004 (single value sampled 2001 or 2002);
4 – calculated from data provided by SWFWMD (Rainbow, Gum, Weeki Wachee), SRWMD (Manatee, Ichetucknee, Wacissa), NWFWMD (Wakulla) and SJRWMD data (Alexander, Blue, Juniper, Rock, Silver, Silver Glen, Wekiwa)

pool. The springshed area for Juniper Spring has not been determined to date. Two other springs contribute to Juniper Creek, Fern Hammock Spring, which flows into the creek downstream of Juniper Spring, and Sweetwater Spring, which flows into the creek near the State Road (SR) 19 crossing. Fern Hammock is a second magnitude spring with a mean flow of 11 cfs (Appendix A). Sweetwater Spring is also a second magnitude spring with a mean flow of 13 cfs (Appendix A). Juniper Creek flows 16.33 km from the headspring to a confluence with Lake George. Juniper and Fern Hammock are both calcium bicarbonate springs, while Sweetwater is a salt spring (Woodruff 1993). Nutrient concentrations (NOx-N and TP) in Juniper Spring are at or below background levels (<0.10 mg/L NOx-N; 0.05 mg/L TP). Visitor use of the recreational area at the headspring is moderate to high, but attendance figures were not available. The upper half of Juniper Creek (above the SR 19 crossing) is closed to motorized boat traffic but has moderate to heavy use by canoes and kayaks. The lower half of the creek is open to boat traffic, but shallow depths generally preclude most motorized craft from navigating all but the lower part of the creek, near the confluence with Lake George.

Rock Springs Run. Originates at Rock Springs in Kelly Park, Orange County. Rock Springs is a second magnitude spring, with a mean annual flow of 54 cfs (Appendix A). The flow emerges from two cave openings in a vertical rock face at the headspring. The springshed area of Rock Springs is approximately 43.51 km^2 (Walsh et al. 2009). A small spring known as Sulphur Spring contributes flow to the run downstream of Rock Springs. It is a fourth magnitude spring with a mean annual flow of 0.74 cfs (www.sjrwmd.com/waterways/springs/list/). Rock Springs Run flows 14.46 km to a confluence with the Wekiva River. Both Rock Springs and Sulphur Spring are calcium bicarbonate water chemistry types (Woodruff 1993), although the latter gets its name from the odor of hydrogen sulfide in the spring water. Rock Springs is characterized by elevated NOx-N ($\geq$2.0 mg/L) and somewhat elevated TP (0.08 mg/L). Recreational use of the spring is high, with an average monthly attendance of 54,373. Annual attendance over the period 1998-2005 ranged from 73,626-214,983 (201.7-589 persons/day; Wetland Solutions Inc. 2007). Rock Springs Run is closed to motorized boat traffic but has moderate to heavy use by canoes and kayaks.

Silver River. The Silver River is a tributary of the Ocklawaha River. The headspring area of the river is known as the Silver Springs group (after Copeland 2003), because it consists of at least 30 mapped, named spring vents (Munch et al. 2006). Historically, Silver Springs was the largest inland spring in the state by discharge, with a mean annual flow of 820 cfs (Scott et al. 2004). Based on current data, the mean average flow of the Silver Springs group is 722 cfs (Sutherland et al. 2017). About half of this flow is discharged from the main headspring, known as Mammoth Spring or Silver Spring. Flow in the Silver River is influenced by backwater effects during high stage on the Ocklawaha River (Baird et al. Unpublished Report). The springshed area of the springs group is listed as 2,238 km^2, which constitutes the “1,000-year capture zone” as delineated by groundwater modeling (Munch et al. 2006). The Silver River runs 8.5 km to the Ocklawaha River confluence. The Silver Springs group is a calcium bicarbonate water chemistry type (Woodruff 1993). Nitrate concentrations discharged from the springs group are elevated (averaging 1.1-1.3 mg/L NOx-N). TP is at background concentration (0.04 mg/L P). Since the 1920s, the headspring area of Silver Springs has been a tourist attraction, one of the main features being glass-bottom boat rides to view the underwater communities, accompanied by narration from the boat captain (which continues today). The Silver River is now part of Silver River State Park and the Ocklawaha River Aquatic Preserve. Total annual attendance at the park in 2016–2017 was 480,272. The Silver River is open to motorized boat traffic up to the headspring and is also used heavily by canoes and kayaks.

Silver Glen Spring Run. Originates at Silver Glen Springs in the Ocala National Forest in Marion County. Silver Glen is a first magnitude spring with a mean annual flow of 101 cfs (Appendix A). Since 2010, the flow of the spring has rarely reached over 100 cfs (SJRWMD unpublished data), and historically the mean annual flow of the spring has been listed as 110.5 cfs (Scott et al. 2004). The flow emerges from two vents, the main vent (Silver Glen) and a secondary vent known as the "Natural Well". Flow and water level in the spring and spring run are influenced by backwater from the adjacent St. Johns River. The springshed area of Silver Glen Springs has not been determined to date. The run flows for 1.13 km to a confluence with Lake George. Silver Glen Spring is characterized as a salt spring due to high levels of dissolved solids (Woodruff 1993). Nutrient concentrations in Silver Glen Springs are at or below background levels (<0.1 mg/L NOx-N; <0.06 mg/L TP). Recreational use of the headspring and run is very high. Boat traffic is permitted, and large numbers of motorized boats use the spring run, with no restriction on size or draft. A rope barrier prevents boats from entering the headspring pool. Attendance figures were unavailable.

Wekiva River. Originates at Wekiwa Springs (the spring spelling is different from the river) in Wekiwa Springs State Park, Orange County. The Wekiva River mainstem and all or portions of the tributaries are part of the Wekiva River Aquatic Preserve. Wekiwa Springs is a second magnitude spring with a mean annual flow of 62 cfs (Appendix A). The flow originates primarily from a single main vent but there is a secondary vent in the spring pool that occasionally exhibits flow. Flow and water level are occasionally affected by backwater effects during high stage on the St. Johns River (SJRWMD unpublished data). The springshed area of Wekiwa Springs is approximately 81.84 km^2 (Walsh et al. 2009). The Wekiva River runs 25.47 km to its confluence with the St. Johns River downstream of Lake Monroe. The river receives inflow from three major tributary streams; Rock Springs Run, the Little Wekiva River, and Blackwater Creek. All of these tributaries receive some of their flow from a number of smaller springs, ranging from second to sixth magnitude. A total of 31 named springs contribute flow to the Wekiva River and its tributaries. Wekiwa Spring is a calcium bicarbonate water chemistry type. Nutrient concentrations in the spring are elevated relative to background conditions; NOx-N has been as high as >2 mg/L and TP concentrations average 0.12 mg/L. Recreational use of Wekiwa Spring is high, with an annual state park attendance in 2016–2017 of 399,040. Annual visitor attendance over the period 1993–2006 ranged from 94,962–166,738 (260.2–456.8 persons/day; Wetland Solutions Inc. 2007). The Wekiva River below the Rock Springs Run confluence is open to boat traffic, but shallow depths and abundant woody snags restrict boat use to smaller vessels.

Rainbow River. Originates from a complex of multiple spring vents known as the Rainbow Springs group. The river is located in western Marion County, near the city of Dunnellon, and is a tributary of the southern Withlacoochee River. Total length of the river is 9.7 km. The Rainbow Springs group is a first magnitude springs group, with a median flow of 687 cfs

(SWFWMD 2015). Flow in the lower Rainbow River is influenced by backwater effects during high stages on the Withlacoochee River (SWFWMD 2015). Historically, the springs group was the third largest spring in Florida by discharge. The springshed of the springs group encompasses about 1,904 km^2 (SWFWMD 2015). The base water chemistry of the Rainbow Springs group is a calcium bicarbonate type (Woodruff 1993). Nitrate concentrations are elevated, averaging over 2 mg/L NOx-N. Phosphorus levels are at background concentrations (<0.06 mg/L TP). The headspring area and part of the upper Rainbow River are within Rainbow Springs State Park, and the entire Rainbow River is a state-designated Aquatic Preserve. Annual attendance in the park in 2016-17 was 316,796 persons. Historically the springs were privately owned and operated as a tourist attraction, featuring "submarine boat" tours of the headspring area. The Rainbow River is open to boat traffic and there are many private residences on the river, but the headspring area is closed to motorized boat traffic and only canoes and kayaks are allowed.

Gum Slough. Originates at the Gum Springs group, a complex of at least 6–7 spring vents (Scott et al. 2004). The land surrounding the springs and much of the slough is in private ownership. The headsprings and slough are in Sumter County and the slough discharges to the southern Withlacoochee River upstream of the Rainbow River confluence. Total length of the slough is about 8 km. The Gum Springs group is a second magnitude springs group with a mean annual flow of 81 cfs (King 2014). The base water quality of the springs is a calcium bicarbonate water quality type. As reported in King (2014), the headsprings exhibit elevated nitrate concentrations (1.4 mg/L NOx-N). Phosphorus concentrations are below background concentrations (<0.03 mg/L TP).

Weeki Wachee River. Originates at Weeki Wachee Spring in Hernando County. The spring is a first magnitude spring, with a mean annual flow of 171 cfs (SWFWMD 2017). The Weeki Wachee springshed encompasses 622 km^2 (SWFWMD 2017). The Weeki Wachee River is about 12 km in length and discharges to the Gulf of Mexico near Bayport. The lower part of the river is affected by tidal fluctuation from the adjacent Gulf of Mexico. The base water chemistry of Weeki Wachee Spring is a calcium bicarbonate water quality type (Woodruff 1993). Nitrate concentrations in Weeki Wachee Spring are elevated (>0.9 mg/L NOx-N). TP concentrations are very low (0.01 mg/L). The headspring and upper river are part of Weeki Wachee Springs State Park. Historically the headspring was privately owned and operated as a tourist attraction, the main draw being an underwater theatre where visitors would watch performances featuring women portraying mermaids and other characters. The state park continues to operate the underwater show today, along with pontoon boat tours on the river. Annual attendance at the park in 2016–2017 was 418,844. Downstream of the headspring/state park there are many private residences and subdivisions along the river, and it receives heavy recreational use by boats, canoes, and kayaks.

Manatee Spring Run. Manatee Spring is located in Manatee Springs State Park, near the city of Chiefland in Levy County. The spring is a first magnitude spring with a historic mean annual flow of 181 cfs (Scott et al. 2004). The spring run is 0.37 km in length and discharges to the lower Suwannee River. During low river flows in the Suwannee, water levels in the spring are affected by tidal fluctuation. The springshed area of Manatee Spring has not been determined because it is difficult to delineate it from the adjacent Fanning Springs springshed. Manatee Spring is a calcium bicarbonate water quality type (Woodruff 1993). Nitrate concentrations are elevated ($\geq$2.0 mg/L NOx-N). TP concentrations are below background (<0.06 mg/L). The spring run is closed to motorized boat traffic, but canoes and kayaks are allowed on the spring run. The state park experiences heavy recreational use by swimmers, snorkelers, and divers. Annual attendance in 2016–2017 was 308,175.

Ichetucknee River. Originates at the Ichetucknee Springs group; a complex of seven named springs. The springs and river are at the border of Suwannee and Columbia Counties, near the town of Fort White. The springs group and the upper half of the Ichetucknee River are within Ichetucknee Springs State Park. The mean annual flow of the springs group is 326 cfs (Katz et al. 2009). About half of that flow comes from Ichetucknee Spring (second magnitude; mean flow 45 cfs) and the Blue Hole or Jug Spring (first magnitude; mean flow 144 cfs). The springshed area encompasses 960 km^2 (Katz et al. 2009). The Ichetucknee River flows for 8.8 km to the lower Santa Fe River, a tributary of the middle Suwannee River. The springs of the Ichetucknee group all exhibit a calcium bicarbonate water quality type (Woodruff 1993). Nitrate concentrations in most of the springs in the spring group are elevated (>0.50 mg/L NOx-N). TP concentrations are within the background range (0.04-0.06 mg/L TP). The upper half of the river within the state park is closed to motorized boat traffic, but is heavily used for tubing, swimming, snorkeling, and canoeing/kayaking, particularly between Memorial Day and Labor Day. Total annual attendance in the park in 2016-17 was 416,892. The lower half of the river is bordered by private residences with docks and boats are permitted to access this part of the river.

Wacissa River. Originates at the Wacissa Springs group, a complex of at least 16 known springs (Hornsby and Ceryak 2000). The springs and river are in Jefferson County. Much of the land around the river is state-owned as part of the Aucilla Wildlife Management Area. The Wacissa River is a tributary of the Aucilla River and runs 21.7 km from the headsprings group to the Aucilla River confluence. The mean annual flow of the springs group is 439 cfs, making it the fourth largest spring in the state by discharge (Hornsby and Ceryak 2000). The springshed area has not been determined. The base water chemistry of the springs comprising the springs group is a calcium bicarbonate type. Nitrate concentrations in many of the springs are somewhat elevated over natural background (varying from 0.2-0.4 mg/L NOx-N), although not as much as seen in many of the other spring-run streams in this study. TP concentrations are at background levels (<0.06 mg/L). The river is mainly accessed from a county park at the headspring group and at the Goose Pasture public recreation area on the river, but attendance figures were not available.

Wakulla River. The Wakulla River begins at Wakulla Spring. The spring and the upper third of the Wakulla River are within Wakulla Springs State Park. The springs and river lie entirely within Wakulla County. The river runs 14.5 km to its confluence with the St. Marks River near where it empties into the Gulf of Mexico near the town of St. Marks. The mean annual flow of Wakulla Spring is 417 cfs (K. Coates, NWFWMD Pers. Comm.). The springshed area cannot be delineated from the overlapping springsheds of the Springs Creek Springs group on the coast and the St. Marks River Rise (K. Coates, NWFWMD Pers. Comm.). The overall area of these is 5,180 km^2. The base water chemistry of Wakulla Spring is a calcium bicarbonate type. Nitrate concentrations are elevated over background (>0.5 mg/L NOx-N), although nitrate concentrations have been decreasing over the past decade with the implementation of improved domestic wastewater effluent disposal practices in the upper springshed (K. Coates, NWFWMD Pers. Comm.). TP concentrations are below natural background (<0.06 mg/L). Annual attendance at the state park in 2016–2017 was 239,270.

METHODS

SAMPLING STATIONS

Figure 1 shows the locations of the 14 spring-run streams in this study. Two sampling locations were established at 10 of these streams, consisting of a transect across the stream channel from bank-to-bank and perpendicular to the channel thalweg. One transect (always Transect 1) was established upstream, close to the main headspring or headspring group. The other transect was established at a downstream location in the spring-run stream proper. Three transects were established on the Silver River (upstream, mid-reach, and downstream) to help support other scientific work being conducted on that stream. On the three shorter spring runs (Manatee Spring, Volusia Blue Spring, and Silver Glen Spring), a single transect was established downstream of the headspring in the run itself. The locations of the transects were not established randomly; they were selected based on the occurrence of beds of SAV (macrophytes and algae) and professional judgement. Table 2 presents descriptive and location data on the transects in the study and the site abbreviations used in subsequent tables, figures, and appendices. Appendix B presents maps showing the transect locations and the locations of related long-term ambient water quality sampling stations.

FIELD METHODS

A detailed summary of all methods used in this study was presented in Amec Foster Wheeler (2016a). A general summary of the methodology is presented in this report. Field methods and QA/QC for water quality sampling followed Standard Operating Procedures (SOPs) of SJRWMD and U.S. Geological Survey (Amec Foster Wheeler 2016a). Physicochemical data (current velocity, *in situ* water chemistry, and stream channel characteristics such as depth and tree canopy cover) were collected at each sample transect in 2015 on six separate sampling dates. Biological sampling of SAV and macroinvertebrates was conducted concurrently on two of these sampling dates in spring (May-June) and fall (September-October); biological data included taxonomy and abundance of macrophytes, algae and SAV-associated macroinvertebrates.

Physicochemical Sampling

Physicochemical sampling was conducted along a tag line stretched across the stream channel along with a measuring tape. Current velocity was measured and recorded with a SonTek FlowTracker handheld Acoustic Doppler Velocimeter (ADV) at up to 10 individual locations across the stream channel at depths above the top of the SAV canopy. *In situ* water quality was measured using a multi-parameter sonde and a hand-held turbidity meter at a mid-stream point on the transect. Chemical measurements were taken using a YSI Series 5 multi-parameter probe. The following variables were measured at each transect:

- Total water depth
- Height of the macrophyte canopy (as total depth minus depth to the top of the canopy)

Table 2. Location data and description of the sampling transects in this study.

Station ID	Latitude (decimal degrees)	Longitude (decimal degrees)	Description
ALE1	29.08259003	-81.57825003	Alexander Springs Creek near headspring
ALE2	29.07929	-81.56691997	Alexander Springs Creek downstream of County Road 445
GUM1	28.95340999	-82.23836998	Gum Slough near headspring group
GUM2	28.95974999	-82.23209001	Gum Slough between Gum Springs 3 & 4
ICH1	29.9799	-82.7589	Ichetucknee River downstream of Blue Hole Spring
ICH2	29.957241	-82.780301	Ichetucknee River above U.S. 27
JUN1	29.18449004	-81.70372999	Juniper Creek near headspring
JUN2	29.21174997	-81.65322003	Juniper Creek downstream of State Road 19
MAN1	29.48948003	-82.97798002	Manatee Spring Run downstream of headspring
RAI1	29.09076667	-82.42656667	Rainbow River near headsprings group
RAI2	29.06896667	-82.42753333	Rainbow River downstream of K.P. Hole Park
ROC1	28.77171667	-81.50291667	Rock Springs Run downstream of King's Landing
ROC2	28.7411	-81.46794002	Rock Springs Run near Indian Mound camp site
SIL1	29.21573333	-82.04845	Silver River in headspring group (near Christmas Tree Spring)
SIL2	29.21528333	-82.0417	Silver River at USGS gauge/1,200 meter station
SIL3	29.20348333	-82.015	Silver River near SJRWMD minimum flows and levels transect 5
SLG1/SILG1	29.24471	-81.64127001	Silver Glen Spring Run downstream of headspring
VOL1	28.94707	-81.33972	Volusia Blue Spring Run downstream of headspring
WAC1	30.327034	-83.987714	Wacissa River near headspring group
WAC2	30.203283	-83.970364	Wacissa River at Goose Pasture
WAK1	30.234019	-84.294372	Wakulla River near headspring
WAK2	30.211438	-84.259876	Wakulla River downstream of County Road 365
WEE1	28.51895	-82.573891	Weeki Wachee River near headspring
WEE2	28.519443	-82.583234	Weeki Wachee River downstream
WEK1	28.71415	-81.45805	Wekiva River near headspring (downstream of lagoon)
WEK2	28.79926667	-81.4144	Wekiva River upstream of State Road 46

- Tree canopy cover (using a Model-C spherical densiometer)
- Current velocity
- Surface water elevation (if a staff gauge was present at the sampling transect)
- Conductivity (specific conductance)
- Dissolved oxygen (DO)
- pH
- Water temperature
- Turbidity (hand-held turbidimeter)

Benthic Macroinvertebrate Sampling

Sampling of the benthic macroinvertebrate community associated with SAV (macrophytes and algae) was conducted along a belt transect straddling the tag line along which physicochemical data were collected (Figure 2). The belt transect "straddled" the measuring tape and tag line along which the physicochemical measurements were taken. Sampling in SAV habitat was conducted with a modified Hess-type sampler; three (3) replicate macrophyte and three (3) replicate macroalgae samples were collected at each biological sampling event (spring and fall 2015).

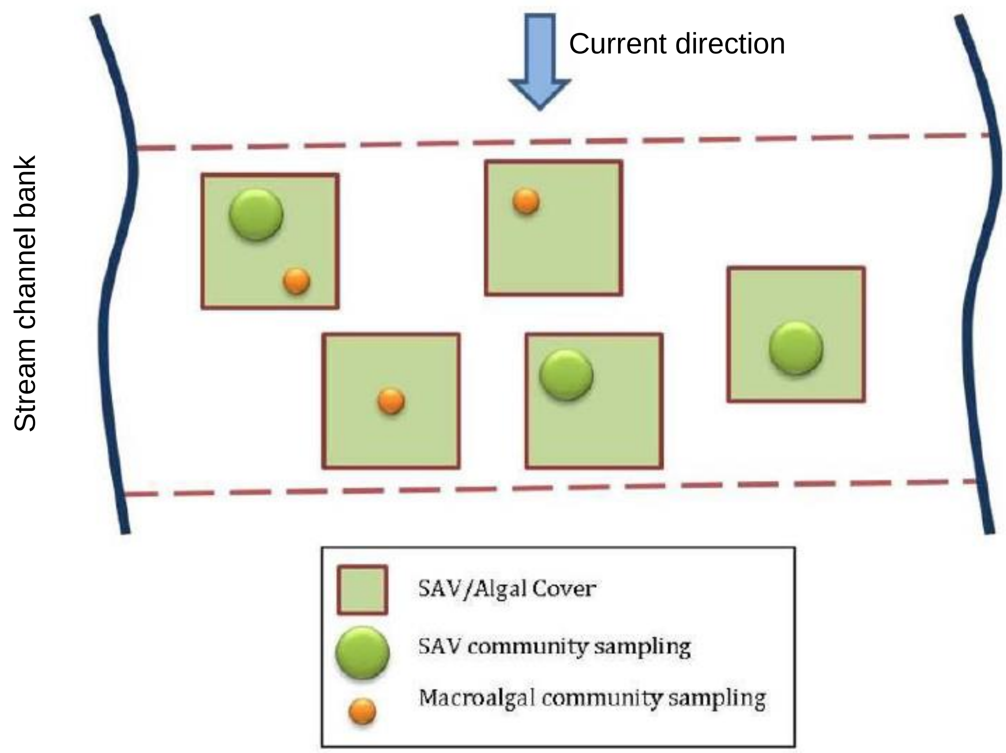


Figure 2. Schematic diagram showing the arrangement of replicate samples for SAV habitat sampling for macroinvertebrates. Source: Amec Foster Wheeler 2016a.

Transects and SAV habitat samples were placed where beds of SAV (macrophytes and/or macroalgae) were present in locations that appeared to us to be representative of the reach/area in which we located the transect. Replicate samples for macroinvertebrates in SAV habitat were also taken non-randomly (generally systematically across the stream channel from bank-to-bank); samples were collected where SAV was present.

Macroinvertebrate communities associated with SAV habitat were sampled using the modified Hess sampler; the sampler was placed over an area of vegetation (macrophyte bed or macroalgal mat) and all material within the sampler was collected. Samples were stored in plastic bags and preserved on ice until processed in the laboratory.

LABORATORY METHODS

In the laboratory, all collected SAV samples were kept cold on ice and processed within 24 hours of collection. This followed Florida Department of Environmental (FDEP) SOP (FS7400) for macroinvertebrate samples. All macroinvertebrate sample processing and taxonomic identification followed FDEP SOPs. Initially, vegetation with invertebrates was rinsed over a standard US #30 sieve to catch loose invertebrates. Plant material (macrophyte leaves and algal filaments) were separated and gently scraped by hand and rinsed into the same sieve. Dislodged macroinvertebrates from each sample were preserved in 10% buffered formalin stained with rose Bengal until further analysis.

Additional sorting of macroinvertebrates was done by emptying the preserved sample into a US #30 mesh sieve and rinsing. Decanted formalin was emptied into a waste bucket for proper disposal. The sample was rinsed with tap water and transferred to white trays for sorting. Sorting took place using a dissecting microscope (approximately 10X power). All invertebrates observed were removed and preserved in 80% ethanol. QA/QC checks were performed by resorting at least 10% of the samples by a second observer to look for any missed specimens.

Macroinvertebrate identification was performed by experienced taxonomists using the most recent keys developed for various invertebrate groups. Again, taxonomy was done following FDEP SOPs for processing macroinvertebrate samples (Amec Foster Wheeler 2016a). Invertebrates collected in each sample were identified to the lowest practical taxonomic level (LPTL) and enumerated. Chironomid midges and oligochaete worms were mounted per FDEP SOPs for taxonomic identification.

The following measures were determined from the sorted invertebrate samples for samples from both macrophyte and macroalgal habitat:

- Taxa richness – the number of taxa (to LPTL) in the sample
- Abundance as population density – abundance was calculated in two ways: as # individuals/m^2 (dividing the # individuals in the sample by the area sampled by the Hess sampler) and # individuals/g plant dry weight (dividing the # individuals in the sample by the dry weight of macrophytes or macroalgae in the Hess sample)

- Shannon-Wiener diversity index (H') – an index of diversity commonly used in many benthic macroinvertebrate studies and is also a biological criterion in state water quality standards. Calculated as:

  $\Sigma P_i \times (\log_e P_i)$, where P_i is the proportion of the i^{th} species in the sample

- Margalef's Species Richness index – another index of diversity used in many benthic studies. Calculated as: $(d)=(S-1)/\log_e(N)$, here S is # taxa and N is # individuals
- Pielou's Evenness – calculated as: $(J') = H'/\log_e S$, where H' is the Shannon index for the sample and S is the # taxa in the sample. Also used in many benthic studies.
- Functional feeding group (FFG) category – assigned to each species or taxon in a sample using the categorization developed by FDEP (Amec Foster Wheeler 2016a) supplemented by information presented in Merritt and Cummins (1996) and Warren et al. (2000)
- Life habit category – assigned to each species or taxon using Merritt and Cummins (1996)
- Long-lived taxa – assigned using the FDEP database defining these taxa (Amec Foster Wheeler 2016a). This metric was not analyzed in this report.
- "Sensitive" and "very tolerant" taxa as defined by FDEP in their databases (Amec Foster Wheeler 2016a). This metric was also not analyzed in this report.

Statistical Analysis Methods

All data summary and analysis were performed by District staff (RAM, DLH, and MQG). Physicochemical and macroinvertebrate data were summarized in tabular and graphical form, using Minitab™ version 18 software and the PRIMER™ software. Due to the non-random placement of transects and sample sites within transects and the non-independence of transects within streams and sample sites within transects, statistical analysis using conventional statistics (both parametric and/or nonparametric) were considered not appropriate. Consequently, the purpose of our analyses was to indicate general trends and relationships, rather than indicating statistically significant differences. Graphical and tabular summaries of the data were used to compare macroinvertebrate taxa richness and composition and abundance among spring-run streams and to compare macroinvertebrate community and physicochemical characteristics. The physical, chemical, and biological data from spring and fall sampling events are presented separately.

Multivariate analyses of the physicochemical and macroinvertebrate data were conducted using the PRIMER™ software (Clarke and Gorley 2015), which was developed to specifically deal with species-by-sample data in the assessment of biological changes in response to changes in the abiotic environment (Clarke 1993). These permutation tests were conducted in an exploratory fashion to look for patterns in the data. Transects (e.g., upstream, downstream) within streams were analyzed separately. However, replicate data was averaged within each transect (means of taxa richness, abundance, and diversity, rather than individual replicate samples). Data for spring and fall sampling events were analyzed separately to avoid seasonal differences that might overwhelm inter-transect differences. Physicochemical variables were log-transformed and normalized prior to analysis and Euclidean distance was used to calculate resemblance matrices to test for similarities among transects. Macroinvertebrate richness and abundance data were Log (x+1) transformed prior to analysis and the Bray-Curtis similarity index (Bray and Curtis 1957) was used to calculate resemblance matrices to test for similarities among transects. Macroinvertebrate analyses were run and compared using all taxa collected in the samples and rerun after removing “rare” taxa, defined as those taxa comprising <3% of the total abundance in a sample (Clarke and Warwick 2001).

The following analyses were performed:

Principal Components Analysis (*PCA*) was used to orthogonally transform the set of physicochemical variables into a smaller set of linearly uncorrelated axes to look for similarities among transects. Orthogonal axes are created based on how much of the variability between transects in the physicochemical variables is captured by the combination of the original variables, with the most variability captured in the first axis, the second axis accounting for the greatest amount of the remaining variability, and so on until most of the variability between transects is accounted for. When the axes are plotted against one another, transects with similar values for the suite of physicochemical variables will occur close together.

Cluster Analysis (*CLUSTER*) was used to search for similarities among transects based on physicochemical or macroinvertebrate compositional differences. Simultaneously, a Similarity Profile test (*SIMPROF*) was used to assess the significance of cluster groups. *SIMPROF* runs permutations of the macroinvertebrate community or physicochemical composition at each node in the cluster to determine whether there is any evidence of multivariate structure within the group. If multivariate structure is detected, then the transects within the group at that node are considered significantly different from the other transects.

Analysis of Similarity (*ANOSIM*) was used to determine whether there were any differences among the 14 spring-run streams, and between upstream and downstream transects within a stream, based on their physicochemical or macroinvertebrate community composition. The test statistic is “R”, and a significant difference is a permutation probability (P_{perm}) <0.05. When differences were found between groups (i.e., SJR vs O or upstream vs downstream), a Similarity Percentages (*SIMPER*) routine was used to pinpoint which variables or species accounted for those differences.

The Bio-Env Stepwise procedure (*BEST*) was used to determine if there was a correlation between the distribution of stream sites based on the composition of the macroinvertebrate community and the distribution of sites based on the physicochemical variables collected at each site. The test compares resemblance matrices based on invertebrate community and physicochemical similarities and determines what combination of physicochemical variables accounts for the pattern in macroinvertebrate species composition among transects. The test statistic is “R” and there is no test for significance. For purposes of this analysis, weak or low correlation was $R \leq 0.3$, moderate correlation was $R > 0.3$ to < 0.7 and high correlation was ≥ 0.7.

RESULTS AND DISCUSSION

PHYSICOCHEMICAL DATA

Table 3 shows the physicochemical data collected at the transects in spring and fall 2015. Channel width at each transect was generally similar in the spring and fall; variation is likely due to changes in water levels in the stream channel or sampling in a slightly different location. Tree canopy cover was variable, with generally higher tree cover associated with narrower stream channels. Current velocity likewise exhibited considerable variation; in some systems the downstream transect had higher velocities (e.g., Wekiva River), but in others the upstream transects were higher (e.g., Gum Slough). Water temperatures were consistent both among and within spring-run stream systems, varying from ~20–24 ^{o}C across all transects, and generally being similar at both upstream and downstream transects in all streams and in both spring and fall sampling episodes. In many cases, the fall water temperature was slightly cooler than the spring. The more northern springs (WAC and WAK) generally had lower mean water temperature than the springs further south. Highest conductivity was measured at the downstream Juniper Creek site (JUN2) and the Silver Glen Run transect (SLG1). JUN2 conductivity was much higher than JUN1 due to more saline groundwater inflow downstream. Like water temperature, pH was very consistent among and within all stream systems; pH was generally circumneutral to slightly alkaline. Higher pH values (>8) appeared to generally be associated with high (supersaturated) dissolved oxygen (DO) concentrations, suggesting an effect of plant photosynthesis. DO was generally lower at upstream sites, nearer to the headspring discharge, but two upstream sites exhibited particularly high DO concentrations (JUN1 and RAI1). Turbidity was uniformly very low among and within the streams. The highest single turbidity was a value of 9.66 NTU at the Silver Glen Run transect in the fall. This may be due to recreational use of the spring on that day causing an increase in suspended sediments.

Principal Components Analysis showed that the same five variables accounted for over 80% of the variation among the transects across seasons: stream width, canopy cover, pH, DO, and current velocity accounted for 83.6% of the variation in the spring season, and 86.9% of the variation in the fall. Cluster analysis (Figure 3) showed no significantly different clusters based on water quality in both seasons, but in general spring-run streams on the St. Johns River mainstem (SJR) clustered together and "Other" streams (O - not on the mainstem of the St. Johns) also tended to cluster, especially in the spring. However, ANOSIM showed significant differences between SJR spring-run streams vs. O streams (R=0.300; P_{perm}=0.001 in spring; R=0.245; P_{perm} =0.007 in fall). There were also significant upstream versus downstream differences in spring (R=0.167, P_{perm} = 0.019). The SIMPER analysis indicated that conductivity, turbidity, current velocity, and water depth were main factors separating SJR streams from O streams in both seasons. The SJR streams generally had higher conductivity and turbidity, while O streams had greater water depth and/or current velocity (depending on season). The average dissimilarity between SJR and O transects was ≥ 20%, regardless of season. SIMPER analysis of the upstream versus downstream differences seen in the ANOSIM

Table 3. Physicochemical measurements collected at the sampling transects in spring and fall 2015. ND = no data.

TRANSECT	Channel Width (m)	Canopy Cover (%)	Current Velocity (m/sec)	Water Temp (ºC)	Conductivity (µmhos/cm)	pH	Dissolved O_2 (mg/L)	Turbidity (NTU)
ALE1 sprg	41.0	1.5	0.05	24.35	1,172	7.56	2.64	0.17
ALE1 fall	47.0	8.3	0.06	24.13	1,073	7.42	2.28	0.57
ALE2 sprg	64.0	0	0.09	26.28	1,164	8.28	5.95	0.07
ALE2 fall	64.0	0	0.15	24.30	1,080	7.92	5.59	1.40
GUM1 sprg	15.0	62.5	0.14	23.55	363	7.24	5.62	0.27
GUM1 fall	9.0	58.5	0.15	23.24	355	7.48	6.02	0.61
GUM2 sprg	20.0	66.8	0.13	23.42	356	6.60	4.99	0.73
GUM2 fall	18.0	64.8	0.07	23.23	364	7.65	4.96	0.92
ICH1 sprg	13.7	54.8	0.10	21.67	312	7.28	3.70	0.27
ICH1 fall	13.7	52.8	0.24	21.76	287	7.18	2.80	0.31
ICH2 sprg	21.9	43.5	0.16	23.71	320	7.21	9.56	0.87
ICH2 fall	21.3	38.3	0.28	22.04	304	7.26	4.54	1.14
JUN1 sprg	6.0	41.8	0.32	23.13	143	7.17	8.17	1.45
JUN1 fall	ND	ND	ND	ND	ND	ND	ND	ND
JUN2 sprg	20.0	2.3	0.34	23.20	2,050	7.42	6.72	1.41
JUN2 fall	17.0	6.25	0.08	23.76	1,940	8.00	7.75	0.97
MAN1 sprg	29.0	14.5	0.00	22.31	524	7.06	1.48	0.79
MAN1 fall	26.0	36.3	0.07	22.54	534	7.26	1.37	0.19
RAI1 sprg	33.5	1.0	0.23	23.39	259	7.75	7.51	0.88
RAI1 fall	29.0	4.0	0.18	23.41	284	7.36	7.91	0.52
RAI2 sprg	51.8	5.0	0.17	23.63	265	8.01	8.85	0.75
RAI2 fall	42.7	2.5	0.20	24.27	283	7.89	10.70	0.35
ROC1 sprg	17.7	51.8	0.18	23.71	266	7.88	4.74	0.68
ROC1 fall	19.2	30.5	0.13	24.08	273	7.47	8.77	0.18
ROC2 sprg	11.6	16.0	0.13	24.44	271	7.93	7.15	1.51
ROC2 fall	9.1	31.0	0.44	23.00	350	6.97	6.55	1.04
SIL1 sprg	30.5	16.0	0.15	23.58	441	7.34	3.61	0.98
SIL1 fall	36.6	1.25	0.14	23.49	456	6.95	3.20	0.20

Table 3. Continued.

TRANSECT	Channel Width (m)	Canopy Cover (%)	Current Velocity (m/sec)	Water Temp (ºC)	Conductivity (µmhos/cm)	pH	Dissolved O_2 (mg/L)	Turbidity (NTU)
SIL2 sprg	54.9	1.5	0.24	24.12	430	7.87	5.94	0.61
SIL2 fall	54.9	0	0.20	23.60	434	7.09	3.85	0.44
SIL3 sprg	31.4	36.0	0.19	24.73	446	7.47	7.86	1.29
SIL3 fall	27.4	26.3	0.14	23.89	393	6.65	4.32	2.28
SLG1 sprg	64.0	5.5	0.04	24.03	2,013	8.18	5.10	0.79
SLG1 fall	64.0	0	0.04	23.45	1,897	7.96	4.07	9.66
VOL1 sprg	23.2	54.3	0.07	23.27	1,934	7.38	0.52	0.18
VOL1 fall	25.9	52.5	0.06	23.10	2,348	7.3	0.42	0.09
WAC1 sprg	54.9	1.0	0.10	20.72	223	7.47	5.64	0.88
WAC1 fall	54.9	1.3	0.14	20.71	279	7.34	4.02	0.38
WAC2 sprg	77.7	1.5	0.19	26.69	295	8.20	10.17	1.15
WAC2 fall	73.2	0	0.20	23.41	304	8.17	9.85	0.43
WAK1 sprg	57.9	1.5	0.06	21.16	286	7.69	4.26	1.09
WAK1 fall	62.2	0	0.22	20.67	308	7.30	2.48	0.38
WAK2 sprg	25.6	21.5	0.07	23.19	298	8.04	8.78	2.38
WAK2 fall	24.4	11.5	0.22	21.36	308	7.58	5.43	1.47
WEE1sprg	29.0	26.8	0.10	23.85	325	7.62	2.07	0.88
WEE1 fall	21.3	78.3	0.15	23.84	343	7.52	2.25	0.22
WEE2 sprg	13.7	32.3	0.39	24.38	325	7.78	4.52	0.62
WEE2 fall	15.2	49.3	0.42	24.32	341	7.74	5.06	0.17
WEK1 sprg	21.3	8.5	0.07	24.57	357	7.93	2.51	0.88
WEK1 fall	15.2	10.0	0.06	24.05	358	7.17	2.29	0.41
WEK2 sprg	35.1	0.8	0.18	25.39	356	7.66	5.84	3.03
WEK2 fall	36.6	1.0	0.12	22.69	353	7.06	4.80	2.13

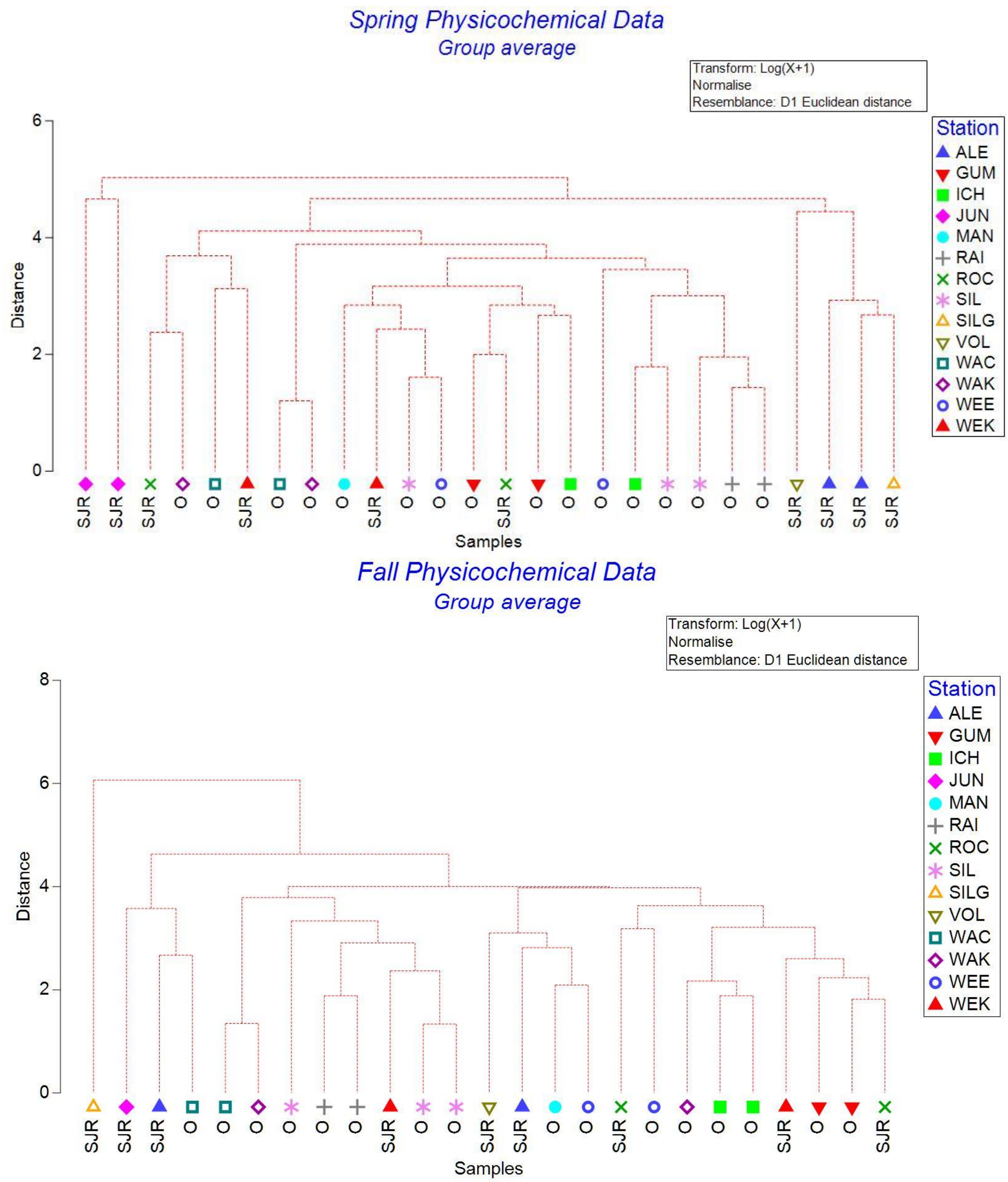


Figure 3. Cluster analysis of the physicochemical data at the spring-run stream transects. Each symbol is an individual transect on a stream. No significant differences among clusters were detected. See Table 2 for definitions of site abbreviations. SJR=springs connected to the St. Johns River mainstem; O=springs not connected to the St. Johns River.

on the spring physicochemical data, showed that downstream sites had higher DO, water temperature, turbidity, current velocity, pH and conductivity with an average 19.30% dissimilarity between upstream and downstream sites.

MACROINVERTEBRATE DATA

Macroinvertebrate communities were sampled in two types of habitats in the 14 spring-run streams (Figure 4); macrophyte habitat refers to areas dominated by rooted vascular plants (Figure 4A), macroalgal habitat refers to sampled areas dominated by filamentous algal mats (Figure 4B). Two spring systems (VOL and MAN) did not support macrophyte habitat.

Benthic Invertebrates in Macrophyte Habitat

Overall Taxa Composition

A total of 230 macroinvertebrate taxa or "potential taxa" were collected in macrophyte habitat in both spring and fall 2015 (Table 4). The term "potential taxa" refers to those taxa identified to family level or higher; these may include taxa which have been identified to genus and species and/or may include other species not listed. A more detailed breakdown of which invertebrate taxa occurred at which transect in spring and fall separately is presented in Appendix C-Tables 1-4. Groups with the most taxa overall were Chironomidae (non-biting midges – 47 taxa), Trichoptera (caddisflies – 28 taxa), and Annelida (worms and leeches – 42 taxa). Transects fed by more "saline" springs (JUN2, SLG1) had estuarine invertebrates in the benthic community, such as the polychaete *Namalycastis* spp., the tubicolous amphipod *Grandidierella bonnieroides*, the isopods *Cyathura polita*, *Cassidinidea ovalis* and *Edotia triloba*, and the tanaids *Hargeria rapax* and an unidentified leptochelid. The St. Johns River in particular, is known for the phenomenon of "marine invasions" (McLane 1955; Odum 1953), including both fish and macroinvertebrates.

Taxa Richness

Spring 2015. Highest total taxa richness (total number of taxa collected) in spring (Tables 1 and 2 in Appendix C) was seen at JUN2 (downstream Juniper Creek – 64 taxa), ROC2 (downstream Rock Springs Run – 58 taxa), WAC1 (upstream Wacissa River – 54 taxa), and WEE1 (upstream Weeki Wachee River – 50 taxa). Summary statistics (mean, standard deviation, etc.) for taxa richness are presented in Appendix E.

Mean taxa richness (mean of the 3 replicate samples) generally mirrored total taxa richness (Figure 5); transects with highest mean richness ($\geq$30) included JUN2, WAC1, and WEE2. Most transects had mean taxa richness between 20-30 (Figure 5). Cluster analysis using the taxa richness data found no significant groupings of transects. ANOSIM analysis showed significant differences in taxa richness in the spring between transects on SJR springs, those on the mainstem of the St. Johns River, and transects on non-SJR springs ("O"), those not connected to the St. Johns River, including Silver Springs/River ($R=0.284$; $P_{perm}=0.008$). SIMPER analysis showed the non-SJR transects had higher taxa richness than SJR transects.

A.

B.

Figure 4. Photographs of A) macrophyte habitat, and B) macroalgal habitat.

Table 4. Master list of macroinvertebrate taxa collected in macrophyte habitat. Spring and fall collections combined.

PLATYHELMINTHES
Unidentified flatworm taxa

NEMERTEA
Prostoma spp.

NEMATODA
Unidentified nematode taxa

MOLLUSCA

Gastropoda
Amnicola spp.
Laevapex fuscus
Melanoides tuberculata
Melanoides spp.
Menetus floridensis
Notogillia wetherbyi
Physella cubensis
Planorbella scalaris
Planorbella spp.
Pleurocera floridensis
Pomacea paludosa
Tarebia granifera
Viviparus georgianus
Unidentified Ancylidae spp.
Unidentified Hydrobiidae spp.
Unidentified gastropod taxa

Bivalvia
Corbicula fluminea
Elliptio spp.
Musculium spp.
Pisidium spp.
Sphaerium spp.
Utterbackia imbecillus
Unidentified Sphaeriidae spp.

ANNELIDA

Oligochaeta
Aulodrilus paucichaeta
Aulodrilus pigueti
Bratislavia unidentata
Dero digitata
Dero flabelliger
Dero nivea
Dero pectinate
Dero spp.
Eclipidrilus palustris
Eclipidrilus spp.
Haber speciosus
Ilyodrilus templetoni
Limnodrilus hoffmeisteri
Lumbriculus cf. *variegatus*
Nais communis
Nais pardalis
Nais pseudobtusa
Pristina aequiseta
Pristina leidyi
Psammoryctides convolutus
Quistadrilus multisetosus
Sparganophilus pearsei
Sparganophilus spp.
Varichaetadrilus angustipenis
Unidentified Enchytraeidae spp.
Unidentified Lumbriculidae spp.
Unidentified Naididae spp.
Unidentified Naidinae spp.
Unidentified Tubificinae spp.
Unidentified Oligochaeta spp.

Polychaeta
Namalycastis spp.

Hirudinea
Alboglossiphonia heteroclita
Erpobdella punctata
Erpobdella tetragon
Erpobdella spp.
Helobdella elongata
Helobdella papillate
Helobdella stagnalis
Placobdella phalera
Placobdella spp.
Unidentified Glossiphoniidae spp.
Unidentified Hirudinida spp.

ARTHROPODA

Chelicerata - Acarina
Arrenurus spp.
Atractides spp.
Clathrosperchon spp.
Geayia spp.
Hydrodroma spp.
Hygrobates spp.
Lebertia spp.
Limnesia spp.
Mideopsis spp.
Neumania spp.
Piona spp.
Sperchon spp.

Table 4. Continued.

Acarina-continued
Sperchonopsis spp.
Unidentified Limnesiidae spp.
Unidentified Acariformes taxa
Unidentified Oribatida spp.
Unidentified Trombidiformes spp.

Crustacea - Amphipoda
Gammarus spp.
Grandidierella bonnieroides
Hyalella azteca group spp.
Unidentified Gammaridea spp.

Crustacea - Isopoda
Caecidotea spp.
Cassidinidea ovalis
Cyathura polita
Edotia triloba
Sphaeroma spp.
Unidentified Isopod taxa

Crustacea – Tanaidacea
Hargeria rapax
Unidentified Leptochellidae spp.

Crustacea - Mysidacea
Unidentified taxa

Crustacea - Decapoda
Palaemonetes spp.
Unidentified Cambaridae spp.

INSECTA
Collembola
Unidentified taxa

Odonata - Zygoptera
Argia spp.
Enallagma basidens
Enallagma coecum
Enallagma spp.
Hetaerina titia
Hetaerina spp.
Unidentified Coenagrionidae spp.

Odonata - Anisoptera
Aphylla williamsoni
Dromogomphus spinosus
Hagenius brevistylus
Libellula spp.
Macromia illinoensis georgina
Unidentified Gomphidae spp.

Ephemeroptera
Acentrella alachua
Baetis intercalaris
Caenis diminuta
Caenis spp.
Callibaetis floridanus
Hexagenia spp.
Maccaffertium exiguum
Procloeon spp.
Sparburus maculatus
Tricorythodes albilineatus
Unidentified Baetidae spp.
Unidentified Heptageniidae spp.
Unidentified Ephemeroptera taxa

Megaloptera
Corydalus cornutus

Lepidoptera
Elophila spp.
Paraponyx spp.
Petrophila santafealis
Unidentified Crambidae spp.
Unidentified Lepidoptera taxa

Trichoptera
Cernotina spp.
Cheumatopsyche spp.
Cyrnellus fraternus
Helicopsyche borealis
Hydropsyche rossi
Hydropsyche spp.
Hydroptila spp.
Macrostemum carolina
Mayatrichia ayama
Nectopsyche candida/exquisita
Nectopsyche tavara
Neotrichia spp.
Neureclipsis crepuscularis
Neureclipsis spp.
Nyctiophylax spp.
Ochrotrichia spp.
Oecetis avara
Oecetis sp. E
Oecetis spp.
Orthotrichia spp.
Oxyethira spp.
Triaenodes injustus
Triaenodes spp.
Unidentified Hydropsychidae spp.
Unidentified Hydroptilidae spp.
Unidentified Leptoceridae spp.

Table 4. Continued.

Trichoptera - continued
Unidentified Polycentropodidae spp.
Unidentified Trichoptera taxa

Hemiptera
Pelocoris spp.
Unidentified heteropteran taxa

Coleoptera
Dineutus spp.
Donacia spp.
Dubiraphia spp.
Gyrinus spp.
Microcylloepus pusillus
Stenelmis spp.
Unidentified Elmidae spp.

Diptera – Ceratopogonidae
Unidentified Ceratopogonidae spp.

Diptera – Empididae
Hemerodromia spp.
Unidentified Empididae spp.

Diptera – Ephydridae
Hydrellia spp.
Unidentified Ephydridae spp.

Diptera – Simuliidae
Simulium spp.
Unidentified Simuliidae spp.

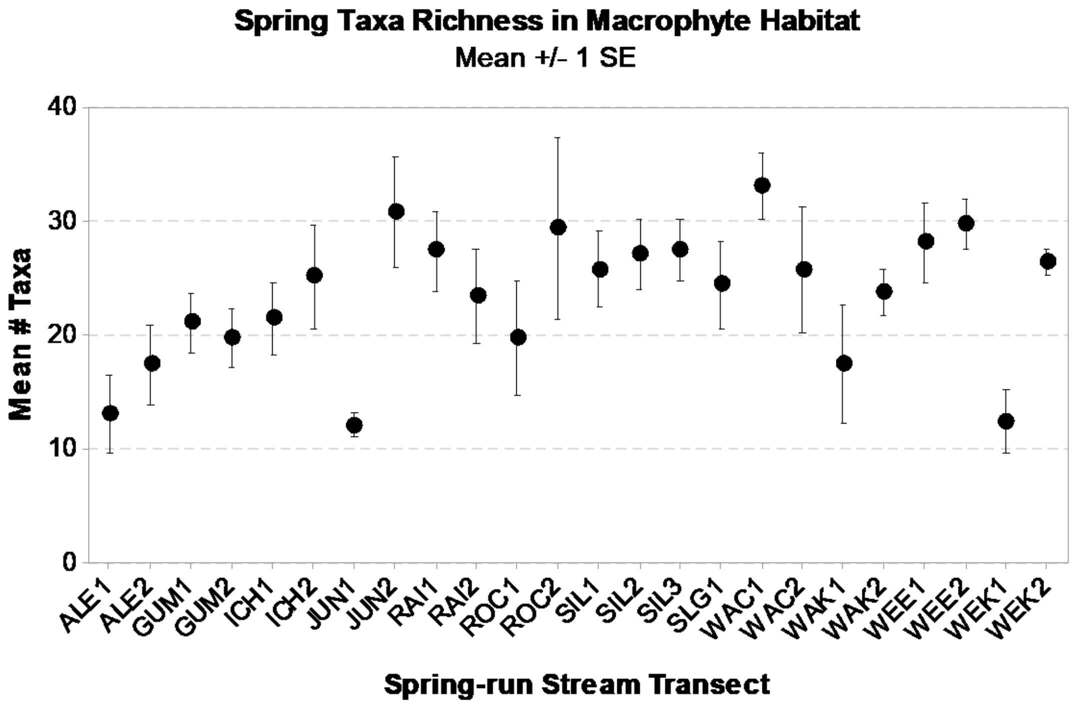
Diptera – Tipulidae
Unidentified Tipulidae spp.

Diptera - Phoridae
Unidentified Phoridae spp.

Diptera - Tanyderidae
Unidentified Tanyderidae spp.

Diptera - Chironomidae
Ablabesmyia mallochi
Ablabesmyia ramphe group
Beardius truncatus
Beardius spp.
Chironomus spp.
Cladopelma spp.
Cladotanytarsus spp.
Clinotanypus spp.
Cricotopus/Orthocladius spp.
Cricotopus spp.

Chironomidae – continued
Cryptochironomus spp.
Cryptotendipes spp.
Dicrotendipes modestus
Dicrotendipes neomodestus
Dicrotendipes spp.
Epoicocladius spp.
Glyptotendipes spp.
Labrundinia spp.
Larsia spp.
Nanocladius spp.
Parachironomus spp.
Paracladopelma spp.
Paralauterborniella nigrohalteralis
Paralauterborniella spp.
Paratanytarsus spp.
Pentaneura inconspicua
Polypedilum convictum
Polypedilum halterale group
Polypedilum illinoense group
Polypedilum scalaenum group
Procladius spp.
Pseudochironomus spp.
Rheotanytarsus spp.
Stenochironomus spp.
Tanypus punctipennis
Tanypus spp.
Tanytarsus buckleyi
Tanytarsus spp.
Thienemanniella similis
Thienemanniella xena
Thienemanniella spp.
Thienemannimyia group spp.
Tribelos fuscicorne
Unidentified Tanytarsini spp.
Unidentified Tanypodinae spp.
Unidentified Chironomidae taxa
Unidentified Diptera taxa



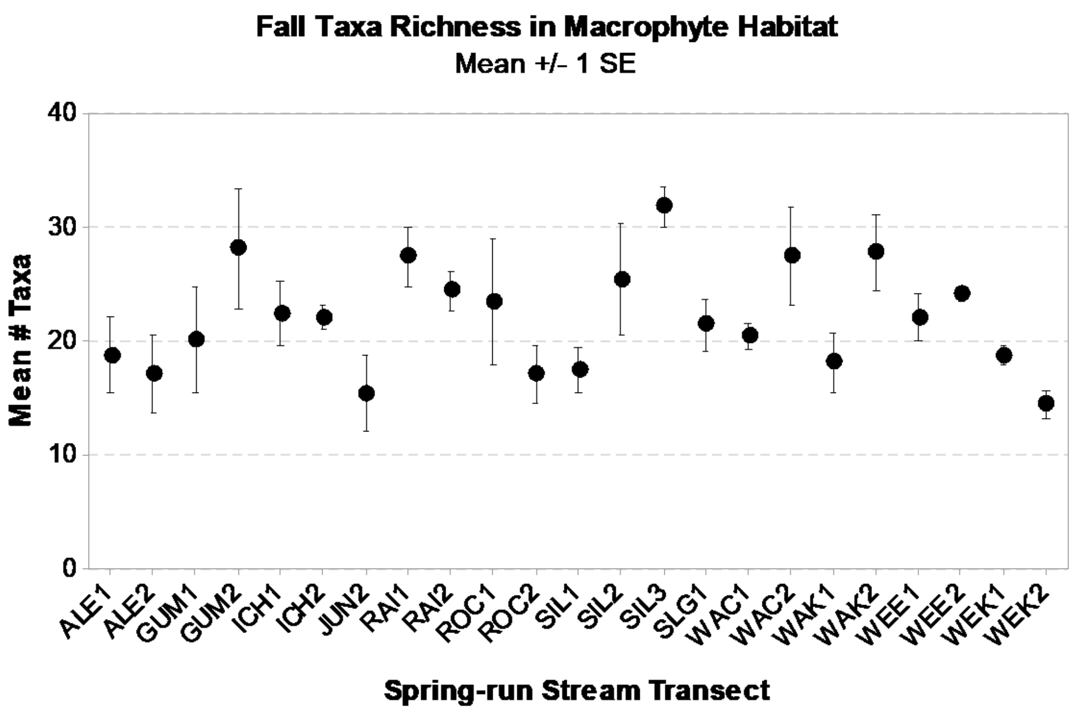


Figure 5. Mean invertebrate taxa richness (± 1 standard error) in macrophyte habitat in the spring and fall 2015. See Table 2 for definitions of site abbreviations.

Fall 2015. Highest total taxa richness in fall (Tables 3 and 4 in Appendix C) was seen at SIL3 (downstream Silver River – 54 taxa), WAC2 (downstream Wacissa River – 48 taxa), and GUM2 (downstream Gum Slough – 47 taxa). Summary statistics for fall taxa richness are presented in Appendix E.

As in the spring, mean taxa richness in fall generally mirrored total taxa richness (Figure 5); the transect with highest mean taxa richness ($\geq$30) was SIL3. WAC2 and GUM2 also had among the highest mean taxa richness. Most transects had mean taxa richness between 20-30 in the fall (Figure 5). Cluster analysis using the taxa richness data found no significant groupings of transects based on taxa richness in fall. ANOSIM analysis showed no significant differences in taxa richness among transects in fall (R=0.07; P_{perm}=0.19).

Diversity

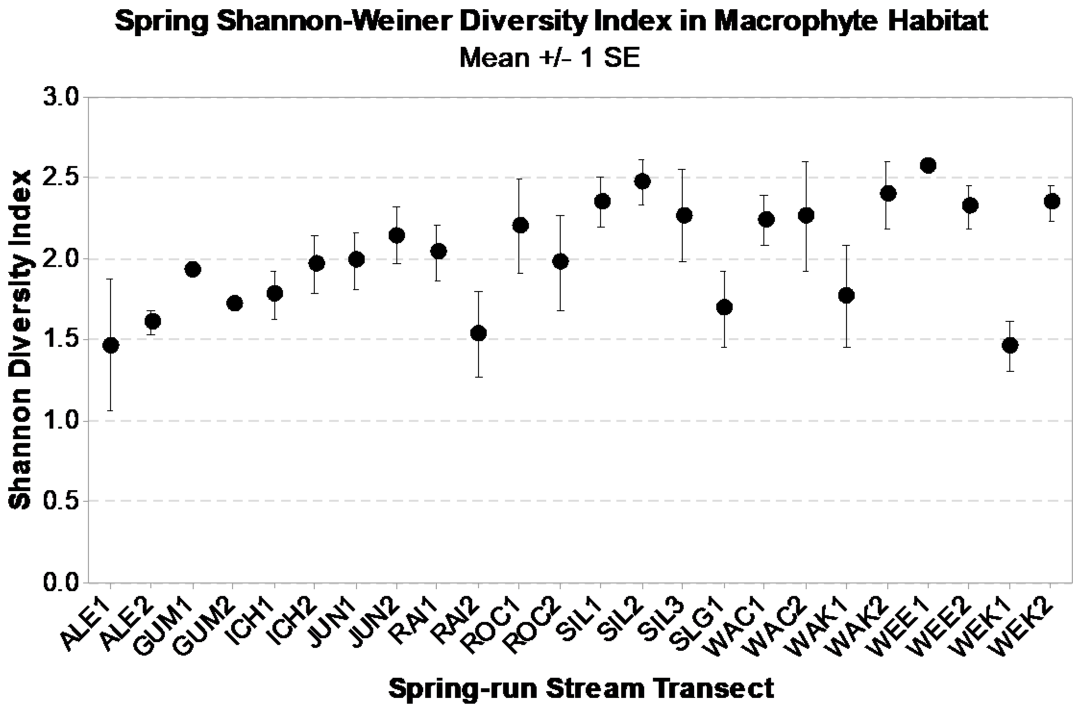
Species diversity was measured using two measures, H'- the Shannon-Weiner Diversity Index (Shannon Index for brevity) and (d) - Margalef's Species Richness Index (Margalef's Index). The Shannon Index is derived from information theory and considers both taxa richness and the relative abundance of the taxa in a sample in determining its diversity. Margalef's Index takes the species richness of a sample and divides by the natural log of the number of individuals in the sample. This index is an effort to compensate for the fact that larger samples tend to have higher species richness (and, typically, higher diversity). Summary statistics for both measures of diversity are in Appendix E.

Spring 2015. Highest diversity in spring as measured by the Shannon Index (generally $\geq$2.5) was seen at transects SIL2 and WEE1 (Figure 6). About half of the transects in spring (13) had a Shannon Index of 2 to <2.5. Ten transects had a Shannon Index of 1.5 to <2 (Figure 6). The Margalef's Index was different (Figure 7), with highest index values (>4) seen at JUN2, ROC2, SIL3, WAC1, WAK2, WEE2, and WEK2 (Figure 7). The diversity index data were not analyzed using the PRIMER software.

Fall 2015. Highest diversity in the fall as measured by the Shannon Index (>2.5) was seen at SIL3 (Figure 6). Again, about half of the transects (13) had a Shannon Index of 2 to <2.5, and 9 transects had a Shannon Index of 1.5 to <2, but in many cases, these were not the same transects as in the spring (Figure 6). Margalef's Index values displayed similar patterns. Five transects had a Margalef's Index generally $\geq$ 4 (Figure 7), but two of these were not the same as those with this value in the spring (GUM2 and ROC1), while three were the same (SIL3, WAK2 and WEE2).

Abundance and Density

Across both seasons, of the top 25 most abundant taxa (based on total number of individuals collected), most of these (10) were chironomid midges (Table 5). The single most abundant taxon was the trichopteran *Hydroptila* spp., and five of the top 25 most abundant taxa were trichopterans. Amphipods in the *Hyalella azteca* group were the second most abundant taxon,



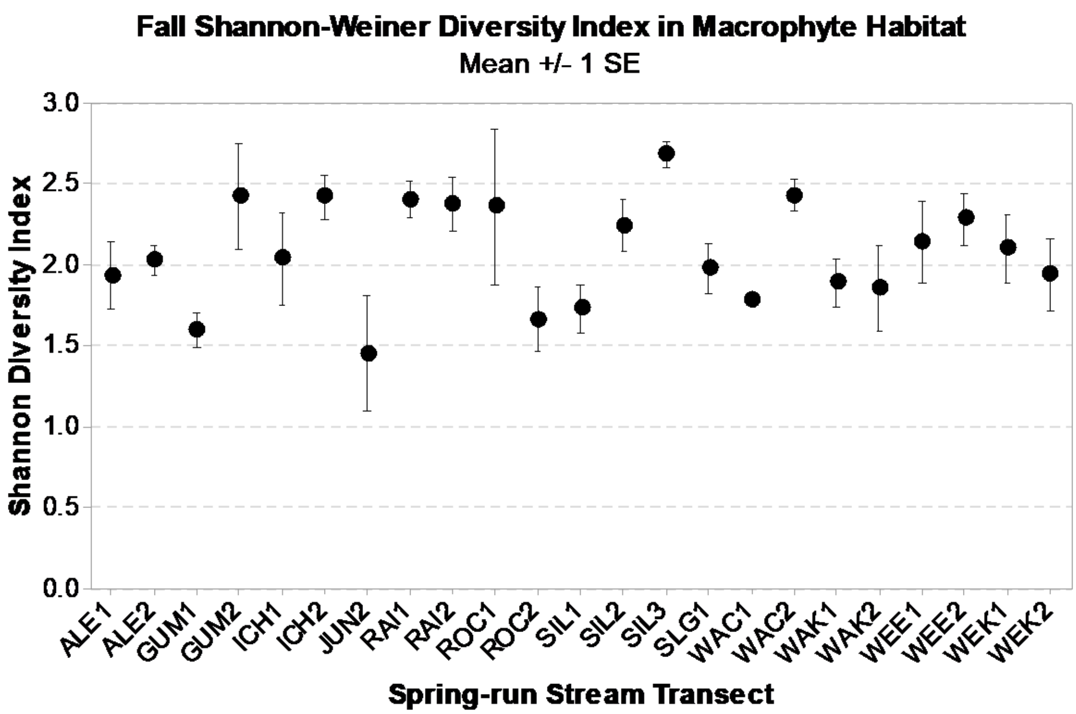
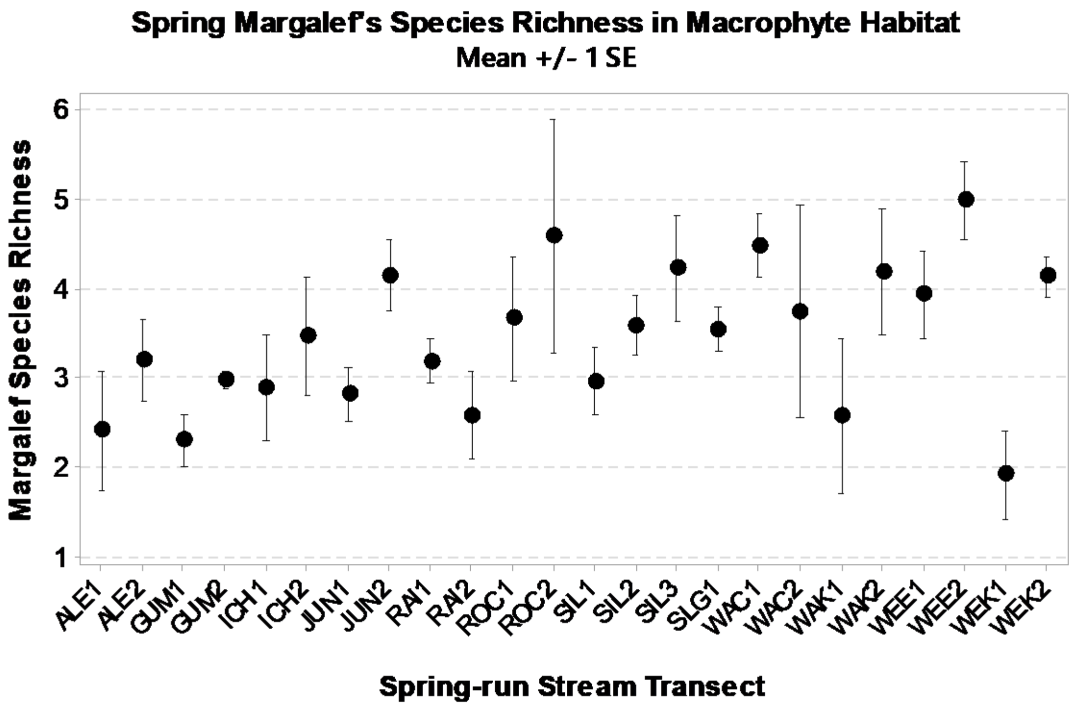


Figure 6. Mean Shannon-Weiner Diversity Index values (± 1 standard error) in macrophyte habitat in spring and fall 2015.



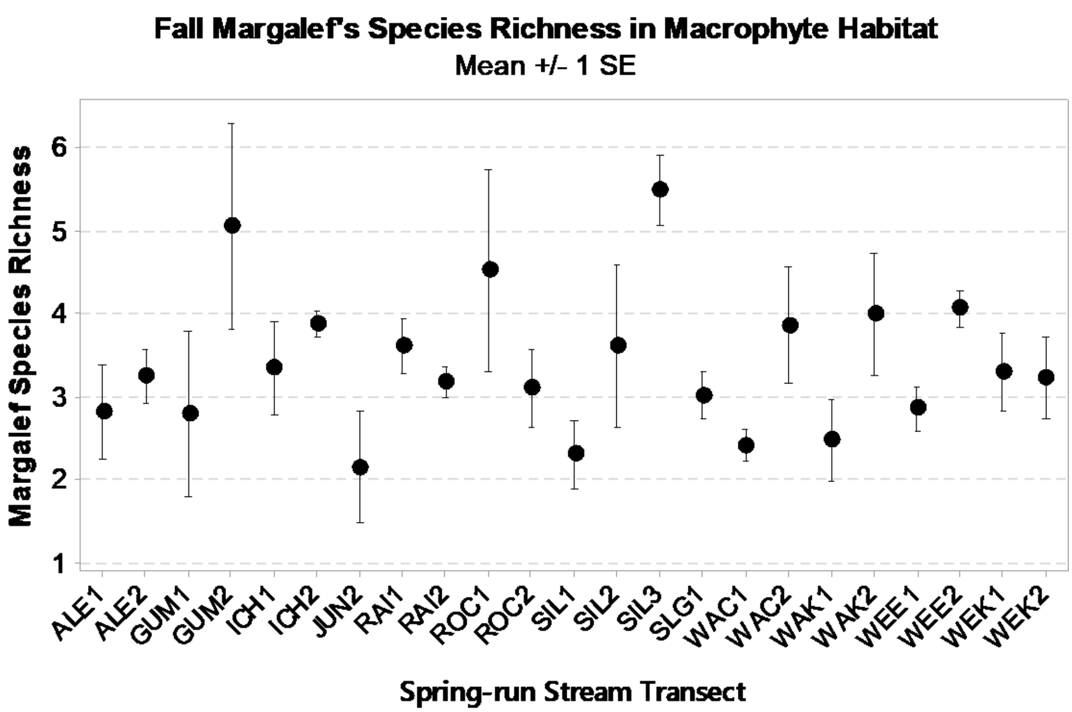


Figure 7. Mean Margalef's Species Richness Index values (+ 1 standard error) in macrophyte habitat in spring and fall 2015.

Table 5. List of the top 25 most abundant taxa in macrophyte habitat. Data are for all transects combined in both spring and fall seasons in 2015.

Taxon	Major group	Total abundance
Hydroptila spp.	Trichoptera (caddisfly)	33,470
Hyalella azteca group spp.	Amphipoda (scud crustacean)	32,837
Cricotopus/Orthocladius spp.	Chironomidae (midge)	15,391
Rheotanytarsus spp.	Chironomidae (midge)	10,317
Dicrotendipes modestus	Chironomidae (midge)	8,278
Petrophila santafealis	Lepidoptera (moth)	8,078
Pseudochironomus spp.	Chironomidae (midge)	7,695
Dicrotendipes spp.	Chironomidae (midge)	6,209
Hydroptilidae spp.	Trichoptera (caddisfly)	5,261
Hydropsyche rossi	Trichoptera (caddisfly)	4,192
Leptocheliidae spp.	Tanaidacea (tanaid crustacean)	3,756
Tubificinae spp.	Oligochaeta (worm)	3,593
Simulium spp.	Simuliidae (blackfly)	3,413
Hydrobiidae spp.	Gastropoda (silt snails)	3,362
Cheumatopsyche spp.	Trichoptera (caddisfly)	3,361
Hemerodromia spp.	Diptera (Empidid fly)	3,080
Polypedilum convictum	Chironomidae (midge)	2,471
Tanytarsus buckleyi	Chironomidae (midge)	2,267
Tricorythodes albilineatus	Ephemeroptera (mayfly)	2,255
Oxyethira spp.	Trichoptera (caddisfly)	1,838
Gammarus spp.	Amphipoda (scud crustacean)	1,649
Tanytarsus spp.	Chironomidae (midge)	1,496
Chironomidae spp.	Chironomidae (midge)	1,429
Nais pardalis	Oligochaeta (worm)	1,089
Thienemannimyia grp. spp.	Chironomidae (midge)	982

and the remaining three top five were chironomid midges, *Cricotopus/Orthocladius* spp., *Rheotanytarsus* spp., and *Dicrotendipes modestus*. In spring-run streams, molluscs and crustaceans tend to be better-represented, in terms of taxa richness and relative abundance, compared to Florida streams fed more by surface water runoff. That is seen here, in that there are three crustaceans (the amphipods *Hyalella* and *Gammarus* and tanaids in the family Leptocheliidae) and a gastropod (unidentified snails in the family Hydrobiidae) among the top 25 most abundant taxa. Summary statistics for abundance are presented in Appendix E.

Spring 2015. Macroinvertebrate abundance was measured as density in two ways; number of individuals per m^2 of sampled area (based on the area sampled by the Hess sampler) and number of individuals per g of plant biomass (the plant dry weight collected in the Hess sample).

Highest mean macroinvertebrate density in spring as # individuals/m^2 (>60,000/m^2) was seen at transects GUM1, RAI1, RAI2, and SIL1 (Figure 8). Many transects (13) had mean densities <20,000/m^2. Seven transects had moderate densities of >20,000 to <40,000/m^2 (Figure 8). Some similarity was seen expressing density as mean # individuals/g plant biomass as dry weight (Figure 9); highest mean density (>500/g plant biomass) was seen at GUM1 and RAI2. Most of the other transects were <200/g plant biomass (Figure 9).

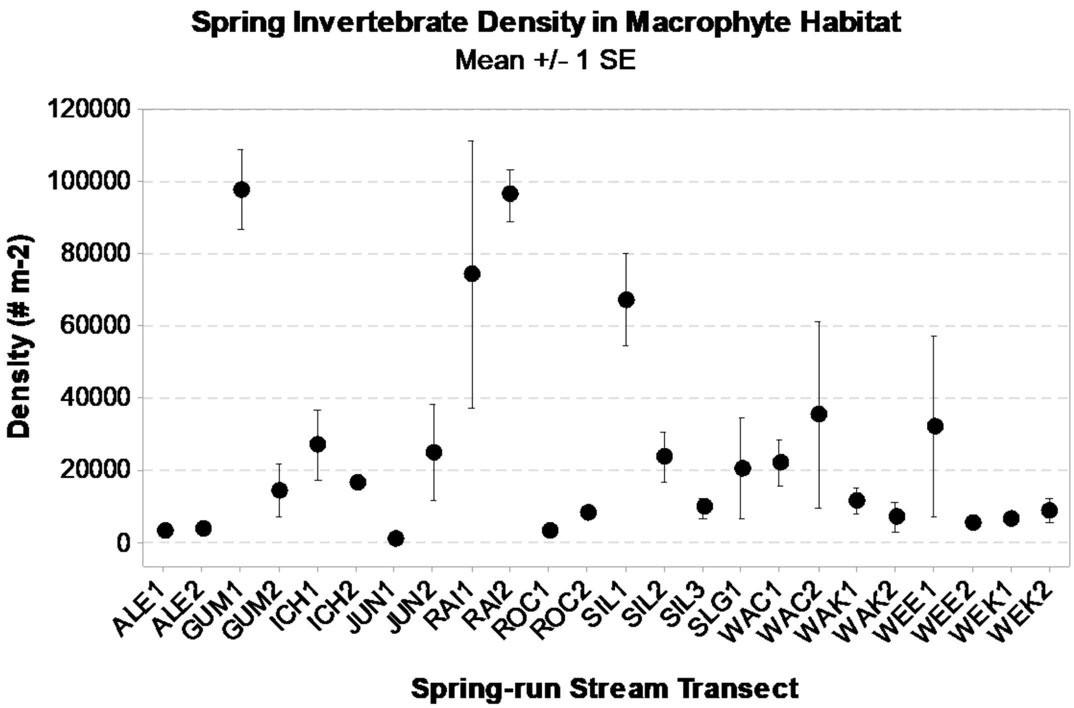
Cluster analysis of the raw abundance (counts) showed a number of significantly different clusters in spring (Figure 10). Most "O" (non-SJR) sites grouped together, with SJR sites as outlying clusters. Differences in taxa composition were complex. ANOSIM results showed that there were significant differences in SJR versus non-SJR streams based on density (R=0.466; P_{perm}=0.001). SIMPER analysis showed that differences between SJR and non-SJR spring-run streams were due to the latter being more dominated by the aquatic lepidopteran *Petrophila santafealis*, the midge *Rheotanytarsus* spp, the trichopteran *Hydroptila* spp and amphipods in the *Hyalella azteca* group, but differences in taxa composition among the transects overall was complex and did not exhibit clear patterns (Appendix C).

<u>*Fall 2015*</u>. Highest mean macroinvertebrate density in fall as # individuals/m^2 (>40,000/m^2) was seen at only one transect, WAC1 (Figure 8). All other transects had mean densities <40,000/m^2 and most of those (14) had mean density <20,000/m^2 (Figure 8). Mean density expressed as # individuals/g plant biomass showed a generally similar relationships among the transects in fall (Figure 9), with only one transect (GUM1) exhibiting highest density (>300/g plant biomass). All other transects had mean densities of <200/g plant biomass (Figure 9).

Cluster analysis of the fall abundance data showed four significantly different clusters (Figure 10), based on the distinction between SJR versus non-SJR springs. ANOSIM indicated significant differences among transects based on density (R=0.482; P_{perm}=0.001). Similar to the spring, SIMPER analysis showed that the density differences were due to higher relative abundance of *P. santafealis*, *Rheotanytarsus* spp., *H. azteca* group and *Hydroptila* spp. in the non-SJR springs, although in both spring and fall, species compositional differences were complex and no really clear patterns were evident from the analysis.

<u>Seasonal and Spatial Differences in Invertebrates of Macrophyte Habitat</u>

Because of the relatively stable physical-chemical conditions in springs over time (mainly spring flow and water quality), it has been generally thought that seasonal variation in spring biota and natural communities is likewise minimal (Odum 1957b; Knight and Notestein 2008). This may still be an open question due to the general lack of long-term biological data collection in springs, but the data which exist do indicate that there is some seasonal variation, likely due to seasonal changes in solar energy input, corresponding changes in primary production, the life histories of aquatic biota (particularly macroinvertebrates), and seasonal migration patterns of larger fauna such as fish, birds, and mammals.



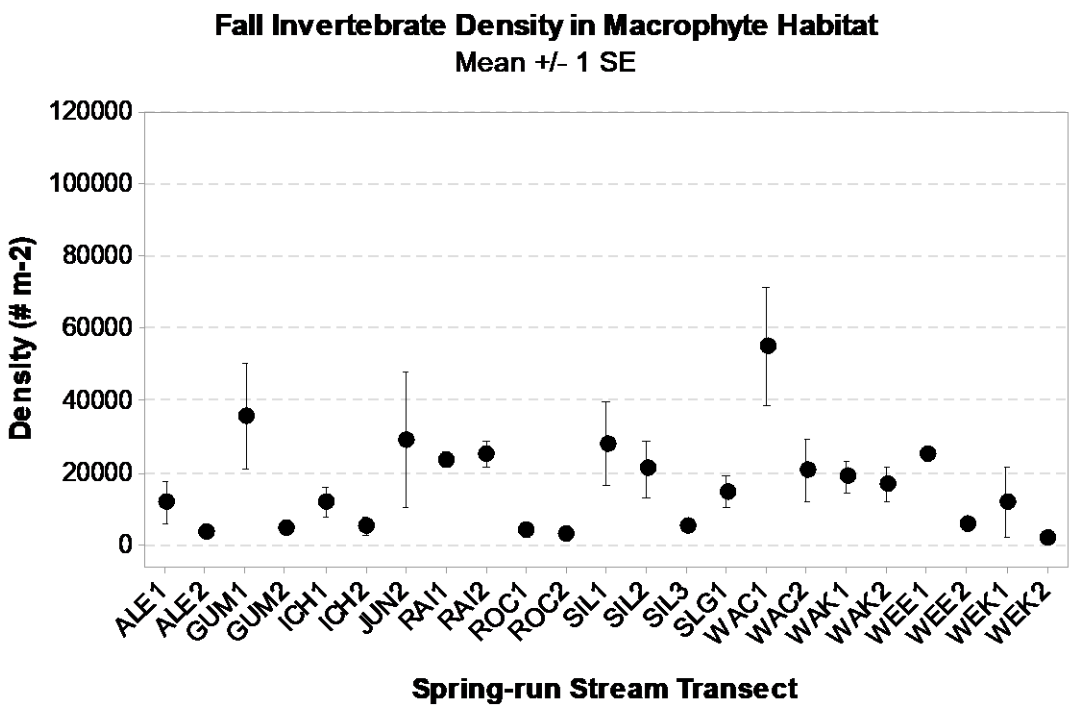
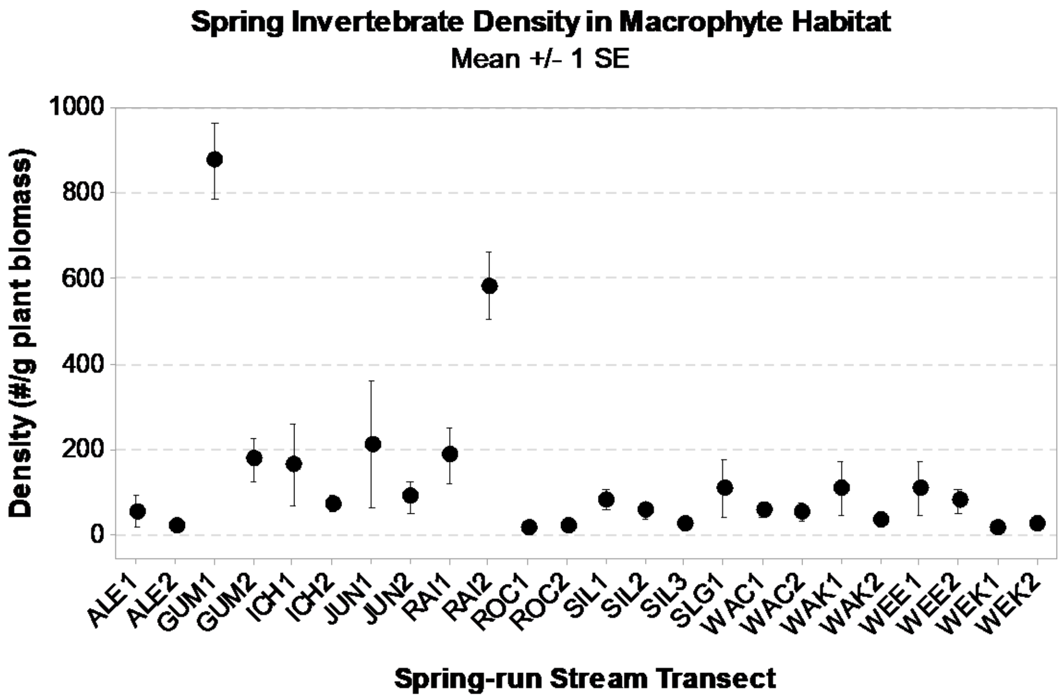


Figure 8. Mean macroinvertebrate density ($\pm$ 1 standard error) at the transects in spring and fall 2015 expressed as number of individuals/m^2 (based on the area of the Hess sampler).



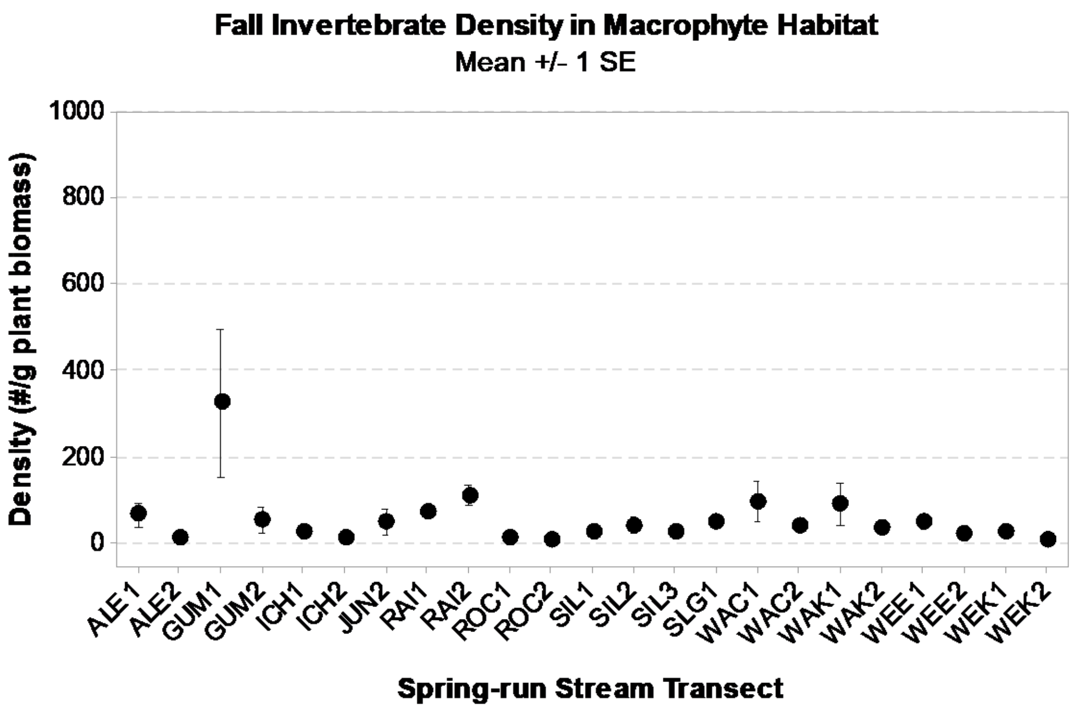


Figure 9. Mean macroinvertebrate density (± 1 standard error) at the transects in spring and fall 2015 expressed as number of individuals/g plant biomass (as dry weight).

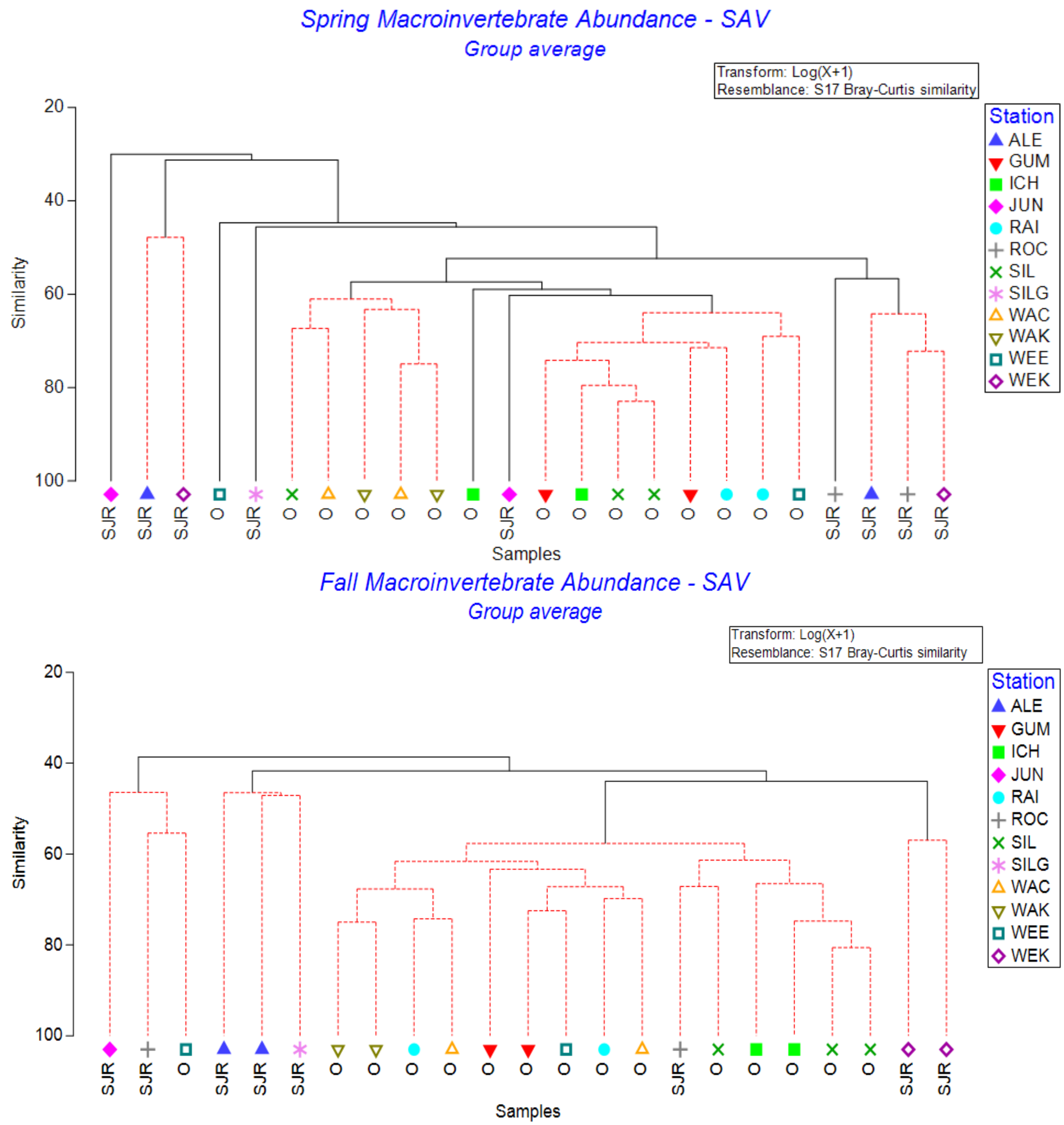


Figure 10. Cluster analysis results of macroinvertebrate abundance in macrophyte (=SAV) habitat. Solid line indicates statistically significant difference. SJR=springs connected to the St. Johns River mainstem; O=springs not connected to the St. Johns River.

A total of 197 taxa of macroinvertebrates were collected in spring and 171 taxa in fall in macrophyte habitat. In breaking up the taxa composition data by season (spring and fall), the same overall trends were seen as for overall taxa composition (Figure 11), with chironomids, trichopterans, and annelids generally comprising the largest proportions of the overall taxa richness. Annelids made up a slightly larger proportion of the macroinvertebrate community in the fall (Figure 11B), while the other major taxa were similar in terms of percent taxa composition.

Generally, total taxa richness in the fall was lower than or similar to that in spring at most transects (Figure 12 and Appendix C). There were a few exceptions, with a few transects exhibiting higher fall total taxa richness (e.g., GUM2, SIL3, and WEK1). Seasonal changes in mean taxa richness (Figure 5) and diversity (Figures 6 and 7) were not as clear or consistent. Generally, most or all transects had mean taxa richness between 10 and 30 taxa in both spring and fall (Figure 5), and both Shannon Diversity and Margalef's Index likewise remained within the same ranges at most or all transects in both spring and fall (Figures 6 and 7). There were changes at the individual transect level, for example mean taxa richness at GUM2 was higher in fall (28 taxa) than in spring (19.7 taxa), but in contrast mean taxa richness at JUN2 was considerably higher in spring (30.7 taxa) than in fall (15.3 taxa). Lack of overlap of the standard errors in both of these suggest these differences might be statistically significant.

Seasonal changes in mean density were somewhat clearer (Figures 8 and 9). Abundance as density for both # individuals/m^2 and # individuals/g plant biomass were generally lower in the fall than in the spring, although again, there were a few exceptions (e.g., WAC1 had higher abundance as #/m^2 in fall versus spring). Some systems exhibited little change in density between spring and fall (e.g., ROC1 and ROC2). Seasonal changes in macroinvertebrate taxa richness, diversity, and abundance could be driven in part by seasonal variation in primary production and also by life histories of individual taxa of invertebrates. This is an area which would benefit from additional study.

Spatial variability of macroinvertebrate community characteristics, both among and within spring-run streams, was relatively high, in many cases higher than seasonal variation. Taxa richness (Figure 5), diversity (Figures 6 and 7), and density (Figures 8 and 9) exhibited spatial variation and no distinct patterns were discerned, either by visual examination of the plots or by the multivariate analyses. The one pattern which was detected by the PRIMER analyses was a general difference in species composition based on abundance between SJR and non-SJR springs. Prior work (Sloan 1954) has shown that invertebrate taxa richness and abundance are lower at the headspring area versus downstream in the spring run proper, but that spatial pattern was not consistently seen in this study. In some instances, taxa richness, diversity, and/or abundance were higher at the downstream transect in a stream, but in other streams one or more of these characteristics were higher at the upstream transect. Low DO concentrations are generally thought to be responsible for these spatial patterns (Sloan 1954; Dormsjo 2008), and it may be that our upstream transects were located sufficiently downstream from the headsprings such that DO was not an issue, although some transects (ALE1, MAN1, WEE1) did exhibit low DO values (<3 mg/L; Table 3).

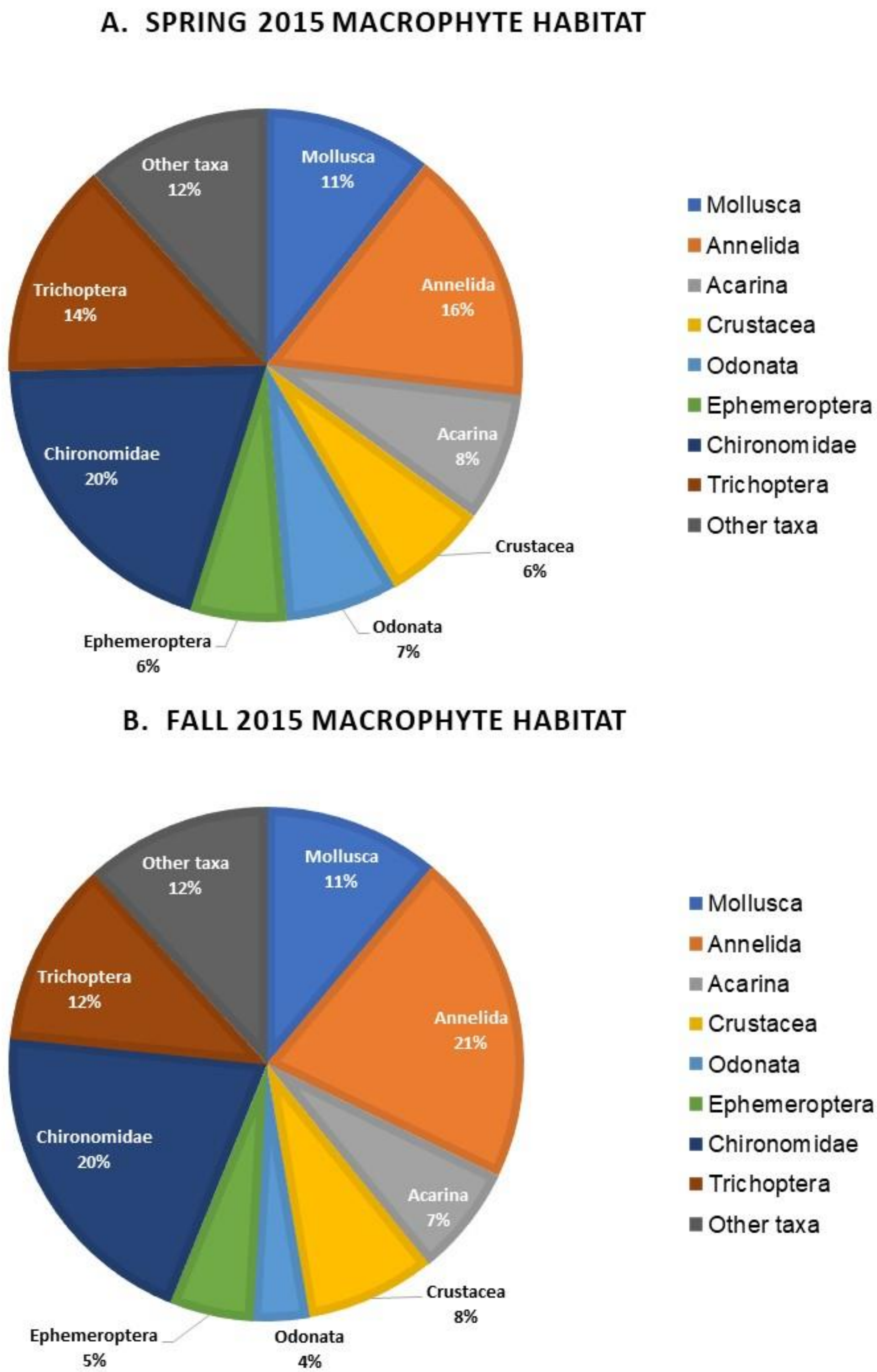
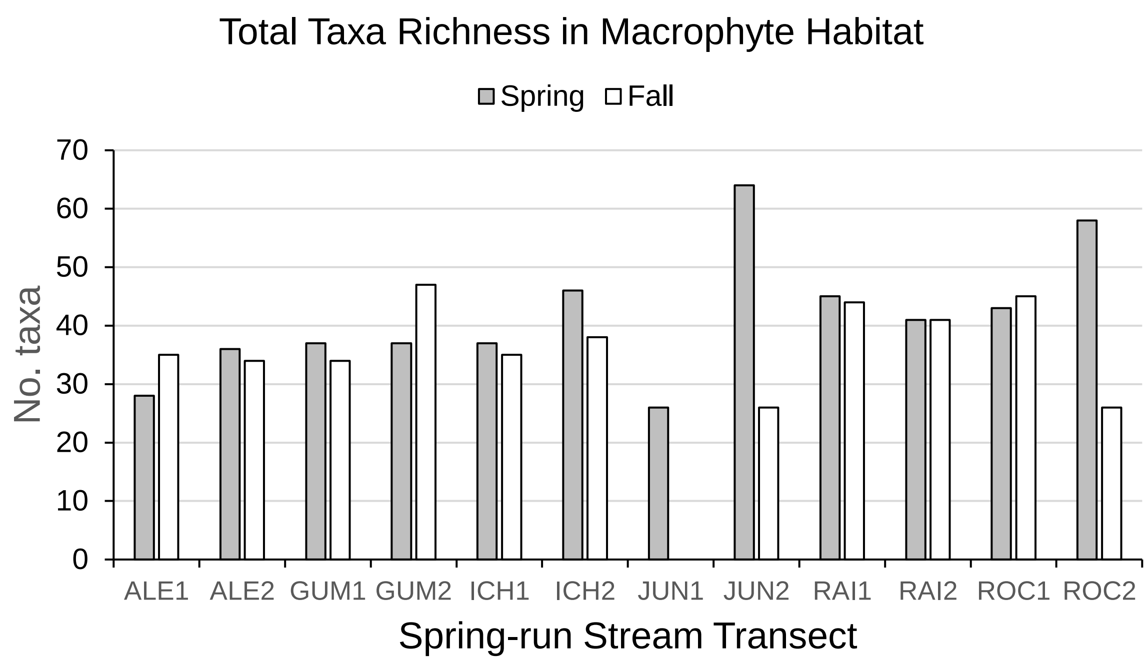


Figure 11. Pie charts of major taxa composition (as percent of the total taxa richness) in macrophyte habitat in A) spring, and B) fall. All transects combined.



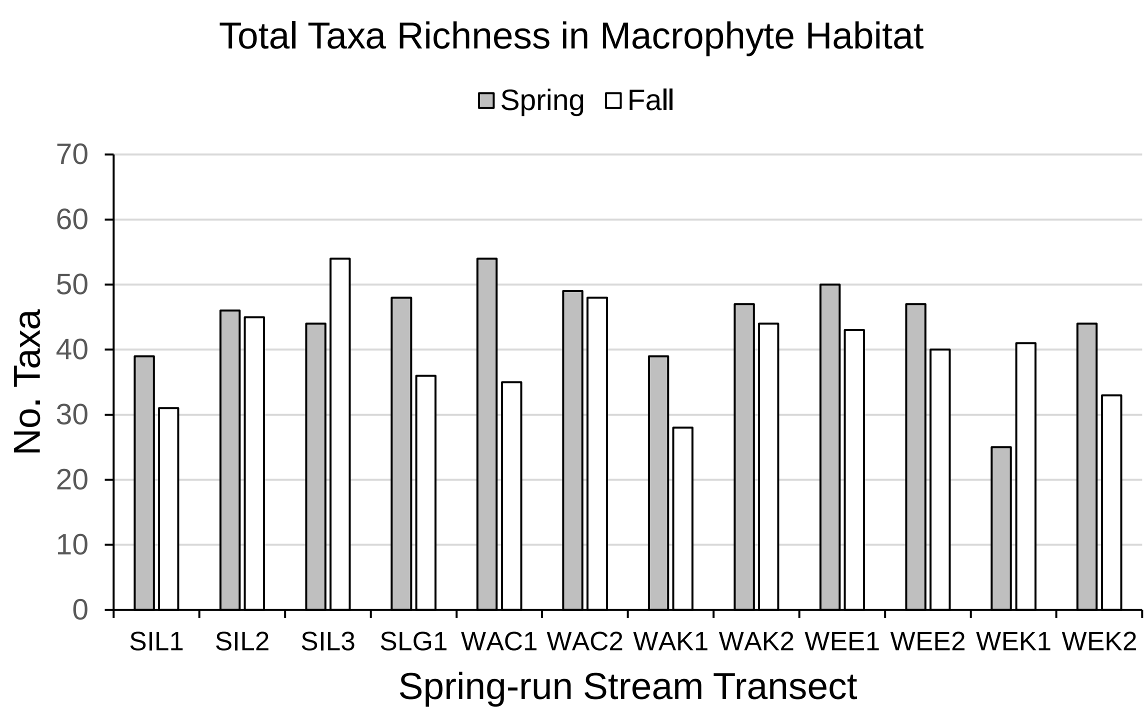


Figure 12. Seasonal differences in invertebrate total taxa richness in macrophyte habitat at all transects. JUN1 not sampled in fall.

Benthic Invertebrates in Macroalgal Habitat

Overall Taxa Composition

As noted earlier, “Macroalgal Habitat” refers to the mats of filamentous algal taxa and their attached epiphytes (Figure 4B). A total of 136 macroinvertebrate taxa or potential taxa were collected in macroalgal habitat (Table 6; spring and fall collections combined). A more detailed breakdown of which invertebrate taxa occurred at particular transects in spring and fall is presented in Appendix D. Some springs supported macroalgal mats only in spring (ALE1, ROC1, SLG1) and one spring only had macroalgal mats in fall (GUM1) As in the macrophyte habitat, groups with the largest number of taxa were chironomid midges (43 taxa), trichopterans (14 taxa) and annelids (worms and leeches – 20 taxa). Similar to the macrophyte habitats, the more saline springs (SLG1, ALE1) had estuarine taxa (*G. bonnieroides, C. polita*, *H. rapax*; Appendix D) in the invertebrate community of macroalgal habitat. Summary statistics for taxa richness in macroalgal habitat are presented in Appendix F.

Taxa Richness

Spring 2015. Highest total taxa richness in spring (Table 1 in Appendix D) was seen at WAK2 (43 taxa), SLG 1 (35 taxa) and WEE1 (33 taxa). Macroalgal habitat at most transects in spring supported 30 or less total taxa.

Mean taxa richness was similar to total taxa richness. Highest mean taxa richness in spring ($\geq$15) was seen at WAK2 and WEE1 Figure 13). Most transects had mean taxa richness <20 (Figure 13). Cluster and ANOSIM analyses showed no significant differences among transects based on taxa richness in macroalgal habitat. Overlap of standard errors at many of the transects (Figure 13) also suggests no significant differences in mean taxa richness among transects in the spring.

Fall 2015. Highest total taxa richness in fall (table 2 in Appendix D) was seen at WEE2 (33 taxa). All other transects in the fall had total taxa richness <30 (Table 2 in Appendix D). Seasonal differences in total taxa richness (spring versus fall) are compared and discussed further on in this section.

Mean taxa richness in the fall (Figure 13) was similar to total taxa richness. WEE2 had highest mean taxa richness (21.3). The transect with the second highest total taxa richness, RAI2 (29 taxa), also had the second highest mean taxa richness (16.7). As in the spring, most transects had mean taxa richness <20 (Figure 13). Cluster and ANOSIM analyses indicated no significant differences in taxa richness among transects in the fall.

Diversity

Invertebrate diversity in macroalgal habitat was evaluated using the Shannon-Weiner diversity index and Margalef’s Species Richness Index. Summary statistics for these are presented in Appendix F.

Table 6. Master list of macroinvertebrate taxa collected in macroalgal habitat. Spring and fall collections combined.

PLATYHELMINTHES

Unidentified flatworm taxa

MOLLUSCA

Gastropoda

Laevapex fuscus
Melanoides tuberculate
Melanoides spp.
Menetus floridensis
Notogillia wetherbyi
Physella cubensis
Planorbella scalaris
Planorbella trivolvis
Pleurocera floridensis
Pomacea paludosa
Pomacea spp.
Viviparus georgianus
Unidentified Hydrobiidae spp.
Unidentified gastropod taxa

Bivalvia

Corbicula fluminea
Unidentified Spaeriidae
Unidentified Unionidae spp.

ANNELIDA

Oligochaeta

Aulodrilus paucichaeta
Dero digitata
Eclipidrilus palustris
Ilyodrilus templetoni
Limnodrilus hoffmeisteri
Nais communis
Nais pardalis
Pristina leidyi
Quistadrilus multisetosus
Sparganophilus spp.
Unidentified Lumbriculidae spp.
Unidentified Tubificinae spp.

Hirudinea

Erpobdella punctata
Erpobdella tetragon
Erpobdella spp.
Helobdella elongata
Helobdella stagnalis
Helobdella spp.
Placobdella spp.
Unidentified Hirudinida spp.

ARTHROPODA

Chelicerata - Acarina

Arrenurus spp.
Atractides spp.
Frontipoda spp.
Geayia spp.
Hygrobates spp.
Lebertia spp.
Limnesia spp.
Unionicola spp.

Crustacea - Amphipoda

Gammarus spp.
Grandidierella bonnieroides
Hyalella azteca group spp.
Unidentified Gammaridea spp.

Crustacea - Isopoda

Caecidotea spp.
Cyathura polita

Crustacea – Tanaidacea

Hargeria rapax
Unidentified Leptocheliidae spp.

Crustacea - Mysidacea

Taphromysis bowmani

Crustacea - Decapoda

Palaemonetes spp.
Unidentified Cambaridae spp.

INSECTA

Odonata - Zygoptera

Argia spp.
Enallagma coecum

Odonata - Anisoptera

Dromogomphus spinosus
Epicordulia princeps regina
Libellula spp.
Macromia illinoiensis georgina
Unidentified Libellulidae spp.

Ephemeroptera

Caenis diminuta
Caenis spp.
Hexagenia spp.
Tricorythodes albilineatus

Table 6. Continued

Ephemeroptera-continued
Unidentified Baetidae spp.
Unidentified Ephemeroptera taxa

Coleoptera
Dineutus spp.
Dubiraphia spp.
Stenelmis spp.

Trichoptera
Cernotina spp.
Cheumatopsyche spp.
Helicopsyche borealis
Hydropsyche rossi
Hydropsyche spp.
Hydroptila spp.
Mayatrichia ayama
Nectopsyche candida/exquisita
Oecetis avara
Oecetis spp.
Oxyethira spp.
Triaenodes florida
Triaenodes spp.
Unidentified Hydroptilidae spp.

Lepidoptera
Paraponyx spp.
Petrophila santafealis

Hemiptera
Unidentified Heteroptera taxa

Diptera – Ceratopogonidae
Unidentified Ceratopogonidae spp.

Diptera - Empididae
Hemerodromia spp.
Unidentified Empididae spp.

Diptera - Chironomidae
Ablabesmyia mallochi
Ablabesmyia ramphe group
Apedilum spp.
Beardius spp.
Chironomus spp.
Cladotanytarsus spp.
Clinotanypus spp.
Coelotanypus spp.
Cricotopus/Orthocladius spp.
Cricotopus spp.
Cryptochironomus spp.
Cryptotendipes spp.
Dicrotendipes modestus
Dicrotendipes neomodestus
Dicrotendipes spp.
Epoicocladius spp.
Glyptotendipes spp.
Harnischia spp.
Labrundinia pilosella
Larsia spp.
Paralauterborniella nigrohalteralis
Paralauterborniella spp.
Paratanytarsus spp.
Pentaneura inconspicua
Pentaneura spp.
Polypedilum convictum
Polypedilum halterale group
Polypedilum illinoense group
Polypedilum scalaenum group
Procladius spp.
Pseudochironomus spp.
Rheotanytarsus spp.
Stempellinella fimbriata
Tanypus spp.
Tanytarsus buckleyi
Tanytarsus spp.
Thienemanniella xena
Thienemanniella spp.
Theinemannimyia group spp.
Unidentified Chironominae spp.
Unidentified Tanypodinae spp
Unidentified Chironomidae taxa
Unidentified Diptera taxa

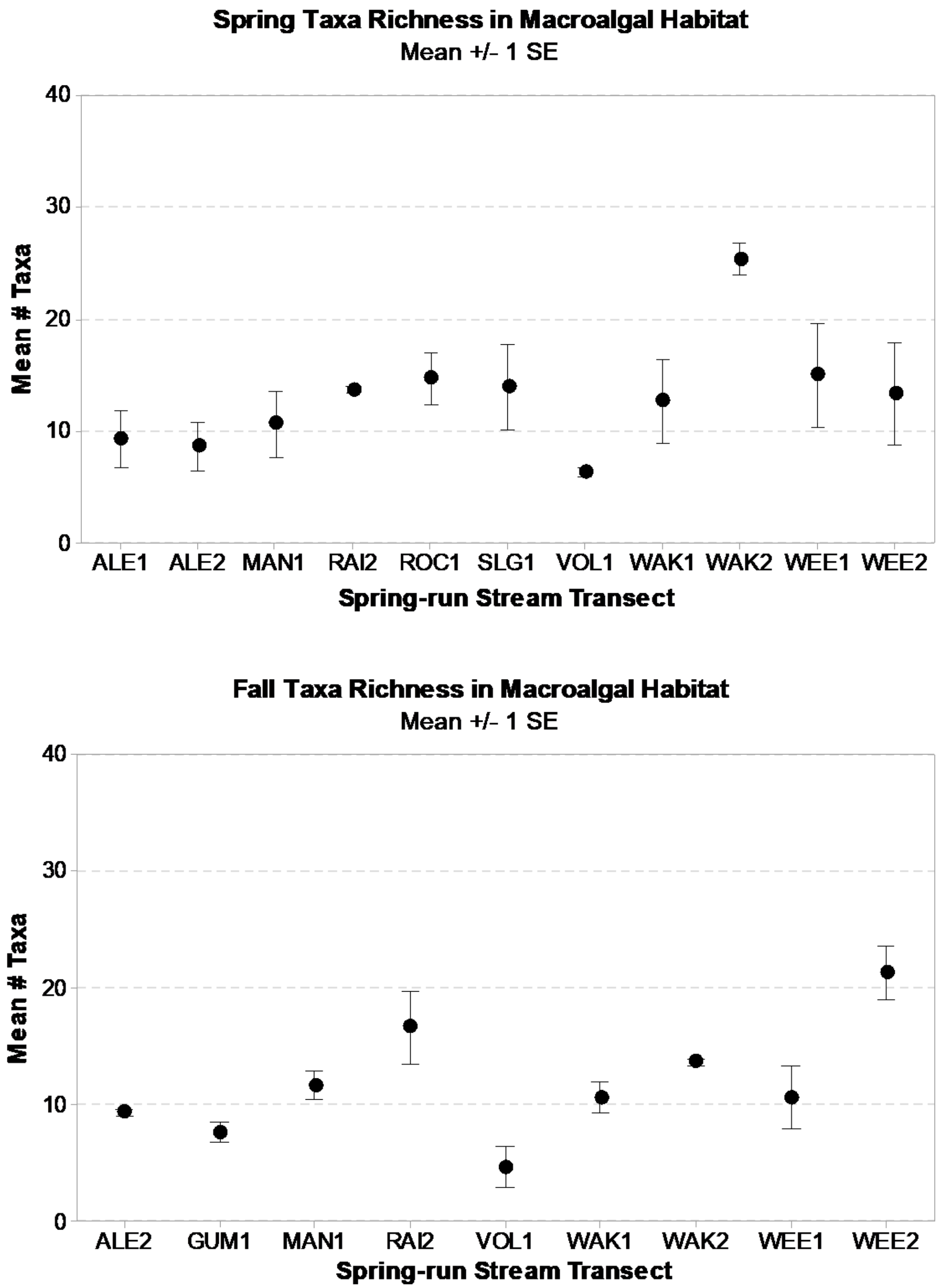


Figure 13. Mean invertebrate taxa richness (± 1 standard error) in macroalgal habitat in the spring and fall 2015. See Table 2 for definitions of site abbreviations.

Spring 2015. Highest mean Shannon Index in spring (>2.0) was seen at WAK2 (2.4; Figure 14). Most of the transects supporting macroalgal habitat in the spring (7 of 11) had mean Shannon diversity <1.5 (Figure 14). Mean Margalef's Index was also highest at WAK2 in the spring (4.2; Figure 15). All other transects in spring had mean Margalef's Index values <3 (Figure 15).

Fall 2015. Highest mean Shannon Index in the fall (1.6) was seen at WEE2 (Figure 14). All other transects in the fall had Shannon diversity <1.5. Mean Margalef's Index exhibited a similar pattern, with highest mean richness at WEE2 (3.5) and all other transects had mean Margalef's Index of <3 (Figure 15). Comparisons of seasonal differences (spring versus fall) in macroalgal habitat are made in a section below, as well as comparisons of macrophyte versus macroalgal habitat.

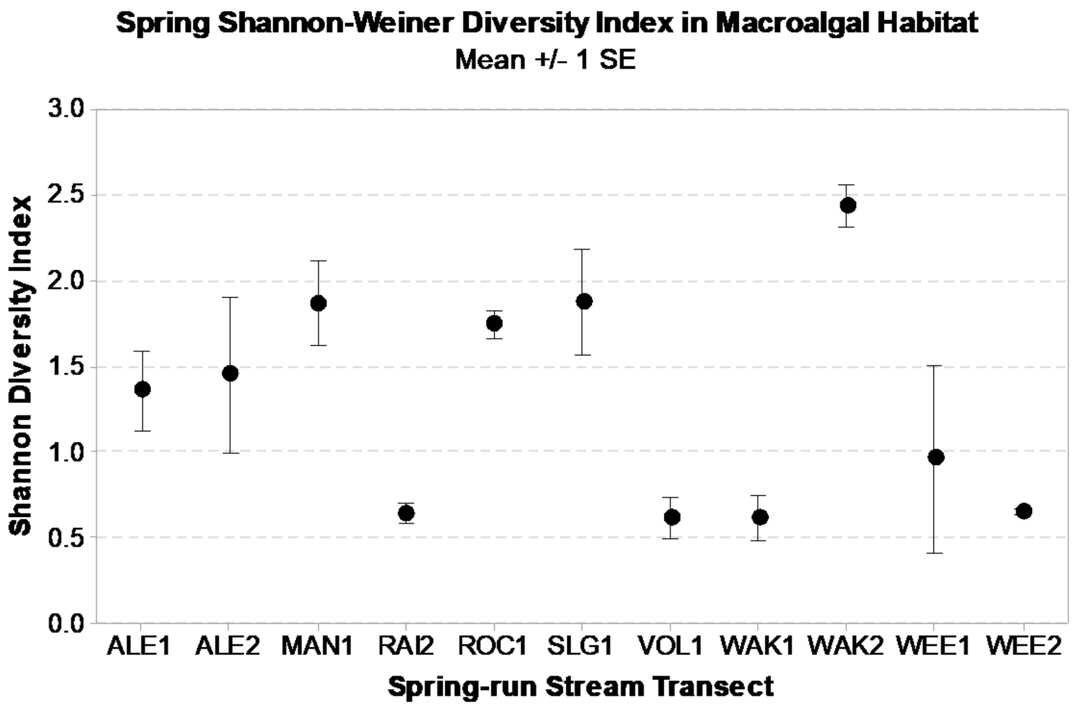
Abundance and Density

Of the top 25 most abundant taxa (collected over both seasons), amphipods in the *Hyalella azteca* sp. complex were by far most abundant (Table 7). Hydrobiid snails were the second most abundant taxon in macroalgal habitat. Nine of the 25 most abundant taxa were chironomids. In addition to hydrobiids, other molluscs included the clam *Corbicula fluminea* and gastropods *Pleurocera floridensis* and *Melanoides* spp. (Table 7). In addition to the *Hyalella* group, crustaceans in the top 25 included the amphipod *Gammarus* spp., the isopod *Caecidotea* spp., unidentified crayfish (Cambaridae) and the grass shrimp *Palaemonetes* spp.

Spring 2015. As with the macroinvertebrate community in macrophyte habitat, abundance was expressed as density as # individuals/m^2 (based on the area sampled by the Hess sampler), and as # individuals/g plant biomass. Highest mean density as #/m^2 (>20,000 individuals/ m^2) was seen at RAI2, VOL1, and WEE1 (Figure 16). Most transects had mean density <40,000/ m^2, but WEE1 had a very high mean density of 110,151/ m^2 in macroalgal habitat. Density expressed as per g plant biomass was typically much lower than when expressed as per m^2, most mean values were <4,000/g plant biomass (Figure 17). Highest density for this abundance measure was seen at WAK1 (1,650/g plant biomass) and WEE1 (2,610/g plant biomass). Summary statistics for density are presented in Appendix F.

Cluster analysis showed no statistically significant clusters, but St. Johns River (SJR) springs tended to cluster together based on both abundance measures. ANOSIM showed significant differences in community composition based on density as per m^2 ($R=0.355$; $P_{perm}=0.024$), and on per g plant biomass ($R=0.352$; $P_{perm}=0.015$). SIMPER analysis showed that the differences were mainly based on higher abundances of the amphipod *Hyalella* group, the mayfly *Tricorythodes albilineatus*, and the midge *Pseudochironomus* in non-SJR ("O") springs and higher abundance of the amphipod *Gammarus* spp. and hydrobiid snails in SJR springs.

Fall 2015. Highest mean density in fall (>20,000/m^2) was seen at transects GUM1 and WEE1 (Figure 16) and transect GUM1 (>1,000/g plant biomass; Figure 17).



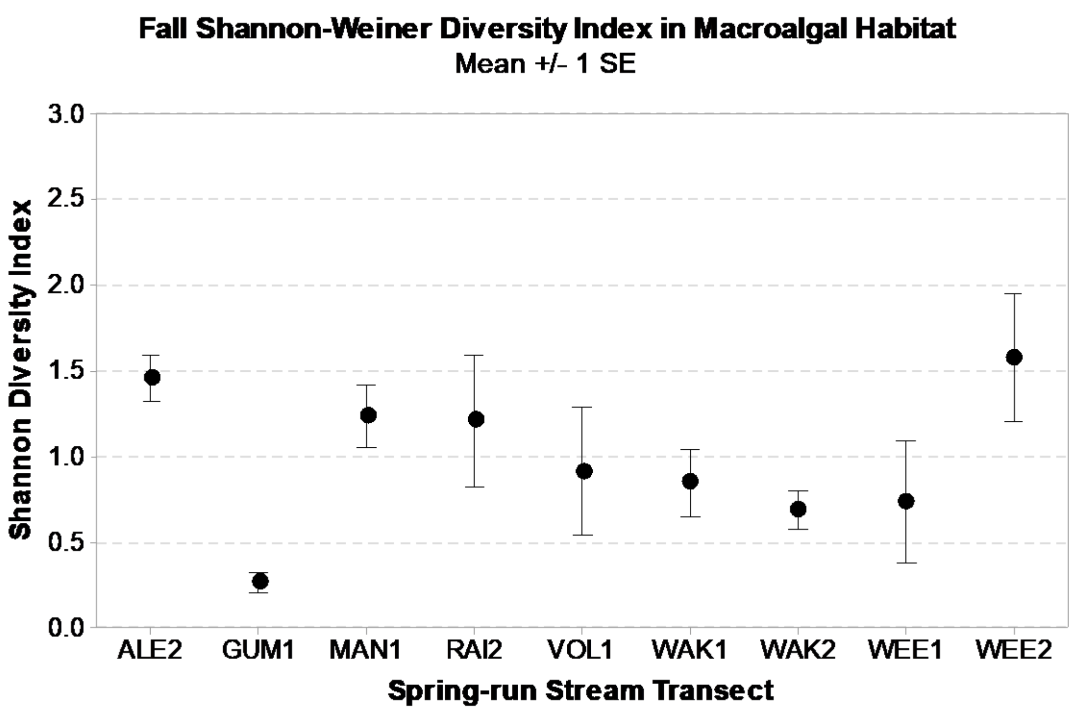
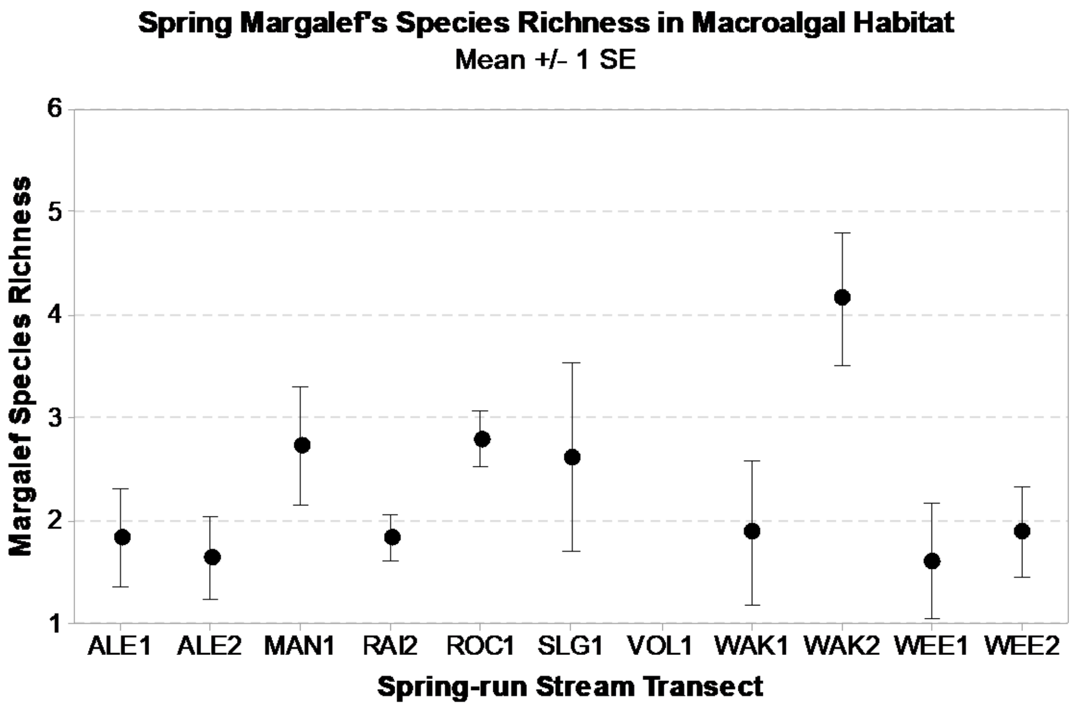


Figure 14. Mean Shannon-Weiner Diversity Index values (± 1 standard error) in macroalgal habitat in spring and fall 2015.



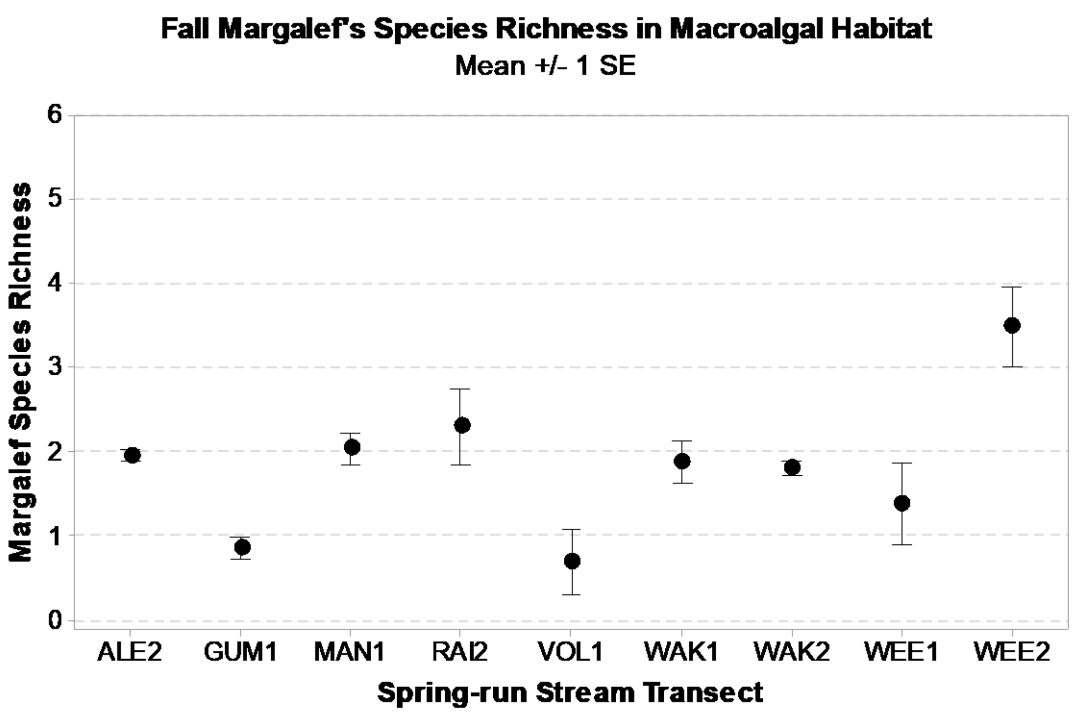


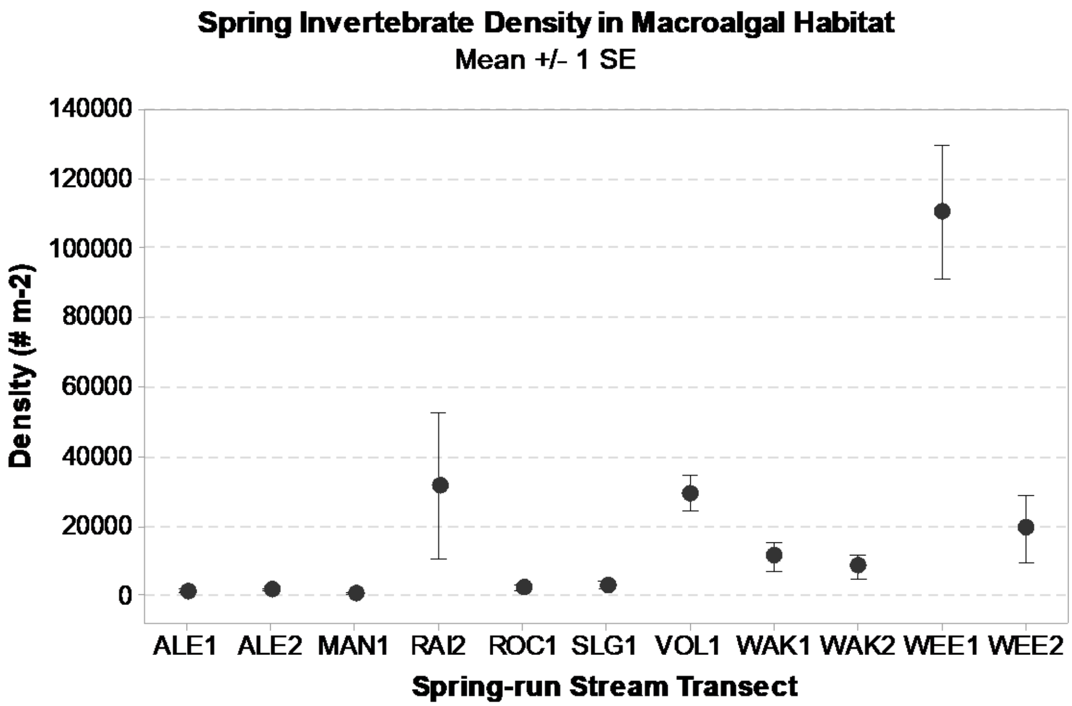
Figure 15. Mean Margalef's Species Richness values (± 1 standard error) in macroalgal habitat in spring and fall 2015.

Table 7. List of the top 25 most abundant taxa in macroalgal habitat. Data are for all transects combined in both spring and fall seasons in 2015.

Taxon	Major group	Total abundance
Hyalella azteca sp. complex	Amphipoda (scud crustacean)	49,775
Hydrobiidae spp.	Gastropoda (silt snails)	4,035
Tanytarsus buckleyi	Chironomidae (midge)	2,142
Chironomus spp.	Chironomidae (midge)	1,745
Tricorythodes albilineatus	Ephemeroptera (mayfly)	1,534
Gammarus spp.	Amphipoda (scud crustacean)	894
Pseudochironomus spp.	Chironomidae (midge)	848
Tubificinae spp.	Oligochaeta (worm)	669
Cricotopus/Orthocladius	Chironomidae (midge)	459
Hydroptila spp.	Trichoptera (caddisfly)	415
Dicrotendipes modestus	Chironomidae (midge)	310
Corbicula fluminea	Bivalve (Asian clam)	275
Oxyethira spp.	Trichoptera (caddisfly)	271
Tanytarsus spp.	Chironomidae (midge)	258
Pleurocera floridensis	Gastropoda (River horn snail)	255
Melanoides spp.	Gastropoda (exotic snail)	209
Caecidotea spp.	Isopoda (sowbug crustacean)	181
Limnodrilus hoffmeisteri	Oligochaeta (worm)	167
Ablabesmyia mallochi	Chironomidae (midge)	142
Ceratopogonidae spp.	Biting midges	131
Pentaneura inconspicua	Chironomidae (midge)	131
Cambaridae spp.	Decapoda (crayfish)	128
Cheumatopsyche spp.	Trichoptera (caddisfly)	121
Palaemonetes spp.	Decapoda (grass shrimp)	121
Chironomidae spp.	Non-biting midges	111

As seen in the spring data, density as #/g plant biomass was generally much lower than abundance expressed as #/m^2. Summary statistics for density are presented in Appendix F.

Cluster analysis revealed no significant clusters, but as in the spring, SJR and non-SJR transects tended to group together. ANOSIM showed significant differences based on abundance as #/m^2 (R=0.474; P_{perm}=0.028) but not based on #/g plant biomass (R=0.13; P_{perm}=0.306). SIMPER analysis showed that the differences were mainly based on higher abundances of hydrobiid snails, the amphipod *Gammarus* spp., the midge *Chironomus* spp., and oligochaetes (*Limnodrilus hoffmeisteri* and Tubificinae) in non-SJR (“O”) springs and higher abundances of the midge *Tanytarsus* spp. and the mayfly *Tricorythodes albilineatus* in SJR springs.



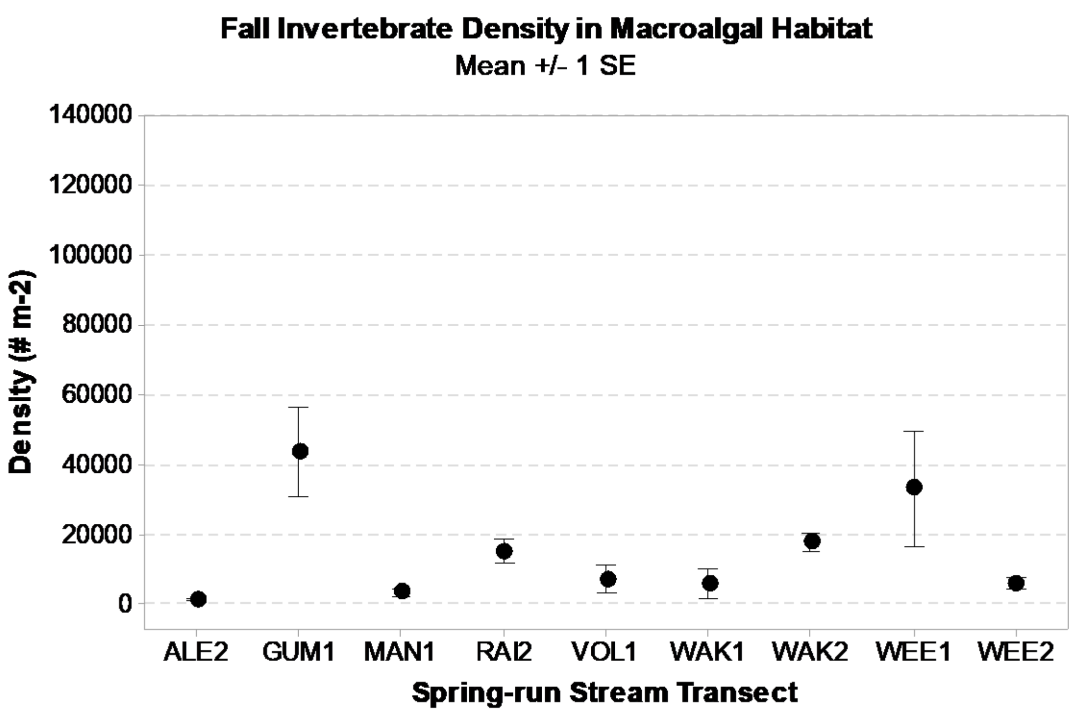
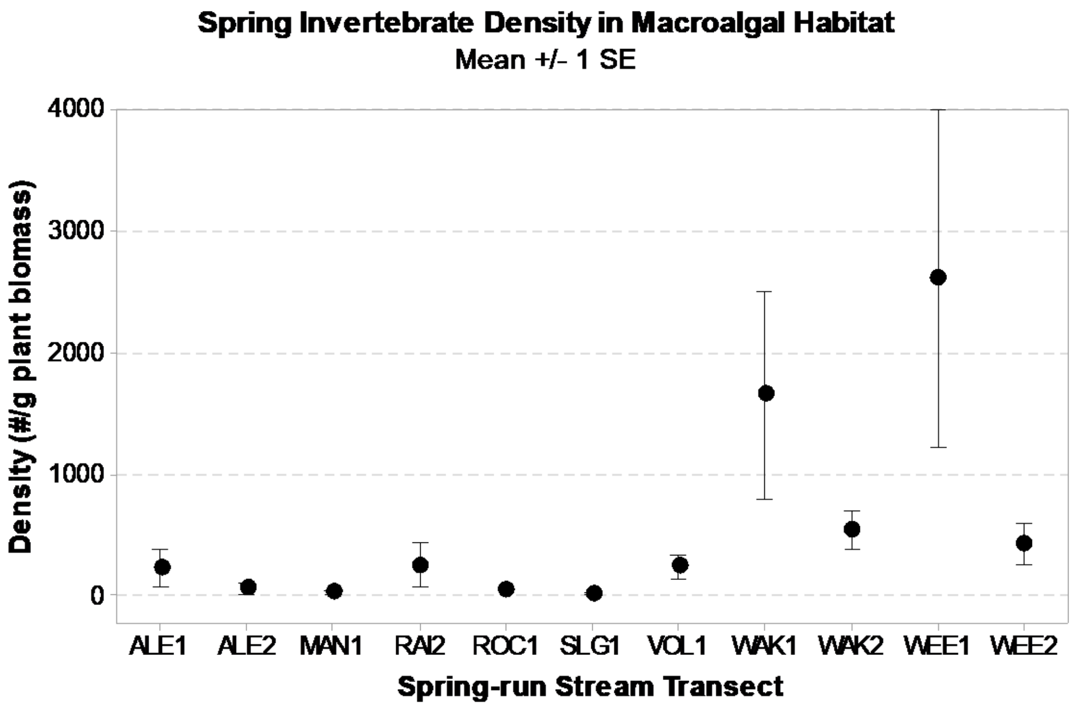


Figure 16. Macroinvertebrate mean density (± 1 standard error) at the transects in spring and fall 2015 expressed as Number of individuals/m^2 (based on the area of the Hess sampler).



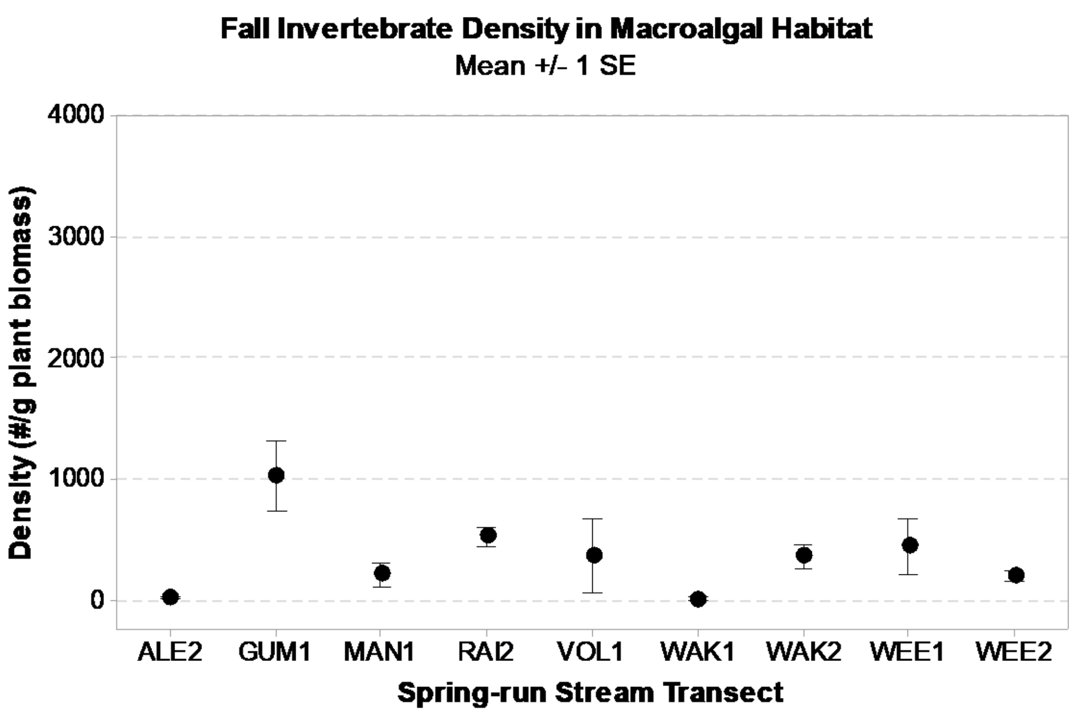


Figure 17. Macroinvertebrate mean density (± 1 standard error) at the transects in spring and fall 2015 expressed as Number of individuals/g plant biomass (as dry weight).

Seasonal Differences in Invertebrates of Macroalgal Habitat

An overall total of 120 taxa of invertebrates were collected in spring and 84 taxa in fall. This trend was similar to that for total taxa richness in macrophyte habitat. Chironomids, annelids, and molluscs generally comprised most of the taxa richness in both spring and fall (Figure 18) and taxa composition did not change appreciably between the two seasons (Figure 18).

Total taxa richness at individual transects was generally similar in both seasons or was somewhat higher in the spring (Figure 19; Appendix D). Slightly higher total taxa richness in fall was seen at MAN1 and WEE2 (Figure 19). As with macrophyte habitat, seasonal changes in mean taxa richness (Figure 13) and mean Shannon Index and Margalef's Index (Figures 14 and 15) in macroalgal habitat were not clearly evident or consistent. Some transects had higher mean taxa richness, Shannon diversity, and/or Margalef's Index in spring (MAN1, WAK2) and some had higher fall means (RAI2, WEE2).

Seasonal changes in mean abundance were not as clear in macroalgal habitat. Overall highest mean abundance at a particular transect was seen in spring (WEE1 as #/m^2 and WAK1 and WEE1 as #/g plant biomass). Higher abundance as #/m^2 was seen at RAI2 and VOL1 in spring (Figure 16), but as #/g plant biomass these two transects exhibited higher fall abundance (Figure 17).

ECOLOGICAL RELATIONSHIPS

Environmental Drivers of Invertebrates of Macrophyte Habitat

A variety of physical factors (flow, sediment type, habitat architecture), chemical factors (DO, conductivity, etc.) and biological factors (food, habitat, predation, etc.) influence the composition and abundance of the benthic macroinvertebrate communities in streams (Hynes 1970). BIO-ENV analysis showed that invertebrate taxa richness had moderate correlation with water depth, conductivity, DO and macrophyte biomass in spring and low correlation with water depth, water temperature, conductivity, pH, and current velocity in fall (Table 8). Abundance measures in spring showed moderate to low correlation with water depth, conductivity, water temperature, DO, current velocity, stream width and macrophyte biomass (Table 8). In fall abundance measures had moderate to almost strong correlation with conductivity, current velocity and turbidity.

Conductivity, DO, and current velocity appeared to be the environmental variables that most consistently identified in the BEST analyses as influencing invertebrate community characteristics (Table 8). Conductivity is important for osmotic regulation (Allan 1995), and molluscs and crustaceans, in particular, tend to be more abundant in spring-run streams due to higher ionic strength (primarily calcium to build their shells or exoskeletons). DO is necessary for cellular respiration and certain taxa (species of mayflies and caddisflies, selected crayfish and gastropod taxa) are sensitive to and affected by reduced DO (Osborne et al. 2017; Dormsjo 2008; Leibowitz et al. 2014). Current velocity has long been known to be a

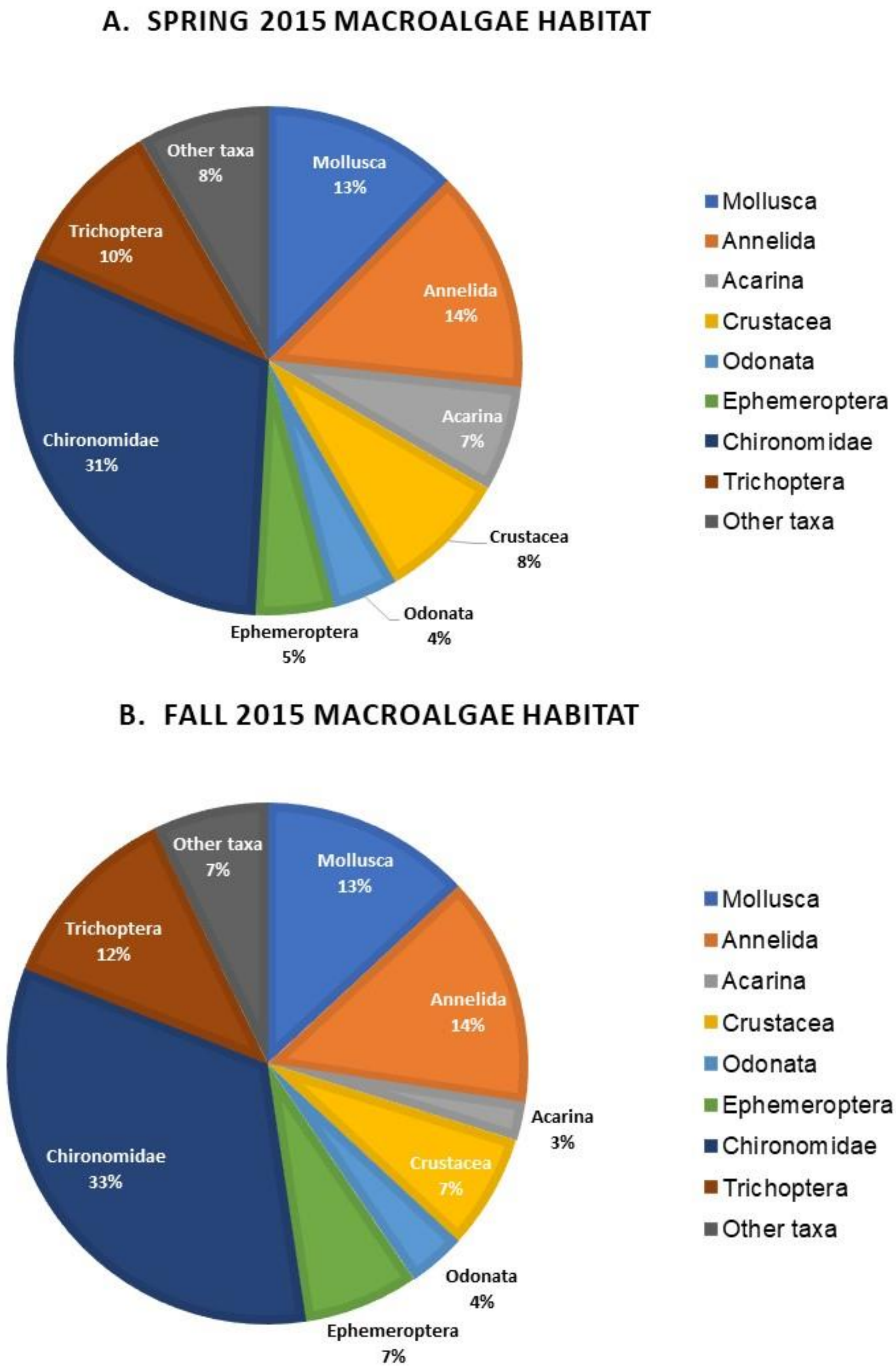


Figure 18. Pie charts of major taxa composition (as percent of the total taxa richness) in macroalgal habitat in A) spring, and B) fall. All transects combined.

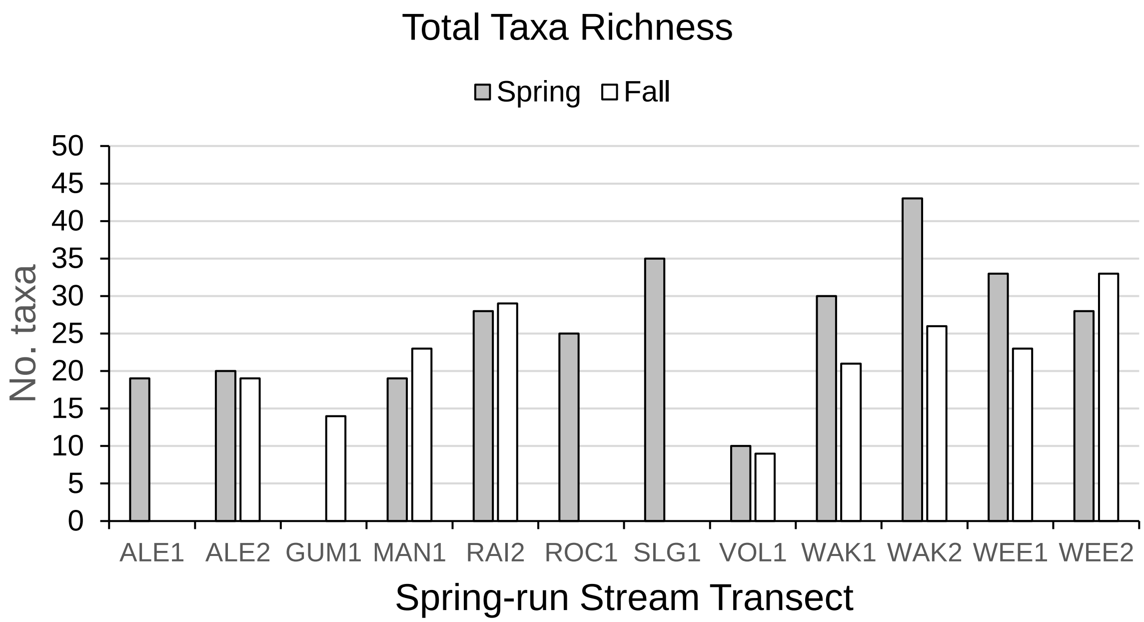


Figure 19. Seasonal differences in invertebrate total taxa richness in macroalgal habitat at all transects. Macroalgal habitat was not present at ALE1, ROC1 and SLG1 in fall and not present at GUM1 in spring.

factor influencing macroinvertebrate communities, as certain taxa are "rheophilic", requiring current to conduct filter feeding (hydropsychid caddisflies and midges in *Rheotanytarsus*) and to "refresh" the water around them with oxygen.

Environmental Drivers of Invertebrates of Macroalgal Habitat

The BIO-ENV analysis showed that taxa richness in macroalgal habitat had moderate to nearly strong correlation with DO and turbidity in spring and with water depth, conductivity, DO, stream width and current velocity in fall (Table 8). Abundance measures exhibited moderate correlation in spring with water depth, conductivity, pH, DO, and turbidity (Table 8). In fall the abundance measures had strong correlation with canopy cover, water depth, pH, DO, current velocity, and algal biomass. Overall, in macroalgal habitat, DO, conductivity, turbidity, and current velocity appeared to be the environmental variables that most commonly influenced macroinvertebrate community structure. The reasons for the importance of conductivity, DO, and current were noted above. Turbidity may be important as a reflection of the amount of suspended food material in the water for filter-feeding invertebrates or may affect light penetration through the water column and the production and abundance of attached algae (Hynes 1970).

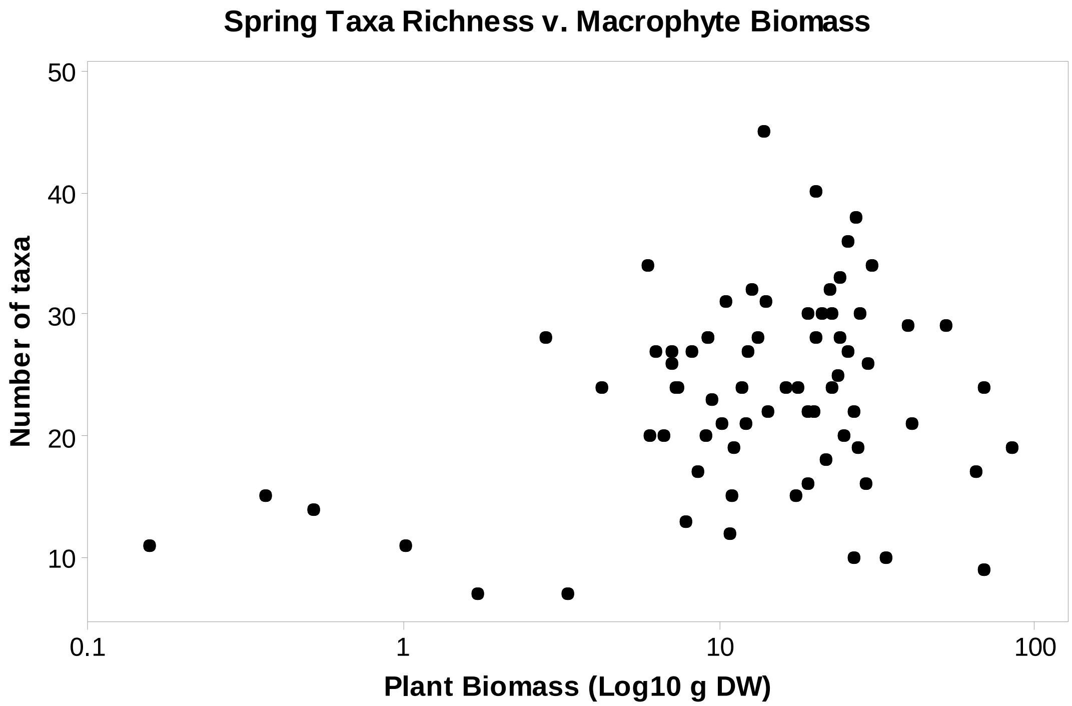
SAV habitat has been shown to be important for macroinvertebrate communities in aquatic ecosystems spanning from marine to freshwater (Rozas and Odum 1987). In freshwater SAV

Table 8. Summary of BIO-ENV correlation of macroinvertebrate community measures with environmental variables in macrophyte and macroalgal habitat.

Habitat	Season	Invertebrate metric	BEST Correlation Coefficient	Environmental variables
Macrophyte	Spring	Taxa richness	R=0.413	Water depth, conductivity, DO, SAV biomass
	Spring	#/m^2	R=0.492	Conductivity, DO, current velocity, SAV biomass
	Spring	#/g plant biomass	R=0.287	Water depth, conductivity, DO, stream width, SAV biomass
	Fall	Taxa richness	R=0.207	Water depth, water temperature, conductivity, pH, current velocity
	Fall	#/m^2	R=0.661	Conductivity, current velocity
	Fall	#/g plant biomass	R=0.512	Conductivity, turbidity, current velocity
Macroalgae	Spring	Taxa richness	R=0.659	DO, turbidity
	Spring	#/m^2	R=0.482	Water depth, conductivity, pH, DO, turbidity
	Spring	#/g plant biomass	R=0.420	Conductivity, pH, turbidity
	Fall	Taxa richness	R=0.610	Water depth, conductivity, DO, stream width, current velocity
	Fall	#/m^2	R=0.756	Canopy cover, water depth, pH, DO, current velocity
	Fall	#/g plant biomass	R=0.799	Canopy cover, water depth, pH, current velocity, algal biomass

habitat, invertebrate taxa richness and abundance are generally significantly higher than in unvegetated bottom sediments (Rozas and Odum 1987; Thorp et al. 1997; Strayer and Malcom 2007). In contrast to these studies, Warren et al. (2000) found similar taxa richness and higher abundance of macroinvertebrates in unvegetated sediments versus beds of *Vallisneria americana* in the Wekiva River. Our study did not compare the macroinvertebrate communities of vegetated versus unvegetated habitats. A comparison of macrophyte versus macroalgal habitats will be made in the next section.

SAV habitat (both macrophytes and macroalgae) provides invertebrate communities with places to attach (e.g., filter feeding chironomids and trichopterans), shelter from predators, feeding areas (attached epiphytic algae and macrophyte detritus), and shelter from current (Camp et al. 2014). Studies have attempted to quantify the "value" of SAV habitat by comparing invertebrate community measures with plant biomass. In this study, macroinvertebrate taxa richness was somewhat positively related to macrophyte biomass (Figure 20) with a stronger relationship in spring versus fall. Taxa richness seemed to be highest at intermediate macrophyte biomass levels (~10 to 50 g DW). We found no studies in the literature examining this relationship. It might be that macrophyte beds with lower biomass have overall "less" habitat area to occupy, while beds with higher biomass have higher levels of physical disturbance due to the leaves of the plants rubbing against one another in the river current.



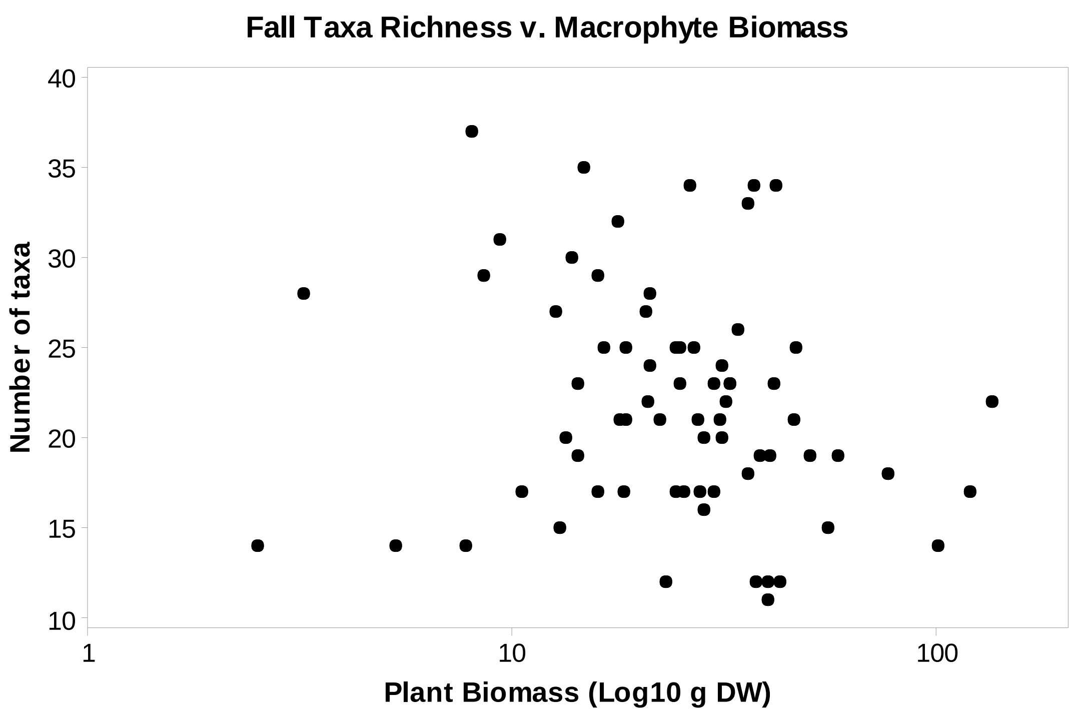


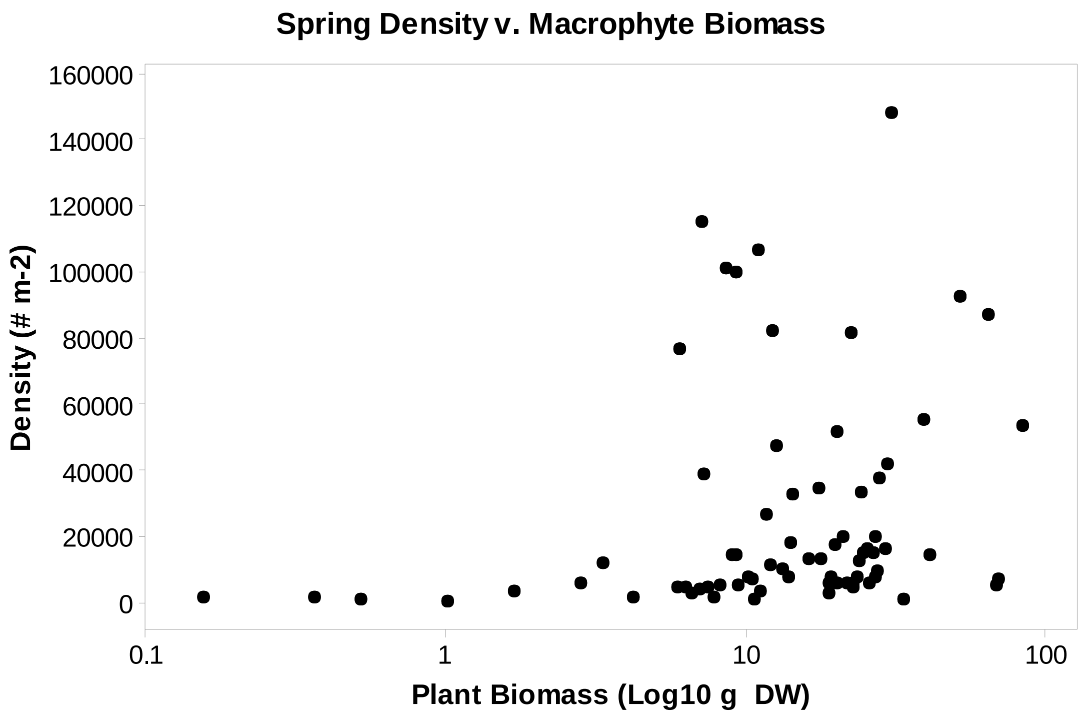
Figure 20. Plots of macroinvertebrate taxa richness versus macrophyte biomass (Log10 g Dry Weight) in spring and fall. All transects combined.

In contrast, numerous studies have examined macroinvertebrate abundance versus macrophyte biomass. In this study, we found a somewhat positive relationship in the spring between invertebrate density (as #/m^2) and plant dry weight (Figure 21). The relationship appeared to be weaker in the fall collection (Figure 21). A similar relationship was seen in an earlier study of SAV and macroinvertebrate communities in the Ichetucknee River (Figure 22; data from PBS&J and UF 2003). Strayer and Malcom (2007) identified strong (statistically significant) relationships between macroinvertebrate abundance (also as #/m^2) and plant dry weight biomass in the tidal freshwater region of the Hudson River (dominated by beds of *V. americana*). In contrast, Rozas and Odum (1987) observed no relationships between macroinvertebrate density and plant biomass in tidal freshwater SAV beds in the Chesapeake Bay region. These beds were dominated by *Najas minor* with lower amounts of *Najas guadalupensis* and *Ceratophyllum demersum*. They opined that the more complex branching architecture of these plants may have provided equivalent habitat for invertebrates at low as well as high plant biomass, in contrast to the "simpler" habitat provided by the strap-leaved plants such as *V. americana* and *Sagittaria kurziana*.

Differences in Macroinvertebrate Communities of Macrophyte vs Macroalgal Habitat

A key question is, "Is macroalgal habitat equivalent to macrophyte habitat for macroinvertebrate communities?" This question is highly relevant for Florida spring-run streams due to an ongoing trend of replacement of beds of submerged macrophytes by filamentous algal mats (Camp et al. 2014; Mattson et al. 2021). Even more broadly, this may be a global phenomenon (Hudon et al. 2014). For a given spring-run stream in this study (combining all data from all transects and both sampling seasons), where macrophyte beds and macroalgal mats were both present, higher mean invertebrate taxa richness was seen in the macrophytes (Figure 23). The multivariate analyses with PRIMER showed two significant clusters in spring and one major cluster and an outlier in fall; these separated as SJR versus O (non-SJR) spring-run systems, and within these the macroinvertebrate communities of the two habitats tended to cluster separately (Figure 24). ANOSIM analyses showed significant differences between the invertebrate communities of macrophyte versus macroalgal habitat ($R=0.282$; $P_{perm}=0.014$). Although the differences in community composition between the two habitats was complex, a general trend was higher abundance of *Hyalella* group amphipods and hydrobiid snails in macroalgae versus higher abundance of caddisflies, *Hydroptila*, in macrophyte habitat (e.g., compare Tables 7 and 5). Camp et al. (2014) also documented differences in the community assemblage structure of small fishes and macroinvertebrates in macroalgal versus macrophyte habitat in the Homosassa and Chassahowitzka Rivers in west central Florida.

Macroalgal habitat supports lower overall (total) taxa richness than macrophyte habitat. As discussed above, 230 taxa were collected in macrophyte habitat and 136 in macroalgal habitat. Macrophyte habitat in most transects supported ~30 or more total invertebrate taxa (Figure 12), while macroalgal habitat at most transects supported <30 total taxa (Figure 19). Mean taxa richness was also consistently lower in macroalgal habitat in stream systems where both habitats were present at one or more transects and seasons (Figure 23). In spring-run streams where only one habitat was present, macroalgal habitat typically had lower mean taxa



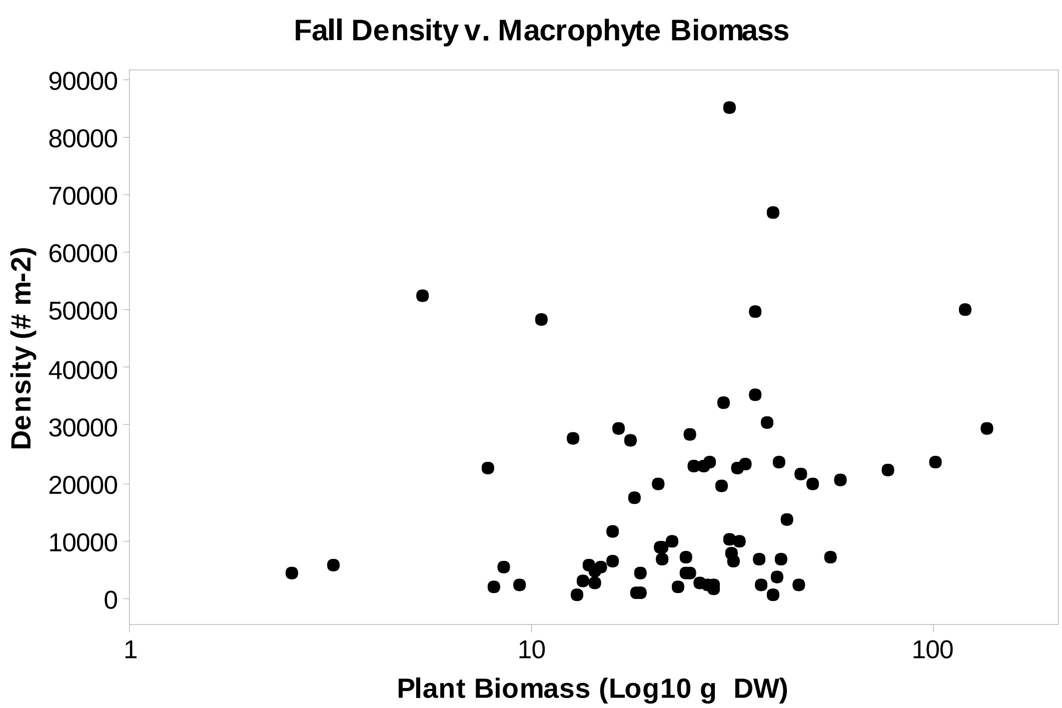


Figure 21. Comparison of macroinvertebrate density (as #/m^2) versus macrophyte dry weight biomass in spring and fall seasons. All transects combined.

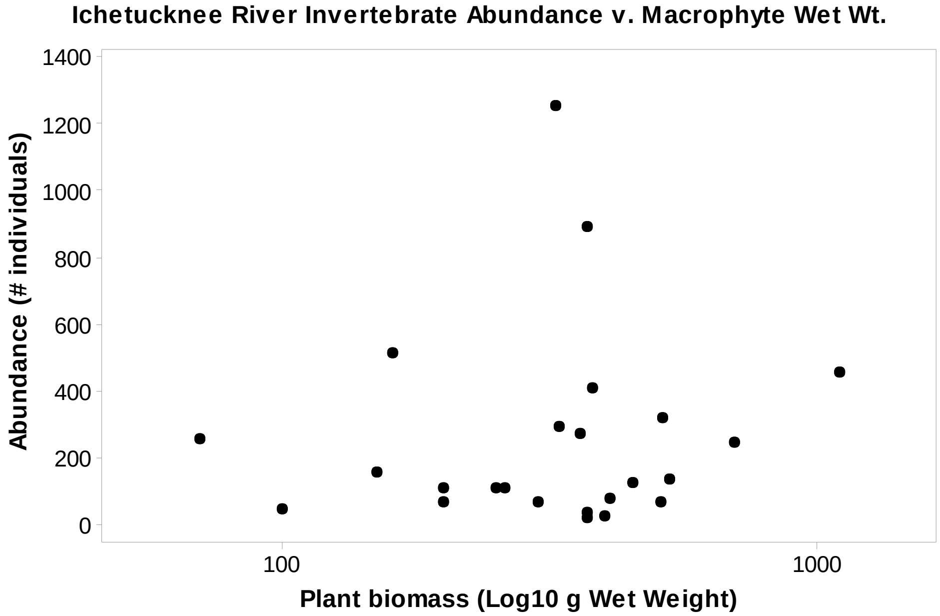


Figure 22. Comparison of macroinvertebrate abundance (as # individuals) versus macrophyte wet weight biomass in the Ichetucknee River. Data from PBS&J and UF 2003.

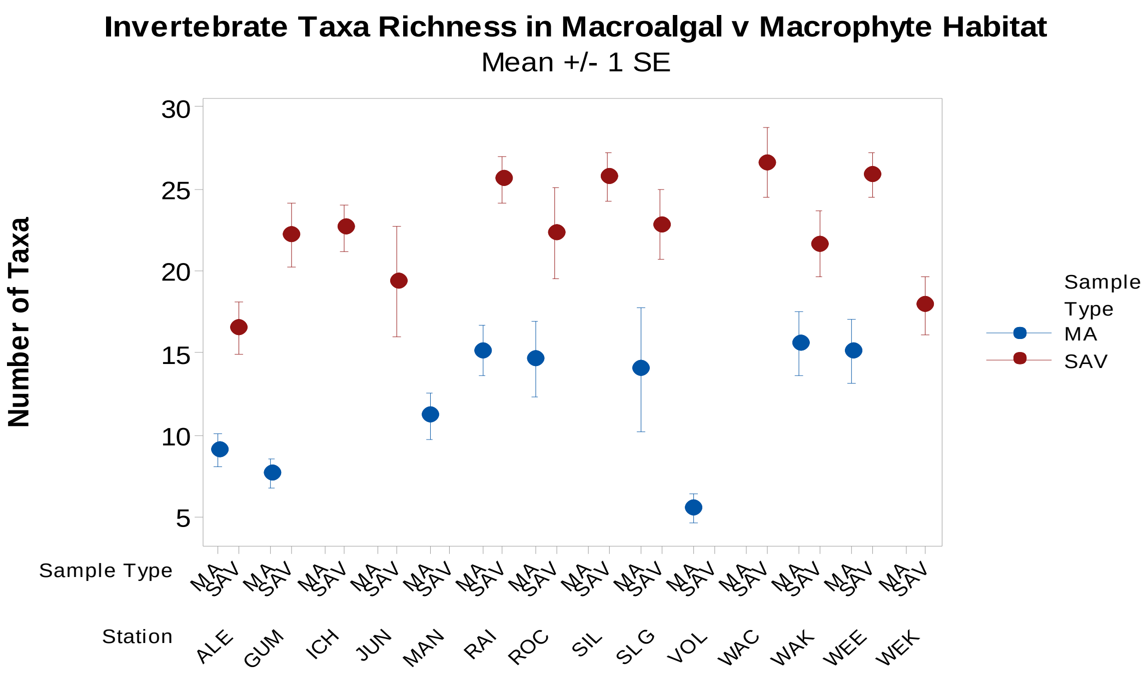


Figure 23. Comparison of mean taxa richness (all transects and sample dates combined) in macroalgal (MA) and macrophyte (SAV) habitats in the 14 spring-run streams sampled in this study. Note that while both habitats were present in most streams, they may not have been present on the sampled transects.

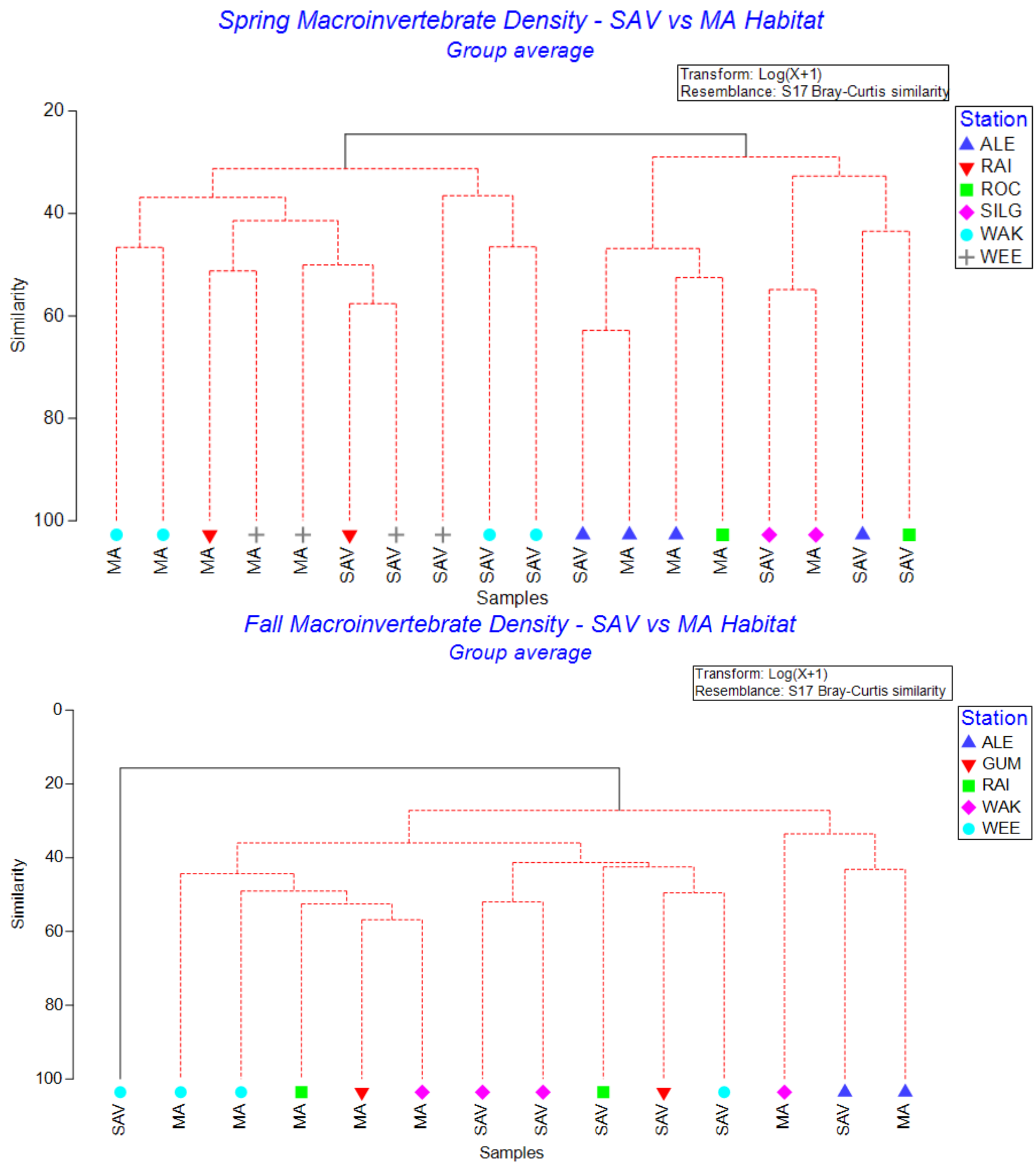


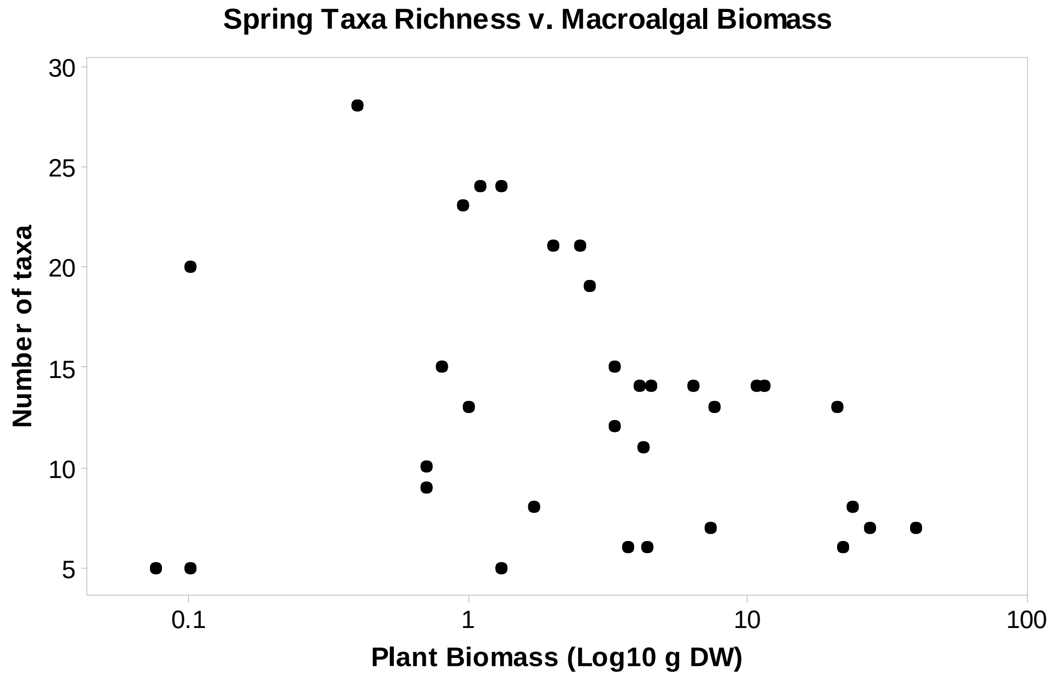
Figure 24. Cluster analysis of taxonomic composition (by density) in macrophyte (=SAV) versus macroalgal (=MA) habitat. Solid line indicates statistically significant difference. SJR=springs connected to the St. Johns River mainstem; O=springs not connected to the St. Johns River.

richness than streams that only had macrophyte habitat at the sampling transects (e.g., MAN and VOL versus ICH and SIL). It should be noted that low macroinvertebrate taxa richness at VOL is also due to stressful physical-chemical conditions (very low DO and high conductivity).

Lower invertebrate taxa richness was generally associated with higher macroalgal biomass in the spring-run streams sampled in this study (Figure 25). Mattson (2009) compared invertebrate taxa richness and algal abundance data from the Ichetucknee River presented in Steigerwalt (2005 – on snag habitat) and PBS&J & UF (2003 – in macrophyte habitat) and found weak positive relationships between algal abundance and macroinvertebrate taxa richness. Dudley et al. (1986) experimentally evaluated the effects of macroalgal growth (the filamentous chlorophyte *Cladophora* and the cyanobacterium *Nostoc*) on macroinvertebrate communities; they found overall increases in invertebrate taxa richness and abundance with increasing algal abundance. They noted that different invertebrate taxa respond differently to algal abundance:

1) Some taxa (*Simulium* spp. and *Blepharicera* spp.) were negatively affected (reduced abundance) due to competition for space with algae.
2) Other taxa (*Rheotanytarsus*) were positively affected (higher abundance) due to creation of additional structural habitat by the algal filaments.
3) Other taxa (baetid mayflies, other chironomid taxa) were positively affected due to the combination of additional habitat and food resources (either the macroalgal filaments or attached epiphytes).

Power (1990) found that chironomids (primarily *Pseudochironomus* spp.) were the dominant invertebrate taxon in floating mats of *Cladophora* and more sensitive taxa (mayflies and stoneflies) were less abundant in the mats. In this study, we found macrophyte habitat supported more taxa of odonates, mayflies, caddisflies, and dipteran taxa than did macroalgal habitat (compare Tables 4 and 6). Mattson (2009) compared macroinvertebrate and algal community data collected by the Florida Department of Environmental Protection stream bioassessment program in spring-run streams and found significantly reduced taxa richness and “EPT Score” (combined taxa richness of mayflies, stoneflies, and caddisflies – all regarded as sensitive taxa) with increasing relative abundance of Cyanobacteria and Chlorophyta, which tend to be the “nuisance taxa” that form filamentous algal mats. Camp et al. (2014) found a less diverse assemblage of small fishes and macroinvertebrates in macroalgal mats in the Homosassa and Chassahowitzka Rivers. The main macroinvertebrate that appeared to be affected was the crayfish *Procambarus* sp., which is an important food item in the diets of many sportfish. Mattson (2009), using data collected in snag habitat in the Ichetucknee River from Steigerwalt (2005), found lower diversity (H’ – Shannon Index) with higher periphyton biomass, which appeared to mainly be due to reduced evenness, since taxa richness was slightly increased at higher algal biomass. All these results lead to the general conclusion that mats of filamentous macroalgae are generally poorer habitat than macrophyte beds due to a different habitat architecture (smaller interstitial pore spaces; Camp et al. 2014), more widely varying physical-chemical conditions (DO, pH, etc.; Power 1990), and overall competition for space (Dudley et al. 1986).



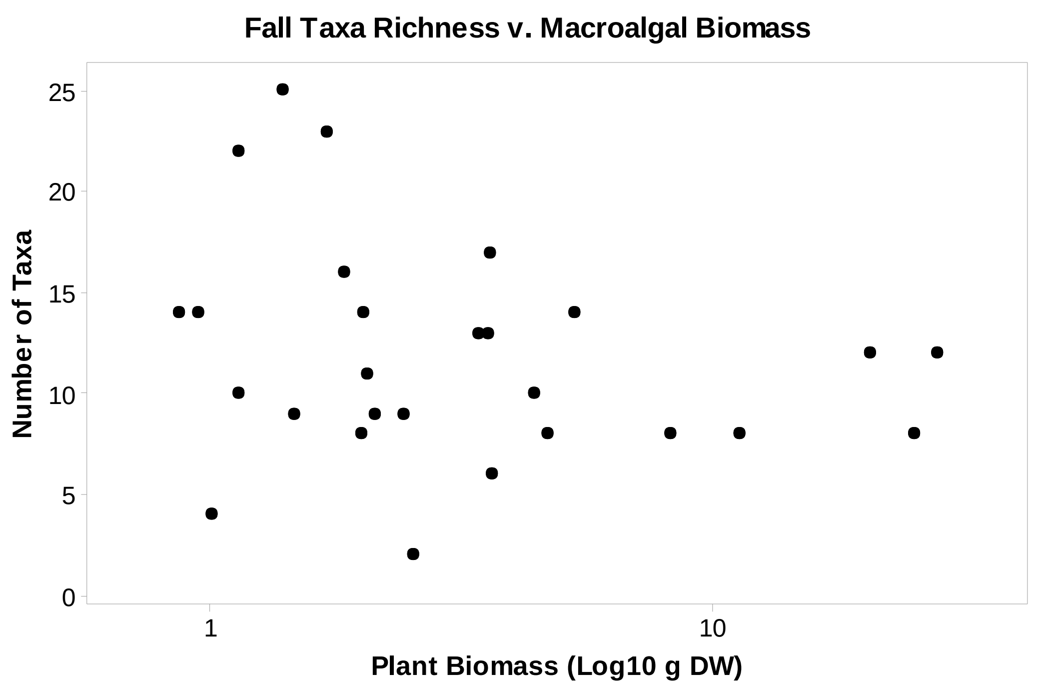


Figure 25. Plots of macroinvertebrate taxa richness versus macroalgal biomass (Log10 g Dry Weight) in spring and fall. All transects combined

In contrast, some studies show higher invertebrate abundance in macroalgal habitat vs. macrophytes. Camp et al. (2014) saw this in the Homosassa and Chassahowitzka Rivers. Results from this study were generally mixed on this (Figure 26). In one stream, higher mean invertebrate density was seen in macroalgal habitat (WEE). In many streams (ALE, GUM, ROC, WAK) mean densities were similar in both habitats. In a few streams (RAI, SLG) mean invertebrate density was higher in macrophyte habitat.

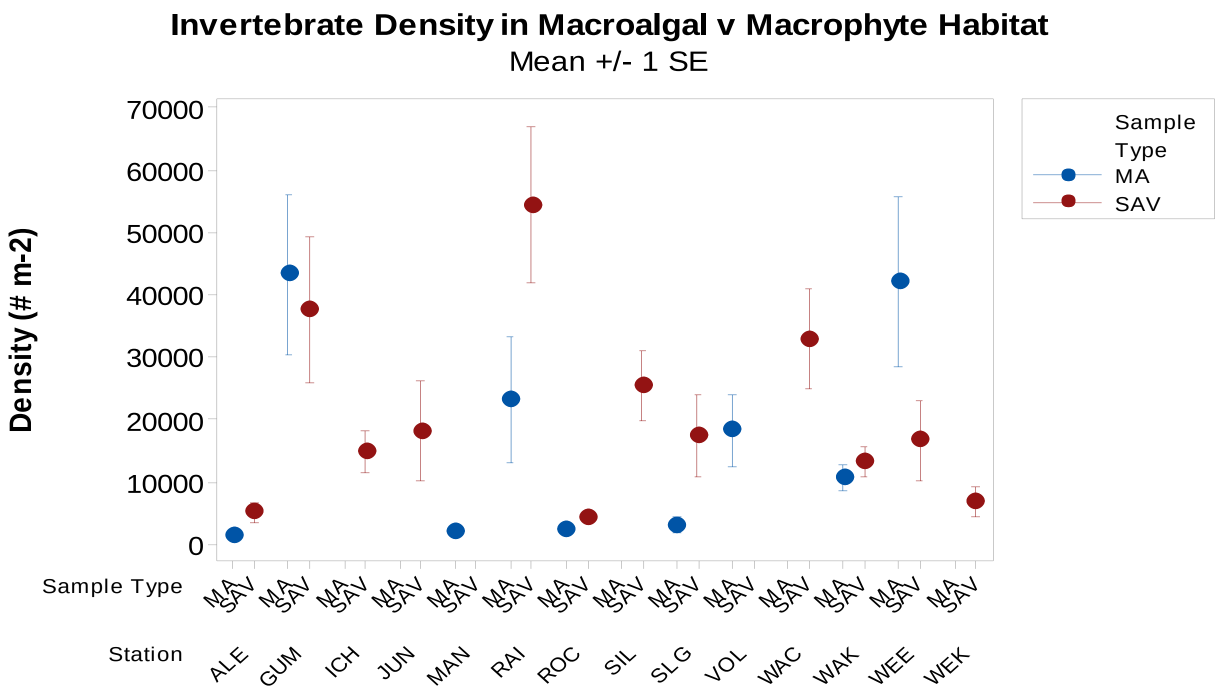
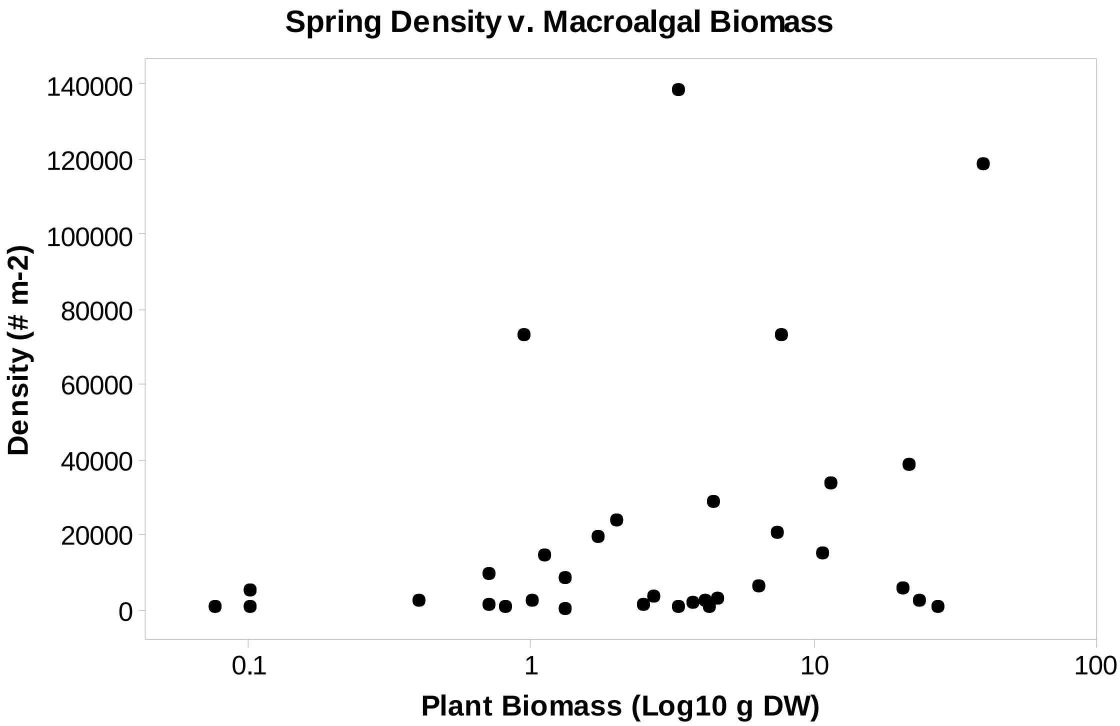


Figure 26. Comparison of mean density (#/m^2, all transects and sample dates combined) in macroalgal (MA) and macrophyte (SAV) habitats in the 14 spring-run streams sampled in this study. Note that while both habitats were present in most streams, they may not have been present on the sampled transects.

Mattson (2009) conducted meta-analyses using invertebrate and algal data collected in Florida spring-run streams and generally found significant positive correlations between algal abundance and invertebrate abundance. In this study, we observed somewhat positive relationships between macroalgal and invertebrate abundance (Figure 27), with a stronger relationship observed in spring versus fall (Figure 27). As with the comparison of macrophyte biomass and invertebrate density, highest invertebrate density was associated with moderate algal biomass, particularly in fall (Figure 27). The explanation for these positive relationships is similar to that advanced when discussing taxa richness: increased food resources, habitat availability, and certain taxa having a competitive advantage.



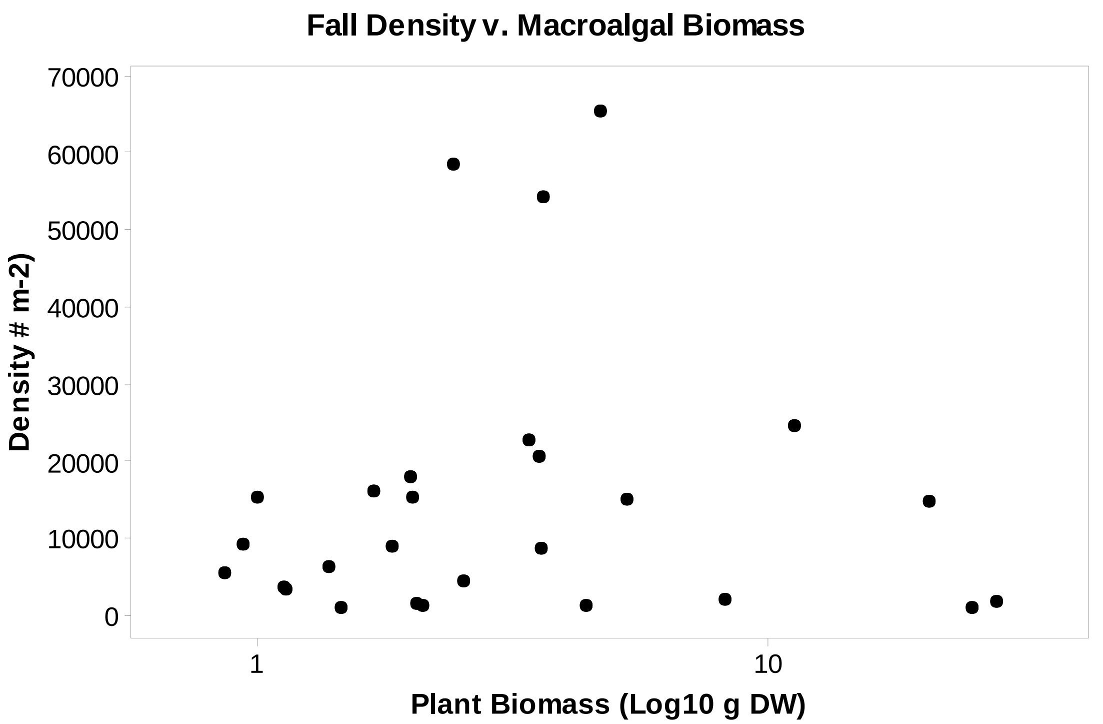


Figure 27. Comparison of macroinvertebrate density versus macroalgal dry weight biomass in spring and fall seasons. All transects combined.

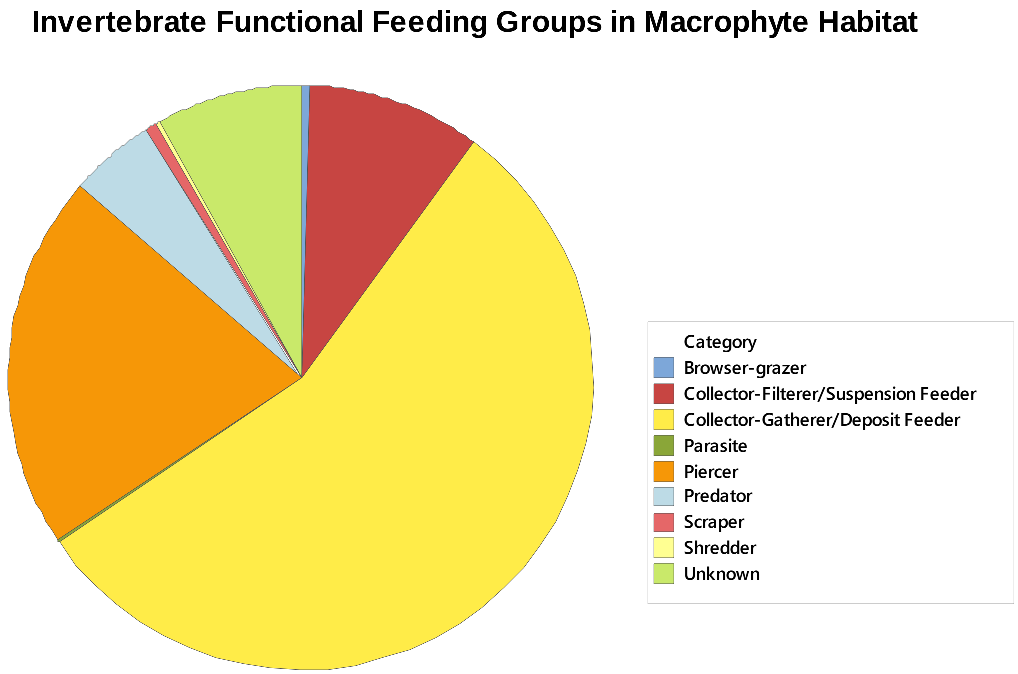
Overall, the data and analyses in this study, and the prior work by Camp et al. (2014) and Mattson (2009) indicate that macroalgal proliferation in Florida spring-run streams (and its replacement of macrophyte beds) results in alterations in macroinvertebrate communities which would likely have negative effects on the overall ecology of these streams, largely by affecting the macroinvertebrate food base available to higher trophic levels, particularly sport fish sought by anglers, and other wildlife (Camp et al. 2014). Frazer et al. (2017), using stable isotopes of C and N in the Silver River, found that the main food base for macroinvertebrates was the macrophyte/epiphyte complex, as did Odum (1957b) in earlier work. The stable isotope work showed that few invertebrate taxa (hydroptilid caddisflies and certain chironomids) used macroalgae directly as a food resource.

Other Ecological Characteristics – Functional Feeding Groups

Because many benthic macroinvertebrates feed on a variety of food resources, the conventional categorization as “carnivore”, “herbivore”, etc. is problematic. Cummins and Klug (1979) addressed this by developing categories of “functional feeding groups” (FFG) in stream invertebrates, accounting for morphological and behavioral differences in feeding mode or style. This concept has been refined over the years and has been adapted to the macroinvertebrate communities of Florida freshwater ecosystems. A brief description of the categories used in this study:

- Browser-grazer – feeds on attached algae and associated organic material and biota (e.g., many herbivorous insects, amphipods)
- Collector-filterer – feeds on small particles suspended in the water column (many bivalves, hydropsychid caddisflies, simuliids)
- Collector-gatherer – feeds on detrital material on surfaces or in sediment (oligochaetes, many insects)
- Parasite – parasitic on larger fauna (Acarina/water mites, some leeches)
- Piercer – feeds on algae or macrophytes by piercing the cell wall and sucking the cytoplasm (hydroptilid caddisflies)
- Predator – preys on other fauna, either by consuming all or part of the prey (odonates, megalopterans) or piercing and sucking body fluids (most hemipterans)
- Scraper – feeds on attached algae and associated organic material using a radula or similar feature (many gastropods, some caddisflies)
- Shredder – feeds on live or detrital macrophyte material (crayfish, lepidopterans, some caddisflies)
- Unknown/Other – FFG not known

The macroinvertebrate community in macrophyte habitat was primarily dominated by collector-gatherers (Figure 28), which comprised 55.4% of the abundance (all transects from all streams combined). Some of the more abundant taxa included tubificid worms, various chironomids (e.g., *Dicrotendipes* spp., *Cricotopus*/*Orthocladius* spp.) and amphipods in the *Hyalella azteca* group. Piercers were the next most abundant FFG (20.8%) and these were primarily hydroptilid caddisflies. Other FFG were less than 10% of the total abundance in macrophyte habitat.



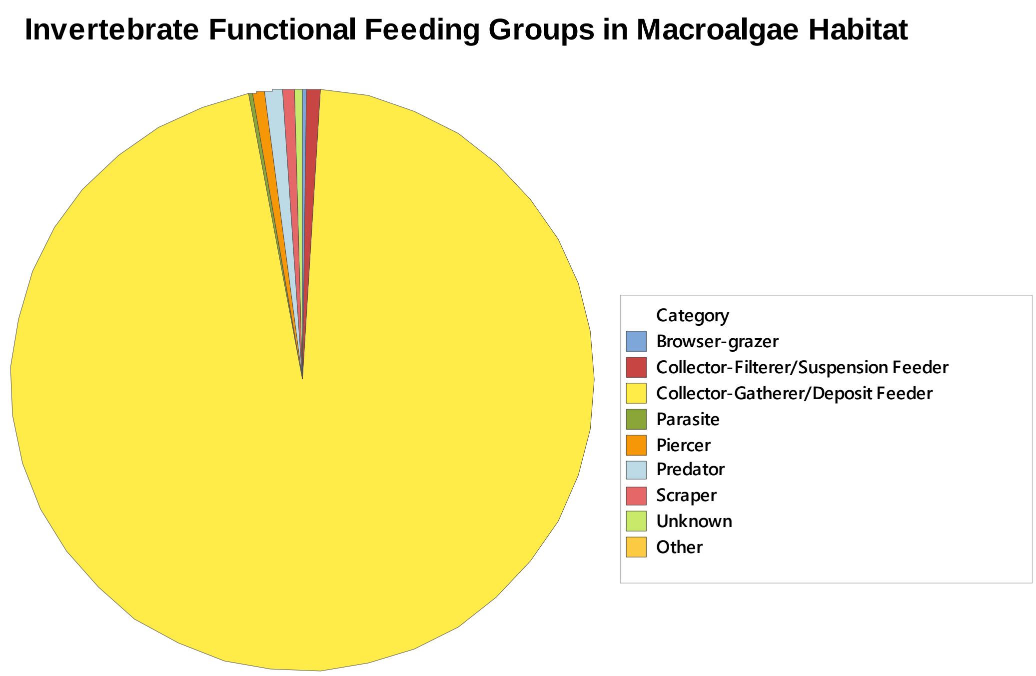


Figure 28. Graphs showing proportional composition (by abundance) of functional feeding groups in macrophyte and macroalgae habitats.

In contrast, the macroinvertebrate community of macroalgae habitat was overwhelmingly dominated, 96.1 %, by collector-gatherers (Figure 28). This is likely due to the structural differences between the two habitats, as well as differences in food resource availability. Amec Foster Wheeler (2016b) found that collector-gatherers were similarly overwhelmingly dominant (by abundance) in both macrophyte and macroalgae habitat in the Chassahowitzka and Weeki Wachee Rivers and dominant in macroalgae habitat in the Homosassa River.

Other Ecological Characteristics – Life Habit

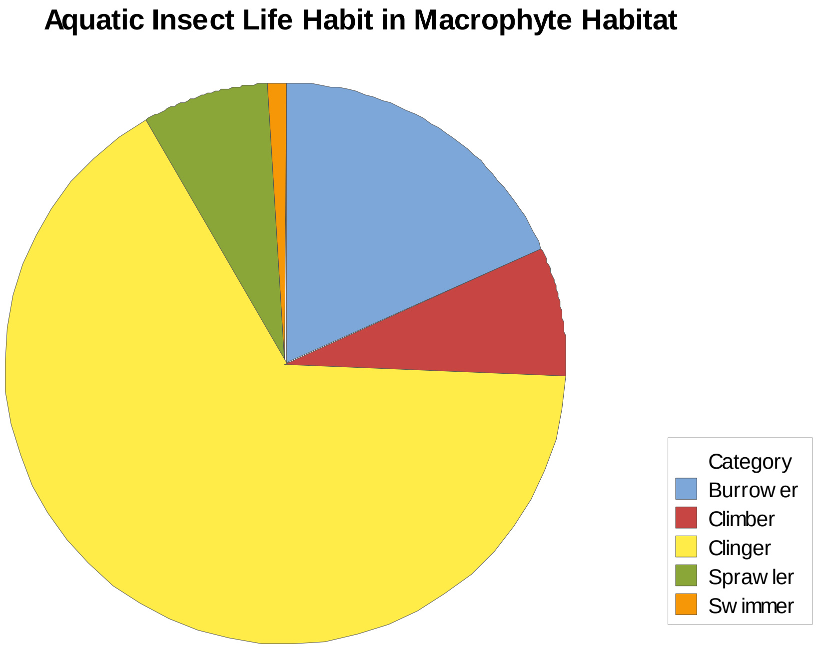
Merritt and Cummins (1996) categorize aquatic insect taxa based on "life habit" or mode of existence (habit, locomotion, attachment, and/or concealment). These encompass and include the adaptations and behaviors that each insect taxon uses to survive in its preferred habitat. Categories used in this study were:

- Burrowers – inhabit benthic sediments, either by constructing a defined burrow or tunneling through sediments (tubificid oligochaetes, many chironomid larvae)
- Climbers – adapted for living on macrophytes other submerged "structure", e.g., tree branches, roots, etc. (aeshnid dragonflies, some mayflies, many zygopterans)
- Clingers – behavioral or morphological adaptations to attach to surfaces in habitats with stronger currents or wave action (heptageniid mayflies, hydropsychid caddisflies, simuliids)
- Sprawlers – lay on surface of bottom sediments, vegetation, or "leaf pack" (libelullid and some gomphid dragonflies)
- Swimmers – able to freely move through the water column under their own power (baetid mayflies, some aquatic beetles)

This scheme has not yet been adapted for other groups of freshwater aquatic invertebrates, so is only applied to the aquatic insects collected in this study.

Clingers comprised the majority, 66%, of the aquatic insect fauna in macrophyte habitat (Figure 29). In many of the spring-run streams sampled in this study, the macrophyte habitats tended to have higher current velocities. Burrowers made up the second highest proportion of the insect abundance, 18.3%, in the macrophyte habitat (Figure 29). The remaining life habit groups each constituted <10% of the relative abundance.

In macroalgae habitat, no single life habit type comprised a majority of the relative abundance (>50%; Figure 29). Burrowers (32.5%), climbers (29.6%) and sprawlers (24.7%) made up the majority, collectively, of the aquatic insect abundance in macroalgae habitat. We could not find other studies comparing proportions of aquatic insect life habits in different habitats in spring-run streams.



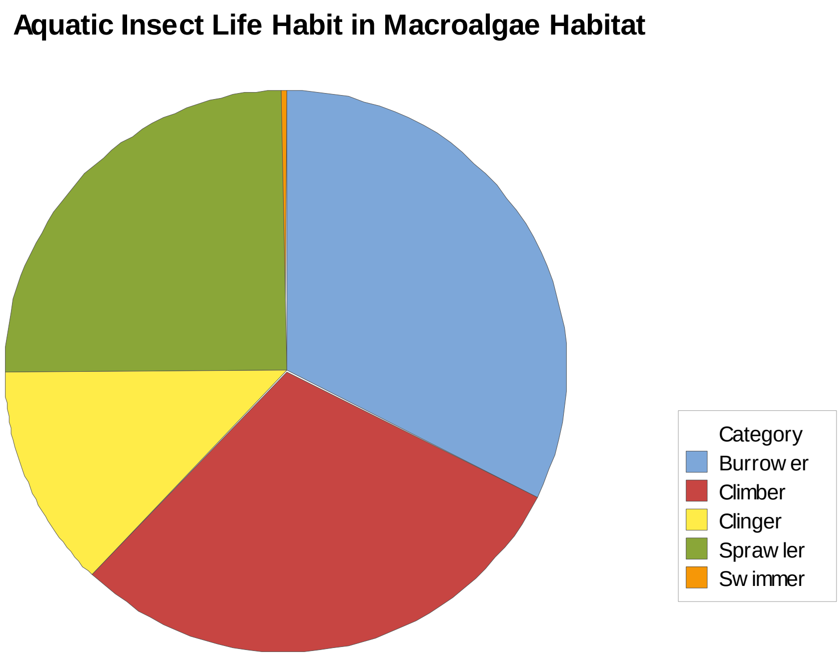


Figure 29. Graphs showing proportional composition (by abundance) of aquatic insect life habits in macrophyte and macroalgae habitats.

Comparison with Prior Studies of Florida Spring-Run Streams

Prior sampling and studies of macroinvertebrate communities have been conducted in several of the springs and spring-run streams sampled in this study. A common issue with comparing the macroinvertebrate data of this and previous efforts is non-comparable methodology, mostly different sampling equipment used to collect macroinvertebrates. Other differences include differing locations, sampling in different habitats, and changes in taxonomy over time. For purposes of this comparison, we will mainly focus on springs on the St. Johns River and compare species lists and describe the differences in collection methodology to give the reader a general assessment of differences over time.

Alexander Springs Creek

Alexander Spring was sampled four times in 2007 by Walsh et al. (2009). They sampled in the headspring area and used two different methods:

a) The Stream Condition Index (SCI) methodology developed by the FDEP. This involves sampling with a D-frame dip net (500 micron mesh; 0.3 m width) in multiple habitats over a 100 m stretch of stream. 20 sweeps with the net were made per the SCI procedure and all collected material was composited.
b) Sampling unvegetated sediments with petite ponar dredge (15.2 X 15.2 cm area); three replicate grabs with the ponar were taken at each sampling date.

Their data were compared with the data we collected at transect ALE1, which was in roughly the same headspring area (Table 9). They did not sample downstream in the spring-run stream itself. Total taxa richness in the dip net samples was 8-17 over the four periods they

Table 9. Comparison of macroinvertebrate community metrics collected at ALE1 in this study and those collected by Walsh et al. (2009) in the headspring area of Alexander Springs Creek. H' (Shannon-Weiner Index) is a pooled or average value.

Date	Total # Taxa (Walsh et al.)	$\log_e$ H' (Walsh et al.)	Date	Total # Taxa (This study)	$\log_e$ H' (This study)
Dip Net			Macrophyte Habitat		
2/1/2007	10	1.13			
5/10/2007	8	0.43	5/19/2015	28	1.46
8/7/2007	10	1.37			
10/10/2007	17	2.11	10/12/2015	35	1.93
Petite Ponar			Macroalgal Habitat		
2/1/2007	22	2.02			
5/10/2007	16	1.0	5/19/2015	19	1.36
8/7/2007	5	1.39			
10/10/2007	21	1.49	10/12/2015	No sample	No sample

sampled and in the ponar samples was 5-22. This is lower than the 28 total taxa we collected in spring and 35 taxa in fall in macrophyte habitat (Appendix C, Tables 1A and 2A). We collected a total of 19 taxa in spring in macroalgal habitat (Appendix D, Table 1), which was closer to their results. A total of 51 taxa were collected at Alexander Springs headspring area in the Walsh et al. study (both gear types and all sampling dates combined) and a total of 53 taxa were collected in this study (both habitats and both sampling dates combined). Shannon diversity in the Walsh et al. study was 0.43-2.11 in the dip net samples and 1.0-2.02 in the ponar samples (Table 9). We measured a mean Shannon diversity of 1.46 in spring and 1.93 in fall in macrophyte habitat and 1.36 in spring in macroalgal habitat. These numbers are similar to those collected with both gear types by Walsh et al. and, combined with the similar total taxa richness collected in both studies, suggest no substantial changes in macroinvertebrate community diversity in Alexander Spring between 2007-2015. The higher total taxa richness we measured in macrophyte habitat was most likely due to differences in sampling methodologies (gear types and specific habitats sampled).

The general species composition in Walsh et al. was similar to that collected in this study (Table 10). Molluscs (primarily gastropods), annelids (oligochaetes and leeches), and chironomids comprised the majority of the taxa richness in both studies (Table 10). Walsh et al. collected more gastropod taxa, but this is likely due to a greater level of effort in identifying the hydrobiid snails to species. This study collected more annelid taxa, but this may be due to differences in gear types and habitats sampled. Water mite (Acarina) and crustacean taxa composition was similar between both studies, with the same or similar taxa collected and identified. A similar assemblage of mayfly taxa was collected in both studies although very few odonate taxa were collected. The chironomid assemblage was overall similar in terms of number of taxa (12 taxa in both studies), but the composition was somewhat different, with many taxa collected only in one or the other study. Again, this may be due to differences in gear types and habitats sampled, and also life history variation among the chironomid taxa.

In their petite ponar samples, Walsh et al. noted that hydrobiid snails and oligochaetes accounted for most of the abundance (70.2 and 22.1 percent, respectively). The dip net samples were likewise dominated by hydrobiids (74.8%). In Walsh et al., the hydrobiid *Spilochlamys gravis* was the single most abundant taxon. Hydrobiids were not identified to species in this study. In scanning through the raw data of this study, amphipods in the *Hyalella* group and hydrobiid snails were consistently the most abundant taxa in the replicate samples from ALE1 in both seasons. Secondary in abundance were selected oligochaete taxa (*Nais pardalis*, *Pristina leidyi*, and unidentified Naidinae). Overall, the macroinvertebrate community at Alexander Spring in 2015 was similar to the community in 2007.

Volusia Blue Spring

Blue Spring and run were sampled in 2007-2008 by the FDEP using their SCI methodology (Wetland Solutions, Inc. 2009). SJRWMD staff sampled the spring using the same SCI methodology in 2015-2016. Three 100 m reaches were sampled in both of these efforts: an upper reach near the headspring, a middle reach about halfway down the spring run, and a

Table 10. Comparison of taxa collected at Alexander Spring by Walsh et al. 2009 (collected in 2007; all equipment types and dates combined) with taxa collected in this study at ALE1 (macrophyte and macroalgal habitat and both seasons combined).

Taxon	Walsh et al.	This study	Taxon	Walsh et al.	This study
PLATYHELMINTHES			*Limnodrilus hoffmeisteri*	xx	xx
UnID flatworm	xx		*Nais communis*		xx
			Nais pardalis		xx
NEMATODA			*Pristina aequiseta*		xx
UnID nematode taxa		xx	*Pristina leidyi*	xx	xx
			Pristina spp.	xx	
MOLLUSCA			*Slavinia appendiculata*	xx	
Gastropoda			*Sparganophilus* spp.		xx
Amnicola dalli	xx		UnID Naididae spp.	xx	xx
Aphaostracon spp./cf *Aphaostracon* spp.	xx		UnID Naidinae spp.		xx
Laevapex fuscus		xx	UnID Tubificinae spp.		xx
Melanoides turricula	xx				
Melanoides spp.		xx	Hirudinea		
Physella (Haitia) cubensis	xx		*Erpobdella* spp.		xx
Planorbella scalaris	xx	xx	*Helobdella elongata*	xx	xx
Pleurocera floridensis	xx	xx	*Helobdella fusca*	xx	
Pomacea paludosa	xx		*Helobdella papillata*		xx
Spilochlamys gravis	xx		*Mooreobdella microstoma*	xx	
cf *Tarebia* spp.	xx		*Placobdella phalera*		xx
Viviparus georgianus		xx	*Placobdella* spp.		xx
UnID Hydrobiidae spp.	xx	xx	UnID Glossiphoniidae spp.	xx	
			UnID Hirudinea taxa	xx	
Bivalvia					
Pisidium spp.		xx	**ARTHROPODA**		
			Chelicerata-Acarina		
ANNELIDA			*Neumania* spp.	xx	
Oligochaeta			*Unionicola* spp.		xx
Bratislavia unidentata		xx			
Dero digitata	xx	xx	Crustacea-Amphipoda		
Dero nivea		xx	*Gammarus* cf *tigrinus*	xx	
Dero pectinata	xx		*Gammarus* spp.	xx	xx
Dero spp.	xx	xx	*Hyalella azteca* spp. complex	xx	xx
Eclipidrilus palustris		xx	UnID Gammaridea spp.	xx	xx

Table 10. Continued

Taxon	Walsh et al.	This study	Taxon	Walsh et al.	This study
Crustacea-Amphipoda			*Chironomus* spp.	xx	
UnID Amphipoda taxa	xx		*Cladopelma* spp.	xx	xx
			Cricotopus spp.		xx
Crustacea-Isopoda			*Cricotopus/Orthocladius* spp.		xx
Cassidinidea ovalis	xx		*Dicrotendipes* spp.	xx	xx
Cyathura polita		xx	*Larsia* spp.		xx
			Nanocladius spp.		xx
Crustacea-Decapoda			*Paralauterborniella nigrohalteralis*		xx
Palaemonetes paludosus	xx		*Polypedilum halterale* group	xx	
Palaemonetes spp.		xx	*Polypedilum nubifer*	xx	
Procambarus spp.	xx		*Polypedilum scalaenum* group	xx	
			Polypedilum spp.	xx	
INSECTA			*Pseudochironomus* spp.	xx	xx
Odonata-Zygoptera			*Tanypus carinatus*	xx	
Enallagma basidens		xx	*Tanypus* spp.	xx	xx
UnID Coenagrionidae spp.		xx	*Tanytarsus* spp.	xx	xx
			UnID Chironomidae spp.		xx
Odonata-Anisoptera					
Epitheca princeps regina	xx		Trichoptera		
			UnID Leptoceridae spp.	xx	
Ephemeroptera					
Caenis diminuta	xx	xx	Hemiptera		
Caenis spp.	xx	xx	*Trepobates subnitidus*	xx	
Callibaetis floridanus	xx		**TOTAL TAXA**	51	53
Tricorythodes albilineatus		xx			
UnID Baetidae spp.		xx			
Diptera-Ceratopogonidae					
UnID Ceratopogonidae spp.		xx			
Diptera-Chironomidae					
Ablabesmyia mallochi	xx				
Beardius truncatus		xx			

Table 11. Comparison of macroinvertebrate taxa richness collected at VOL1 in this study and those collected by FDEP (2007-2008) and SJRWMD (2015-2016) in the headspring area of Volusia Blue Spring.

Date	Total # Taxa (FDEP)	Total # Taxa (SJRWMD)	Date	Total # Taxa (This study)
Dip Net/SCI			Macroalgal Habitat	
10/10/2007	15			
2/12/2008	15			
6/23/2008	17			
11/5/2008	14			
			7/1/2015	10
			10/5/2015	9
11/12/2015		7		
3/16/2016		7		
6/9/2016		9		
9/21/2016		8		

lower reach near the confluence with the St. Johns River. The upper reach in these SCI efforts and transect VOL1 sampled in approximately the same area. Total taxa richness is one of the metrics calculated to determine the SCI, and these are compared among the various sampling efforts in Table 11. Taxa richness appeared to be higher in the earlier sampling by FDEP. Taxa richness collected by SJRWMD about the same time as this study was similar to the values collected in this study. Based on this comparison, taxa richness in the macroinvertebrate community may have declined over the past 8-9 years. The macroinvertebrate community in this spring has always been depauperate due to very low DO concentrations and high conductivity. The spring did go through a sustained low-flow period between 2012-2016. DO concentrations were minimal, and conductivities were at their highest, which may have contributed to the trends seen in the macroinvertebrate community.

The actual list of species collected by FDEP was not available. Over the one year of study, the most abundant taxa in the FDEP collections were the amphipods in the *Hyalella azteca* group, the oligochaete *Limnodrilus hoffmeisteri*, hydrobiid snails, and the chironomid *Chironomus* sp. Most of these were the most abundant taxa in this study; the amphipod, hydrobiids, and the midge. The oligochaete was not as abundant in this study. Overall, the composition of the macroinvertebrate community in Blue Spring appears similar between 2007-2008 and 2015, although overall taxa richness appears to have declined.

<u>Ichetucknee River</u>

The benthic macroinvertebrate community in the Ichetucknee River was sampled by a contractor for the Suwannee River Water Management District in 2003 (PBS&J and UF 2003). They sampled 31 stations one time in April 2003. They used a plankton net to sample the above-ground portion of submerged macrophyte habitat in a method similar to use of the

Hess sampler in this study; an area of vegetation was enclosed by the net and all above-ground plant material was harvested and captured in the net (with associated macroinvertebrates). Three replicate samples were collected at each station across the stream channel. Invertebrates were sorted from the collected plant material and identified to lowest practical taxonomic level. Because of limited budget in this earlier study, chironomids were not identified and enumerated by taxon as they were in this study. A qualitative subsample of chironomids from one replicate was examined to determine dominant genera present.

Total taxa richness was very similar in the two studies, 83 taxa in PBS&J and 81 taxa in this study (Table 12). Groups with highest taxa richness in one or both studies were molluscs, annelids (oligochaetes and leeches), chironomids and trichopterans (caddisflies; Table 12). Slightly higher gastropod taxa richness was seen in PBS&J, but this appears to be due to more complete identification; this study did not identify hydrobiids and ancylids to species whereas the earlier study did. Overall annelid taxa richness was similar in both studies (17 taxa), but there were some differences in composition. A similar assemblage of crustaceans and mayflies (Ephemeroptera) was seen in both studies. The overall aquatic insect composition was similar in both studies with some differences in the actual taxa collected, probably due to life history variation in individual insect taxa. A higher number of chironomid taxa were collected in this study, but that is probably due to the higher level of effort at identification and enumeration in the lab. Within each study, mean taxa richness at upstream and downstream reach locations was similar (Table 13), but mean taxa richness was considerably lower in the earlier PBS&J study compared to this study in both reaches (Table 13). Maybe this is due to differences in sampling devices, as the modified Hess sampler used in this study was designed for this type of sampling, whereas the plankton net was not.

Scanning through the individual replicate data at each station, highest abundance in the PBS&J study was exhibited by chironomids as a group and water mites (hydracarina). At a few of the downstream stations, the snail *Pleurocera floridensis* and oligochaete *Nais variabilis* exhibited highest abundance. At many stations the next most abundant taxon was the caddisfly *Hydroptila* spp. In this study, the chironomids *Dicrotendipes modestus* and *Cricotopus*/*Orthocladius* spp. exhibited the highest abundance, with the aquatic lepidopteran *Petrophila santafealis* exhibiting the next highest abundance at ICH1 in spring. At ICH2 in spring, highest abundance was exhibited by *Cricotopus*/*Orthocladius* spp. and *P. santafealis*; the chironomid *Pseudochironomus* spp. also exhibited high abundance at ICH2 in spring. In fall, highest abundance at ICH1 was exhibited by the chironomid *Dicrotendipes* spp. and *P. santafealis*, and at ICH2 by *Cricotopus*/*Orthcladius* spp., an unidentified tubificinid worm, and the chironomid *Rheotanytarsus* spp. Overall, chironomids dominated the abundance in both studies. However, in the earlier study water mites were generally the second most abundant taxon while in this study the aquatic moth *P. santafealis* was second in abundance.

<u>Rock Springs Run</u>

Lobinske et al. (1997) sampled the benthic macroinvertebrate community in Rock Springs Run from February 1993 to January 1995. They sampled 10 stations spaced equidistantly down the stream from headspring area to near the confluence with the Wekiwa Spring Run.

Table 12. Comparison of taxa collected in Ichetucknee River by PBS&J and UF 2003 (macrophyte habitat, collected April 2003, all stations combined) and this study (macrophyte habitat; both stations and seasons combined).

Taxon	PBS&J and UF	This study	Taxon	PBS&J and UF	This study
PLATYHELMINTHES			*Dero flabelliger*		xx
UnID flatworm	xx	xx	*Eclipidrilus palustris*		xx
			Eclipidrilus spp.	xx	xx
NEMERTEA			*Haber speciosus*		xx
UnID nemertean	xx		*Ilyodrilus templetoni*	xx	xx
			Limnodrilus claparedeianus	xx	
NEMATODA			*Limnodrilus hoffmeisteri*	xx	xx
UnID nematode taxa		xx	*Lumbriculus variegatus*	xx	
			Nais variabilis	xx	
MOLLUSCA			*Pristina leidyi*	xx	
Gastropoda			*Psammoryctides convolutus*		xx
Hebetancylis excentricus	xx		*Quistidrilus multisetosus*	xx	xx
Laevapex fuscus	xx		*Sparganophilus* spp.		xx
Menetus dilatatus	xx		*Varichaetadrilus angustipennis*		xx
Notogillia wetherbyi		xx	UnID Enchytraeidae spp.		xx
Physella cubensis		xx	UnID Naididae spp.	xx	
Physella spp.	xx		UnID Tubificidae spp.	xx	xx
Planorbella duryi	xx				
Planorbella spp.	xx		Hirudinea		
Pleurocera floridensis	xx	xx	*Batracobdella phalera*	xx	
UnID Ancylidae spp.	xx	xx	*Erpobdella punctata*		xx
UnID Hydrobiidae spp.	xx	xx	*Erpobdella* spp.		xx
UnID Gastropod taxa	xx		*Helobdella elongata*	xx	xx
			Helobdella fusca	xx	
Bivalvia			*Helobdella stagnalis*	xx	
Pisidium spp.		xx	*Helobdella triserialis*	xx	
Sphaerium spp.	xx		*Placobdella phalera*		xx
ANNELIDA			**ARTHROPODA**		
Oligochaeta			Chelicerata - Acarina		
Aulodrilus paucichaeta		xx	*Lebertia* spp.		xx
Aulodrilus pigueti	xx		*Limnesia* spp.		xx
Dero digitata	xx		*Mideopsis* spp.		xx

Table 12. Continued.

Taxon	PBS&J and UF	This study	Taxon	PBS&J and UF	This study
Sperchon spp.		xx	Ephemeroptera		
UnID Acarina	xx		*Caenis* spp.	xx	xx
			Tricorythodes albilineatus		xx
Crustacea-Amphipoda			*Tricorythodes* spp.	xx	
Gammarus cf *tigrinus*	xx		UnID Baetidae spp.	xx	xx
Gammarus spp.		xx	UnID Ephemeroptera taxa	xx	xx
Hyalella azteca spp. complex	xx	xx			
cf *Talitroides topotum*	xx		Coleoptera		
			Dineutus spp.	xx	
Crustacea-Isopoda			*Dubiraphia* spp.	xx	xx
Caecidotea spp.	xx	xx	*Stenelmis* spp.	xx	
UnID Isopod taxa		xx			
			Diptera-Ceratopogonidae		
Crustacea-Decapoda			*Palpmyia/Bezzia* spp.	xx	
Palaemonetes paludosus	xx		UnID Ceratopogonidae spp.		xx
Palaemonetes spp.		xx			
Procambarus spp.	xx		Diptera-Empididae		
UnID Cambaridae spp.		xx	*Hemerodromia* spp.	xx	xx
			UnID Empididae spp.		xx
INSECTA					
Collembola			Diptera-Stratiomyidae		
UnID taxa	xx		*Odontomyia* spp.	xx	
Odonata-Zygoptera			Diptera-Phoridae		
Argia spp.	xx		UnID Phoridae spp.		xx
Ischnura spp.	xx				
UnID Coenagrionidae spp.	xx		Diptera-Simuliidae		
			UnID Simuliidae spp.	xx	
Odonata-Anisoptera					
Hagenius brevistylus	xx	xx	Diptera-Chironomidae		
Pachydiplax longipennis	xx		*Ablabesmyia mallochi*	xx	xx
UnID Gomphidae spp.		xx	*Beardius* spp.		xx
UnID Libellulidae spp.	xx		*Chironomus* spp.	xx	xx

Table 12. Continued.

Taxon	PBS&J and UF	This study	Taxon	PBS&J and UF	This study
Clinotanypus sp.	xx	xx	*Hydroptila* spp.	xx	xx
Cricotopus spp.	xx		*Ochrotrichia* spp.		xx
Cricotopus/Orthocladius spp.		xx	*Oecetis* spp.	xx	xx
Cryptochironomus spp.		xx	*Orthotrichia* spp.	xx	xx
Dicrotendipes modestus		xx	*Oxyethira* spp.	xx	xx
Dicrotendipes spp.	xx	xx	*Polycentropus* spp.	xx	
Labrundinia pilosella	xx		*Triaenodes injustus*		xx
Labrundinia spp.	xx	xx	*Triaenodes* pp.	xx	
Paratanytarsus spp.	xx	xx	UnID Hydropsychidae spp.	xx	
Pentaneura inconspicua		xx	UnID Hydroptilidae spp.		xx
Pentaneura spp.	xx		UnID Leptoceridae spp.	xx	xx
Polypedilum convictum	xx	xx	UnID Polycentropodidae spp.	xx	
Polypedilum halterale group		xx	**TOTAL TAXA**	83	81
Polypedilum illinoense group	xx	xx			
Procladius spp.	xx	xx			
Pseudochironomus spp.	xx	xx			
Rheotanytarsus spp.	xx	xx			
Tanytarsus buckleyi		xx			
Tanytarsus spp.	xx	xx			
Thienemanniella xena		xx			
Thienemanniella spp.	xx	xx			
Thienemannimyia group spp.		xx			
UnID Chironomidae spp.		xx			
Lepidoptera					
Petrophila santafealis		xx			
Petrophila spp.	xx				
Trichoptera					
Cernotina spp.		xx			
Cheumatopsyche spp.	xx	xx			
Cyrnellus fraternus	xx				
Hydropsyche spp.		xx			

Table 13. Mean taxa richness in upstream and downstream reaches of the Ichetucknee River (range in parentheses).

	Mean # Taxa Upstream	Mean # Taxa Downstream
PBS&J and UF	Headspring Reach (Transects 1-4)	Floodplain Reach (Transects 15-31)
2003	8 (5-17)	8 (2-26)
This study spring	ICH1	ICH2
2015	21.3 (15-25)	25 (16-31)
This study fall	ICH1	ICH2
2015	22.3 (19-28)	22 (21-24)

Sampling was conducted using an Eckman dredge mounted on a pole. Samples were field sieved with a 350 micron mesh screen in the field, which was somewhat finer than the mesh size used in this study. Sampling was conducted monthly over the 2-year period and a single dredge sample was collected at each station each month. Some macroinvertebrate groups were identified to species or LPTL, while others (all crustacean groups, annelids, and Trichoptera) were only identified to major group (class, order, or family).

Walsh et al. (2009) sampled the headspring area near Rock Springs in 2005-06. As in Alexander Spring, they used two types of sampling equipment (as described above for Alexander Spring): the FDEP Stream Condition Index method, sampling with a dip net in a 100 m stretch (multiple habitats sampled) and a petite ponar dredge in areas of sandy sediment (three replicate samples). Sampling was conducted on four dates: December 2005 and March, June and September 2006.

Highest total taxa richness was seen in this study (95 taxa; Table 14). Walsh collected the next highest, and somewhat similar, taxa richness (83). Lobinske collected the fewest taxa (58). These are most likely due to differences in habitats sampled, sampling devices used and level of taxonomic effort. The Eckman grab used by Lobinske is designed to sample soft sediments, and it is likely he sampled in unvegetated areas that may have had some organic debris. Walsh used a larger grab (petite ponar) and supplemented this with the dip net sampling. This study sampled in vegetated habitat, which typically has higher taxa richness than unvegetated substrata (Camp et al. 2014), although see discussion in subsequent section. Lobinske did not identify oligochaetes, leeches, or crustaceans to species or LPTL, whereas the two later studies did.

Molluscs, annelids (oligochaetes and leeches) and chironomids generally dominated the taxa richness in the Walsh and this study (Table 14). Molluscs and chironomids were the dominant groups (in terms of taxa richness) in Lobinske (Table 14). Mollusc taxa composition was variable among the three studies, with few taxa common to all three (Table 14). Walsh collected more oligochaete taxa than in this study, while more leech taxa were collected in the latter (Table 14). Crustacean and aquatic insect taxa composition was somewhat similar in all three studies (Table 14), with Walsh and this study collecting more

Table 14. Comparison of taxa collected in Rock Springs Run by Lobinske, et al. 1997 (collected 1993-95); Walsh et al. 2009 (collected 2005-06) and this study. All habitats, stations, equipment types and dates combined in all studies.

Taxon	Lobinske et al.	Walsh et al.	This study	Taxon	Lobinske et al.	Walsh et al.	This study
COELENTERATA				UnID Hydrobiidae spp.		xx	xx
Hydra spp.		xx		UnID Gastropod taxa		xx	
PLATYHELMINTHES				Bivalvia			
UnID Tricladida taxa		xx		*Corbicula fluminea*	xx		xx
UnID flatworm		xx		*Elliptio* spp.	xx		
NEMATODA				**ANNELIDA**			
UnID nematode taxa	xx		xx	Oligochaeta			
				Allonais inaequalis		xx	
MOLLUSCA				*Bratislavia unidentata*		xx	
Gastropoda				*Dero digitata*		xx	
Amnicola dalli		xx		*Dero furcata*		xx	
Campeloma floridense		xx		*Dero* spp.		xx	
Elimia vanhyningiana	xx			*Eclipidrilus palustris*		xx	
Floridobia floridana	xx			*Eclipidrilus* spp.		xx	
Floridobia vanhyningi	xx			*Haber speciosus*		xx	
cf *Floridobia* spp.		xx		*Ilyodrilus templetoni*		xx	
Laevapex peninsulae		xx		*Limnodrilus hoffmeisteri*		xx	xx
Melanoides tuberculata	xx	xx	xx	*Lumbriculus variegatus*		xx	
Melanoides turricula		xx		*Lumbriculus* spp.		xx	
Melanoides spp. (immature)		xx		*Nais communis* complex		xx	
Notogillia wetherbyi			xx	*Nais* spp.		xx	
Physella cubensis			xx	*Pristina leidyi*		xx	
Planorbella scalaris			xx	*Slavinia appendiculata*		xx	
Planorbella trivolvis			xx	*Sparganophilus* spp.			xx
Pleurocera floridensis	xx	xx	xx	*Varichaetadrilus angustipennis*		xx	xx
Pomacea paludosa	xx	xx	xx	UnID Lumbriculidae spp.			xx
Pomacea spp.			xx	UnID Naididae spp.		xx	
Pyrgophorus platyrachis		xx		UnID Tubificidae spp.		xx	xx
Spilochlamys gravis	xx			UnID Oligochaete taxa	xx		
cf *Tarebia* spp.		xx					
UnID Ancylidae spp.		xx	xx				

Table 14. Continued.

Taxon	Lobinske et al.	Walsh et al.	This study	Taxon	Lobinske et al.	Walsh et al.	This study
Hirudinea				**INSECTA**			
Helobdella elongata			xx	Odonata-Zygoptera			
Helobdella papillata			xx	*Argia* spp.		xx	
Helobdella stagnalis		xx	xx	*Calopteryx dimidiata*	xx		
Placobdella spp.			xx	*Calopteryx maculata*	xx		
UnID Glossiphoniidae taxa			xx	*Enallagma* spp.		xx	
UnID Hirudinea taxa	xx			*Hetaerina titia*	xx		xx
				Ischnura kellicotti	xx		
ARTHROPODA				*Ischnura posita*	xx		
Chelicerata-Acarina							
Hydrodroma spp.		xx		Odonata-Anisoptera			
Lebertia spp.		xx	xx	*Aphylla williamsoni*	xx		
Limnesia spp.		xx	xx	*Dromogomphus armatus*	xx		
Mideopsis spp.			xx	*Dromogomphus spinosus*			xx
				Gomphus dilatatus	xx		
Crustacea-Amphipoda				*Macromia tainiolata*	xx		
Gammarus cf *tigrinus*		xx		*Macromia* spp.		xx	
Gammarus spp.		xx	xx	UnID Gomphidae spp.			xx
Grandidierella bonnieroides			xx				
Hyalella azteca spp. complex		xx	xx	Ephemeroptera			
UnID Ampipod taxa	xx			*Acentrella alachua*			xx
				Caenis diminuta	xx	xx	
Crustacea-Isopoda				*Caenis* spp.			xx
Caecidotea spp.		xx	xx	*Hexagenia limbata*	xx		
Cassidinidea ovalis		xx		*Hexagenia* spp.			xx
UnID Isopod taxa	xx			*Maccaffertium exiguum*			xx
				Neoephemera youngi	xx		
Crustacea-Decapoda				*Stenonema exiguum*	xx		
Palaemonetes paludosus		xx		*Tricorythodes albilineatus*		xx	xx
Palaemonetes spp.			xx	UnID Baetidae spp.			xx
Procambarus spp.		xx		UnID Heptageniidae spp.			xx
UnID Cambaridae spp.			xx				
UnID Decapod taxa	xx			Coleoptera			
				Dineutus spp.			xx

Table 14. Continued.

Taxon	Lobinske et al.	Walsh et al.	This study	Taxon	Lobinske et al.	Walsh et al.	This study
Dubiraphia spp.			xx	*Cladotanytarsus* spp.	xx		xx
Stenelmis spp.			xx	*Clinotanypus* spp.	xx		xx
UnID Elmidae spp.			xx	*Coelotanypus spp.*			xx
				Cricotopus bicinctus		xx	
Megaloptera				*Cricotopus politus*		xx	
Corydalus cornutus			xx	*Cricotopus* spp.		xx	xx
UnID Megaloptera taxa	xx			*Cricotopus/Orthocladius* spp.	xx		xx
				Cryptochironomus spp.	xx	xx	xx
Hemiptera				*Cryptotendipes* spp.	xx		
Merragata spp.		xx		*Demicryptochironomus* spp.	xx		
Mesovelia mulsanti		xx		*Dicrotendipes modestus*		xx	xx
				Dicrotendipes neomodestus		xx	xx
Diptera-Ceratopogonidae				*Dicrotendipes* spp.	xx	xx	xx
Palpmyia/Bezzia spp.		xx		*Epoicocladius* spp.	xx		xx
UnID Ceratopogonidae spp.			xx	*Fissimentum* spp.	xx		
				Labrundinia spp.			xx
Diptera-Empididae				*Larsia decolorata*		xx	
Hemerodromia spp.			xx	*Microtendipes* spp.	xx		
UnID Empididae spp.			xx	*Paracladopelma* spp.	xx		xx
				Paralauterborniella nigrohalteralis		xx	
Diptera-Ephydridae				*Paralauterborniella* spp.	xx		
Hydrellia spp.			xx	*Paramerina* spp.	xx		
UnID Ephydridae spp.			xx	*Paratanytarsus* spp.	xx		
				Pentaneura inconspicua		xx	
Diptera-Tipulidae				*Phaenopsectra* spp.	xx		
UnID Tipulidae spp.		xx		*Polypedilum convictum*			xx
				Polypedilum flavum		xx	
Diptera-Chironomidae				*Polypedilum illinoense* group			xx
Ablabesmyia mallochi			xx	*Polypedilum scalaenum* group		xx	xx
Ablabesmyia ramphe group		xx	xx	*Polypedilum tritum*		xx	
Ablabesmyia spp.	xx			*Polypedilum* spp.	xx		
Apedilum spp.	xx			*Procladius* spp.	xx		
Beardius spp.			xx	*Pseudochironomus* spp.	xx	xx	xx
Chironomus spp.	xx	xx		*Rheotanytarsus* spp.			xx

Table 14. Continued.

Taxon	Lobinske et al.	Walsh et al.	This study	Taxon	Lobinske et al.	Walsh et al.	This study
Stelechomyia spp.	xx			UnID Hydropsychidae spp.	xx	xx	
Stempellinella fimbriata		xx		UnID Hydroptilidae spp.	xx		xx
Stempellinella spp.		xx		UnID Leptoceridae spp.	xx		
Stenochironomus spp.	xx	xx	xx	**TOTAL TAXA**	58	83	95
Tanypus spp.	xx						
Tanytarsus buckleyi			xx				
Tanytarsus spp.	xx	xx	xx				
Thienemanniella similis			xx				
Thienemanniella xena			xx				
Thienemanniella spp.	xx	xx	xx				
Thienemannimyia group spp.			xx				
Tribelos spp.		xx					
UnID Orthcladiinae spp.		xx					
UnID Chironomidae spp.			xx				
UnID Dipteran taxa			xx				
Lepidoptera							
Paraponyx spp.			xx				
Petrophila santafealis			xx				
UnID Crambidae spp.			xx				
Trichoptera							
Cernotina spp.		xx	xx				
Cheumatopsyche spp.		xx	xx				
Hydropsyche rossi			xx				
Hydroptila spp.			xx				
Macrostemum carolina			xx				
Mayatrichia ayama			xx				
Nectopsyche pavida		xx					
Neureclipsis crepuscularis			xx				
Neureclipsis spp.			xx				
Nyctiophylax spp.			xx				
Oecetis spp.			xx				
Oxyethira spp.			xx				

crustacean taxa (due to more complete identification). Lobinske collected more odonate taxa than either of the later studies. All three collected similar numbers of chironomid taxa (26 in Lobinske, 23 in Walsh, 29 in this study). This study collected more trichopteran taxa than the two earlier studies (Table 14), which may be due to the vegetated habitats sampled in this study. Overall, a general conclusion of changes in benthic macroinvertebrate community composition in Rock Springs Run over time cannot be made from these data due to differences in sampling devices used, habitats sampled, and level of taxonomic effort.

<u>Silver Glen Spring</u>

Walsh et al. (2009) sampled the headspring area at Silver Glen Springs in 2007. As in Alexander Spring, they used two types of sampling equipment (as described above for Alexander Spring): the FDEP Stream Condition Index method, sampling with a dip net in a 100 m stretch (multiple habitats sampled) and a petite ponar dredge in areas of sandy sediment (three replicate samples). Sampling was conducted on four dates in 2007: January, May, August, and October. Their data were compared with the data we collected at SLG1.

Total taxa richness was similar in the two studies (Table 15), with this study collecting slightly more total taxa (74) than Walsh et al. (61). As with the other comparisons of this study and Walsh et al., differences are probably due to sampling devices and habitats sampled. Molluscs, annelids (oligochaetes and leeches), and chironomids were the most taxa-rich groups in Walsh et al., while annelids and chironomids had the most taxa in this study. Walsh et al. collected more taxa of molluscs (12 taxa vs. 4 in this study) and this study collected more taxa of chironomids (18 vs. 13 in Walsh et al.). Overall taxonomic composition was somewhat similar in the two studies (Table 15), with differences again due to sampling devices, habitats sampled, and life history variation in the taxa of invertebrates collected.

As seen in the other more mineralized ("salty") springs, a number of estuarine crustaceans were collected in Silver Glen Spring in both studies, with Walsh et al. collecting more taxa of both amphipods (7 vs. 3) and isopods (5 vs. 2). Estuarine amphipods included *Gammarus mucronatus* and *Grandidierella bonnieroides* (the latter collected in both studies). Estuarine isopods include *Cassidinidea ovalis*, *Cyathura polita* (both of which were collected in both studies) and *Uromunna reynoldsi*. Walsh et al. also collected an estuarine grass shrimp, *Palaemonetes vulgaris*, and this study collected two estuarine tanaid taxa.

Over the four sampling dates they sampled, Walsh et al. collected 19-24 taxa with the petite ponar grab and 14-19 taxa with the dip net (Table 16). This study collected substantially more total taxa, with 48 taxa collected in macrophyte habitat in May 2015 and 36 in October 2015 (Table 16). A total of 35 taxa were collected in macroalgal habitat in May 2015 (Table 16) and macroalgae habitat was not present at the sampling transect in October 2015.These differences are probably due to differences in sampling equipment and habitats sampled.

Table 15. Comparison of taxa collected at Silver Glen Spring by Walsh et al. 2009 (collected in 2007; all equipment types and dates combined) with taxa collected in this study (macrophyte and macroalgal habitat and both seasons combined).

Taxon	Walsh et al.	This study	Taxon	Walsh et al.	This study
PLATYHELMINTHES			*Haber speciosus*		xx
UnID Tricladida	xx		*Ilyodrilus templetoni*	xx	
UnID flatworm	xx	xx	*Limnodrilus hoffmeisteri*	xx	xx
			Lumbriculus spp.	xx	
NEMATODA			*Nais pardalis*		xx
UnID nematode taxa		xx	*Pristina aequiseta*		xx
			Pristina breviseta	xx	
MOLLUSCA			*Pristina leidyi*	xx	
Gastropoda			*Pristina* spp.	xx	
Aphaostracon spp./cf *Aphaostracon* spp.	xx		*Sparganophilus pearsei*		xx
cf *Floridobia* spp.	xx		*Sparganophilus* spp.		xx
Laevapex spp.	xx		*Varichaetadrilus angustipennis*		xx
Melanoides tuberculata	xx		UnID Enchytraeidae spp.		xx
Melanoides turricula	xx		UnID Lumbriculidae spp.		xx
Melanoides spp.	xx	xx	UnID Naididae spp.	xx	xx
Menetus floridensis		xx	UnID Naidinae spp.		xx
Planorbella scalaris	xx		UnID Tubificinae spp.		xx
Pleurocera floridensis	xx	xx	UnID Oligochaete taxa		xx
cf *Pyrgophorus platyrachis*	xx				
cf *Spilochlamys* spp.	xx		Polychaeta		
cf *Tarebia* spp.	xx		*Namalycastis* spp.		xx
UnID Hydrobiidae spp.	xx	xx			
			Hirudinea		
ANNELIDA			*Erpobdella punctata*		xx
Oligochaeta			*Erpobdella tetragon*		xx
Bratislavia unidentata		xx	*Gloiobdella elongata*	xx	
Chaetogaster diaphanus	xx		*Helobdella elongata*		xx
Dero digitata	xx	xx	*Helobdella stagnalis*		xx
Deero lodeni	xx				
Dero nivea		xx	**ARTHROPODA**		
Dero pectinata		xx	Chelicerata-Acarina		
Dero spp.	xx		*Arrenurus* spp.	xx	xx
Eclipidrilus palustris	xx	xx	*Atractides* spp.		xx

Table 15. Continued.

Taxon	Walsh et al.	This study	Taxon	Walsh et al.	This study
Frontipoda spp.		xx	Odonata-Zygoptera		
Limnesia spp.		xx	UnID Coenagrionidae spp.		xx
Unionicola spp.		xx			
			Ephemeroptera		
Crustacea-Amphipoda			*Caenis* spp.	xx	
Gammarus mucronatus	xx		*Callibaetis floridanus*		xx
Gammarus cf *tigrinus*	xx		*Callibaetis* spp.	xx	
Gammarus spp.	xx	xx	*Tricorythodes albilineatus*		xx
Grandidierella bonnieroides	xx	xx	UnID Ephemeroptera taxa		xx
Hyalella azteca spp. complex	xx	xx			
UnID Aoridae spp.	xx		Diptera-Ceratopogonidae		
UnID Amphipod taxa	xx		*Bezzia*/*Palpomyia* complex	xx	
			UnID Ceratopogonidae spp.		xx
Crustacea-Isopoda					
Caecidotea racovitzai australis	xx		Diptera-Simuliidae		
Caecidotea spp.	xx		UnID Simuliidae spp.		xx
Cassidinidea ovalis	xx	xx			
Cyathura polita	xx	xx	Diptera-Tipulidae		
Uromunna reynoldsi	xx		UnID Tipulidae spp.		xx
Crustacea-Tanaidacea			Diptera-Chironomidae		
Hargeria rapax		xx	*Ablabesmyia mallochi*		xx
UnID Leptocheliidae spp.		xx	*Chironomus* spp.	xx	
			Cladopelma spp.		xx
Crustacea-Decapoda			*Cladotanytarsus* cf *daviesi*	xx	
Palaemonetes paludosus	xx		*Cricotopus politus*	xx	
Palaemonetes vulgaris	xx		cf *Cricotopus* spp.	xx	
Procambarus spp.	xx		*Cricotopus*/*Orthocladius* spp.		xx
UnID Cambaridae spp.	xx	xx	*Cryptochironomus* spp.	xx	
			Dicrotendipes modestus		xx
INSECTA			*Dicrotendipes neomodestus*		xx
Collembola			*Dicrotendipes* spp.	xx	xx
UnID taxa		xx	*Goeldichironomus carus*	xx	
			Labrundinia spp.		xx

Table 15. Continued.

Taxon	**Walsh et al.**	**This study**			
Parachironomus spp.		xx			
Paracladopelma spp.		xx			
Polypedilum halterale group		xx			
Polypedilum illinoense group	xx	xx			
Polypedilum tritum/illinoense group	xx				
Procladius spp.		xx			
Pseudochironomus spp.	xx	xx			
Rheotanytarsus spp.		xx			
Tanypus spp.		xx			
Tanytarsus buckleyi		xx			
Tanytarsus limneticus	xx				
Tanytarsus spp.	xx	xx			
UnID Tanypodinae spp.	xx				
UnID Chironomidae spp.		xx			
Trichoptera					
Cernotina spp.		xx			
Hydroptila spp.		xx			
Orthotrichia spp.		xx			
UnID Hydroptilidae spp.		xx			
Hemiptera					
Pelocoris spp.		xx			
UnID Hemiptera taxa	xx	xx			
TOTAL TAXA	61	74			

Table 16. Comparison of invertebrate total taxa richness in Silver Glen Spring among sampling dates in Walsh et al. (2009) and this study.

Walsh et al. 2009	31 Jan 2007	10 May 2007	7 Aug 2007	10 Oct 2007
Petite ponar	22	24	21	19
Dip net	14	19	15	16
This study		20 May 2015		12 Oct 2015
Macrophyte habitat		48		36
Macroalgae habitat		35		No sample

Weeki Wachee River

One of the earliest studies of macroinvertebrate communities in Florida springs was conducted by Sloan (1954). He sampled aquatic insects in the Homosassa and Weeki Wachee Rivers. Six sampling stations were established on the Weeki Wachee River, from the headspring (Station W-1) to near the river mouth at the Gulf of Mexico (Station W-6). Invertebrates were sampled semi-quantitatively using a dip net ("25 meshes per inch"); five sweeps with the net were taken at each station each sampling date. Although not specified, it appears he largely sampled in submerged and emergent macrophyte habitats. Sampling was conducted between June 1953 and February 1954 and the biological sampling was conducted once at each sampling station.

The macroinvertebrate community of Weeki Wachee Spring and River was also sampled by Amec Foster Wheeler (2016b) in 2015. Six sampling stations were established on the river, from the headspring to the "head of tide" (the point where daily tidal variation in the river stage begins). They sampled multiple habitats (macrophyte, rock, woody snag, macroalgae, and sediment), largely using a dip net; an area of 0.125 m^2 was swept four times with the net to sample a total area of 0.5 m^2. Sediments were sampled with a petite ponar dredge. Sampling was conducted one time during the summer months of 2015 (July-September).

Sloan collected from 16 to 59 total taxa of aquatic insects. Fewer total taxa of insects were collected in this study; 19-36. Taxonomic composition was somewhat similar between Sloan and this study (Figure 30); in Sloan, dipterans (flies and midges), mayflies (Ephemeroptera), odonates and caddisflies (Trichoptera) comprised most if the overall taxa richness (Figure 30). In this study, dipterans (mostly chironomid midges), caddisflies, and mayflies comprised most of the taxa richness (Figure 30). The differences in sampling devices used and sampling locations make conclusions from this comparison tentative as to whether there has been a real change in the aquatic insect community in the river. Overall, taxa composition appears similar between 1953-54 and 2015, but declines in overall taxa richness or in taxa richness of certain groups such as mayflies, odonates and caddisflies may have occurred. WEE1 and WEE2 both appear to lie between W-1 and W-2 of Sloan. Additionally, Sloan only identified chironomids to tribe, whereas this study went to LPTL (genus or species in most cases).

In the 2015 study by Amec Foster Wheeler (2016b), their stations WEE-R-1 to WEE-R-4 sampled the same reach of the upper river as we sampled with WEE1 and WEE2. Basic

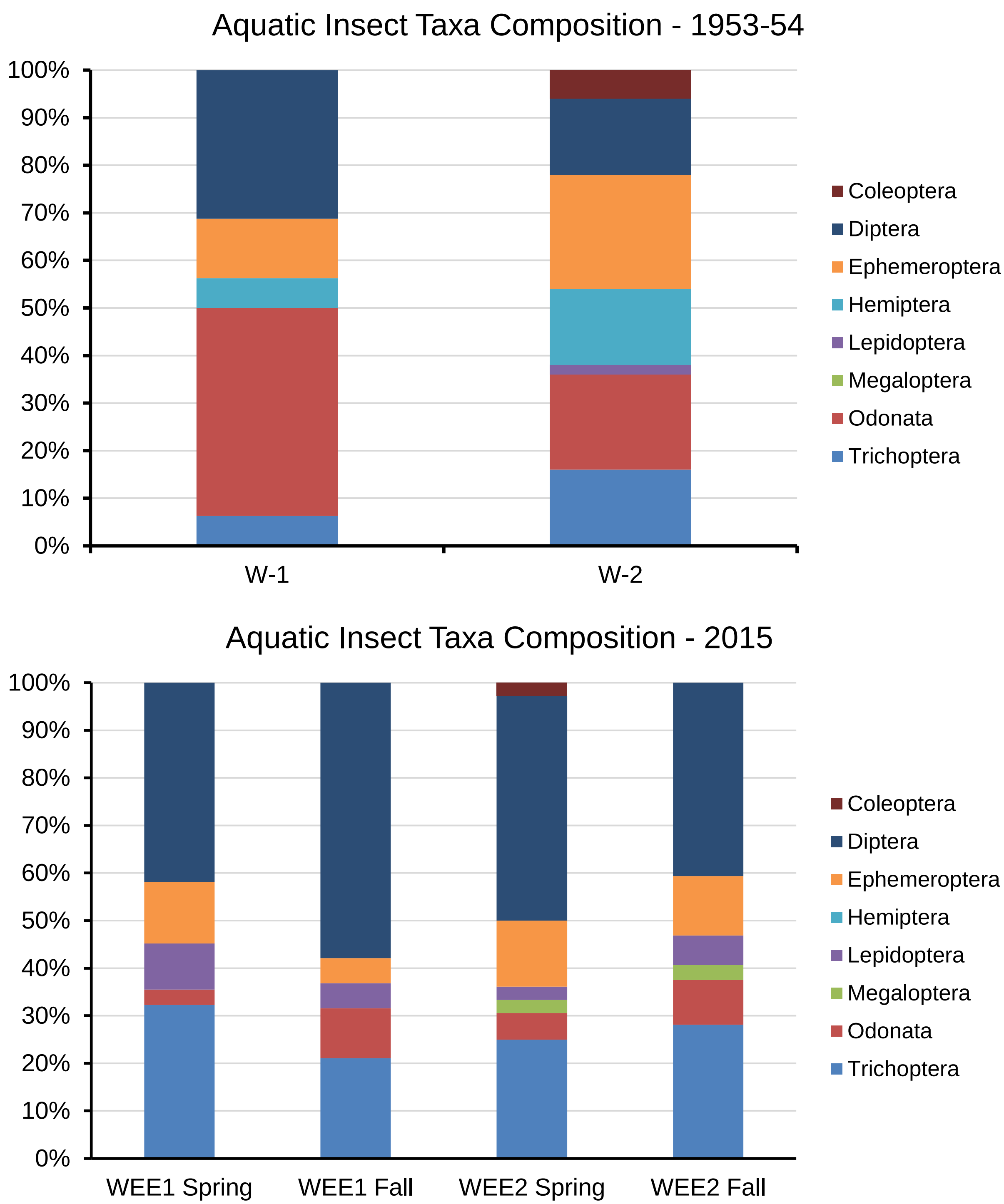


Figure 30. Aquatic insect major taxa composition in the upstream reach of the Weeki Wachee River from Sloan (1954) and this study. Compare W1 with WEE1 and W2 with WEE2.

descriptive statistics (mean taxa richness, mean density, and mean Shannon-Weiner Index) are compared in Figure 31. Mean taxa richness and diversity were very similar among the two studies. Abundance as density, however, was generally higher in this study (Figure 31).

Amec Foster Wheeler (2016b) found that crustaceans (mainly amphipods in the *Hyalella azteca* complex) and dipterans (mainly chironomid midges) were the major taxonomic groups present in macrophyte habitat on the Weeki Wachee River. Crustaceans (*Hyalella*) dominated the taxa composition in macroalgal habitat. This study had somewhat similar results; amphipods, chironomids, and hydroptilid caddisflies were the major taxonomic groups based on abundance in macrophyte habitat and amphipods and chironomids were dominant in macroalgal habitat. Multivariate analysis (Non-metric multidimensional scaling and ANOSIM) by Amec Foster Wheeler found that the macroinvertebrate community of macroalgal habitat was significantly different from the community associated with macrophyte habitat, similar to the results of this study. BEST (BIO-ENV) analysis found that DO, pH, turbidity and tree canopy cover were the environmental variables with the strongest influence on macroinvertebrate community structure, similar to the results of this study.

<u>Wekiva River</u>

Warren et al. (2000) sampled benthic macroinvertebrate communities in the Wekiva River in spring 1997 (May-June) and fall 1997 (October). They established three sampling stations in each of three reaches (100-200 m in length) in the upper, middle, and lower Wekiva River. Macroinvertebrates were sampled in multiple habitats, including submerged macrophyte, snag, floating-leaved marsh, emergent marsh (primarily beds of *Nuphar advena*), and unvegetated sediment. For sampling in submerged macrophyte habitat, they used a modified Hess-type sampler very similar to the device used in this study. They supplemented this quantitative sampling with additional sampling with dip net and sampling of sediment in macrophyte beds with a core sampler.

Walsh et al. (2009) sampled macroinvertebrates in the Wekiwa Spring headspring area on four dates between December 2005 and September 2006. As in the other springs they sampled, they used a petite ponar dredge in unvegetated sediments and the SCI method in a 100 m reach downstream of Wekiwa Spring.

Because of the comparability of the sampling equipment used, the taxa collected by Warren et al. and in this study were compared (Table 17). In this comparison, we are only listing the taxa collected in submerged macrophyte habitat in this study and in Warren et al. Warren et al. collected a substantially higher number of total taxa, 178, than this study, 77. This is in part due to greater sampling intensity, and to the use of multiple gear types in submerged macrophyte habitat (Hess sampler, core, and dip net). In both studies, molluscs, annelids (oligochaetes and leeches), and chironomids were the most species-rich major taxa (Table 17). While this study did not collect as many overall taxa as the earlier study by Warren et al., many of the taxa collected in this study were also collected in the earlier study (Table 17).

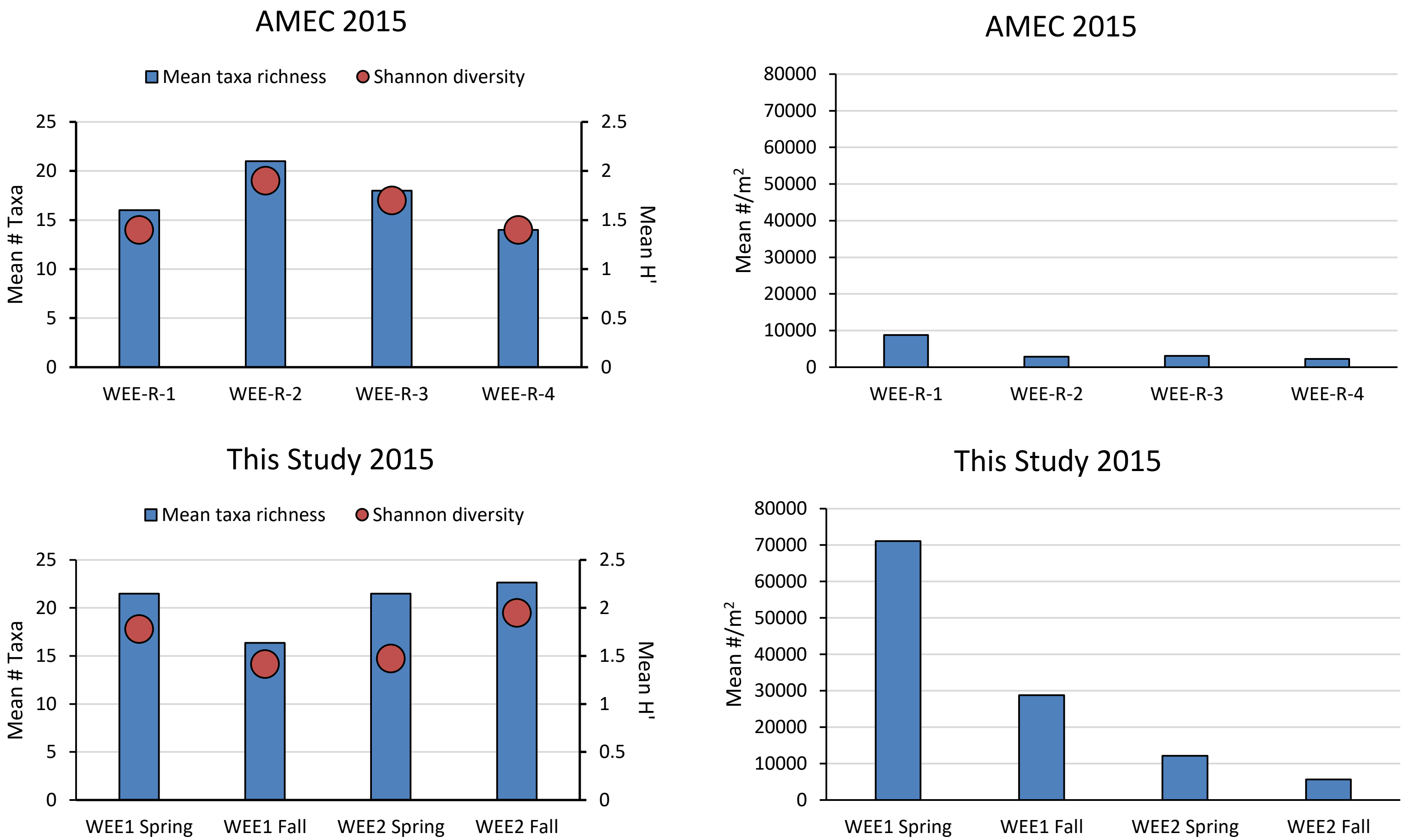


Figure 31. Comparison of mean taxa richness, Shannon-Weiner Diversity, and mean density of the macroinvertebrate community in the upper Weeki Wachee River sampled by Amec Foster Wheeler (2016b) and this study. All habitats combined. Compare Amec Foster Wheeler WEE-R-1 and WEE-R-2 with WEE1 and WEE-R-3 and WEE-R-4 with WEE2.

Table 17. Comparison of taxa collected in submerged macrophyte habitat in the Wekiva River by Warren et al. 2000 (collected 1997) and this study. All sample dates combined for both studies.

Taxon	Warren et al.	This study	Taxon	Warren et al.	This study
PORIFERA	xx		*Pomacea paludosa*	xx	xx
			Viviparus georgianus	xx	xx
CNIDARIA			UnID Ancylidae spp.	xx	xx
Cordylophora lacustris	xx		UnID Hydrobiidae spp.	xx	xx
Hydra spp.	xx		UnID gastropod taxa	xx	
PLATYHELMINTHES			Bivalvia		
UnID flatworm	xx		*Corbicula fluminea*	xx	xx
			Elliptio icterina	xx	
NEMERTEA			*Elliptio* spp.	xx	xx
UnID nemertean	xx		*Toxolasma* spp.	xx	
			Villosa spp.	xx	
NEMATODA			UnID Sphaeriidae spp.	xx	
UnID nematode taxa	xx	xx	UnID Unionidae spp.	xx	
			UnID bivalve taxa	xx	
MOLLUSCA					
Gastropoda			**ANNELIDA**		
Amnicola dalli	xx		Oligochaeta		
Amnicola dalli dalli	xx		*Allonais inequalis*	xx	
Campeloma floridense	xx		*Aulodrilus pigueti*	xx	
Gyraulus parvus	xx		*Bratislavia unidentata*	xx	xx
Hebetancylus excentricus	xx		*Chaetogaster diaphanous*	xx	
Laevapex fuscus	xx	xx	*Chaetogaster diastrophus*	xx	
Melanoides tuberculata		xx	*Chaetogaster* spp.	xx	
Melanoides turricula	xx		*Dero furcata*	xx	
Notogillia wetherbyi	xx		*Dero nivea*	xx	
Physella cubensis	xx	xx	*Dero pectinata*	xx	
Physella cubensis cubensis	xx		*Dero trifida*	xx	
Physella heterostropha pomila	xx		*Dero* spp.	xx	
Physella spp.	xx		*Eclipidrilus palustris*	xx	xx
Planorbella duryi	xx		*Limnodrilus hoffmeisteri*		xx
Planorbella scalaris	xx	xx	*Lumbriculus variegatus*/cf *variegatus*	xx	xx
Pleurocera floridensis	xx	xx	*Lumbriculus* spp.	xx	

Table 17. Continued

Taxon	Warren et al.	This study	Taxon	Warren et al.	This study
Nais communis	xx		Crustacea-Amphipoda		
Nais elinguis	xx		*Gammarus* spp.	xx	xx
Nais pardalis		xx	*Hyalella azteca* spp. complex	xx	xx
Nais variabilis	xx		UnID amphipod taxa	xx	
Nais spp.	xx				
Pristina aequiseta	xx		Crustacea-Isopoda		
Pristina leidyi	xx		*Caecidotea* spp.		xx
Pristina synclites	xx		*Cassidinidea ovalis*	xx	
Pristina spp.	xx		*Sphaeroma* spp.		xx
Pristinella osborni	xx				
Slavinia appendiculata	xx		Crustacea-Mysidacea		
Sparganophilus spp.		xx	*Taphromysis bowmani*	xx	
Stephensoniana trivandrana	xx				
Varichaetadrilus angustipennis	xx	xx	Crustacea-Decapoda		
UnID Enchytraeidae spp.	xx		*Palaemonetes paludosus*	xx	
UnID Lumbriculidae spp.		xx	Palaemonetes spp.		xx
UnID Naididae spp.	xx	xx	UnID Cambaridae spp.	xx	xx
UnID Tubificidae spp.	xx	xx			
UnID Aeolosomatidae spp.	xx		**INSECTA**		
			Collembola		
HIRUDINEA			UnID taxa	xx	
Erpobdella spp.		xx			
Helobdella elongata		xx	Odonata-Zygoptera		
Helobdella papillata		xx	*Enallagma coecum*	xx	
Helobdella stagnalis		xx	*Enallagma* spp.	xx	xx
UnID hirudinean taxa	xx		*Hetaerina titia*	xx	
			Ischnura spp.	xx	
ARTHROPODA			UnID Coenagrionidae	xx	
Chelicerata-Acarina					
Hydrodroma spp.		xx	Odonata-Anisoptera		
Lebertia spp.		xx	*Epitheca* spp.	xx	
Sperchon spp.		xx	*Macromia illinoiensis georgina*		xx
UnID Hydracarina spp.	xx		UnID anisopteran taxa	xx	
UnID Oribatidae spp.	xx				

Table 17. Continued.

Taxon	Warren et al.	This study	Taxon	Warren et al.	This study
Ephemeroptera			*Atrichopogon/Forcipomyia* spp.	xx	
Acentrella alachua	xx		*Ceratopogon* spp.	xx	
Baetis intercalaris	xx		*Palpomyia/Bezzia* spp.	xx	
Baetis spp.	xx		*Probezzia* spp.	xx	
Caenis diminuta	xx		UnID Ceratopogonidae spp.	xx	xx
Caenis spp.		xx			
Callibaetis floridanus	xx		Diptera-Empididae		
Hexagenia limbata	xx		*Hemerodromia* spp.	xx	xx
Procloeon hobbsi	xx				
Procloeon viridoculare	xx		Diptera-Ephydridae		
Procloeon spp.	xx		*Hydrellia spp.*		xx
Pseudocloeon ephippiatum	xx		*Notiphila* spp.	xx	
Pseudocloeon spp.	xx		UnID Ephydridae spp.	xx	
Sparburus maculatus	xx				
Tricorythodes albilineatus	xx	xx	Diptera-Muscidae		
UnID Baetidae spp.	xx	xx	UnID Muscidae spp.		
UnID Heptegeniidae spp.	xx				
			Diptera-Simuliidae		
Coleoptera			UnID Simulliidae spp.		xx
Dineutus spp.	xx	xx			
Gyrinus spp.	xx		Diptera-Tabanidae		
Microcylloepus pusillus	xx		UnID Tabanidae spp.	xx	
Stenelmis spp.	xx	xx			
UnID Elmidae spp.	xx		Diptera-Chironomidae		
UnID Gyrinidae spp.	xx		*Ablabesmyia mallochi*	xx	
			Ablabesmyia (*Karelia*) spp.	xx	
Hemiptera			*Ablabesmyia* spp.	xx	
Mesovelia mulsanti	xx		*Beardius truncatus*	xx	
			Beardius spp.		xx
Hymenoptera			*Cladopelma* spp.		xx
UnID Scelionidae spp.	xx		*Cladotanytarsus* spp.	xx	
			Clinotanypus spp.	xx	xx
Diptera-Ceratopogonidae			*Corynoneura* spp.	xx	
Atrichopogon spp.	xx		*Cricotopus bicinctus*	xx	

Table 17. Continued.

Taxon	Warren et al.	This study	Taxon	Warren et al.	This study
Cricotopus spp.		xx	*Thienemannimyia* group spp.		xx
Cricotopus/Orthocladius spp.	xx	xx	*Tribelos fuscicorne*		xx
Cryptochironomus spp.	xx	xx	UnID Chironomini spp.	xx	
Cryptotendipes spp.	xx		UnID Orthocladiinae spp.	xx	
Dicrotendipes modestus		xx	UnID Tanypodinae spp.	xx	
Dicrotendipes neomodestus	xx		UnID Tanytarsini spp.	xx	
Dicrotendipes spp.	xx	xx	UnID Chironomidae spp.		xx
Glyptotendipes spp.		xx			
Endotribelos hesperium	xx		Lepidoptera		
Labrundinia becki	xx		*Eoparargyractis* spp.	xx	
Labrundinia pilosella	xx		*Neargyractis* spp.	xx	
Labrundinia spp.	xx		*Paraponyx* spp.	xx	xx
Larsia decolorata	xx		*Petrophila drumalis*	xx	
Larsia indistincta	xx		*Petrophila* spp.	xx	
Larsia spp.	xx	xx	UnID Crambidae spp.		xx
Nanocladius spp.	xx		UnID lepidopteran taxa	xx	
Pagastiella spp.	xx				
Pentaneura inconspicua	xx		Trichoptera		
Polypedilum convictum		xx	*Cernotina* spp.	xx	
Polypedilum flavum	xx		*Cheumatopsyche* spp.	xx	xx
Polypedilum fallax group	xx		*Hydropsyche rossi/venularis*	xx	
Polypedilum halterale group	xx	xx	*Hydropsyche* spp.	xx	
Polypedilum illinoense group	xx	xx	*Hydroptila* spp.	xx	xx
Polypedilum scalaenum group	xx	xx	*Mayatrichia ayama*	xx	xx
Polypedilum tritum	xx		*Nectopsyche pavida*	xx	
Polypedilum spp.	xx		*Nectopsyche* spp.	xx	
Pseudochironomus spp.	xx	xx	*Neotrichia* spp.	xx	xx
Rheotanytarsus spp.	xx	xx	*Neureclipsis crepuscularis*		xx
Stempellinella spp.	xx		*Nyctiophylax* spp.	xx	
Tanytarsus buckleyi		xx	*Oecetis* spp.	xx	
Tanytarsus spp	xx	xx	*Orthotrichia* spp.	xx	
Thienemanniella cf. *similis*	xx		*Oxyethira* spp.	xx	xx
Thienemanniella xena		xx	UnID Hydropsychidae spp.	xx	
Thienemanniella spp.	xx	xx	UnID Hydroptilidae spp.	xx	

Table 17. Continued.

Taxon	**Warren et al.**	**This study**			
UnID Leptoceridae spp.	xx				
UnID Polycentropodidae spp.	xx				
TOTAL TAXA	178	77			

Many of the top 10 most abundant taxa collected by Warren et al. were also among the most abundant taxa in this study (Table 5). This includes the caddisflies *Hydroptila* spp. (rank #1 in this study, #2 in Warren et al.); the midges *Rheotanytarsus* spp. (rank #4 in this study, #1 in Warren et al.), the mayfly *Tricorythodes albilineatus* (rank #19 in this study, #6 in Warren et al.), and other midges (*Cricotopus*/*Orthocladius* spp., *Tanytarsus* spp.).

Mean taxa richness, mean density, and mean Shannon diversity (all stations and both sampling dates combined) were all lower in this study than measured by Warren et al. (Table 18). From this comparison, it is difficult to conclude that the benthic macroinvertebrate community in the Wekiva River has declined due to the high spatial and temporal variability characteristically exhibited by macroinvertebrate communities (Rosenberg and Resh 1993). The overall taxonomic composition of the macroinvertebrate community appears to be roughly similar between the two studies (Table 17), including the dominant taxa (discussion above).

Table 18. Comparison of descriptive statistics (mean, coefficient of variation in parentheses) for the macroinvertebrate community in submerged macrophyte habitat in the Wekiva River from Warren et al. (2000) and this study. All stations combined in both studies.

	Spring 1997	**Fall 1997**	**Spring 2015**	**Fall 2015**
Taxa richness	33 (0.19)	34 (0.18)	19.3 (0.24)	16.5 (0.12)
Density (#/m^2)	19,543 (0.52)	21,837 (0.79)	7,378 (0.19)	6,354 (0.99)
Diversity (H’)	3.20 (0.13)	3.32 (0.16)	1.9 (0.13)	2.0 (0.19)

A comparison of the abundance data collected in unvegetated sediments by Warren et al. (2000) with similar data collected by Walsh et al. (2009) indicates considerable variation in population density in the sediments (Figure 32), possibly due to different sample locations. Overall, it appears abundance in sediments has not changed appreciably over the period 1997-2006. There was less similarity in the dominant taxa collected by Warren et al. versus Walsh et al. Most abundant taxa in Warren et al. included the midges *Cladotanytarsus* spp. and *Polypedilum scalaenum* group (rank #1 and 2, respectively), the clam *Corbicula fluminea* (rank #3), the amphipod *Gammarus* spp. (rank #4) and unidentified oligochaetes. In Walsh et al. the most abundant taxon was the hydrobiid snail *Amnicola dalli*, second most abundant were midges in the genus *Tanytarsus*, third were unidentified hydrobiid snails, and fourth was the leech *Helobdella stagnalis*.

<u>Benthic macroinvertebrate communities of different spring-run habitats</u>

It is well-known that habitat is an important factor affecting benthic macroinvertebrate community structure (Merritt and Cummins 1996; Warren et al. 2000). Some macroinvertebrate taxa are specialized to exploit a particular habitat, while others are more generalist and found in a wide variety of habitats. In Florida spring-run streams, major

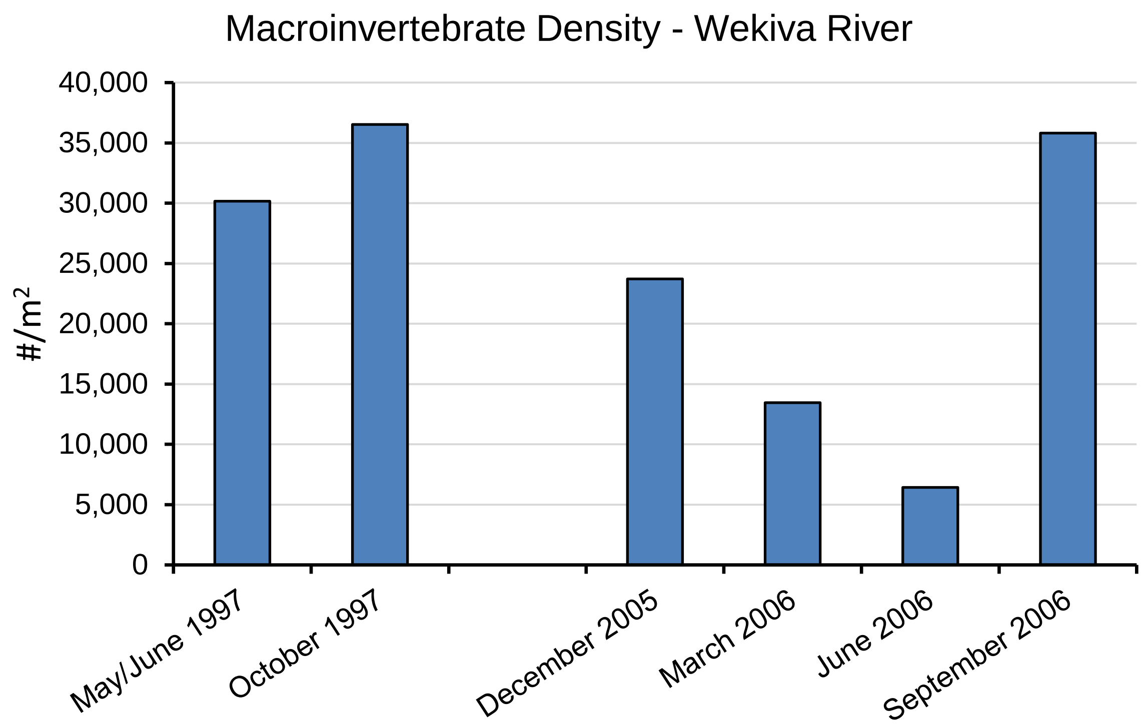


Figure 32. Comparison of macroinvertebrate abundance (as density, #/m^2) in unvegetated sediments collected in 1997 by Warren et al. (2000) and 2005-06 by Walsh et al. (2009) in the Wekiva River. Warren data are from multiple sites on the river while Walsh data are from the headspring area only.

habitats include bottom sediments (ranging from silt to sand), submerged macrophytes, macroalgal beds, snags (also called large woody debris), floating plant communities (water hyacinth, water lettuce, pennywort), and emergent marsh (with floating-leaved plants and emergent grasses, rushes, sedges, etc.). In this study we compared the macroinvertebrate communities of macrophyte and macroalgal habitat. As discussed above, other studies in Florida spring-run streams have sampled multiple habitats.

In general, submerged macrophyte and snag habitat support the most taxa-rich, diverse macroinvertebrate communities (Table 19). Unvegetated sediment and macroalgal beds generally supported lower total taxa richness compared to these two habitats, although Warren et al. (2000) measured highest total taxa richness in sediments versus the other habitats they sampled (Table 19). Lowest total taxa richness in the Wekiva River was measured in marsh habitat (dominated by *Nuphar advena*), possibly because of different habitat architecture. There have been few studies of macroinvertebrate communities in Florida marshes to compare this. Total taxa richness in the Homosassa River was somewhat higher in macroalgal habitat compared to the other spring-run streams, possibly because this is one of the dominant habitats in that river system (Table 19). Warren et al. (2000) and Steigerwalt (2005) measured considerably higher total taxa richness in the habitats they sampled, possibly due to more intensive sampling effort, resulting in more taxa collected.

Table 19. Comparison of macroinvertebrate total taxa richness in major spring-run stream habitats. Sources listed using superscripts. Blank cells indicate no samples were collected in that habitat or the habitat was not present at the sampling site/transect.

	Sediment	Macroalgae	Macrophyte	Snag	Nuphar
Alexander Springs Creek	46[3]	40[1]	81[1]		
Volusia Blue Spring		13[1]	N		
Chassahowitzka River	46[2]	50[2]	72[2]	80[2]	
Gum Slough		14[1]	80[1]		
Homosassa River	57[2]	68[2]		74[2]	
Ichetucknee River			81[1]; 83[4]	181[6]	
Juniper Creek			76[1]		
Manatee Spring		31[1]			
Rainbow River		42[1]	90[1]		
Rock Springs Run	66[3]	25[1]	94[1]		
Silver River			95[1]		
Silver Glen Spring	47[3]	35[1]	66[1]		
Wacissa River			95[1]		
Wakulla River		65[1]	82[1]		
Weeki Wachee River	29[2]	61[1]; 58[2]	94[1]; 76[2]	61[2]	
Wekiva River	39[3]; 166[5]		77[1]; 127[5]	163[5]	76[5]

1 – This study 2 – Amec Foster Wheeler 2016b 3 – Walsh et al. 2009 4 – PBS&J and UF 2003 5 – Warren et al. 2000 6 – Steigerwalt 2005

Changes in benthic macroinvertebrate communities over time

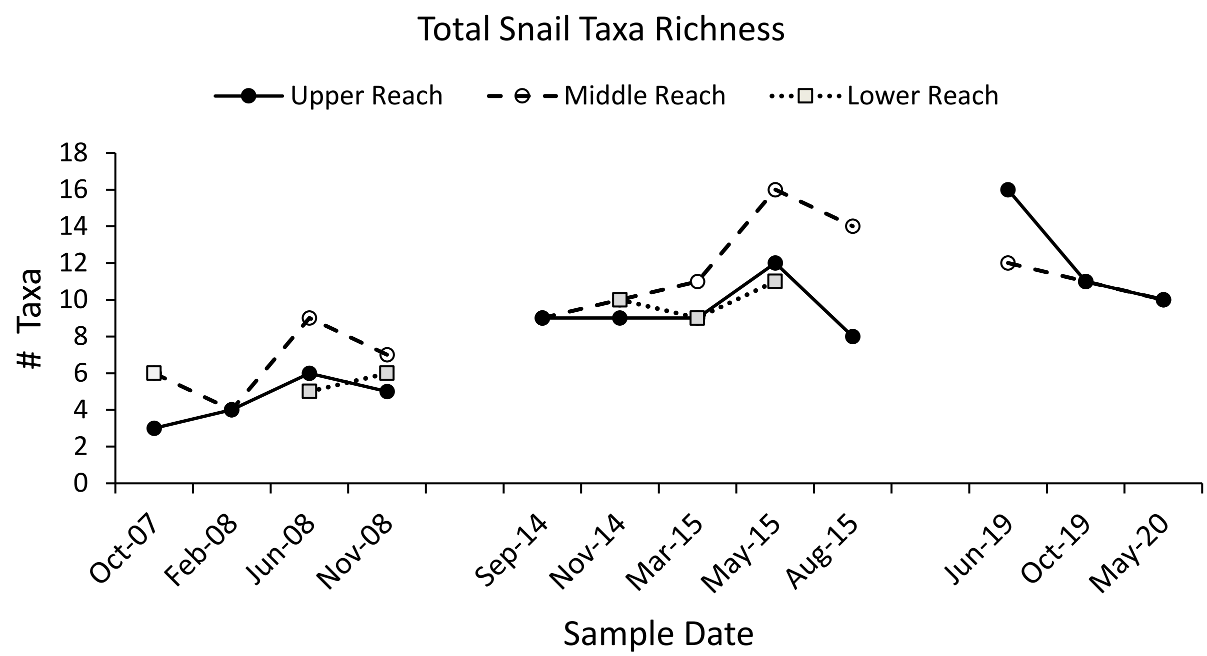
As may be seen in the discussions above, it is difficult to make conclusions or even general statements about changes in the benthic macroinvertebrate communities of Florida springs and spring-run streams over time due to the lack of consistently collected data over a long period (10-20 years or more). In terms of taxa richness and species composition, some systems appear to be relatively unchanged over the period assessed (Alexander Spring, Ichetucknee River), some may have experienced a decline in taxa richness (Volusia Blue Spring), and for some no conclusions can be drawn (Rock Springs Run, Silver Glen Springs, Wekiva River, Weeki Wachee River).

Even less can be concluded about changes in abundance over time. Differences in sampling devices used preclude making direct comparisons in abundance. The two studies where somewhat comparable equipment was used were in the Ichetucknee River (PBS&J and UF 2003) and the Wekiva River (Warren et al. 2000). Invertebrate abundance in the Ichetucknee ranged from 19-5,337 individuals (the actual count in the samples, not expressed per unit area). In this study abundance in the individual replicate samples from ICH1 and ICH2 ranged from 139-2,481 individuals, suggesting abundance is similar or somewhat lower now than historically, but again, several factors could contribute to the differences (sampling devices, life history characteristics, locations). In the Wekiva River, considerably lower mean abundance, as density, was measured in macrophyte habitat in this study versus that in Warren et al. (2000). Population density in unvegetated sediments appears not to have changed greatly comparing the data collected with petite ponar dredge in the Wekiva River by Warren et al. (2000) and Walsh et al. (2009), although the former sampled more of the river.

Monitoring of benthic macroinvertebrate communities has been used as a biological assessment tool in aquatic ecosystems for over a century (Rosenberg and Resh 1993, Merritt and Cummins 1996). More regular and consistent long-term monitoring of macroinvertebrates in spring-run streams would provide valuable data to assess their condition over time. Monitoring the entire benthic community is important but can be time-consuming and costly because of the effort and related cost to process the samples (sorting, identification, and enumeration). As seen in this study, gastropods (snails) are common, diverse, and abundant in spring-run stream ecosystems. Monitoring of snail populations in springs and spring-run streams may be a useful surrogate tool to evaluate the overall benthic macroinvertebrate community. In part, this is suggested because of evident changes in populations of some species in springs. The snail *Pleurocera* (formerly *Elimia*) *floridensis* was historically very abundant in many Florida springs. Franz (2002) noted the disappearance of this snail from Troy Spring (Lafayette County on the Suwannee River) and one of us (RAM) saw this snail disappear in Manatee Spring between 1989-2005. Dutoit (1979) did some quantitative sampling of snails in the Ichetucknee River in the late 1970s and measured a maximum abundance of *P. floridensis* of 11,889/m^2. PBS&J and UF (2003) measured a maximum abundance of 2,982/m^2. This study measured a maximum of 2,438/m^2, and it was only collected in one replicate at both ICH1 and ICH2. These observations suggest a broad-scale decline in the abundance of this snail in Florida springs.

At Volusia Blue Spring, the benthic macroinvertebrate community is known to be depauperate due to very low DO and high dissolved solids concentrations (WSI 2009). Despite this, a relatively species-rich snail fauna is present in the spring (Figure 33), and snails are abundant, reaching densities in the tens of thousands per m^2 (Figure 33). The snail population in this spring has been monitored three times since 2007 and appears to be stable (Figure 33). The snail community at Blue Spring is dominated by hydrobiids. Two of these are endemic to Blue Spring: the Blue Spring hydrobe (*Aphaostracon asthenes*) and the Pygmy siltsnail (*Floridobia parva*). Both are still routinely sampled in the spring and run, and *F. parva* is one of the most abundant snail taxa present and appears to stable over time (Figure 34).

A combination of the potential sensitivity of some snail taxa (e.g., *P. floridensis*) and the persistence of a relatively diverse snail population in Blue Spring, despite generally harsh physicochemical conditions, suggests that monitoring snail populations as a “sentinel group” for spring biology may be useful. Monitoring the entire benthic community would be most valuable in terms of the data generated, but snail population monitoring may be a viable alternative for monitoring springs biology.



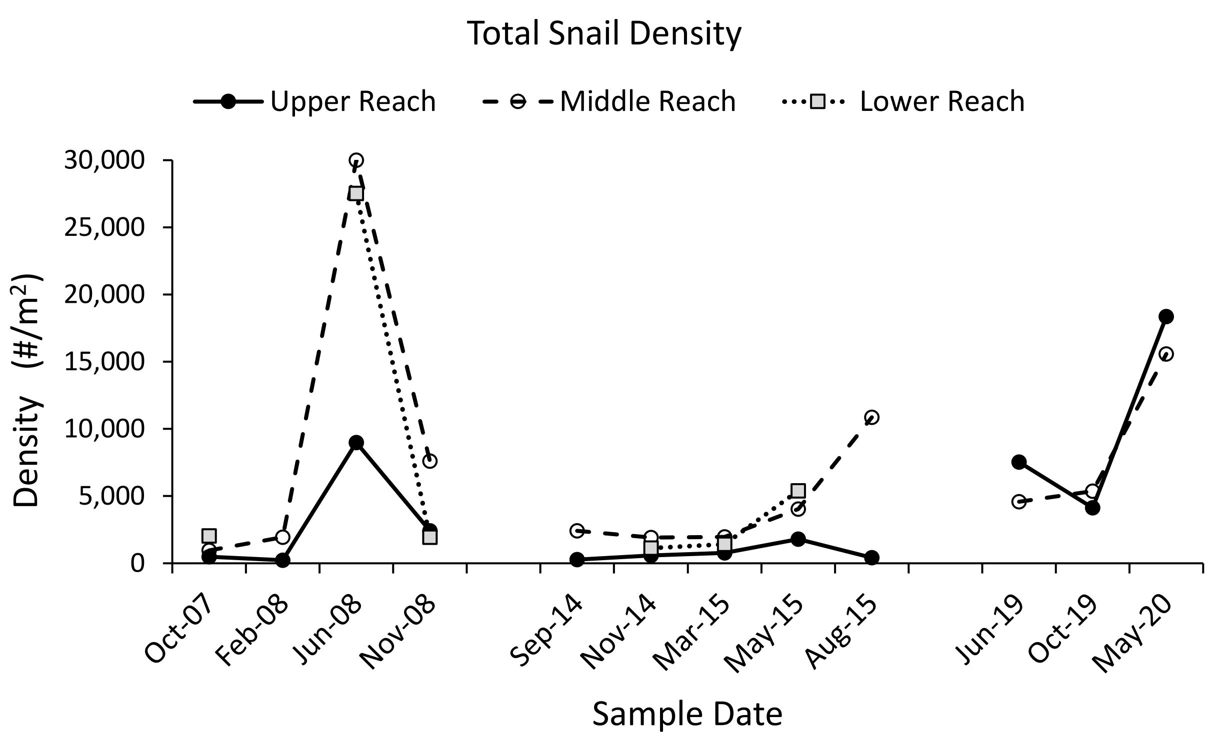


Figure 33. Taxa richness and density of snails in Volusia Blue Spring and run over the period 2007-2020. Data from Wetland Solutions, Inc. (2009) and unpublished SJRWMD data.

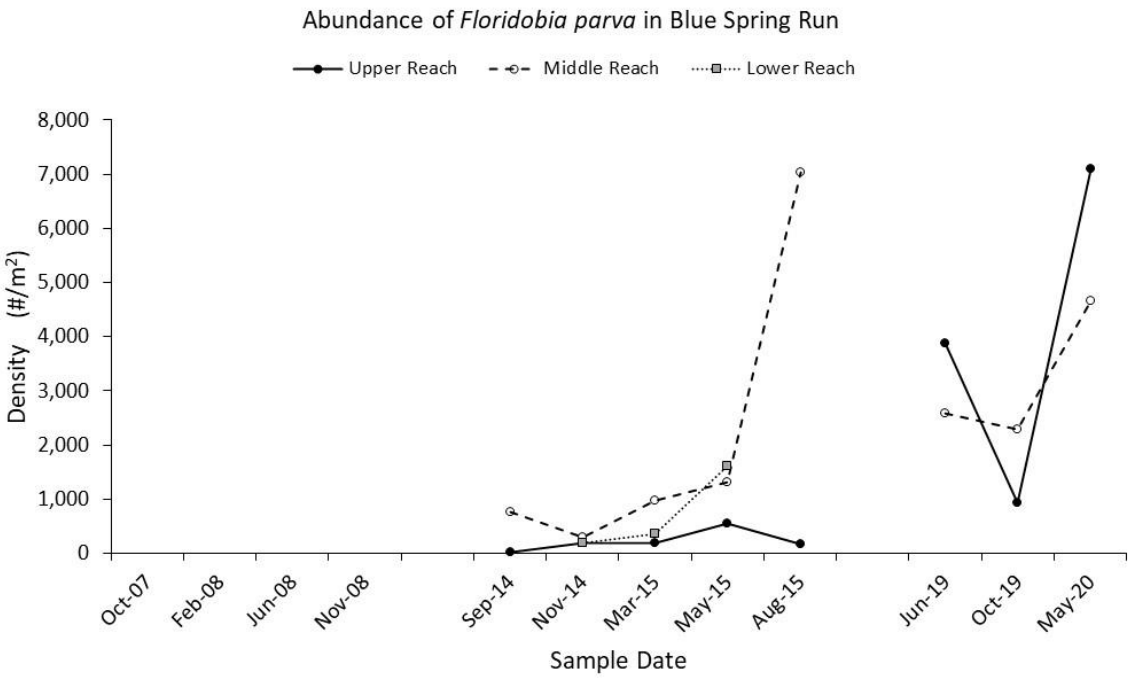


Figure 34. Density of *Floridobia parva* in Volusia Blue Spring. Snails not identified to species in the 2007-2008 period.

CONCLUSIONS AND RECOMMENDATIONS

Fourteen springs and their associated spring-run streams in north and central Florida were intensively sampled in 2015 for selected physicochemical characteristics and quantitative measurement of submerged aquatic vegetation (SAV – macrophytes and algae) and associated macroinvertebrates. This report is the third and last in the series, "Synoptic Biological Survey of 14 Spring-Run Streams in North and Central Florida". This report presents the macroinvertebrate community data.

Florida springs and their associated spring-run streams exhibit a wide range of flow and water chemistry characteristics (dissolved solids, nutrient concentrations, etc.). Springs along the mainstem of the St. Johns River system generally exhibited higher concentrations of dissolved salts and minerals than non-SJR associated springs.

Macroinvertebrates were sampled in two SAV habitats in the 14 spring-run streams: macrophytes and macroalgal beds. On most streams, two sampling transects were established; one near the headspring area and the other downstream in the spring run proper. Three transects were established on Silver River (one in the headspring area and two downstream) and one transect was established on the systems with short spring-runs (Volusia Blue, Manatee, and Silver Glen Springs). Sampling was conducted in the spring and fall of 2015. No consistent trends in macroinvertebrate community measures (taxa richness, diversity or abundance as density) were seen between upstream and downstream sampling locations

A total of 230 macroinvertebrate taxa was collected from submerged macrophyte habitat. Dominant major groups (highest taxa richness) included chironomid midges, annelids (oligochaetes and leeches), and trichopterans (caddisflies). Highest total taxa richness in spring was seen at the downstream Juniper Creek transect; in fall highest total taxa richness was seen at the downstream Silver River transect. Mean taxa richness exhibited considerable spatial and temporal variation and no clear trends among streams or between the two sampling seasons were seen. Shannon-Weiner diversity and Margalef's Species Richness likewise varied considerably, and no clear trends were evident spatially or temporally.

Abundance was measured in two ways; as number of individuals per m^2 based on the area of the sampling device used, and number of individuals per gram of plant dry weight in the sample. In macrophyte habitat, mean abundance was generally similar or lower in the fall sampling period versus spring. Highest mean abundance in the spring was seen at the upstream Gum Slough transect (both as $\#/m^2$ and #/g dry wt plant biomass). Highest abundance in the fall was seen at the upstream Wacissa River transect as $\#/m^2$ and at the upstream Gum Slough transect as #/g dry weight biomass). The most abundant macroinvertebrate taxon in macrophyte habitat was the caddisfly *Hydroptila* spp.

A total of 136 macroinvertebrate taxa was collected from macroalgal beds. Similar to the macrophyte habitat, dominant major groups by number of taxa were chironomids, annelids, and caddisflies. Highest total taxa richness in spring was seen at the downstream Wakulla

River transect; highest fall total taxa richness was seen at the downstream transect on the Weeki Wachee River. Mean taxa richness generally mirrored total taxa richness and no clear spatial or temporal trends were discerned. Shannon-Wiener diversity and Margalef's Species Richness tended to mirror spatial and temporal trends in mean taxa richness. Total and mean taxa richness was generally similar in both seasons (spring and fall) at many transects. Differences in Shannon diversity and Margalef's Species Richness were variable among transects and seasons, with no clear patterns evident.

Highest mean abundance in macroalgal habitat was typically seen at the upstream Weeki Wachee transect, WEE1 (both measures of abundance), except for fall abundance as #/g plant biomass, when GUM1 exhibited highest abundance. No clear trends in seasonal differences (spring versus fall) were evident, although highest abundance was seen in spring.

Environmental drivers that were most commonly identified by the BIO-ENV analysis as influencing macroinvertebrate community structure were conductivity, DO, pH, water depth and current velocity. In macrophyte habitat, generally higher invertebrate taxa richness and abundance was associated with higher macrophyte biomass. In macroalgal habitat, higher taxa richness was associated with lower macroalgal biomass, while higher abundance was associated with higher algal biomass.

Macrophyte habitat consistently supported higher invertebrate mean taxa richness than macroalgal habitat. Comparisons of invertebrate mean abundance were mixed, with higher abundance in macrophyte habitat in some transects and the opposite (higher abundance in macroalgal habitat) at other transects. This and other studies comparing invertebrate communities in macrophyte versus macroalgal habitat indicate similar patterns; higher invertebrate taxa richness and diversity in macrophyte habitat but higher abundance in macroalgal habitat.

Invertebrate functional feeding guilds in macrophyte habitat were primarily collector-gatherer and piercer groups (as relative abundance). Collector-filtering invertebrates had moderate abundance, as they use the blades of the macrophytes for attachment. In macroalgal habitat, collector-gatherers overwhelmingly dominated the relative abundance. In macrophyte habitat, aquatic insect life habit modes were mostly clinger taxa. In macroalgal habitat, burrowers, climbers, and sprawlers comprised the bulk of the life habit modes. These differences are likely due to a combination of structural/architectural differences in the two habitats and food resource availability.

Direct comparisons of the macroinvertebrate data collected in this study with prior surveys in these spring-run streams are problematic due to differences in sampling equipment used, differences in locations sampled, and level of taxonomic effort, along with taxonomic changes over time. Some streams appear to have an invertebrate community similar to past studies (Alexander Springs Creek, Ichetucknee River), some may have exhibited a decline in the community as taxa richness, diversity, and/or abundance (Volusia Blue Spring, maybe Wekiva River). In many streams no definitive conclusions can be drawn (Rock Springs Run, Weeki Wachee, Wekiva River). In comparing overall taxa composition in this and previous studies, chironomid midges, annelids, molluscs, and/or caddisflies tended to be the dominant major groups in terms of number of taxa.

A program to regularly monitor the benthic macroinvertebrate community in some of these spring-run streams would generate valuable data to evaluate biological condition over time, as macroinvertebrate communities have been used as bioassessment tools for decades. In lieu of this, monitoring of snail populations in these streams may be valuable as a surrogate for the overall benthic macroinvertebrate community and may be done more cost-effectively.

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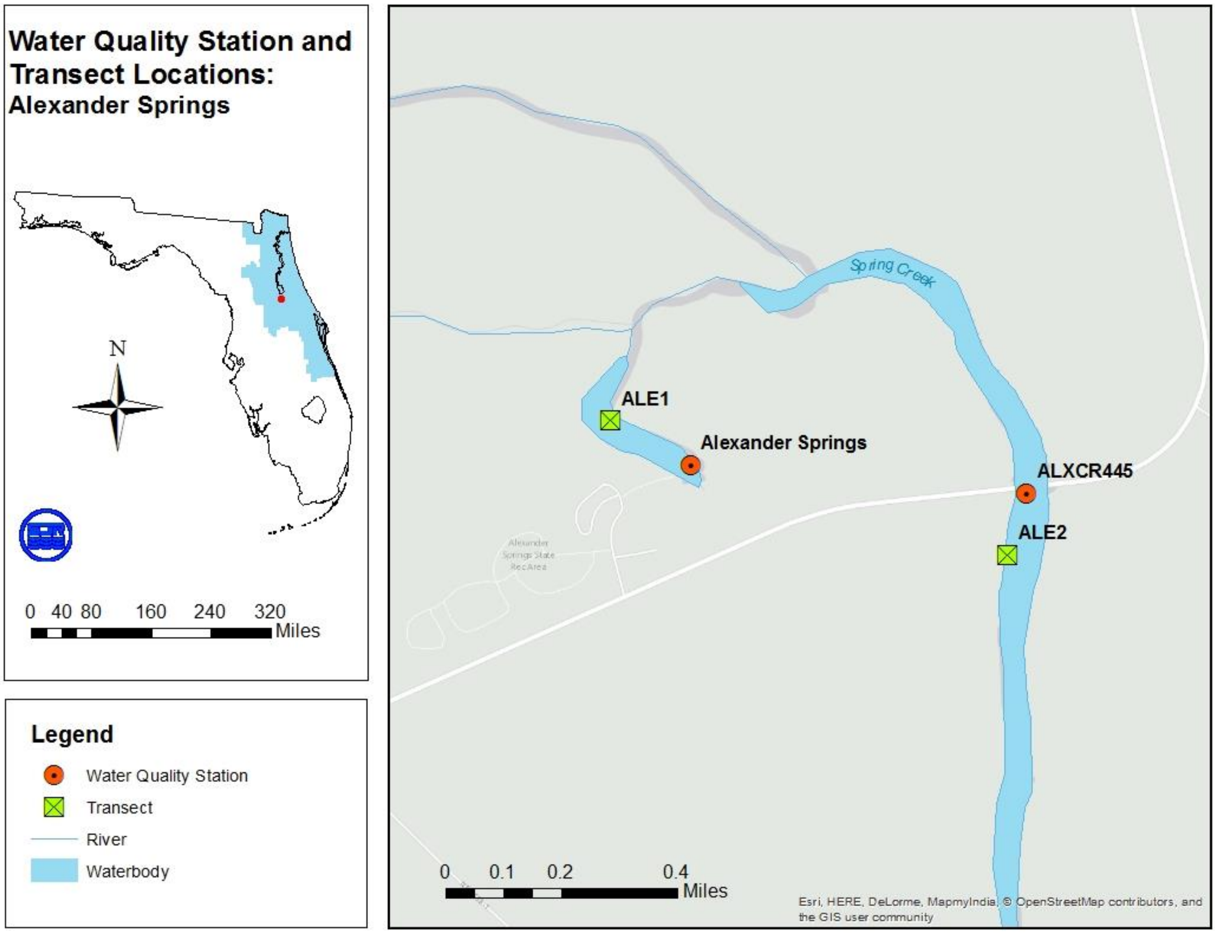
APPENDIX A—TABLE OF ST. JOHNS RIVER SPRINGS DISCHARGE DATA

Appendix A Table1. Average discharge rate, magnitude, and data period of record of 25 springs in SJRWMD. Shading indicates first, second, and third magnitude. Data from SJRWMD databases and table from Di and Mattson (unpublished report).

Spring	Mean Discharge (cfs)	Magnitude	Start	End*
Silver Springs	714	First	10/1932	04/2014
Blue Spring - Volusia	144	First	03/1932	09/2013
Alexander Springs	102	First	02/1931	04/2014
Silver Glen Springs	101	First	03/1931	09/2011
Salt Springs	79	Second	02/1929	06/2014
Croaker Hole Spring	69	Second	07/1998	03/2014
Wekiwa Springs	62	Second	03/1932	03/2014
Rock Springs	54	Second	02/1931	05/2014
Apopka Spring	25	Second	05/1971	03/2014
Ponce De Leon Springs	23	Second	02/1983	06/2014
Sanlando Springs	19	Second	11/1941	05/2014
Sweetwater Springs	13	Second	11/1980	06/2014
Starbuck Spring	12	Second	07/1944	05/2014
Bugg Spring Run	11	Second	03/1990	10/2013
Fern Hammock Springs	11	Second	12/1935	04/2014
Juniper Springs	11	Second	04/1935	04/2014
Gemini Springs	10	Second	04/1972	05/2014
Palm Springs - Seminole	6	Third	11/1941	05/2014
Miami Springs	5	Third	08/1945	05/2014
Orange Spring	3	Third	09/1972	06/2014
Holiday Springs Dstm	3	Third	04/1946	10/2011
Green Cove Spring	3	Third	02/1929	06/2014
Blue Spring Yal Run	3	Third	01/2002	10/2011
Double Run Spring	2	Third	10/1991	10/2011
Green Springs	1	Third	04/1972	05/2014

APPENDIX B—MAPS OF SAMPLING SITES


Water Quality Station and Transect Locations:
Alexander Springs
N
0 40 80 160 240 320
Miles
Legend
Water Quality Station
Transect
River
Waterbody
Spring Creek
ALE1
Alexander Springs
ALXCR445
ALE2
0 0.1 0.2 0.4
Miles
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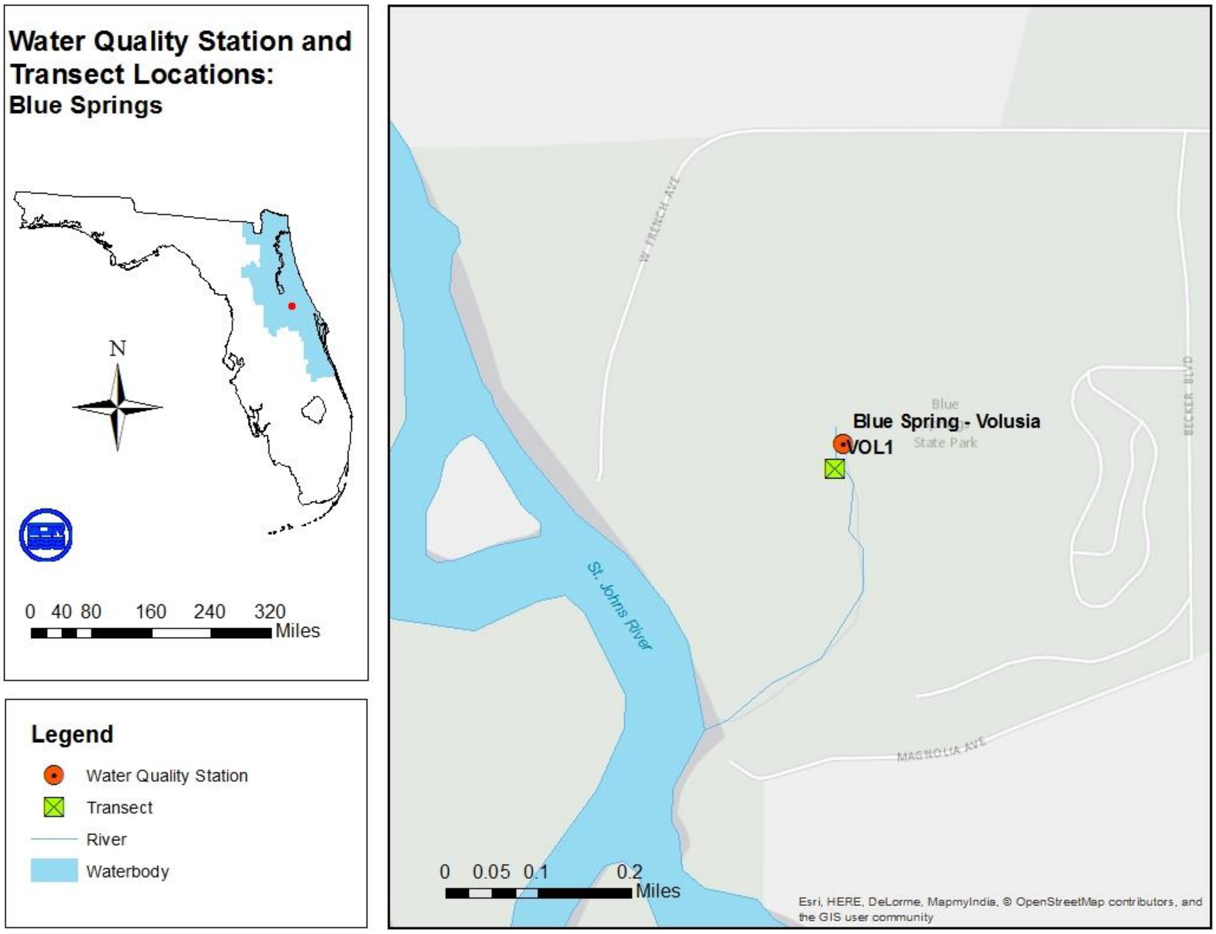
Water Quality Station and Transect Locations:
Blue Springs
N
0 40 80 160 240 320
Miles
Legend
Water Quality Station
Transect
River
Waterbody
W FRENCH AVE
Blue Spring - Volusia
VOL1
Blue Spring State Park
St. Johns River
MAGNOLIA AVE
0 0.05 0.1 0.2
Miles
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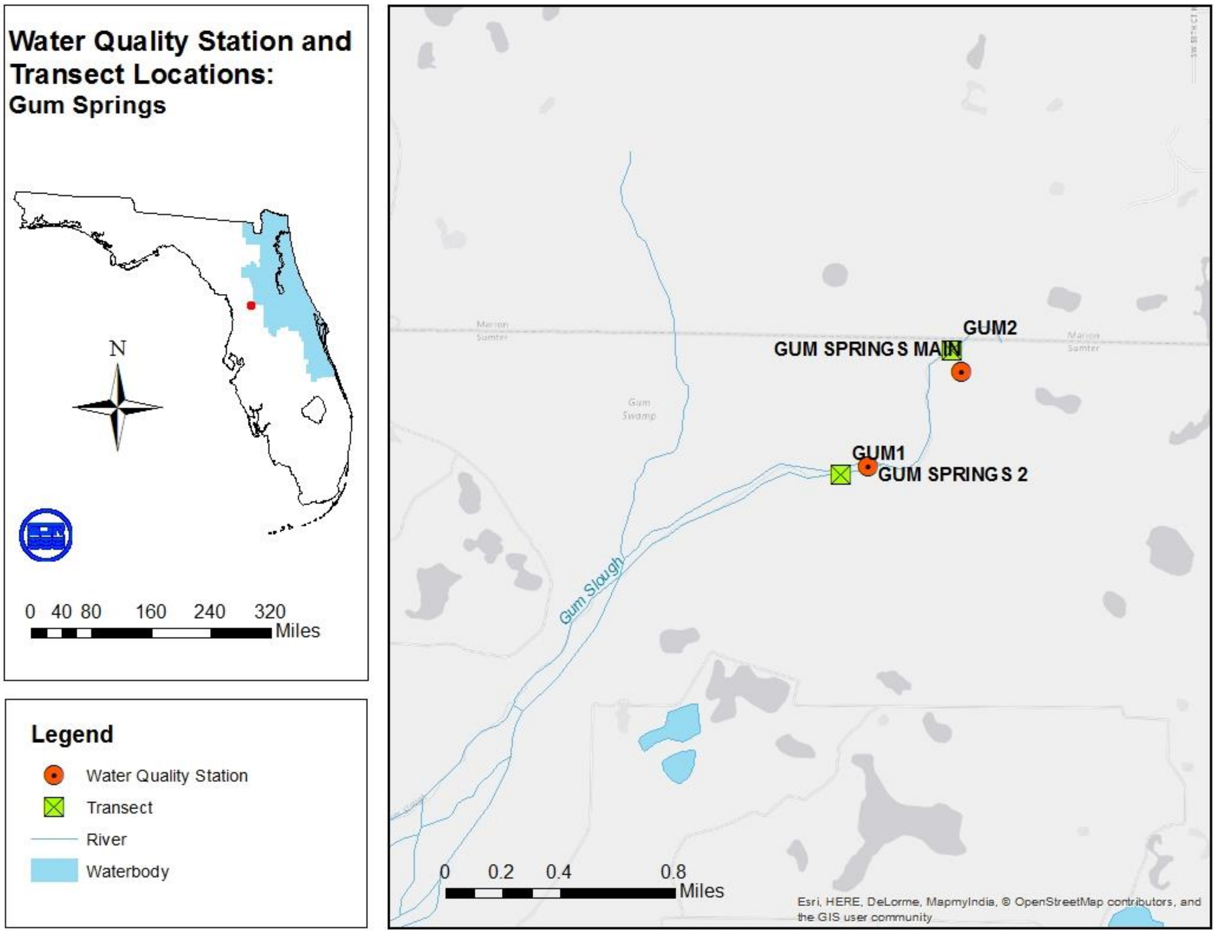
Water Quality Station and Transect Locations:
Gum Springs
N
0 40 80 160 240 320
Miles
Legend
Water Quality Station
Transect
River
Waterbody
GUM2
GUM SPRINGS MAIN
GUM1
GUM SPRINGS 2
Gum Slough
0 0.2 0.4 0.8
Miles
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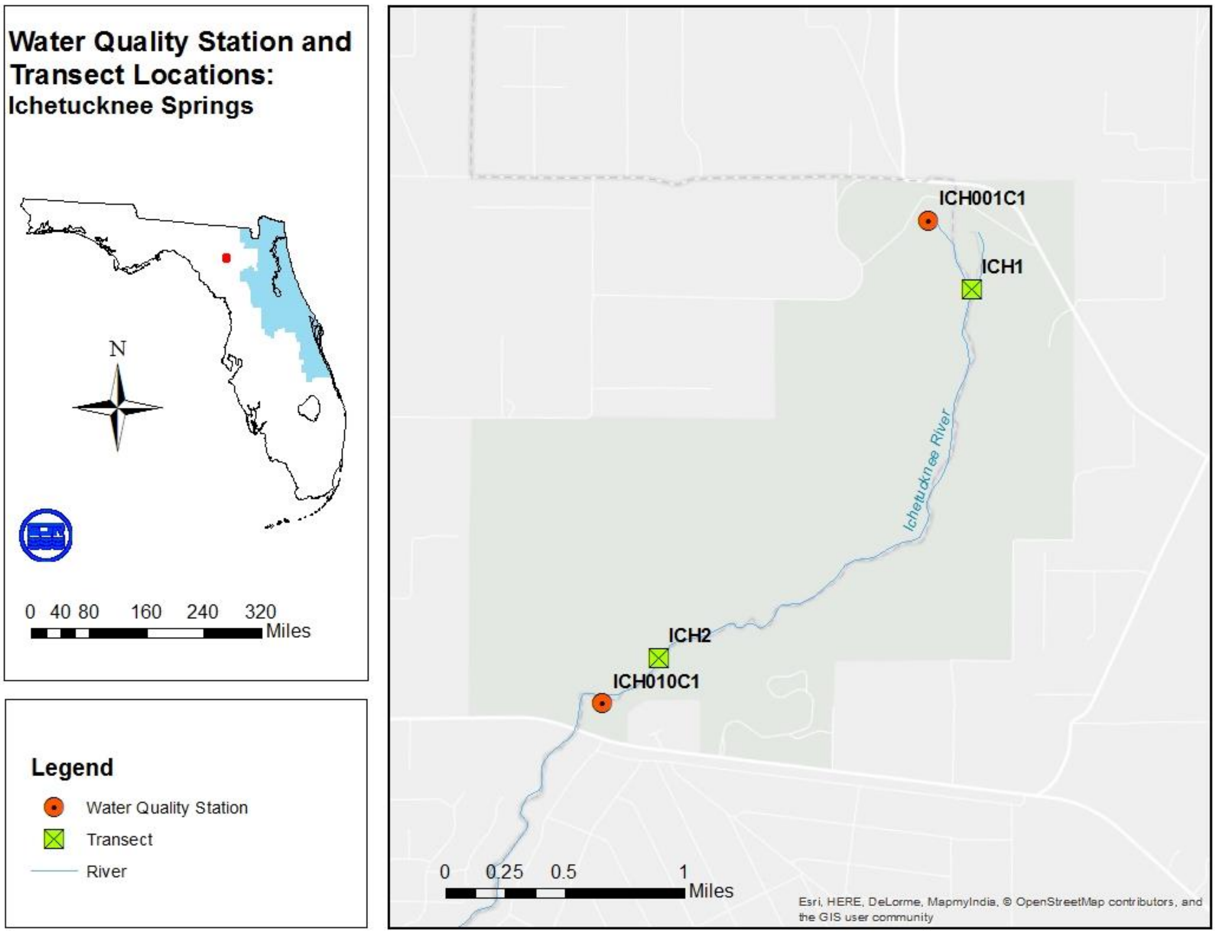
Water Quality Station and Transect Locations:
Ichetucknee Springs
N
0 40 80 160 240 320
Miles
Legend
Water Quality Station
Transect
River
ICH001C1
ICH1
Ichetucknee River
ICH2
ICH010C1
0 0.25 0.5 1
Miles
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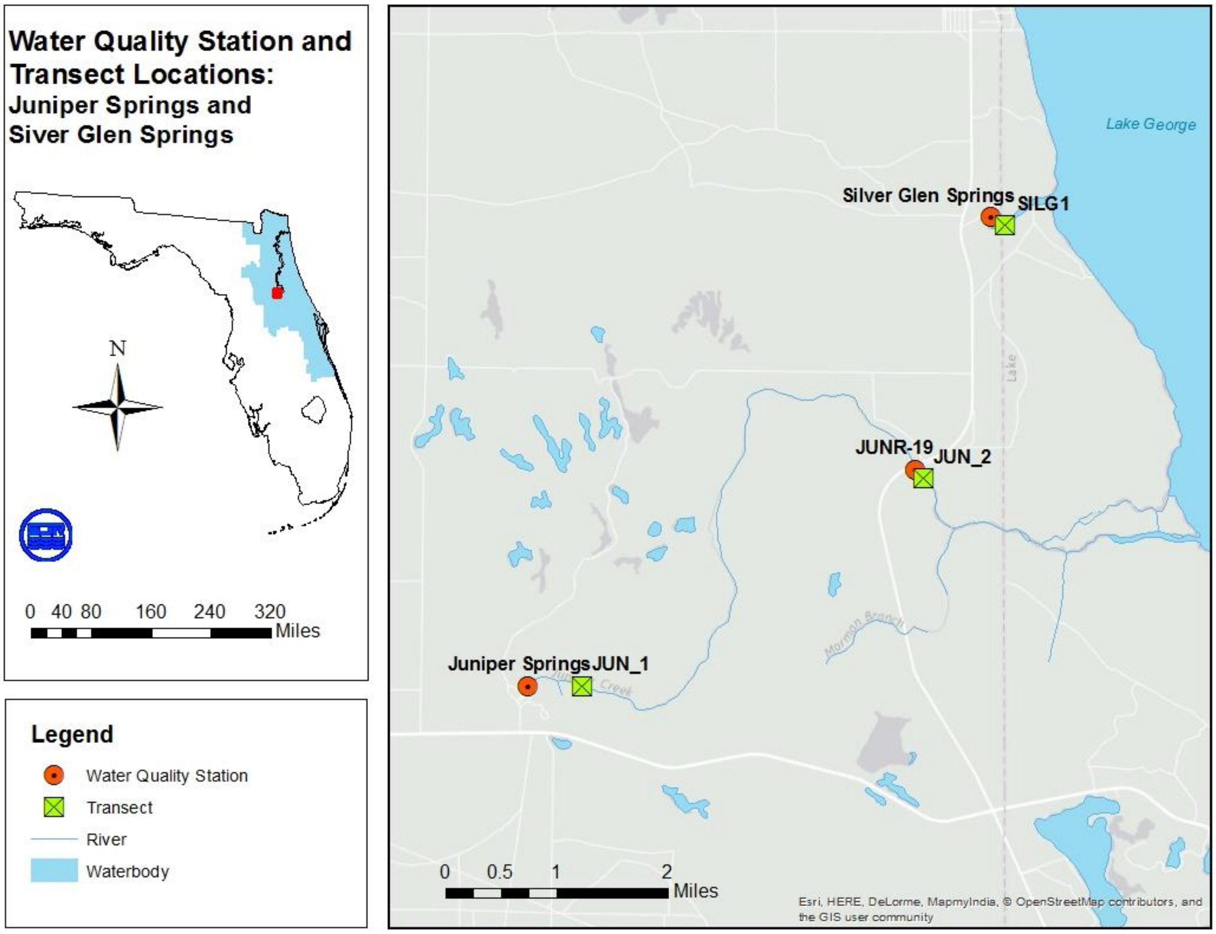
Water Quality Station and
Transect Locations:
Juniper Springs and
Siver Glen Springs
N
0 40 80 160 240 320
Miles
Legend
Water Quality Station
Transect
River
Waterbody
Lake George
Silver Glen Springs
SILG1
JUNR-19
JUN_2
Juniper Springs
JUN_1
Mormon Branch
Lake
0 0.5 1 2
Miles
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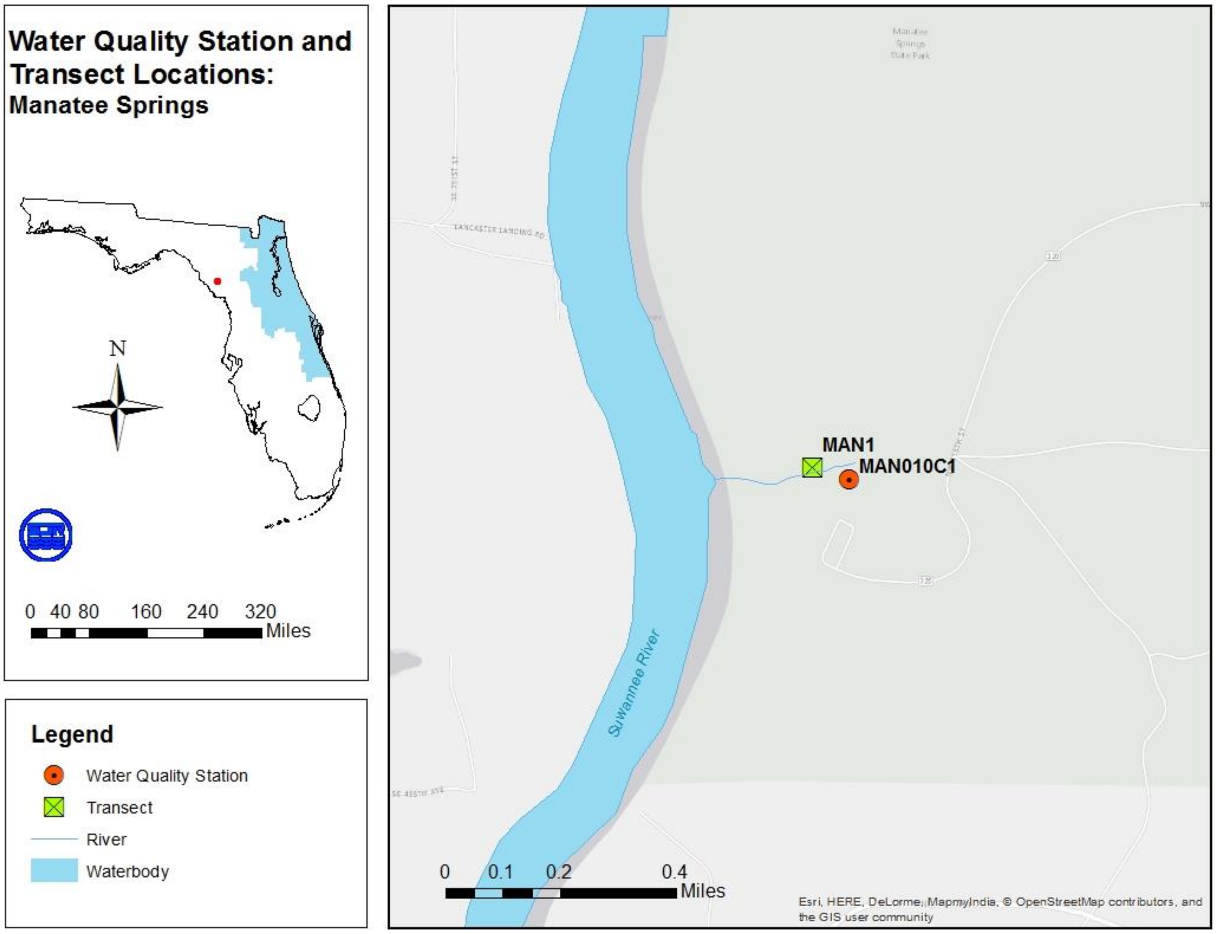
Water Quality Station and Transect Locations:
Manatee Springs
N
0 40 80 160 240 320
Miles
Legend
Water Quality Station
Transect
River
Waterbody
MAN1
MAN010C1
Suwannee River
0 0.1 0.2 0.4
Miles
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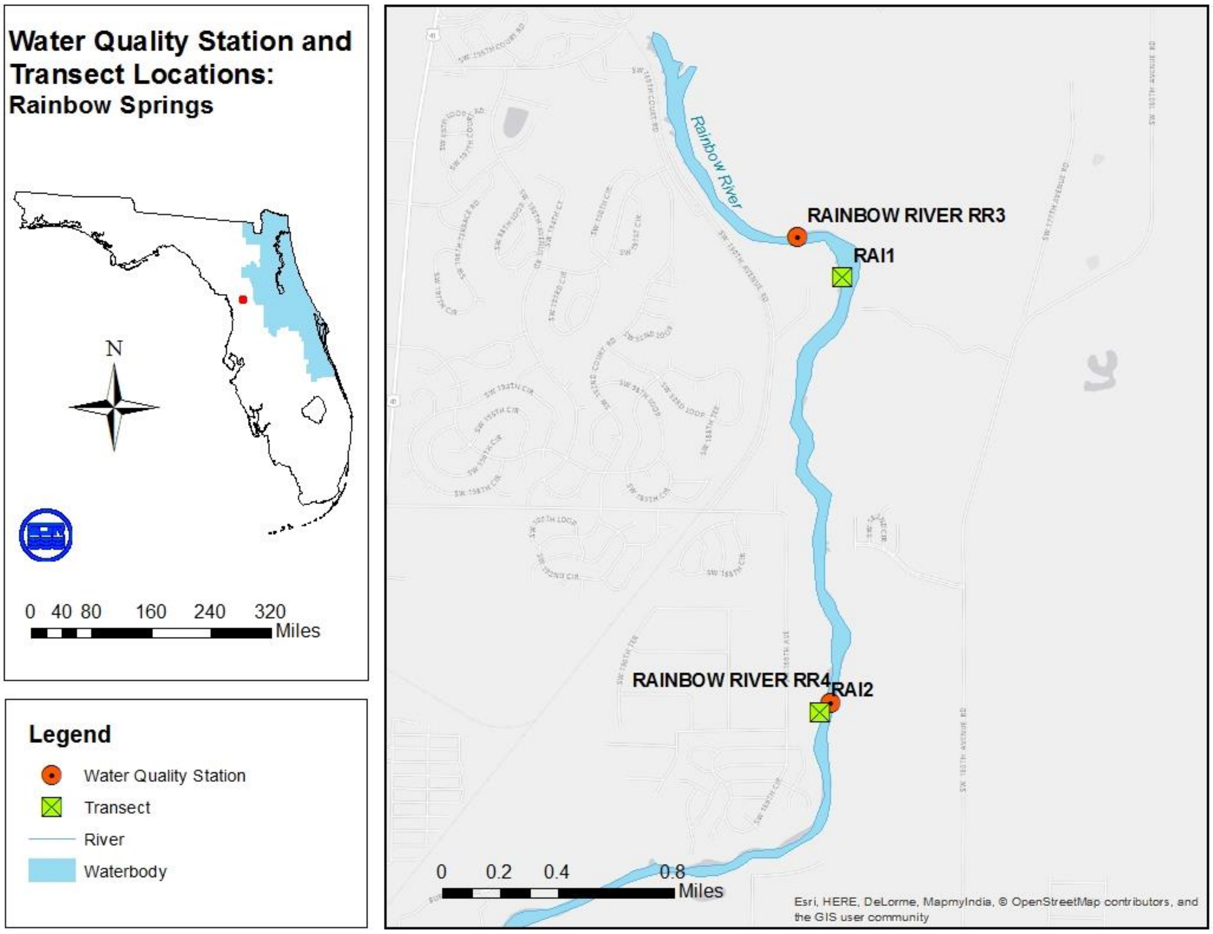
Water Quality Station and Transect Locations:
Rainbow Springs
N
0 40 80 160 240 320
Miles
Legend
Water Quality Station
Transect
River
Waterbody
Rainbow River
RAINBOW RIVER RR3
RAI1
RAINBOW RIVER RR4
RAI2
0 0.2 0.4 0.8
Miles
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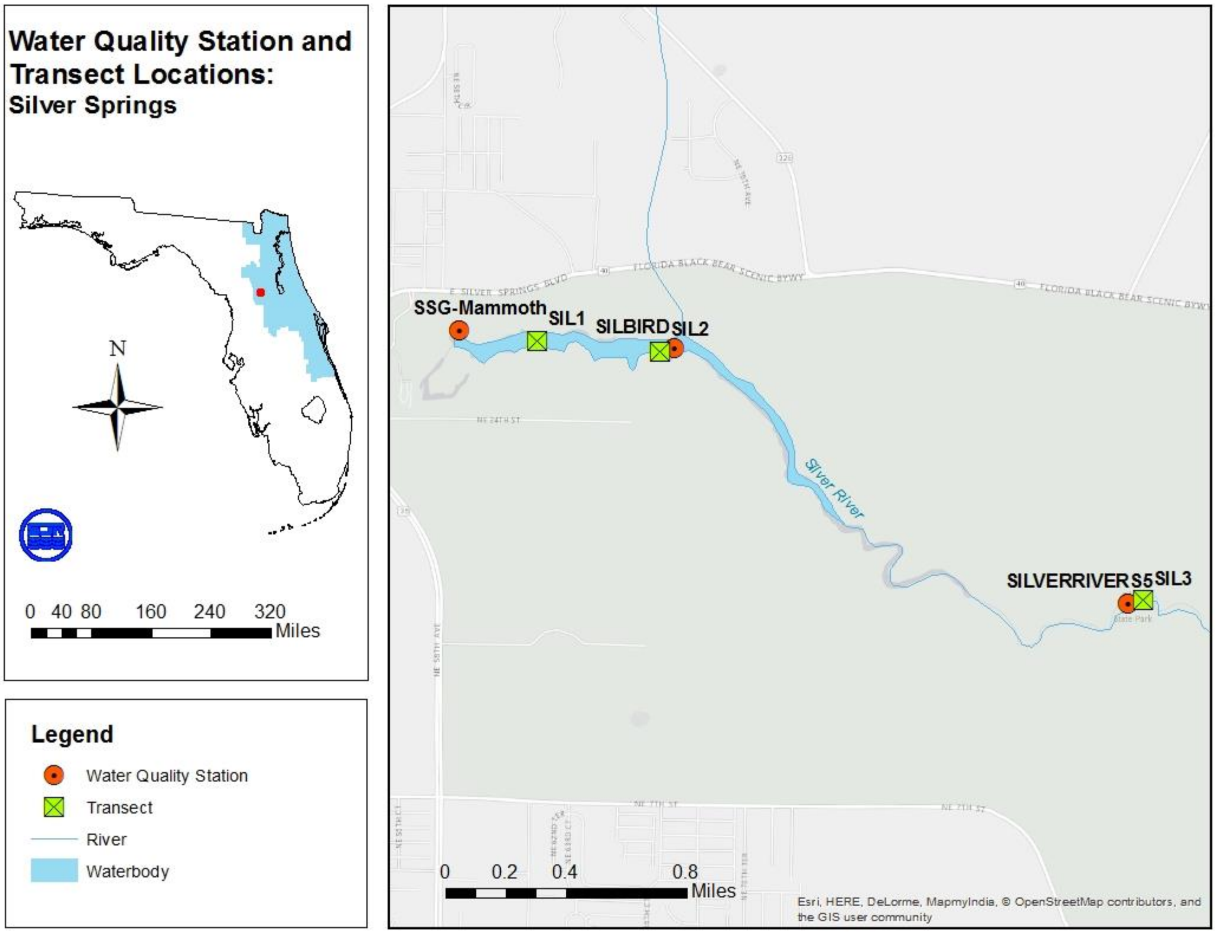
Water Quality Station and Transect Locations:
Silver Springs
N
0 40 80 160 240 320
Miles
Legend
Water Quality Station
Transect
River
Waterbody
SSG-Mammoth
SIL1
SILBIRD
SIL2
Silver River
SILVERRIVERS5
SIL3
0 0.2 0.4 0.8
Miles
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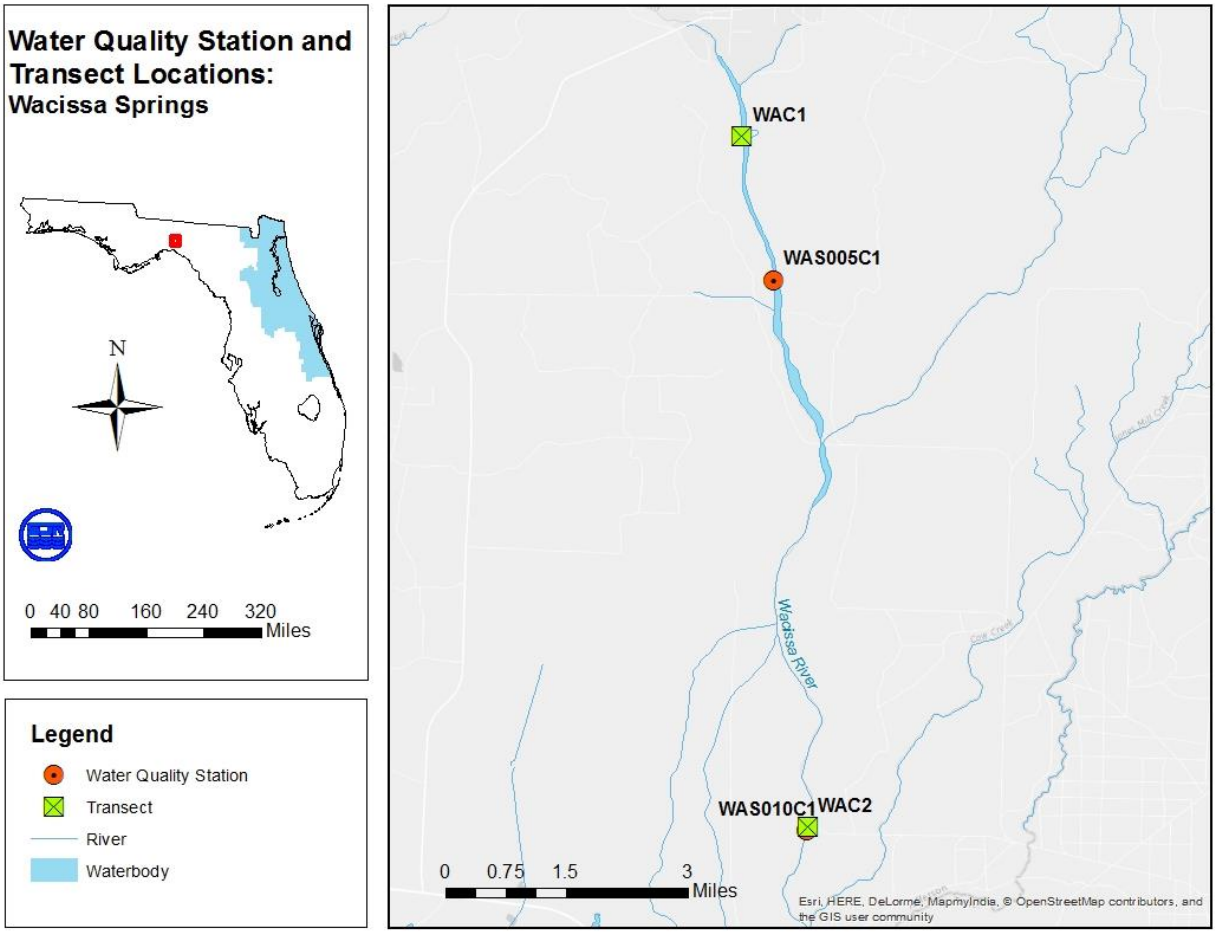
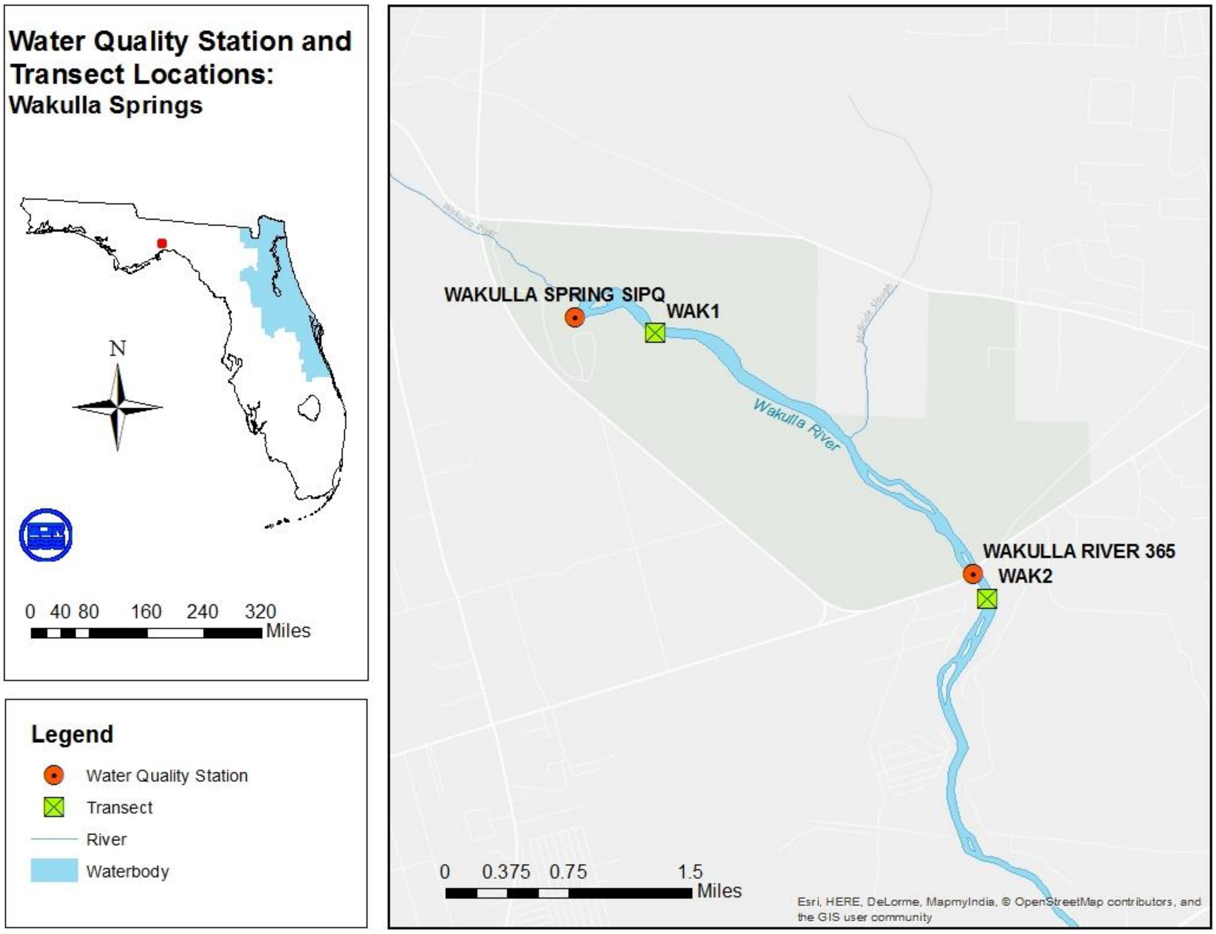

Water Quality Station and Transect Locations:
Wacissa Springs
N
0 40 80 160 240 320
Miles
Legend
Water Quality Station
Transect
River
Waterbody
WAC1
WAS005C1
Wacissa River
WAS010C1
WAC2
0 0.75 1.5 3
Miles
Esri, HERE, DeLorme, MapmyIndia, © OpenStreetMap contributors, and the GIS user community


Water Quality Station and Transect Locations:
Wakulla Springs
N
0 40 80 160 240 320
Miles
Legend
Water Quality Station
Transect
River
Waterbody
WAKULLA SPRING SIPQ
WAK1
Wakulla River
WAKULLA RIVER 365
WAK2
0 0.375 0.75 1.5
Miles
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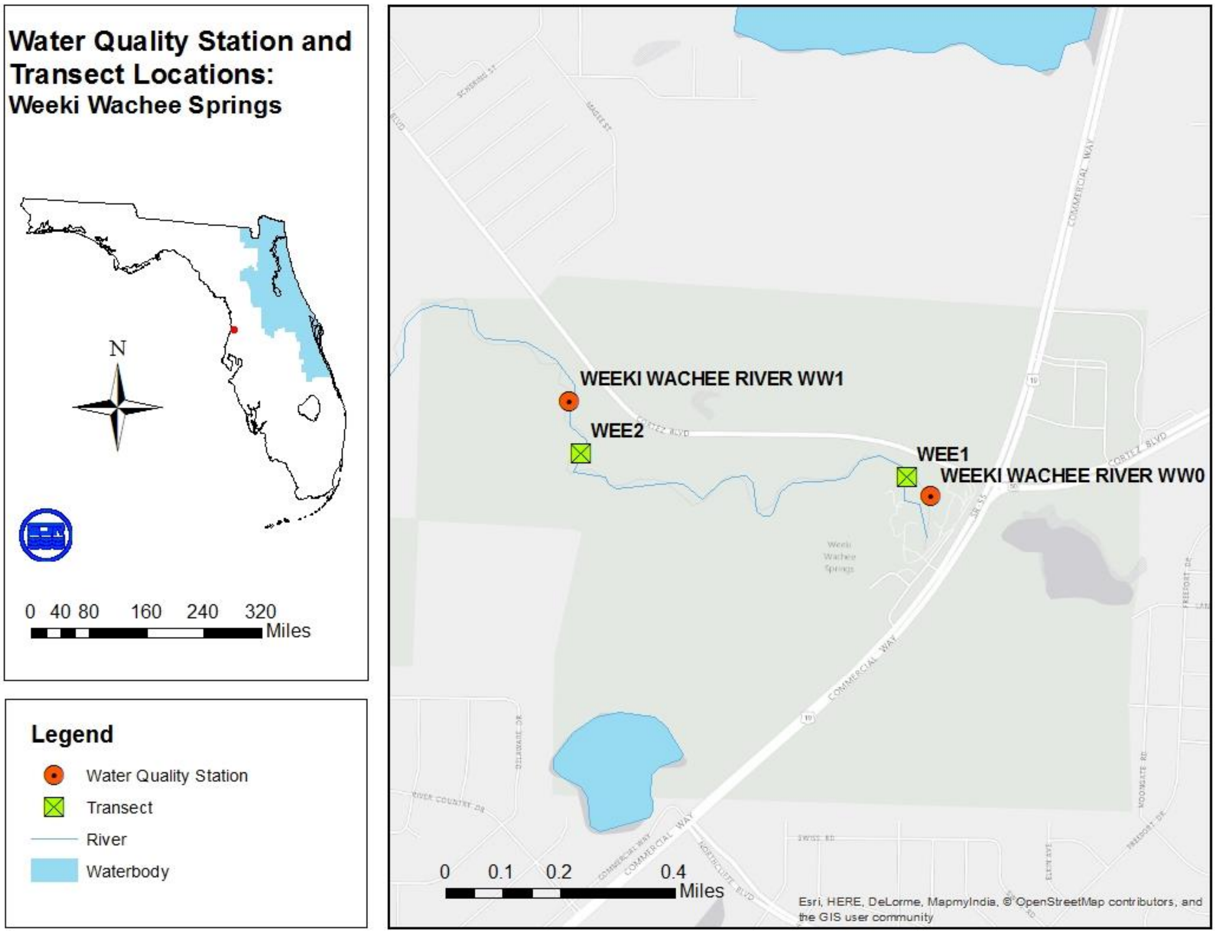
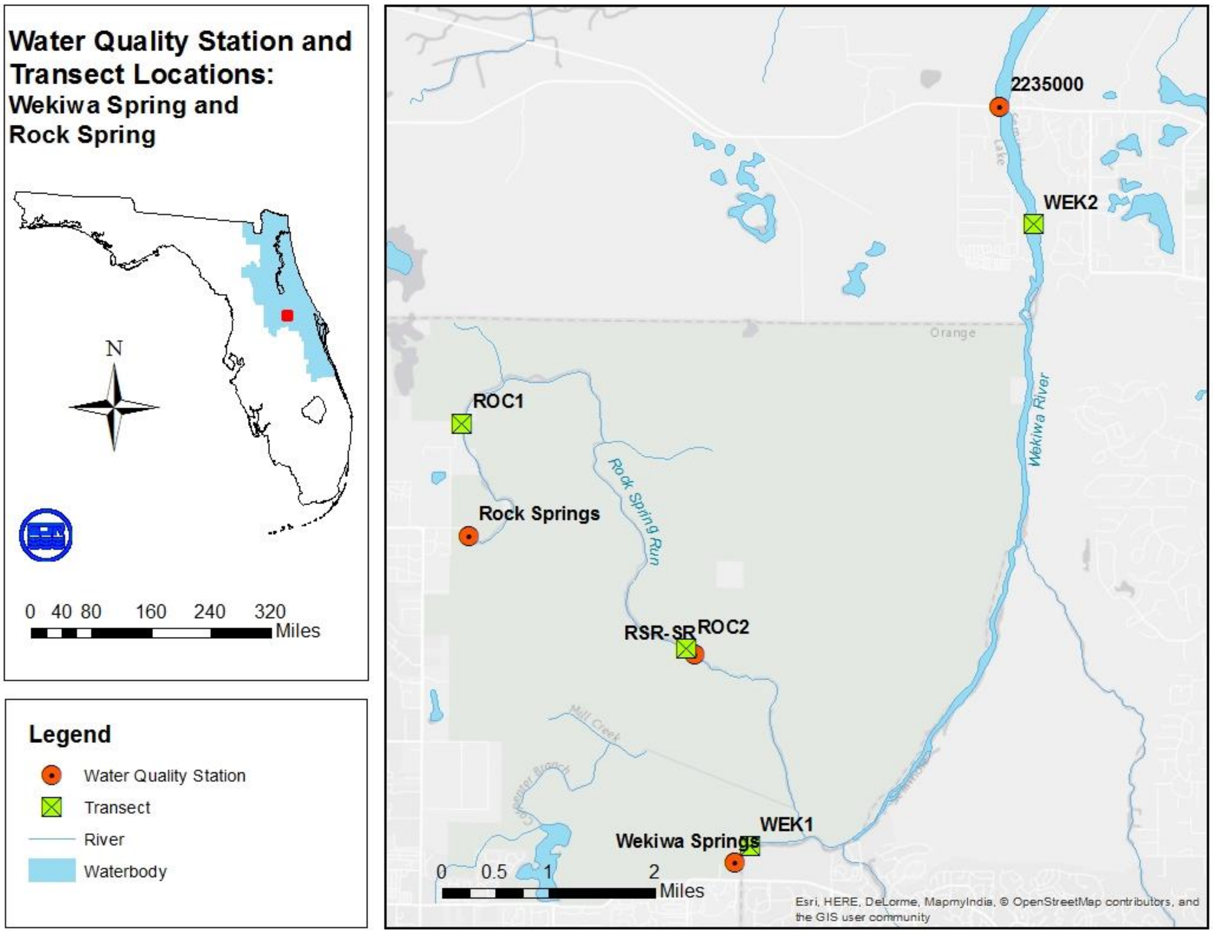

Water Quality Station and Transect Locations:
Weeki Wachee Springs
N
0 40 80 160 240 320
Miles
Legend
Water Quality Station
Transect
River
Waterbody
WEEKI WACHEE RIVER WW1
WEE2
WEE1
WEEKI WACHEE RIVER WW0
0 0.1 0.2 0.4
Miles
Esri, HERE, DeLorme, MapmyIndia, © OpenStreetMap contributors, and the GIS user community


Water Quality Station and Transect Locations:
Wekiwa Spring and Rock Spring
N
0 40 80 160 240 320 Miles
Legend
Water Quality Station
Transect
River
Waterbody
2235000
WEK2
Orange
Wekiwa River
ROC1
Rock Spring Run
Rock Springs
RSR-SR
ROC2
Mill Creek
WEK1
Wekiwa Springs
0 0.5 1 2 Miles
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Appendix C—Summaries of Macroinvertebrate Taxa in Macrophyte Habitat at each Transect in Spring and Fall

Appendix C. Table 1. Macroinvertebrate taxa list for macrophyte habitat in spring 2015. Number of times collected shown (out of the 3 replicates collected at each sampling transect).

TAXON	ALE1	ALE2	GUM1	GUM2	ICH1	ICH2	JUN1	JUN2	RAI1	RAI2	ROC1	ROC2
PLATYHELMINTHES												
UnID flatworm			1							1		
NEMERTEA												
Prostoma spp.												
NEMATODA												
UnID nematode taxa					2	1				1		
MOLLUSCA												
Gastropoda												
Amnicola spp.									1			
Laevapex fuscus	1	1										
Melanoides tuberculata											2	
Melanoides spp.	1									2		
Menetus floridensis												
Notogillia wetherbyi					2	2					1	
Physella cubensis			2	1		1		1	1	1		
Planorbella scalaris	1	2						1			1	1
Planorbella trivolvis											1	
Pleurocera floridensis						1	2	1	3	3		
Pomacea paludosa											1	
Tarebia granifera									1			
UnID Ancylidae spp.						1						1
UnID Hydrobiidae spp.	3	1	1	1				1	2		3	3
UnID Gastropoda spp.									1			
Bivalvia												
Corbicula fluminea		1									1	1
Elliptio spp.												

TAXON	ALE1	ALE2	GUM1	GUM2	ICH1	ICH2	JUN1	JUN2	RAI1	RAI2	ROC1	ROC2
Musculium spp.												
Pisidium spp.	1					1						
Sphaerium spp.												
UnID Sphaeriidae spp.												
ANNELIDA												
Oligochaeta												
Aulodrilus paucichaeta						1						
Bratislavia unidentata												
Dero digitata	1											
Dero flabelliger						1						
Eclipidrilus palustris	1		1			1						
Eclipidrilus spp.				1	1	1						
Haber speciosus						1						
Limnodrilus hoffmeisteri	1				1	2		1		1		1
Lumbriculus cf. *variegatus*												
Nais pardalis		1						2				
Nais pseudobtusa												
Pristina aequiseta												
Pristina leidyi		1										
Sparganophilus pearsei												
Sparganophilus spp.	1				3	3	1	1	2	2	2	2
Varichaetadrilus angustipennis												
UnID Enchytraeidae spp.					1							
UnID Lumbriculidae spp.							1			1		1
UnID Naididae spp.										1		
UnID Naidinae spp.												
UnID Tubificinae spp.		1	1	2	2	3	2	2		2	2	3
Polychaeta												
Namalycastis spp.												

TAXON	ALE1	ALE2	GUM1	GUM2	ICH1	ICH2	JUN1	JUN2	RAI1	RAI2	ROC1	ROC2
Hirudinea												
Alboglossiphonia heteroclita												
Erpobdella tetragon		1		1						1		
Erpobdella spp.												
Helobdella elongata					1	1				2	1	
Helobdella papillata	1											1
Helobdella stagnalis			2							2	1	2
Placobdella phalera	1	1		1								
Placobdella spp.	1										1	
UnID Glossiphoniidae spp.												1
UnID Hirudinea spp.	1									1		
ARTHROPODA												
Chelicerata - Acarina												
Arrenurus spp.												
Atractides spp.			1	1				1		1		
Clathrosperchon spp.									3			
Geayia spp.			1						2	1		
Hydrodroma spp.			1									
Hygrobates spp.			3					1				
Lebertia spp.				1	1	3	1	2	2	1	1	3
Limnesia spp.						2			2			
Mideopsis spp.			1			1			1			
Piona spp.												
Sperchon spp.					2							
Torrenticola spp.									1			
Unionicola spp.												
UnID Limnesiidae spp.									1			
UnID Oribatida spp.			1					1	2			
UnID Trombidiformes spp.									1			

TAXON	ALE1	ALE2	GUM1	GUM2	ICH1	ICH2	JUN1	JUN2	RAI1	RAI2	ROC1	ROC2
Crustacea-Amphipoda												
Gammarus spp.	3	3			3	3	2	1		2	3	3
Grandidierella bonnieroides								1			1	1
Hyalella azteca spp. complex	3	3	3	3	2	1		3	3	3	1	3
UnID Gammaridea spp.		1								1		
Crustacea-Isopoda												
Caecidotea spp.		1	1		2	2				1		
Cassidinidea ovalis								2				
Cyathura polita								1				
Edotia triloba								1				
Sphaeroma spp.												
Crustacea-Tanaidacea												
Hargeria rapax												
UnID Leptocheliidae spp.							1					
Crustacea-Decapoda												
Palaemonetes spp.	3	1								1		
UnID Cambaridae spp.		1								1		
INSECTA												
Collembola												
UnID taxa												
Odonata-Zygoptera												
Argia spp.									1			
Enallagma basidens	1											
Enallagma coecum												
Enallagma spp.			1					1				
Hetaerina titia								1				1
Hetaerina spp.								1				

TAXON	ALE1	ALE2	GUM1	GUM2	ICH1	ICH2	JUN1	JUN2	RAI1	RAI2	ROC1	ROC2
UnID Coenagrionidae spp.	1		1					1	1			
Odonata-Anisoptera												
Aphylla williamsoni												
Dromogomphus spinosus											1	2
Hagenius brevistylus						1						
Libellula spp.												
Macromia illinoiensis georgina												
Somatochlora spp.												
UnID Gomphidae spp.					1		1	1	1		1	
Ephemeroptera												
Acentrella alachua												1
Baetis intercalaris								1				
Caenis diminuta	1											
Caenis spp.	2					2					1	1
Callibaetis floridanus												
Hexagenia spp.		1									1	
Procloeon spp.												
Sparburus maculatus												
Tricorythodes albilineatus				2		1		3		2	1	1
UnID Baetidae spp.		1						1	1			1
UnID Heptageniidae spp.												1
UnID Ephemeroptera spp.			2	2	1		1	3	3			
Coleoptera												
Dineutus spp.							1	1				1
Donacia spp.												
Dubiraphia spp.												1
Gyrinus spp.								1				
Microcylloepus pusillus							1					
Stenelmis spp.							1			1	2	3

TAXON	ALE1	ALE2	GUM1	GUM2	ICH1	ICH2	JUN1	JUN2	RAI1	RAI2	ROC1	ROC2
Megaloptera												
Corydalus cornutus												
Diptera-Ceratopogonidae												
UnID Ceratopogonidae spp.	1			1	2	1	1				3	1
Diptera-Chironomidae												
Ablabesmyia mallochi		2	1	1	1	1		1				1
Ablabesmyia rhamphe group								1			1	
Beardius truncatus	1											
Beardius spp.					2							
Chironomus spp.			1									
Cladopelma spp.	2											
Cladotanytarsus spp.				1			1					1
Clinotanypus spp.				1		1						1
Cricotopus spp.	1			1			1	1			1	1
Cricotopus/Orthocladius spp.		2	3	2	3	3	1	2	3	3	1	2
Cryptochironomus spp.						1	2	1			2	2
Cryptotendipes spp.												
Dicrotendipes modestus		2		1	3	3			3	2	1	1
Dicrotendipes neomodestus								1			1	
Dicrotendipes spp.		1										
Epoicocladius spp.											1	
Labrundinia spp.			1									
Larsia spp.												
Paracladopelma spp.											1	
Paralauterborniella nigrohalteralis		1										
Pentaneura inconspicua				1								
Polypedilum convictum								1	1	1	1	1
Polypedilum halterale group						2	1	1				
Polypedilum illinoense group		1	1	1	1	2		1				
Polypedilum scalaenum group				1			1				1	1

TAXON	ALE1	ALE2	GUM1	GUM2	ICH1	ICH2	JUN1	JUN2	RAI1	RAI2	ROC1	ROC2
Procladius spp.				1		1						
Pseudochironomus spp.	1	1	3	3	2	3			3	3	2	1
Rheotanytarsus spp.		2	2	3	3	2		1	3	3		1
Tanypus spp.	2											
Tanytarsus buckleyi		2	3	2	2			1	2	2		2
Tanytarsus spp.	1	1		1	1			1				2
Thienemanniella similis												
Thienemanniella xena		1			1			1			1	1
Thienemanniella spp.								1			1	1
Thienemannimyia group spp.		2	3	2		1		1	2	3		1
Tribelos fuscicorne												
UnID Chironomidae spp.	1		1	2	2	2	2	3	2	1		1
UnID Tanytarsini spp.								1				
UnID Dipteran spp.			1									1
Diptera-Empididae												
Hemerodromia spp.		2	3	2	3	3	3	3	3	2		1
UnID Empididae spp.			2		1	2		1	2			1
Diptera - Ephydridae												
Hydrellia spp.		1									1	
Diptera – Simuliidae												
Simulium spp.								2				
UnID Simuliidae spp.												
Lepidoptera												
Elophila spp.			1	1								
Parapoynx spp.				2				3	1			1
Petrophila santafealis			3	2	3	3	1	1	3	3		
UnID Crambidae spp.											1	1
UnID Lepidoptera taxa			1	2			1	1				

TAXON	ALE1	ALE2	GUM1	GUM2	ICH1	ICH2	JUN1	JUN2	RAI1	RAI2	ROC1	ROC2
Trichoptera												
Cernotina spp.				1	1				1	1		1
Cheumatopsyche spp.					1			2	3	1		3
Cyrnellus fraternus												
Helicopsyche borealis												
Hydropsyche rossi								2	1	3		1
Hydropsyche spp.									2			
Hydroptila spp.		3	3	3	3	1	3	3	3	3	3	3
Macrostemum carolina												
Mayatrichia ayama								2			2	3
Nectopsyche candida/exquisita							1	1				
Nectopsyche tavara												
Neotrichia spp.		1						1				
Neureclipsis crepuscularis												1
Neureclipsis spp.												2
Nyctiophylax spp.		1										1
Ochrotrichia spp.			1		1	2		2				
Oecetis avara								1	1			
Oecetis sp. E						1						
Oecetis spp.					1						2	
Orthotrichia spp.		2				1			2			
Oxyethira spp.		2	2	2	1			3	1		1	3
Triaenodes injustus						1						
UnID Hydropsychidae spp.								1	1	1		
UnID Hydroptilidae spp.			3	3	1		1	3	2	2	1	1
UnID Leptoceridae spp.						1		1				
UnID Polycentropodidae spp.												
UnID Trichoptera taxa									1			
Hemiptera												
UnID Heteroptera spp.												
TOTAL TAXA	28	36	37	37	37	46	26	64	45	41	43	58

Appendix C. Table 2. Macroinvertebrate taxa list for macrophyte habitat in spring 2015. Number of times collected shown (out of the 3 replicates collected at each sampling transect).

TAXON	SIL1	SIL2	SIL3	SLG1	WAC1	WAC2	WAK1	WAK2	WEE1	WEE2	WEK1	WEK2
PLATYHELMINTHES												
UnID flatworm				1								
NEMERTEA												
Prostoma spp.		1										
NEMATODA												
UnID nematode taxa	2	3		1		1						
MOLLUSCA												
Gastropoda												
Amnicola spp.		1										
Laevapex fuscus					2					2		
Melanoides tuberculata											2	
Melanoides spp.									2	3		
Menetus floridensis				1								
Notogillia wetherbyi									1			
Physella cubensis						1			1			1
Planorbella scalaris									2		3	2
Planorbella trivolvis												
Pleurocera floridensis					1		1	2	3	3	2	
Pomacea paludosa											1	
Tarebia granifera												
UnID Ancylidae spp.					1			1				
UnID Hydrobiidae spp.	3	1		2	2			1	3	2	3	
UnID Gastropoda spp.					1		1		1	1		
Bivalvia												
Corbicula fluminea						1		2				2
Elliptio spp.						2						1

TAXON	SIL1	SIL2	SIL3	SLG1	WAC1	WAC2	WAK1	WAK2	WEE1	WEE2	WEK1	WEK2
Musculium spp.		1										
Pisidium spp.						1						
Sphaerium spp.					1							
UnID Sphaeriidae spp.						1				2		
ANNELIDA												
Oligochaeta												
Aulodrilus paucichaeta												
Bratislavia unidentata				1								
Dero digitata												
Dero flabelliger												
Eclipidrilus palustris	1	1	3	2								
Eclipidrilus spp.												
Haber speciosus				1								
Limnodrilus hoffmeisteri	1	1	1	2	1		1	1				
Lumbriculus cf. *variegatus*		1										1
Nais pardalis		2	2	1	1							3
Nais pseudobtusa		1										
Pristina aequiseta				1								
Pristina leidyi												
Sparganophilus pearsei				1								
Sparganophilus spp.	2	2	3	2	2	1		2	1	3		3
Varichaetadrilus angustipennis	1	1	1							1		
UnID Enchytraeidae spp.				2								
UnID Lumbriculidae spp.			2	2							1	2
UnID Naididae spp.			1									
UnID Naidinae spp.				1	1							
UnID Tubificinae spp.	3	3	3	3	2	1		1	2	2	2	3
Polychaeta												
Namalycastis spp.			1	1								

TAXON	SIL1	SIL2	SIL3	SLG1	WAC1	WAC2	WAK1	WAK2	WEE1	WEE2	WEK1	WEK2
Hirudinea												
Alboglossiphonia heteroclita			1									
Erpobdella tetragon	1			1	2	1						
Erpobdella spp.									1			
Helobdella elongata		1	2	1					1	3		
Helobdella papillata					1	1						
Helobdella stagnalis				1	1	1	2				2	1
Placobdella phalera												
Placobdella spp.								1				
UnID Glossiphoniidae spp.					1		1	1	1			
UnID Hirudinea spp.										1		
ARTHROPODA												
Chelicerata - Acarina												
Arrenurus spp.									1			
Atractides spp.						1		1				
Clathrosperchon spp.									1			
Geayia spp.	2	2	1									
Hydrodroma spp.												
Hygrobates spp.					2		1		1			
Lebertia spp.	2	3	2		1	1		1	2			3
Limnesia spp.	2	1			3							
Mideopsis spp.												
Piona spp.		1										
Sperchon spp.	2											
Torrenticola spp.												
Unionicola spp.					1							
UnID Limnesiidae spp.	2	1										
UnID Oribatida spp.	2	1							1			
UnID Trombidiformes spp.												

TAXON	SIL1	SIL2	SIL3	SLG1	WAC1	WAC2	WAK1	WAK2	WEE1	WEE2	WEK1	WEK2
Crustacea-Amphipoda												
Gammarus spp.	2	2	3	3	1	2	2				1	3
Grandidierella bonnieroides				3								
Hyalella azteca spp. complex	3	3	1	2	3	2	3	2	3	3	3	2
UnID Gammaridea spp.						1	2					
Crustacea-Isopoda												
Caecidotea spp.					2	1	2	2				
Cassidinidea ovalis		1		2								
Cyathura polita	2			1								
Edotia triloba												
Sphaeroma spp.												1
Crustacea-Tanaidacea												
Hargeria rapax				2								
UnID Leptocheliidae spp.				3								
Crustacea-Decapoda												
Palaemonetes spp.					1		1	1	2		1	1
UnID Cambaridae spp.		1	1	2	1		1				1	
INSECTA												
Collembola												
UnID taxa				1								
Odonata-Zygoptera												
Argia spp.												
Enallagma basidens												
Enallagma coecum			1									
Enallagma spp.										1	1	1
Hetaerina titia												
Hetaerina spp.												

TAXON	SIL1	SIL2	SIL3	SLG1	WAC1	WAC2	WAK1	WAK2	WEE1	WEE2	WEK1	WEK2
UnID Coenagrionidae spp.				1		2						
Odonata-Anisoptera												
Aphylla williamsoni		1	1									
Dromogomphus spinosus												
Hagenius brevistylus												
Libellula spp.									1			
Macromia illinoiensis georgina										1		
Somatochlora spp.								1				
UnID Gomphidae spp.												
Ephemeroptera												
Acentrella alachua												
Baetis intercalaris												
Caenis diminuta									1			
Caenis spp.									1		1	
Callibaetis floridanus				1								
Hexagenia spp.								1				
Procloeon spp.										1		
Sparburus maculatus						1						
Tricorythodes albilineatus		1	2	1	2	2		2	3	3	1	2
UnID Baetidae spp.					1	1			1	2		1
UnID Heptageniidae spp.										1		
UnID Ephemeroptera spp.		1	2	1			1			2		
Coleoptera												
Dineutus spp.						1	1					1
Donacia spp.						1						
Dubiraphia spp.												
Gyrinus spp.					1							
Microcylloepus pusillus												
Stenelmis spp.			2		1	3	1	2		2	1	2

TAXON	SIL1	SIL2	SIL3	SLG1	WAC1	WAC2	WAK1	WAK2	WEE1	WEE2	WEK1	WEK2
Megaloptera												
Corydalus cornutus										1		
Diptera-Ceratopogonidae												
UnID Ceratopogonidae spp.	2	1	1		1	2		1	1	3		1
Diptera-Chironomidae												
Ablabesmyia mallochi				1	1		1					
Ablabesmyia rhamphe group												
Beardius truncatus												
Beardius spp.									3			1
Chironomus spp.									1	1		
Cladopelma spp.												
Cladotanytarsus spp.												
Clinotanypus spp.						1		1	1			1
Cricotopus spp.										2	1	
Cricotopus/Orthocladius spp.	3	3	3	2	3	2	2	3	3	1	1	3
Cryptochironomus spp.												
Cryptotendipes spp.			1									
Dicrotendipes modestus	3	3	3	2	3		2	3	3			3
Dicrotendipes neomodestus				1								
Dicrotendipes spp.										1		
Epoicocladius spp.												
Labrundinia spp.					1			1				
Larsia spp.											1	
Paracladopelma spp.												
Paralauterborniella nigrohalteralis												
Pentaneura inconspicua										2		
Polypedilum convictum			3		2	3	2	3	1	3		2
Polypedilum halterale group					3						1	1
Polypedilum illinoense group	1	1		1	3	2	1	1	2	1		3
Polypedilum scalaenum group						1				1		1

TAXON	SIL1	SIL2	SIL3	SLG1	WAC1	WAC2	WAK1	WAK2	WEE1	WEE2	WEK1	WEK2
Procladius spp.				1			1	1				
Pseudochironomus spp.	2	2		3	3		1	2	3			1
Rheotanytarsus spp.	1	3	3	1	3	3		2		1		1
Tanypus spp.												
Tanytarsus buckleyi	2	2	2	2	3	1	2	1	3	1	2	3
Tanytarsus spp.			1	1	1			1		2	1	
Thienemanniella similis										2		
Thienemanniella xena		2	3			2	1			1		3
Thienemanniella spp.						2		1				
Thienemannimyia group spp.	2				3		1	3	1	1	1	1
Tribelos fuscicorne												1
UnID Chironomidae spp.	2	2	2	1	3	3	1	1	3	3		
UnID Tanytarsini spp.												
UnID Dipteran spp.	1		1		1	1			1			
Diptera-Empididae												
Hemerodromia spp.	3	3	3		3	3	1	2		1		2
UnID Empididae spp.	1	1			3	1						
Diptera - Ephydridae												
Hydrellia spp.								1				1
Diptera – Simuliidae												
Simulium spp.												
UnID Simuliidae spp.						1						
Lepidoptera												
Elophila spp.					1			1	1			
Parapoynx spp.	1	1	1		3	1			1	3	1	
Petrophila santafealis	3	3	3		3	2	2	1	2			
UnID Crambidae spp.												1
UnID Lepidoptera taxa		2			1	1						

TAXON	**SIL1**	**SIL2**	**SIL3**	**SLG1**	**WAC1**	**WAC2**	**WAK1**	**WAK2**	**WEE1**	**WEE2**	**WEK1**	**WEK2**
Trichoptera												
Cernotina spp.	3	3	1	2				1				
Cheumatopsyche spp.	1		3		2	3	1	3		3		2
Cyrnellus fraternus	1											
Helicopsyche borealis								1				
Hydropsyche rossi			1		2	2	1	1	1	3		
Hydropsyche spp.			1					2				
Hydroptila spp.	3	3	2	1	3	2	1	3	3	3		3
Macrostemum carolina							1					
Mayatrichia ayama												1
Nectopsyche candida/exquisita												
Nectopsyche tavara									1			
Neotrichia spp.												1
Neureclipsis crepuscularis												3
Neureclipsis spp.												
Nyctiophylax spp.												
Ochrotrichia spp.			2			3	2			2		
Oecetis avara						2		1	1	2		
Oecetis sp. E												
Oecetis spp.						1	1		1			
Orthotrichia spp.	3	2					2		2			
Oxyethira spp.	2	3	3		2		1	2	3	2	2	3
Triaenodes injustus												
UnID Hydropsychidae spp.							1	1		3		
UnID Hydroptilidae spp.	3	2	2	1	2			1	3	2		
UnID Leptoceridae spp.									1			
UnID Polycentropodidae spp.							1					
UnID Trichoptera taxa	1		1			1	1		1	1		
Hemiptera												
UnID Heteroptera spp.				2								
TOTAL TAXA	39	46	44	48	54	49	39	47	50	47	25	44

Appendix C. Table 3. Macroinvertebrate taxa list for macrophyte habitat in fall 2015. Number of times collected shown (out of the 3 replicates collected at each sampling transect). JUN1 not sampled in fall (no vegetation).

TAXON	ALE1	ALE2	GUM1	GUM2	ICH1	ICH2	JUN1	JUN2	RAI1	RAI2	ROC1	ROC2
PLATYHELMINTHES												
UnID flatworm					1		-					
NEMERTEA												
Prostoma spp.				1			-		1	1		
NEMATODA												
UnID nematode taxa	1	1		3	1	2	-		1	1	1	
MOLLUSCA												
Gastropoda												
Laevapex fuscus							-					
Melanoides tuberculata							-				1	
Melanoides spp.		1					-					
Notogillia wetherbyi					1	2	-		2			
Physella cubensis			3	2		1	-		2		2	
Planorbella scalaris	3			1			-				2	
Planorbella spp.							-					
Pleurocera floridensis				1	1		-	1			1	
Pomacea paludosa							-					
Tarebia granifera							-					
Viviparus georgianus							-					
UnID Ancylidae spp.							-					
UnID Hydrobiidae spp.	3		1	2	2	1	-			1	3	2
Bivalvia												
Corbicula fluminea							-					
Elliptio spp.							-			1		
Musculium spp.							-					
Pisidium spp.						2	-		1			

TAXON	ALE1	ALE2	GUM1	GUM2	ICH1	ICH2	JUN1	JUN2	RAI1	RAI2	ROC1	ROC2
Utterbackia imbecilis		1					-					
UnID Sphaeriidae spp.							-					
ANNELIDA												
Oligochaeta												
Aulodrilus pigueti							-					
Bratislavia unidentata	3						-					
Dero digitata	1						-					
Dero nivea	2						-					
Dero pectinata							-					
Dero spp.	2						-					
Eclipidrilus palustris		1		2	3		-			1		
Haber speciosus					1		-					
Ilyodrilus templetoni						1	-					
Limnodrilus hoffmeisteri		2		1		2	-					
Lumbriculus cf. *variegatus*							-					
Nais communis	1						-					
Nais pardalis	2			1			-		1			
Nais pseudobtusa							-		1			
Pristina aequiseta	1						-					
Pristina leidyi	2						-		1			
Psammoryctides convolutus					2		-					
Quistadrilus multisetosus					2		-					
Sparganophilus spp.	1	2	1	1	3	3	-		1	2	3	1
Varichaetadrilus angustipennis					3	2	-			1	2	
UnID Enchytraeidae spp.							-					
UnID Lumbriculidae spp.		1					-		1	1		
UnID Naididae spp.	1						-					
UnID Naidinae spp.	2						-		1			
UnID Tubificinae spp.	1	2	3	3	3	3	-		3	1	3	
UnID Oligochaete taxa							-		1			

TAXON	ALE1	ALE2	GUM1	GUM2	ICH1	ICH2	JUN1	JUN2	RAI1	RAI2	ROC1	ROC2
Polychaeta												
Namalycastis spp.							-					
Hirudinea												
Erpobdella punctata					1		-		3			
Erpobdella tetragon							-					1
Erpobdella spp.	1	1		1	1		-					
Helobdella elongata	1	2	3	3	1	1	-		2	1	1	
Helobdella papillata				2			-					
Helobdella stagnalis		2	2				-			1	2	
Placobdella phalera						1	-		1			
Placobdella spp.	1	2					-				1	
UnID Glossiphoniidae spp.							-					
ARTHROPODA												
Chelicerata - Acarina												
Atractides spp.							-					
Geayia spp.				1			-					
Hydrodroma spp.							-					
Hygrobates spp.							-	1				
Lebertia spp.		1	3	2		1	-	3	2		1	3
Limnesia spp.					2	1	-				1	
Mideopsis spp.							-					2
Neumania spp.							-					
Sperchon spp.							-					
Sperchonopsis spp.							-			1		
Unionicola spp.							-					
UnID Acariformes spp.				1			-			1		
Crustacea-Amphipoda												
Gammarus spp.	2	1			3	3	-				2	
Grandidierella bonnieroides							-					

TAXON	ALE1	ALE2	GUM1	GUM2	ICH1	ICH2	JUN1	JUN2	RAI1	RAI2	ROC1	ROC2
Hyalella azteca spp. complex	3	3	3	3	1	2	-	1	3	3	3	2
UnID Gammaridea spp.	1	2					-					
Crustacea-Isopoda												
Caecidotea spp.		2	3			1	-				1	
Cassidinidea ovalis							-	1				
Cyathura polita	1	1					-					
Sphaeroma spp.							-					
UnID Isopod taxa						1	-					
Crustacea-Tanaidacea												
Hargeria rapax							-					
UnID Leptocheliidae spp.							-					
Crustacea - Mysidacea												
UnID Mysida spp.							-					
Crustacea-Decapoda												
Palaemonetes spp.	1	1	1	1	1		-			1	1	
UnID Cambaridae spp.		1				1	-			1	1	
INSECTA												
Odonata-Zygoptera												
Argia spp.							-					
Enallagma coecum							-	1				
UnID Coenagrionidae spp.			1				-					
Odonata-Anisoptera												
Hagenius brevistylus							-					
Macromia illinoiensis georgina			1				-					
UnID Gomphidae spp.							-				1	

TAXON	ALE1	ALE2	GUM1	GUM2	ICH1	ICH2	JUN1	JUN2	RAI1	RAI2	ROC1	ROC2
Ephemeroptera												
Acentrella alachua			1				-					
Baetis intercalaris							-	2				
Caenis spp.	2						-				1	
Hexagenia spp.							-					
Maccaffertium exiguum							-				1	
Tricorythodes albilineatus	1	2	1	2			-	2	3	3	1	
UnID Baetidae spp.	1	1	1	2	1		-	1		2	1	3
UnID Heptageniidae spp.							-					
UnID Ephemeroptera spp.		1			1		-		2	2		
Coleoptera												
Dubiraphia spp.						1	-					
Stenelmis spp.				2			-					1
UnID Elmidae spp.							-					1
Megaloptera												
Corydalus cornutus							-					2
Diptera-Ceratopogonidae												
UnID Ceratopogonidae spp.	2	3	1	1	2	2	-				3	
Diptera-Chironomidae												
Ablabesmyia mallochi			1	2			-		1	2		
Ablabesmyia rhamphe group		1					-				1	
Beardius spp.				1			-				1	
Chironomus spp.					1		-		1			
Cladopelma spp.	3						-					
Cladotanytarsus spp.							-					2
Clinotanypus spp.					1		-					
Cricotopus/Orthocladius spp.	1	3	3	3	3	3	-	2	3	3	3	3
Cryptochironomus spp.							-				2	

TAXON	ALE1	ALE2	GUM1	GUM2	ICH1	ICH2	JUN1	JUN2	RAI1	RAI2	ROC1	ROC2
Dicrotendipes spp.	3		1	2	3	3	-		3	3	3	3
Glyptotendipes spp.							-					
Labrundinia spp.		1	1			1	-				1	
Larsia spp.	1						-					
Nanocladius spp.	1						-					
Parachironomus spp.							-					
Paralauterborniella nigrohalteralis	1						-					
Paralauterborniella spp.				2			-					
Paratanytarsus spp.			1	3		1	-		3	2		
Pentaneura inconspicua			1			1	-	1	2	2		
Polypedilum convictum				1		3	-	2		3	1	1
Polypedilum halterale group				1	3		-					
Polypedilum illinoense group					2		-	1	2		1	3
Polypedilum scalaenum group			1	2			-					1
Pseudochironomus spp.	2	3	3	3			-		3	2	1	1
Rheotanytarsus spp.		1	1	3	3	3	-	3	3	3	1	1
Stenochironomus spp.							-				1	
Tanypus punctipennis												
Tanypus spp.							-					
Tanytarsus spp.	1	1	3	2			-	1	3	3	2	1
Thienemanniella similis							-	2			1	
Thienemanniella xena							-	1	1	1		
Thienemanniella spp.		1		1	1	3	-		1	2		3
Thienemannimyia group spp.				2		1	-		2	2		
UnID Chironomidae spp.				2	3	2	-		3	3		
UnID Tanypodinae spp.		1					-					
Diptera-Empididae												
Hemerodromia spp.			2	1		3	-	3	2		1	2
UnID Empididae spp.							-		1	1		

TAXON	ALE1	ALE2	GUM1	GUM2	ICH1	ICH2	JUN1	JUN2	RAI1	RAI2	ROC1	ROC2
Diptera - Ephydridae												
UnID Ephydridae spp.							-				1	
Diptera – Phoridae												
UnID Phoridae spp.						1	-					
Diptera – Simuliidae												
Simulium spp.							-	2				
UnID Simuliidae spp.							-					
Diptera – Tanyderidae												
UnID Tanyderidae spp.				1			-					
Diptera - Tipulidae												
UnID Tipulidae spp.							-					
Lepidoptera												
Parapoynx spp.		1	1	1			-				2	
Petrophila santafealis			3	3	3	3	-	2	3	3	2	2
UnID Lepidoptera taxa							-					
Trichoptera												
Cernotina spp.		1	1	1	3		-		3		2	
Cheumatopsyche spp.			1			1	-	2	1	2		3
Cyrnellus fraternus							-	1				
Hydropsyche rossi							-					
Hydropsyche spp.						1	-	1	1	3		
Hydroptila spp.			3	3	3	1	-	3	3	3	2	3
Macrostemum carolina							-					1
Mayatrichia ayama							-	3				3
Neotrichia spp.							-	2				
Neureclipsis crepuscularis							-					

TAXON	ALE1	ALE2	GUM1	GUM2	ICH1	ICH2	JUN1	JUN2	RAI1	RAI2	ROC1	ROC2
Ochrotrichia spp.						1	-					
Oecetis avara							-		1			
Oecetis spp.							-			1		
Orthotrichia spp.							-		2			
Oxyethira spp.			3	3	1		-		1	1	1	
Triaenodes spp.							-					
UnID Hydropsychidae spp.							-			1		
UnID Hydroptilidae spp.				1			-					
UnID Polycentropodidae spp.			1				-			1		
UnID Trichoptera taxa				1			-					
Hemiptera												
Pelocoris spp.							-					
TOTAL TAXA	35	34	34	47	35	38	-	26	44	41	45	26

Appendix C. Table 4. Macroinvertebrate taxa list for macrophyte habitat in fall 2015. Number of times collected shown (out of the 3 replicates collected at each sampling transect).

TAXON	SIL1	SIL2	SIL3	SLG1	WAC1	WAC2	WAK1	WAK2	WEE1	WEE2	WEK1	WEK2
PLATYHELMINTHES												
UnID flatworm				1		1	1	1	1			
NEMERTEA												
Prostoma spp.					2			1				
NEMATODA												
UnID nematode taxa	1	1	2	1	1	2		2	1		1	
MOLLUSCA												
Gastropoda												
Laevapex fuscus											1	
Melanoides tuberculata											2	
Melanoides spp.									1	1		
Notogillia wetherbyi	1	2							1			
Physella cubensis		1	2			1			2			
Planorbella scalaris					1				1		1	
Planorbella spp.									1			
Pleurocera floridensis			1					1	1			
Pomacea paludosa			2						1		1	1
Tarebia granifera					1							
Viviparus georgianus											1	
UnID Ancylidae spp.	1	1	1							1		1
UnID Hydrobiidae spp.	3	3	2		1	2			3	1	2	1
Bivalvia												
Corbicula fluminea						1		1				
Elliptio spp.	1		1			1						
Musculium spp.			2									
Pisidium spp.												

TAXON	SIL1	SIL2	SIL3	SLG1	WAC1	WAC2	WAK1	WAK2	WEE1	WEE2	WEK1	WEK2
Utterbackia imbecilis												
UnID Sphaeriidae spp.									1			
ANNELIDA												
Oligochaeta												
Aulodrilus pigueti			1						1			
Bratislavia unidentata											3	1
Dero digitata				1								
Dero nivea				1								
Dero pectinata				1								
Dero spp.												
Eclipidrilus palustris	1	2	3						1		2	1
Haber speciosus												
Ilyodrilus templetoni												
Limnodrilus hoffmeisteri	1	2	1	2		1	1	1		1	1	
Lumbriculus cf. *variegatus*		1	1									
Nais communis			1									
Nais pardalis			1		3			1			1	1
Nais pseudobtusa												
Pristina aequiseta												
Pristina leidyi			1		1							
Psammoryctides convolutus			1						1			
Quistadrilus multisetosus												
Sparganophilus spp.		3	2	2	1	2	2	3	1	1		1
Varichaetadrilus angustipennis	1	3	2	3		2	1	3	1		1	
UnID Enchytraeidae spp.				1								
UnID Lumbriculidae spp.			3						1		1	1
UnID Naididae spp.		1	2	1	1			1	1		1	
UnID Naidinae spp.				1							1	
UnID Tubificinae spp.	2	3	3	3	2	3	3	3	3	3	2	2
UnID Oligochaete taxa			2	1								

TAXON	SIL1	SIL2	SIL3	SLG1	WAC1	WAC2	WAK1	WAK2	WEE1	WEE2	WEK1	WEK2
Polychaeta												
Namalycastis spp.	1	1	1									
Hirudinea												
Erpobdella punctata		1		1				1				
Erpobdella tetragon	1				1	1						
Erpobdella spp.					1			2			1	
Helobdella elongata		1		2	1	1	2	2	1		2	1
Helobdella papillata												1
Helobdella stagnalis						1	3	2		1	2	
Placobdella phalera												
Placobdella spp.					1	1						
UnID Glossiphoniidae spp.		1										
ARTHROPODA												
Chelicerata - Acarina												
Atractides spp.						1						
Geayia spp.												
Hydrodroma spp.												1
Hygrobates spp.												
Lebertia spp.		1	1			2	2	2	2		1	
Limnesia spp.	1	1			2	1		1				
Mideopsis spp.						2						
Neumania spp.		1										
Sperchon spp.											1	
Sperchonopsis spp.												
Unionicola spp.	1											
UnID Acariformes spp.		1										
Crustacea-Amphipoda												
Gammarus spp.	1	2	3	3		1		3			3	2
Grandidierella bonnieroides				3								

TAXON	SIL1	SIL2	SIL3	SLG1	WAC1	WAC2	WAK1	WAK2	WEE1	WEE2	WEK1	WEK2
Hyalella azteca spp. complex	3	3	2	2	3	3	3	3	3	3	3	3
UnID Gammaridea spp.												
Crustacea-Isopoda												
Caecidotea spp.		1			1	1	2	2	1		1	
Cassidinidea ovalis		1	2									
Cyathura polita	2	2	2									
Sphaeroma spp.												1
UnID Isopod taxa												
Crustacea-Tanaidacea												
Hargeria rapax				2								
UnID Leptocheliidae spp.				3								
Crustacea - Mysidacea												
UnID Mysida spp.								3				
Crustacea-Decapoda												
Palaemonetes spp.			1					1	1		1	1
UnID Cambaridae spp.			3			1	1				1	
INSECTA												
Odonata-Zygoptera												
Argia spp.										1		
Enallagma coecum									1			
UnID Coenagrionidae spp.					1							
Odonata-Anisoptera												
Hagenius brevistylus										1		
Macromia illinoiensis georgina			1							1		1
UnID Gomphidae spp.			1			1			1			

TAXON	SIL1	SIL2	SIL3	SLG1	WAC1	WAC2	WAK1	WAK2	WEE1	WEE2	WEK1	WEK2
Ephemeroptera												
Acentrella alachua												
Baetis intercalaris												
Caenis spp.					1	1					1	
Hexagenia spp.		1	2			2		2				
Maccaffertium exiguum												
Tricorythodes albilineatus	1	2	3		2	3	2	3	1	2		2
UnID Baetidae spp.						3				3	1	1
UnID Heptageniidae spp.						1		1		1		
UnID Ephemeroptera spp.			1					1		2		
Coleoptera												
Dubiraphia spp.												
Stenelmis spp.			1		1	3	2	3				
UnID Elmidae spp.								1				
Megaloptera												
Corydalus cornutus										2		
Diptera-Ceratopogonidae												
UnID Ceratopogonidae spp.		1		2		2		1	1	1		1
Diptera-Chironomidae												
Ablabesmyia mallochi												
Ablabesmyia rhamphe group												
Beardius spp.									2			
Chironomus spp.												
Cladopelma spp.				1								2
Cladotanytarsus spp.										2		
Clinotanypus spp.												1
Cricotopus/Orthocladius spp.	3	3	3	3	3	3	3	3	3	3	2	1
Cryptochironomus spp.		1				1						

TAXON	SIL1	SIL2	SIL3	SLG1	WAC1	WAC2	WAK1	WAK2	WEE1	WEE2	WEK1	WEK2
Dicrotendipes spp.	3	3	2	3	3	2	3	2	3	1	1	1
Glyptotendipes spp.						1	1				2	
Labrundinia spp.				1								
Larsia spp.											1	1
Nanocladius spp.												
Parachironomus spp.				1								
Paralauterborniella nigrohalteralis	1											
Paralauterborniella spp.							1		1			
Paratanytarsus spp.												
Pentaneura inconspicua			1		2	1		3		1		
Polypedilum convictum			3			3	2	3		3	1	1
Polypedilum halterale group			1	2	1	2						
Polypedilum illinoense group	2	1	2			1			1		1	1
Polypedilum scalaenum group							1			2		2
Pseudochironomus spp.		1	1	2	3			1	3	1	1	
Rheotanytarsus spp.	3	3	3		2	3	1	3	1	2		
Stenochironomus spp.										1		
Tanypus punctipennis		1										
Tanypus spp.				2								
Tanytarsus spp.			3	2	3	1		1	3	1	2	1
Thienemanniella similis												
Thienemanniella xena												
Thienemanniella spp.	1	1	2		3	2	3	1		3	1	2
Thienemannimyia group spp.												
UnID Chironomidae spp.	2	3	1	2			3	1	2	3		1
UnID Tanypodinae spp.												
Diptera-Empididae												
Hemerodromia spp.	1	2			1	2		2	1			
UnID Empididae spp.												

TAXON	SIL1	SIL2	SIL3	SLG1	WAC1	WAC2	WAK1	WAK2	WEE1	WEE2	WEK1	WEK2
Diptera - Ephydridae												
UnID Ephydridae spp.												
Diptera – Phoridae												
UnID Phoridae spp.												
Diptera – Simuliidae												
Simulium spp.												
UnID Simuliidae spp.				2							1	
Diptera – Tanyderidae												
UnID Tanyderidae spp.												
Diptera - Tipulidae												
UnID Tipulidae spp.			1	1								
Lepidoptera												
Parapoynx spp.					2					2	1	
Petrophila santafealis	3	3	3			3	1	3	2	1		
UnID Lepidoptera taxa		1										
Trichoptera												
Cernotina spp.	1	3	3	3								
Cheumatopsyche spp.		1	1		3	3	2	1		3		
Cyrnellus fraternus												
Hydropsyche rossi								1		3		
Hydropsyche spp.							1					
Hydroptila spp.	3	3	2		3	3	3	3	2	2	1	3
Macrostemum carolina												
Mayatrichia ayama												
Neotrichia spp.												
Neureclipsis crepuscularis												1

TAXON	SIL1	SIL2	SIL3	SLG1	WAC1	WAC2	WAK1	WAK2	WEE1	WEE2	WEK1	WEK2
Ochrotrichia spp.												
Oecetis avara										1		
Oecetis spp.					1	1				2		
Orthotrichia spp.	2	1		1		1			1			
Oxyethira spp.	2		1		2	1	2	3	3	2	1	
Triaenodes spp.							2					
UnID Hydropsychidae spp.										3		
UnID Hydroptilidae spp.	2	1							2	2		
UnID Polycentropodidae spp.			1									
UnID Trichoptera taxa										2		
Hemiptera												
Pelocoris spp.				1								
TOTAL TAXA	31	45	54	36	35	48	28	44	43	40	41	33

Appendix D— Summaries of Macroinvertebrate Taxa in Macroalgal Habitat at each Transect in Spring and Fall

Appendix D. Table 1. Macroinvertebrate taxa list for macroalgal habitat in spring 2015. Number of times collected shown (out of the 3 replicates collected at each sampling transect).

TAXON	ALE1	ALE2	MAN1	RAI2	ROC1	SLG1	VOL1	WAK1	WAK2	WEE1	WEE2
PLATYHELMINTHES											
UnID flatworm											1
MOLLUSCA											
Gastropoda											
Laevapex fuscus											1
Melanoides tuberculata					2		1				
Melanoides spp				1		2				1	
Menetus floridensis						1					
Notogillia wetherbyi			3								
Physella cubensis										1	1
Planorbella scalaris										2	
Planorbella trivolvis			1								
Pleurocera floridensis	1	2		3	1	1		2	2	1	1
Pomacea spp					1						
Viviparus georgianus	1										
UnID Hydrobiidae spp	3	1	3	1	3	2	3		2	3	2
UnID Gastropoda spp				1				1			
Bivalvia											
Corbicula fluminea					3				3		
UnID Sphaeriidae spp								1			1
ANNELIDA											
Oligochaeta											
Aulodrilus paucichaeta			3								
Dero digitata	1						1				
Eclipidrilus palustris						1					
Limnodrilus hoffmeisteri	1	1	1		2	1	1	1			1
Nais communis	1										

TAXON	ALE1	ALE2	MAN1	RAI2	ROC1	SLG1	VOL1	WAK1	WAK2	WEE1	WEE2
Nais pardalis	1										
Pristina leidyi	1										
Quistadrilus multisetosus			1								
Sparganophilus spp					1						
UnID Lumbriculidae spp											1
UnID Tubificinae spp	2	2	3		2	2	2	1	3	2	2
Hirudinea											
Erpobdella tetragon											1
Erpobdella spp				1							
Helobdella elongata	1			3		1					
Helobdella stagnalis			1	1	1	1		1	1	1	
Placobdella spp	1				2		2	1			
UnID Hirudinea spp		1									
ARTHROPODA											
Chelicerata - Acarina											
Arrenurus spp						1					
Atractides spp				1		1				1	
Frontipoda spp						1					
Geayia spp				1						1	
Hygrobates spp										1	
Lebertia spp		1								1	
Limnesia spp						1				1	
Unionicola spp	1					1					
Crustacea-Amphipoda											
Gammarus spp	3	3			3	3		2	1		
Grandidierella bonnieroides						1					
Hyalella azteca spp complex	3	3	3	3	3	2	3	3	3	3	3
UnID Gammaridea spp		1						1			

TAXON	ALE1	ALE2	MAN1	RAI2	ROC1	SLG1	VOL1	WAK1	WAK2	WEE1	WEE2
Crustacea-Isopoda											
Caecidotea spp		1	2	2			2	1	1		
Crustacea-Tanaidacea											
Hargeria rapax						1					
UnID Leptocheliidae spp.						2					
Crustacea-Mysidacea											
Taphromysis bowmani									1		
Crustacea-Decapoda											
Palaemonetes spp			1					2		1	
UnID Cambaridae spp			2	1				1			
INSECTA											
Odonata-Zygoptera									1		
Argia spp											1
Enallagma coecum											
Odonata-Anisoptera											
Dromogomphus spinosus				1	1				1		
Epicordulia princeps regina								1			
UnID Libellulidae spp										1	
Ephemeroptera											
Caenis diminuta	1		1							1	
Caenis spp.	2				1					1	
Hexagenia spp		1							2		
Tricorythodes albilineatus				2		1		1	3	2	3
UnID Baetiddae spp											1
UnID Ephemeroptera spp			1	1	1	1			1	2	2

TAXON	ALE1	ALE2	MAN1	RAI2	ROC1	SLG1	VOL1	WAK1	WAK2	WEE1	WEE2
Coleoptera											
Dineutus spp									1		
Dubiraphia spp								1	1		
Stenelmis spp				1	3			2	3		1
Diptera-Ceratopogonidae											
UnID Ceratopogonidae spp	1		1	2	1	1					2
Diptera-Chironomidae											
Ablabesmyia mallochi						1		1	3		
Ablabesmyia rhamphe group					2						
Apedilum spp								1			
Beardius spp										1	
Chironomus spp							3		1		
Cladotanytarsus spp									3		1
Coelotanypus spp					1						
Cricotopus spp			1	1							
Cricotopus/Orthocladius spp		1		1		1			2	1	
Cryptochironomus spp					2				2		
Cryptotendipes spp									1		
Dicrotendipes modestus						1			3		
Dicrotendipes neomodestus								2			
Dicrotendipes spp	1			2				1			
Harnischia spp		1									
Labrundinia pilosella										1	
Labrundinia spp						1					
Larsia spp										1	
Paracladopelma spp		1				1			2		
Paralauterborniella nigrohalteralis		1						1	1		
Pentaneura inconspicua				1						2	1

TAXON	ALE1	ALE2	MAN1	RAI2	ROC1	SLG1	VOL1	WAK1	WAK2	WEE1	WEE2
Polypedilum convictum		1						1	2		
Polypedilum halterale group		1				1		2			
Polypedilum illinoense group			1				1		2		
Polypedilum scalaenum group					2				1		1
Procladius spp						1		1			2
Pseudochironomus spp	2	1		3		1		1	3	1	
Rheotanytarsus spp									1		
Stempellinella fimbriata									1		
Tanypus spp		1									
Tanytarsus buckleyi						1			2	1	
Tanytarsus spp				1		1		1	2	1	2
Thienemanniella xena				1							
Thienemannimyia group spp				1				1	3		
UnID Chironominae spp											1
UnID Chironomidae spp						1		1		2	1
UnID Tanypodinae spp		1									
UnID Dipteran spp				1							
Diptera-Empididae											
Hemerodromia spp			2								
Lepidoptera											
Parapoynx spp									1		
Petrophila santafealis			1	2							
Trichoptera											
Cernotina spp						1					
Cheumatopsyche spp					1				2	1	
Helicopsyche borealis									2		
Hydroptila spp				1	3				3	2	1
Hydropsyche rossi									1		2
Mayatrichia ayama					1						

TAXON	ALE1	ALE2	MAN1	RAI2	ROC1	SLG1	VOL1	WAK1	WAK2	WEE1	WEE2
Nectopsyche candida/exquisita										1	
Oecetis avara									1		1
Oecetis spp					1						
Oxyethira spp								1	1	2	2
Triaenodes florida									1		
UnID Hydroptilidae spp										1	
Hemiptera											
UnID Heteroptera spp						1					
TOTAL TAXA	19	20	19	28	25	35	10	30	43	33	28

Appendix D. Table 2. Macroinvertebrate taxa list for macroalgal habitat in fall 2015. Number of times collected shown (out of the 3 replicates collected at each sampling transect).

TAXON	ALE2	GUM1	MAN1	RAI2	VOL1	WAK1	WAK2	WEE1	WEE2
PLATYHELMINTHES									
UnID flatworm								2	
MOLLUSCA									
Gastropoda									
Melanoides tuberculata					1				
Melanoides spp								1	2
Notogillia wetherbyi								1	
Physella cubensis								3	2
Planorbella scalaris						1	1	1	
Pleurocera floridensis						3	1	1	1
Pomacea paludosa	1								
UnID Hydrobiidae spp			3		3			3	2
Bivalvia									
Corbicula fluminea							3		
UnID Sphaeriidae spp								1	
UnID Unionidae spp				1					
ANNELIDA									
Oligochaeta									
Aulodrilus paucichaeta			2						
Dero digitata								1	
Eclipidrilus palustris			1	1					
Ilyodrilus templetoni			2				1		
Limnodrilus hoffmeisteri	2		2		1		2		3
Quistadrilus multisetosus			1						
Sparganophilus spp	1								
UnID Tubificinae spp	2		3	1	1	1	2	1	3

TAXON	ALE2	GUM1	MAN1	RAI2	VOL1	WAK1	WAK2	WEE1	WEE2
Hirudinea									
Erpobdella punctata									1
Helobdella elongata	1	2		1	1				1
Helobdella stagnalis			2	3	1	2			
Helobdella spp								1	
ARTHROPODA									
Chelicerata - Acarina									
Hygrobates spp		2							
Lebertia spp						3			
Crustacea-Amphipoda									
Gammarus spp	3		1			3	3		
Hyalella azteca spp complex	3	3	3	3	3	3	3	3	3
Crustacea-Isopoda									
Caecidotea spp	1	2	1	1		2	1	1	1
Cyathura polita	1								
Crustacea-Decapoda									
Palaemonetes spp	1					1	1	2	
UnID Cambaridae spp			1			2	1		
INSECTA									
Odonata-Zygoptera									
Argia spp									2
Odonata-Anisoptera									
Dromogomphus spinosus									1
Macromia illinoensis georgina									1

TAXON	ALE2	GUM1	MAN1	RAI2	VOL1	WAK1	WAK2	WEE1	WEE2
Ephemeroptera									
Caenis diminuta			1						
Caenis spp			2						
Hexagenia spp	1						1		
Tricorythodes albilineatus	1	1		3		1	1	1	3
UnID Baetiddae spp									2
UnID Ephemeroptera spp				1					2
Coleoptera									
Stenelmis spp						1	2		
Diptera-Ceratopogonidae									
UnID Ceratopogonidae spp	1		1	1			1		2
Diptera-Chironomidae									
Ablabesmyia mallochi	1	2	1	3					
Ablabesmyia rhamphe group			1						
Apedilum spp							1		
Beardius spp								1	
Chironomus spp					2				
Cladotanytarsus spp									3
Clinotanypus spp	2								
Cricotopus/Orthocladius spp	2			3		1	2	1	2
Cryptochironomus spp			1						2
Dicrotendipes spp			1	3	1	1	1	1	1
Epoicocladius spp							1		
Glyptotendipes spp								1	
Larsia spp								1	
Paralauterborniella spp				1		1			2
Paratanytarsus spp				1					
Pentaneura inconspicua		2				1	2		2

TAXON	ALE2	GUM1	MAN1	RAI2	VOL1	WAK1	WAK2	WEE1	WEE2
Pentaneura spp				1					
Polypedilum convictum							2		
Polypedilum halterale group	1								
Polypedilum scalaenum group									3
Procladius spp			1						
Pseudochironomus spp	2	2	1	3			2	1	2
Rheotanytarsus spp		1		1					
Tanytarsus spp		2	2	2		1	2	2	2
Thienemanniella xena				1					
Thienemanniella spp		1				1			
Thienemannimyia group spp				2					
UnID Chironomidae spp	1			3					2
UnID Dipteran spp		1							
Diptera-Empididae									
UnID Empididae spp				1					
Lepidoptera									
Petrophila santafealis				1					
Trichoptera									
Cernotina spp				1					
Cheumatopsyche spp				1		1	1		3
Hydroptila spp		1		2			1		2
Hydropsyche rossi									1
Hydropsyche spp				3					
Oecetis avara				1					
Oecetis spp									1
Oxyethira spp		1				1	2	1	2
Triaenodes spp						1			
UnID Hydroptilidae spp									2
TOTAL TAXA	19	14	23	29	9	21	26	23	33

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APPENDIX E—SUMMARY STATISTICS FOR MACROINVERTEBRATE TAXA RICHNESS, ABUNDANCE, AND DIVERSITY IN MACROPHYTE HABITAT IN SPRING AND FALL

Column Headings in Tables

Mean – mean value
St. Deviation – Standard deviation
CV – Coefficient of Variation (%)
Minimum – Minimum value
25 %-ile – 25th Percentile value
Median – Median value
75 %-ile – 75th Percentile value
Maximum – Maximum value

Appendix E. Table 1. Summary statistics of macroinvertebrate taxa richness (no. taxa) in spring in macrophyte habitat at transects with this habitat.

Transect	Mean	St. Deviation	CV (%)	Minimum	25th %-ile	Median	75th %-ile	Maximum
ALE1	13.00	6.00	46.15	7.00	7.00	13.00	19.00	19.00
ALE2	17.33	6.11	35.25	12.00	12.00	16.00	24.00	24.00
GUM1	21.00	4.58	21.82	17.00	17.00	20.00	26.00	26.00
GUM2	19.67	4.51	22.93	15.00	15.00	20.00	24.00	24.00
ICH1	21.33	5.51	25.82	15.00	15.00	24.00	25.00	25.00
ICH2	25.00	7.94	31.75	16.00	16.00	28.00	31.00	31.00
JUN1	12.00	1.73	14.43	11.00	11.00	11.00	14.00	14.00
JUN2	30.67	8.33	27.15	24.00	24.00	28.00	40.00	40.00
RAI1	27.33	6.11	22.35	22.00	22.00	26.00	34.00	34.00
RAI2	23.33	7.23	31.00	15.00	15.00	27.00	28.00	28.00
ROC1	19.67	8.74	44.42	10.00	10.00	22.00	27.00	27.00
ROC2	29.33	13.80	47.03	19.00	19.00	24.00	45.00	45.00
SIL1	25.67	5.77	22.49	19.00	19.00	29.00	29.00	29.00
SIL2	27.00	5.20	19.25	21.00	21.00	30.00	30.00	30.00
SIL3	27.33	4.62	16.90	22.00	22.00	30.00	30.00	30.00
SLG1	24.33	6.66	27.36	20.00	20.00	21.00	32.00	32.00
WAC1	33.00	5.00	15.15	28.00	28.00	33.00	38.00	38.00
WAC2	25.67	9.61	37.44	17.00	17.00	24.00	36.00	36.00
WAK1	17.33	8.96	51.71	7.00	7.00	22.00	23.00	23.00
WAK2	23.67	3.51	14.84	20.00	20.00	24.00	27.00	27.00
WEE1	28.00	6.08	21.72	21.00	21.00	31.00	32.00	32.00
WEE2	29.67	3.79	12.76	27.00	27.00	28.00	34.00	34.00
WEK1	12.33	4.93	40.00	9.00	9.00	10.00	18.00	18.00
WEK2	26.33	2.08	7.91	24.00	24.00	27.00	28.00	28.00

Appendix E. Table 2. Summary statistics of macroinvertebrate population density (# individuals/m^2) in spring in macrophyte habitat at transects with this habitat.

Transect	Mean	St. Deviation	CV (%)	Minimum	25th %-ile	Median	75th %-ile	Maximum
ALE1	2693	1290	47.92	1203	1203	3406	3469	3469
ALE2	3557	2576	72.41	672	672	4375	5625	5625
GUM1	97516	19368	19.86	76688	76688	100875	114984	114984
GUM2	14234	12542	88.11	1547	1547	14531	26625	26625
ICH1	26943	16919	62.80	7563	7563	34500	38766	38766
ICH2	16135	2031	12.59	14094	14094	16156	18156	18156
JUN1	844	343	40.61	547	547	766	1219	1219
JUN2	24781	22913	92.46	10156	10156	13000	51188	51188
RAI1	74031	63706	86.05	32813	32813	41875	147406	147406
RAI2	95875	12741	13.29	81750	81750	99375	106500	106500
ROC1	2740	2119	77.37	797	797	2422	5000	5000
ROC2	7891	1294	16.40	7000	7000	7297	9375	9375
SIL1	66958	21813	32.58	53500	53500	55250	92125	92125
SIL2	23667	12081	51.05	14125	14125	19625	37250	37250
SIL3	9432	4870	51.63	5531	5531	7875	14891	14891
SLG1	20380	23805	116.80	2656	2656	11047	47438	47438
WAC1	21719	10720	49.36	12281	12281	19500	33375	33375
WAC2	35214	44792	127.20	5656	5656	13234	86750	86750
WAK1	11458	6226	54.34	5063	5063	11813	17500	17500
WAK2	6651	7039	105.84	1578	1578	3688	14688	14688
WEE1	32042	42832	133.68	7188	7188	7438	81500	81500
WEE2	5057	791	15.65	4453	4453	4766	5953	5953
WEK1	6026	1235	20.50	5141	5141	5500	7438	7438
WEK2	8729	6221	71.27	4313	4313	6031	15844	15844

Appendix E. Table 3. Summary statistics of macroinvertebrate Shannon-Weiner diversity (H’) in spring in macrophyte habitat at transects with this habitat.

Transect	Mean	St. Deviation	CV (%)	Minimum	25^{th} %-ile	Median	75^{th} %-ile	Maximum
ALE1	1.46	0.71	48.37	0.67	0.67	1.67	2.03	2.03
ALE2	1.60	0.13	7.78	1.47	1.47	1.63	1.71	1.71
GUM1	1.93	0.04	2.15	1.90	1.90	1.91	1.98	1.98
GUM2	1.72	0.05	2.70	1.67	1.67	1.74	1.76	1.76
ICH1	1.78	0.26	14.53	1.50	1.50	1.81	2.01	2.01
ICH2	1.96	0.32	16.26	1.61	1.61	2.05	2.23	2.23
JUN1	1.98	0.29	14.71	1.65	1.65	2.13	2.17	2.17
JUN2	2.14	0.30	13.95	1.80	1.80	2.26	2.36	2.36
RAI1	2.03	0.31	15.16	1.82	1.82	1.89	2.39	2.39
RAI2	1.53	0.46	29.69	1.01	1.01	1.79	1.80	1.80
ROC1	2.19	0.50	22.97	1.61	1.61	2.45	2.52	2.52
ROC2	1.97	0.52	26.18	1.43	1.43	2.03	2.46	2.46
SIL1	2.35	0.26	11.04	2.06	2.06	2.40	2.57	2.57
SIL2	2.47	0.25	10.23	2.18	2.18	2.56	2.66	2.66
SIL3	2.26	0.50	21.89	1.71	1.71	2.42	2.66	2.66
SLG1	1.69	0.41	24.14	1.23	1.23	1.83	2.00	2.00
WAC1	2.24	0.26	11.74	1.95	1.95	2.31	2.45	2.45
WAC2	2.26	0.59	26.09	1.69	1.69	2.22	2.86	2.86
WAK1	1.76	0.54	30.63	1.14	1.14	2.03	2.12	2.12
WAK2	2.39	0.35	14.84	2.14	2.14	2.23	2.80	2.80
WEE1	2.57	0.06	2.33	2.52	2.52	2.55	2.64	2.64
WEE2	2.32	0.25	10.61	2.03	2.03	2.43	2.48	2.48
WEK1	1.46	0.26	17.86	1.25	1.25	1.38	1.75	1.75
WEK2	2.34	0.19	7.98	2.13	2.13	2.41	2.48	2.48

Appendix E. Table 4. Summary statistics of macroinvertebrate taxa richness (no. taxa) in fall in macrophyte habitat at transects with this habitat. JUN1 not sampled in fall (macrophyte habitat not present).

Transect	Mean	St. Deviation	CV (%)	Minimum	25th %-ile	Median	75th %-ile	Maximum
ALE1	18.67	5.69	30.46	14.00	14.00	17.00	25.00	25.00
ALE2	17.00	6.00	35.29	11.00	11.00	17.00	23.00	23.00
GUM1	20.00	7.94	39.69	14.00	14.00	17.00	29.00	29.00
GUM2	28.00	9.00	32.14	19.00	19.00	28.00	37.00	37.00
ICH1	22.33	4.93	22.09	19.00	19.00	20.00	28.00	28.00
ICH2	22.00	1.73	7.87	21.00	21.00	21.00	24.00	24.00
JUN2	15.33	5.77	37.65	12.00	12.00	12.00	22.00	22.00
RAI1	27.33	4.51	16.50	23.00	23.00	27.00	32.00	32.00
RAI2	24.33	3.06	12.56	21.00	21.00	25.00	27.00	27.00
ROC1	23.33	9.71	41.63	15.00	15.00	21.00	34.00	34.00
ROC2	17.00	4.36	25.64	12.00	12.00	19.00	20.00	20.00
SIL1	17.33	3.51	20.26	14.00	14.00	17.00	21.00	21.00
SIL2	25.33	8.50	33.57	17.00	17.00	25.00	34.00	34.00
SIL3	31.67	3.06	9.65	29.00	29.00	31.00	35.00	35.00
SLG1	21.33	4.04	18.94	17.00	17.00	22.00	25.00	25.00
WAC1	20.33	2.08	10.24	18.00	18.00	21.00	22.00	22.00
WAC2	27.33	7.37	26.97	19.00	19.00	30.00	33.00	33.00
WAK1	18.00	4.58	25.46	14.00	14.00	17.00	23.00	23.00
WAK2	27.67	5.69	20.55	23.00	23.00	26.00	34.00	34.00
WEE1	22.00	3.61	16.39	18.00	18.00	23.00	25.00	25.00
WEE2	24.00	1.00	4.17	23.00	23.00	24.00	25.00	25.00
WEK1	18.67	1.53	8.18	17.00	17.00	19.00	20.00	20.00
WEK2	14.33	2.08	14.52	12.00	12.00	15.00	16.00	16.00

Appendix E. Table 5. Summary statistics of macroinvertebrate population density (# individuals/m^2) in fall in macrophyte habitat at transects with this habitat. JUN1 not sampled in fall (macrophyte habitat not present).

Transect	Mean	St. Deviation	CV (%)	Minimum	25^{th} %-ile	Median	75^{th} %-ile	Maximum
ALE1	11339	9954	87.79	4344	4344	6938	22734	22734
ALE2	3031	2233	73.66	453	453	4297	4344	4344
GUM1	35219	25821	73.32	5500	5500	48000	52156	52156
GUM2	4073	1845	45.30	2047	2047	4516	5656	5656
ICH1	11406	7150	62.69	6766	6766	7813	19641	19641
ICH2	4844	4520	93.32	2172	2172	2297	10063	10063
JUN2	28865	32818	113.70	6438	6438	13625	66531	66531
RAI1	23078	3831	16.60	19688	19688	22313	27234	27234
RAI2	24776	6389	25.79	17484	17484	27453	29391	29391
ROC1	3583	3236	90.32	969	969	2578	7203	7203
ROC2	2781	718	25.80	2344	2344	2391	3609	3609
SIL1	27677	20443	73.86	9625	9625	23531	49875	49875
SIL2	20583	13451	65.35	6797	6797	21281	33672	33672
SIL3	4667	2104	45.09	2328	2328	5266	6406	6406
SLG1	14422	7468	51.78	8719	8719	11672	22875	22875
WAC1	54531	28112	51.55	29156	29156	49688	84750	84750
WAC2	20417	14797	72.48	5656	5656	20344	35250	35250
WAK1	18526	7664	41.37	9703	9703	22344	23531	23531
WAK2	16406	8560	52.18	6750	6750	19406	23063	23063
WEE1	24578	3179	12.94	21984	21984	23625	28125	28125
WEE2	5297	3179	60.02	2703	2703	4344	8844	8844
WEK1	11458	16441	143.48	969	969	3000	30406	30406
WEK2	1250	668	53.44	500	500	1469	1781	1781

Appendix E. Table 6. Summary statistics of macroinvertebrate Shannon-Weiner diversity (H’) in fall in macrophyte habitat at transects with this habitat. JUN1 not sampled in fall (macrophyte habitat not present).

Transect	Mean	St. Deviation	CV (%)	Minimum	25th %-ile	Median	75th %-ile	Maximum
ALE1	1.93	0.37	19.15	1.63	1.63	1.82	2.34	2.34
ALE2	2.02	0.16	7.74	1.90	1.90	1.97	2.20	2.20
GUM1	1.60	0.19	11.57	1.38	1.38	1.70	1.70	1.70
GUM2	2.42	0.56	23.12	2.06	2.06	2.14	3.07	3.07
ICH1	2.03	0.49	23.87	1.63	1.63	1.89	2.57	2.57
ICH2	2.42	0.24	9.92	2.14	2.14	2.52	2.59	2.59
JUN2	1.45	0.62	42.83	0.98	0.98	1.21	2.16	2.16
RAI1	2.40	0.19	7.87	2.18	2.18	2.47	2.54	2.54
RAI2	2.37	0.29	12.22	2.03	2.03	2.50	2.57	2.57
ROC1	2.36	0.83	35.20	1.40	1.40	2.75	2.91	2.91
ROC2	1.66	0.35	21.11	1.38	1.38	1.55	2.05	2.05
SIL1	1.72	0.26	15.21	1.44	1.44	1.77	1.96	1.96
SIL2	2.24	0.28	12.29	2.03	2.03	2.13	2.55	2.55
SIL3	2.68	0.13	4.90	2.53	2.53	2.75	2.76	2.76
SLG1	1.98	0.27	13.65	1.67	1.67	2.08	2.19	2.19
WAC1	1.78	0.06	3.33	1.72	1.72	1.78	1.84	1.84
WAC2	2.42	0.17	6.95	2.23	2.23	2.49	2.55	2.55
WAK1	1.89	0.25	13.29	1.60	1.60	2.01	2.05	2.05
WAK2	1.85	0.46	24.90	1.44	1.44	1.78	2.35	2.35
WEE1	2.13	0.44	20.83	1.62	1.62	2.36	2.42	2.42
WEE2	2.28	0.28	12.08	2.07	2.07	2.18	2.59	2.59
WEK1	2.10	0.36	17.15	1.68	1.68	2.29	2.31	2.31
WEK2	1.93	0.39	20.23	1.54	1.54	1.94	2.32	2.32

APPENDIX F—SUMMARY STATISTICS FOR MACROINVERTEBRATE TAXA RICHNESS, ABUNDANCE, AND DIVERSITY IN MACROALGAL HABITAT IN SPRING AND FALL

Column Headings in Tables

Mean – mean value
St. Deviation – Standard deviation
CV – Coefficient of Variation (%)
Minimum – Minimum value
25 %-ile – 25^{th} Percentile value
Median – Median value
75 %-ile – 75^{th} Percentile value
Maximum – Maximum value

Appendix F. Table 1. Summary statistics for macroinvertebrate taxa richness (# taxa) at the sampling transects supporting algal mats in spring 2015.

Transect	Mean	St. Deviation	CV (%)	Minimum	25th %-ile	Median	75th %-ile	Maximum
ALE1	9.33	4.51	48.31	5.00	5.00	9.00	14.00	14.00
ALE2	8.67	3.79	43.68	6.00	6.00	7.00	13.00	13.00
MAN1	10.67	5.13	48.11	5.00	5.00	12.00	15.00	15.00
RAI2	13.67	0.58	4.22	13.00	13.00	14.00	14.00	14.00
ROC1	14.67	4.04	27.56	11.00	11.00	14.00	19.00	19.00
SLG1	14.00	6.56	46.84	8.00	8.00	13.00	21.00	21.00
VOL1	6.33	0.58	9.12	6.00	6.00	6.00	7.00	7.00
WAK1	12.67	6.43	50.76	8.00	8.00	10.00	20.00	20.00
WAK2	25.33	2.31	9.12	24.00	24.00	24.00	28.00	28.00
WEE1	15.00	8.00	53.33	7.00	7.00	15.00	23.00	23.00
WEE2	13.33	8.02	60.16	5.00	5.00	14.00	21.00	21.00

Appendix F. Table 2. Summary statistics for macroinvertebrate population density (# individuals/m^2) at the sampling transects supporting algal mats in spring 2015.

Transect	Mean	St. Deviation	CV (%)	Minimum	25th %-ile	Median	75th %-ile	Maximum
ALE1	1385	678	48.96	828	828	1188	2141	2141
ALE2	1724	790	45.82	875	875	1859	2438	2438
MAN1	542	323	59.56	172	172	688	766	766
RAI2	31354	36354	115.95	5969	5969	15094	73000	73000
ROC1	2417	1456	60.24	766	766	2969	3516	3516
SLG1	3125	2203	70.49	1469	1469	2281	5625	5625
VOL1	29302	8921	30.44	20688	20688	28719	38500	38500
WAK1	11313	7143	63.15	5250	5250	9500	19188	19188
WAK2	8385	6109	72.86	2266	2266	8406	14484	14484
WEE1	110151	33487	30.40	73203	73203	118750	138500	138500
WEE2	19255	17141	89.02	391	391	23500	33875	33875

Appendix F. Table 3. Summary statistics for macroinvertebrate Shannon-Weiner diversity (H’) at the sampling transects supporting algal mats in spring 2015.

Transect	Mean	St. Deviation	CV (%)	Minimum	25th %-ile	Median	75th %-ile	Maximum
ALE1	1.36	0.40	29.76	0.90	0.90	1.50	1.67	1.67
ALE2	1.45	0.78	53.87	0.86	0.86	1.16	2.34	2.34
MAN1	1.87	0.42	22.65	1.41	1.41	1.93	2.25	2.25
RAI2	0.64	0.10	15.17	0.59	0.59	0.59	0.76	0.76
ROC1	1.74	0.14	8.08	1.62	1.62	1.71	1.89	1.89
SLG1	1.87	0.53	28.10	1.31	1.31	1.95	2.35	2.35
VOL1	0.62	0.22	35.26	0.39	0.39	0.65	0.82	0.82
WAK1	0.62	0.23	37.81	0.40	0.40	0.59	0.86	0.86
WAK2	2.43	0.21	8.75	2.24	2.24	2.40	2.66	2.66
WEE1	0.96	0.95	99.04	0.10	0.10	0.80	1.99	1.99
WEE2	0.65	0.02	3.56	0.63	0.63	0.66	0.67	0.67

Appendix F. Table 4. Summary statistics for macroinvertebrate taxa richness (# taxa) at the sampling transects supporting algal mats in fall 2015.

Transect	Mean	St. Deviation	CV (%)	Minimum	25th %-ile	Median	75th %-ile	Maximum
ALE2	9.33	0.58	6.19	9.00	9.00	9.00	10.00	10.00
GUM1	7.67	1.53	19.92	6.00	6.00	8.00	9.00	9.00
MAN1	11.67	2.08	17.84	10.00	10.00	11.00	14.00	14.00
RAI2	16.67	5.51	33.05	13.00	13.00	14.00	23.00	23.00
VOL1	4.67	3.06	65.47	2.00	2.00	4.00	8.00	8.00
WAK1	10.67	2.31	21.65	8.00	8.00	12.00	12.00	12.00
WAK2	13.67	0.58	4.22	13.00	13.00	14.00	14.00	14.00
WEE1	10.67	4.62	43.30	8.00	8.00	8.00	16.00	16.00
WEE2	21.33	4.04	18.94	17.00	17.00	22.00	25.00	25.00

Appendix F. Table 5. Summary statistics for macroinvertebrate population density (# individuals/m^2) at the sampling transects supporting algal mats in fall 2015.

Transect	Mean	St. Deviation	CV (%)	Minimum	25th %-ile	Median	75th %-ile	Maximum
ALE2	1125	231	20.55	859	859	1234	1281	1281
GUM1	43349	22231	51.28	17797	17797	54000	58250	58250
MAN1	3490	1994	57.15	1391	1391	3719	5359	5359
RAI2	15177	5679	37.42	9156	9156	15938	20438	20438
VOL1	7203	7084	98.35	1906	1906	4453	15250	15250
WAK1	5771	7674	132.97	1047	1047	1641	14625	14625
WAK2	17651	4256	24.11	15063	15063	15328	22563	22563
WEE1	32938	29054	88.21	8969	8969	24594	65250	65250
WEE2	6063	2519	41.55	3469	3469	6219	8500	8500

Appendix F. Table 6. Summary statistics for macroinvertebrate Shannon-Weiner diversity (H’) at the sampling transects supporting algal mats in fall 2015.

Transect	Mean	St. Deviation	CV (%)	Minimum	25th %-ile	Median	75th %-ile	Maximum
ALE2	1.45	0.23	16.08	1.25	1.25	1.41	1.71	1.71
GUM1	0.26	0.11	39.99	0.15	0.15	0.29	0.35	0.35
MAN1	1.23	0.31	25.28	0.97	0.97	1.15	1.58	1.58
RAI2	1.21	0.67	55.03	0.66	0.66	1.03	1.95	1.95
VOL1	0.91	0.65	71.10	0.40	0.40	0.69	1.65	1.65
WAK1	0.85	0.34	40.28	0.55	0.55	0.77	1.22	1.22
WAK2	0.69	0.19	27.87	0.50	0.50	0.69	0.89	0.89
WEE1	0.73	0.62	84.76	0.34	0.34	0.41	1.45	1.45
WEE2	1.58	0.65	41.33	0.83	0.83	1.87	2.04	2.04