Special Publication SJ2001-SP9

Benthic Macroinvertebrate Data from 20 Surface Water Sites Within the Lower St. Johns River Basin

By

David L. Evans, Ph.D.
Water & Air Research, Inc.
6821 SW Archer Road
Gainesville, Florida 32608

John Higman
St. Johns River Water Management District
Highway 100 West
Palatka, Florida 32177

April 2001
99-5057-01

Contents

Contents, Continued

Figures

Tables

Appendices

Executive Summary

One of the long-term goals of the St. Johns River Water Management District is determining the degree to which biological communities in the District's water bodies have been impaired. To further this goal, a survey of the benthic macroinvertebrate communities of the Lower St. Johns River and its tributaries was performed. Between March and August 2000, District staff collected four replicate petite Ponar grab sediment samples at each of 20 surface water sites. Water & Air Research, Inc. (Water & Air) was retained to conduct laboratory analysis of samples and preliminary evaluation of benthic invertebrate community composition and structure.

Benthic macroinvertebrate data were summarized using four metrics: average organism density, total number of taxa observed, percent dominance of pollution-tolerant taxa, and pooled Shannon-Weiner species diversity index for each sampling site. Average organism density ranged from 344 to 7,103 m^{-2}, total number of taxa from 1 to 11, and Shannon-Weiner species diversity index from 0.00 to 3.04. Percent dominance by pollution-tolerant species ranged from 47 to 100 percent.

Gross morphological deformities in chironomid menta were recorded during organism identification. Morphological deformities were observed at 11 of the 20 sites, with percent occurrence ranging from 30.16 percent to 100.00 percent. Highest numbers of deformed larvae were collected at Cedar River CED01D (61), Little Fish Weir LFW01 (38), Cedar River CED062 (10), Ortega River ORT051 (9), Ortega River ORT361 (9) and Julington Creek JUL021 (9). Approximately 97 percent of the recorded deformities were observed at severely impaired sites, suggesting presence of metals or other contaminants at those sites.

The assessed sites were placed into the following two classes:

- Class A - moderate diversity (2 to 3); pollution-tolerant taxa moderately dominant to dominant (30 to 100 percent)
- Class B - low diversity (<2); dominated by pollution-tolerant taxa (> 60 percent)

This evaluation revealed 7 Class A and 11 Class B sites (Table 3). The Class B sites were located in the following tributaries: Cedar River, Little Fish Weir, Ortega River, Julington Creek, Trout River, Ribault River, Moncrief Creek and Goodby's Creek (Figures A-5 and A-6).

Sites were then ranked according to the degree of biological impairment using best professional judgment and a combination of factors including: (1) the site classification; (2) the number of larval deformities; (3) the Shannon-Weiner species diversity index; and (4) the percent dominance by pollution-tolerant taxa.

Following the ranking process, an Impairment Category was assigned to 18 of the 20 sites. The remaining two sites were not ranked due to insufficient information. All of the ranked sites were considered to be impaired to some degree. Each of the 18 ranked sites was assigned to one of the following Impairment Categories:

1. Moderately Impaired - Site Class A; No Larval Deformities; Diversity > 2.00; Percent Dominance by Pollution-tolerant Taxa 45 to 100%
2. Moderately Impaired - Site Class A; One Deformed Larva; Diversity > 2.00; Percent Dominance by Pollution-tolerant Taxa 45 to 100%

3. Severely Impaired – Site Class B; No Larval Deformities; Diversity Index <2.00; Percent Dominance by Pollution-tolerant Taxa 75 to 100%
4. Severely Impaired – Site Class B; One Deformed Larva; Diversity Index <2.00; Percent Dominance by Pollution-tolerant Taxa 75 to 100%
5. Very Severely Impaired – Site Class B; Larval Deformities greater than or equal to nine; Diversity Index <2.00; Percent Dominance by Pollution-tolerant Taxa 75 to 100%

Based on this evaluation, the greatest degree of biological impairment was associated with eleven sites in Impairment Categories 3, 4 and 5. These sites were located at Cedar River, Little Fish Weir, Ortega River, Julington Creek, Ribault River, Moncrief Creek, Goodby's Creek and Trout River (Table 6 and Figure A-7). The remaining seven sites were moderately impaired. No sites were considered to be unimpaired.

An agglomerative hierarchical cluster analysis with average linkage performed on benthic invertebrate data from the 20 sampling sites yielded some clusters (d and e) with relatively low diversity (< 0.86). Other site groupings (Clusters b and c) exhibited moderately low to moderately high diversity (1.03 to 2.68). Cluster a exhibited the highest number of unique taxa (11). Clustering was not influenced by the percent dominance by salt-tolerant taxa. Furthermore, there were no pairwise relationships between percent dominance by salt-tolerant taxa and organism density, number of taxa, or diversity.

Benthic macroinvertebrate data are valuable for assessing ecosystem response to toxic substances and other sources of environmental stress. Although study results indicate the degree to which sampled sites were biologically impaired, they do not in themselves identify sources of stress, which may include toxic substances, low dissolved oxygen, poor substrate quality, or a combination of factors. Future analysis of sediment chemistry and water quality data collected during this study and the use of bioassay techniques should help greatly in establishing causality.

The data collected for this study should be further evaluated to identify ecologically meaningful relationships between water quality, sediment quality and biological communities and to guide water resource managers in decision-making. To further investigate these relationships, additional biological, water, and sediment samples should be collected along environmental gradients (e.g. metal content) at impaired sites. Additional data, in combination with sediment toxicity testing results, would strengthen statements that can be made regarding the influence of sediment quality on benthic invertebrate communities and guide water resource managers in decision-making.

1 Introduction

The State of Florida created the St. Johns River Water Management District (SJRWMD) in 1972, and authorized it to protect and preserve the state's water resources. Additional authority was provided by the state, through the Surface Water Improvement and Management (SWIM) Act of 1987, to restore and protect the Lower St. Johns River Basin (LSJRB). In response to these directives, SJRWMD developed the LSJRB - SWIM plan, with the goals to (1) restore and protect the basin's surface water quality to Class III or better, and to (2) restore and protect the natural systems associated with the basin's surface water. To achieve these goals, there is a need for information on the LSJRB benthic community structure. This information can be used to guide and prioritize restoration efforts.

Benthic macroinvertebrate communities, like other biological communities, are influenced by their environment and can serve as indicators of water and sediment quality. Benthic invertebrates are particularly useful as biological indicators because they are stationary and unable to avoid stressful environmental conditions. Changes in benthic invertebrate communities also may affect other biological communities. Because benthic macroinvertebrates provide an important food resource for many types of fish, invertebrate abundance and diversity can influence fisheries production. Because of the potential usefulness of benthic invertebrate data in making water resource management decisions, a preliminary survey of the benthic invertebrate communities in specific areas of the Lower St. Johns River and its tributaries was conducted from March through August 2000.

SJRWMD retained Water & Air to conduct laboratory analysis of benthic macroinvertebrate samples and to evaluate the data collected at each of 20 surface water sites. This report presents a preliminary evaluation of the data.

2 Methods

2.1 Description of Sampling Locations

Locations of the 20 sampling sites, including freshwater and estuarine rivers and streams within the Lower St. Johns River Basin in northeast Florida are depicted in Figures A-1 and A-2 of Appendix A. These 20 benthic sampling locations were selected for one or more of the following reasons: (a) long-term water quality data existed for the location, (b) sediments in the location were known or suspected to be contaminated, (c) concurrent sediment samples were to be taken and analyzed for contamination and/or (d) organisms had been collected from the locations and tissue had been analyzed for contaminants. Site names, sampling dates, and latitude/longitude coordinates are presented in Table 1.

2.2 Laboratory Analysis, Data Tabulation, and Benthic Community Metrics

Samples were analyzed in Water & Air's biological laboratory in accordance with Water & Air's state-approved Comprehensive Quality Assurance Plan (CQAP, #900322). This plan addresses sample logging/tracking/custody, verification of sorting completeness, accuracy of taxonomic identification, verification of data entry, and other processes.

Four replicate petite Ponar grabs were collected from each site and preserved in the field. Samples were not composited. Each grab sample was sorted independently in the laboratory and organisms were identified to the lowest practical identification level and enumerated. Gross morphological deformities in chironomid menta were recorded during organism identification. The number of deformed chironomid larvae and the percent occurrence of morphological deformities were calculated for each taxon with recorded deformities. After all samples were processed and organisms were identified and enumerated, data were tabulated and the following benthic community metrics were calculated: total organism density, number of taxa, Shannon-Weiner species diversity, percent dominance by pollution-tolerant taxa, percent dominance by salt-tolerant taxa, and the number and percent occurrence of deformities in chironomid larvae.

2.3 Site Evaluation and Classification

Sites were evaluated based on four metrics: organism density, number of taxa, Shannon-Weiner species diversity, and the degree of dominance by pollution-tolerant taxa. Based on best professional judgement, using Shannon-Weiner species diversity and the degree of dominance by pollution-tolerant taxa, the assessed sites were placed into the following two classes:

- Class A - moderate diversity (2 to 3); pollution-tolerant taxa moderately dominant to dominant (30 to 100 percent).
- Class B - low diversity (<2); dominated by pollution-tolerant taxa (> 60 percent).

Bias in these community metric measures can occur when site replication is inadequate to characterize the benthic invertebrate population. A larger sample size is required to adequately characterize populations of low density and clumped distribution. An insufficient number of replicates were collected at two of the 20 sites: the Dunn's Creek and Welaka sites. Three of the four replicates collected at the Dunn's Creek and Welaka sites contained two or fewer organisms (Appendix B) and the total number of organisms collected was very low (16 or less). These two sites were not classified due to insufficient sample size.

2.4 Impairment Ranking of Sites

Sites were ranked according to the degree of biological impairment using best professional judgment and a combination of factors including: (1) the site classification; (2) the number of larval deformities; (3) the Shannon-Weiner species diversity index; and (4) the percent dominance by pollution-tolerant taxa.

The sites were assigned Impairment Categories as follows:

1. Moderately Impaired - Site Class A; No Larval Deformities; Diversity > 2.00; Percent Dominance by Pollution-tolerant Taxa 45 to 100%
2. Moderately Impaired - Site Class A; One Deformed Larva; Diversity > 2.00; Percent Dominance by Pollution-tolerant Taxa 45 to 100%
3. Severely Impaired – Site Class B; No Larval Deformities; Diversity Index <2.00; Percent Dominance by Pollution-tolerant Taxa 75 to 100%

4. Severely Impaired – Site Class B; One Deformed Larva; Diversity Index <2.00; Percent Dominance by Pollution-tolerant Taxa 75 to 100%
5. Very Severely Impaired – Site Class B; Larval Deformities greater than or equal to nine; Diversity Index <2.00; Percent Dominance by Pollution-tolerant Taxa 75 to 100%

Only benthic invertebrate data collected during this assessment were used to rank and categorize the sites by degree of impairment.

2.5 Statistical Analysis

The data were analyzed using exploratory data analysis techniques (e.g. matrix scatter plots, cluster analysis) to elucidate patterns and groupings among the sites. Multiple sites represented some water bodies. For the purposes of these analyses, each site was considered to be independent. Four replicate petite Ponar grabs were collected from each site and processed separately in the laboratory. These data were summarized with four variables: average organism density, total number of taxa observed, pooled Shannon-Weiner species diversity index, and percent dominance by salt-tolerant taxa. Mean organism density was transformed using the $\log_{10}$ transformation.

An agglomerative hierarchical cluster analysis with average linkage was performed on the 20 sites (Johnson and Wichern 1992). In this class of cluster analysis, each site starts in its own cluster. The two clusters that are the most similar (determined by using average linkage) are joined into one cluster. This hierarchical process continues until only one cluster remains. Initially, a cluster analysis was performed using the first three variables: average organism density, total number of taxa, and pooled Shannon-Weiner species diversity index. A second analysis was performed using the first three variables as well as percent dominance by salt-tolerant taxa to determine whether salinity tolerance helps to differentiate the 20 sites.

3 Results and Discussion

3.1 Community Metrics and Species Composition

Species abundance tables are presented for each sampling site in Appendix B. The 20 sites exhibited wide ranges in organism density (344 to 7,103 m^{-2}), number of taxa (1 to 11), and Shannon-Weiner species diversity (0.00 to 3.04).

Table 2 presents a list of taxa collected at the 20 sites. The most diverse taxonomic groups were annelid worms (15 taxa), chironomid larvae (10 taxa), and amphipods (8 taxa).

Percent dominance by pollution-tolerant taxa at the sites ranged from 47 to 100 percent (Table 3). Percent dominance was greater than 60 percent at all sites, except for a single site in Rice Creek that receives liquid oxygen injection to enhance dissolved oxygen availability.

3.2 Morphological Deformities

Elevated metal concentrations, particularly lead and copper, can cause deformities and perhaps growth inhibition in *Chironomus* larvae (Janssens de Bisthoven, Timmerans, and Ollevier 1992). Some organic compounds (e.g. pesticides) also are hypothesized to induce morphological deformities (Hamilton and Saether 1971, Warwick 1980). Other potential causes of deformities are not known. The presence of deformities indicates the potential presence of contaminants at sub lethal concentrations.

Gross morphological deformities in chironomid menta were recorded during organism identification, as previously described in Section 2.2. Percent occurrence of morphological deformities was calculated for each taxon with recorded deformities.

Morphological deformities occurred at 11 of the 20 sites (Table 4). Deformities occurred in *Chironomus* spp. and *Coelotanypus concinnus* at Cedar River, Little Fish Weir, Ortega River, Julington Creek, Ribault River, Moncrief Creek, Rice Creek McCullough Creek, and Cedar Creek (Table 4, Figures A-3 and A-4). No deformities were observed at the remainder of the sampling locations.

As shown in Table 4 the highest numbers of deformed larvae were collected at Cedar River (CED062= 61), Little Fish Weir (LFW01= 38), Cedar River (CED01D= 10), Ortega River (ORT051= 9), Ortega River (ORT361= 9), and Julington Creek (JUL021= 9). Approximately 97 percent of the total number of deformities recorded (141) were observed at these sites, suggesting presence of metals or other contaminants. One deformed larva was recorded at each of the following sites: Ribault River (RIB105), Moncrief Creek (MON104), Rice Creek (RC051), McCullough Creek (MCC01), and Cedar Creek (CDRC02).

Where deformities were observed, percent occurrence within the deformed taxa ranged from approximately 20 percent to 100 percent (Table 4). These deformities, and perhaps reduced larval growth rates, may be caused by the presence of elevated concentrations of metals or other contaminants in sediments (Janssens de Bisthoven, Timmerans, and Ollevier 1992). Sediment and water quality data can be evaluated to reveal possible relationships between contaminant concentrations and the frequency of occurrence of morphological deformities.

3.3 Site Evaluation and Classification

Based on community metrics, sites were placed into two classes (A and B) as described in Section 2.3. The classification of 18 of 20 sites is found in Table 3. The two sites, located at Dunn's Creek and Welaka, were not classified because of insufficient sample replication, as explained in Section 2.3.

This evaluation revealed 7 Class A and 11 Class B sites (Table 3). The Class B sites were located in the following tributaries: Cedar River, Little Fish Weir, Ortega River, Julington Creek, Trout River, Ribault River, Moncrief Creek and Goodby's Creek (Figures A-5 and A-6).

Mean values for organism density, number of taxa, diversity, percent dominance of pollution-tolerant organisms, and the percentage of total deformities within Classes A and B are presented in Table 5. Class ranges and means for organism density, number of taxa, and Shannon-Weiner species diversity are depicted in Figures 1, 2, and 3, respectively. Organism density can be highly variable depending on the type of environmental stress imposed on the benthic community. Low diversity, low organism density with a high dominance of pollution tolerant taxa at some Class B sites may be due to low dissolved oxygen and/or presence of toxic contaminants. Conversely other Class B sites with high organism densities in combination with low species diversity and a moderate to high dominance of pollution tolerant taxa may be primarily affected by low dissolved oxygen and high organic loading (Figures 1 and 3, Table 3).

Sites in Class A with a moderate level of diversity perhaps are influenced by mechanisms similar to those hypothesized for Class B sites, but to a lesser degree (Figure 3, Table 3).

3.4 Impairment Ranking

For decision-making purposes related to water resource management, it is useful to evaluate the data to estimate which of the sites can be considered impaired and which sites are relatively unimpaired. Simply stated, "Where are biological impacts most apparent?" To answer this question additional information is necessary (e.g. dissolved oxygen, water quality, sediment type and quality), but due to the limited scope of this project, these variables were not included as part of this preliminary data analysis report. Only the benthic invertebrate data collected during this assessment were used to evaluate and rank the sites according to the estimated degree of impairment.

Following the ranking process each site was assigned an Impairment Category based on professional judgment and a combination of factors including the site's class, number of deformed chironomid larvae, diversity and percent dominance by pollution-tolerant taxa (Table 6). An Impairment Category was assigned to 18 of the 20 sites. The remaining two sites were not ranked due to insufficient information. All of the ranked sites were considered to be impaired to some degree. Each of the 18 ranked sites was assigned to one of the five Impairment Categories described in Section 2.4.

Sites that are biologically impaired tend to have the following characteristics: low numbers of taxa, low Shannon-Weiner diversity values, abundant pollution-tolerant taxa, and a relatively high number of deformed chironomid larvae. Seven of the 18 sites were given a moderately impaired ranking (see Impairment Categories 1 and 2) because these sites typically had a moderate diversity index - greater than 2.00, moderate to high dominance of pollution-tolerant taxa, and few or no deformed larvae (Table 6). The remaining eleven sites had greater impairment. The severely impaired sites (see Impairment Categories 3 and 4) typically had a low species diversity less than 2.00, strong dominance of pollution-tolerant taxa, and few or no deformed chironomid larvae (Table 6). The very severely impaired sites (see Impairment Category 5) typically had a diversity index less than 2.00, were dominated by pollution-tolerant taxa, and many deformed chironomid larvae (Table 6). Site locations by Impairment Category are depicted in Figure A-7.

<u>Impairment Category 1</u>: Four of the seven moderately impaired sites without chironomid larvae deformities were assigned to Impairment Category 1 (Table 6). Two of these sites were located in tributaries, one in the mouth of the Arlington River (ARL109), and the other in Rice Creek (RICE02) just upstream of the highway 17 bridge. The remaining two sites were located in the mainstem of the river, one near Green Cove Springs (GCRB11) outside of the docking facility in Red Bay, and the other near the Naval Air Station (NAS01) adjacent to the outfall of the Southside waste water treatment plant (Figure A-7).

<u>Impairment Category 2</u>: A single deformed chironomid larva was recorded at each of the three remaining moderately impaired sites. These three sites were assigned to Impairment Category 2. One site was located in Cedar Creek (CDRC02), a tributary of the St. Johns River (Figure A-7). The other two sites were located on the St. Johns River

mainstem near McCullough Slough (MCC01) and near the mouth of Rice Creek (RC051).

Impairment Category 3: No deformed larvae were found at three of the five severely impaired sites in Impairment Category 3. Two of these sites were located in the mainstem of the St. Johns River near the mouth of Goodby's Creek (GBY01, GBY02). The third site was located in the Trout River tributary (TRT01).

Impairment Category 4: A single deformed chironomid larva was recorded at the two severely impaired sites in Impairment Category 4. Both of these sites were located in tributaries, one in Moncrief Creek (MON104) and the other in the Ribault River (RIB105).

Impairment Category 5: The six sites in Impairment Category 5 were very severely impaired. Five of the six sites were tributary sites located in the Ortega River watershed (Figure A-7), including two Ortega River sites (ORT361, ORT051), Little Fish Weir (LFW01), and two Cedar River sites (CED062, CED01D). Low diversity (<1.30) and a high percentage of pollution-tolerant taxa were observed at all five of these sites (Table 6). At four of these sites, more than 30 percent of *Chironomus* and *Coelotanypus* larvae were deformed (Table 4). Approximately 20 percent of the *Chironomus* and *Coelotanypus* larvae at ORT361 were deformed. The sixth site in Impairment Category 5 was located in the mainstem of the St. Johns River near the mouth of Julington Creek (JUL021) (Figure A-7). This Julington Creek site (JUL021) also had a high percentage of pollution-tolerant taxa and 50 percent of *Coelotanypus* larvae were deformed. In contrast to the other sites in this Category, the diversity at Julington Creek was moderately high due to relatively high evenness of distribution in organism abundance, but only 4 taxa were collected at the site (Table 3 and Appendix B).

Based on this evaluation, the greatest degree of biological impairment was associated with eleven sites in Impairment Categories 3, 4 and 5. These sites were located at Cedar River, Little Fish Weir, Ortega River, Julington Creek, Ribault River, Moncrief Creek, Goodby's Creek and Trout River (Table 6 and Figure A-7). The remaining seven sites were moderately impaired. No sites were considered to be unimpaired.

Although these results may indicate the degree to which sampled sites were biologically impaired, they do not in themselves identify sources of stress, which may include toxic substances, low dissolved oxygen, poor substrate quality (e.g. flocculent sediments), or a combination of factors.

3.5 Exploratory Data Analysis

Initial exploratory analysis consisted of a series of matrix scatterplots presenting density ($\log_{10}$), number of taxa, Shannon-Weiner species diversity, and percent dominance by salt-tolerant taxa (Figures 4 through 7; see Table 7 for key to site names). The scatterplots present scales for each variable both horizontally and vertically. For example, the density $\log_{10}$ horizontal scale is presented in the lower left corner and the vertical scale is found in the upper right corner. The number of taxa scales are shown horizontally at the top of the middle column of plots and vertically on the left side of the middle row of plots. Finally, diversity scales are displayed horizontally at the bottom of the right column and vertically at the right side of the lower row of plots.

The matrix scatterplot allows the reader to view relationships in two ways. For example, to view the relationship between number of taxa and diversity, the reader can look at the lower middle plot or the plot on the right side of the middle row.

In Figure 4, all sites are displayed in a matrix scatter plot including organism density $\log_{10}$, number of taxa, and diversity. There do not appear to be any obvious groups in the samples. A strong positive association between number of taxa and Shannon-Weiner species diversity also is visible. Figure 5 depicts a matrix scatterplot, with sites dominated by freshwater and salt-tolerant taxa represented with different color symbols. Percent salt-tolerance values are presented in Table 7. Figure 6 includes a fourth variable, the percent dominance by salt-tolerant taxa (PerSaltTol). Organism density, number of taxa, and Shannon-Weiner species diversity do not appear to have any pairwise relationship with percent dominance by salt-tolerant taxa. Figure 7 presents a scatterplot of organism density, number of taxa, and diversity with each site labeled with a unique identification number (see Table 7 for key to site names).

An agglomerative hierarchical cluster analysis with average linkage performed on the 20 sites is presented in a dendogram (Figure 8). Each site was given a unique identification number (Table 7) presented at the bottom of the dendrogram. To interpret the dendrogram, read it from the bottom up. The two most similar clusters were joined together first, then the next two most similar clusters, etc. The height of the lines represents the distance of the two clusters to be joined. The data were arbitrarily divided into 5 clusters: a, b, c, d, and e (Table 7).

The highest number of taxa (11) were collected at the two sites in Cluster a. Clusters b and c exhibited moderate organism density and moderately low to moderately high diversity values (1.03 to 2.68). Cluster d sites had relatively high organism densities (> 5,200 m^{-2}) and low diversity values (< 0.86). Both diversity (0.0 to 0.83) and number of taxa (1 to 3) were lowest in Cluster e.

A second cluster analysis, presented in Figure 9, included the three initial variables ($\log_{10}$ density, number of taxa, and diversity) as well as percent dominance of salt-tolerant taxa (PerSaltTol). The sites divided into clusters very similar to those in the previous analysis, indicating that accounting for salt-tolerance adds little information different from the information provided by the three initial variables. This result is not surprising given the scatterplots shown in Figures 5 and 6, indicating no pairwise relationships between dominance by salt-tolerant taxa and the remaining three variables.

4 Summary of Findings

Benthic macroinvertebrate data were summarized using five metrics: average organism density, total number of taxa observed, percent dominance of pollution-tolerant taxa, pooled Shannon-Weiner species diversity index, and the total number of deformed larvae at each sampling site. Average organism density ranged from 344 to 7,103 m^{-2}, total number of taxa from 1 to 11, and Shannon-Weiner species diversity index from 0.00 to 3.04. Percent dominance by pollution-tolerant taxa ranged from 47 to 100 percent.

Gross morphological deformities in chironomid menta were recorded during organism identification. Morphological deformities were observed at 11 of the 20 sites, with percent occurrence ranging from almost 20 percent to 100 percent. Highest numbers of deformed larvae were collected at Cedar River CED01D (61), Little Fish Weir LFW01 (38), Cedar River CED062 (10), Ortega River ORT051 (9), Ortega River ORT361 (9) and Julington

Creek JUL021 (9). Deformed larvae were also noted at Ribault River RIB01 (1), Moncrief Creek MON01 (1), Cedar Creek CDRC01 (1), McCullough Creek MCC01 (1) and Rice Creek RC051 (1). Approximately 97 percent of the recorded deformities were observed at six sites (CED01D, LFW01, CED062, ORT051, ORT361, and JUL021), suggesting presence of metals or other contaminants at those sites.

Eighteen sites were placed in two classes, based primarily on organism diversity and the degree of dominance by pollution tolerant taxa (Table 3):

Class A - moderate diversity (2 to 3); pollution-tolerant taxa moderately dominant to dominant (30 to 100 percent).

Class B - low diversity (<2); dominated by pollution-tolerant taxa (> 60 percent).

This evaluation revealed 7 Class A and 11 Class B sites (Table 3, Figures A-5 and A-6).

Sites were ranked and categorized by severity of impairment based on best profession judgement using a combination of factors including site classification, Shannon-Weiner species diversity, the degree of dominance by pollution-tolerant taxa, and the total number of deformities recorded. Each site was assigned an Impairment Category (Table 6 and Figure A-7). The Cedar River (CED01D; CED062), Little Fish Weir (LFW01), and Ortega River sites (ORT051; ORT361) were the most severely impaired. All five of these sites had low diversity and high percentages of pollution-tolerant taxa. At four of the sites, more than 30 percent of *Chironomus* larvae were deformed. Approximately 20 percent of the *Chironomus* and *Coelotanypus* larvae at ORT361 were deformed. At the Julington Creek site (JUL021) a high percentage of pollution-tolerant taxa was recorded and 50 percent of *Coelotanypus* larvae were deformed. Although these results may indicate the degree to which sampled sites were biologically impaired, they do not in themselves identify sources of stress, which may include toxic substances, low dissolved oxygen, poor substrate quality (e.g. flocculent sediments), or a combination of factors.

An agglomerative hierarchical cluster analysis with average linkage performed on benthic invertebrate data from the 20 sampling sites yielded some clusters with relatively low diversity (Clusters d and e). Other site groupings exhibited moderate diversity (Clusters b and c). Cluster a exhibited the highest number of unique taxa. Clustering was not influenced by the percent dominance by salt-tolerant taxa. Furthermore, there were no pairwise relationships between percent dominance by salt-tolerant taxa and organism density, number of taxa, or diversity.

5 Conclusions and Recommendations

This descriptive data evaluation suggests that benthic invertebrate data may provide a useful tool in assessing biological response to toxic substances, and other sources of environmental stress. Although study results indicate the degree to which sampled sites were biologically impaired, they do not in themselves identify sources of stress, which may include toxic substances, low dissolved oxygen, poor substrate quality, or a combination of factors. A review and statistical analysis of biological and water/sediment quality data can be performed to identify ecologically meaningful relationships that can be of use to water resource managers in decision-making.

To further investigate the relationship between sediment quality and biological communities, it may be useful to collect additional biological, water, and sediment samples along environmental gradients (e.g. metal content) at the impaired sites. These data combined with sediment toxicity testing results will strengthen statements that can be made regarding the influence of sediment quality on benthic invertebrate communities. Some sites could not be adequately evaluated due to insufficient sample size. These sites can be further evaluated after conducting a pilot study to determine sufficient sample size.

Since benthic invertebrates are a major food resource for fisheries and sediment quality may have both direct and indirect influence on fish, it may be desirable to conduct fish community assessments (inventories, tissue analysis) at the impaired sites.

6 Literature Cited

Hamilton, A.L. and O.A. Saether. 1971. The occurrence of characteristic deformities in chironomid larvae of several Canadian lakes. Canadian Entomologist 103:363-368.

Janssens de Bisthoven, L.G., K.R. Timmermanns, and F. Ollevier. 1992. The concentration of cadmium, lead, copper, and zinc in *Chironomus* gr. *thummi* larvae (Diptera: Chironomidae) with deformed versus normal menta. Hydrobiologia 239:141-149.

Johnson, R.A. and D.W. Wichern. 1992. Applied Multivariate Statistical Analysis. Third-Edition. Prentice-Hall, Inc. Englewood Cliffs, New Jersey.

Warwick, W.F. 1980. Chironomidae (Diptera) responses to 2800 years of cultural influence: a paleolimnological study with special reference to sedimentation, eutrophication, and contamination processes. Canadian Entomologist 112:1193-1238.

7 Glossary

Agglomerative Hierarchical Cluster Analysis – Grouping of items based on similarities. Similarity is evaluated using the distance between two *p*-dimensional items. Clustering is accomplished by a series of successive mergers of the items. Most similar items are grouped first, and subgroups continue to be merged until there is only one cluster.

Average Linkage – Method of evaluating the distance (or dissimilarity) between two clusters. Distance between two clusters is the average distance between all pairs of items, where one member of a pair belongs to each cluster. Distance between two *p*-dimensional items is calculated using the Euclidean (i.e., straight-line) distance.

Average Organism Density – The average number of invertebrate organisms collected per unit area. Usually presented as the number of individuals per square meter.

Benthic – Associated with sediments or other substrates on the bottom of water bodies.

CQAP – Comprehensive Quality Assurance Plan, a document submitted to and approved by the Florida Department of Environmental Protection.

Dendogram – Two-dimensional diagram used for displaying the results of a cluster analysis. Mergers of items and/or clusters made at successive levels are illustrated.

Estuarine – Pertaining to waterbodies where ocean water and fresh water mix.

Eutrophic – Nutrient-enriched. In this context, waters that have relatively high concentrations of inorganic plant nutrients and abundant algal populations.

Flocculent – Sediments formed by converting dissolved material into very fine particulate material. Such sediments tend to have a low settling rate and can remain suspended in the water for long periods.

Hypoxia – Containing a low concentration of dissolved oxygen.

Macroinvertebrate – An invertebrate organism that is retained by U.S. Standard No. 30 mesh sieve.

Metrics – Measured variables.

Petite Ponar Grab – A sediment sample taken with a petite Ponar dredge (dimensions: 6" by 6").

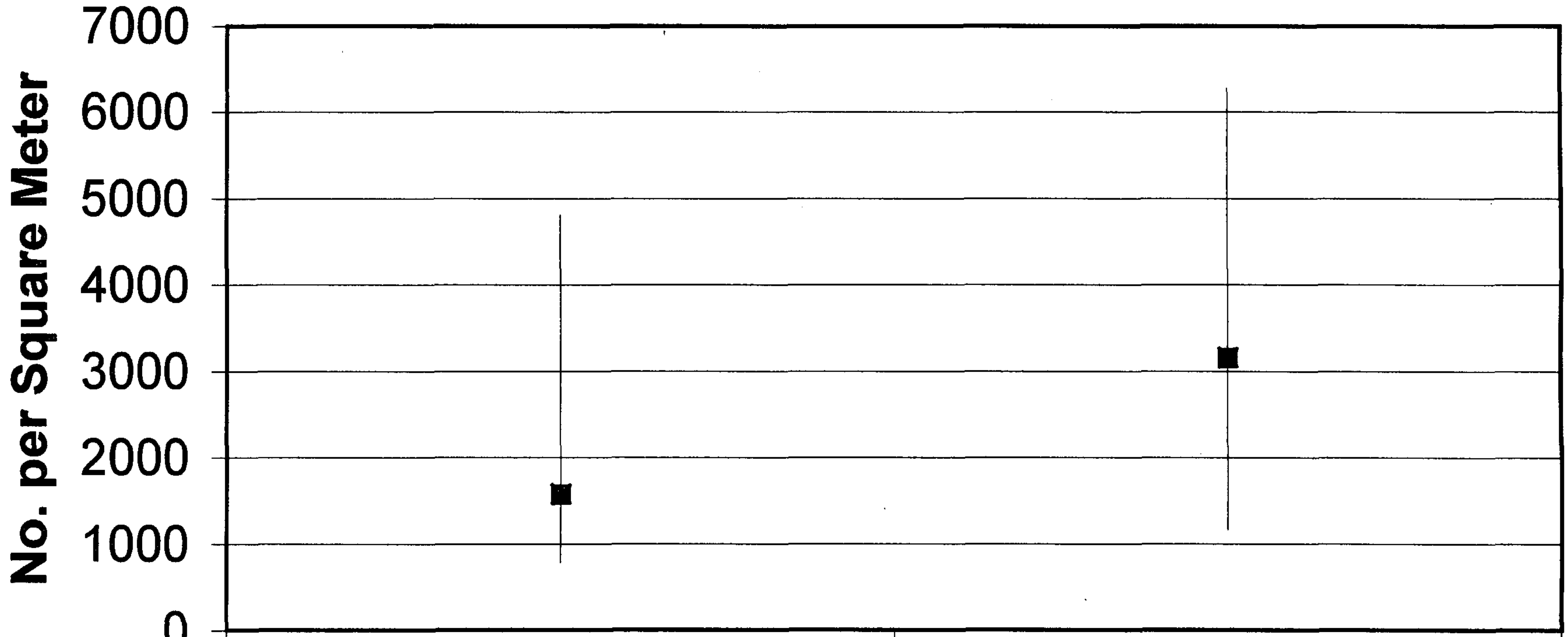
Replicate Samples – Multiple grab samples collected at the same sampling location.

Shannon-Weiner Species Diversity Index – A calculated index value expressing the degree of species diversity in a given sample or group of samples. The calculation is influenced by both the number of species present as well as the evenness of abundance among the species. Values generally range from 0 to 5, with values at the high end of the range indicating high species diversity. This index also is known as the Shannon-Weaver Species Diversity Index.

Taxa – The plural form of taxon (taxonomic unit). A taxon is a morphologically unique set of organisms. A taxon may consist of one or more species.

Figures

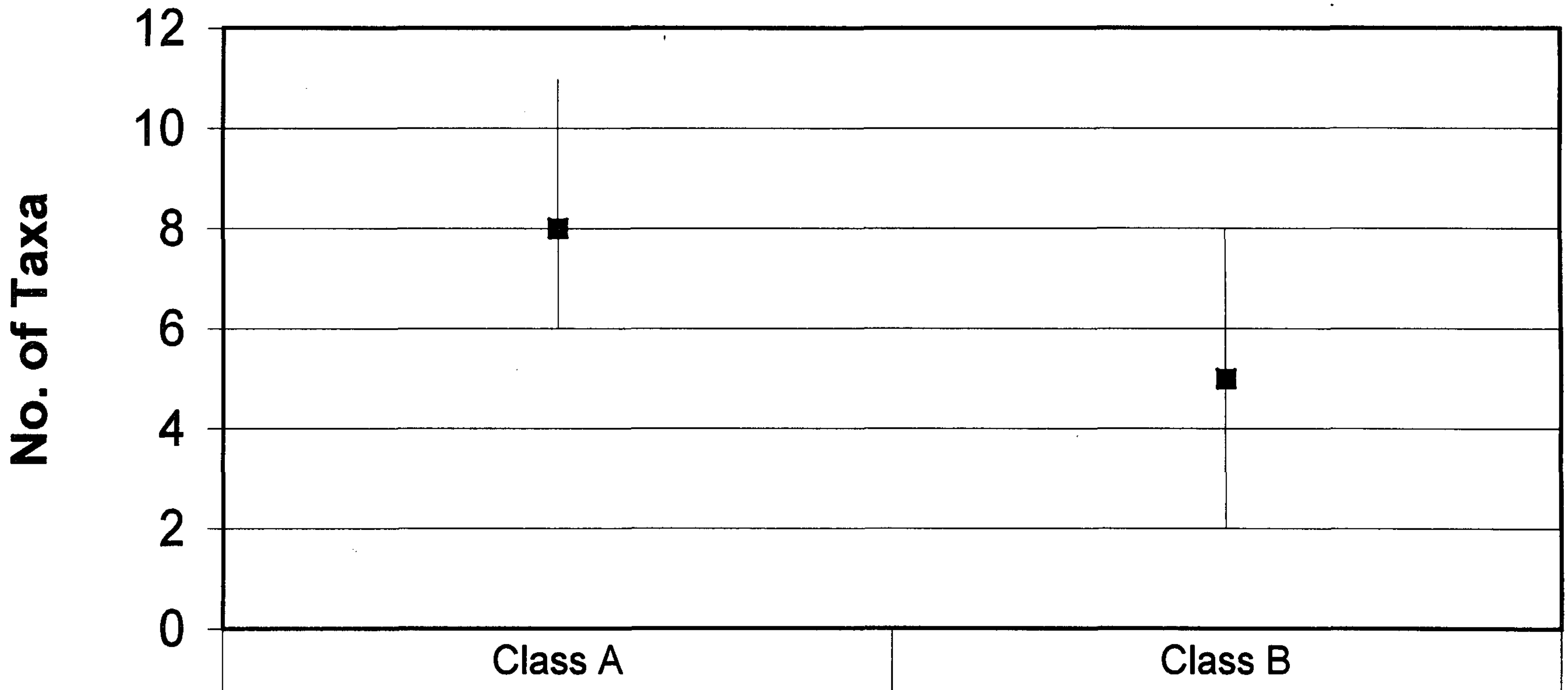
Figure 1. Density by Site Class



	Class A	Class B
Max	4821	6285
Min	775	1162
■ Mean	1574	3158

Site Class

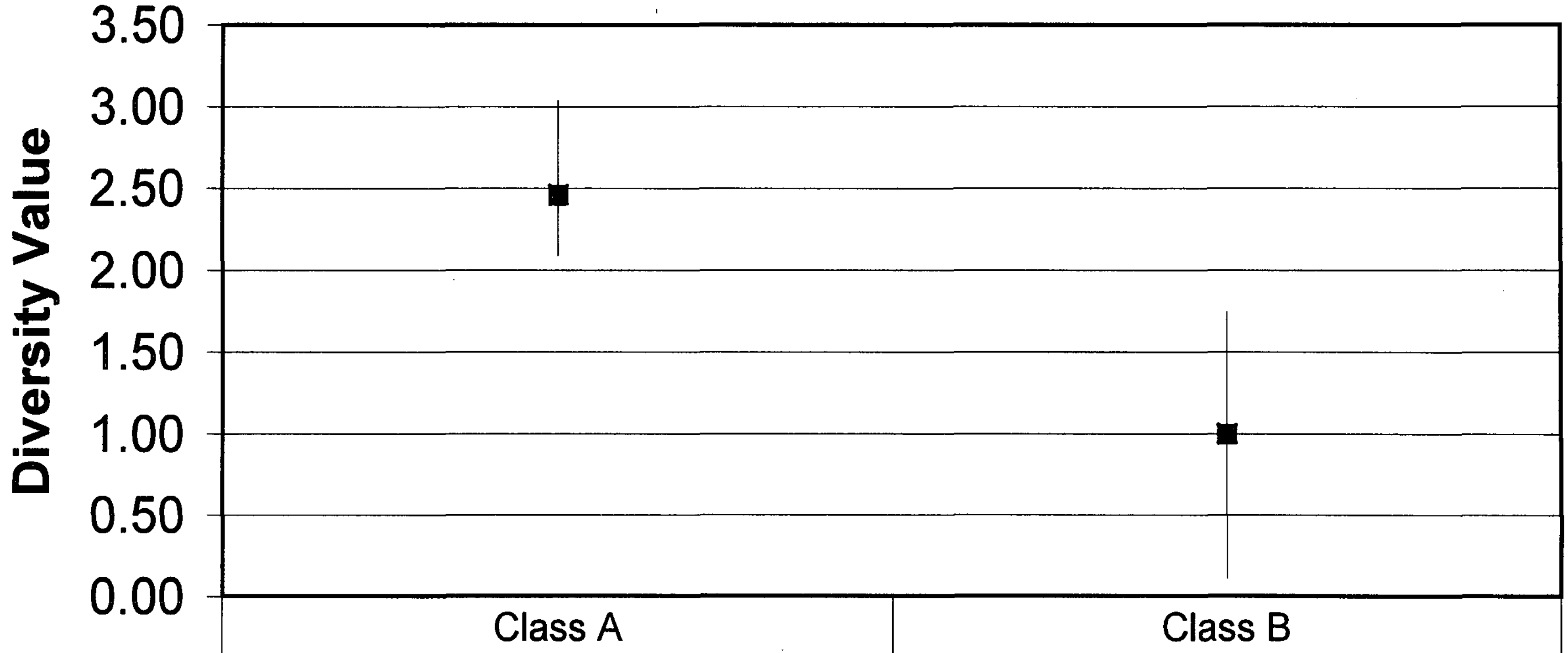
Figure 2. No. of Taxa by Site Class



	Class A	Class B
Max	11	8
Min	6	2
■ Mean	8	5

Site Class

Figure 3. Diversity by Site Class



	Class A	Class B
Max	3.04	1.75
Min	2.09	0.11
■ Mean	2.46	1.00

Site Class

Figure 4

Density, Taxa, and Diversity

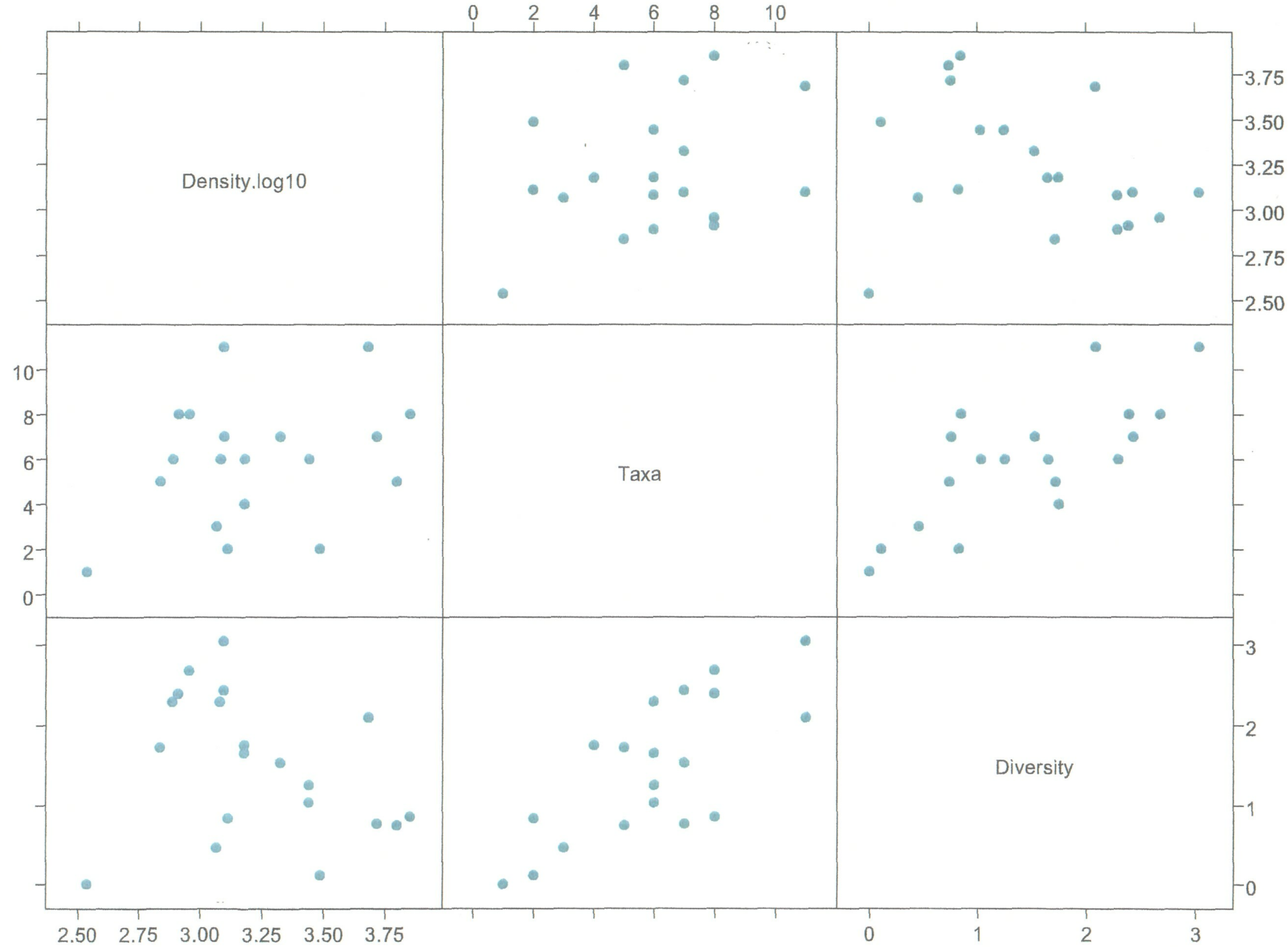


Figure 5

Freshwater vs. Saltwater sites

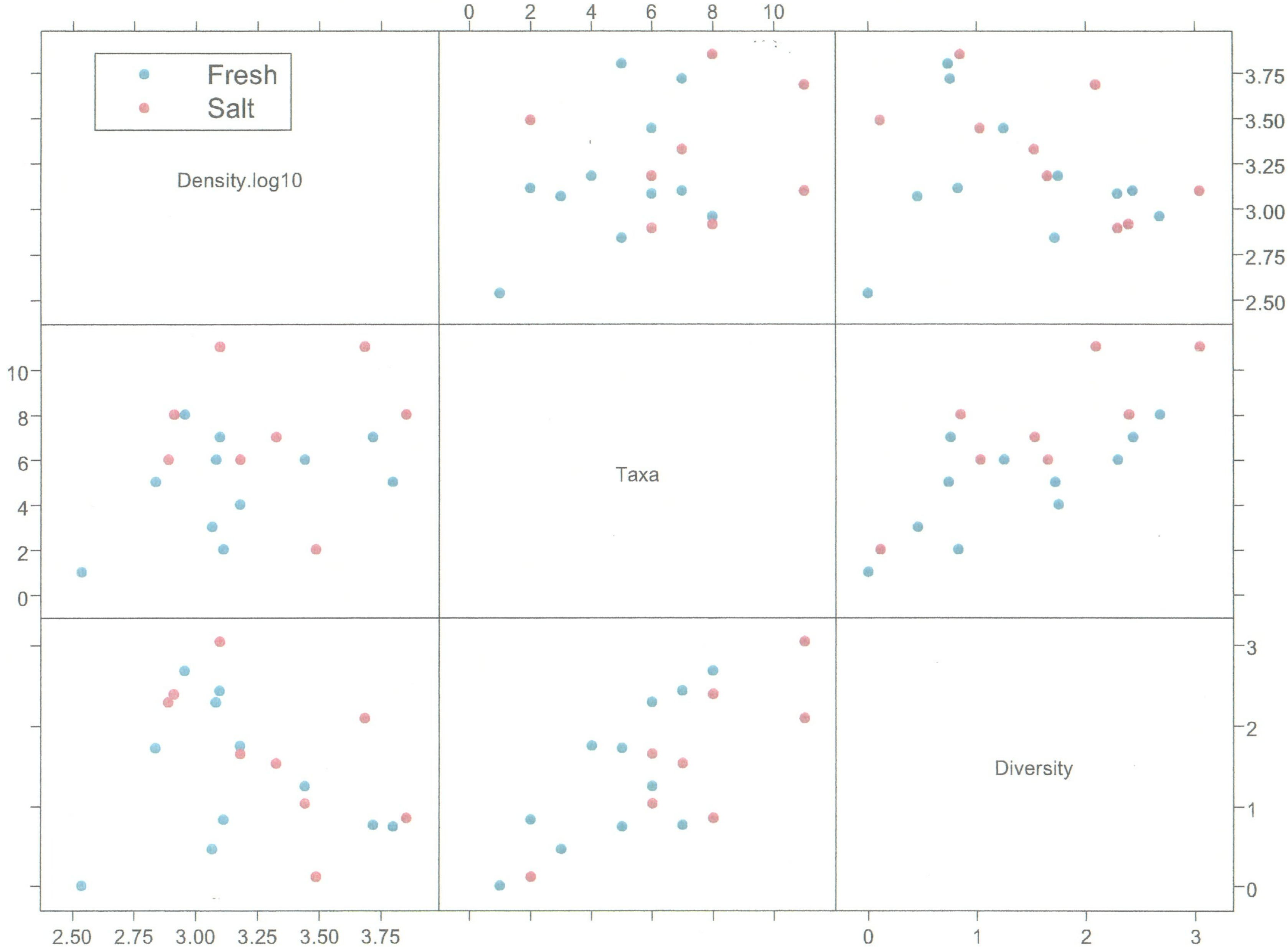


Figure 6

Density, Taxa, Diversity, Percent Salt-Tolerance(PersaltTOL)

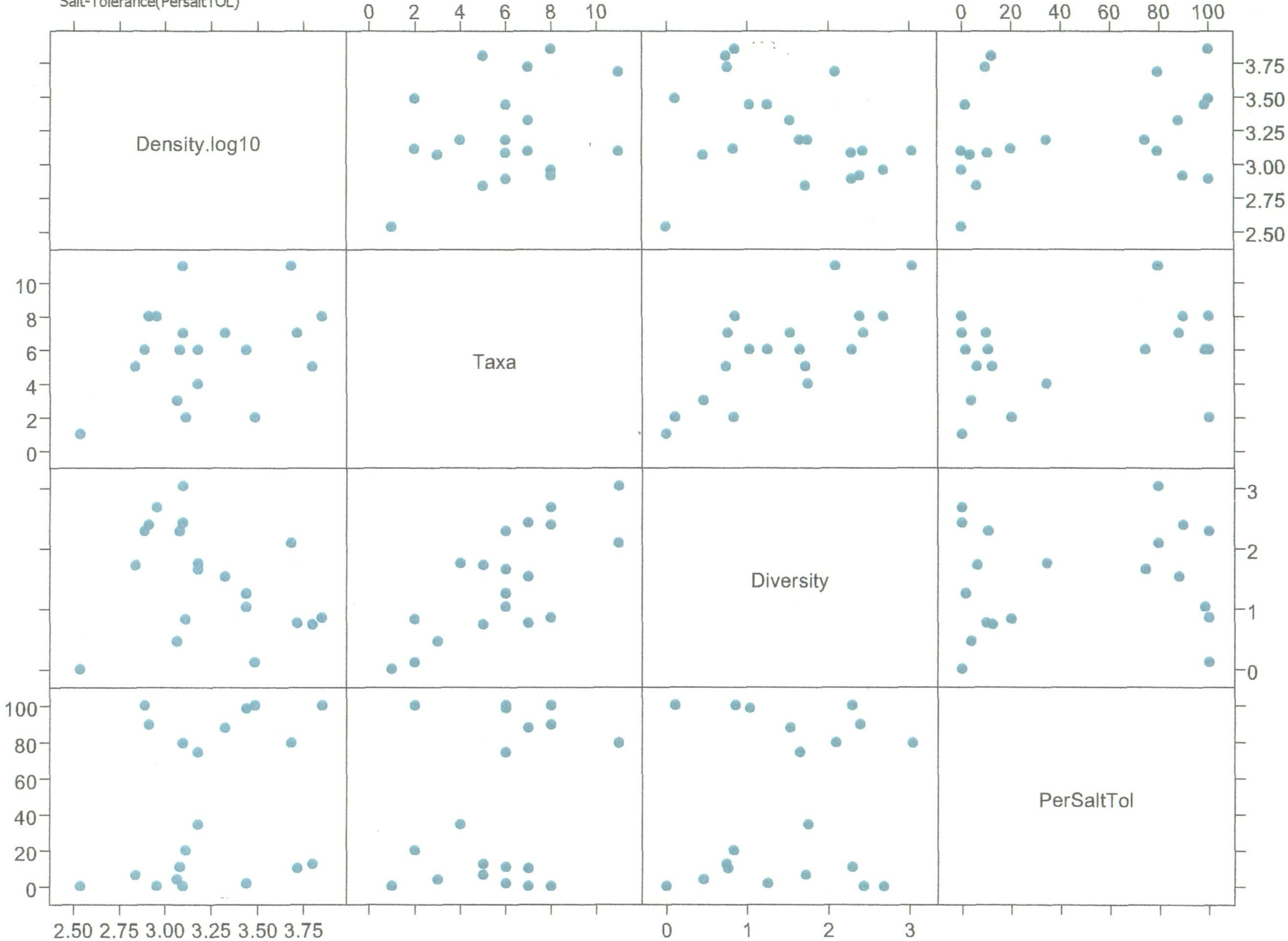


Figure 7
Site Identification Numbers

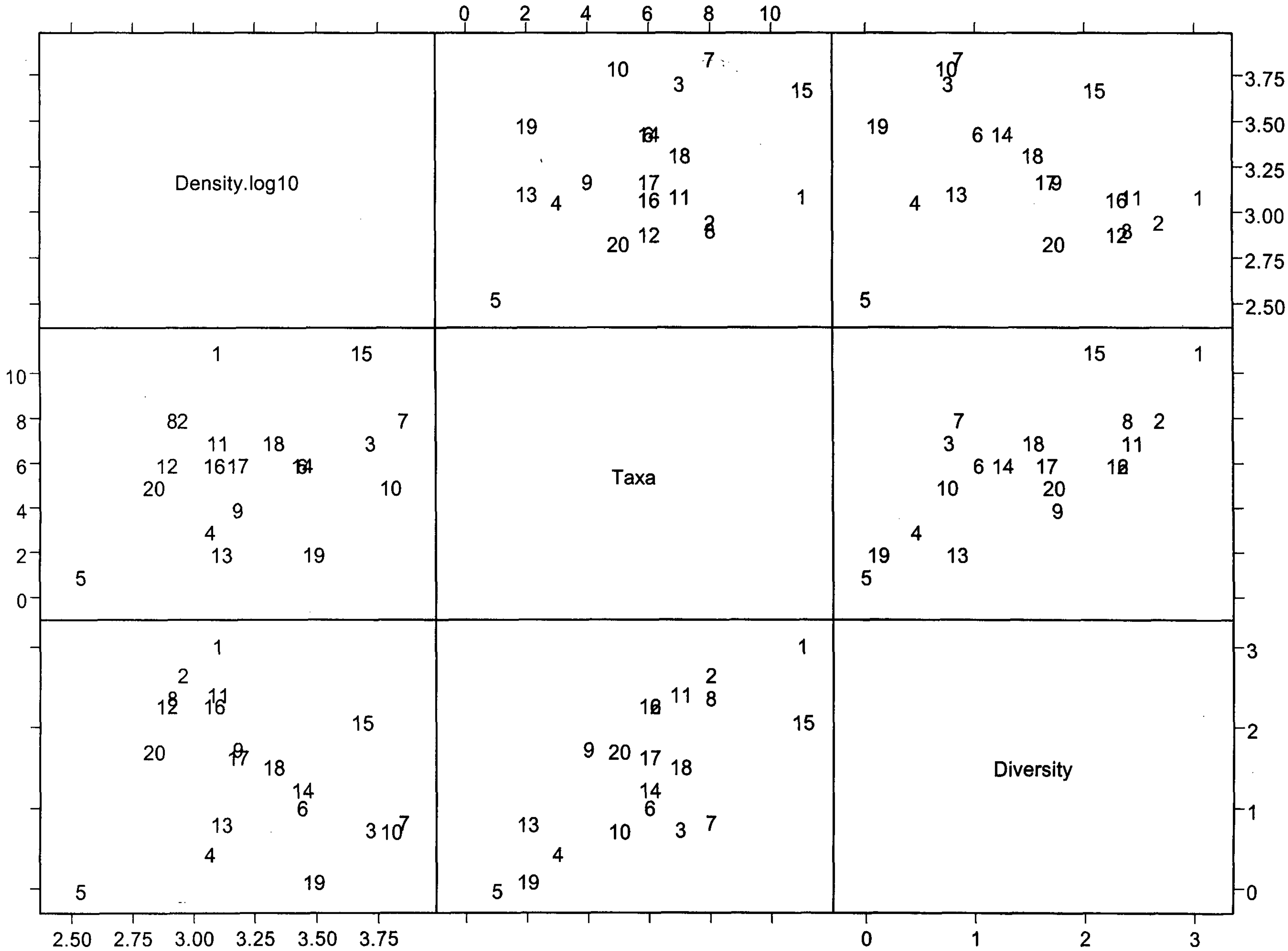


Figure 8
Agglomerative heirarchical cluster analysis

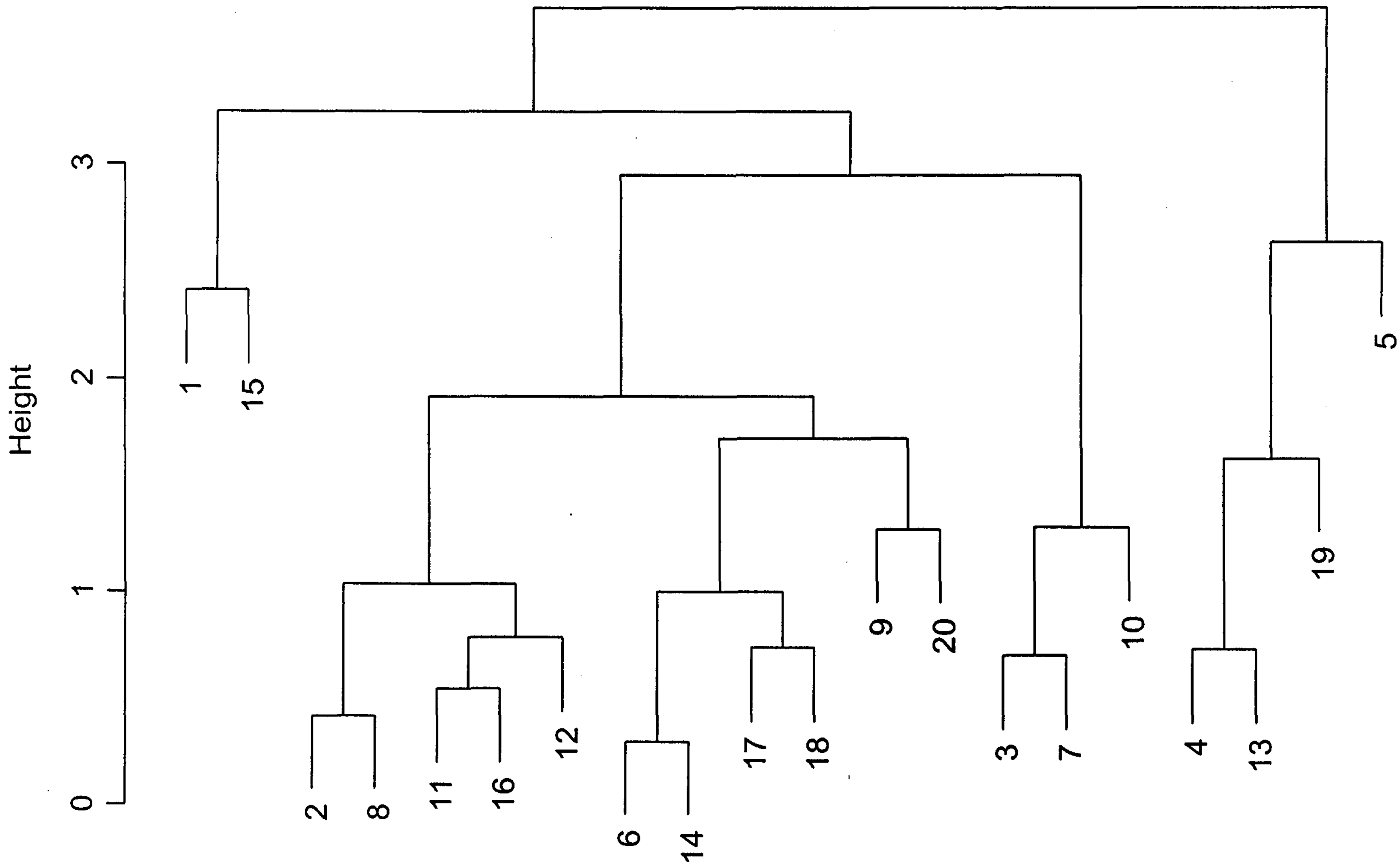
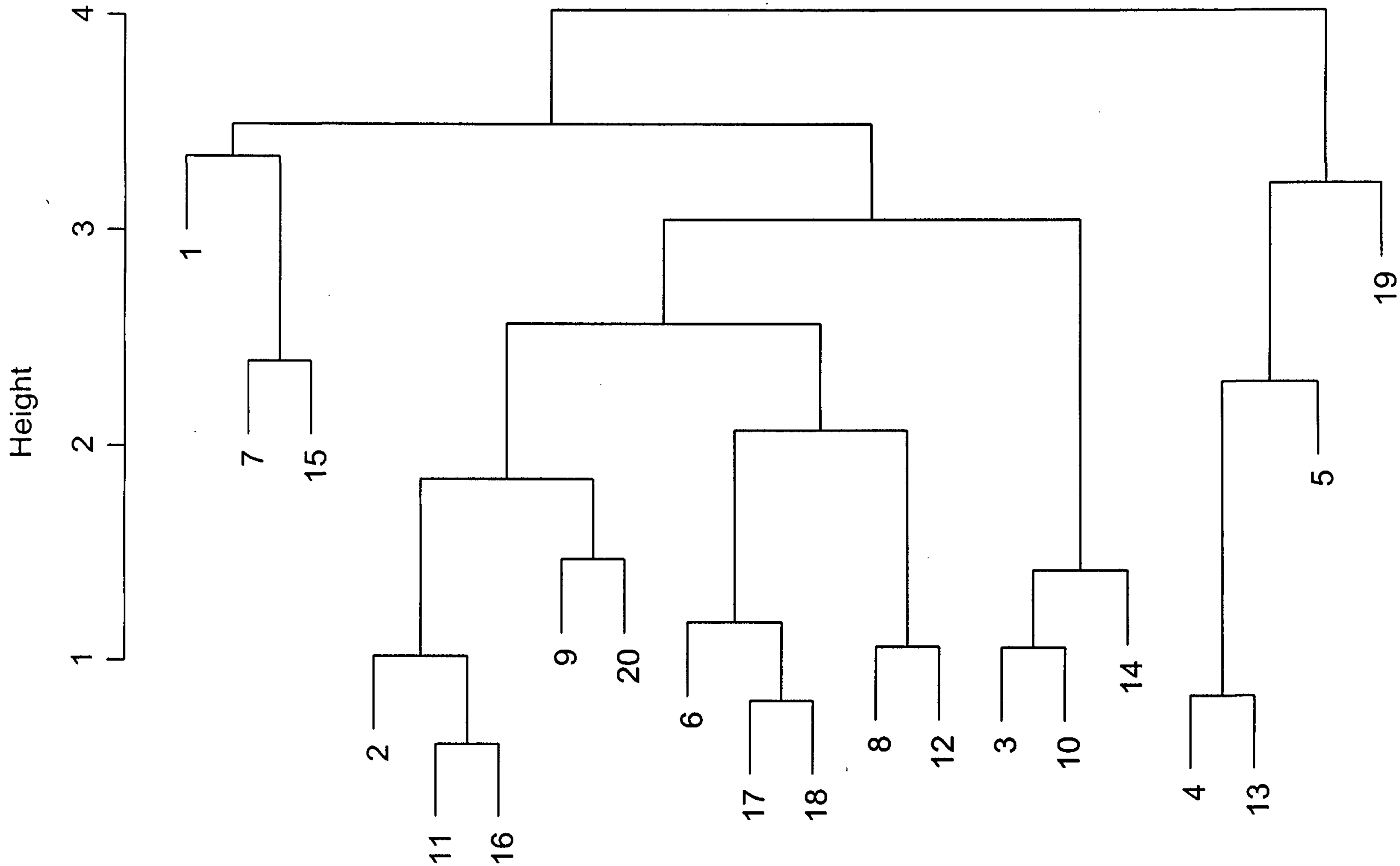


Figure 9
Agglomerative hierarchical cluster analysis, with PerSaltTol



Tables

Table 1
Benthic Sampling Locations and Collection Dates

Station Identification Code	Site Location	Sampling Date Time	Latitude (DDMMSS) NORTH	Longitude (DDMMSS) WEST
LFW01	Little Fish Weir	3/20/2000 10:30	301727	814237
JUL021	Julington Creek	4/6/2000 14:55	300711	813840
TRT01	Trout River	4/3/2000 14:15	302506	814114
ARL109	Arlington River	4/3/2000 10:00	301909	813643
NAS01	NAS Jax Outfall	4/7/2000 14:15	301504	814048
RIB105	Ribault River	4/3/2000 11:30	302418	814035
RICE02	Rice Creek	4/5/2000 11:45	294205	813958
RC051	Rice Creek	4/5/2000 13:10	294154	813904
CDRC02	Cedar Creek	3/14/2000 10:00	294828	813526
CED01D	Cedar River	3/14/2000 14:50	301715	814423
GCRB11	Green Cove Springs - Red Bay	5/17/2000 10:40	295923	813815
ORT361	Ortega River	3/20/2000 13:50	301546	814304
ORT051	Ortega River	3/20/2000 11:35	301644	814240
CED062	Cedar River	3/20/2000 12:40	301611	814347
MCC01	McCullough Creek	3/14/2000 11:40	294746	813205
DUNN02	Dunn's Creek	3/22/2000 14:05	293614	813640
WEK021	Welaka	3/22/2000 11:50	292838	814053
MON104	Moncrief Creek	3/17/2000 10:10	302335	813942
GBY01	Goodby's Creek	8/1/2000 11:25	301308	813734
GBY02	Goodby's Creek	8/25/2000 13:00	301239	813809

Table 2
List of Macroinvertebrate Taxa Collected from 20 Sites in the Lower St. Johns River Basin, Florida

Major Taxonomic Group	Scientific Name	Pollution Tolerance	Salt Tolerance
Nematoda			
	Nematoda sp. C	T	F
Nemertea			
	Nemertea	T	S
Annelida			
Polychaeta			
	Capitellidae (LPIL)	T	S
	Eteone heteropoda	T	S
	Neanthes succinea	T	S
	Nereidae (LPIL)	T	S
	Paraprionospio pinnata	T	S
	Polydora sp.	T	S
	Prionospio sp.	T	S
	Spionidae (LPIL)	T	S
	Spionidae sp. A	T	S
	Syllidae (LPIL)	T	S
Oligochaeta			
	Aulodrilus pigueti	T	F
	Limnodrilus hoffmeisteri	T	F
	Quistadrilus multisetosus	T	F
	Tubificidae (LPIL)	T	F
Hirudinea			
	Hirudinea (LPIL)	T	F
Crustacea			
Cumacea			
	Almyracuma sp.	I	S
Mysidacea			
	Mysidacea (LPIL)	I	S
Amphipoda			
	Amphipoda sp. A	I	S
	Corophium lacustre	T	S
	Corophium sp.	I	S
	Gammarus near tigrinus	T	S
	Melita nitida Complex	I	S
	Monoculodes edwardsi	I	S
	Monoculodes nyei	I	S
	Monoculodes sp.	I	S
Insecta			
Odonata			
	Macromia taeniolata	I	F
Diptera - Chironomidae			
	Chironomus crassicaudatus	T	F
	Chironomus sp.	T	F
	Cladotanytarsus sp.	I	F
	Coelotanypus concinnus	T	F
	Coelotanypus sp.	T	F
	Coelotanypus tricolor	T	F
	Djalmabatista pulchra	I	F
	Procladius (Holotanypus) sp.	I	F
	Procladius sp.	I	F
	Tanytarsus sp.	I	F
Plecoptera			
	Plecoptera (LPIL)	I	F
Molluca			
Pelecypoda			
	Corbicula fluminea	I	F
	Macoma tenta	T	S
	Mulinia lateralis	T	S
	Mytilopsis leucophaeta	T	S
	Pelecypoda (LPIL)	T	S
	Rangia cuneata	T	S

LPIL - Lowest Practical Identification Level
T - Pollution-tolerant
I - Pollution-intolerant
S - Salt-tolerant
F - Freshwater

Table 3

Benthic Community Metrics and Site Classification

Station Identification Code	Site Location	Density	No. of Taxa	Diversity	% Dominance by Tolerant Taxa	Site Class
ARL109	Arlington River	1248	11	3.04	100	A
CDRC02	Cedar Creek	904	8	2.68	81	A
MCC01	McCullough Creek	1248	7	2.43	69	A
GCRB11	Green Cove Springs	818	8	2.39	74	A
NAS01	NAS Jax Outfall	775	6	2.29	72	A
RICE02	Rice Creek	1205	6	2.29	86	A
RC051	Rice Creek	4821	11	2.09	47	A
JUL021	Julington Creek	1507	4	1.75	100	B
MON104	Moncrief Creek	1507	6	1.65	100	B
RIB105	Ribault River	2109	7	1.53	100	B
ORT361	Ortega River	2755	6	1.25	77	B
GBY01	Goodby's Creek	2755	6	1.03	99	B
GBY02	Goodby's Creek	7103	8	0.85	97	B
ORT051	Ortega River	1291	2	0.83	100	B
CED062	Cedar River	5209	7	0.76	99	B
LFW01	Little Fish Weir	6285	5	0.74	99	B
CED01D	Cedar River	1162	3	0.46	100	B
TRT01	Trout River	3056	2	0.11	100	B

Class A - Sites with moderate diversity; pollution-tolerant taxa dominant to moderately dominant

Class B - Sites with low diversity; dominated by pollution-tolerant taxa

Table 4

Number and Percent Occurrence of Morphological Deformities Observed at 20 Sites in the Lower St. Johns River Basin, Florida

Station Identification Code	Site Location	Taxon	No. of Deformities	Total Count for Taxon	% Occurrence Deformities
CED062	Cedar River	Chironomus sp.	61	107	57.01
LFW01	Little Fish Weir	Chironomus sp.	38	126	30.16
CED01D	Cedar River	Chironomus sp.	10	25	40.00
ORT361	Ortega River	Chironomus sp./Coelotanypus	9	47	19.15
ORT051	Ortèga River	Chironomus sp.	9	25	36.00
JUL021	Julington Creek	Coelotanypus concinnus	9	18	50.00
RIB105	Ribault River	Chironomus sp.	1	1	100.00
MON104	Moncrief Creek	Chironomus sp.	1	1	100.00
RC051	Rice Creek	Coelotanypus concinnus	1	3	33.33
MCC01	McCullough Creek	Chironomus sp.	1	1	100.00
CDRC02	Cedar Creek	Chironomus sp.	1	1	100.00
TRT01	Trout River	N/A	0	N/A	0.00
ARL109	Arlington River	N/A	0	N/A	0.00
NAS01	NAS Jax Outfall	N/A	0	N/A	0.00
RICE02	Rice Creek	N/A	0	N/A	0.00
GCRB11	Green Cove Springs - Red Bay	N/A	0	N/A	0.00
DUNN02	Dunn's Creek	N/A	0	N/A	0.00
WEK021	Welaka	N/A	0	N/A	0.00
GBY01	Goodby's Creek	N/A	0	N/A	0.00
GBY02	Goodby's Creek	N/A	0	N/A	0.00

Table 5

Summary of Community Metrics by Site Class

Metrics	Class A	Class B
Number of Sites	7	11
Mean Organism Density (No. m^{-2})	1574	3158
Mean No. of Unique Taxa	8.1	5.1
Mean Shannon-Weiner Diversity	2.46	1.00
Mean % Dominance Tolerant Taxa	76	97
% of Total No. of Deformities	2	98

Table 6
Impairment Ranking and Categorization

Station Identification Code	Site Location	Site Class	No. of Deformed Larvae	Diversity Index	% Dominance by Tolerant Taxa	Degree of Impairment	Impairment Category
ARL109	Arlington River	A	0	3.04	100	**Moderate**	**1**
GCRB11	Green Cove Springs	A	0	2.39	74	**Moderate**	**1**
NAS01	NAS Jax Outfall	A	0	2.29	72	**Moderate**	**1**
RICE02	Rice Creek	A	0	2.29	86	**Moderate**	**1**
CDRC02	Cedar Creek	A	1	2.68	81	**Moderate**	**2**
MCC01	McCullough Creek	A	1	2.43	69	**Moderate**	**2**
RC051	Rice Creek	A	1	2.09	47	**Moderate**	**2**
GBY01	Goodby's Creek	B	0	1.03	99	**Severe**	**3**
GBY02	Goodby's Creek	B	0	0.85	97	**Severe**	**3**
TRT01	Trout River	B	0	0.11	100	**Severe**	**3**
MON104	Moncrief River	B	1	1.65	100	**Severe**	**4**
RIB105	Ribault River	B	1	1.53	100	**Severe**	**4**
JUL021	Julington Creek	B	9	1.75	100	**Very Severe**	**5**
ORT361	Ortega River	B	9	1.25	77	**Very Severe**	**5**
ORT051	Ortega River	B	9	0.83	100	**Very Severe**	**5**
CED01D	Cedar River	B	10	0.46	100	**Very Severe**	**5**
LFW01	Little Fish Weir	B	38	0.74	99	**Very Severe**	**5**
CED062	Cedar River	B	61	0.76	99	**Very Severe**	**5**

Table 7
Sampling Sites Listed by Dendogram Identification Number

Dendogram Identification No.	Cluster	Station Identification Code	Site Location	Density (No. m^{-2})	Density ($\log_{10}$)	Number of Taxa	Diversity	Total Raw Count	Total No. Salt-tolerant	Percent Salt-tolerant	Salt/Fresh Dominance
1	a	ARL109	Arlington River	1248	3.10	11	3.04	29	23	79	S
2	b	CDRC02	Cedar Creek	904	2.96	8	2.68	21	0	0	F
3	d	CED062	Cedar River	5209	3.72	7	0.76	121	12	10	F
4	e	CED01D	Cedar River	1162	3.07	3	0.46	27	1	4	F
5	e	DUNN02	Dunn's Creek	344	2.54	1	0.00	8	0	0	F
6	c	GBY01	Goodby's Creek	2755	3.44	6	1.03	64	63	98	S
7	d	GBY02	Goodby's Creek	7103	3.85	8	0.85	165	165	100	S
8	b	GCRB11	Green Cove Springs	818	2.91	8	2.39	19	17	89	S
9	c	JUL021	Julington Creek	1507	3.18	4	1.75	35	12	34	F
10	d	LFW01	Little Fish Weir	6285	3.80	5	0.74	146	18	12	F
11	b	MCC01	McCullough Creek	1248	3.10	7	2.43	29	0	0	F
12	b	NAS01	NAS Jax Outfall	775	2.89	6	2.29	18	18	100	S
13	e	ORT051	Ortega River	1291	3.11	2	0.83	30	6	20	F
14	c	ORT361	Ortega River	2755	3.44	6	1.25	64	1	2	F
15	a	RC051	Rice Creek	4821	3.68	11	2.09	112	89	79	S
16	b	RICE02	Rice Creek	1205	3.08	6	2.29	28	3	11	F
17	c	MON104	Moncrief Creek	1507	3.18	6	1.65	35	26	74	S
18	c	RIB105	Ribault River	2109	3.32	7	1.53	49	43	88	S
19	e	TRT01	Trout River	3056	3.49	2	0.11	71	71	100	S
20	c	WEK021	Welaka	689	2.84	5	1.72	16	1	6	F

F - Dominated by freshwater organisms (> 50 percent)
S - Dominated by salt-tolerant organisms (> 50 percent)

Appendix A

Site Location Maps

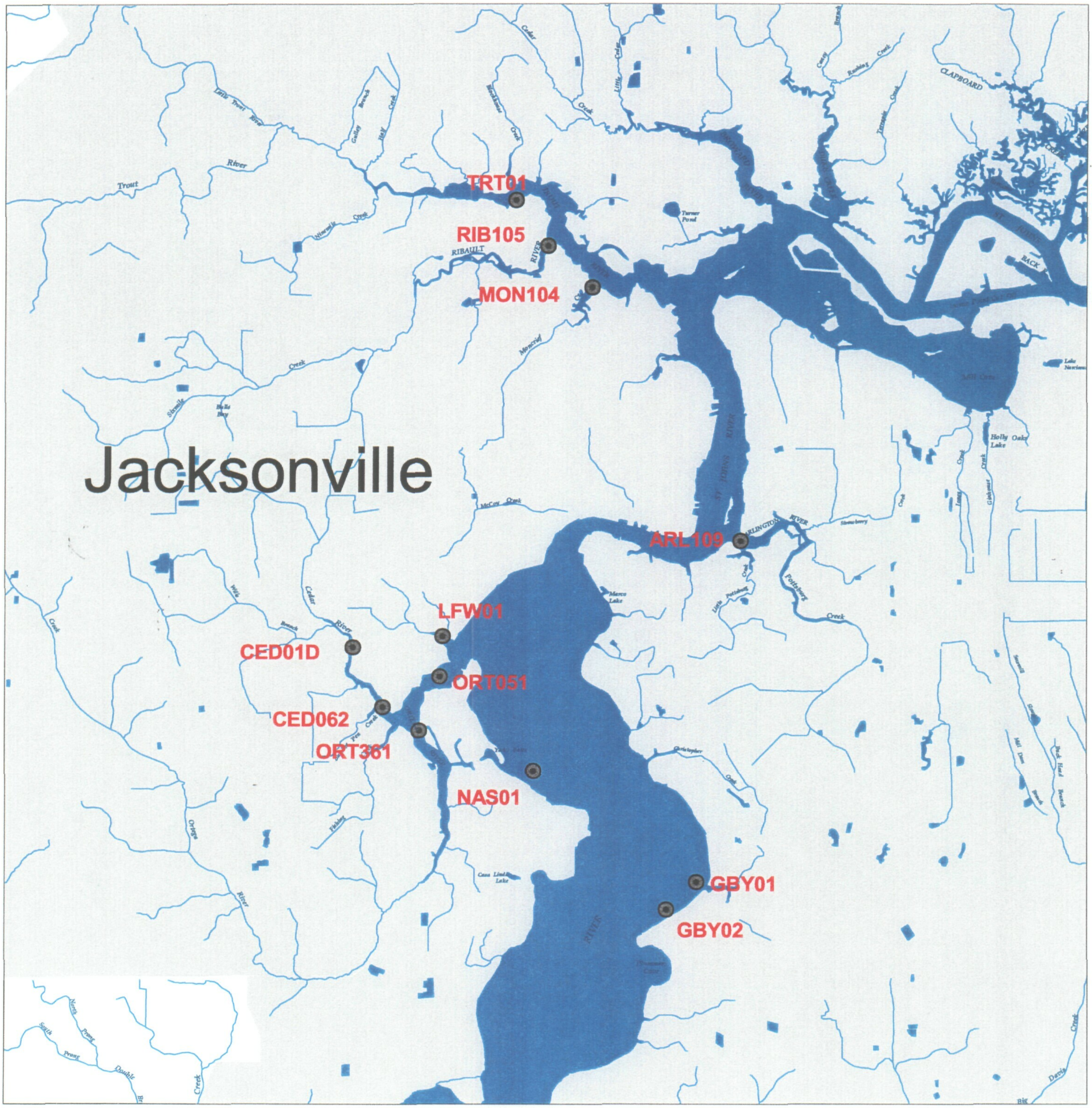


Figure A-1. Site Location Map

LSJ Sites North of Doctors Lake

0 1 2 Miles

1:175000

Benthic Site Locations

The St. Johns River Water Management District prepares and uses this information for its own purposes and this information may not be suitable for other purposes. This information is provided "as is". Further documentation of this data can be obtained by contacting: St. Johns River Water Management District, Geographic Information Systems, Program Management, P.O. Box 1429, Palatka, Florida 32178-1429. (904) 329-4176.

Source: /sjr/es4/mwalker/lsjrb/higman/arcview/sedsites_new.apr 04/12/01

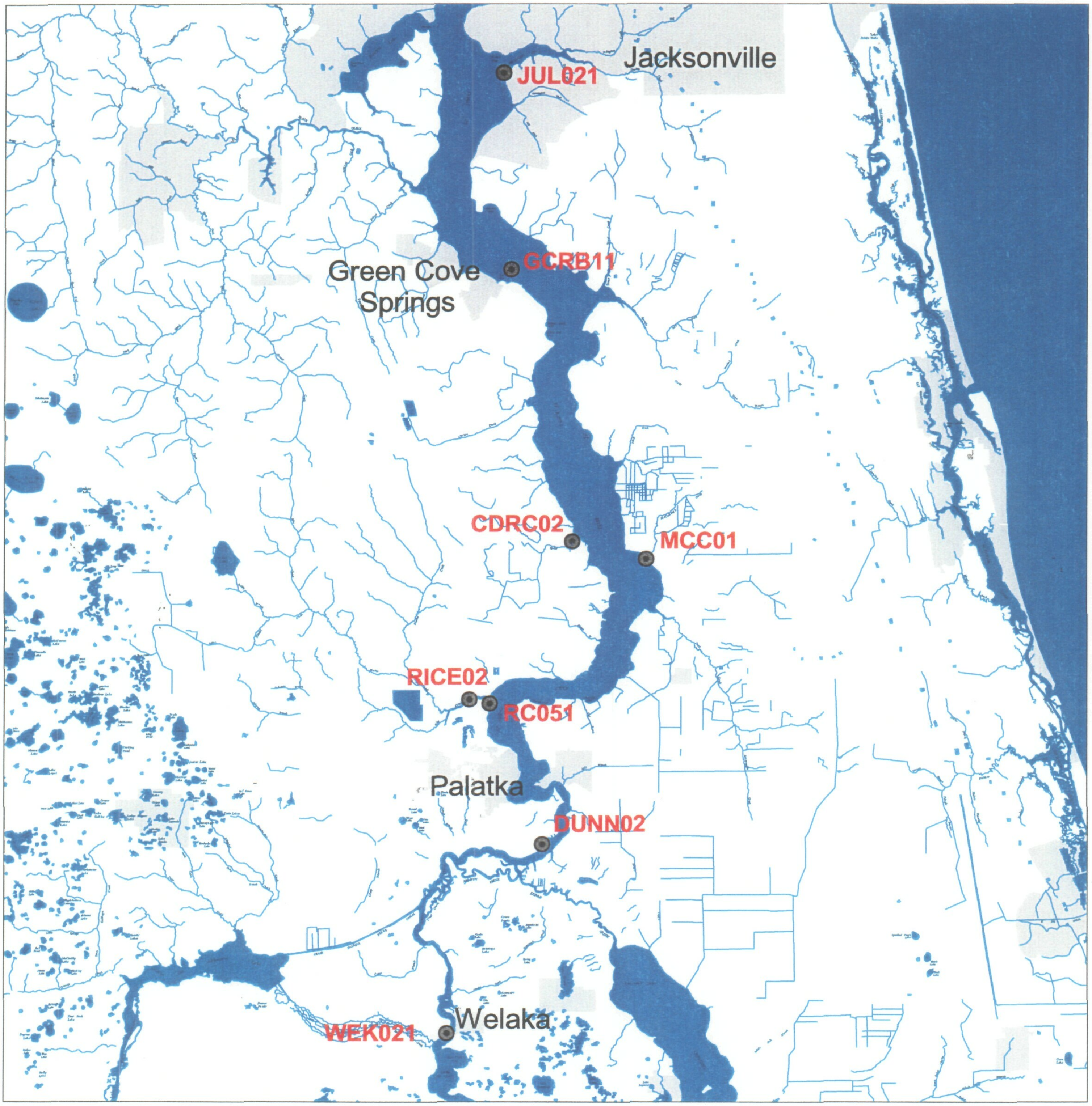
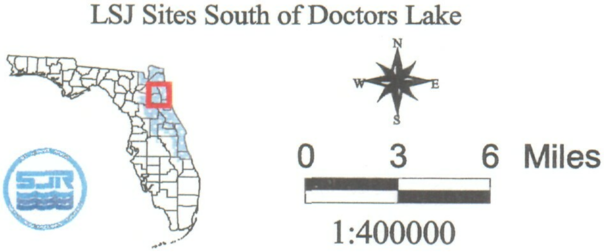


Figure A-2. Site Location Map

LSJ Sites South of Doctors Lake



Benthic Site Locations

The St. Johns River Water Management District prepares and uses this information for its own purposes and this information may not be suitable for other purposes. This information is provided "as is". Further documentation of this data can be obtained by contacting: St. Johns River Water Management District, Geographic Information Systems, Program Management, P.O. Box 1429, Palatka, Florida 32178-1429. (904) 329-4176.

Source: /sjr/es4/mwalker/lsjrb/higman/arcview/sedsites_new.apr 04/12/01

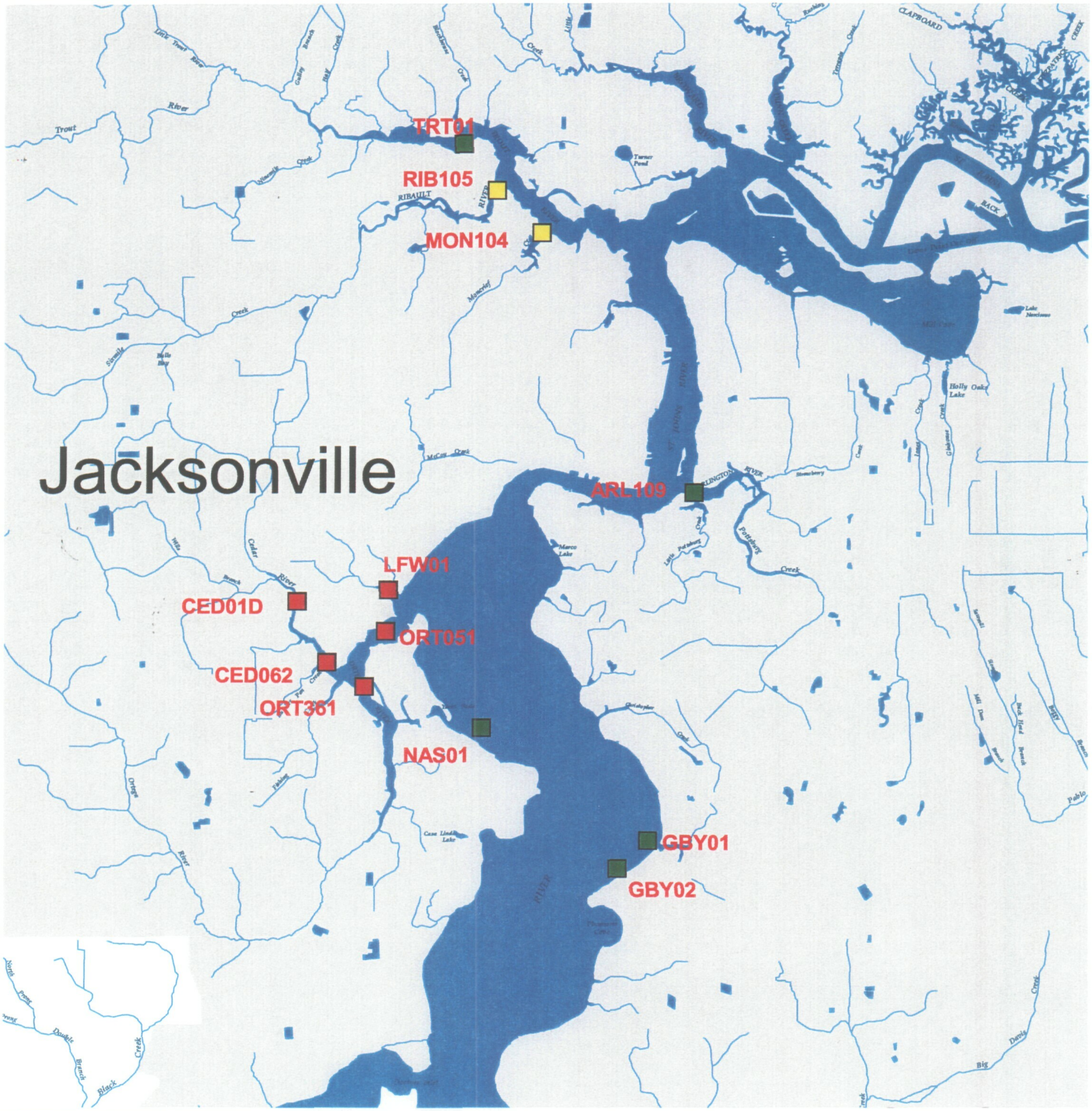


Figure A-3. Larval Chironomid Deformities (North).

0 1 2 Miles

1:175000

Number of Deformities

- None
- 1
- 9 or more

The St. Johns River Water Management District prepares and uses this information for its own purposes and this information may not be suitable for other purposes. This information is provided "as is". Further documentation of this data can be obtained by contacting: St. Johns River Water Management District, Geographic Information Systems, Program Management, P.O. Box 1429, Palatka, Florida 32178-1429. (904) 329-4176.

Source: /sjr/es4/mwalker/lsjrb/higman/arc view/sedsites new.apr 04/12/01

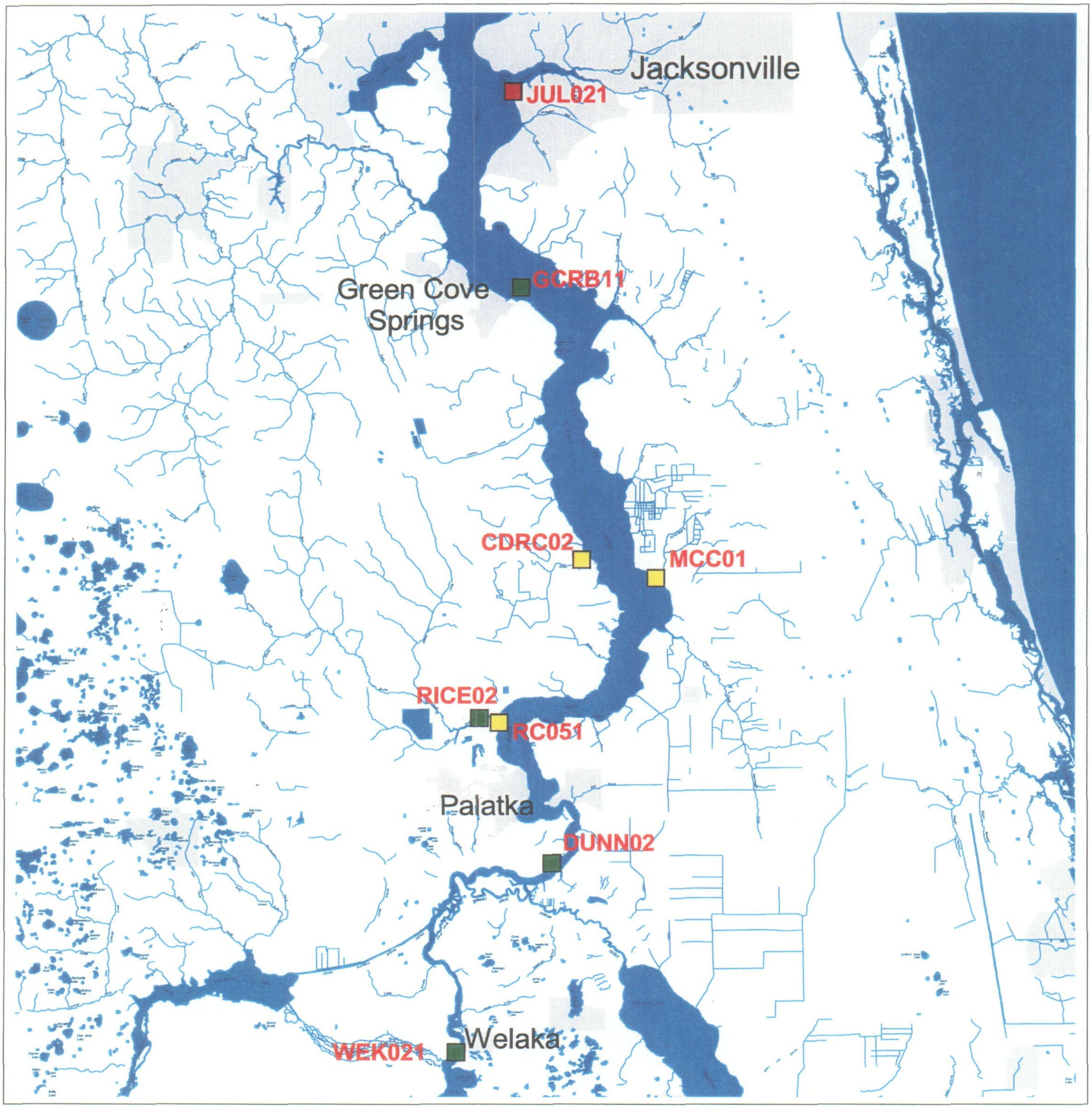


Figure A-4. Larval Chironomid Deformities (South).

N
W E
S

0 3 6 Miles

1:400000

Number of Deformities
- None
- 1
- 9 or more

The St. Johns River Water Management District prepares and uses this information for its own purposes and this information may not be suitable for other purposes. This information is provided "as is". Further documentation of this data can be obtained by contacting: St. Johns River Water Management District, Geographic Information Systems, Program Management, P.O. Box 1429, Palatka, Florida 32178-1429. (904) 329-4176.

Source: /sir/es4/mwalker/lsirb/higman/arc_view/sedsites_new.apr 04/12/01

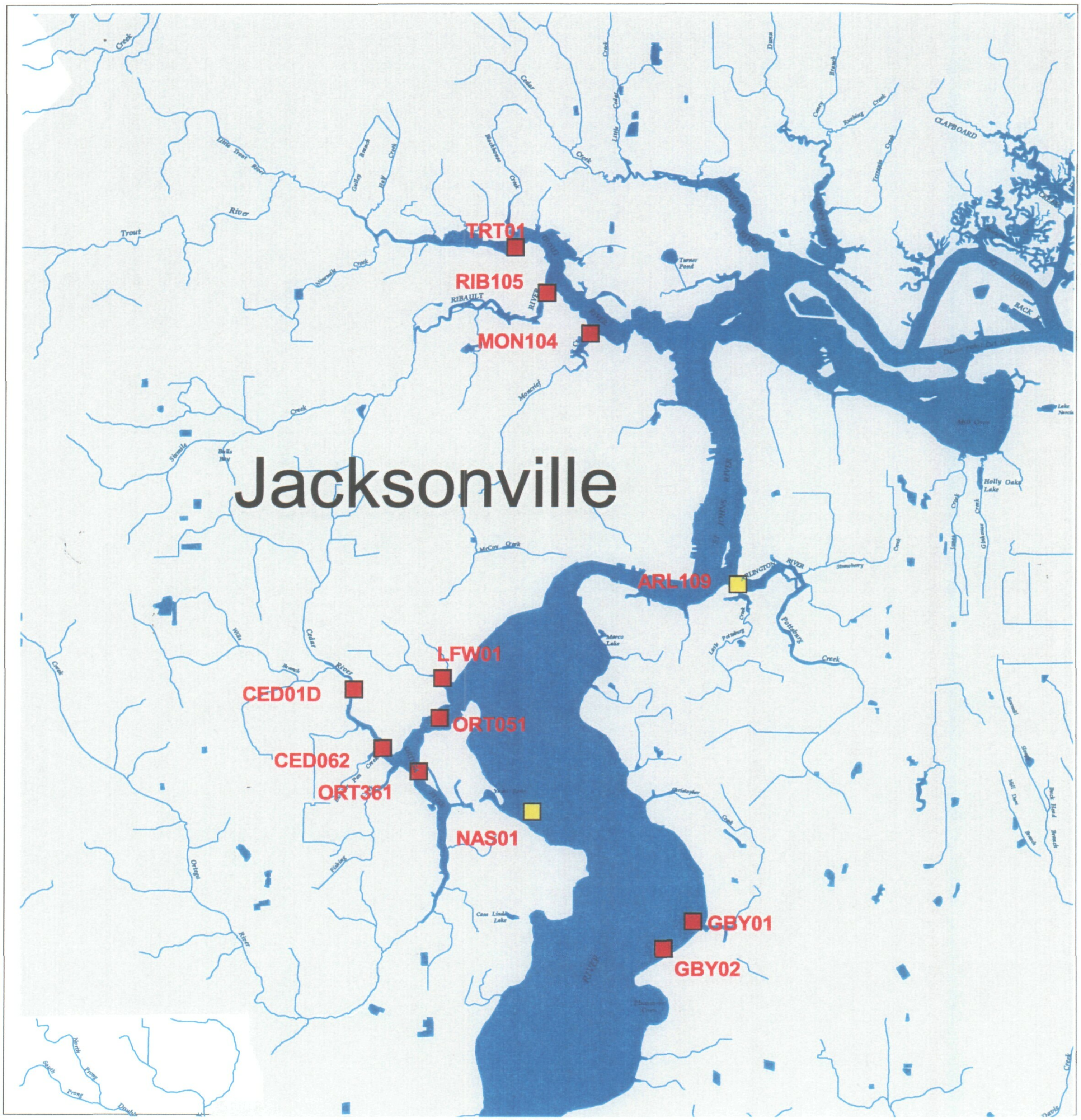


Figure A-5. Site Class (North)

0 1 2 Miles

1:175000

Site Class

- Not Applicable
- Class A
- Class B

The St. Johns River Water Management District prepares and uses this information for its own purposes and this information may not be suitable for other purposes. This information is provided "as is". Further documentation of this data can be obtained by contacting: St. Johns River Water Management District, Geographic Information Systems, Program Management, P.O. Box 1429, Palatka, Florida 32178-1429. (904) 329-4176.

Source: /sjr/es4/mwalker/lsjrb/higman/arc_view/sedsites_new.apr 04/12/01

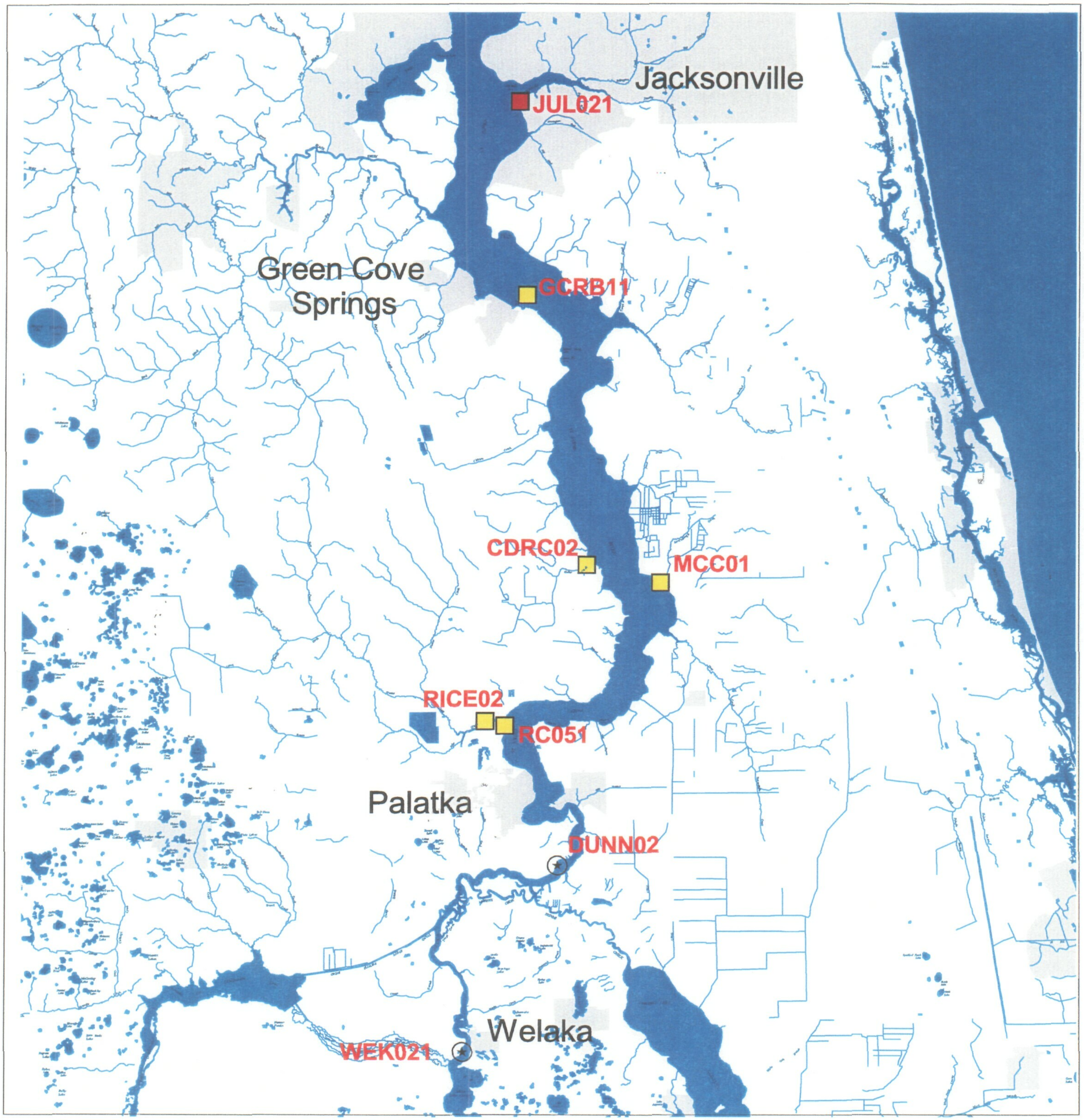


Figure A-6. Site Class (South)

0 2 4 Miles

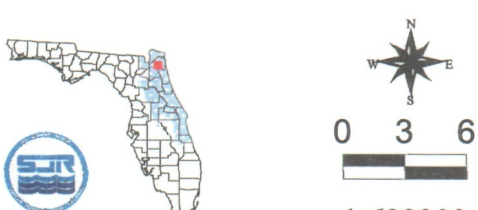
1:400000

Site Class
- Not Applicable
- Class A
- Class B

The St. Johns River Water Management District prepares and uses this information for its own purposes and this information may not be suitable for other purposes. This information is provided "as is". Further documentation of this data can be obtained by contacting: St. Johns River Water Management District, Geographic Information Systems, Program Management, P.O. Box 1429, Palatka, Florida 32178-1429. (904) 329-4176.

Source: /sjr/es4/mwalker/lsjrb/higman/arc_view/sedsites_new.apr 04/12/01

Figure A-7. Impairment Ranking



1:600000

Impairment Category

- Insufficient data
- 1. Moderate
- 2. Moderate
- 3. Severe
- 4. Severe
- 5. Very Severe

Source: /sjr/es4/mwalker/lsjrb/higman/arc_view/sedsites_new.apr 03/20/01

Appendix B

Species Abundance Tables

LFW01 Little Fish Weir

Taxa	Rep 1	Rep 2	Rep 3	Rep 4	Totals	Means
Chironomus sp.	27	39	30	30	126	31.5
Neanthes succinea	3	6	5	1	15	3.75
Paraprionospio pinnata		1			1	0.25
Syllidae (LPIL)				2	2	0.5
Procladius (Holotanypus) sp.		2			2	0.5
Total Abundance	30	46	35	33	146	37
Organism Density (No./M^2)	1291	1980	1507	1421	6285	1571
Total No. Taxa	2	3	2	3	5	2.5
Shannon-Weiner Diversity	0.47	0.93	0.59	0.52	0.74	0.63

ORT361 Ortega River

Taxa	Rep 1	Rep 2	Rep 3	Rep 4	Totals	Means
Chironomus crassicaudatus				1	1	0.25
Chironomus sp.	8	10	20	8	46	11.5
Coelotanypus concinnus	1				1	0.25
Macromia taeniolata	4	4	4	1	13	3.25
Neanthes succinea				1	1	0.25
Procladius (Holotanypus) sp.	1	1			2	0.5
Total Abundance	13	14	24	11	64	16
Organism Density (No./M^2)	560	603	1033	474	2755	689
Total No. Taxa	3	2	2	4	6	2.75
Shannon-Weiner Diversity	1.52	1.16	0.65	1.28	1.25	1.15

ORT051 **Ortega River**

Taxa	Rep 1	Rep 2	Rep 3	Rep 4	Totals	Means
Chironomus sp.	5	15	3	2	25	6.25
Macoma tenta	2	2		1	5	1.25
Prionospio sp.		1			1	0.25
Total Abundance	7	18	3	3	30	8
Organism Density (No./M^2)	301	775	129	129	1291	323
Total No. Taxa	2	3	1	2	2	2.00
Shannon-Weiner Diversity	0.86	0.80	0.00	0.92	0.83	0.65

CED062 Cedar River

Taxa	Rep 1	Rep 2	Rep 3	Rep 4	Totals	Means
Chironomus crassicaudatus	1				1	0.25
Chironomus sp.	4	35	41	27	107	26.75
Hirudinea	1				1	0.25
Macoma tenta	2	1	1	2	6	1.5
Mysidacea	1				1	0.25
Nemertea				1	1	0.25
Prionospio sp.	1			3	4	1
Total Abundance	9	36	42	33	121	30
Organism Density (No./M^2)	387	1550	1808	1421	5209	1302
Total No. Taxa	5	2	2	4	7	3.25
Shannon-Weiner Diversity	2.32	0.18	0.16	0.95	0.76	0.90

DUNN02 **Dunn's Creek**

Taxa	Rep 1	Rep 2	Rep 3	Rep 4	Totals	Means
Coelotanypus tricolor		8			8	2
Total Abundance	0	8	0	0	8	2
Organism Density (No./M^2)	0	344	0	0	344	86
Total No. Taxa	0	1	0	0	1	0.25
Shannon-Weiner Diversity	0.00	0.00	0.00	0.00	0.00	0.00

WEK021 Welaka

Taxa	Rep 1	Rep 2	Rep 3	Rep 4	Totals	Means
Coelotanypus concinnus				1	1	0.25
Coelotanypus sp.				1	1	0.25
Limnodrilus hoffmeisteri				4	4	1
Monoculodes nyei			1		1	0.25
Tubificidae (LPIL)	1	1	1	6	9	2.25
Total Abundance	1	1	2	12	16	4
Organism Density (No./M^2)	43	43	86	517	689	172
Total No. Taxa	1	1	2	4	5	2.00
Shannon-Weiner Diversity	0.00	0.00	1.00	1.63	1.72	0.66

MON104 **Moncrief Creek**

Taxa	Rep 1	Rep 2	Rep 3	Rep 4	Totals	Means
Chironomus sp.	1	1	4	1	7	1.75
Macoma tenta	7	6	5	4	22	5.5
Neanthes succinea	1	1			2	0.5
Nemertea	1				1	0.25
Prionospio sp.	1				1	0.25
Tubificidae (LPIL)			2		2	0.5
Total Abundance	11	8	11	5	35	9
Organism Density (No./M^2)	474	344	474	215	1507	377
Total No. Taxa	5	3	3	2	6	3.25
Shannon-Weiner Diversity	1.67	1.06	1.49	0.72	1.65	1.24

MCC01 **McCullough Creek**

Taxa	Rep 1	Rep 2	Rep 3	Rep 4	Totals	Means
Coelotanypus concinnus	1				1	0.25
Coelotanypus sp.		3	2	4	9	2.25
Coelotanypus tricolor	2	1		1	4	1
Limnodrilus hoffmeisteri	2				2	0.5
Procladius (Holotanypus) sp.	2	3	1	2	8	2
Tanytarsus sp.	1				1	0.25
Tubificidae (LPIL)	2		2		4	1
Total Abundance	10	7	5	7	29	7
Organism Density (No./M^2)	430	301	215	301	1248	312
Total No. Taxa	6	3	3	3	7	3.75
Shannon-Weiner Diversity	2.52	1.45	1.52	1.38	2.43	1.72

JUL021 Julington Creek

Taxa	Rep 1	Rep 2	Rep 3	Rep 4	Totals	Means
Coelotanypus concinnus		3	6	9	18	4.5
Mulinia lateralis	4	2	3	1	10	2.5
Mytilopsis leucophaeta		1		1	2	0.5
Tubificidae (LPIL)	1	3	1		5	1.25
Total Abundance	5	9	10	11	35	9
Organism Density (No./M^2)	215	387	430	474	1507	377
Total No. Taxa	2	4	3	3	4	3.00
Shannon-Weiner Diversity	0.72	1.89	1.30	0.87	1.75	1.20

TRT01 **Trout River**

Taxa	Rep 1	Rep 2	Rep 3	Rep 4	Totals	Means
Macoma tenta	22	5	25	18	70	17.5
Rangia cuneata	1				1	0.25
Total Abundance	23	5	25	18	71	18
Organism Density (No./M^2)	990	215	1076	775	3056	764
Total No. Taxa	2	1	1	1	2	1.25
Shannon-Weiner Diversity	0.26	0.00	0.00	0.00	0.11	0.07

ARL109 Arlington River

Taxa	Rep 1	Rep 2	Rep 3	Rep 4	Totals	Means
Capitellidae (LPIL)	2	2			4	1
Chironomus sp.	1		3		4	1
Hirudinea	1				1	0.25
Macoma tenta		2	4	4	10	2.5
Mulinia lateralis		1		2	3	0.75
Nereidae (LPIL)		2			2	0.5
Pelecypoda (LPIL)	1				1	0.25
Syllidae (LPIL)			1		1	0.25
Prionospio sp.			1		1	0.25
Spionidae (LPIL)				1	1	0.25
Tubificidae (LPIL)			1		1	0.25
Total Abundance	5	7	10	7	29	7
Organism Density (No./M^2)	215	301	430	301	1248	312
Total No. Taxa	4	4	5	3	11	4
Shannon-Weiner Diversity	1.92	1.95	2.05	1.38	3.04	1.83

NAS01 **NAS Jax Outfall**

Taxa	Rep 1	Rep 2	Rep 3	Rep 4	Totals	Means
Corophium sp.				1	1	0.25
Monoculodes nyei		1			1	0.25
Monoculodes sp.	3				3	0.75
Mytilopsis leucophaeta	2			3	5	1.25
Prionospio sp.	1			5	6	1.5
Rangia cuneata	1			1	2	0.5
Total Abundance	7	1	0	10	18	5
Organism Density (No./M^2)	301	43	0	430	775	194
Total No. Taxa	4	1	0	4	6	2.25
Shannon-Weiner Diversity	1.84	0.00	0.00	1.69	2.29	0.88

RIB105 Ribault River

Taxa	Rep 1	Rep 2	Rep 3	Rep 4	Totals	Means
Chironomus sp.	1	2	1	1	5	1.25
Eteone heteropoda			1		1	0.25
Macoma tenta	7	5	10	12	34	8.5
Neanthes succinea			1		1	0.25
Nemertea	2		1	3	6	1.5
Nereidae (LPIL)		1			1	0.25
Tubificidae (LPIL)		1			1	0.25
Total Abundance	10	9	14	16	49	12
Organism Density (No./M^2)	430	387	603	689	2109	527
Total No. Taxa	3	4	5	3	7	3.75
Shannon-Weiner Diversity	1.16	1.66	1.43	1.01	1.53	1.32

RICE02 **Rice Creek**

Taxa	Rep 1	Rep 2	Rep 3	Rep 4	Totals	Means
Coelotanypus sp.			1	1	2	0.5
Limnodrilus hoffmeisteri				1	1	0.25
Monoculodes nyei		3			3	0.75
Procladius (Holotanypus) sp.		1			1	0.25
Quistadrilus multisetosus		1	1		2	0.5
Tubificidae (LPIL)	1		9	9	19	4.75
Total Abundance	1	5	11	11	28	7
Organism Density (No./M^2)	43	215	474	474	1205	301
Total No. Taxa	1	3	3	3	6	2.5
Shannon-Weiner Diversity	0.00	1.37	0.87	0.87	2.29	0.78

RC051 **Rice Creek**

Taxa	Rep 1	Rep 2	Rep 3	Rep 4	Totals	Means
Amphipoda sp. A	26	7		10	43	10.75
Chironomus sp. Im.	1				1	0.25
Cladotanytarsus sp.	1				1	0.25
Coelotanypus concinnus	1	3			4	1
Coelotanypus sp.				1	1	0.25
Coelotanypus tricolor	1	1			2	0.5
Corophium lacustre	30	6		9	45	11.25
Djalmabatista pulchra	3				3	0.75
Gammarus near tigrinus	1				1	0.25
Procladius sp. (imm)			1		1	0.25
Procladius (Holotanypus) sp.	3	5		2	10	2.5
Total Abundance	67	22	1	22	112	28
Organism Density (No./M^2)	2884	947	43	947	4821	1205
Total No. Taxa	9	5	1	4	11	4.75
Shannon-Weiner Diversity	1.90	2.12	0.00	1.56	2.09	1.40

CDRC02 Cedar Creek

Taxa	Rep 1	Rep 2	Rep 3	Rep 4	Totals	Means
Aulodrilus pigueti		1	1		2	0.5
Chironomus sp.		1			1	0.25
Coelotanypus concinnus			1		1	0.25
Coelotanypus tricolor	1		1		2	0.5
Limnodrilus hoffmeisteri	1	4		1	6	1.5
Plecoptera (LPIL)				1	1	0.25
Procladius sp.			2	1	3	0.75
Tubificidae (LPIL)		2	2	1	5	1.25
Total Abundance	2	8	7	4	21	5
Organism Density (No./M^2)	86	344	301	172	904	226
Total No. Taxa	2	4	5	4	8	3.75
Shannon-Weiner Diversity	1.00	1.75	2.24	2.00	2.68	1.75

CED01D **Cedar River**

Taxa	Rep 1	Rep 2	Rep 3	Rep 4	Totals	Means
Chironomus sp.	3	4	15	3	25	6.25
Mulinia lateralis				1	1	0.25
Nematoda sp. C		1			1	0.25
Total Abundance	3	5	15	4	27	7
Organism Density (No./M^2)	129	215	646	172	1162	291
Total No. Taxa	1	2	1	2	3	1.50
Shannon-Weiner Diversity	0.00	0.72	0.00	0.81	0.46	0.38

GCRB11 Green Cove Springs - Red Bay

Taxa	Rep 1	Rep 2	Rep 3	Rep 4	Totals	Means
Corophium sp. (LPIL)	1				1	0.25
Melita nitida Complex		1			1	0.25
Mulinia lateralis			9		9	2.25
Monoculodes sp.			2		2	0.5
Spionidae (LPIL)			1		1	0.25
Corbicula fluminea			1		1	0.25
Polydora sp.				3	3	0.75
Tanytarsus sp.				1	1	0.25
Total Abundance	1	1	13	4	19	4.75
Organism Density (No./M^2)	43	43	560	172	818	204
Total No. Taxa	1	1	4	2	8	2.00
Shannon-Weiner Diversity	0.00	0.00	1.35	0.81	2.39	0.54

GBY01 **Goodby's Creek**

Taxa	Rep 1	Rep 2	Rep 3	Rep 4	Totals	Means
Coelotanypus concinnus		1			1	0.25
Almyracuma sp.		1			1	0.25
Macoma tenta	4	2	1	2	9	2.25
Monoculodes sp.				1	1	0.25
Mulinia lateralis			1		1	0.25
Prionospio sp.	9	15	2	25	51	12.75
Total Abundance	13	19	4	28	64	16
Organism Density (No./M^2)	560	818	172	1205	2755	689
Total No. Taxa	2	4	3	3	6	3.00
Shannon-Weiner Diversity	0.89	1.06	1.50	0.59	1.03	1.01

GBY02 Goodby's Creek

Taxa	Rep 1	Rep 2	Rep 3	Rep 4	Totals	Means
Eteone heteropoda		1			1	0.25
Macoma tenta		1	1	1	3	0.75
Monoculodes sp.	1				1	0.25
Mulinia lateralis	3	1	1	2	7	1.75
Mytilopsis leucophaeta		1		1	2	0.5
Neanthes succinea		1			1	0.25
Nemertea	3		1	2	6	1.5
Prionospio sp.	44	40	23	37	144	36
Total Abundance	51	45	26	43	165	41
Organism Density (No./M^2)	2195	1937	1119	1851	7103	1776
Total No. Taxa	4	6	4	5	8	4.75
Shannon-Weiner Diversity	0.78	0.76	0.70	0.85	0.85	0.77