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# Infaunal Abundance and Diversity in Vegetated and Unvegetated Areas of a Georgia Salt Marsh

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# INFAUNAL ABUNDANCE AND DIVERSITY IN VEGETATED AND UNVEGETATED AREAS OF A GEORGIA SALT MARSH

by

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(Under the Direction of Sophie B. George)

ABSTRACT

Various commercially important marine species are known to utilize the salt marsh; research has shown that marsh infauna play an important role in the diets of these species. The distribution and abundance of some of these infauna has been shown to be influenced by vegetative cover. In 2001, salt marshes along the coast of Georgia began to die, resulting in the loss of the dominant vegetation. During the summer of 2005, six 0.5 x 0.5 meter quadrats were haphazardly placed and set up permanently in the low marsh at two study sites along the Crooked River in vegetated and unvegetated areas. Core samples were taken from each quadrat at low tide during 3 months. Taxa richness and diversity was described at each site to determine if unvegetated areas at each site displayed lower infaunal abundance and diversity. The effects of the absence of vegetation varied between sites and across sampling months. There were no significant differences in organic content between the vegetated and unvegetated quadrats; abiotic measurements taken from each site were similar.

INDEX WORDS: Wetlands, Georgia, Salt marsh, Infauna, Benthos, Die-back, Estuary, Diversity, Meiofauna, Macrofauna, Unvegetated marsh

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by

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MASTER OF BIOLOGY

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# DEDICATION

This document is dedicated to my family, without them I would not have made it this far.

# ACKNOWLEDGMENTS

I would like to acknowledge everyone who has provided support, emotional, academic, and otherwise, during this endeavor.  Dr. Sophie George for her advisement and expertise and Sarah Mock for being there when I needed encouragement the most.

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# CHAPTER 1

# INTRODUCTION

The salt marshes of the southeastern United States are ecologically and economically vital ecosystems. A variety of commercially important species, blue crab and panaeid shrimp, among others, are known to utilize the salt marsh as nurseries and feeding grounds (Valiela *et al.* 2004) and research has shown that salt marsh infauna play an important role in the diets of many of these species (Bell and Coull 1978, Gleason and Wellington 1988, Kneib 1992). A strong trophic link exists between the infauna of the salt marsh and the associated nekton; the abundance and availability of the infauna may contribute greatly to the high fishery productivity associated with coastal marshes (Whaley and Minello 2002).

In salt marshes, the distribution and abundance of some of the most common infauna, nematodes, copepods, and annelids, (Kneib 1984, Moy and Levin 1991), has been shown to be influenced by vegetative cover. Osenga and Coull (1983) reported a positive association between nematode abundance and the presence of living vegetation in a South Carolina salt marsh, while additional studies conducted in North Carolina, Georgia, and Texas reported similar associations regarding annelids and a variety of crustaceans (Radar 1984, Healy and Walters 1994, Whaley and Minello 2002). Studies suggest that *S. alterniflora* roots can supply an appreciable quantity of oxygen and labile organic substrates to the surrounding mud which may be utilized by the infauna (Teal and Kanwisher 1966, Teal and Wieser 1966). Rovira (1969) indicates that exudates from live plant roots may enrich the surrounding porewater in labile organic substrates increasing microbial growth and therefore potential food for infauna (Osenga and Coull 1983).

In 2001, salt marshes along the coast of Georgia began to die, resulting in open mudflats and areas of receding marsh which affected both *Spartina alterniflora* and *Juncus romerianus* (Ogburn and Alber 2006). Almost 2000 acres of coastal marsh were lost to what is now believed to be a drought-induced dieback, an epidemic which also afflicted Louisiana salt marsh in 1999 (Silliman *et al.* 2005). Coast wide surveys and transplant experiments indicated that there were no differences between healthy and unhealthy marsh aside from the presence of dead vegetation and recent studies suggest that the cause of the dieback is no longer present (Ogburn and Alber 2004, Ogburn and Alber 2006). While recovery is occurring, the Georgia Coastal Research Council reports that it is slow and patchy along the coast; many sites still display unvegetated areas of salt marsh (Ogburn and Alber 2006). The loss of salt marsh vegetation such as *S. alterniflora* may result in decreased abundance and diversity of infaunal organisms through lack of suitable habitat and resources in these areas.

This study focused on the Crooked River. This river is one of many less well-known and smaller rivers along the coast of Georgia; however, the Crooked River supports valuable salt marsh habitat and may serve as a suitable model for future studies conducted on many similar rivers along the coast. The Crooked River was specifically chosen because areas with no vegetative cover (*S. alterniflora*) were observed along the river as one moved inland. The abundances of various taxa from the low marsh at each of two sites were described and taxa richness and diversity were compared to address the following question. Do unvegetated areas at these sites along the Crooked River display lower infaunal abundance and diversity?

# CHAPTER 2

# MATERIALS AND METHODS

## Study Sites

This study was conducted at two sites in the estuary of the Crooked River, which is approximately 35 kilometers long and lies entirely within the coastal plain of Georgia (Fig 1). The first site (referred to as Sheffield Island - 30°50’07.70”N, 81°36’45.74”W) was located approximately 23 kilometers from the river mouth and was dominated by *S. alterniflora* with *J. romerianus* occurring in a few small patches among the *Spartina*. The second site (referred to as Harriett’s Bluff - 30°50’38.35”N, 81°37’58.35”W) was located approximately 26 kilometers from the river mouth and was dominated by *J. romerianus* with *S. alterniflora* occurring in a band along the borders of the creek and in patches among the *Juncus*. Average salinity at the mouth of the Crooked River during 2005 was approximately 25ppt. Various abiotic characteristics of each study site are shown in Table 1.

## Sampling Methods

During the summer of 2005, six 0.5 x 0.5 meter quadrats were haphazardly placed and set up permanently in the low marsh at each study site. Three of the six quadrats at each site were placed within the vegetation and the remaining three within unvegetated areas (Fig. 2). At sites with *J. romerianus* occurring in the sample area, quadrats were restricted to stands of *Spartina* in order to avoid possible differences in infaunal abundance and diversity due to vegetation type. Three random core samples were taken from each quadrat at each site during low tide in June, August, and October using 50ml centrifuge tubes (8cm long, 2.5cm wide) with the bottoms cut off. All core samples were placed on ice and then frozen in the lab at -20° Celsius until processing. A total of 108 core samples were obtained throughout the course of this study that were used to determine infaunal abundances.

Benthic infauna are commonly divided into two major categories, macrofauna (organisms retained on a 500 µm sieve) and meiofauna (organisms which pass through a 500 µm sieve but are retained on a 63 µm sieve) (Kneib 1984). Thus, to determine infaunal abundances at each study site, the top 5 centimeters of each infaunal core sample were removed (Moy and Levin 1991) and wet-sieved through 500 µm and 63 µm mesh. Samples retained on each sieve were stored in 70% ethanol and stained with Rose Bengal to aid in sorting. Samples were examined under a dissecting microscope and compound microscope, and all organisms counted and identified to lowest feasible taxonomic level.

To estimate organic content of the sediment at each study site, 3 additional core samples were taken from each quadrat (18 per site), stored on ice, and frozen in the lab at -20° C until processing. Sediment organic content is known to stay relatively constant on an annual time scale in well established natural marshes (Whitlatch 1981), thus was only sampled once in August. Using methods adapted from Moy and Levin (1991), the top five centimeters of each core sample set aside for organic content analysis was removed, placed in pre-weighed containers and oven-dried at 60° C for 48 hours. Following drying, each sample was weighed and combusted in a furnace at 550° C for 30 minutes in order to eliminate all organic material. Samples were removed from the furnace, allowed to cool to room temperature, and weighed. Difference in weight before and after combustion provided an estimate of the organic content of each sample.

## Statistical Analysis

*T*-tests were used to determine if unvegetated areas at each study site displayed significantly lowered infaunal diversity and abundances of common taxa (nematodes, copepods) in comparison to vegetated areas. Sediment organic content in unvegetated and vegetated areas was also compared using *t*-tests. Diversity was measured in each quadrat of both sites using the Shannon-Weiner index (H') (Krebs 1999). Diversity measures excluded questionable taxa (e.g. unidentified juveniles, highly damaged specimens) and were calculated with nematodes removed. Extremely high abundance of nematodes can reduce clarity of results and are often excluded from analysis (Levin *et al.* 2002, Turnipseed *et al.* 2003, Craig and Wilson 2004). All data were tested for normality and equality of variance; infaunal abundances were ln(y + 1) transformed prior to all analyses in order to better meet the assumptions of normality. If the assumptions of parametric procedures were violated and could not be corrected with mathematical transformation of the data, the appropriate nonparametric statistical procedure was applied. All statistical procedures used in this study are described in Sokal and Rohlf (1995) and were calculated using JMP 5.1 statistical software. Effects were considered significant at $p < .05$.

# CHAPTER 3

# RESULTS

Nematodes were the most abundance taxa at both sites, of approximately 11,000 specimens collected, 9,000 were nematodes (Table 2). Copepods were second in abundance during each month of sampling at Sheffield Island and were also abundant at Harriett's Bluff, however, members of the phylum Kinorhyncha were as abundant, and in one case more abundant, than copepods at this site (Table 2). The number of individual taxa collected from each site during the study averaged 7.6 at Sheffield Island and 8 at Harriett's Bluff (Table 2).

Mean abundance of nematodes did not vary significantly between unvegetated and vegetated quadrats in June at either site (Fig. 3), however, mean copepod abundance was significantly higher in vegetated quadrats at Sheffield Island ($p=.012$, Fig. 3) and in unvegetated quadrats at Harriet's Bluff ($p=.047$, Fig. 3). In August, at Sheffield Island, the mean abundances of both nematodes ($p=.009$) and copepods ($p=<.001$) were significantly higher in unvegetated quadrats (Fig. 3), while at Harriett's Bluff, the abundance of nematodes and copepods in vegetated and unvegetated quadrats were similar (Fig. 3). No significant differences were detected in regards to infaunal abundances in October between vegetated and unvegetated quadrats (Fig. 3).

With the exception of some differences detected in August, vegetated and unvegetated quadrats displayed a high degree of similarity regarding taxa richness, diversity, and evenness (Fig. 4). In August, at Sheffield Island, mean diversity and mean evenness were significantly higher in vegetated quadrats ($p = .017$ and .015, respectively, Fig. 4) and at Harriett's Bluff, mean taxa richness was significantly higher in vegetated quadrats ($p = .019$, Fig. 4).

There were no significant differences in organic content between the vegetated and unvegetated quadrats at either Harriett's Bluff or Sheffield Island (Fig. $p = .357$ and .598, respectively; Fig. 5). However, sediment organic content was significantly lower at Sheffield Island in comparison to Harriett's Bluff (Fig. 5).

Table 1. Average temperature, pH, and salinity ± standard error as measured from each study site during sampling. Averages based on 3 replicate measurements. Sediment grain size distribution adapted from Stocks and Grassle (2003). Mean sediment organic content based on 18 replicate cores taken at random from quadrats at each study site

| | **Sheffield Island** | **Harriett's Bluff** |
|---|---|---|
| Temperature (˚C) | 30 ± 1.6 | 30 ± 1.6 |
| pH | 7.42 ± .23 | 7.45 ± .11 |
| Salinity (ppt) | 16.6 ± 6.8 | 15.6 ± 2.3 |
| Elevation (m) | 1.0 | 1.0 |
| Sediment Grain Size | >50% < 63µm | >50% < 63µm |

Table 2. Summary of all taxa counted during June, August, and October at each sampling site.

| | June | | | | August | | | | October | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Sheffield Island | | Harriett's Bluff | | Sheffield Island | | Harriett's Bluff | | Sheffield Island | | Harriett's Bluff | |
| Taxon | Veg. | Un. | Veg. | Un. | Veg. | Un. | Veg. | Un. | Veg. | Un. | Veg. | Un. |
| Nematoda | 590 | 966 | 223 | 423 | 511 | 963 | 1929 | 1892 | 144 | 172 | 523 | 684 |
| Kinorhyncha | 18 | 9 | 29 | 70 | 42 | 3 | 165 | 223 | 1 | 4 | 10 | 34 |
| Oligochaeta | | | | | | | | | | | | |
| Sp. A | 5 | 3 | | | 15 | 35 | 10 | 7 | 3 | 2 | 8 | 7 |
| Sp. B | | | | | | | | | | | | |
| Polychaeta | | | | | | | | | | | | |
| Nereidae | | 1 | 3 | 2 | | 1 | 3 | | | | | |
| Capitellidae | | | | | 1 | 2 | | | | | | |
| Sabellidae | 8 | 2 | | | 3 | 2 | 7 | | | | | 2 |
| Malacostraca | | | | | | | | | | | | |
| Amphipoda | | | | | | | | | | | | |
| Tanaidacea | 1 | | 32 | 18 | | | | | | | | |
| Maxillopoda | | | | | | | | | | | | |
| Harpacticoida | 132 | 37 | 23 | 41 | 133 | 427 | 262 | 171 | 16 | 7 | 41 | 32 |
| Ostracoda | 13 | 8 | 4 | 9 | 6 | 9 | 9 | 8 | 3 | 8 | | |
| Arachnida | | | | | | | | | | | | |
| Acarina | | | 2 | 1 | | | 3 | | | | 3 | 1 |
| Insecta | | | | | | | | | | | | |
| Dipteran larvae | | | | | | | | | | | | |
| Ceratopogonidae | 16 | 9 | 19 | 7 | 8 | 2 | 3 | 2 | | | | |
| Dolichopodidae | | | | | | | | | | | | 1 |
| Total | 783 | 1035 | 335 | 571 | 719 | 1444 | 2391 | 2303 | 167 | 193 | 585 | 761 |

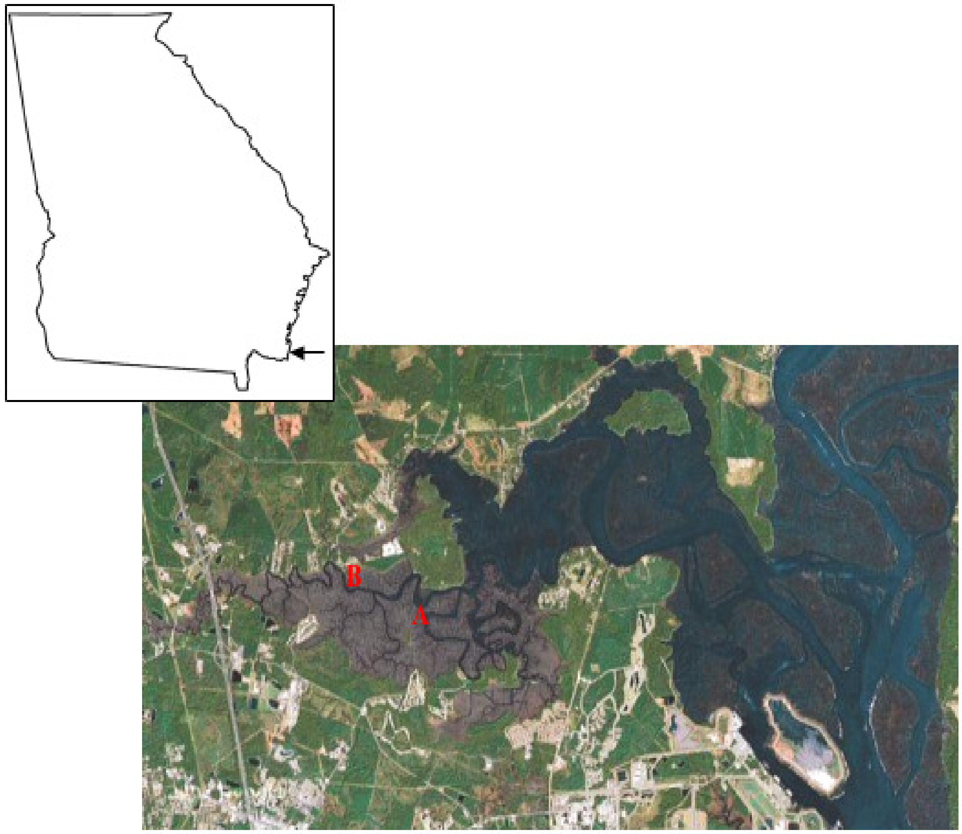


Figure 1. The Crooked River in Camden County, Georgia showing sites sampled: Sheffield Island (A) and Harriett's Bluff (B).

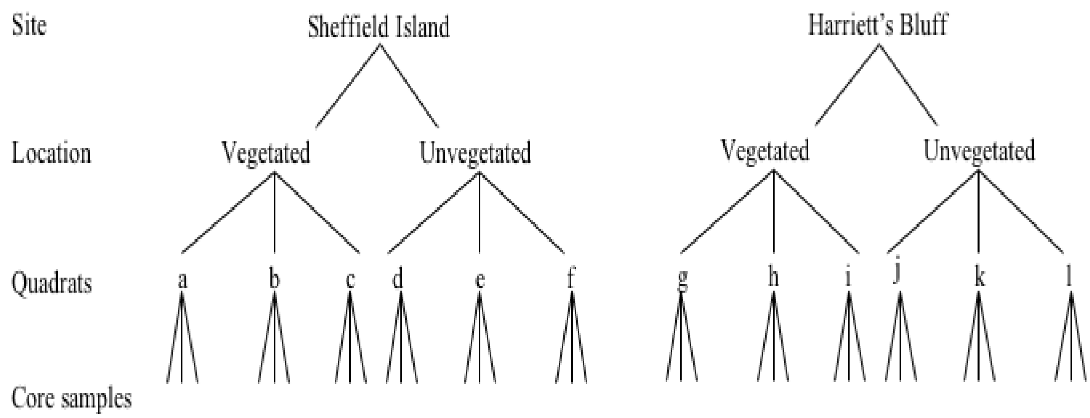


Figure 2. Sampling design used in this study to collect infauna and to determine sediment organic content. Six quadrats were nested within each of 2 sites, 3 in vegetated areas and 3 in unvegetated areas. Three replicate cores were collected from each quadrat.

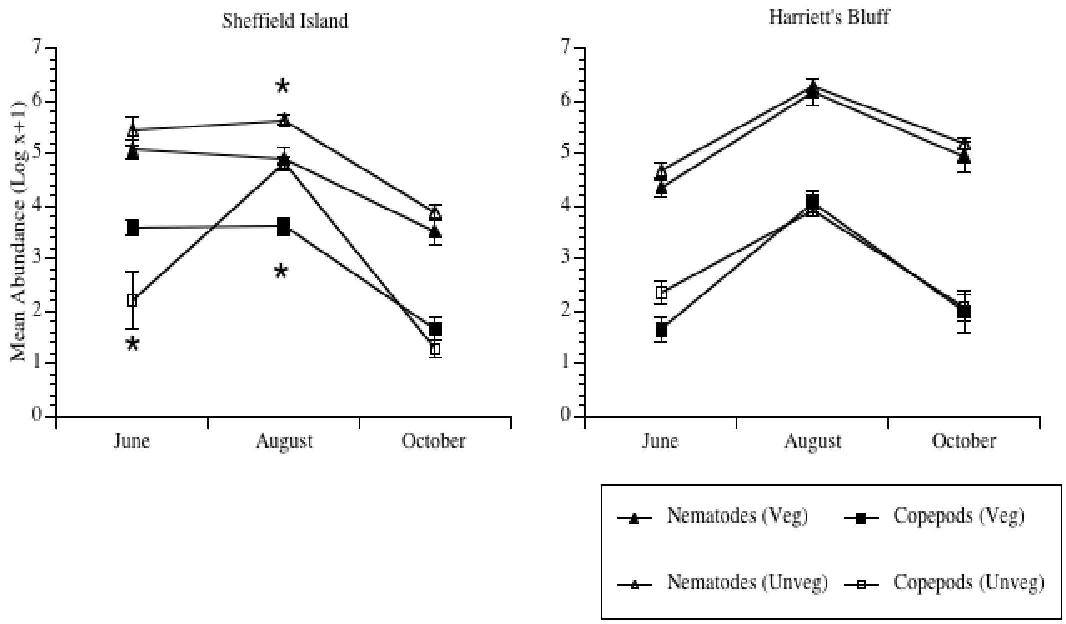


Figure 3. Mean abundances of nematodes and copepods during each of three sampling months at each site along the Crooked River in vegetated quadrats (veg) and unvegetated quadrats (unveg). Bars represent standard error. Asterisks indicate significant differences.

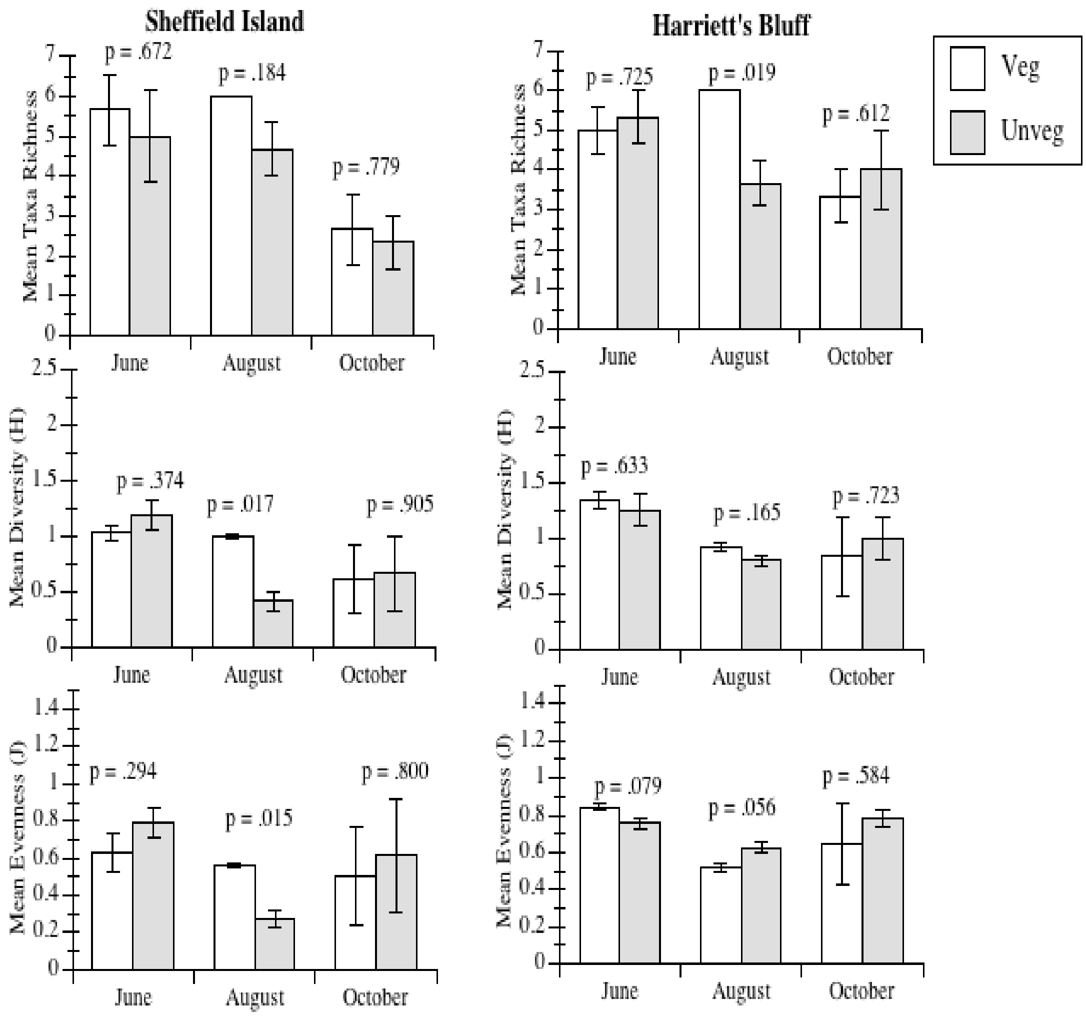


Figure 4. Taxa richness and diversity (H) and evenness (J) as measured by the Shannon-Weiner Index in vegetated (veg) and unvegetated (unveg) quadrats at two sites along the Crooked River. Plotted values are means ± standard error.

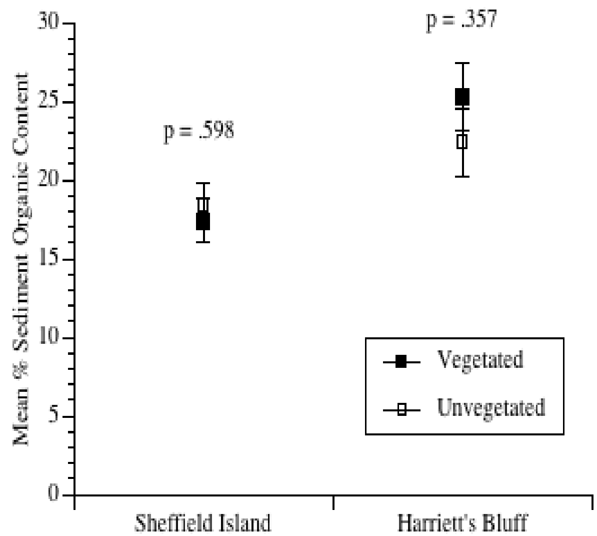


Figure 5. Mean percentage sediment organic content in vegetated and unvegetated quadrats at each study site. Bars represent standard error.

# CHAPTER 4

# DISCUSSION

The effects of the absence of vegetation on infaunal abundance and diversity varied between sites and across sampling months. Significant differences in infaunal abundances between vegetated and unvegetated quadrats were detected at both Harriett's Bluff and Sheffield Island. These differences were only detected during June and August and most of these differences involved copepods, of which most displayed significantly higher abundances in unvegetated quadrats. Similar results regarding copepod abundances are presented in a previous study conducted in South Carolina in the low marsh setting which reported that copepods were significantly more numerous in areas lacking live *Spartina alterniflora* culms (Osenga and Coull 1983).

Contrary to previous studies, nematode abundance was found to be similar in vegetated and unvegetated quadrats and in one case was significantly higher in unvegetated quadrats. Rader (1984) reported significantly higher abundances of meiofauna and macrofauna from samples including *Spartina* culms than in samples of bare sediment. Osenga and Coull (1983) found a positive association between nematode abundance and living *Spartina* roots. Samples from vegetated quadrats in this study were taken between *Spartina* culms and perhaps missed the concentration of infauna which associate with the oxygen rich sediment around the *Spartina* roots.

When higher temperatures increase desiccation stress and evaporation during summer months, infauna would most likely benefit from vegetative cover which strongly ameliorates these stresses (Bertness and Leonard 1997). In addition, vegetation may serve as a refuge and help to counteract predation in late summer and early fall when populations of various nektonic predators are known to increase (Kneib 1984, Kneib 1992). This may help to explain the higher taxa richness observed in vegetated quadrats at Harriett's Bluff in August as well as the higher diversity and evenness in vegetated quadrats at Sheffield Island in the same month. The decreased diversity and evenness detected in unvegetated quadrats at Sheffield Island during August may be directly related to the high abundances of copepods and nematodes observed within those quadrats.

Numerous studies have reported nematodes and copepods to be very abundant in the salt marsh benthos (Bell *et al.* 1978, Osenga and Coull 1983, Kneib 1984, Moy and Levin 1991). Results from this study demonstrate the same; nematodes were numerically dominant throughout followed in abundance by copepods at both sites. Another taxa, the kinorhynchs, also displayed notable abundances at Harriett's Bluff. At this site, kinorhynchs were comparable to copepods in abundance. Gosner (1971) reported that kinorhynchs feed mainly on organic detritus and microscopic algae. The elevated sediment organic content of this site may help explain the high abundance of kinorhynchs; additional research would be needed to determine their distribution along the Crooked River (Table 2, appendix).

The degree of influence of the absence of vegetation seemed to be affected by both location and month. A majority of the differences observed between vegetated and unvegetated quadrats occurred at Sheffield Island in mid to late summer. Organic content and sediment grain size were similar in vegetated and unvegetated quadrats, thus could not explain the differences. It is known that small-scale patterns of distribution and abundance often result from habitat heterogeneity (Kneib 1984). Patchy distribution of food sources and biogenic structures can have significant effects on local abundances of infauna.

This study indicates that the effects of vegetative cover may be better observed during periods of increased environmental stress, such as during summer months, when vegetative cover may be more beneficial. An abundance of rainfall and inclement weather which occurred close to sampling times in June and October may have served to counteract high surface temperatures and, therefore, some of the physical stress to the infauna during this study. It is also possible that the harsh weather conditions during this study may have been partially responsible for the observed patterns of infaunal abundance and distribution. The structure of infaunal assemblages may be greatly influenced by unusual climatic events, including major storms which disturb the sediment (Turner *et al.* 1995).

Future studies may want to address the effects of vegetation on infaunal abundance and diversity along the entire length of the river. Sampling conducted at two sites located closer to the mouth of the river seemed to indicate that the infaunal community structure was different from that of the sites located further inland. These sites displayed higher abundances of all taxa, including annelids, which were almost absent at Harriett's Bluff and Sheffield Island. Additionally, kinorhynchs were less abundant at sites closer to the river mouth (Table 2, appendix). This study successfully illustrated the patchy distribution of benthic infauna across varying spatial scales in the salt marsh and was the first to document the differences in infaunal abundance and diversity along the Crooked River, a river like many others along the coast of Georgia. Additional research may wish to focus attention on the various abiotic factors known to influence the benthos in order to determine which may be driving the differences in community structure observed between sites closer to the river mouth and those further upstream.

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# APPENDIX A

## ADDITIONAL SAMPLES SITES CLOSER TO THE RIVER MOUTH

Table A1. Average temperature, pH, and salinity ± standard error as measured from two additional study sites located towards the river mouth. Averages based on 3 replicate measurements. Sediment grain size distribution adapted from Stocks and Grassle (2003). Mean sediment organic content based on 18 replicate cores taken at random from quadrats at each study site.

| | **State Park** | **Mush Bluff** |
|---|---|---|
| Temperature (˚C) | 30 ± .33 | 30 ± 0.0 |
| pH | 7.03 ± .57 | 6.98 ± .06 |
| Salinity (ppt) | 18.3 ± 6.17 | 14.3 ± 4.66 |
| Elevation (m) | 1.0 | 1.0 |
| Sediment Grain Size | >50% < 63µm | >50% < 63µm |

Table A2. Summary of all taxa counted during June, August, and October at each sampling site

| | June | | August | | October | |
|---|---|---|---|---|---|---|
| | State Park | Mush Bluff | State Park | Mush Bluff | State Park | Mush Bluff |
| Taxon | | | | | | |
| Nematoda | 4018 | 1736 | 4332 | 2712 | 2003 | 998 |
| Kinorhyncha | 14 | 88 | 51 | 103 | 42 | 10 |
| Oligochaeta | | | | | | |
| Sp. A | 78 | 55 | 70 | 47 | 33 | 13 |
| Sp. B | 7 | 64 | 46 | 3 | 14 | |
| Polychaeta | | | | | | |
| Nereidae | 9 | | 3 | | 2 | |
| Capitellidae | 68 | 9 | 114 | 2 | 15 | |
| Sabellidae | 324 | 412 | 148 | 123 | 67 | 3 |
| Malacostraca | | | | | | |
| Amphipoda | | 3 | | | | |
| Tanaidacea | 214 | 1 | 14 | | 1 | |
| Maxillopoda | | | | | | |
| Harpacticoida | 199 | 343 | 304 | 403 | 154 | 81 |
| Ostracoda | 128 | 35 | 95 | 23 | 66 | 1 |
| Arachnida | | | | | | |
| Acarina | 18 | 2 | 6 | 3 | 8 | 1 |
| Insecta | | | | | | |
| Dipteran larvae | | | | | | |
| Ceratopogonidae | 7 | 76 | 2 | 47 | 2 | |
| Dolichopodidae | 3 | 5 | 1 | 3 | 2 | |
| Total | 5087 | 2829 | 5186 | 3469 | 2409 | 1107 |


Figure A1. The Crooked River in Camden County, Georgia showing additional sites sampled: State Park (A) and Mush Bluff (B).

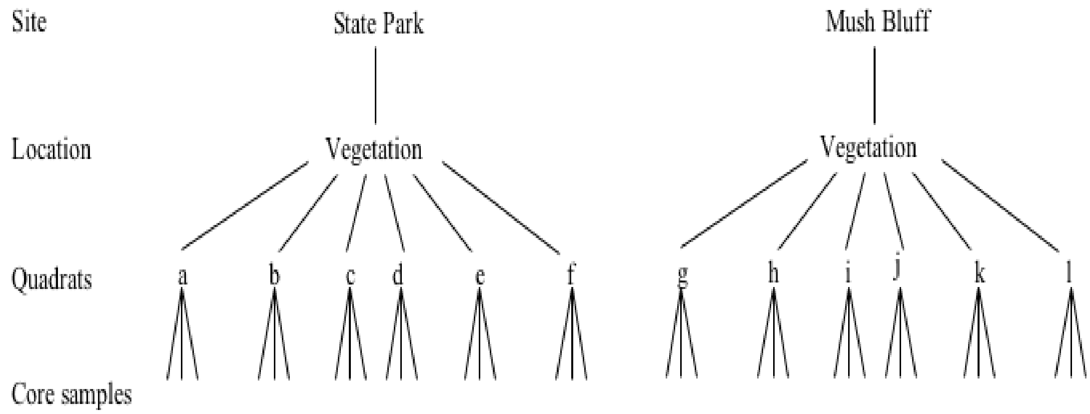


Figure A2. Sampling design used in this study to collect infauna and to determine sediment organic content. Six quadrats were nested within each of 2 sites, all in vegetated areas. Three replicate cores were collected from each quadrat.

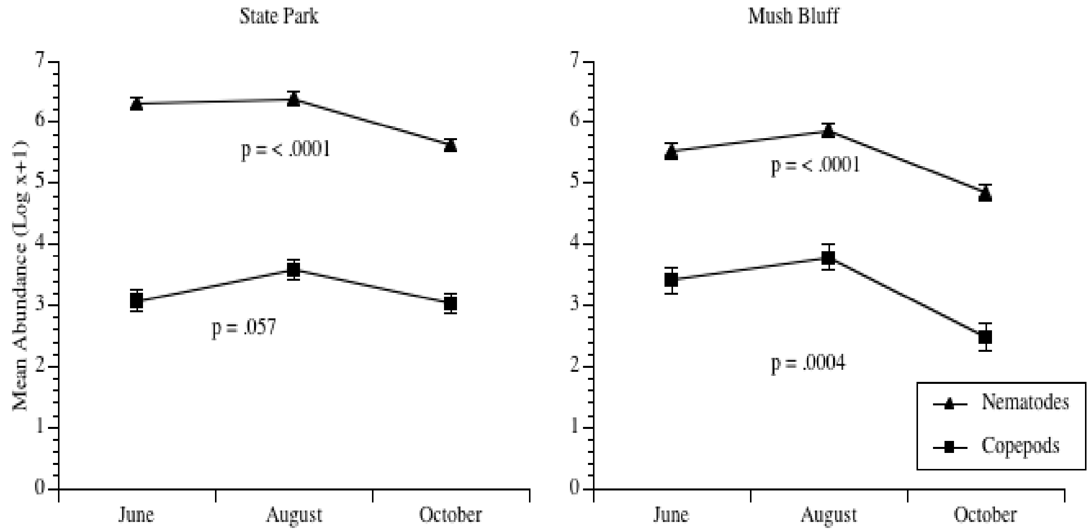


Figure A3. Mean abundances of nematodes and copepods during each of three sampling months at two additional study sites located towards the river mouth. Bars represent standard error.

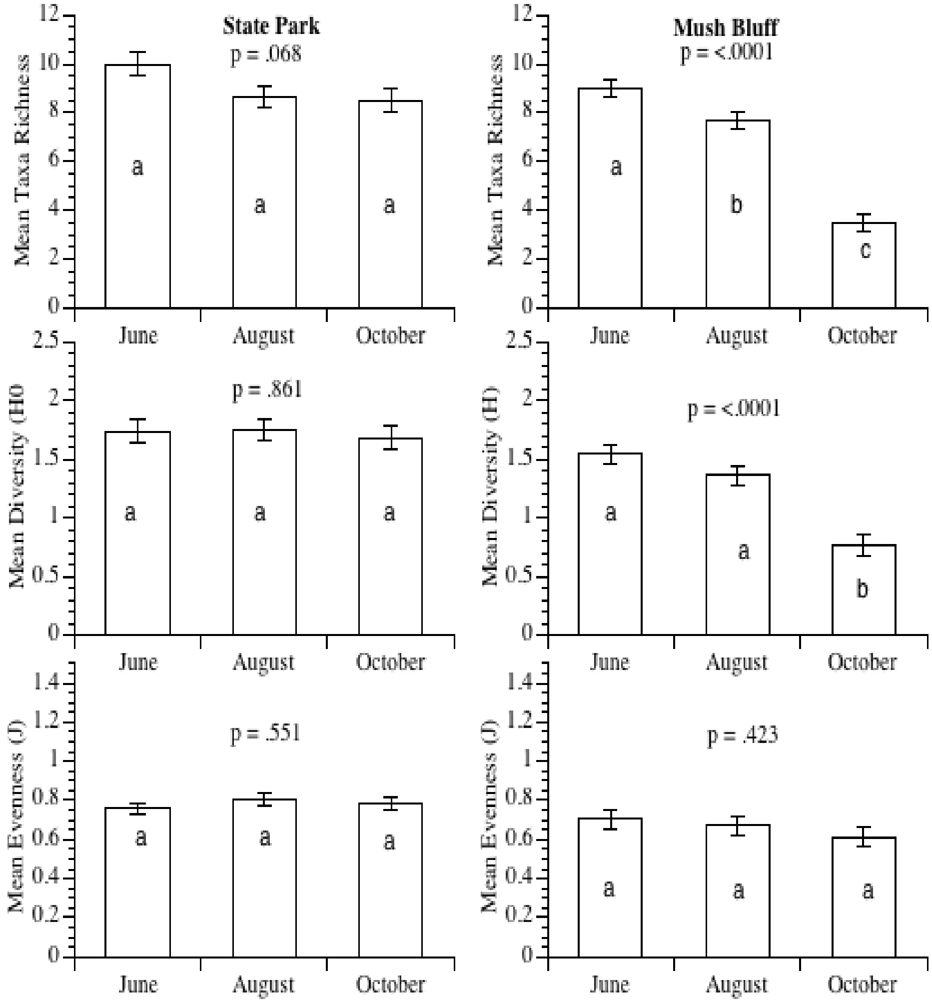


Figure A4. Taxa richness and diversity (H) and evenness (J) as measured by the Shannon-Weiner Index at two additional study sites located towards the river mouth. Plotted vaues are means ± standard error.

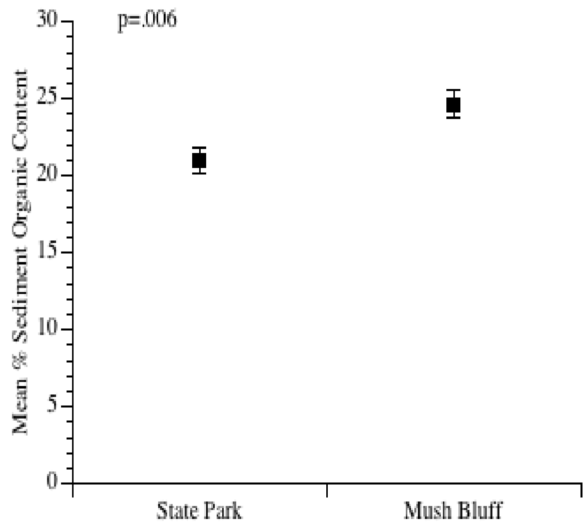


Figure A5. Mean percentage sediment organic content in vegetated and unvegetated quadrats at each study site. Bars represent standard error.