

FACTORS AFFECTING PERIPHYTON ABUNDANCE ON MACROPHYTES IN A
SPRING-FED RIVER IN FLORIDA

By

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To my family

ACKNOWLEDGEMENTS

I thank my family and friends for their support and my advisors for their tutelage.

TABLE OF CONTENTS

	<u>page</u>
ACKNOWLEDGEMENTS.....	4
LIST OF TABLES.....	6
LIST OF FIGURES.....	7
ABSTRACT.....	8
CHAPTER	
1 INTRODUCTION.....	10
2 MATERIALS AND METHODS.....	12
Quantitative River and Spring Survey.....	12
Chemical and Physical Parameters.....	13
Vegetation Sampling.....	13
Quantifying Periphyton Associated with SAV.....	14
Translocation Experiment.....	15
Statistical Analyses.....	16
3 RESULTS.....	19
Survey Results.....	19
Translocation Experiment.....	20
4 DISCUSSION.....	33
LIST OF REFERENCES.....	37
BIOGRAPHICAL SKETCH.....	40

LIST OF TABLES

<u>Table</u>	<u>page</u>
3-1. Summary of 2007 Survey Data – Means \pm Standard Errors (n = # of samples)	22

LIST OF FIGURES

<u>Figure</u>	<u>page</u>
2-1. Map of the Ichetucknee River course through the Ichetucknee Springs State Park. All transect sampling was carried out in the upper portion of the river within the confines of the park. Experimental work was conducted near Singing Spring, Devils Eye (also known as Boiling Spring) and Mill Pond Spring.	17
2-2. Collapsed and expanded view of plant sampling apparatus.	18
3-1. Mean dissolved oxygen concentration with increasing distance downstream in the main stem of the Ichetucknee River. Numbers along the x-axis correspond to river transects with ascending values representing distance downstream.	23
3-2. Mean dissolved oxygen concentration in the main stem of the Ichetucknee River and three associated feeder springs (i.e. Singing Spring, Devil’s Eye Spring, and Mill Pond Spring).	24
3-3. Mean stream velocity with increasing distance downstream in the main stem of the Ichetucknee River. Numbers along the x-axis correspond to river transects with ascending values representing distance downstream.	25
3-4. Mean stream velocity in the main stem of the Ichetucknee River and three associated feeder springs (i.e. Singing Spring, Devil’s Eye Spring, and Mill Pond Spring).	26
3-5. Mean periphyton abundance with increasing distance downstream in the main stem of the Ichetucknee River. Numbers along the x-axis correspond to river transects with ascending values representing distance downstream.	27
3-6. Mean periphyton abundance in the main stem of the Ichetucknee River and three associated feeder springs (i.e. Singing Spring, Devil’s Eye Spring, and Mill Pond Spring).	28
3-7. Mean plant biomass with increasing distance downstream in the main stem of the Ichetucknee River. Numbers along the x-axis correspond to river transects with ascending values representing distance downstream.	29
3-8. Mean plant biomass in the main stem of the Ichetucknee River and three associated feeder springs (i.e. Singing Spring, Devil’s Eye Spring, and Mill Pond Spring).	30
3-9. Mean plant biomass in the main stem of the Ichetucknee River and three associated feeder springs (i.e. Singing Spring, Devil’s Eye Spring, and Mill Pond Spring) following a four week translocation experiment.	31
3-10. Mean periphyton abundance in the main stem of the Ichetucknee River and three associated feeder springs (i.e. Singing Spring, Devil’s Eye Spring, and Mill Pond Spring) following a four week translocation experiment.	32

Abstract of Thesis Presented to the Graduate School
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Past and present land use activities in Florida have resulted in broad-scale nutrient concentration increases in the groundwater system. Nutrient contaminated groundwater is not only a health concern, but also represents a potentially serious ecological problem. Because Florida's extensive system of aquifers exist within a very permeable karst geology, there are myriad of pathways by which nutrient laden groundwater can enter and be mixed with surface water systems. Freshwater springs, for example, provide a direct conduit for contaminated groundwater discharge to surface water systems. It is in the surface waters where nutrients, such as nitrogen and phosphorus, have the greatest potential to negatively alter the ecology of aquatic ecosystems. Along the Ichetucknee River, several feeder springs have experienced vegetation losses over the past decade. The springs are not only enriched in nutrients, but also exhibit low dissolved oxygen concentrations, and low stream velocities. While eutrophication appears to be a plausible explanation for vegetation loss, this study investigated the possibility that nutrient contamination alone may not be responsible for vegetation loss. I hypothesized that low dissolved oxygen concentrations near spring vents and seeps preclude the existence of primary grazers and, as a consequence, macrophytes in these areas of low stream velocity accumulate more periphyton and grow more slowly than vegetation in more oxygenated, swiftly flowing

portions of the river. An initial characterization of the abiotic environment and the macrophyte community of the Ichetucknee River indicated that the proposed pattern of interaction was evident throughout the system. Subsequently, a four-week translocation experiment was carried out where genets of the most abundant macrophyte, *Sagittaria kurziana*, were relocated to several river and spring locations to evaluate site specific differences in the rate of periphyton accumulation and potential effects on macrophyte growth. Results suggest that periphyton accumulation on *S. kurziana* is more rapid in feeder spring environments than in the main stem of the Ichetucknee River. The differences were likely due to low dissolved oxygen concentrations, low stream velocities and reduced grazer abundance in the feeder springs. There were, however, no detectable effects on macrophyte growth probably due to the short duration of the study.

CHAPTER 1 INTRODUCTION

The structure and function of aquatic ecosystems is determined by many chemical, physical and biological processes. Chemically driven processes that influence primary production with consequences for higher-order organisms are typically classified as “bottom-up” processes. In contrast, “top-down” processes are those in which higher-order organisms exert a strong influence on the structure and function of the system. Although opposing in nature, “bottom-up” and “top-down” processes co-occur (Heck et al. 2006). In some cases, however, the balance between these opposing processes is disrupted with marked ecological consequences (Turner et al. 1994).

Nutrient over-enrichment, for example, can lead to excessive primary production and changes in habitat and community structure. In extreme cases, microalgae flourish and become so abundant as to lethally shade benthic macrophytes and macroalgae (Duarte 1995). Eutrophication is common in water bodies bordered by human development and ecologists are becoming increasingly aware of the potential effects of anthropogenic nutrient enrichment (Caccia and Boyer 2007).

Nutrient over-enrichment is of great concern in north central Florida where many aquatic systems are affected by changing land use activities. The region’s permeable karst geology allows for pollutants to percolate into an extensive aquifer system. Nutrient pollutants in Florida’s groundwater, nitrogen and phosphorus in particular, are delivered to surface waters in the region via more than 300 individual freshwater springs (Notestein et al. 2003). Many aquatic ecosystems throughout north central Florida have experienced increases in nutrient pollution and reports of vegetation loss attributable to algal overgrowth from prolonged anthropogenic nutrient enrichment are increasingly common (e.g., Wright and McDonald 1986a, 1986b).

Nutrient enrichment, however, may not be the only factor contributing to vegetation loss in spring-fed river systems. Low concentrations of dissolved oxygen and low stream velocities may also play a role. For instance, aquifer water supplying spring-fed systems in Florida is often hypoxic (Rosenau et al. 1977), presumably due to the microbial remineralization of organic substrates. Additionally, when aquifer water enters the surface waters of a system it often does so at a very low velocity (Kurz 2004). Low dissolved oxygen concentration could preclude the existence of periphyton grazers and low stream velocity could facilitate the accumulation of periphyton by reducing the shear force near the boundary layer surrounding macrophyte blades. Together, these factors may facilitate a pattern of vegetation loss whereby areas of low dissolved oxygen concentration may have low populations of periphyton grazers and low stream velocities, which allows periphyton to accumulate, in the absence of scouring, to levels capable of negatively impacting the growth of rooted macrophytes.

The Ichetucknee River, located in north central Florida, is predominantly spring-fed and a reduction in the abundance of rooted macrophytes in the system has been observed over the past decade in conjunction with an increase in periphyton (Evans 2007). These findings are consistent with a nutrient enrichment scenario and the Ichetucknee River does show elevated levels of nitrate and phosphorus (Kurz 2004). I propose, however, that the pattern of vegetation loss is dependent on dissolved oxygen concentrations and stream velocities which, in combination, control the presence of periphyton grazers and the magnitude of the scouring force of water. I hypothesize specifically that the growth potential of macrophytes in areas of low dissolved oxygen concentrations and low stream velocities will be compromised due to shading from periphytic algae that accumulates in the slow flowing water and proliferates in the absence of grazers.

CHAPTER 2 MATERIALS AND METHODS

Study Site

The Ichetucknee River is a tributary of the Santa-Fe River which is part of the larger Suwannee River basin in north central Florida. The river is fed, in large part, by water derived from the Floridan Aquifer. A 1st magnitude headspring serves as the origin of flow, though numerous feeder springs along the river's length also contribute to the river's flow. Exceptional water clarity is a hallmark of the Ichetucknee system and the main stem of the river is densely populated by submersed aquatic vegetation. The dominant macrophyte throughout the system is *Sagittaria kurziana* (Kurz et al. 2003); however, the smaller feeder springs along the main stem of the Ichetucknee River are often nearly devoid of macrophytes (Kurz et al. 2004).

The Ichetucknee is home to a variety of fish species including *Micropterus*, *Heterandria* and *Lepomis* species in addition to a rich benthic invertebrate community represented by numerous chironomids, crustaceans, and molluscs (McKinsey and Chapman 1998, Mattson et al. 1995). Dominant grazers of periphyton in the system include chironomids and a pleurocerid snail, *Elimia floridensis*, which grows to five centimeters in length and can live for nearly a decade (Huryn et al. 1994). Recent research has shown that *E. floridensis* is more abundant in the main stem of the Ichetucknee River than in the smaller spring runs (Dormsjo 2007), although the presence of chironomids in the smaller spring runs has not been studied.

Quantitative River and Spring Survey

In January of 2007, a temporally focused effort provided estimates for several key chemical and physical parameters as well as a quantitative characterization of submersed aquatic vegetation and associated periphyton. All sampling was carried out at fourteen regularly-spaced transects along 2 km of the main stem of the river as well as three transects along the runs of

three associated feeder springs, i.e. Singing Spring, Devils Eye Spring, Mill Pond Spring (Figure 2-1). Along each transect, three stations were sampled perpendicular to the direction of water flow such that one station was sampled in mid-channel and the other two sampled halfway between the bank of the river or spring run and the mid-channel station.

Chemical and Physical Parameters

Dissolved oxygen concentration (mgL^{-1}), water temperature ($^{\circ}\text{C}$), and pH were measured *in situ* at a depth of 0.5 m with a Yellow Springs Instrument Company model 650 hand-held meter. Water depth (m) was measured at all stations with a collapsible fiberglass survey rod marked in 0.01 m increments. Stream velocities (ms^{-1}) were measured at two-thirds of the water column depth with a Marsh-McBirney model 2000 portable flow meter recording 5-second averages. Li-Cor Instruments, Inc. quantum light sensors were employed to simultaneously collect surface and downwelling light intensity ($\mu\text{mole photons s}^{-1}\text{m}^{-2}$ of photosynthetically active radiation, PAR) at three depths spanning the water column. Light attenuation (K_d) at each station was determined from the equation: $K_d = [\ln(I_o / I_z)] / z$, where I_o is the incident irradiance at the water surface and I_z is the light intensity at depth z (m) (Kirk 1994).

Vegetation Sampling

Submersed aquatic vegetation was collected at each station using a 0.0625-m^2 quadrat, constructed of 4-inch diameter PVC with 90° elbow joints (Figure 2-2). During construction, the frame of the device was sliced in half transversely to make a top u-shape and a bottom u-shape. These two halves were then connected by six-foot panels of 425-micron NITEX mesh. Four panels were used in total, but one panel remained attached to the frame on only one side of the device in order to eventually close the three-sided u-shape into a square. During deployment, the quadrat was collapsed, inserted into the SAV canopy by SCUBA divers and placed on the river bed in its, three-sided form (with the fourth panel tucked back). The fourth panel was then

brought across between the u-shape tips to close the shape into a full square quadrat. The fourth panel was connected to the opposite side of the u-shape by a zipper spanning the entire six-foot length of the panel. With the panel connected, the entire top u-shape of the quadrat could be separated from the bottom u-shape resting on the river bed and lifted, while simultaneously zipping the fourth panel to its adjacent complement. This sample maneuver resulted in the enclosure of all SAV within the confines of the quadrat. In this position, the apparatus was then folded over on itself to cover the top hole of the device and the above-ground SAV was cut at the sediment/water interface. As the sampler was removed from the canopy and placed aboard the research vessel, all gastropods associated with the substrate beneath the sampler were collected as part of a complementary effort. Onboard the boat, the sampler was opened and all vegetation was inspected for gastropods. All gastropods were identified, recorded and returned to the river. Data concerning gastropod abundance and distribution are reported elsewhere (Dormsjo 2007). SAV samples were removed from the device and stored in a zip-lock bag on ice during transport to the laboratory for additional processing. At the laboratory, any incidental below-ground biomass associated with the harvested plants was removed and discarded. The remaining plant material was blotted dry with a paper towel. All leaf lengths were measured (to the nearest mm) and the wet weight of the entire sample was determined (to the nearest mg). Plants were subsequently dried at 60°C for >48 hr to determine a dry weight.

Quantifying Periphyton Associated with SAV

Periphyton associated with SAV at each sample station was measured according to the method originally outlined by Moss (1981) and subsequently modified by Canfield and Hoyer (1988). First, a single blade of the dominant macrophyte at each sampling station was removed from the river and placed in a 1-L Nalgene jar, pre-filled with 500 ml of deionized water. Periphyton was then removed from the host macrophyte sample by vigorously shaking the 1-L

Nalgene jar containing the sample for 30 seconds. The resultant slurry was filtered through a 1-mm screen into a Nalgene beaker. Fresh deionized water was added to the Nalgene jar and the shaking / filtering process was repeated for a total of three times. The resultant slurry after three shaking processes was homogenized and a sub-sample of known volume was filtered through a Gelman type A/E 47 mm glass-fiber filter. The remaining volume of slurry was noted and the filters were stored frozen prior to analysis of chlorophyll (APHA 1995).

Translocation Experiment

In addition to the river survey, a field experiment was performed in March 2007 to quantify the rate of periphyton accumulation on macrophytes in the main river and feeder springs and assess the potential influence of that periphyton accrual on macrophyte growth. This experiment involved the relocation of individual, standardized genets of *S. kurziana* into cleared plots within the river and three adjacent feeder springs, i.e. Singing Spring, Devil's Eye Spring, and Mill Pond Spring. The use of translocated genets of *S. kurziana* was intended to reduce any intrinsic variability between resident river and spring plants.

The genets of *S. kurziana* selected for the study were harvested near the confluence of Devil's Eye Spring run and the main river. Chosen for their morphological uniformity, the 225 plants were severed from their stolon connections and individually placed in terra cotta pots with sandy substrate and a sponge lid to secure the contents throughout the experiment. All potted plants were placed into the main river channel in three groups of 75. Groups were placed just upstream of the confluence of the main stem of the river and each of the three feeder springs, i.e. Singing Spring, Devil's Eye Spring, and Mill Pond Spring. The substrate at each location was cleared of SAV to ensure an adequate light environment for the study plants. The potted plants were allowed one week of acclimation after which, all plants were rubbed clean of periphyton by hand and cut to a standardized blade length of approximately 7.5 cm. Immediately after

standardization, 25 plants were harvested for initial measurements of plant biomass and periphyton abundance. Half of the remaining 50 plants were moved to their respective feeder springs and arrayed just downstream of the primary spring vent. The 25 remaining plants were left in the river channel at the acclimation location and all plants were observed bi-weekly for 4 weeks. After 4 weeks, all experimental plants from the river and spring locations were harvested and measures of plant biomass and periphyton abundance were made following the methods previously described. Abiotic metrics were also sampled for a comparison of pre- and post-experimental conditions.

Statistical Analyses

Standard ANOVA procedures were used to test for differences in chemical, physical and biological characteristics between the main river transects and feeder spring transects (JMP IN v. 5.1 1989). Normality was assessed with the Shapiro-Wilk test and the assumption of equal variance verified with a Brown-Forsythe test. All plant biomass and periphyton abundance data were $\log_{10}+1$ transformed to improve normality and heteroscedasticity.

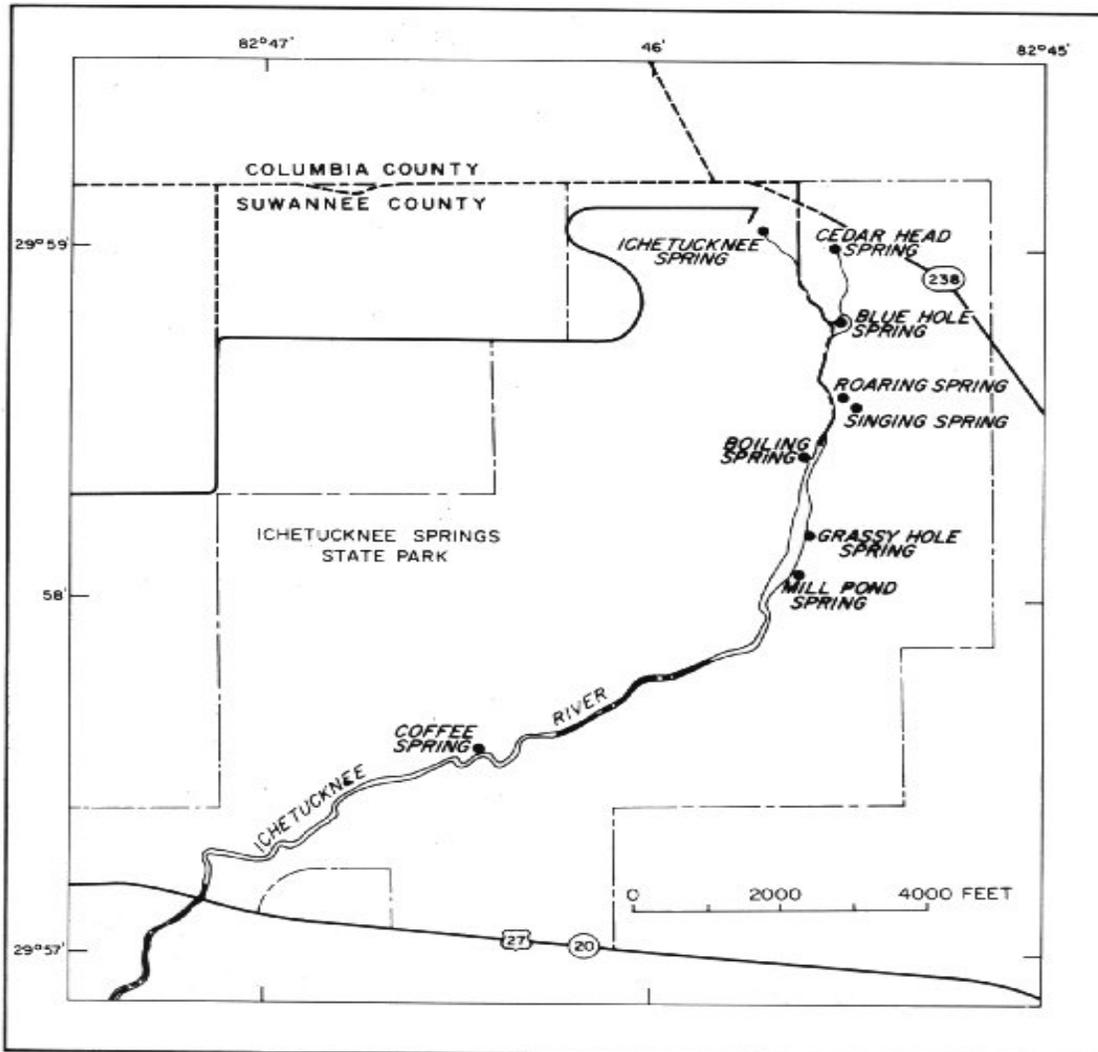


Figure 2-1. Map of the Ichetucknee River course through the Ichetucknee Springs State Park. All transect sampling was carried out in the upper portion of the river within the confines of the park. Experimental work was conducted near Singing Spring, Devils Eye (also known as Boiling Spring) and Mill Pond Spring.

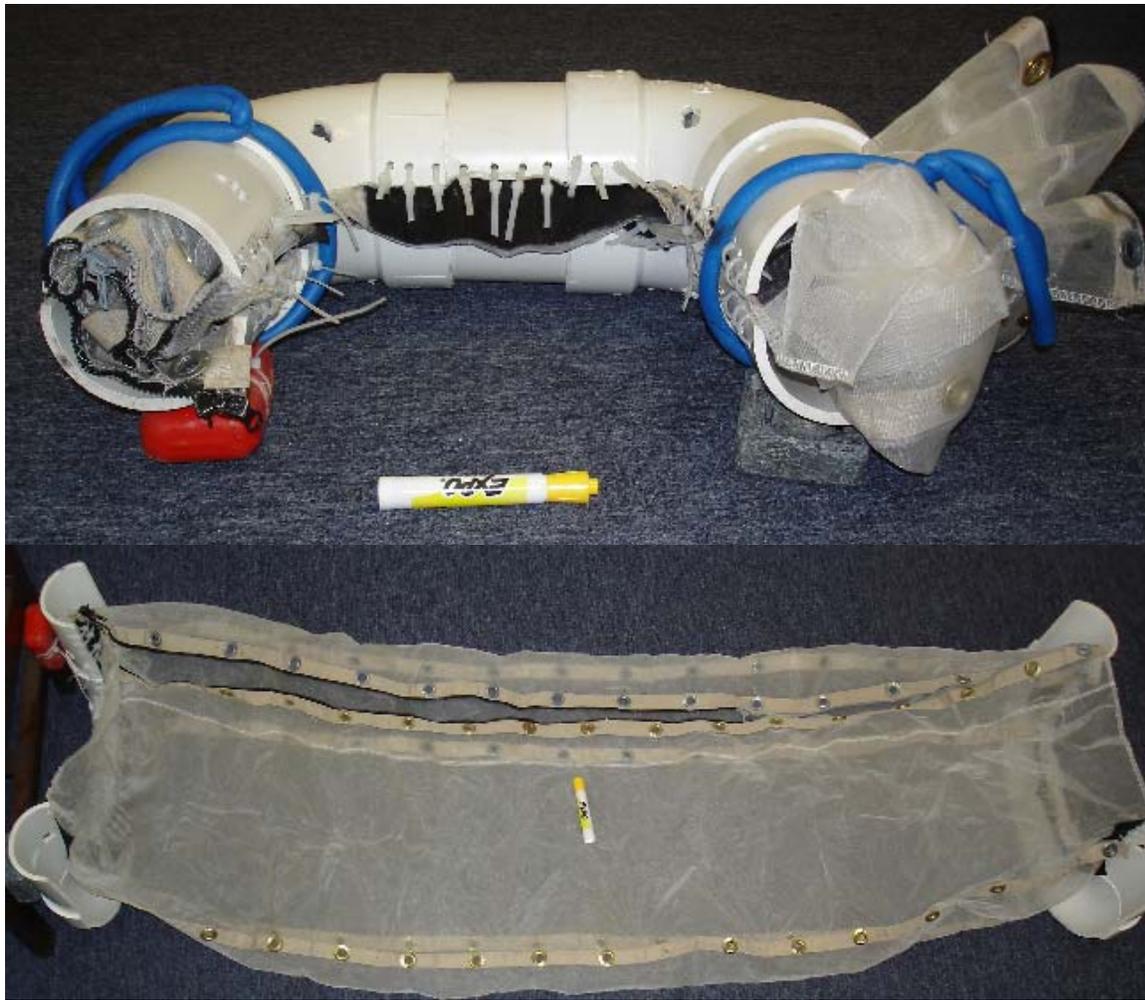


Figure 2-2. Collapsed and expanded view of plant sampling apparatus.

CHAPTER 3 RESULTS

Survey Results

Mean dissolved oxygen concentration in the main stem of the river ranged between 3.2 and 7.4 mg L⁻¹ and exhibited a general increase between feeder spring influences (Figure 3-1). Mean dissolved oxygen concentrations did not differ between the feeder springs (Mean value + SE; Singing Spring = 1.57 mgL⁻¹ ± 0.28; Devil's Eye Spring = 1.05 mgL⁻¹ ± 0.13; Mill Pond Spring = 1.40 mgL⁻¹ ± 0.49) (ANOVA; df = 2, F = 0.56, P = 0.60). Relative to the three feeder springs, the main river exhibited significantly higher dissolved oxygen concentrations (ANOVA; df = 1, F = 86.31, P = <0.0001) (Figure 3-2).

Mean stream velocity in the main stem of river ranged between 0.04 and 0.30 ms⁻¹ and exhibited a general increase between feeder spring influences (Figure 3-3). Mean stream velocity did not differ between the feeder springs (Mean value ± SE; Singing Spring = 0.04 ms⁻¹ ± 0.013; Devil's Eye Spring = 0.04 ms⁻¹ ± 0.0083; Mill Pond Spring = 0.05 ms⁻¹ ± 0.016) (ANOVA; df = 2, F = 0.168, P = 0.85). Relative to the three feeder springs, the main river exhibited significantly higher stream velocities (ANOVA; df = 1, F = 11.63, P = 0.003) (Figure 3-4).

Mean periphyton abundance on macrophytes within the main stem of river ranged between 0.014 and 0.068 mg chl a g WW⁻¹ and showed a trend of decreasing abundance between feeder spring influences (Figure 3-5). Mean periphyton abundance on plants did not differ between the three feeder springs (Mean value ± SE; Singing Spring = 0.30 mg chl a g WW⁻¹ ± 0.13; Devil's Eye Spring = 0.42 mg chl a g WW⁻¹ ± 0.16; Mill Pond Spring = 0.19 mg chl a g WW⁻¹ ± 0.02) (ANOVA; df = 2, F = 0.48, P = 0.64). Overall, the mean periphyton abundance in

spring environments was significantly higher than the mean periphyton abundance within the main stem of the river (ANOVA; $df = 2$, $F = 93.81$, $P < 0.0001$) (Figure 3-6).

Estimates of plant biomass in the main stem of Ichetucknee River ranged between 1172 and 8676 g WW m^{-2} and exhibited a general increase with distance downstream (Figure 3-7). There was no significant difference in plant biomass between the three feeder springs. (Mean value \pm SE; Singing Spring = 1285 g WW $m^{-2} \pm 281.85$; Devils Eye Spring = 1670 g WW $m^{-2} \pm 808.58$; Mill Pond Spring = 1115 g WW $m^{-2} \pm 381.26$) (ANOVA; $df = 2$, $F = 0.0098$, $P = 0.99$). Overall, the mean plant biomass along the main stem of the Ichetucknee River was significantly higher than the mean plant biomass within the spring environments (ANOVA; $df = 2$, $F = 24.07$, $P < 0.0001$) (Figure 3-8).

Translocation Experiment

Overall survivorship of translocated plants during the 4-week study period was 52% in the main stem of the river and 96% in the feeder spring. Surviving plants in the river and feeder springs exhibited no significant difference in growth as determined by a comparison of their mean above ground biomasses (ANOVA; $df = 1$, $F = 1.14$, $P = 0.34$) (Figure 3-9). At time zero, the mean leaf length of all plants was 7.54 cm (± 1.36). After the four week study period, the mean leaf length of river plants was 9.40 cm (± 3.47) and that of the spring plants was 9.74 cm (± 3.01). Mean plant biomass and mean periphyton abundance did not differ between the three feeder springs sites (Mean Plant Biomass (g WW \pm sd); Singing Spring = 2.54 ± 1.48 ; Devil's Eye Spring = 1.29 ± 0.98 ; Mill Pond Spring = 1.40 ± 0.68) (ANOVA; $df = 2$, $F = 0.96$, $P = 0.48$) (Mean Periphyton Abundance (mg chl a g WW⁻¹ \pm sd); Singing Spring = 0.37 ± 0.22 ; Devil's Eye Spring = 1.10 ± 1.14 ; Mill Pond Spring = 0.09 ± 0.065) (ANOVA; $df = 2$, $F = 0.13$, $P = 0.88$). Overall, mean periphyton abundance tended to be greater on plants in the three feeder

springs than in the main river, although this difference was not statistically significant (ANOVA; $df = 2$, $F = 2.68$, $P = 0.18$) (Figure 3-10).

Table 3-1. Summary of 2007 Survey Data – Means \pm Standard Errors (n = # of samples)

Section	Plant Biomass (gWW m⁻²)	Periphyton Abundance (mg chl a g WW⁻¹)	Dissolved Oxygen (mgL⁻¹)	Stream Velocity (ms⁻¹)	Water Depth (m)
River	4417 \pm 611 (n=14)	0.03 \pm 0.005 (n=14)	5.18 \pm 0.31 (n=14)	0.133 \pm 0.02 (n=14)	1.14 \pm 0.09 (n=14)
Spring	1357 \pm 283 (n=9)	0.30 \pm 0.07 (n=9)	1.34 \pm 0.19 (n=9)	0.05 \pm 0.007 (n=3)	0.83 \pm 0.20 (n=3)

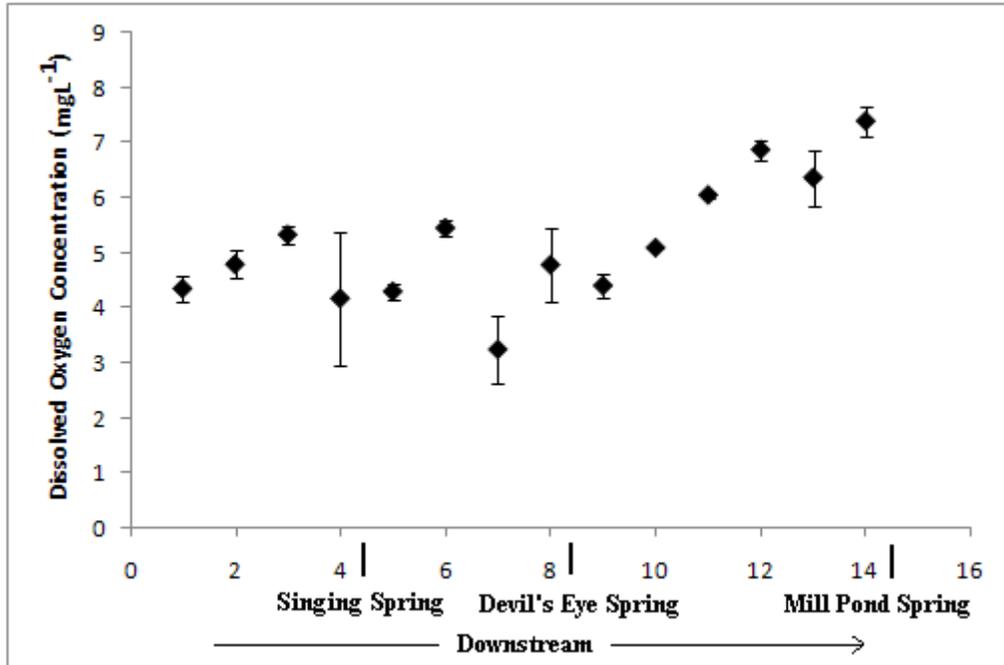


Figure 3-1. Mean dissolved oxygen concentration with increasing distance downstream in the main stem of the Ichetucknee River. Numbers along the x-axis correspond to river transects with ascending values representing distance downstream.

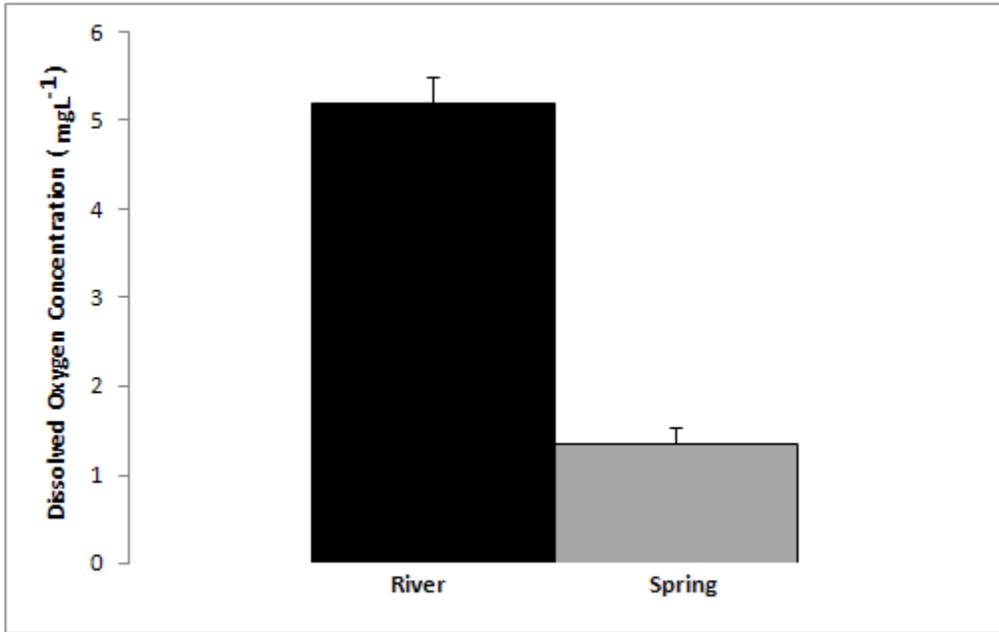


Figure 3-2. Mean dissolved oxygen concentration in the main stem of the Ichetucknee River and three associated feeder springs (i.e. Singing Spring, Devil's Eye Spring, and Mill Pond Spring).

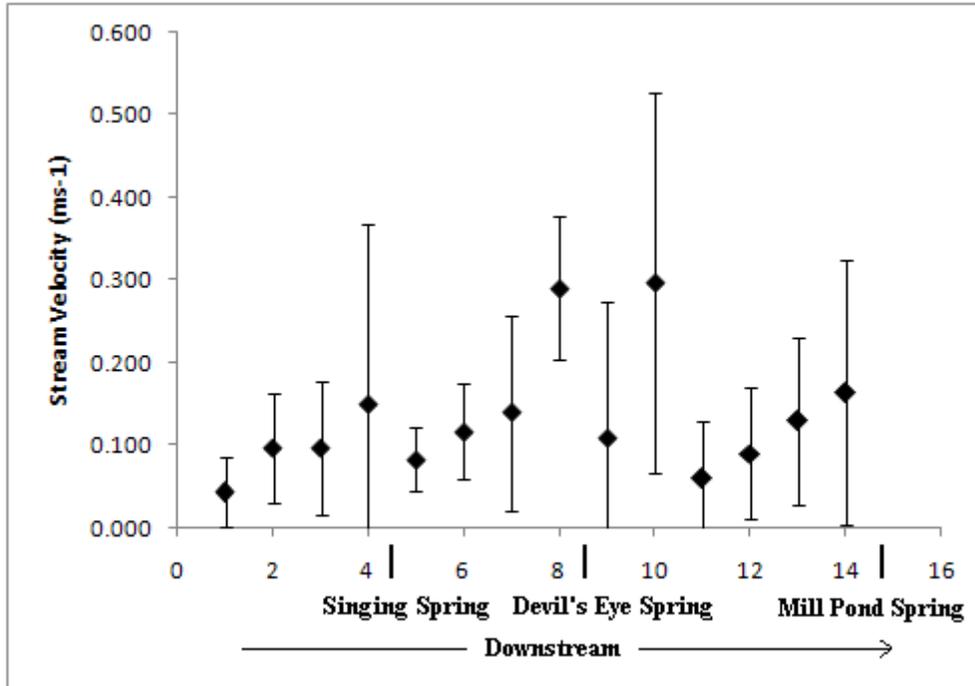


Figure 3-3. Mean stream velocity with increasing distance downstream in the main stem of the Ichetucknee River. Numbers along the x-axis correspond to river transects with ascending values representing distance downstream.

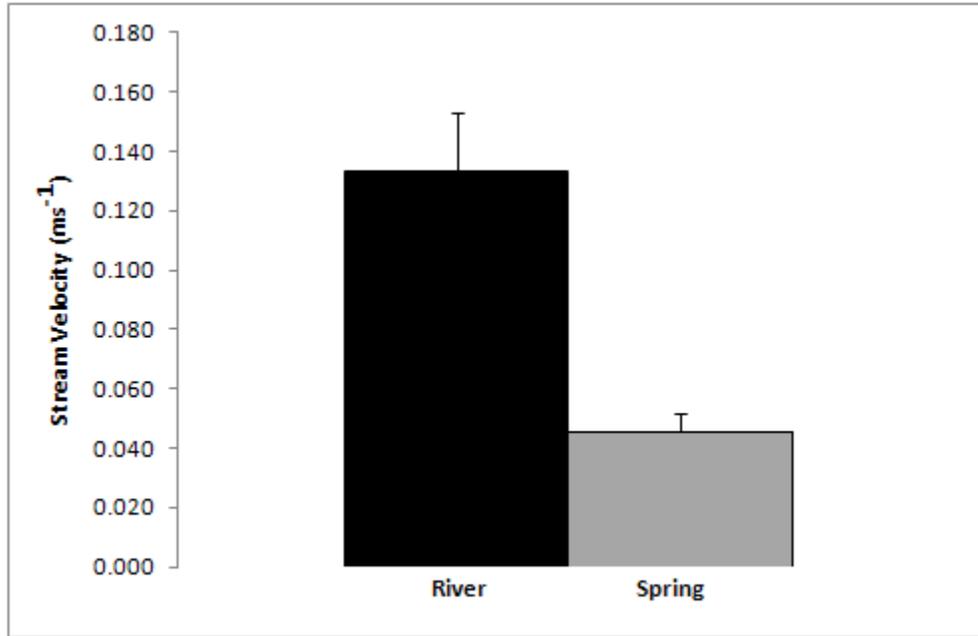


Figure 3-4. Mean stream velocity in the main stem of the Ichetucknee River and three associated feeder springs (i.e. Singing Spring, Devil's Eye Spring, and Mill Pond Spring).

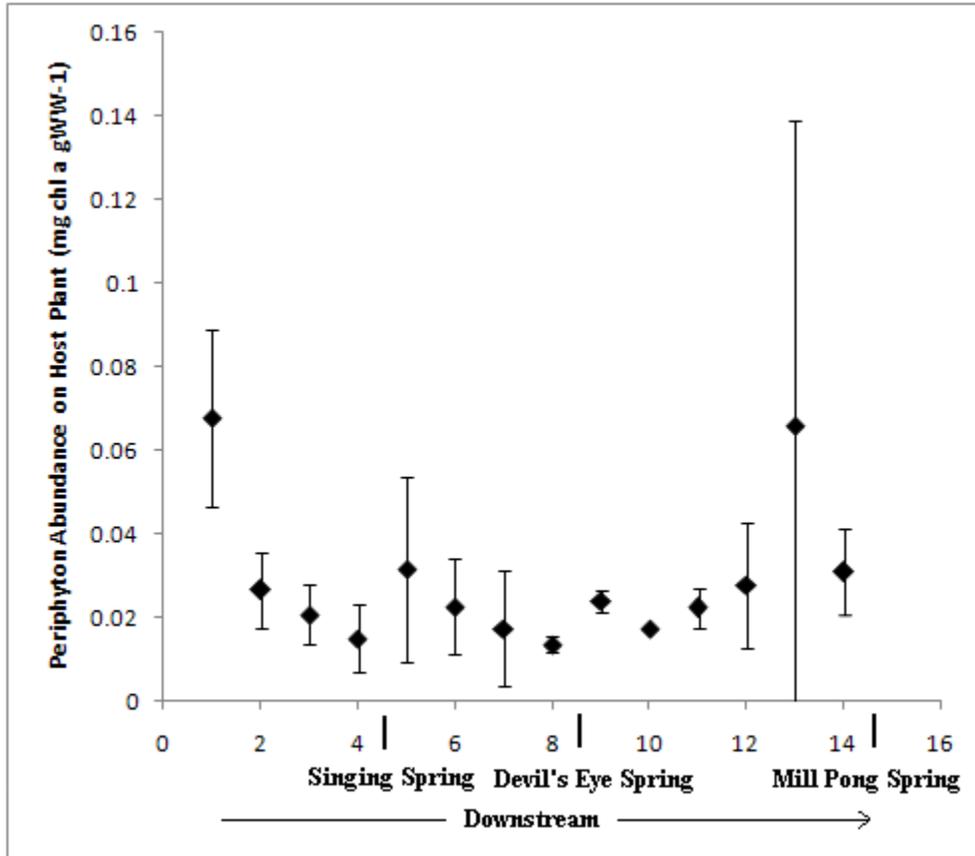


Figure 3-5. Mean periphyton abundance with increasing distance downstream in the main stem of the Ichetucknee River. Numbers along the x-axis correspond to river transects with ascending values representing distance downstream.

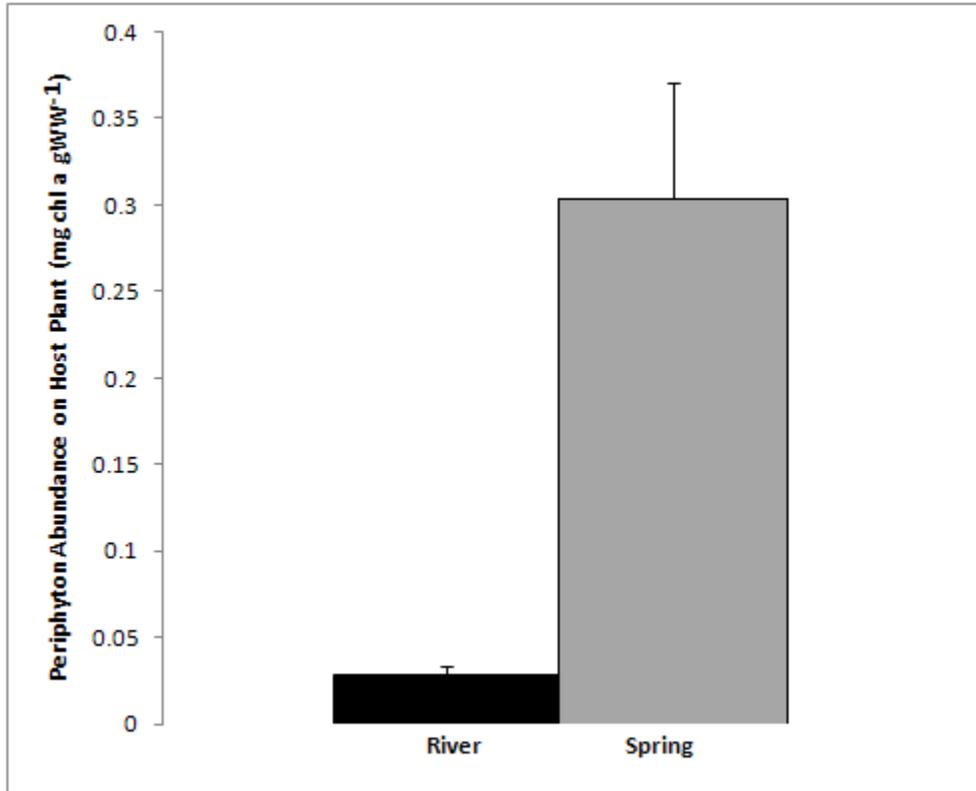


Figure 3-6. Mean periphyton abundance in the main stem of the Ichetucknee River and three associated feeder springs (i.e. Singing Spring, Devil's Eye Spring, and Mill Pond Spring).

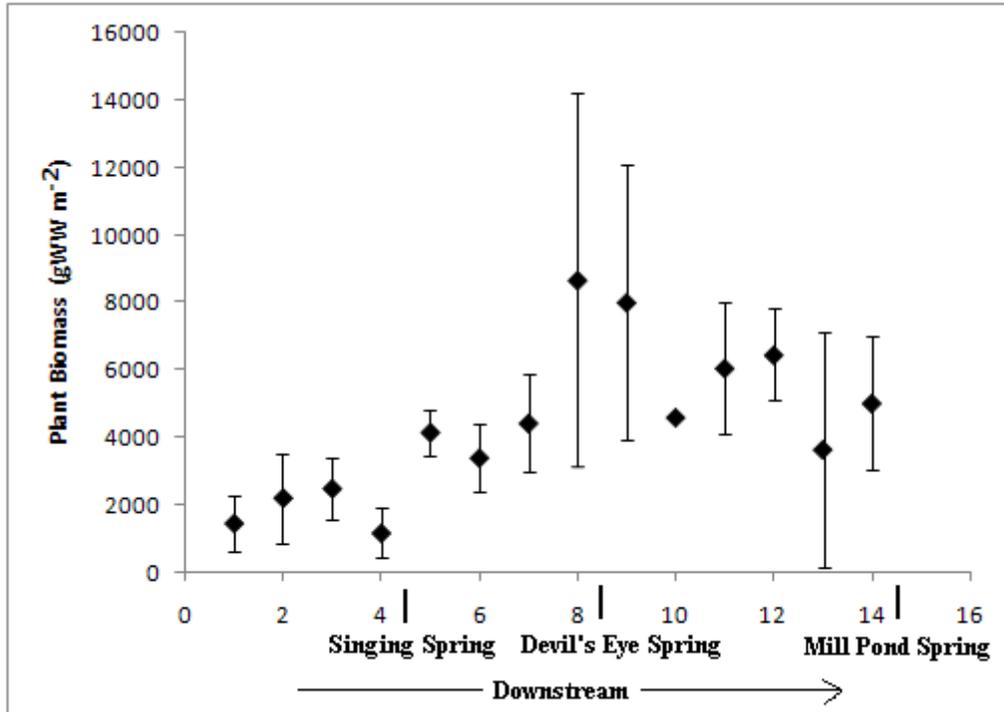


Figure 3-7. Mean plant biomass with increasing distance downstream in the main stem of the Ichetucknee River. Numbers along the x-axis correspond to river transects with ascending values representing distance downstream.

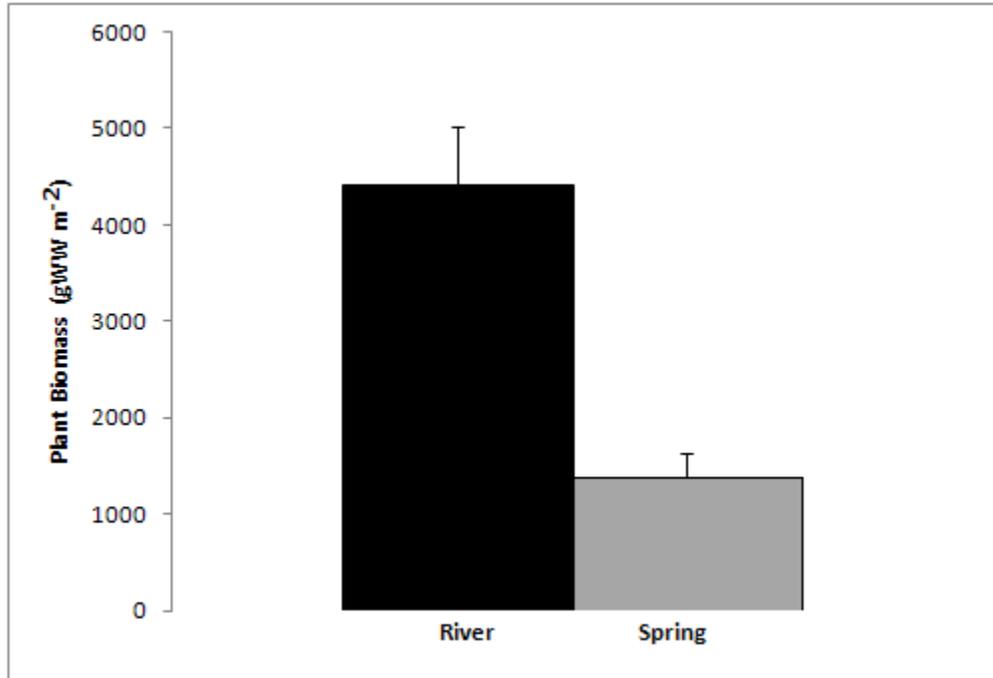


Figure 3-8. Mean plant biomass in the main stem of the Ichetucknee River and three associated feeder springs (i.e. Singing Spring, Devil's Eye Spring, and Mill Pond Spring).

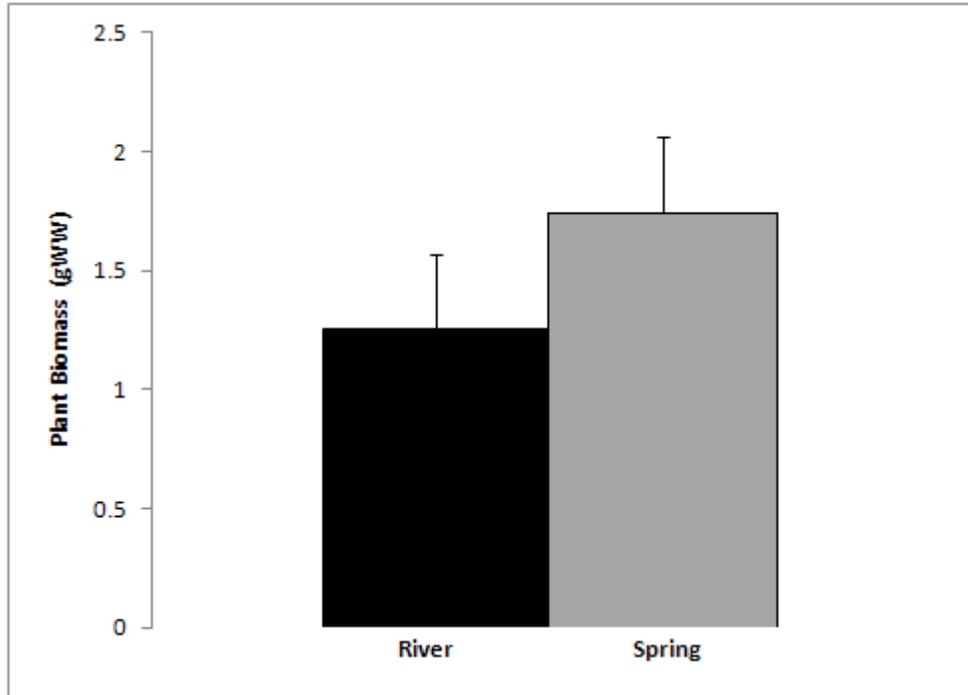


Figure 3-9. Mean plant biomass in the main stem of the Ichetucknee River and three associated feeder springs (i.e. Singing Spring, Devil's Eye Spring, and Mill Pond Spring) following a four week translocation experiment.

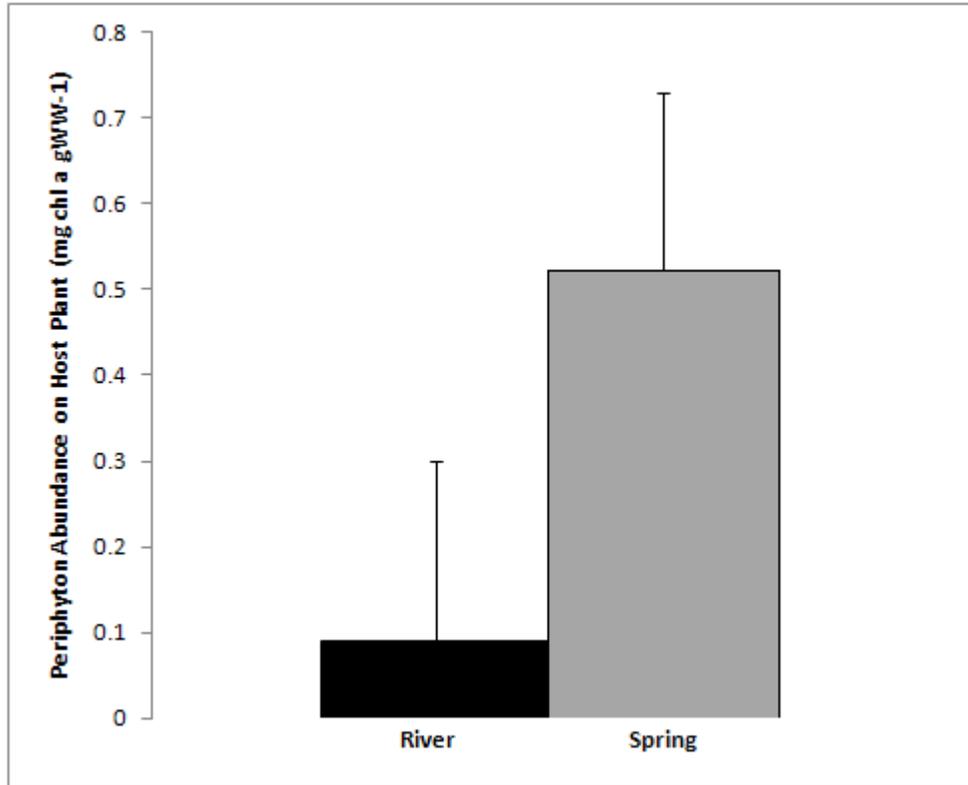


Figure 3-10. Mean periphyton abundance in the main stem of the Ichetucknee River and three associated feeder springs (i.e. Singing Spring, Devil's Eye Spring, and Mill Pond Spring) following a four week translocation experiment.

CHAPTER 4 DISCUSSION

The proposed pattern of interaction between dissolved oxygen, stream velocity, grazer abundance, and periphyton abundance on host macrophytes was well supported by the observations made during the survey of the Ichetucknee River and its feeder springs (see also Dormsjo 2007). Dissolved oxygen concentrations were consistently low near spring sources regardless of whether the spring source was the headspring of the river, any one of the three feeder springs, or the many spring/river confluences along the main stem course. This finding is consistent with data reported previously (Kurz et al. 2003 and 2004). Stream velocity, plant biomass, and grazer abundance exhibited a similar pattern; lowest values for all the aforementioned parameters occurred near spring sources (see also Dormsjo 2007). These findings too are similar to those reported by Kurz et al. (2003 and 2004). As hypothesized, periphyton abundance values were inversely related to dissolved oxygen, stream velocity, grazer abundance, and plant biomass values. Where dissolved oxygen, stream velocity, grazer abundance, and plant biomass values were low, periphyton abundance on host plants was high.

Literature on lotic systems suggests that the patterns reported here exhibit some generality. For example, Sabater et al. (2000) found that benthic algal biomass in the Oria River, a Spanish river with intense human activity in its watershed, was highest in locations where diel variations in dissolved oxygen concentrations resulted in acute hypoxia. Episodes of hypoxia in areas of high algal biomass in the Oria River have been linked to herbivorous fish kills (Sabater 2000) suggesting that oxygen mediated grazing impacts are likely to be an important process in lotic systems.

Additionally, stream velocity is often reported as a significant variable affecting both periphyton and macrophyte abundance. Chambers et al. (1991) showed that sudden increases in

current velocity in two slow-flowing rivers in Canada resulted in decreased plant biomass through uprooting. It's a logical assumption that periphyton abundance on macrophytes within the same rivers would also decrease with increasing current velocity. For example, Giorgi et al. (2005) observed that attached algal biomass decreased during times of flood in Pampean streams suggesting that increasing current velocity exerts a significant scouring force on periphyton communities. Similar conclusions have been reported by several additional research efforts (e.g., Birkett et al. 2007, Katano et al. 2005, Arnon et al. 2007).

The results of the translocation experiment following the quantitative river survey were likely confounded by the low survival rates of *S. kurziana* in the main stem of the river and the short duration of the study. While 96% of the plants in the feeder springs survived, river plants exhibited a relatively large loss (48%) resulting in few data for statistical comparison of periphyton abundance on host plants between the main river and springs. Nevertheless, the rate of periphyton accrual on plants in the feeder springs was marginally greater than on plants in the main stem of the river. This finding is consistent with my hypothesis, but I was unable to detect any statistically significant difference in plant growth that might be attributed to an increase in periphyton load.

Some mortality of the translocated plants was expected during this experiment as short-term mortality is common in such studies. For example, Zimmerman, et al. (1995) transplanted *Zostera marina*, a functionally similar marine macrophyte, in San Francisco Bay, CA, and reported high initial losses. Additionally, Hauxwell et al. (2003) transplanted *Vallisneria americana* (a plant commonly found with *S. kurziana*) in Kings Bay, FL in 2001 and 2002 and observed high initial mortality. In both cases, the investigators emphasized the importance of transplant timing and experiment duration in relocation success (Zimmerman et al. 1995,

Hauxwell et al. 2003). Zimmerman et al. (1995) pointed out that although the eelgrass transplants in San Francisco Bay, CA were partially successful, transplant survival could have been improved by taking into account the role of carbon reserves when timing a transplant event (Zimmerman et al. 1995). Hauxwell et al. (2003) suggested that similar transplant experiments should run for 1-2 years to ensure natural growth responses from the transplants. The four-week experimental period chosen for this study was necessary due to the high human use and disturbance of the system during the summer months. Subsequent efforts to determine the effects of periphyton accumulation on macrophyte growth in the Ichetucknee River will likely require some intervention to lessen such impacts.

In addition to transplant duration and timing, it should be noted that experimental plants in the main stem of the river were maintained at depths of approximately 1.5 m whereas plants in the feeder springs were maintained at approximately 0.75 m. Although water clarity in the Ichetucknee system is superb, it is possible that slight differences in water depth contributed to plant loss in the main river as a consequence of increased light attenuation. The topography of the Ichetucknee River dictated the depth at which the translocated plants would be placed and so no depth standardization was possible. It is unclear whether differences in depth influenced the experimental outcome, but light attenuation has a strong influence on the distribution and abundance of aquatic macrophytes and many studies have shown a negative relationship between increased light attenuation and the biomass of aquatic macrophytes (e.g., De Boer 2007, Loiselle et al. 2007).

Despite the problems associated with plant transplant and translocation, the surviving plants from this study did provide a natural substrate for a first order approximation of the rate of periphyton accumulation. The periphyton loads on macrophytes in the Ichetucknee River

after only a four-week period were similar to standing crop values previously reported in the river by Kurz et al. (2004). In 2004, mean periphyton abundance was $0.15 \text{ mg chl a gWW}^{-1}$ in the main stem of the Ichetucknee River and $0.61 \text{ mg chl a gWW}^{-1}$ in the feeder springs. In 2007 (this study), mean periphyton abundance was $0.09 \text{ mg chl a gWW}^{-1}$ in the main stem of the Ichetucknee River and $0.52 \text{ mg chl a gWW}^{-1}$ in the feeder springs. Interestingly, average rates of stream velocity in the main stem of the Ichetucknee River during 2007 (0.133 ms^{-1}) were lower than those in 2004 (0.160 ms^{-1}) as a consequence of a regional drought that affected spring discharge. Despite these slight differences, my stream velocity and periphyton abundance results are consistent with previous work relating the two variables (Kurz et al. 2003 and 2004). Results from this investigation reinforce the need for additional studies on flow rates and periphyton accrual in this system and how these factors might interact with others such as changes in nutrient loads, oxygen concentrations, light availability and grazing to affect the structure and function of the ecological community.

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BIOGRAPHICAL SKETCH

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