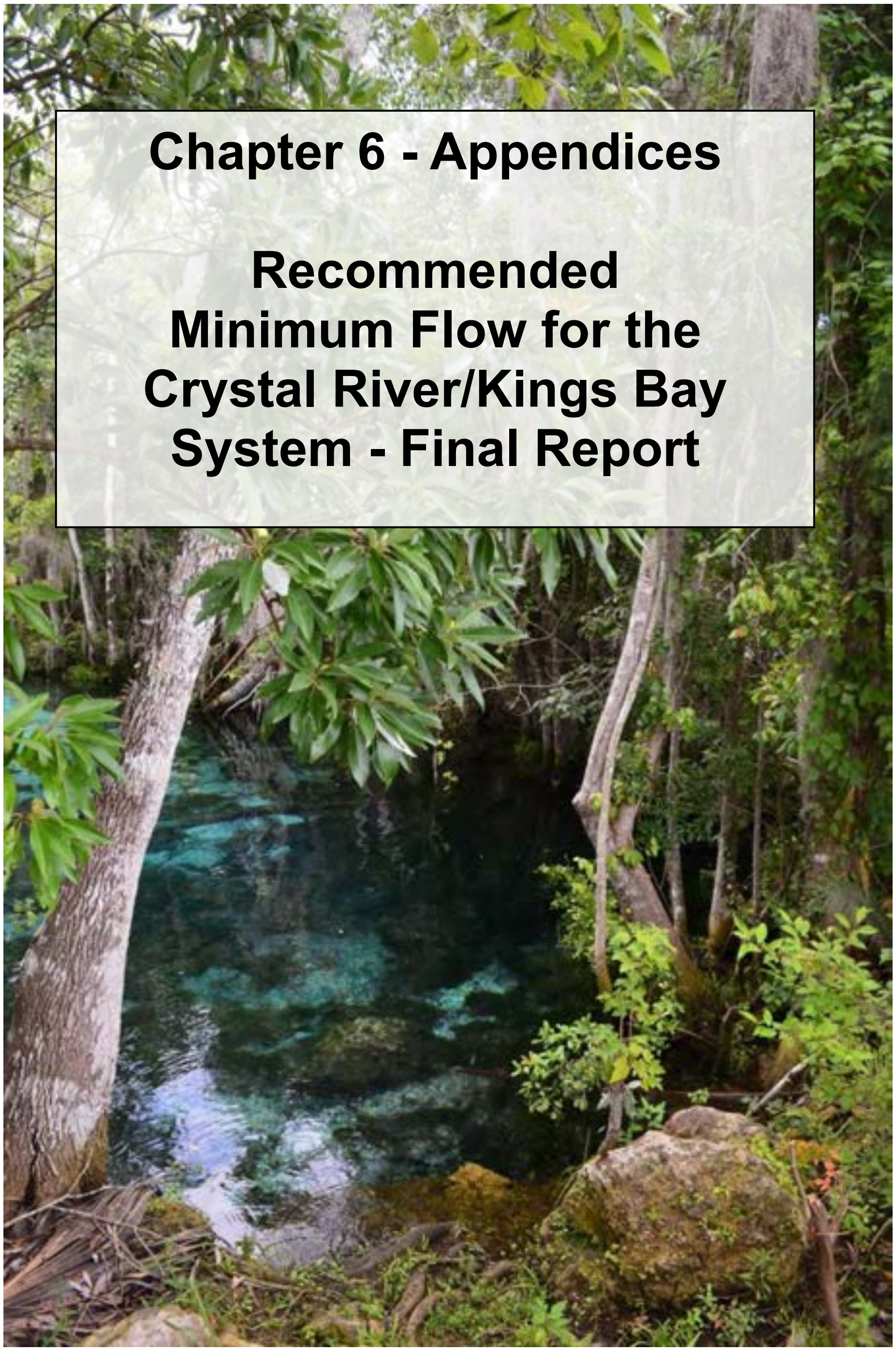
Chapter 6 - Appendices

Recommended Minimum Flow for the Crystal River/Kings Bay System - Final Report



2017

Southwest Florida
Water Management District

CHAPTER 6 - APPENDICES

6.1 List of Appendices

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6.2 Appendices

Appendices identified in Section 6.1 follow, with cover sheets that in some cases include notes.

APPENDIX

Avineon. 2010. Vegetation mapping of the Crystal River in support of the establishment of minimum flows and levels. Clearwater, Florida. Prepared for the Southwest Florida Water Management District, Brooksville, Florida.

VEGETATION MAPPING OF THE CRYSTAL RIVER IN SUPPORT OF THE ESTABLISHMENT OF MINIMUIM FLOWS AND LEVELS

Final Report – September 2010

Funded by:

SOUTHWEST FLORIDA WATER MANAGEMENT DISTRICT

Prepared by:

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Clearwater, FL 33760

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Executive Summary

The purpose of the vegetation mapping effort was to provide data pertinent to the Southwest Florida Water Management District (SWFWMD) in establishing minimum flows and levels (MFLs) for the Crystal River and Kings Bay. MFLs, according to Statute 373.042 F.S of the Florida Water Resources Act., are defined as the limit at which further withdrawals would be “significantly harmful” to the water resources or the ecology of the system (SWFWMD 2001).

Submerged and emergent vegetation (SAV and EAV), as well as altered shorelines, were surveyed along the entire length of the Crystal River and into Kings Bay. SAV and EAV were documented from the mouth of the river to the head near Kings Bay. Only EAV, altered, and natural shorelines were documented in Kings Bay.

The mapping effort was completed in April 2010. Field surveys were vital in establishing SAV species identification as well as providing break points for altered shorelines that were not visible on the aerial imagery. In addition to documenting SAV and EAV using GIS technologies, photographs of field samples and underwater video monitoring were utilized in the mapping effort.

If the flow of freshwater within a river or a stream drops below the “minimum flow” level, the ecology of that system can be affected leaving a negative impact on aquatic plants (EAV, SAV) and associated animal life. This is especially true within Florida‟s estuarine ecosystems. The decrease in flow can also cause salt water intrusion in to the aquifer, which is where the District gets 80% of its drinking water (SWFWMD 2001).

The District can use the data gathered during the study to establish minimum flows and levels by observing the SAV and EAV species present and where changes, if any, have occurred to habitats along the Crystal River and within Kings Bay. SAV and EAV species can be used to determine salinity levels. Thus, monitoring the changes in SAV and EAV species can aid in determining the degree of salt water intrusion into the water system and regular trend analysis of these changes can be used to monitor dynamic salinity gradients.

1.0 Introduction

The goal of mapping submerged aquatic and emergent aquatic vegetation (SAV and EAV) gradients along the length of the Crystal River and within Kings Bay was to assist the Southwest Florida Water Management District (SWFWMD) in establishing minimum flows and levels (MFLs). The distribution of various SAV and EAV species are indicative of specific salinity gradients. Trend analysis of this distribution can reflect changes to the salinity gradient due to reductions or increases of freshwater flows within the Crystal River and/or Kings Bay.

Location

The Crystal River is located in western Citrus County (*Figure 1.1*) and runs approximately 7 miles west-northwest from the headwaters of Kings Bay to the Gulf of Mexico. Kings Bay is situated west of the intersection of US 19 and County Road 44. The Crystal River study area extends from Kings Bay and ends just past Shell Island.

The Crystal River, as well as the Chassahowitzka and Homosassa rivers, is located in an area known as the Springs Coast. The Springs Coast extends from the Pithlachascotee River basin north of Tampa Bay to the Waccasassa River area which is south of the Suwannee River basin. The total area that this watershed is comprised of about 800 square miles where spring-fed systems are abundant. The Crystal River, as well as the two others mentioned above, discharge into the Gulf of Mexico (Hoyer *et al*. 2004).

Figure 1.1 Location of Crystal River and Kings Bay in Citrus County, Florida.

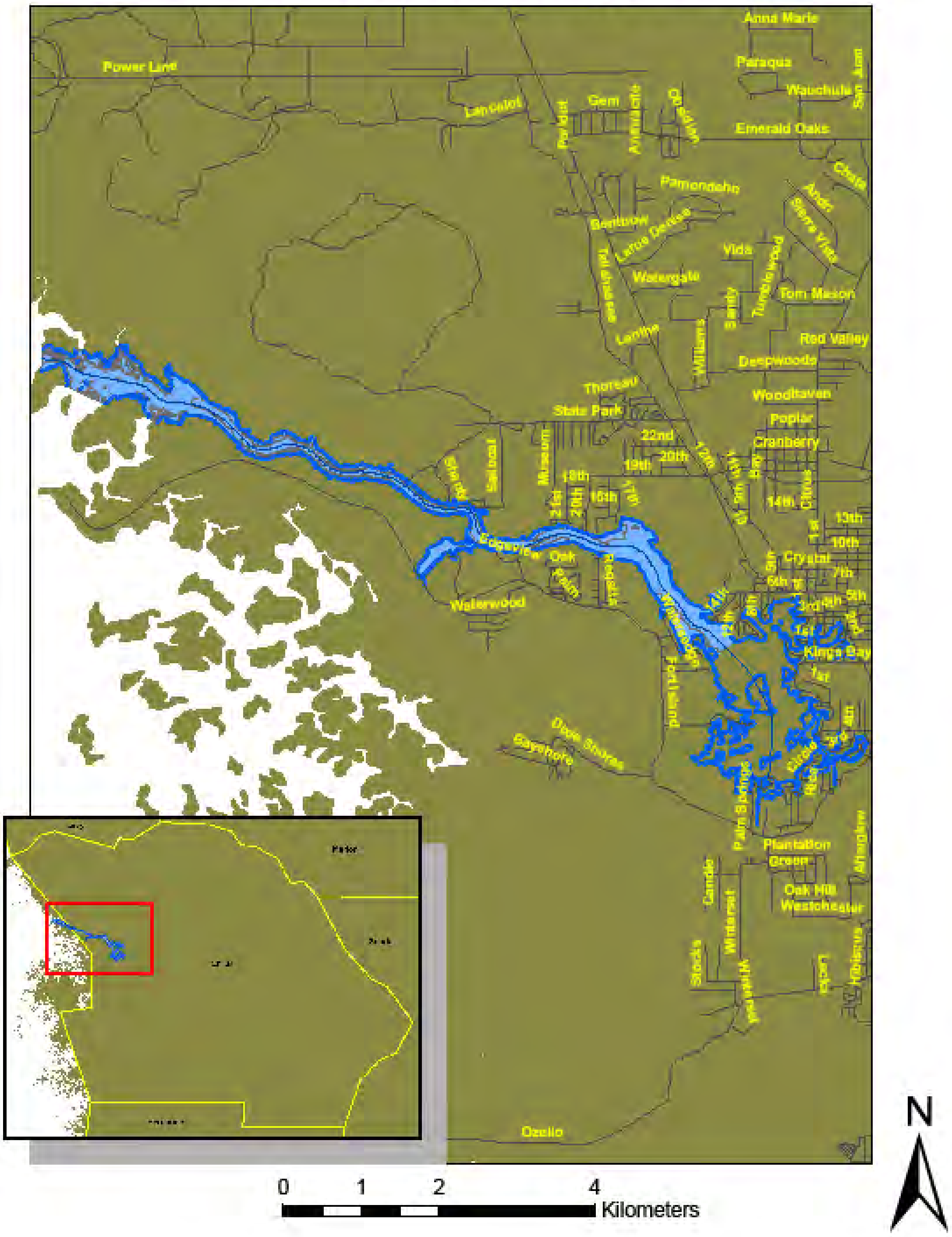

Figure 1.1

2.0 Methods

Field Survey

Five days of field survey were conducted within Kings Bay, the full extent of the Crystal River, and parts of the Salt River. Over the course of the survey, 296 ground truth points and approximately 364 field photographs were collected of various SAV and EAV habitats. A GPS enabled laptop, handheld GPS device, underwater video monitor, and two digital cameras were used during the field survey. The GPS enabled laptop made it possible to log coordinates and input ground-truth data directly into an ESRI shapefile.

The identification of SAV was largely limited as a result of water turbidity and harsh weather conditions. Snorkeling and an underwater video monitor were paramount in effectively identifying individual SAV species. The video monitor also made it possible to run transects moving away from the shoreline in order to determine the edges of SAV communities when moving into deeper water (e.g. river channel).

2.1 Identification of Vegetation Classes and Refinement of Mapping Methods

SAV – Crystal River

There were two obstacles encountered when attempting to classify SAV species: 1) the imagery provided for purposes of photo-interpretation did not allow for the proper and consistent identification of individual SAV species (primarily due to the turbidity of the water making species level identification unfeasible) ; and 2) the aquatic vegetation communities were rarely of a monotypic nature. As a result, the polygons showing the location of SAV communities were mapped with all the species present and the percent cover found in that polygon (i.e., 0%, 1-10%, 10-50%, 50-100%).

EAV – Crystal River

During the field survey it appeared that the shoreline vegetation associated with the Crystal River consisted primarily of *Cladium jamaicense*, *Spartina alterniflora*, *Juncus roemerianus*, and *Typha domingensis*. The change from *Cladium* to *Juncus* that was observed while traveling from the head of the river to the mouth is considered indicative of a salinity gradient. Emergent vegetation along the shoreline of Crystal River, being primarily large continuous communities of freshwater and saltwater graminoids, was identified and mapped at the species level.

EAV – Kings Bay

Field surveys along the banks and islands within Kings Bay revealed that the primary shoreline vegetation consisted of Wetland Forest communities, as well as *Cladium jamaicense,* and *Typha domingensis*. The graminoid communities were very distinguishable on the aerial photography.

It was very difficult to identify individual tree species that populated the shoreline and islands located in Kings Bay. The wetland forests on the islands were particularly dense, with multiple tree canopies overlapping each other, making it very difficult to determine a dominant species.

Even where individual species can be distinguished, the sheer number of line segments needed to map these individual species within a mixed forest community would make shoreline classification very time consuming. Thus, SWFWMD and Avineon agreed that when classifying shorelines adjacent to wetland forest, that the classification be based off the FLUCCS community present (e.g., Bottomland Hardwood Forest) and not on individual species present.

2.2 Field Data Collection and Mapping

Data Collection

Shoreline and SAV features were analyzed in the field by utilizing a GPS enabled tough-book laptop in conjunction with ESRI ArcMap software. Of the points visited in the field, a majority were pre-selected using aerial imagery of the study area. These points were put into a shapefile and accessed in the field using the GSP enabled laptop and software.

Furthermore, a considerable number of points were collected „on the fly" as a result of questions arising during the field work, discovery of new areas of interest or inquiry, and when running underwater transects from the shoreline to the river channel. The points gathered in the field were recorded directly into a field point shapefile and comments and pictures were attributed to each point.

Shoreline Emergent Vegetation Mapping

Mapping of shoreline emergent vegetation was limited to the first five feet of the shoreline. Altered shorelines were classified according to the condition of the shoreline as it pertains to being modified from its natural state. The categories used to classify altered shorelines were “Seawall” and “Rip-rap”. The Natural shoreline categories, “Beach” and “Ancient Reef Outcrop”, were used to denote natural shoreline features where vegetation did not exist. The category „Ancient Reef Outcrop‟ was added to include the outcropping limestone deposits occurring sporadically along the banks of the Crystal River.

Avineon used a species list, approved by the district, as the classification system for mapping the natural shoreline vegetation. Every shoreline feature was classified with a dominate species and any concurring species that did not meet the minimum mapping unit of 10m (but that was mixed throughout the other vegetation), was listed in quantitative order in the fields of the spatial database (i.e., Dominant Vegetation, Subdominant Vegetation, Existing Vegetation 3).

SAV Mapping

SAV mapping efforts were inhibited to a degree by weather conditions and a turbid water column. Visibility was limited to the first one or two feet from the surface of the water. As a result, seagrass sampling techniques were deployed which included snorkeling and sample collection by hand or by rake. In deeper areas where snorkeling or physical collection of a specimen was not practical, an underwater video camera was useful in determining seagrass densities, seagrass species, and substrate type. The underwater video camera was also used to construct transect points along the length of the river, collecting data from shore to channel. The minimal mapping unit used during the SAV mapping effort was set to 225 square meters (15m by 15m).

The SAV feature types included in the mapping effort were „Vegetation‟ and „Bare‟. SAV polygons depicting vegetation were grouped into three separate density categories. The three categories were:

- 1-10 percent cover
- 10-50 percent cover
- 50-100 percent cover

The following table (*Table 2.1*) includes a list of bare (non-vegetated) substrate types and the vegetation species we attempted to identify during the study. The list primarily includes seagrass species commonly found in and around the Crystal River and Kings Bay system. Other species identified in the SAV attribution included vegetation such as water-milfoil (*Myriophyllum spicatum*) and other invasive species. Of the species listed in Table 2.1, only *Halodule wrightii, Myriphyllum spicatum,* and *Vallisneria americana* were found.

Category	Individual Community/Species
Bare	Sand
	Rock - Oyster
	Sand and Rock
	Clay and Silt
	Organic surface
Vegetation	Ceratophyllum demersum
	Halodule wrightii
	Hydrilla verticillata
	Myriophyllum spicatum
	Najas guadalupensis
	Potamogeton pectinatus
	Ruppia maritima
	Sagittaria kurziana
	Sagittaria subulata
	Vallisneria americana

Table 2.1

The „Bare‟ category was used when less than 1% of the area was covered with vegetation. This category included areas dominated by various substrate types and also included areas dominated by oyster beds, dead oyster beds, and/or rock outcrops such as limestone. Many of the oyster beds, especially the beds west of the Salt River toward the Gulf of Mexico, contained epiphytic algae and/or detached algae (*Image 2.1*) which had drifted and accumulated into large mats. The algae appeared to be a *Polysiphonia* species, and it was quite prolific throughout the mouth of the Crystal River south to Salt River.

Image 2.1

3.0 Results and Discussion

The SAV and shoreline vegetation encountered during the field survey and mapped throughout the Crystal River and Kings Bay occurred in locations consistent with the species corresponding salinity tolerances. Tables in the following section list SAV, EAV, altered and natural shoreline types and show the percentage cover for each major feature. Furthermore, reference maps that contain individual SAV, EAV, woody vegetation, altered and natural shoreline features have been included in the appendices section of the report.

3.1 Submersed Aquatic Vegetation

Of the submersed aquatic vegetation species sampled during this study, eel grass (*Vallisneria americana, Appendix A: Figure R)* occurred frequently along the Crystal River from just east of Salt River and south into Kings Bay. The densest areas of eel grass were found growing between the 8 and 10 kilometer markers along Crystal River. There was no eel grass growing in significant quantities north of river kilometer 5 heading toward the river mouth.

Halodule wrightii was found growing in dominate colonies from river kilometer 7 to the mouth of the river (*Appendix A:* Figure P). These colonies were fairly small and occurred in scattered pockets along the river bank between kilometer markers 4 and 7. Between kilometer markers 7 and 10, *Halodule* could be found growing in colonies primarily dominated by *Vallisneria americana*.

Many of these mixed colonies of *Halodule* and *Vallisneria,* growing closer to Kings Bay (marker 8 through 10), were also intermixed with varying densities of the species Eurasian water-milfoil (*Myriophyllum spicatum, Appendix A: Figure Q*). Eurasian water-milfoil, though thoroughly mixed with other submerged species, did not dominate any particular area surveyed along the Crystal River and points near Kings Bay.

Table 3.1 SAV Species Identified along the Crystal River

Common Name	Species	Typical Salinity Conditions
Eurasian water-milfoil	*Myriophyllum spicatum*	Fresh to brackish (< 10 ppt) (University of Florida, UF/IFAS Center for Aquatic and Invasive Plants)
Eel Grass	*Vallisneria americana*	Fresh - Low Mesohaline (0-10 ppt) (University of Florida, UF/IFAS Center for Aquatic and Invasive Plants)
Halodule	*Halodule wrightii*	Polyhaline (20 - 44 ppt) (Zieman and Zieman 1989) (Mazzotti, et al. 2008)

Map Appendix: *Figure P, R*, and *Q* are graphic references showing where each SAV species occurred in the Crystal River. The species distribution was consistent with the salinity tolerance ranges for each individual species. For example, *Vallisneria americana* is a freshwater species with a low level of salt tolerance and was found growing primarily south of the Salt River (UF/IFAS). *Myriophyllum spicatum* was found growing throughout colonies of *Vallisneria americana* which was also south of the Salt River and more extensively nearer the freshwater of Kings Bay.

During the field survey, *Halodule wrightii* was found to be growing in the widest range of salinity zones. *Halodule* was sampled in river kilometer marker 1 as well as in kilometer 10. Possible increasing salinity values throughout the Crystal River may be responsible for the wide distribution of *this species*.

3.2 Shoreline Vegetation

Vegetated shoreline accounted for 63.9% percent of the total 70,860 meters of mapped shoreline of Crystal River and Kings Bay. Along the banks of the river, vegetated shoreline comprised 74.1% of the shoreline. In the Bay, vegetation occurred along 55.9% of the 38,194 meters of mapped shore.

Emergent and woody vegetation within 5 feet of the water were field surveyed and mapped. The majority of the woody vegetation was confined to the islands and shoreline within and around Kings Bay. Most of this woody vegetation occurred within bottomland hardwood forests. Other areas of woody vegetation also occurred on residential lots and in smaller tree stands along the Crystal River and included such species as *Sabal palmetto* and *Juniperus silicicola* (*Appendix A: Figure H & I*).

In contrast, most of the Crystal River from Kings Bay to the mouth of the river was dominated by large expanses of emergent species such as *Cladium jamaicense*, *Spartina alterniflora*, *Juncus roemerianus*, and *Typha domingensis* (*Appendix A: Figure E-G & J-K*). It was apparent during the field survey that the more salt tolerant species of emergent vegetation occurred north of the Salt River toward the mouth of the Crystal River. Species that were less salt tolerant, such as *Cyperus alternifolius* , occurred more frequently in areas south and east of the Salt River and were dominate throughout Kings Bay.

Emergent Aquatic Vegetation

Cladium jamaicense was found growing extensively throughout the Crystal River and Kings Bay. Sawgrass was second only to *Typha domingensis* in total shoreline emergent vegetation found in Kings Bay. Sawgrass made up 12.5% of the total shoreline within Kings Bay. Many of these sawgrass areas were found to be intermixed with *Typha domingensis*. Sawgrass also made up 19.2% of the total shoreline of the Salt and Crystal Rivers and was found in scattered areas from river kilometer marker 1 through 9.

Cladium jamaicense was the most abundant EAV mapped making up a total of 15.6% of the entire shoreline for the project area. The reason for high abundance of this species may be due to the wider salinity ranges in which sawgrass can thrive, often found growing in fresh and brackish conditions (UF/IFAS).

As mentioned above, the most abundant EAV mapped for the entire Kings Bay area was *Typha domingensis.* Although Cattail made up more than 9,963 meters of the total shoreline (14.1%), the species was confined primarily to the lower salinity areas found throughout Kings Bay (25%). A few scattered areas within Salt River and points south contained *Typha* but only constituted 1.2% of the shoreline areas outside of Kings Bay.

Spartina alterniflora was the third most abundant EAV mapped within the project area. It constituted 11.6% or 8,245 meters of the total shoreline area. Because smooth cord grass thrives in high salinity environments (UF/IFAS), it was not found growing in Kings Bay and was confined to growing just south of the Salt River all the way to the mouth of the Crystal River. It was frequently found thriving in the tidal flats and salt marsh communities north of the Salt River.

Juncus roemerianus, or black needlerush, was found growing in abundance in the same areas where *Spartina* was found to be thriving. This is consistent with the higher salinity tolerances for both of these EAV species (UF/IFAS). In fact, these two species were found either growing next to each other in monotypic stands or together within intermixed communities. Black needlerush was not observed within Kings Bay and made up a total of 10.4% of the total shoreline.

Cyperus alternifolius was distributed (*Appendix A: Figure F*) primarily throughout Kings Bay. This species, also known as Umbrella flat sedge, is usually found growing in wet disturbed areas throughout Florida (UF/IFAS). This species comprised 240.18 meters, or 0.63% of the 38,194 meters of shoreline within Kings Bay.

Table 3.2. Significant EAV species and shoreline percent in Kings Bay and the Crystal River.

Species	Shoreline Length (m)	Shoreline Percentages		
		Kings Bay	Crystal (& Salt) Rivers	Total Shoreline*
Cladium jamaicense	11,078.77	12.7	19.2	15.6
Typha domingensis	9,963.18	25.4	1.2	14.1
Spartina alterniflora	8,245.24	0	25.2	11.6
Juncus roemerianus	7,375.78	0	22.6	10.4
Cyperus alternifolius	240.18	0.63	0	0.34

Table 3.2
**Total Shoreline includes all shoreline features within Crystal River and Kings Bay.*

Trees and Woody Species

The majority of the freshwater tree species were found growing along the banks and islands of Kings Bay. Distribution of the freshwater bottomland hardwood forests can be seen on Appendix A: Figure D. The more salt tolerate varieties of trees could be found growing from Kings Bay north past the Salt River to river kilometer marker 5. These species include *Sabal palmetto* and *Juniperus silicicola* (*Appendix A: Figure H & I*).

Natural and Altered Shoreline

Natural shoreline areas, which included ancient reef outcrops and beaches, were mapped for both the Crystal River and Kings Bay. Natural shoreline accounted for 7.1% of the river shoreline, 1.7% of the bay shoreline, and 4.2% of the total combined river/bay shoreline. Beach makes up the largest percentage of natural shoreline areas. Beach accounts for 65.8% (2.8% of the total shoreline) of the total natural shoreline and is scattered throughout eastern Kings Bay and the Crystal River.

Ancient Reef outcrops were found mainly in the Crystal River, occurring in scattered areas from river kilometer marker 1 through 6 near the Salt River branch. Ancient reef outcrops make up the remaining 34.2% (1,018 meters) of the natural shoreline areas and only 1.4% of the total shoreline. All natural shoreline types and their distribution can be viewed on *Appendix A: Figure S*. All natural shoreline types along with length (meters) and percentages are listed below on Table 3.3.

Altered shoreline areas comprised 31.9% of the total shoreline of Kings Bay and the Crystal River. The most extensive areas of altered shoreline were documented in Kings Bay, where 41.8% of the total shoreline of 38,194 meters was altered. The altered shoreline areas of Kings Bay were confined primarily to the north, south, and east sections where urban development is greatest. Most of the altered shoreline in Kings Bay is seawall that has been built along the banks of residential lots.

Seawall was the major altered shoreline type for the Crystal River and Kings Bay, making up approximately 94.1% of all altered shoreline and 29.9% of the total shoreline for the project area. Rip-rap is confined primarily to Kings Bay and a few disturbed areas near the Salt River making up only 5.9% of altered shoreline areas. Non-vegetated areas comprised 36% or 25,564 meters of the total shoreline (70,860 meters) of Kings Bay and the Crystal River. All altered shoreline types and their distribution can be viewed on *Appendix A: Figure B*. All altered shoreline types along with length (meters) and percentages are listed below on Table 3.4.

Table 3.3. Meters of Natural Shoreline and Percent of Natural and Total Shoreline along Crystal River and Kings Bay.

Shoreline Category	Shoreline Length (m)	Percent	
		Natural Shoreline	Total Shoreline
Ancient Reef Outcrops	1,018.28	34.2	1.4
Beach	1,959.99	65.8	2.8
Total	2,978.27	100	4.2

Table 3.3

Table 3.4. Meters of Altered Shoreline and Percent of Altered and Total Shoreline along Crystal River and Kings Bay.

Shoreline Category	Shoreline Length (m)	Percent	
		Altered Shoreline	Total Shoreline
Rip-Rap	1,346.56	5.9	1.9
Seawall	21,239.26	94.1	29.9
Total	22,585.82	100	31.8

Table 3.4

4.0 Conclusions

The results of the mapping effort were consistent with SAV, EAV, and altered shoreline distribution, with regard to individual species salinity tolerances and areas of high urban development. SAV species occurred in greater quantities and densities south of the Salt River toward the entrance to Kings Bay. The waters south of the Salt River became gradually shallower toward Kings Bay and salinity levels are presumably lower, allowing for larger expanses of *Vallisneria americana* to grow.

Moving away from Kings Bay toward the Salt River branch and toward the mouth of the Crystal River, seagrass became increasingly sparse with a higher incidence of *Halodule wrightii* occurring. Moving from river kilometer marker 4 to the mouth of the river, seagrasses were sparse to almost non-existent and was replaced by the alga, *Polysiphonia spp.* This epiphytic algae was extremely dense and was growing on almost every oyster bed or bare rock substrate.

Mapped distributions of EAV were predictable, as the more salt tolerant species such as *Juncus roemerianus* and *Spartina alterniflora* occurred primarily around the Salt River branch and points north where higher salinity concentrations are presumed. The more fresh water varieties of EAV such as *Typha domingensis* were confined to the banks and islands of Kings Bay. *Cladium jamaicense,* with its greater salinity tolerance, was found to be growing from river kilometer marker 1 through 3 and in mixed *Typha* stands throughout Kings Bay.

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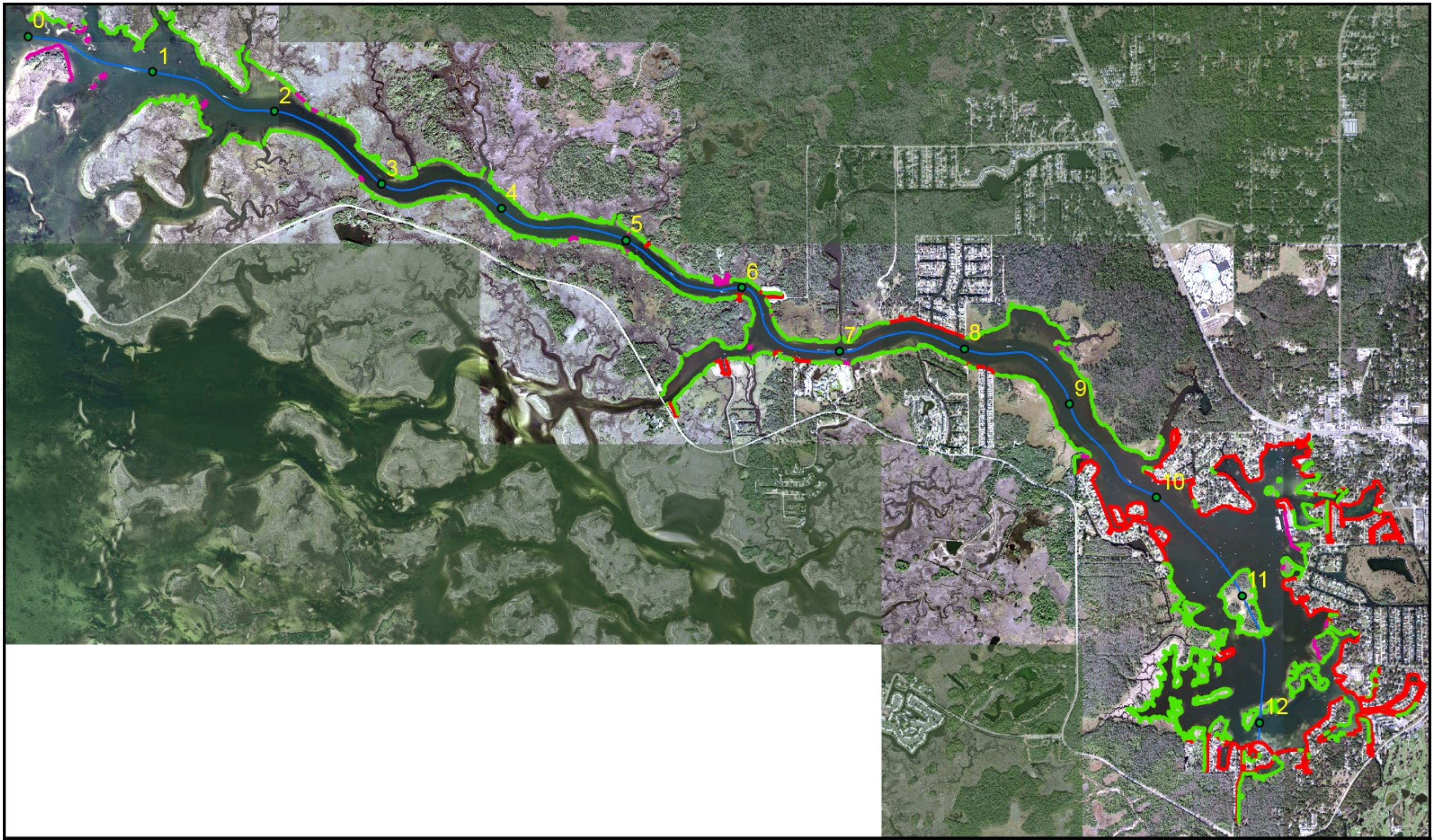
Appendix A - Map Layouts of Vegetation



Crystal River and Kings Bay Shoreline & SAV Mapping 2009

Figure A:
Distribution of Shoreline Types

Legend

- 🟩 Vegetation
- 🟥 Altered Shoreline
- 🟪 Natural Shoreline
- — Crystal_River_Centerline
- ● Crystal_River_1km_pts

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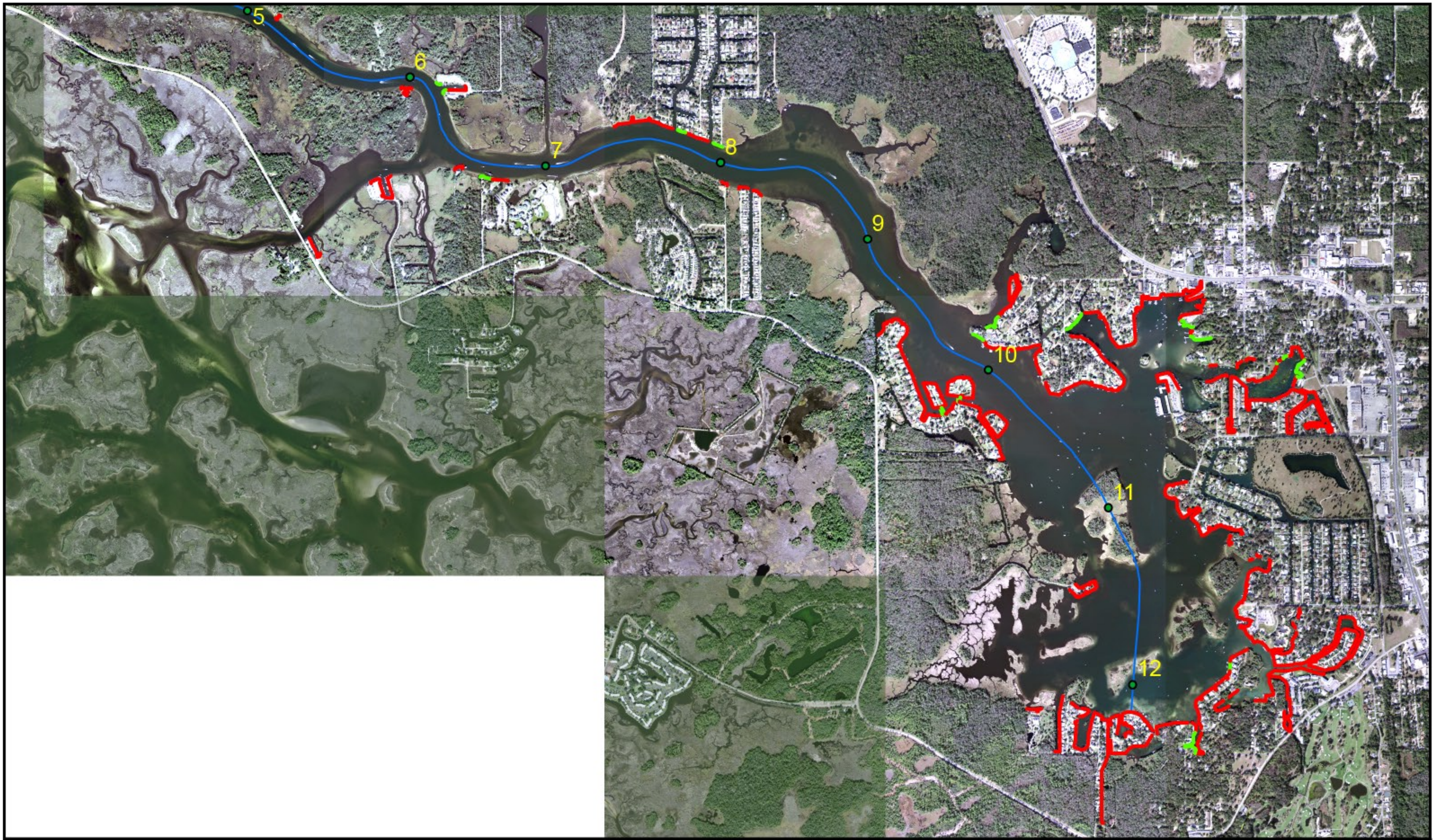

Crystal River and Kings Bay Shoreline & SAV Mapping 2009

Figure B:
Distribution of Altered Shoreline Areas

AVINEON®

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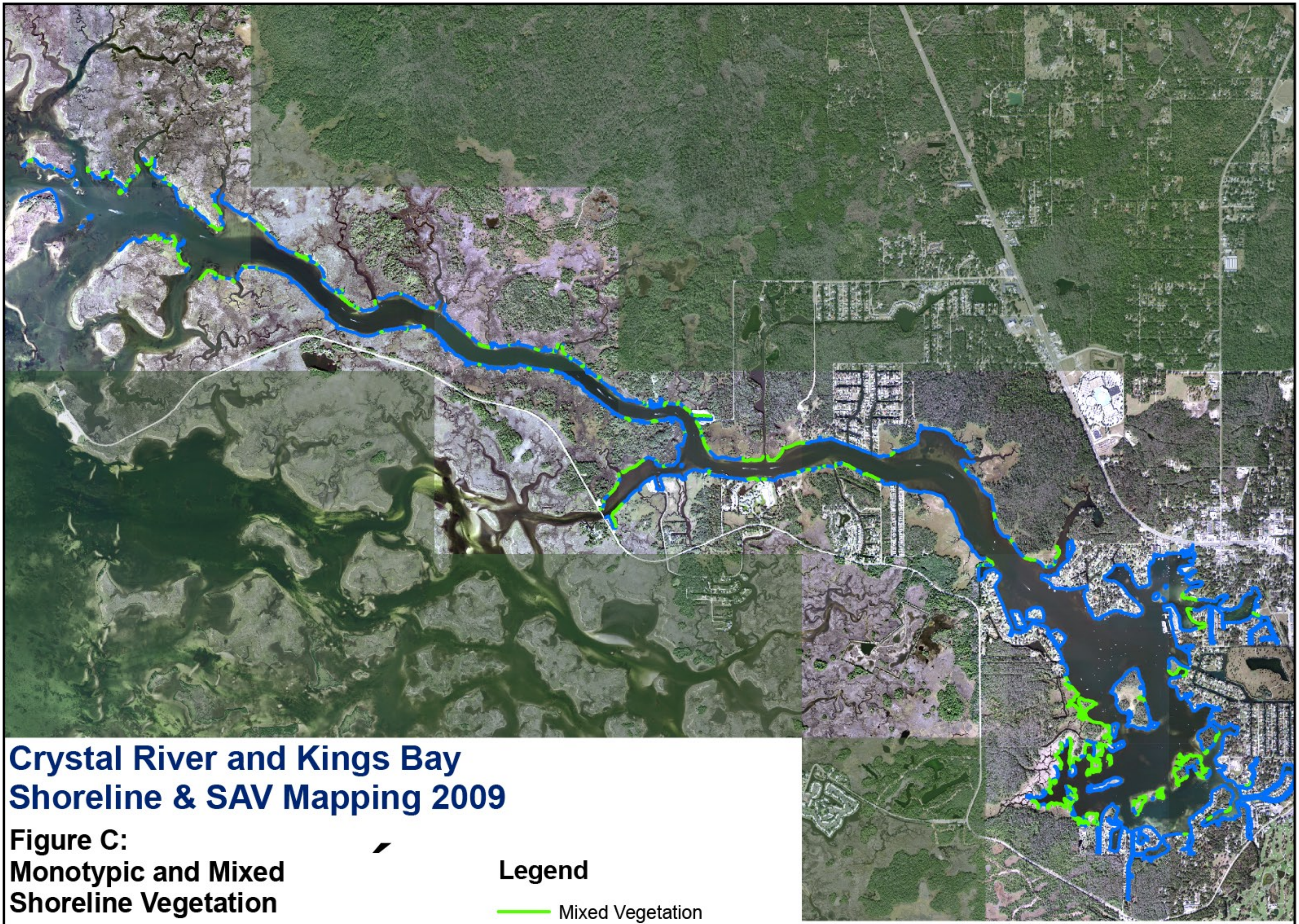
Legend

🟩 Rip-Rap
🟥 Seawall
— Crystal_River_Centerline
● Crystal_River_1km_pts

Crystal River and Kings Bay Shoreline & SAV Mapping 2009

Figure C: Monotypic and Mixed Shoreline Vegetation



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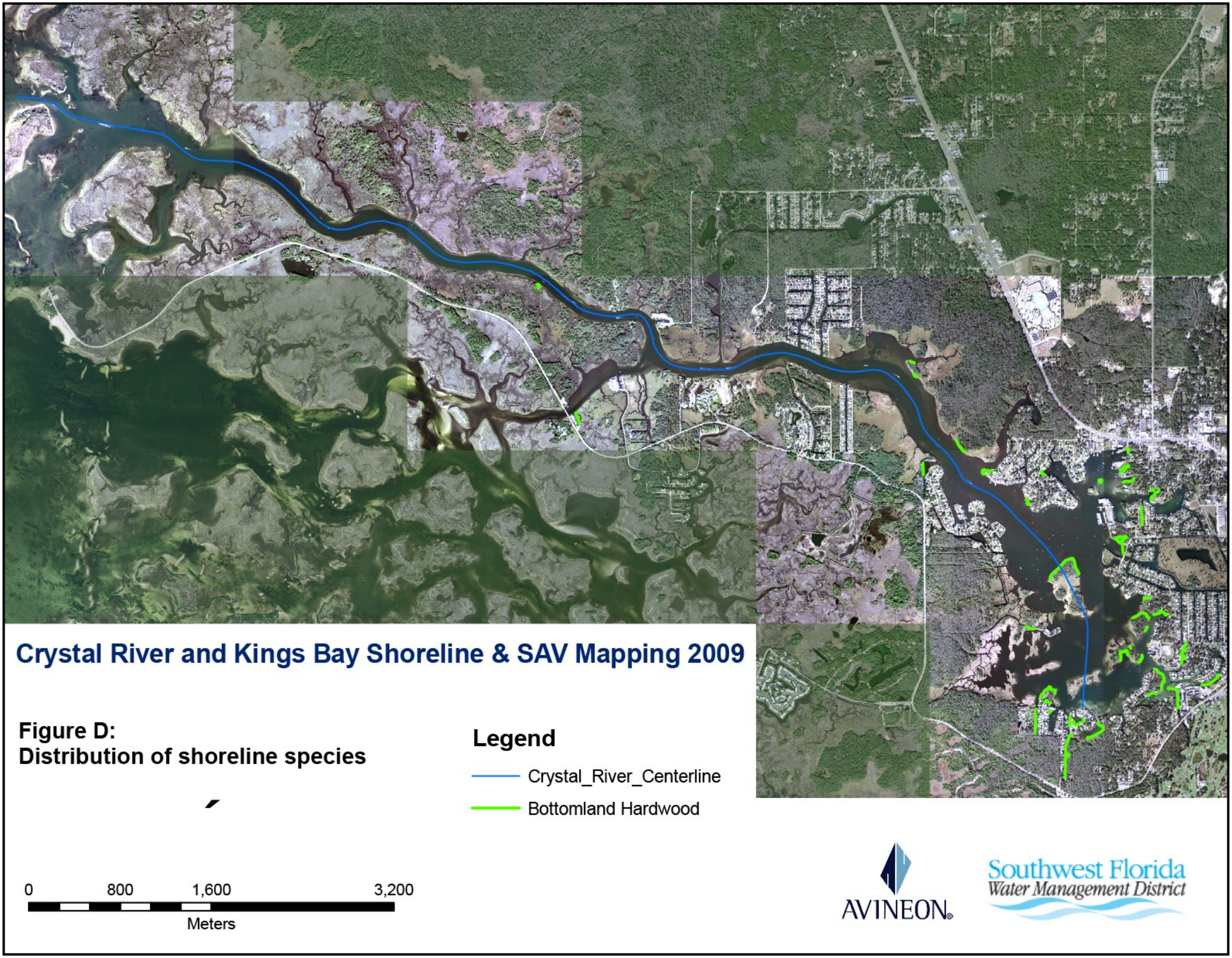

Crystal River and Kings Bay Shoreline & SAV Mapping 2009

Figure D:
Distribution of shoreline species

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Figure F:
Distribution of shoreline species

Legend

— Crystal_River_Centerline

— Cyperus alternifolius

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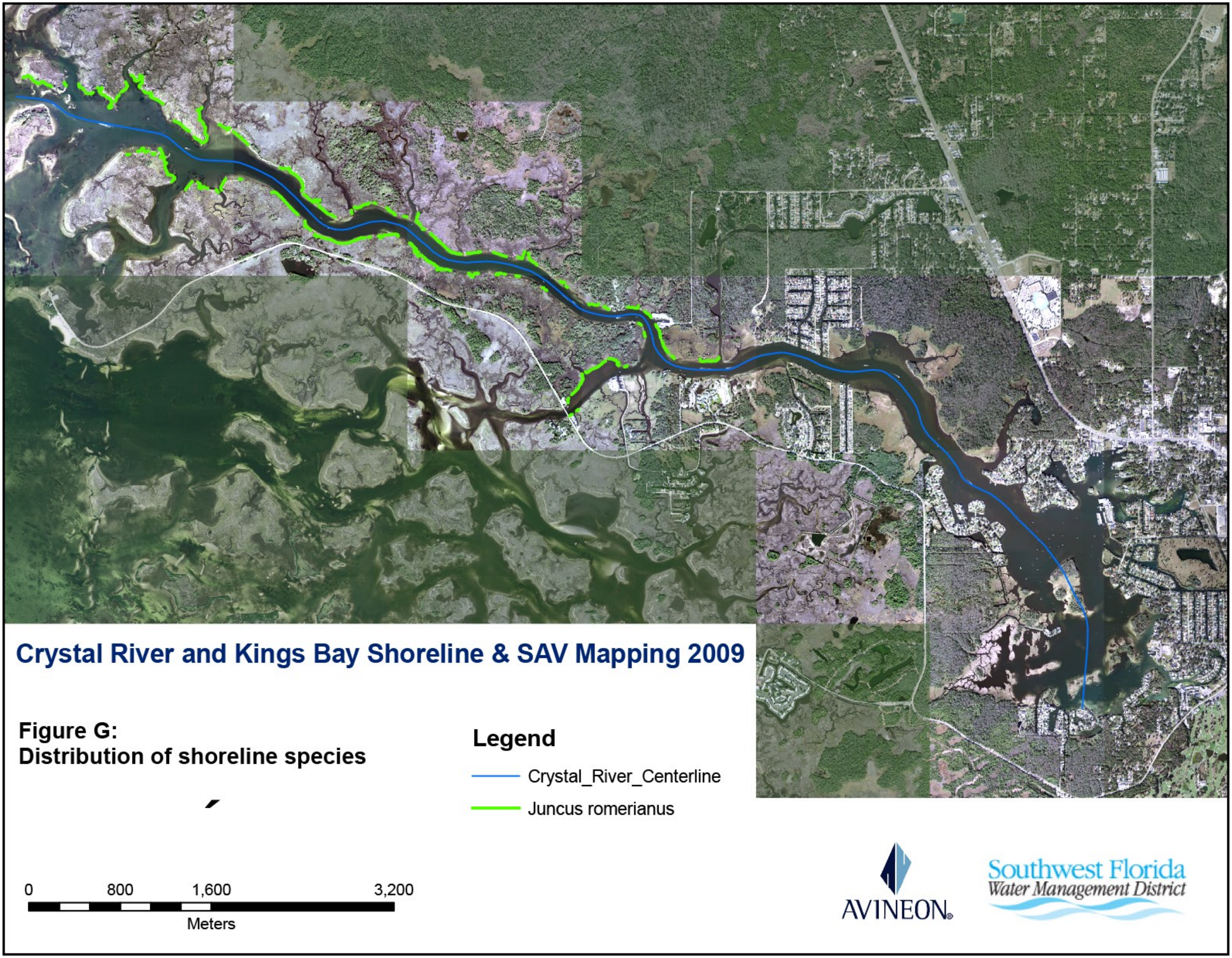

Crystal River and Kings Bay Shoreline & SAV Mapping 2009

Figure G:
Distribution of shoreline species

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Crystal River and Kings Bay Shoreline & SAV Mapping 2009

Figure H:
Distribution of shoreline species

Legend

— Crystal_River_Centerline

— Juniperus silicicola

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Crystal River and Kings Bay Shoreline & SAV Mapping 2009

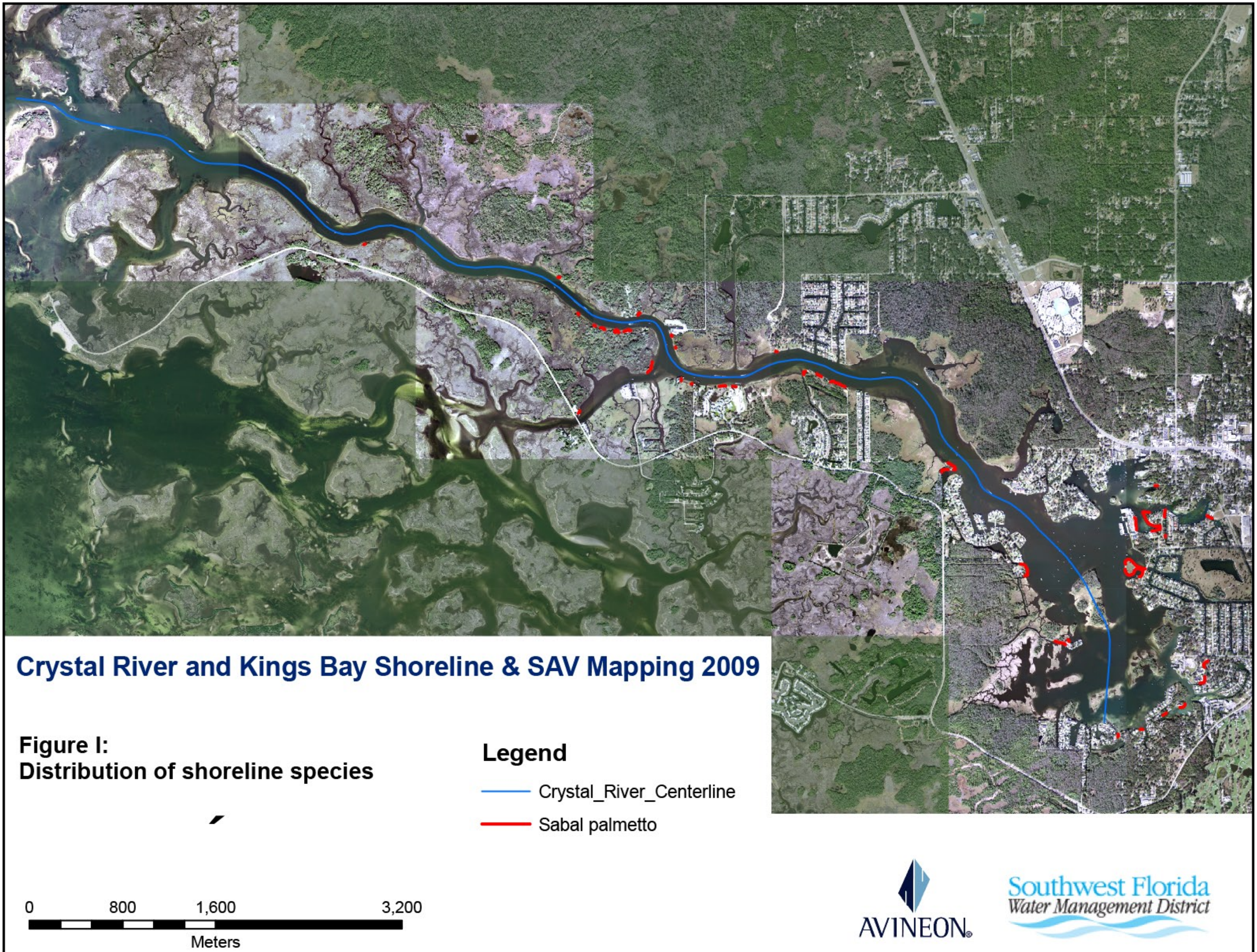

Figure I:
Distribution of shoreline species

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Crystal River and Kings Bay Shoreline & SAV Mapping 2009

Figure J:
Distribution of shoreline species

Crystal River and Kings Bay Shoreline & SAV Mapping 2009

Figure K:
Distribution of shoreline species

Legend

— Crystal_River_Centerline

— Typha domingensis

0 750 1,500 3,000
Meters

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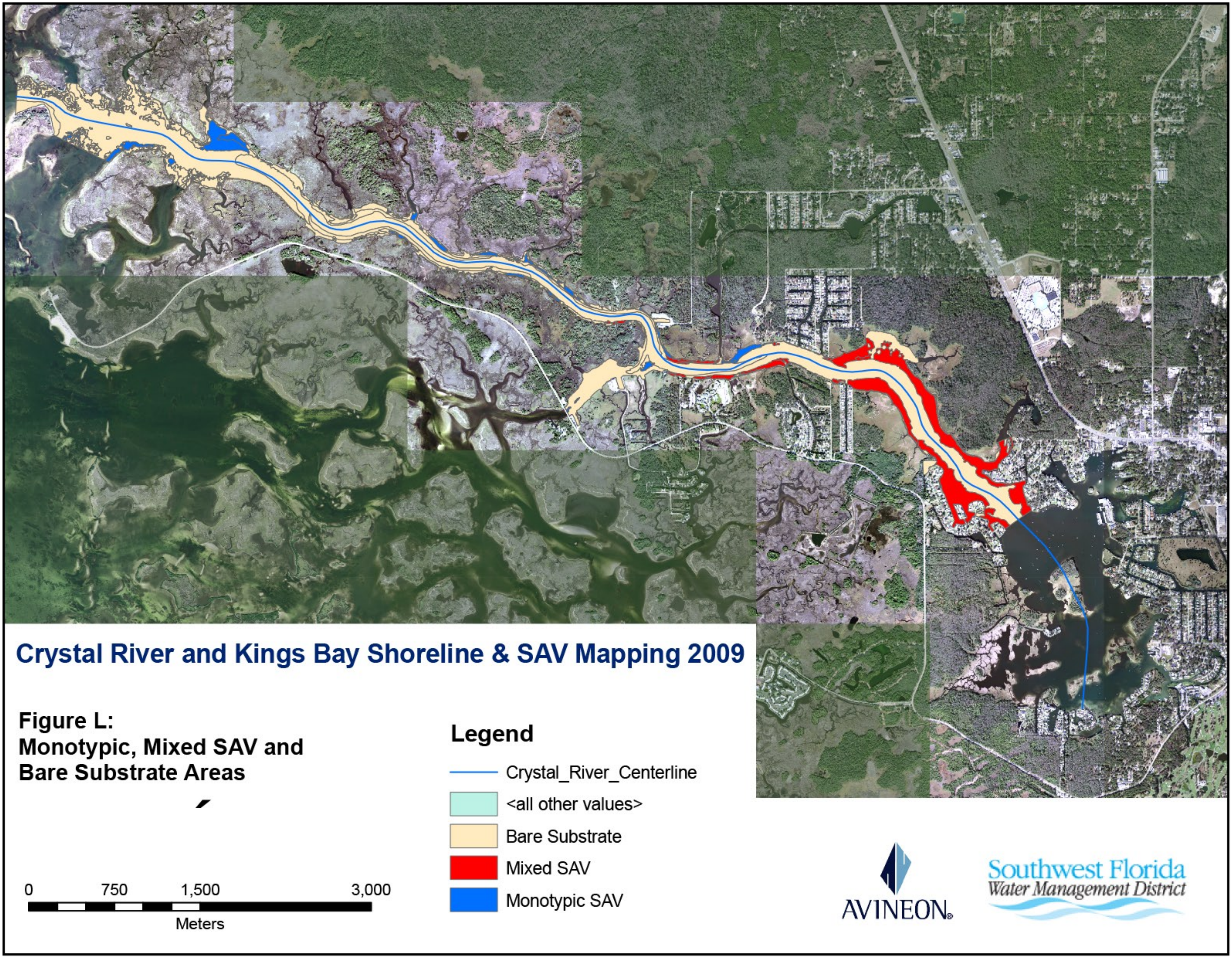

Crystal River and Kings Bay Shoreline & SAV Mapping 2009

**Figure L:
Monotypic, Mixed SAV and
Bare Substrate Areas**

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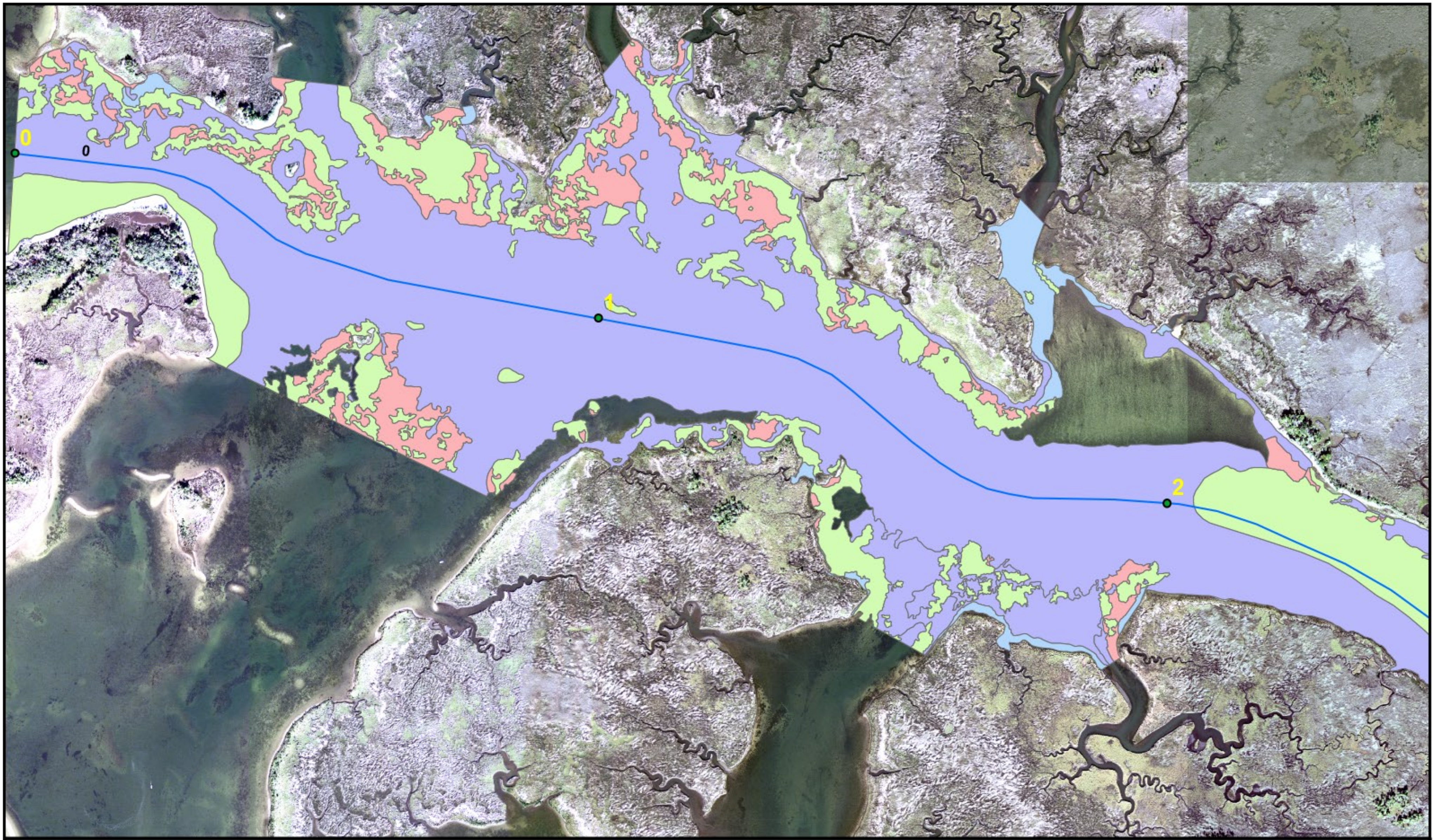
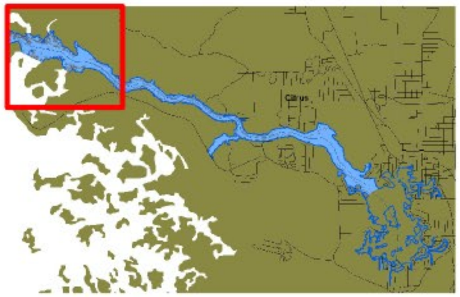


Crystal River and Kings Bay Shoreline & SAV Mapping 2009

Figure M:
Bare Substrate Areas



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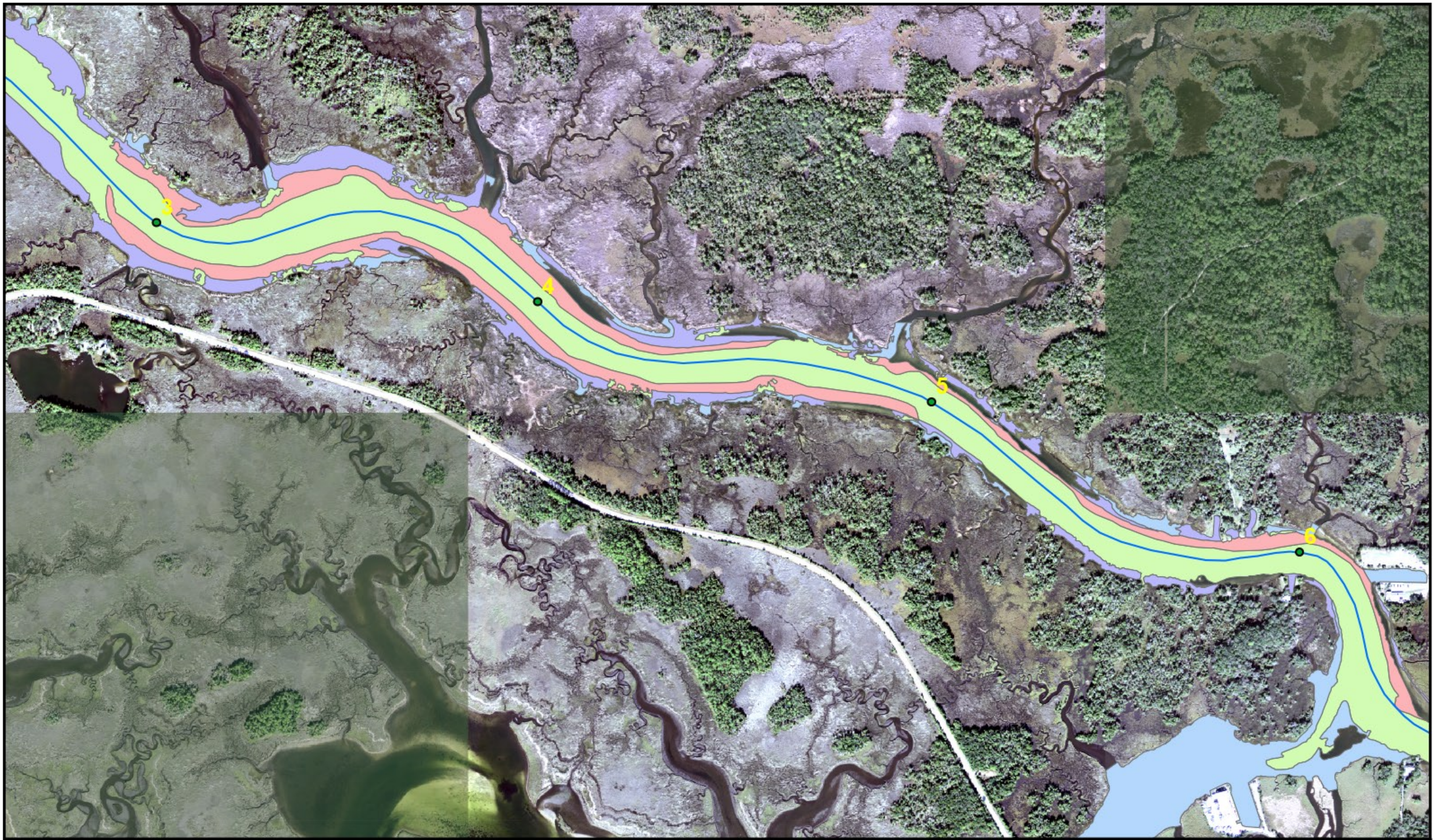
Legend

- 🟨 Clay and Silt
- 🟦 Organic surface
- 🟩 Rock - Oyster
- 🟪 Sand
- 🟥 Sand and Rock



Crystal River and Kings Bay Shoreline & SAV Mapping 2009

Figure N:
Bare Substrate Areas

0 225 450 900
Meters

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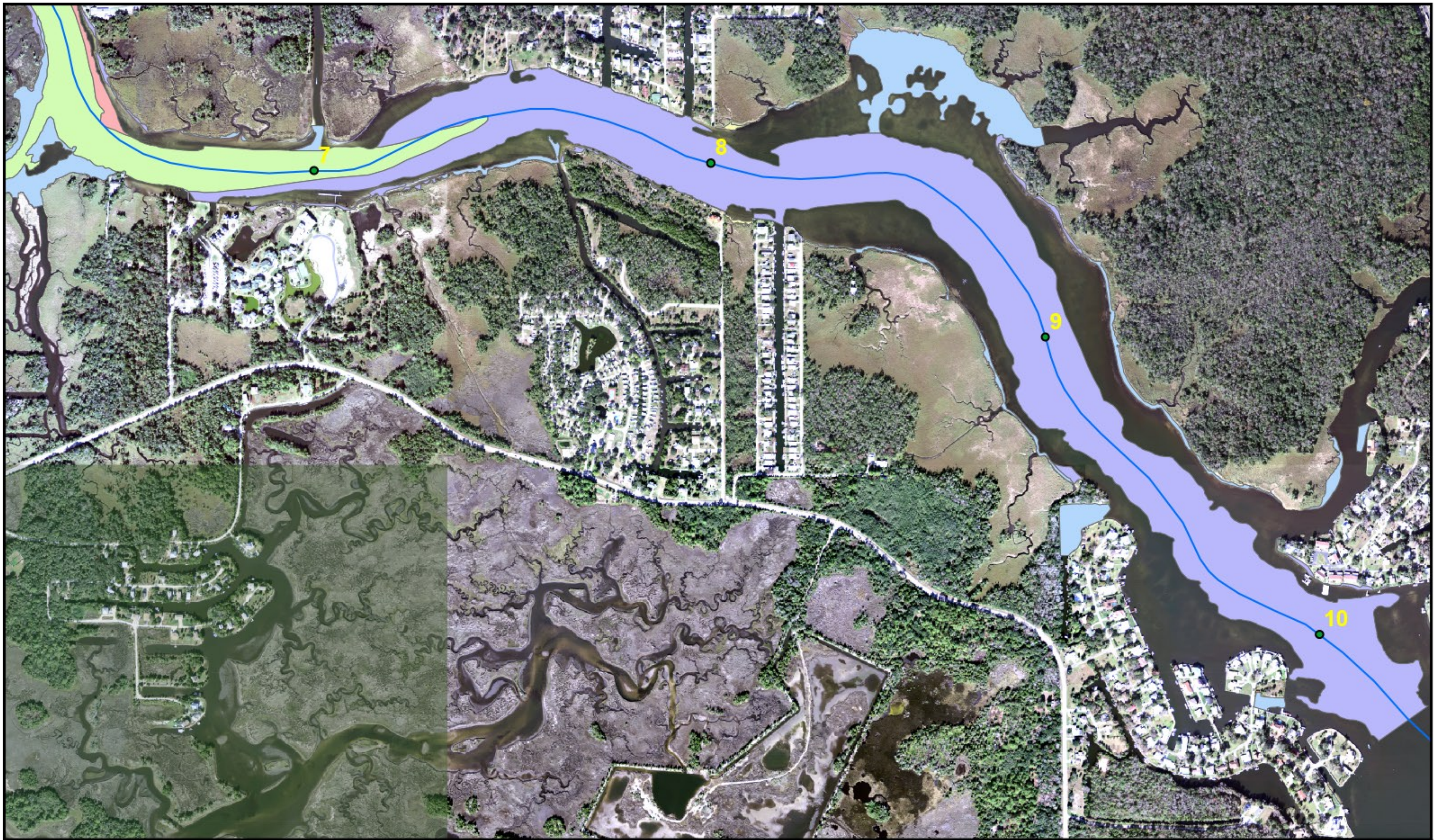
Southwest Florida
Water Management District

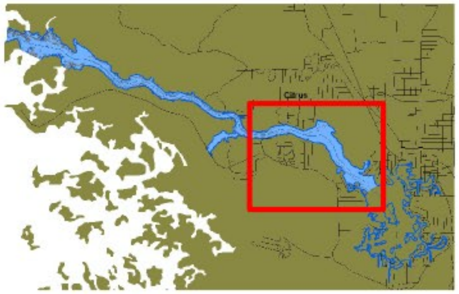
Legend

🟨 Clay and Silt
🟦 Organic surface
🟩 Rock - Oyster
🟪 Sand
🟥 Sand and Rock



Crystal River and Kings Bay Shoreline & SAV Mapping 2009

Figure O:
Bare Substrate Areas



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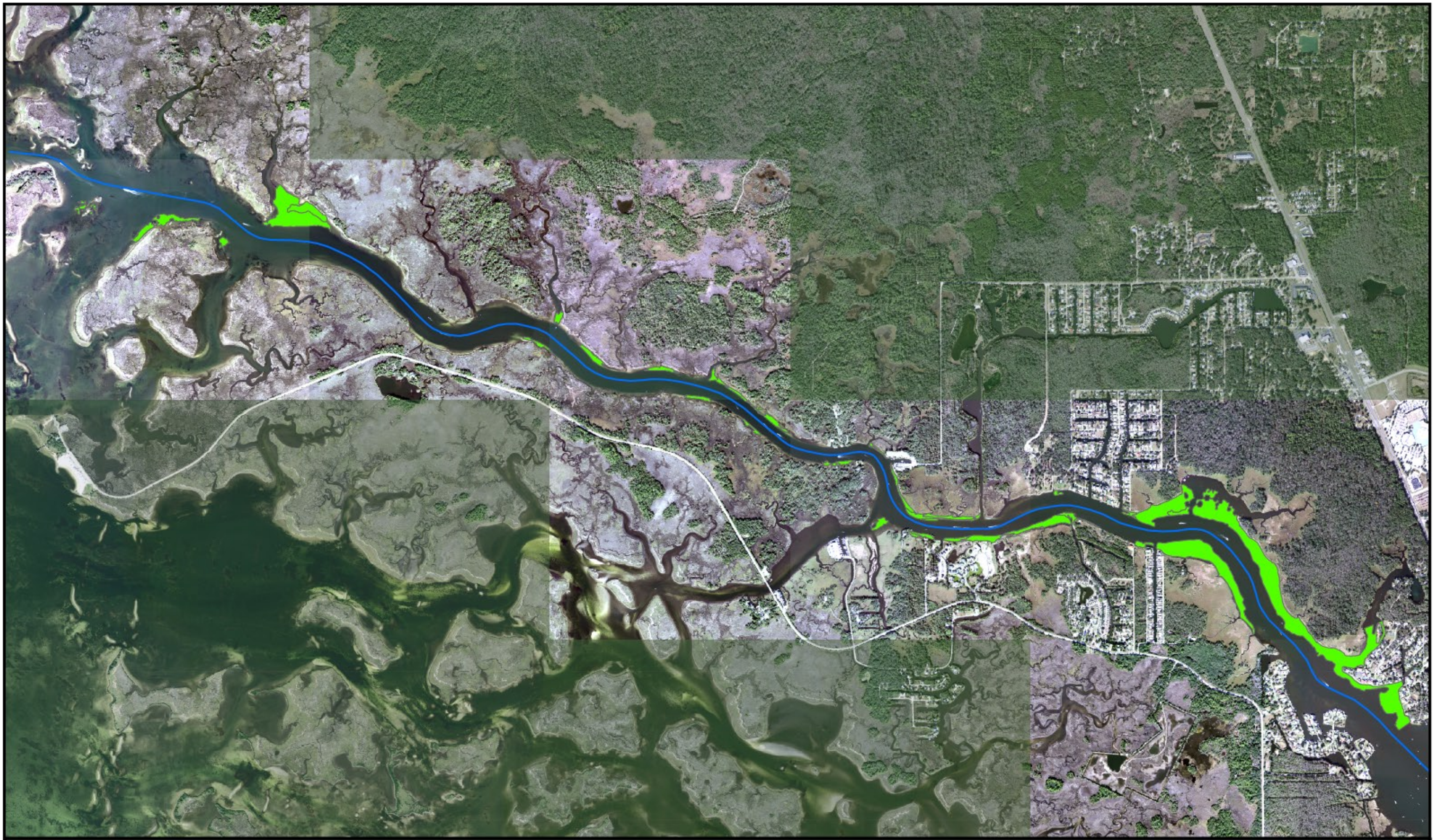
Water Management District

Legend

- 🟨 Clay and Silt
- 🟦 Organic surface
- 🟩 Rock - Oyster
- 🟪 Sand
- 🟥 Sand and Rock



Crystal River and Kings Bay Shoreline & SAV Mapping 2009

Figure P:
Distribution of SAV species

0 750 1,500 3,000
Meters

AVINEON

Southwest Florida
Water Management District

Legend

― Crystal_River_Centerline

🟩 Halodule wrightii

Crystal River and Kings Bay Shoreline & SAV Mapping 2009

Figure Q:
Distribution of SAV species

0 750 1,500 3,000
Meters

AVINEON®

Southwest Florida
Water Management District

Legend

— Crystal_River_Centerline

🟩 Myriophyllum spicatum

Crystal River and Kings Bay Shoreline & SAV Mapping 2009

Figure R:
Distribution of SAV species

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Legend

— Crystal_River_Centerline

🟩 Vallisneria americana

Crystal River and Kings Bay Shoreline & SAV Mapping 2009

Figure S:
Distribution of Natural Shoreline Areas

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Water Management District

Legend

Appendix B – SAV per 10 Meters of River Kilometer

Appendix B is provided as a separate data sheet/spreadsheet (in PDF and Excel format) showing the amount of submersed aquatic vegetation that occurs within 100 meter intervals in the river up to river kilometer 10.3. SAV is expressed in square meters.

SAV Vegetation per 10 Meters of River

7/30/2010

FLUCS1	SEG_MID_	AREA_SQ_	
Sand	0.05	40.18	
Sand	0.05	12,313.24	
Sand	0.05	456.33	
		3	
		12,809.75	
Sand and Rock	0.05	1,418.08	
Sand and Rock	0.05	602.46	
Sand and Rock	0.05	759.47	
		3	Count
		2,780.00	Total
Rock - Oyster	0.05	9,643.90	
Rock - Oyster	0.05	371.20	
Rock - Oyster	0.05	2,279.66	
Rock - Oyster	0.05	1,263.52	
Rock - Oyster	0.05	56.09	
Rock - Oyster	0.05	546.45	
		6	Count
		14,160.83	Total
Organic surface	0.15	984.05	
		1	Count
		984.05	Total
Sand	0.15	10,642.08	
Sand	0.15	367.46	
Sand	0.15	189.13	
		3	Count
		11,198.66	Total
Sand and Rock	0.15	885.65	
Sand and Rock	0.15	348.25	
Sand and Rock	0.15	83.08	
Sand and Rock	0.15	400.64	
Sand and Rock	0.15	8.07	
		5	Count
		1,725.69	Total
Rock - Oyster	0.15	231.57	
Rock - Oyster	0.15	3,594.64	
Rock - Oyster	0.15	0.65	
Rock - Oyster	0.15	305.27	
Rock - Oyster	0.15	751.11	
Rock - Oyster	0.15	4,495.30	
		6	Count
		9,378.55	Total
Organic surface	0.25	1,088.04	
		1	Count
		1,088.04	Total
Sand	0.25	16.88	
Sand	0.25	11,221.19	
		2	Count
		11,238.07	Total
Sand and Rock	0.25	1,002.22	
Sand and Rock	0.25	16.38	

Sand and Rock	0.25	370.65	
		3	Count
		1,389.24	Total
Rock - Oyster	0.25	1,982.35	
Rock - Oyster	0.25	1,958.71	
Rock - Oyster	0.25	108.99	
Rock - Oyster	0.25	2,232.05	
		4	Count
		6,282.10	Total
Sand	0.35	20.63	
Sand	0.35	13,118.93	
Sand	0.35	249.48	
		3	Count
		13,389.04	Total
Sand and Rock	0.35	1,389.33	
Sand and Rock	0.35	795.99	
Sand and Rock	0.35	236.48	
		3	Count
		2,421.80	Total
Rock - Oyster	0.35	4,805.23	
Rock - Oyster	0.35	493.20	
Rock - Oyster	0.35	41.74	
Rock - Oyster	0.35	5,243.03	
		4	Count
		10,583.21	Total
Rock - Oyster	0.45	680.16	
Rock - Oyster	0.45	5,529.63	
Rock - Oyster	0.45	7,053.60	
		3	Count
		13,263.39	Total
Sand	0.45	26,313.12	
Sand	0.45	2,625.97	
Sand	0.45	118.24	
		3	Count
		29,057.33	Total
Sand and Rock	0.45	54.17	
Sand and Rock	0.45	141.28	
Sand and Rock	0.45	39.62	
Sand and Rock	0.45	1,190.37	
Sand and Rock	0.45	236.34	
Sand and Rock	0.45	287.11	
		6	Count
		1,948.89	Total
Sand	0.55	29,180.06	
Sand	0.55	145.60	
		2	Count
		29,325.66	Total
Halodule wrightii	0.55	2,214.62	
Halodule wrightii	0.55	593.07	
Halodule wrightii	0.55	189.05	
Halodule wrightii	0.55	32.38	
		4	Count
		3,029.12	Total
Rock - Oyster	0.55	48.09	
Rock - Oyster	0.55	524.62	
Rock - Oyster	0.55	2,733.08	

Rock - Oyster	0.55	100.42	
Rock - Oyster	0.55	2,862.41	
Rock - Oyster	0.55	364.89	
Rock - Oyster	0.55	4,396.15	
		7	Count
		11,029.65	Total
Sand and Rock	0.55	239.36	
Sand and Rock	0.55	393.27	
Sand and Rock	0.55	258.84	
Sand and Rock	0.55	45.72	
Sand and Rock	0.55	1,302.42	
Sand and Rock	0.55	1,036.68	
Sand and Rock	0.55	541.01	
Sand and Rock	0.55	629.17	
		8	Count
		4,446.47	Total
Halodule wrightii	0.65	850.34	
		1	Count
		850.34	Total
Organic surface	0.65	216.15	
		1	Count
		216.15	Total
Rock - Oyster	0.65	887.70	
Rock - Oyster	0.65	6,459.89	
Rock - Oyster	0.65	5,783.19	
Rock - Oyster	0.65	173.33	
Rock - Oyster	0.65	66.99	
		5	Count
		13,371.11	Total
Sand	0.65	96.70	
Sand	0.65	73.13	
Sand	0.65	339.42	
Sand	0.65	24,385.38	
Sand	0.65	44.54	
		5	Count
		24,939.18	Total
Sand and Rock	0.65	64.09	
Sand and Rock	0.65	152.15	
Sand and Rock	0.65	487.76	
Sand and Rock	0.65	102.16	
Sand and Rock	0.65	488.47	
Sand and Rock	0.65	44.08	
Sand and Rock	0.65	2,010.70	
Sand and Rock	0.65	6,628.16	
		8	Count
		9,977.58	Total
Organic surface	0.75	583.09	
		1	Count
		583.09	Total
Sand	0.75	946.02	
Sand	0.75	31,257.09	
		2	Count
		32,203.12	Total
Sand and Rock	0.75	3,734.31	
Sand and Rock	0.75	7,440.93	
Sand and Rock	0.75	772.93	

		3	Count
		11,948.16	Total
Rock - Oyster	0.75	327.79	
Rock - Oyster	0.75	141.85	
Rock - Oyster	0.75	136.03	
Rock - Oyster	0.75	236.27	
Rock - Oyster	0.75	86.50	
Rock - Oyster	0.75	169.97	
Rock - Oyster	0.75	95.23	
Rock - Oyster	0.75	1,221.02	
Rock - Oyster	0.75	328.43	
Rock - Oyster	0.75	377.88	
Rock - Oyster	0.75	16.10	
Rock - Oyster	0.75	175.90	
Rock - Oyster	0.75	7,318.90	
		13	Count
		10,631.86	Total
Halodule wrightii	0.85	847.27	
		1	Count
		847.27	Total
Sand	0.85	2,413.29	
Sand	0.85	50.67	
Sand	0.85	39,561.00	
Sand	0.85	14.72	
		4	Count
		42,039.68	Total
Sand and Rock	0.85	306.37	
Sand and Rock	0.85	893.06	
Sand and Rock	0.85	200.36	
Sand and Rock	0.85	71.82	
Sand and Rock	0.85	273.01	
Sand and Rock	0.85	425.52	
Sand and Rock	0.85	67.92	
		7	Count
		2,238.07	Total
Rock - Oyster	0.85	160.75	
Rock - Oyster	0.85	10.57	
Rock - Oyster	0.85	277.27	
Rock - Oyster	0.85	202.48	
Rock - Oyster	0.85	77.29	
Rock - Oyster	0.85	152.96	
Rock - Oyster	0.85	688.53	
Rock - Oyster	0.85	145.00	
Rock - Oyster	0.85	1,035.77	
Rock - Oyster	0.85	1,316.06	
Rock - Oyster	0.85	2,351.52	
		11	Count
		6,418.19	Total
Halodule wrightii	0.95	4,414.60	
Halodule wrightii	0.95	291.00	
		2	Count
		4,705.60	Total
Sand	0.95	39,359.47	
Sand	0.95	24.23	
Sand	0.95	1,341.99	
Sand	0.95	98.14	

		4	Count
		40,823.82	Total
Sand and Rock	0.95	27.90	
Sand and Rock	0.95	13.18	
Sand and Rock	0.95	1,095.18	
Sand and Rock	0.95	1,546.19	
Sand and Rock	0.95	6,961.22	
		5	Count
		9,643.67	Total
Rock - Oyster	0.95	886.64	
Rock - Oyster	0.95	428.35	
Rock - Oyster	0.95	1,729.88	
Rock - Oyster	0.95	4.79	
Rock - Oyster	0.95	351.11	
Rock - Oyster	0.95	15.12	
Rock - Oyster	0.95	37.37	
Rock - Oyster	0.95	67.36	
Rock - Oyster	0.95	250.34	
Rock - Oyster	0.95	88.62	
Rock - Oyster	0.95	900.74	
Rock - Oyster	0.95	1,273.15	
Rock - Oyster	0.95	677.27	
Rock - Oyster	0.95	497.41	
Rock - Oyster	0.95	278.43	
Rock - Oyster	0.95	171.09	
		16	Count
		7,657.67	Total
Halodule wrightii	1.05	5,188.17	
Halodule wrightii	1.05	214.44	
Halodule wrightii	1.05	3.48	
		3	Count
		5,406.09	Total
Sand	1.05	1,708.83	
Sand	1.05	41,325.13	
Sand	1.05	1,493.49	
Sand	1.05	2,669.73	
		4	Count
		47,197.18	Total
Rock - Oyster	1.05	322.12	
Rock - Oyster	1.05	210.59	
Rock - Oyster	1.05	252.67	
Rock - Oyster	1.05	840.91	
Rock - Oyster	1.05	24.73	
Rock - Oyster	1.05	226.08	
Rock - Oyster	1.05	3,209.41	
Rock - Oyster	1.05	527.60	
Rock - Oyster	1.05	412.38	
Rock - Oyster	1.05	155.33	
Rock - Oyster	1.05	466.05	
		11	Count
		6,647.87	Total
Sand and Rock	1.05	135.13	
Sand and Rock	1.05	549.64	
Sand and Rock	1.05	206.51	
Sand and Rock	1.05	1,786.67	
Sand and Rock	1.05	256.37	
Sand and Rock	1.05	229.03	

Sand and Rock	1.05	510.65	
Sand and Rock	1.05	1,927.91	
Sand and Rock	1.05	113.12	
Sand and Rock	1.05	69.45	
Sand and Rock	1.05	201.22	
		11	Count
		5,985.71	Total
Halodule wrightii	1.15	2,402.68	
		1	Count
		2,402.68	Total
Sand	1.15	2,297.52	
Sand	1.15	30,976.86	
Sand	1.15	3,771.55	
		3	Count
		37,045.92	Total
Sand and Rock	1.15	299.25	
Sand and Rock	1.15	138.55	
Sand and Rock	1.15	1,774.26	
Sand and Rock	1.15	694.11	
Sand and Rock	1.15	325.83	
		5	Count
		3,231.99	Total
Rock - Oyster	1.15	230.24	
Rock - Oyster	1.15	12.29	
Rock - Oyster	1.15	956.52	
Rock - Oyster	1.15	25.17	
Rock - Oyster	1.15	317.84	
Rock - Oyster	1.15	5,002.72	
Rock - Oyster	1.15	61.25	
Rock - Oyster	1.15	232.13	
Rock - Oyster	1.15	76.99	
Rock - Oyster	1.15	174.20	
Rock - Oyster	1.15	2,130.77	
		11	Count
		9,220.12	Total
Halodule wrightii	1.25	1,461.57	
		1	Count
		1,461.57	Total
Sand	1.25	185.32	
Sand	1.25	27,066.43	
Sand	1.25	866.73	
Sand	1.25	982.94	
Sand	1.25	319.71	
		5	Count
		29,421.13	Total
Sand and Rock	1.25	2,617.50	
Sand and Rock	1.25	89.39	
Sand and Rock	1.25	180.71	
Sand and Rock	1.25	441.44	
Sand and Rock	1.25	302.79	
		5	Count
		3,631.84	Total
Rock - Oyster	1.25	27.34	
Rock - Oyster	1.25	1,493.93	
Rock - Oyster	1.25	246.05	
Rock - Oyster	1.25	942.65	

Rock - Oyster	1.25	5,756.78	
Rock - Oyster	1.25	47.78	
Rock - Oyster	1.25	296.57	
		7	Count
		8,811.11	Total
Rock - Oyster	1.35	2,333.64	
Rock - Oyster	1.35	4,993.46	
		2	Count
		7,327.11	Total
Sand and Rock	1.35	391.01	
Sand and Rock	1.35	842.82	
Sand and Rock	1.35	905.60	
Sand and Rock	1.35	42.03	
		4	Count
		2,181.46	Total
Sand	1.35	832.19	
Sand	1.35	229.87	
Sand	1.35	18,274.76	
Sand	1.35	236.35	
Sand	1.35	697.17	
Sand	1.35	377.70	
		6	Count
		20,648.04	Total
Organic surface	1.45	1,927.63	
Organic surface	1.45	687.66	
		2	Count
		2,615.30	Total
Sand	1.45	1,204.43	
Sand	1.45	21,080.87	
		2	Count
		22,285.30	Total
Sand and Rock	1.45	286.27	
Sand and Rock	1.45	132.42	
Sand and Rock	1.45	237.29	
Sand and Rock	1.45	216.50	
		4	Count
		872.47	Total
Rock - Oyster	1.45	1,144.24	
Rock - Oyster	1.45	66.98	
Rock - Oyster	1.45	4,938.86	
Rock - Oyster	1.45	752.72	
Rock - Oyster	1.45	216.36	
		5	Count
		7,119.17	Total
Halodule wrightii	1.55	2,595.67	
		1	Count
		2,595.67	Total
Sand	1.55	2,365.19	
Sand	1.55	22,219.44	
Sand	1.55	496.86	
		3	Count
		25,081.50	Total
Organic surface	1.55	124.11	
Organic surface	1.55	44.86	
Organic surface	1.55	358.59	
Organic surface	1.55	5,428.09	

		4	Count
		5,955.66	Total
Rock - Oyster	1.55	131.65	
Rock - Oyster	1.55	7.04	
Rock - Oyster	1.55	7,815.79	
Rock - Oyster	1.55	3,835.57	
		4	Count
		11,790.06	Total
Sand and Rock	1.55	22.95	
Sand and Rock	1.55	171.46	
Sand and Rock	1.55	202.99	
Sand and Rock	1.55	323.05	
Sand and Rock	1.55	39.58	
		5	Count
		760.02	Total
Sand and Rock	1.65	1,014.96	
		1	Count
		1,014.96	Total
Halodule wrightii	1.65	81.57	
Halodule wrightii	1.65	112.42	
Halodule wrightii	1.65	12.73	
		3	Count
		206.73	Total
Organic surface	1.65	2,555.35	
Organic surface	1.65	282.97	
Organic surface	1.65	1.48	
Organic surface	1.65	629.85	
		4	Count
		3,469.66	Total
Sand	1.65	869.98	
Sand	1.65	22,284.97	
Sand	1.65	11,374.85	
Sand	1.65	880.48	
Sand	1.65	1,435.28	
		5	Count
		36,845.57	Total
Rock - Oyster	1.65	280.25	
Rock - Oyster	1.65	155.72	
Rock - Oyster	1.65	3,228.05	
Rock - Oyster	1.65	1,039.35	
Rock - Oyster	1.65	155.82	
Rock - Oyster	1.65	833.33	
Rock - Oyster	1.65	1,088.02	
Rock - Oyster	1.65	2,675.04	
Rock - Oyster	1.65	133.91	
Rock - Oyster	1.65	5.13	
Rock - Oyster	1.65	110.60	
		11	Count
		9,705.22	Total
Halodule wrightii	1.75	5,514.45	
		1	Count
		5,514.45	Total
Organic surface	1.75	2,169.22	
Organic surface	1.75	2,780.97	
Organic surface	1.75	417.84	
		3	Count

		5,368.03	Total
Sand and Rock	1.75	295.78	
Sand and Rock	1.75	207.25	
Sand and Rock	1.75	87.04	
		3	Count
		590.08	Total
Sand	1.75	1,282.64	
Sand	1.75	423.32	
Sand	1.75	20,940.34	
Sand	1.75	6,398.25	
Sand	1.75	395.44	
Sand	1.75	402.13	
		6	Count
		29,842.12	Total
Rock - Oyster	1.75	2,108.47	
Rock - Oyster	1.75	2.07	
Rock - Oyster	1.75	601.34	
Rock - Oyster	1.75	43.46	
Rock - Oyster	1.75	96.19	
Rock - Oyster	1.75	1,751.89	
Rock - Oyster	1.75	34.52	
Rock - Oyster	1.75	524.03	
Rock - Oyster	1.75	101.72	
Rock - Oyster	1.75	361.73	
Rock - Oyster	1.75	205.15	
Rock - Oyster	1.75	121.25	
Rock - Oyster	1.75	93.92	
Rock - Oyster	1.75	372.85	
		14	Count
		6,418.60	Total
Halodule wrightii	1.85	607.42	
Halodule wrightii	1.85	19,358.59	
		2	Count
		19,966.01	Total
Organic surface	1.85	746.07	
Organic surface	1.85	270.71	
Organic surface	1.85	1,254.10	
		3	Count
		2,270.88	Total
Rock - Oyster	1.85	27.59	
Rock - Oyster	1.85	1.20	
Rock - Oyster	1.85	305.89	
Rock - Oyster	1.85	45.81	
		4	Count
		380.49	Total
Sand	1.85	417.82	
Sand	1.85	24,208.77	
Sand	1.85	9,167.54	
Sand	1.85	146.82	
		4	Count
		33,940.95	Total
Halodule wrightii	1.95	12,277.55	
Halodule wrightii	1.95	5,006.66	
		2	Count
		17,284.20	Total
Sand and Rock	1.95	1,441.97	

Sand and Rock	1.95	2,292.77	
		2	Count
		3,734.74	Total
Organic surface	1.95	144.48	
Organic surface	1.95	231.10	
Organic surface	1.95	712.56	
		3	Count
		1,088.13	Total
Rock - Oyster	1.95	543.86	
Rock - Oyster	1.95	1,913.88	
Rock - Oyster	1.95	352.39	
		3	Count
		2,810.13	Total
Sand	1.95	20,231.53	
Sand	1.95	701.77	
Sand	1.95	43.42	
Sand	1.95	278.06	
Sand	1.95	2,760.24	
Sand	1.95	135.55	
		6	Count
		24,150.59	Total
Halodule wrightii	2.05	6,232.43	
Halodule wrightii	2.05	7,484.63	
		2	Count
		13,717.06	Total
Rock - Oyster	2.05	71.56	
Rock - Oyster	2.05	4,755.71	
		2	Count
		4,827.27	Total
Sand	2.05	19,324.16	
Sand	2.05	1,641.08	
		2	Count
		20,965.25	Total
Rock - Oyster	2.15	11,834.04	
		1	Count
		11,834.04	Total
Halodule wrightii	2.15	995.96	
Halodule wrightii	2.15	8.96	
		2	Count
		1,004.92	Total
Sand	2.15	10,732.66	
Sand	2.15	2,322.41	
		2	Count
		13,055.07	Total
Sand and Rock	2.15	2,244.88	
Sand and Rock	2.15	160.32	
		2	Count
		2,405.20	Total
Rock - Oyster	2.25	65.23	
Rock - Oyster	2.25	11,376.06	
		2	Count
		11,441.29	Total
Sand	2.25	8,771.16	
Sand	2.25	672.18	
		2	Count
		9,443.34	Total

Sand and Rock	2.25	102.74	
Sand and Rock	2.25	59.21	
		2	Count
		161.94	Total
Rock - Oyster	2.35	10,168.20	
		1	Count
		10,168.20	Total
Sand	2.35	2,909.60	
Sand	2.35	7,270.36	
		2	Count
		10,179.96	Total
Sand and Rock	2.35	57.45	
Sand and Rock	2.35	59.70	
		2	Count
		117.15	Total
Organic surface	2.45	424.23	
		1	Count
		424.23	Total
Rock - Oyster	2.45	10,405.70	
		1	Count
		10,405.70	Total
Sand	2.45	5,557.22	
Sand	2.45	6,487.88	
		2	Count
		12,045.10	Total
Rock - Oyster	2.55	10,038.61	
		1	Count
		10,038.61	Total
Sand	2.55	6,394.44	
Sand	2.55	6,059.90	
		2	Count
		12,454.34	Total
Rock - Oyster	2.65	9,234.20	
Rock - Oyster	2.65	111.36	
		2	Count
		9,345.55	Total
Sand	2.65	2,849.99	
Sand	2.65	592.92	
Sand	2.65	6,493.34	
		3	Count
		9,936.25	Total
Organic surface	2.75	26.97	
		1	Count
		26.97	Total
Sand and Rock	2.75	162.09	
		1	Count
		162.09	Total
Rock - Oyster	2.75	10,853.55	
Rock - Oyster	2.75	54.62	
		2	Count
		10,908.17	Total
Sand	2.75	4,215.31	
Sand	2.75	1,664.66	
		2	Count

		5,879.96	Total
Organic surface	2.85	1,509.72	
		1	Count
		1,509.72	Total
Sand and Rock	2.85	2,611.08	
Sand and Rock	2.85	846.34	
		2	Count
		3,457.42	Total
Rock - Oyster	2.85	325.97	
Rock - Oyster	2.85	0.56	
Rock - Oyster	2.85	11,007.16	
		3	Count
		11,333.69	Total
Sand	2.85	1,164.94	
Sand	2.85	458.09	
Sand	2.85	1,332.78	
		3	Count
		2,955.82	Total
Sand	2.95	34.02	
Sand	2.95	3,544.43	
		2	Count
		3,578.45	Total
Sand and Rock	2.95	2,673.47	
Sand and Rock	2.95	3,884.06	
		2	Count
		6,557.53	Total
Rock - Oyster	2.95	321.96	
Rock - Oyster	2.95	173.20	
Rock - Oyster	2.95	10,163.12	
		3	Count
		10,658.28	Total
Rock - Oyster	3.05	7,487.42	
Rock - Oyster	3.05	27.33	
		2	Count
		7,514.76	Total
Sand	3.05	3,024.03	
Sand	3.05	3,846.96	
		2	Count
		6,870.99	Total
Sand and Rock	3.05	3,717.73	
Sand and Rock	3.05	3,041.98	
		2	Count
		6,759.70	Total
Rock - Oyster	3.15	829.47	
Rock - Oyster	3.15	9,344.02	
		2	Count
		10,173.48	Total
Sand and Rock	3.15	3,771.63	
Sand and Rock	3.15	905.13	
		2	Count
		4,676.76	Total
Sand	3.15	86.50	
Sand	3.15	2,857.72	
Sand	3.15	798.08	
Sand	3.15	2,577.87	

		4	Count
		6,320.16	Total
Organic surface	3.25	261.12	
		1	Count
		261.12	Total
Sand and Rock	3.25	3,189.26	
Sand and Rock	3.25	1,439.10	
		2	Count
		4,628.36	Total
Sand	3.25	2,012.61	
Sand	3.25	226.60	
Sand	3.25	2,071.19	
		3	Count
		4,310.40	Total
Rock - Oyster	3.25	11,297.72	
Rock - Oyster	3.25	92.50	
Rock - Oyster	3.25	352.35	
Rock - Oyster	3.25	40.56	
Rock - Oyster	3.25	555.53	
		5	Count
		12,338.65	Total
Organic surface	3.35	374.02	
Organic surface	3.35	903.15	
		2	Count
		1,277.17	Total
Sand and Rock	3.35	4,567.88	
Sand and Rock	3.35	2,985.82	
		2	Count
		7,553.70	Total
Rock - Oyster	3.35	891.97	
Rock - Oyster	3.35	12,779.27	
Rock - Oyster	3.35	550.83	
Rock - Oyster	3.35	314.96	
		4	Count
		14,537.03	Total
Sand	3.35	69.35	
Sand	3.35	2,617.53	
Sand	3.35	676.93	
Sand	3.35	2.20	
		4	Count
		3,366.02	Total
Organic surface	3.45	265.53	
Organic surface	3.45	141.14	
		2	Count
		406.67	Total
Rock - Oyster	3.45	1,641.92	
Rock - Oyster	3.45	14,103.36	
		2	Count
		15,745.28	Total
Sand	3.45	946.01	
Sand	3.45	5,930.68	
		2	Count
		6,876.68	Total
Sand and Rock	3.45	3,926.22	
Sand and Rock	3.45	2,291.24	
		2	Count

		6,217.47	Total
Organic surface	3.55	1,781.30	
		1	Count
		1,781.30	Total
Sand	3.55	4,605.28	
Sand	3.55	1,570.80	
		2	Count
		6,176.08	Total
Sand and Rock	3.55	2,716.08	
Sand and Rock	3.55	3,170.67	
		2	Count
		5,886.75	Total
Rock - Oyster	3.55	43.69	
Rock - Oyster	3.55	114.11	
Rock - Oyster	3.55	113.49	
Rock - Oyster	3.55	83.82	
Rock - Oyster	3.55	82.33	
Rock - Oyster	3.55	97.39	
Rock - Oyster	3.55	11,016.77	
		7	Count
		11,551.59	Total
Organic surface	3.65	860.60	
		1	Count
		860.60	Total
Halodule wrightii	3.65	247.43	
Halodule wrightii	3.65	753.26	
		2	Count
		1,000.70	Total
Sand and Rock	3.65	1,669.37	
Sand and Rock	3.65	1,675.22	
		2	Count
		3,344.60	Total
Sand	3.65	1,384.61	
Sand	3.65	317.60	
Sand	3.65	1,620.91	
		3	Count
		3,323.12	Total
Rock - Oyster	3.65	368.54	
Rock - Oyster	3.65	8,337.72	
Rock - Oyster	3.65	11.07	
Rock - Oyster	3.65	462.32	
		4	Count
		9,179.65	Total
Halodule wrightii	3.75	2,671.32	
Halodule wrightii	3.75	1,512.07	
		2	Count
		4,183.39	Total
Organic surface	3.75	27.05	
Organic surface	3.75	445.44	
		2	Count
		472.50	Total
Rock - Oyster	3.75	8,259.34	
Rock - Oyster	3.75	1,104.24	
		2	Count
		9,363.58	Total
Sand and Rock	3.75	3,821.51	

Sand and Rock	3.75	1,881.76	
		2	Count
		5,703.27	Total
Sand	3.75	31.98	
Sand	3.75	2,590.66	
Sand	3.75	24.24	
		3	Count
		2,646.88	Total
Halodule wrightii	3.85	26.55	
Halodule wrightii	3.85	402.74	
		2	Count
		429.29	Total
Organic surface	3.85	87.92	
Organic surface	3.85	511.67	
		2	Count
		599.60	Total
Rock - Oyster	3.85	8,045.47	
Rock - Oyster	3.85	295.59	
		2	Count
		8,341.06	Total
Sand	3.85	383.79	
Sand	3.85	1,781.20	
		2	Count
		2,164.99	Total
Sand and Rock	3.85	2,141.72	
Sand and Rock	3.85	5,037.32	
		2	Count
		7,179.04	Total
Halodule wrightii	3.95	721.36	
		1	Count
		721.36	Total
Organic surface	3.95	1,199.03	
		1	Count
		1,199.03	Total
Rock - Oyster	3.95	109.92	
Rock - Oyster	3.95	7,675.38	
		2	Count
		7,785.30	Total
Sand	3.95	2,600.40	
Sand	3.95	1,212.06	
		2	Count
		3,812.45	Total
Sand and Rock	3.95	2,436.67	
Sand and Rock	3.95	3,652.99	
		2	Count
		6,089.66	Total
Halodule wrightii	4.05	2,340.77	
		1	Count
		2,340.77	Total
Rock - Oyster	4.05	7,693.22	
		1	Count
		7,693.22	Total
Organic surface	4.05	582.92	
Organic surface	4.05	206.33	
		2	Count
		789.25	Total

Sand	4.05	234.62	
Sand	4.05	2,259.67	
		2	Count
		2,494.29	Total
Sand and Rock	4.05	3,003.60	
Sand and Rock	4.05	3,049.08	
		2	Count
		6,052.67	Total
Halodule wrightii	4.15	2,157.00	
		1	Count
		2,157.00	Total
Rock - Oyster	4.15	7,980.13	
		1	Count
		7,980.13	Total
Organic surface	4.15	1,049.72	
Organic surface	4.15	702.76	
		2	Count
		1,752.47	Total
Sand	4.15	341.77	
Sand	4.15	1,849.35	
		2	Count
		2,191.12	Total
Sand and Rock	4.15	2,251.04	
Sand and Rock	4.15	2,659.91	
		2	Count
		4,910.95	Total
Organic surface	4.25	8.43	
Organic surface	4.25	987.91	
		2	Count
		996.33	Total
Sand	4.25	1,407.13	
Sand	4.25	929.94	
		2	Count
		2,337.07	Total
Sand and Rock	4.25	2,049.07	
Sand and Rock	4.25	3,531.26	
		2	Count
		5,580.33	Total
Rock - Oyster	4.25	232.11	
Rock - Oyster	4.25	222.59	
Rock - Oyster	4.25	138.36	
Rock - Oyster	4.25	41.31	
Rock - Oyster	4.25	40.15	
Rock - Oyster	4.25	38.12	
Rock - Oyster	4.25	6,678.41	
		7	Count
		7,391.06	Total
Organic surface	4.35	1,161.78	
Organic surface	4.35	593.71	
		2	Count
		1,755.50	Total
Sand	4.35	3,410.67	
Sand	4.35	1,809.25	
		2	Count
		5,219.92	Total
Sand and Rock	4.35	1,579.51	

Sand and Rock	4.35	2,334.71	
		2	Count
		3,914.22	Total
Rock - Oyster	4.35	7,189.85	
Rock - Oyster	4.35	255.92	
Rock - Oyster	4.35	24.35	
		3	Count
		7,470.11	Total
Halodule wrightii	4.45	131.01	
		1	Count
		131.01	Total
Organic surface	4.45	66.78	
Organic surface	4.45	859.87	
		2	Count
		926.64	Total
Sand and Rock	4.45	1,184.99	
Sand and Rock	4.45	2,340.26	
		2	Count
		3,525.25	Total
Rock - Oyster	4.45	963.47	
Rock - Oyster	4.45	40.05	
Rock - Oyster	4.45	7,789.96	
		3	Count
		8,793.48	Total
Sand	4.45	2,893.27	
Sand	4.45	2,360.61	
Sand	4.45	122.14	
		3	Count
		5,376.01	Total
Halodule wrightii	4.55	2,265.40	
		1	Count
		2,265.40	Total
Sand and Rock	4.55	1,455.91	
Sand and Rock	4.55	2,393.64	
		2	Count
		3,849.54	Total
Organic surface	4.55	34.76	
Organic surface	4.55	654.10	
Organic surface	4.55	103.70	
		3	Count
		792.56	Total
Rock - Oyster	4.55	2.98	
Rock - Oyster	4.55	7,635.76	
Rock - Oyster	4.55	499.05	
		3	Count
		8,137.79	Total
Sand	4.55	1,471.56	
Sand	4.55	939.46	
Sand	4.55	786.96	
		3	Count
		3,197.98	Total
Halodule wrightii	4.65	1,291.87	
		1	Count
		1,291.87	Total
Sand	4.65	528.99	
Sand	4.65	238.65	

		2	Count
		767.64	Total
Sand and Rock	4.65	32.56	
Sand and Rock	4.65	2,843.89	
		2	Count
		2,876.45	Total
Organic surface	4.65	303.37	
Organic surface	4.65	823.71	
Organic surface	4.65	483.82	
		3	Count
		1,610.90	Total
Rock - Oyster	4.65	64.26	
Rock - Oyster	4.65	96.64	
Rock - Oyster	4.65	9,842.47	
Rock - Oyster	4.65	147.91	
		4	Count
		10,151.28	Total
Organic surface	4.75	1,387.45	
		1	Count
		1,387.45	Total
Rock - Oyster	4.75	9,402.12	
		1	Count
		9,402.12	Total
Halodule wrightii	4.75	46.71	
Halodule wrightii	4.75	736.24	
		2	Count
		782.95	Total
Sand	4.75	789.17	
Sand	4.75	493.27	
		2	Count
		1,282.43	Total
Sand and Rock	4.75	2,671.93	
Sand and Rock	4.75	368.90	
		2	Count
		3,040.83	Total
Rock - Oyster	4.85	7,655.98	
		1	Count
		7,655.98	Total
Sand and Rock	4.85	1,416.19	
Sand and Rock	4.85	2,538.89	
		2	Count
		3,955.08	Total
Halodule wrightii	4.85	1,852.19	
Halodule wrightii	4.85	1,610.43	
Halodule wrightii	4.85	333.84	
		3	Count
		3,796.45	Total
Organic surface	4.85	202.10	
Organic surface	4.85	45.85	
Organic surface	4.85	2,743.79	
		3	Count
		2,991.74	Total
Sand	4.85	62.66	
Sand	4.85	54.31	
Sand	4.85	528.72	
		3	Count

		645.69	Total
Halodule wrightii	4.95	1,925.82	
Halodule wrightii	4.95	430.71	
		2	Count
		2,356.54	Total
Organic surface	4.95	362.15	
Organic surface	4.95	27.22	
		2	Count
		389.37	Total
Sand and Rock	4.95	1,407.75	
Sand and Rock	4.95	1,871.23	
		2	Count
		3,278.98	Total
Rock - Oyster	4.95	315.33	
Rock - Oyster	4.95	141.05	
Rock - Oyster	4.95	7,891.38	
		3	Count
		8,347.76	Total
Sand	4.95	1,075.10	
Sand	4.95	467.68	
Sand	4.95	65.76	
		3	Count
		1,608.54	Total
Halodule wrightii	5.05	1,482.50	
		1	Count
		1,482.50	Total
Organic surface	5.05	965.63	
		1	Count
		965.63	Total
Sand and Rock	5.05	1,012.93	
		1	Count
		1,012.93	Total
Rock - Oyster	5.05	8,769.56	
Rock - Oyster	5.05	9.32	
		2	Count
		8,778.88	Total
Sand	5.05	1,583.66	
Sand	5.05	978.40	
		2	Count
		2,562.06	Total
Organic surface	5.15	555.78	
		1	Count
		555.78	Total
Rock - Oyster	5.15	8,043.82	
		1	Count
		8,043.82	Total
Sand and Rock	5.15	1,376.98	
		1	Count
		1,376.98	Total
Sand	5.15	1,142.27	
Sand	5.15	618.39	
Sand	5.15	1,128.62	
		3	Count
		2,889.27	Total
Halodule wrightii	5.15	566.76	
Halodule wrightii	5.15	2.17	

Halodule wrightii	5.15	182.91	
Halodule wrightii	5.15	75.71	
Halodule wrightii	5.15	176.65	
Halodule wrightii	5.15	9.40	
		6	Count
		1,013.60	Total
Rock - Oyster	5.25	8,356.59	
		1	Count
		8,356.59	Total
Sand and Rock	5.25	1,166.71	
		1	Count
		1,166.71	Total
Organic surface	5.25	104.13	
Organic surface	5.25	786.24	
		2	Count
		890.36	Total
Sand	5.25	1,291.86	
Sand	5.25	213.76	
		2	Count
		1,505.62	Total
Halodule wrightii	5.25	1.59	
Halodule wrightii	5.25	1,302.58	
Halodule wrightii	5.25	542.71	
Halodule wrightii	5.25	1,281.28	
Halodule wrightii	5.25	147.05	
Halodule wrightii	5.25	86.33	
		6	Count
		3,361.55	Total
Organic surface	5.35	211.02	
		1	Count
		211.02	Total
Rock - Oyster	5.35	9,063.02	
		1	Count
		9,063.02	Total
Sand and Rock	5.35	694.62	
		1	Count
		694.62	Total
Halodule wrightii	5.35	513.99	
Halodule wrightii	5.35	2,745.98	
Halodule wrightii	5.35	5.25	
		3	Count
		3,265.22	Total
Sand	5.35	67.59	
Sand	5.35	965.84	
Sand	5.35	296.92	
		3	Count
		1,330.35	Total
Halodule wrightii	5.45	682.03	
		1	Count
		682.03	Total
Organic surface	5.45	701.15	
		1	Count
		701.15	Total
Rock - Oyster	5.45	8,008.87	
		1	Count
		8,008.87	Total

Sand and Rock	5.45	1,620.24	
		1	Count
		1,620.24	Total
Sand	5.45	1,216.01	
Sand	5.45	347.12	
Sand	5.45	101.76	
Sand	5.45	1,515.27	
		4	Count
		3,180.16	Total
Organic surface	5.55	1,221.29	
		1	Count
		1,221.29	Total
Rock - Oyster	5.55	9,285.28	
		1	Count
		9,285.28	Total
Sand and Rock	5.55	1,276.02	
		1	Count
		1,276.02	Total
Sand	5.55	689.79	
Sand	5.55	1,996.04	
		2	Count
		2,685.83	Total
Organic surface	5.65	2,492.55	
		1	Count
		2,492.55	Total
Rock - Oyster	5.65	9,034.68	
		1	Count
		9,034.68	Total
Sand and Rock	5.65	1,774.42	
		1	Count
		1,774.42	Total
Sand	5.65	114.61	
Sand	5.65	120.57	
Sand	5.65	1,290.13	
Sand	5.65	686.23	
		4	Count
		2,211.54	Total
Halodule wrightii	5.75	913.01	
		1	Count
		913.01	Total
Organic surface	5.75	0.00	
		1	Count
		0.00	Total
Sand and Rock	5.75	1,763.94	
		1	Count
		1,763.94	Total
Rock - Oyster	5.75	50.60	
Rock - Oyster	5.75	8,042.76	
		2	Count
		8,093.36	Total
Sand	5.75	2,364.13	
Sand	5.75	1,981.79	
		2	Count
		4,345.91	Total
Rock - Oyster	5.85	6,598.70	

		1	Count
		6,598.70	Total
Sand and Rock	5.85	2,620.75	
		1	Count
		2,620.75	Total
Vallisneria americana	5.85	36.11	
		1	Count
		36.11	Total
Halodule wrightii	5.85	1,960.63	
Halodule wrightii	5.85	223.50	
		2	Count
		2,184.14	Total
Sand	5.85	68.47	
Sand	5.85	559.90	
Sand	5.85	1,060.50	
Sand	5.85	66.69	
		4	Count
		1,755.57	Total
Halodule wrightii	5.95	367.14	
		1	Count
		367.14	Total
Organic surface	5.95	905.36	
		1	Count
		905.36	Total
Sand	5.95	778.40	
		1	Count
		778.40	Total
Sand and Rock	5.95	3,334.53	
		1	Count
		3,334.53	Total
Rock - Oyster	5.95	371.24	
Rock - Oyster	5.95	6,218.78	
		2	Count
		6,590.02	Total
Vallisneria americana	5.95	268.07	
Vallisneria americana	5.95	423.65	
Vallisneria americana	5.95	3.65	
		3	Count
		695.37	Total
Organic surface	6.05	655.74	
		1	Count
		655.74	Total
Rock - Oyster	6.05	7,128.58	
		1	Count
		7,128.58	Total
Sand and Rock	6.05	1,888.03	
		1	Count
		1,888.03	Total
Vallisneria americana	6.05	227.66	
		1	Count
		227.66	Total
Halodule wrightii	6.05	702.71	
Halodule wrightii	6.05	564.36	
		2	Count
		1,267.07	Total
Sand	6.05	408.49	

Sand	6.05	27.88	
		2	Count
		436.37	Total
Rock - Oyster	6.15	8,420.17	
		1	Count
		8,420.17	Total
Sand and Rock	6.15	1,603.86	
		1	Count
		1,603.86	Total
Halodule wrightii	6.15	315.89	
Halodule wrightii	6.15	325.94	
		2	Count
		641.84	Total
Organic surface	6.15	174.55	
Organic surface	6.15	4,335.17	
		2	Count
		4,509.72	Total
Sand	6.15	846.77	
Sand	6.15	132.99	
		2	Count
		979.76	Total
Halodule wrightii	6.25	1,473.74	
		1	Count
		1,473.74	Total
Organic surface	6.25	910.29	
		1	Count
		910.29	Total
Rock - Oyster	6.25	9,000.69	
		1	Count
		9,000.69	Total
Sand and Rock	6.25	1,125.97	
		1	Count
		1,125.97	Total
Sand	6.25	561.81	
Sand	6.25	463.42	
		2	Count
		1,025.23	Total
Halodule wrightii	6.35	925.96	
		1	Count
		925.96	Total
Organic surface	6.35	12,622.24	
		1	Count
		12,622.24	Total
Rock - Oyster	6.35	12,923.73	
		1	Count
		12,923.73	Total
Sand and Rock	6.35	1,845.92	
		1	Count
		1,845.92	Total
Sand	6.35	221.94	
Sand	6.35	698.65	
		2	Count
		920.59	Total
Sand	6.45	154.02	
		1	Count

		154.02	Total
Sand and Rock	6.45	2,576.92	
		1	Count
		2,576.92	Total
Organic surface	6.45	4,267.76	
Organic surface	6.45	108,954.05	
		2	Count
		113,221.81	Total
Rock - Oyster	6.45	6,938.66	
Rock - Oyster	6.45	14,574.40	
		2	Count
		21,513.06	Total
Vallisneria americana	6.45	684.49	
Vallisneria americana	6.45	547.80	
		2	Count
		1,232.28	Total
Halodule wrightii	6.45	172.21	
Halodule wrightii	6.45	1,292.89	
Halodule wrightii	6.45	2,474.04	
Halodule wrightii	6.45	1,250.15	
		4	Count
		5,189.29	Total
Organic surface	6.55	1,993.24	
		1	Count
		1,993.24	Total
Rock - Oyster	6.55	9,815.27	
		1	Count
		9,815.27	Total
Sand	6.55	403.15	
		1	Count
		403.15	Total
Sand and Rock	6.55	230.68	
		1	Count
		230.68	Total
Halodule wrightii	6.55	783.95	
Halodule wrightii	6.55	2,188.62	
Halodule wrightii	6.55	331.10	
Halodule wrightii	6.55	258.48	
		4	Count
		3,562.14	Total
Organic surface	6.65	93.56	
		1	Count
		93.56	Total
Rock - Oyster	6.65	9,282.14	
		1	Count
		9,282.14	Total
Sand	6.65	158.77	
		1	Count
		158.77	Total
Halodule wrightii	6.65	1,721.31	
Halodule wrightii	6.65	1,129.96	
Halodule wrightii	6.65	703.76	
Halodule wrightii	6.65	851.84	
Halodule wrightii	6.65	1,827.68	
		5	Count
		6,234.54	Total

Organic surface	6.75	440.59	
		1	Count
		440.59	Total
Rock - Oyster	6.75	10,607.02	
		1	Count
		10,607.02	Total
Sand	6.75	1,815.93	
		1	Count
		1,815.93	Total
Halodule wrightii	6.75	1,299.39	
Halodule wrightii	6.75	310.86	
Halodule wrightii	6.75	301.32	
Halodule wrightii	6.75	759.23	
Halodule wrightii	6.75	328.49	
		5	Count
		2,999.29	Total
Rock - Oyster	6.85	9,368.97	
		1	Count
		9,368.97	Total
Vallisneria americana	6.85	154.05	
		1	Count
		154.05	Total
Organic surface	6.85	86.49	
Organic surface	6.85	131.55	
		2	Count
		218.03	Total
Halodule wrightii	6.85	1,982.61	
Halodule wrightii	6.85	469.71	
Halodule wrightii	6.85	1,933.15	
		3	Count
		4,385.47	Total
Sand	6.85	1,898.84	
Sand	6.85	285.35	
Sand	6.85	46.61	
		3	Count
		2,230.80	Total
Organic surface	6.95	697.32	
		1	Count
		697.32	Total
Rock - Oyster	6.95	7,718.46	
		1	Count
		7,718.46	Total
Vallisneria americana	6.95	2,645.42	
		1	Count
		2,645.42	Total
Sand	6.95	1,987.32	
Sand	6.95	364.78	
		2	Count
		2,352.10	Total
Halodule wrightii	6.95	360.40	
Halodule wrightii	6.95	1,195.89	
Halodule wrightii	6.95	1,094.14	
		3	Count
		2,650.42	Total
Halodule wrightii	7.05	44.49	
		1	Count

		44.49	Total
Organic surface	7.05	1,145.08	
		1	Count
		1,145.08	Total
Rock - Oyster	7.05	6,905.69	
		1	Count
		6,905.69	Total
Sand	7.05	3,177.85	
Sand	7.05	613.52	
		2	Count
		3,791.37	Total
Vallisneria americana	7.05	811.74	
Vallisneria americana	7.05	461.19	
Vallisneria americana	7.05	3,801.25	
Vallisneria americana	7.05	573.61	
		4	Count
		5,647.78	Total
Rock - Oyster	7.15	5,975.24	
		1	Count
		5,975.24	Total
Sand	7.15	1,013.53	
Sand	7.15	3,956.82	
Sand	7.15	55.88	
		3	Count
		5,026.23	Total
Vallisneria americana	7.15	644.48	
Vallisneria americana	7.15	1,645.86	
Vallisneria americana	7.15	3,454.55	
		3	Count
		5,744.89	Total
Organic surface	7.25	173.69	
		1	Count
		173.69	Total
Rock - Oyster	7.25	4,198.46	
		1	Count
		4,198.46	Total
Vallisneria americana	7.25	2,021.81	
Vallisneria americana	7.25	5,512.57	
		2	Count
		7,534.38	Total
Sand	7.25	0.02	
Sand	7.25	387.63	
Sand	7.25	9,822.94	
		3	Count
		10,210.58	Total
Organic surface	7.35	869.88	
		1	Count
		869.88	Total
Rock - Oyster	7.35	2,774.19	
		1	Count
		2,774.19	Total
Sand	7.35	12,856.76	
		1	Count
		12,856.76	Total
Vallisneria americana	7.35	2,524.97	
Vallisneria americana	7.35	4,004.46	

		2	Count
		6,529.44	Total
Organic surface	7.45	686.82	
		1	Count
		686.82	Total
Rock - Oyster	7.45	756.42	
		1	Count
		756.42	Total
Sand	7.45	15,155.73	
		1	Count
		15,155.73	Total
Vallisneria americana	7.45	3,930.07	
Vallisneria americana	7.45	1,284.74	
Vallisneria americana	7.45	0.00	
		3	Count
		5,214.82	Total
Organic surface	7.55	644.48	
		1	Count
		644.48	Total
Sand	7.55	14,855.56	
		1	Count
		14,855.56	Total
Vallisneria americana	7.55	309.13	
Vallisneria americana	7.55	1,129.70	
Vallisneria americana	7.55	3,448.87	
Vallisneria americana	7.55	82.41	
Vallisneria americana	7.55	1,108.49	
		5	Count
		6,078.60	Total
Halodule wrightii	7.65	236.20	
		1	Count
		236.20	Total
Organic surface	7.65	839.42	
		1	Count
		839.42	Total
Sand	7.65	126.20	
Sand	7.65	14,647.92	
		2	Count
		14,774.12	Total
Vallisneria americana	7.65	578.05	
Vallisneria americana	7.65	1,962.69	
Vallisneria americana	7.65	620.11	
		3	Count
		3,160.85	Total
Sand	7.75	15,391.45	
		1	Count
		15,391.45	Total
Vallisneria americana	7.75	384.70	
Vallisneria americana	7.75	357.28	
		2	Count
		741.98	Total
Halodule wrightii	7.85	173.67	
		1	Count
		173.67	Total

Sand	7.85	16,560.76	
		1	Count
		16,560.76	Total
Vallisneria americana	7.85	81.69	
Vallisneria americana	7.85	406.33	
Vallisneria americana	7.85	78.56	
		3	Count
		566.58	Total
Clay and Silt	7.95	47.20	
		1	Count
		47.20	Total
Halodule wrightii	7.95	141.93	
		1	Count
		141.93	Total
Sand	7.95	16,000.17	
		1	Count
		16,000.17	Total
Vallisneria americana	7.95	1,407.19	
Vallisneria americana	7.95	11.48	
		2	Count
		1,418.67	Total
Sand	8.05	14,752.56	
		1	Count
		14,752.56	Total
Clay and Silt	8.05	478.08	
Clay and Silt	8.05	378.33	
		2	Count
		856.41	Total
Vallisneria americana	8.05	511.25	
Vallisneria americana	8.05	3,669.56	
Vallisneria americana	8.05	1,702.30	
		3	Count
		5,883.12	Total
Clay and Silt	8.15	35.25	
		1	Count
		35.25	Total
Organic surface	8.15	282.60	
		1	
		282.60	
Sand	8.15	14,180.98	
		1	Count
		14,180.98	Total
Vallisneria americana	8.15	938.90	
Vallisneria americana	8.15	9,240.62	
Vallisneria americana	8.15	1,087.48	
		3	Count
		11,266.99	Total
Organic surface	8.25	107.11	
Organic surface	8.25	167.61	
		2	Count
		274.71	Total
Sand	8.25	134.85	
Sand	8.25	16,449.32	
		2	Count
		16,584.17	Total

Vallisneria americana	8.25	7,751.72	
Vallisneria americana	8.25	1,111.75	
Vallisneria americana	8.25	8,449.92	
		3	Count
		17,313.38	Total
Sand	8.35	16,592.74	
		1	Count
		16,592.74	Total
Organic surface	8.35	713.83	
Organic surface	8.35	469.37	
Organic surface	8.35	5,916.58	
		3	Count
		7,099.78	Total
Vallisneria americana	8.35	274.59	
Vallisneria americana	8.35	2,617.12	
Vallisneria americana	8.35	11,249.03	
Vallisneria americana	8.35	9,693.96	
		4	Count
		23,834.71	Total
Sand	8.45	15,112.00	
		1	Count
		15,112.00	Total
Organic surface	8.45	309.72	
Organic surface	8.45	21,406.88	
		2	Count
		21,716.60	Total
Vallisneria americana	8.45	2,144.42	
Vallisneria americana	8.45	10,379.32	
Vallisneria americana	8.45	8,907.92	
Vallisneria americana	8.45	773.01	
		4	Count
		22,204.67	Total
Sand	8.55	16,795.06	
		1	Count
		16,795.06	Total
Organic surface	8.55	351.07	
Organic surface	8.55	16,603.35	
		2	Count
		16,954.42	Total
Vallisneria americana	8.55	5,649.61	
Vallisneria americana	8.55	809.77	
Vallisneria americana	8.55	16,067.24	
		3	Count
		22,526.62	Total
Organic surface	8.65	333.70	
Organic surface	8.65	9,647.13	
		2	Count
		9,980.83	Total
Sand	8.65	905.31	
Sand	8.65	18,880.60	
		2	Count
		19,785.90	Total
Vallisneria americana	8.65	7,483.37	
Vallisneria americana	8.65	4,741.94	
		2	Count

		12,225.31	Total
Organic surface	8.75	276.71	
		1	Count
		276.71	Total
Sand	8.75	707.76	
Sand	8.75	17,054.19	
		2	Count
		17,761.95	Total
Vallisneria americana	8.75	6,492.20	
Vallisneria americana	8.75	6,422.21	
		2	Count
		12,914.41	Total
Organic surface	8.85	179.90	
Organic surface	8.85	46.99	
		2	Count
		226.89	Total
Sand	8.85	851.23	
Sand	8.85	16,866.37	
		2	Count
		17,717.60	Total
Vallisneria americana	8.85	9,812.04	
Vallisneria americana	8.85	3,747.82	
		2	Count
		13,559.86	Total
Sand	8.95	15,713.17	
		1	Count
		15,713.17	Total
Organic surface	8.95	708.58	
Organic surface	8.95	774.93	
		2	Count
		1,483.51	Total
Vallisneria americana	8.95	11,524.79	
Vallisneria americana	8.95	4,441.67	
		2	Count
		15,966.46	Total
Sand	9.05	16,877.40	
		1	Count
		16,877.40	Total
Organic surface	9.05	723.20	
Organic surface	9.05	890.29	
		2	Count
		1,613.49	Total
Vallisneria americana	9.05	9,234.94	
Vallisneria americana	9.05	3,641.79	
		2	Count
		12,876.72	Total
Sand	9.15	17,476.68	
		1	Count
		17,476.68	Total
Organic surface	9.15	1,028.86	
Organic surface	9.15	573.63	
		2	Count
		1,602.49	Total
Vallisneria americana	9.15	2,048.68	

Vallisneria americana	9.15	6,438.87	
Vallisneria americana	9.15	633.33	
		3	Count
		9,120.88	Total
Organic surface	9.25	701.04	
Organic surface	9.25	871.41	
		2	Count
		1,572.45	Total
Sand	9.25	739.83	
Sand	9.25	12,898.67	
		2	Count
		13,638.50	Total
Vallisneria americana	9.25	241.42	
Vallisneria americana	9.25	5,830.63	
Vallisneria americana	9.25	5,672.70	
		3	Count
		11,744.76	Total
Sand	9.35	470.95	
Sand	9.35	10,145.50	
		2	Count
		10,616.45	Total
Vallisneria americana	9.35	8,736.08	
Vallisneria americana	9.35	4,697.78	
		2	Count
		13,433.86	Total
Organic surface	9.35	6,690.94	
Organic surface	9.35	766.25	
Organic surface	9.35	110.16	
		3	Count
		7,567.35	Total
Sand	9.45	13,846.20	
		1	Count
		13,846.20	Total
Organic surface	9.45	606.96	
Organic surface	9.45	2,125.47	
		2	Count
		2,732.43	Total
Vallisneria americana	9.45	5,650.04	
Vallisneria americana	9.45	4,837.99	
		2	Count
		10,488.02	Total
Organic surface	9.55	597.23	
		1	Count
		597.23	Total
Sand	9.55	13,821.50	
		1	Count
		13,821.50	Total
Vallisneria americana	9.55	4,818.73	
Vallisneria americana	9.55	11,769.69	
Vallisneria americana	9.55	683.17	
		3	Count
		17,271.59	Total
Sand	9.65	16,949.19	
		1	Count

		16,949.19	Total
Organic surface	9.65	412.50	
Organic surface	9.65	144.80	
		2	Count
		557.30	Total
Vallisneria americana	9.65	16,864.81	
Vallisneria americana	9.65	8,014.83	
Vallisneria americana	9.65	67.60	
		3	Count
		24,947.24	Total
Sand	9.75	98.92	
Sand	9.75	16,055.17	
		2	Count
		16,154.09	Total
Vallisneria americana	9.75	12,306.72	
Vallisneria americana	9.75	23,973.52	
		2	Count
		36,280.24	Total
Organic surface	9.75	1,177.81	
Organic surface	9.75	7.50	
Organic surface	9.75	868.47	
		3	Count
		2,053.78	Total
Organic surface	9.85	347.06	
Organic surface	9.85	1,427.05	
		2	Count
		1,774.11	Total
Sand	9.85	571.06	
Sand	9.85	14,226.37	
		2	Count
		14,797.44	Total
Vallisneria americana	9.85	17,263.72	
Vallisneria americana	9.85	24,409.54	
		2	Count
		41,673.25	Total
Organic surface	9.95	1,764.62	
		1	Count
		1,764.62	Total
Sand	9.95	381.06	
Sand	9.95	13,992.15	
		2	Count
		14,373.21	Total
Vallisneria americana	9.95	6,156.91	
Vallisneria americana	9.95	8,300.80	
		2	Count
		14,457.72	Total
Organic surface	10.05	258.12	
		1	Count
		258.12	Total
Sand	10.05	25,144.38	
Sand	10.05	644.04	
		2	Count
		25,788.42	Total
Vallisneria americana	10.05	8,927.32	
Vallisneria americana	10.05	2,611.80	

		2	Count
		11,539.13	Total
Sand	10.15	19,476.86	
Sand	10.15	15.20	
		2	Count
		19,492.06	Total
Vallisneria americana	10.15	5,445.16	
Vallisneria americana	10.15	16,710.06	
		2	Count
		22,155.22	Total
Sand	10.25	750.34	
Sand	10.25	15,615.71	
		2	Count
		16,366.05	Total
Vallisneria americana	10.25	2,598.87	
Vallisneria americana	10.25	11,455.39	
		2	Count
		14,054.26	Total
		981	
		3,002,438.61	

Appendix C - EAV per 10 Meters of River Kilometer

Appendix C is provided as a separate data sheet/spreadsheet (in PDF and Excel format) showing the amount of shoreline vegetation that occurs within 100 meter intervals in the river up to kilometer 10.3. Shorelines types (both vegetation classes and altered types) are expressed in meters.

EAV Vegetation per 10 Meters of River

7/30/2010

FLUCS1	SEG_MID_	LENGTH_M	
Beach	0.05	122.79	
		1	Count
		122.79	Total
Juncus romerianus	0.05	30.94	
		1	Count
		30.94	Total
Spartina alterniflora	0.05	32.05	
Spartina alterniflora	0.05	71.09	
		2	Count
		103.14	Total
Beach	0.15	106.79	
		1	Count
		106.79	Total
Juncus romerianus	0.15	148.20	
		1	Count
		148.20	Total
Beach	0.25	98.68	
Beach	0.25	37.39	
		2	Count
		136.07	Total
Juncus romerianus	0.25	51.58	
Juncus romerianus	0.25	13.36	
Juncus romerianus	0.25	40.76	
		3	Count
		105.71	Total
Juncus romerianus	0.35	38.54	
		1	Count
		38.54	Total
Spartina alterniflora	0.35	34.49	
		1	Count
		34.49	Total
Beach	0.35	1.00	
Beach	0.35	111.81	
Beach	0.35	144.11	
		3	Count
		256.91	Total
Cladium jamaicense	0.45	6.10	
		1	Count
		6.10	Total
Beach	0.45	99.57	
Beach	0.45	78.68	
		2	Count
		178.25	Total
Beach	0.55	62.12	
		1	Count
		62.12	Total
Cladium jamaicense	0.55	18.56	
		1	Count

		18.56	Total
Juncus romerianus	0.55	38.28	
Juncus romerianus	0.55	10.37	
		2	Count
		48.64	Total
Ancient Reef Outcrops	0.65	139.79	
		1	Count
		139.79	Total
Spartina alterniflora	0.65	28.58	
		1	Count
		28.58	Total
Cladium jamaicense	0.65	26.49	
Cladium jamaicense	0.65	24.78	
		2	Count
		51.27	Total
Juncus romerianus	0.65	68.56	
Juncus romerianus	0.65	15.79	
		2	Count
		84.35	Total
Cladium jamaicense	0.75	28.14	
Cladium jamaicense	0.75	12.68	
		2	Count
		40.82	Total
Spartina alterniflora	0.75	12.70	
Spartina alterniflora	0.75	16.91	
		2	Count
		29.60	Total
Juncus romerianus	0.75	18.75	
Juncus romerianus	0.75	38.47	
Juncus romerianus	0.75	17.97	
Juncus romerianus	0.75	37.21	
		4	Count
		112.41	Total
Spartina alterniflora	0.85	58.23	
		1	Count
		58.23	Total
Juncus romerianus	0.85	20.72	
Juncus romerianus	0.85	105.30	
Juncus romerianus	0.85	19.05	
		3	Count
		145.08	Total
Cladium jamaicense	0.85	11.93	
Cladium jamaicense	0.85	10.04	
Cladium jamaicense	0.85	10.33	
Cladium jamaicense	0.85	76.94	
		4	Count
		109.24	Total
Juncus romerianus	0.95	15.37	
Juncus romerianus	0.95	16.02	
Juncus romerianus	0.95	84.89	
		3	Count
		116.28	Total
Cladium jamaicense	0.95	12.37	
Cladium jamaicense	0.95	33.86	
Cladium jamaicense	0.95	144.31	

Cladium jamaicense	0.95	13.36	
Cladium jamaicense	0.95	14.32	
Cladium jamaicense	0.95	0.89	
		6	Count
		219.12	Total
Spartina alterniflora	1.05	43.70	
		1	Count
		43.70	Total
Cladium jamaicense	1.05	38.40	
Cladium jamaicense	1.05	45.69	
Cladium jamaicense	1.05	42.84	
Cladium jamaicense	1.05	71.64	
		4	Count
		198.56	Total
Juncus romerianus	1.05	67.28	
Juncus romerianus	1.05	20.47	
Juncus romerianus	1.05	68.04	
Juncus romerianus	1.05	50.45	
Juncus romerianus	1.05	30.54	
		5	Count
		236.78	Total
Spartina alterniflora	1.15	50.46	
		1	Count
		50.46	Total
Cladium jamaicense	1.15	20.53	
Cladium jamaicense	1.15	0.60	
Cladium jamaicense	1.15	11.02	
		3	Count
		32.14	Total
Juncus romerianus	1.15	65.06	
Juncus romerianus	1.15	70.43	
Juncus romerianus	1.15	18.28	
Juncus romerianus	1.15	38.66	
		4	Count
		192.43	Total
Spartina alterniflora	1.25	99.76	
		1	Count
		99.76	Total
Cladium jamaicense	1.25	115.92	
Cladium jamaicense	1.25	35.12	
		2	Count
		151.04	Total
Juncus romerianus	1.25	42.72	
Juncus romerianus	1.25	59.55	
Juncus romerianus	1.25	15.32	
Juncus romerianus	1.25	2.86	
Juncus romerianus	1.25	6.54	
		5	Count
		126.98	Total
Cladium jamaicense	1.35	49.86	
		1	Count
		49.86	Total
Juncus romerianus	1.35	45.36	
Juncus romerianus	1.35	34.29	
		2	Count

		79.65	Total
Spartina alterniflora	1.35	30.13	
Spartina alterniflora	1.35	114.53	
Spartina alterniflora	1.35	18.90	
		3	Count
		163.55	Total
Ancient Reef Outcrops	1.45	167.21	
		1	Count
		167.21	Total
Cladium jamaicense	1.45	10.90	
Cladium jamaicense	1.45	26.02	
		2	Count
		36.91	Total
Spartina alterniflora	1.45	33.44	
Spartina alterniflora	1.45	21.09	
		2	Count
		54.52	Total
Juncus romerianus	1.45	41.46	
Juncus romerianus	1.45	50.98	
Juncus romerianus	1.45	74.14	
Juncus romerianus	1.45	22.98	
Juncus romerianus	1.45	54.92	
Juncus romerianus	1.45	83.75	
		6	Count
		328.23	Total
Cladium jamaicense	1.55	64.59	
		1	Count
		64.59	Total
Spartina alterniflora	1.55	80.81	
Spartina alterniflora	1.55	60.27	
		2	Count
		141.08	Total
Juncus romerianus	1.55	13.02	
Juncus romerianus	1.55	3.94	
Juncus romerianus	1.55	15.04	
Juncus romerianus	1.55	183.75	
Juncus romerianus	1.55	37.40	
		5	Count
		253.15	Total
Cladium jamaicense	1.65	0.07	
Cladium jamaicense	1.65	10.77	
		2	Count
		10.84	Total
Spartina alterniflora	1.65	38.83	
Spartina alterniflora	1.65	28.27	
		2	Count
		67.10	Total
Juncus romerianus	1.65	74.29	
Juncus romerianus	1.65	27.43	
Juncus romerianus	1.65	57.63	
Juncus romerianus	1.65	37.93	
		4	Count
		197.29	Total
Cladium jamaicense	1.75	29.52	
Cladium jamaicense	1.75	45.40	

		2	Count
		74.92	Total
Spartina alterniflora	1.75	47.51	
Spartina alterniflora	1.75	18.14	
		2	Count
		65.64	Total
Juncus romerianus	1.75	36.34	
Juncus romerianus	1.75	76.67	
Juncus romerianus	1.75	16.50	
Juncus romerianus	1.75	33.73	
Juncus romerianus	1.75	12.82	
Juncus romerianus	1.75	92.00	
		6	Count
		268.06	Total
Cladium jamaicense	1.85	76.37	
		1	Count
		76.37	Total
Spartina alterniflora	1.85	77.98	
		1	Count
		77.98	Total
Juncus romerianus	1.85	20.96	
Juncus romerianus	1.85	31.09	
Juncus romerianus	1.85	20.47	
		3	Count
		72.51	Total
Spartina alterniflora	1.95	38.55	
		1	Count
		38.55	Total
Juncus romerianus	1.95	109.27	
Juncus romerianus	1.95	8.11	
Juncus romerianus	1.95	122.57	
		3	Count
		239.95	Total
Juncus romerianus	2.05	44.33	
Juncus romerianus	2.05	72.35	
		2	Count
		116.67	Total
Spartina alterniflora	2.05	40.85	
Spartina alterniflora	2.05	46.52	
Spartina alterniflora	2.05	28.10	
Spartina alterniflora	2.05	18.58	
		4	Count
		134.06	Total
Beach	2.15	104.63	
		1	Count
		104.63	Total
Juncus romerianus	2.15	23.62	
Juncus romerianus	2.15	17.65	
		2	Count
		41.26	Total
Spartina alterniflora	2.15	14.91	
Spartina alterniflora	2.15	13.37	
Spartina alterniflora	2.15	12.90	
Spartina alterniflora	2.15	44.72	
		4	Count

		85.89	Total
Beach	2.25	33.38	
		1	Count
		33.38	Total
Juniperus silicicola	2.25	39.55	
		1	Count
		39.55	Total
Spartina alterniflora	2.25	66.58	
Spartina alterniflora	2.25	43.91	
Spartina alterniflora	2.25	30.08	
		3	Count
		140.57	Total
Beach	2.35	11.49	
		1	Count
		11.49	Total
Juncus romerianus	2.35	12.53	
		1	Count
		12.53	Total
Juniperus silicicola	2.35	92.76	
		1	Count
		92.76	Total
Spartina alterniflora	2.35	54.65	
Spartina alterniflora	2.35	40.20	
		2	Count
		94.85	Total
Juniperus silicicola	2.45	81.34	
		1	Count
		81.34	Total
Spartina alterniflora	2.45	50.00	
Spartina alterniflora	2.45	19.28	
		2	Count
		69.28	Total
Cladium jamaicense	2.45	19.48	
Cladium jamaicense	2.45	2.38	
Cladium jamaicense	2.45	10.60	
		3	Count
		32.46	Total
Juncus romerianus	2.45	15.59	
Juncus romerianus	2.45	18.99	
Juncus romerianus	2.45	30.21	
Juncus romerianus	2.45	19.09	
Juncus romerianus	2.45	34.07	
		5	Count
		117.95	Total
Cladium jamaicense	2.55	27.12	
		1	Count
		27.12	Total
Juncus romerianus	2.55	106.54	
Juncus romerianus	2.55	66.50	
		2	Count
		173.03	Total
Cladium jamaicense	2.65	19.68	
		1	Count
		19.68	Total

Spartina alterniflora	2.65	53.40	
		1	Count
		53.40	Total
Juncus romerianus	2.65	10.04	
Juncus romerianus	2.65	55.67	
Juncus romerianus	2.65	15.41	
Juncus romerianus	2.65	101.59	
		4	Count
		182.70	Total
Spartina alterniflora	2.75	12.75	
Spartina alterniflora	2.75	18.14	
		2	Count
		30.90	Total
Juncus romerianus	2.75	10.49	
Juncus romerianus	2.75	69.78	
Juncus romerianus	2.75	14.50	
Juncus romerianus	2.75	91.20	
		4	Count
		185.96	Total
Ancient Reef Outcrops	2.85	48.73	
		1	Count
		48.73	Total
Juncus romerianus	2.85	12.59	
Juncus romerianus	2.85	41.98	
Juncus romerianus	2.85	45.88	
Juncus romerianus	2.85	10.53	
		4	Count
		110.97	Total
Spartina alterniflora	2.85	50.81	
Spartina alterniflora	2.85	23.41	
Spartina alterniflora	2.85	55.89	
Spartina alterniflora	2.85	55.10	
		4	Count
		185.21	Total
Juncus romerianus	2.95	14.53	
Juncus romerianus	2.95	62.96	
		2	Count
		77.49	Total
Spartina alterniflora	2.95	93.57	
Spartina alterniflora	2.95	54.77	
		2	Count
		148.33	Total
Juncus romerianus	3.05	118.99	
		1	Count
		118.99	Total
Spartina alterniflora	3.05	7.54	
Spartina alterniflora	3.05	16.56	
Spartina alterniflora	3.05	36.99	
Spartina alterniflora	3.05	16.05	
		4	Count
		77.13	Total
Juncus romerianus	3.15	147.41	
		1	Count
		147.41	Total

Spartina alterniflora	3.15	67.21	
		1	Count
		67.21	Total
Spartina alterniflora	3.25	118.30	
		1	Count
		118.30	Total
Juncus romerianus	3.25	8.70	
Juncus romerianus	3.25	30.27	
Juncus romerianus	3.25	107.13	
		3	Count
		146.11	Total
Spartina alterniflora	3.35	40.63	
		1	Count
		40.63	Total
Juncus romerianus	3.35	66.46	
Juncus romerianus	3.35	5.84	
Juncus romerianus	3.35	4.29	
Juncus romerianus	3.35	86.71	
		4	Count
		163.30	Total
Juncus romerianus	3.45	64.94	
Juncus romerianus	3.45	12.44	
		2	Count
		77.38	Total
Spartina alterniflora	3.45	9.45	
Spartina alterniflora	3.45	18.58	
Spartina alterniflora	3.45	87.07	
Spartina alterniflora	3.45	38.87	
		4	Count
		153.97	Total
Juncus romerianus	3.55	49.26	
Juncus romerianus	3.55	34.68	
Juncus romerianus	3.55	53.66	
		3	Count
		137.60	Total
Spartina alterniflora	3.55	95.56	
Spartina alterniflora	3.55	35.99	
Spartina alterniflora	3.55	2.79	
		3	Count
		134.34	Total
Spartina alterniflora	3.65	70.71	
Spartina alterniflora	3.65	18.25	
Spartina alterniflora	3.65	33.40	
		3	Count
		122.36	Total
Juncus romerianus	3.65	23.71	
Juncus romerianus	3.65	29.92	
Juncus romerianus	3.65	40.16	
Juncus romerianus	3.65	26.94	
		4	Count
		120.73	Total
Spartina alterniflora	3.75	82.18	
Spartina alterniflora	3.75	18.02	

Spartina alterniflora	3.75	12.49	
Spartina alterniflora	3.75	30.87	
Spartina alterniflora	3.75	78.95	
		5	Count
		222.51	Total
Juncus romerianus	3.85	29.70	
Juncus romerianus	3.85	43.48	
Juncus romerianus	3.85	140.44	
		3	Count
		213.62	Total
Spartina alterniflora	3.85	45.21	
Spartina alterniflora	3.85	59.45	
Spartina alterniflora	3.85	8.66	
		3	Count
		113.31	Total
Spartina alterniflora	3.95	29.69	
Spartina alterniflora	3.95	56.85	
		2	Count
		86.55	Total
Juncus romerianus	3.95	63.83	
Juncus romerianus	3.95	41.30	
Juncus romerianus	3.95	50.30	
Juncus romerianus	3.95	50.66	
		4	Count
		206.10	Total
Spartina alterniflora	4.05	17.70	
Spartina alterniflora	4.05	40.39	
		2	Count
		58.09	Total
Juncus romerianus	4.05	75.47	
Juncus romerianus	4.05	46.77	
Juncus romerianus	4.05	52.78	
Juncus romerianus	4.05	29.70	
Juncus romerianus	4.05	9.59	
		5	Count
		214.32	Total
Spartina alterniflora	4.15	35.98	
		1	Count
		35.98	Total
Juncus romerianus	4.15	15.81	
Juncus romerianus	4.15	19.58	
Juncus romerianus	4.15	17.80	
Juncus romerianus	4.15	54.01	
Juncus romerianus	4.15	123.50	
		5	Count
		230.69	Total
Juncus romerianus	4.25	20.29	
Juncus romerianus	4.25	6.60	
Juncus romerianus	4.25	68.20	
		3	Count
		95.09	Total
Spartina alterniflora	4.25	37.83	
Spartina alterniflora	4.25	63.67	
Spartina alterniflora	4.25	11.46	

Spartina alterniflora	4.25	15.67	
		4	Count
		128.62	Total
Juncus romerianus	4.35	10.44	
		1	Count
		10.44	Total
Spartina alterniflora	4.35	43.22	
Spartina alterniflora	4.35	68.03	
Spartina alterniflora	4.35	35.10	
Spartina alterniflora	4.35	164.06	
		4	Count
		310.41	Total
Spartina alterniflora	4.45	10.33	
Spartina alterniflora	4.45	8.94	
Spartina alterniflora	4.45	9.60	
Spartina alterniflora	4.45	16.95	
		4	Count
		45.83	Total
Juncus romerianus	4.45	5.07	
Juncus romerianus	4.45	36.53	
Juncus romerianus	4.45	47.10	
Juncus romerianus	4.45	18.82	
Juncus romerianus	4.45	95.01	
		5	Count
		202.53	Total
Ancient Reef Outcrops	4.55	45.52	
		1	Count
		45.52	Total
Beach	4.55	12.62	
		1	Count
		12.62	Total
Juncus romerianus	4.55	13.36	
		1	Count
		13.36	Total
Spartina alterniflora	4.55	128.18	
Spartina alterniflora	4.55	58.16	
		2	Count
		186.34	Total
Beach	4.65	20.19	
		1	Count
		20.19	Total
Juncus romerianus	4.65	86.55	
Juncus romerianus	4.65	5.90	
Juncus romerianus	4.65	5.89	
		3	Count
		98.34	Total
Spartina alterniflora	4.65	10.90	
Spartina alterniflora	4.65	14.18	
Spartina alterniflora	4.65	48.38	
Spartina alterniflora	4.65	16.66	
Spartina alterniflora	4.65	19.02	
		5	Count
		109.14	Total
Juncus romerianus	4.75	26.09	

Juncus romerianus	4.75	7.64	
Juncus romerianus	4.75	17.02	
		3	Count
		50.74	Total
Spartina alterniflora	4.75	28.04	
Spartina alterniflora	4.75	50.49	
Spartina alterniflora	4.75	149.30	
		3	Count
		227.83	Total
Juncus romerianus	4.85	11.94	
Juncus romerianus	4.85	51.66	
Juncus romerianus	4.85	38.39	
Juncus romerianus	4.85	34.43	
		4	Count
		136.42	Total
Spartina alterniflora	4.85	35.18	
Spartina alterniflora	4.85	20.96	
Spartina alterniflora	4.85	10.59	
Spartina alterniflora	4.85	17.56	
Spartina alterniflora	4.85	46.36	
Spartina alterniflora	4.85	29.74	
		6	Count
		160.41	Total
Juncus romerianus	4.95	29.60	
		1	Count
		29.60	Total
Ancient Reef Outcrops	4.95	2.22	
Ancient Reef Outcrops	4.95	35.18	
		2	Count
		37.40	Total
Spartina alterniflora	4.95	102.81	
Spartina alterniflora	4.95	0.97	
Spartina alterniflora	4.95	11.78	
Spartina alterniflora	4.95	13.37	
Spartina alterniflora	4.95	18.59	
Spartina alterniflora	4.95	66.24	
		6	Count
		213.76	Total
Bottomland Hardwood	5.05	44.92	
		1	Count
		44.92	Total
Ancient Reef Outcrops	5.05	26.10	
Ancient Reef Outcrops	5.05	48.11	
		2	Count
		74.21	Total
Spartina alterniflora	5.05	24.22	
Spartina alterniflora	5.05	104.27	
Spartina alterniflora	5.05	6.69	
Spartina alterniflora	5.05	20.91	
		4	Count
		156.09	Total
Bottomland Hardwood	5.15	6.47	
		1	Count
		6.47	Total
Seawall	5.15	53.91	

		1	Count
		53.91	Total
Juncus romerianus	5.15	12.75	
Juncus romerianus	5.15	19.09	
		2	Count
		31.84	Total
Spartina alterniflora	5.15	25.05	
Spartina alterniflora	5.15	47.30	
Spartina alterniflora	5.15	60.39	
Spartina alterniflora	5.15	24.73	
Spartina alterniflora	5.15	54.77	
		5	Count
		212.24	Total
Juncus romerianus	5.25	46.83	
		1	Count
		46.83	Total
Spartina alterniflora	5.25	16.45	
Spartina alterniflora	5.25	18.57	
Spartina alterniflora	5.25	36.92	
Spartina alterniflora	5.25	30.26	
Spartina alterniflora	5.25	99.12	
		5	Count
		201.32	Total
Spartina alterniflora	5.35	119.80	
Spartina alterniflora	5.35	4.30	
Spartina alterniflora	5.35	120.52	
		3	Count
		244.62	Total
Sabal palmetto	5.45	19.92	
		1	Count
		19.92	Total
Spartina alterniflora	5.45	5.97	
Spartina alterniflora	5.45	106.84	
Spartina alterniflora	5.45	97.57	
		3	Count
		210.39	Total
Sabal palmetto	5.55	17.37	
		1	Count
		17.37	Total
Juncus romerianus	5.55	17.27	
Juncus romerianus	5.55	13.14	
		2	Count
		30.41	Total
Spartina alterniflora	5.55	98.08	
Spartina alterniflora	5.55	32.77	
Spartina alterniflora	5.55	15.67	
Spartina alterniflora	5.55	63.31	
		4	Count
		209.83	Total
Juncus romerianus	5.65	57.41	
		1	Count
		57.41	Total
Juniperus silicicola	5.65	47.69	
		1	Count

		47.69	Total
Spartina alterniflora	5.65	73.50	
Spartina alterniflora	5.65	69.74	
Spartina alterniflora	5.65	15.44	
		3	Count
		158.68	Total
Ancient Reef Outcrops	5.75	102.44	
		1	Count
		102.44	Total
Juniperus silicicola	5.75	4.29	
		1	Count
		4.29	Total
Sabal palmetto	5.75	100.43	
		1	Count
		100.43	Total
Spartina alterniflora	5.75	22.01	
Spartina alterniflora	5.75	36.54	
Spartina alterniflora	5.75	42.31	
Spartina alterniflora	5.75	4.62	
Spartina alterniflora	5.75	23.68	
Spartina alterniflora	5.75	18.12	
		6	Count
		147.28	Total
Ancient Reef Outcrops	5.85	327.22	
		1	Count
		327.22	Total
Juniperus silicicola	5.85	74.24	
		1	Count
		74.24	Total
Spartina alterniflora	5.85	56.10	
		1	Count
		56.10	Total
Ancient Reef Outcrops	5.95	14.00	
		1	Count
		14.00	Total
Juncus romerianus	5.95	71.76	
		1	Count
		71.76	Total
Sabal palmetto	5.95	38.66	
		1	Count
		38.66	Total
Seawall	5.95	142.39	
		1	Count
		142.39	Total
Spartina alterniflora	5.95	74.77	
		1	Count
		74.77	Total
Seawall	6.05	19.53	
		1	Count
		19.53	Total
Spartina alterniflora	6.05	27.10	
Spartina alterniflora	6.05	50.34	
Spartina alterniflora	6.05	14.04	
		3	Count

		91.49	Total
Juncus romerianus	6.05	18.49	
Juncus romerianus	6.05	18.35	
Juncus romerianus	6.05	36.03	
Juncus romerianus	6.05	19.17	
		4	Count
		92.04	Total
Cladium jamaicense	6.15	136.45	
		1	Count
		136.45	Total
Seawall	6.15	138.70	
		1	Count
		138.70	Total
Juncus romerianus	6.15	11.87	
Juncus romerianus	6.15	27.38	
		2	Count
		39.24	Total
Rip-Rap	6.15	26.13	
Rip-Rap	6.15	27.57	
		2	Count
		53.69	Total
Spartina alterniflora	6.15	66.05	
Spartina alterniflora	6.15	33.94	
		2	Count
		99.99	Total
Sabal palmetto	6.25	14.82	
		1	Count
		14.82	Total
Beach	6.25	11.94	
Beach	6.25	8.66	
		2	Count
		20.60	Total
Juncus romerianus	6.25	13.93	
Juncus romerianus	6.25	66.20	
		2	Count
		80.14	Total
Spartina alterniflora	6.25	9.82	
Spartina alterniflora	6.25	53.87	
Spartina alterniflora	6.25	41.39	
		3	Count
		105.07	Total
Beach	6.35	13.05	
		1	Count
		13.05	Total
Juniperus silicicola	6.35	12.58	
		1	Count
		12.58	Total
Sabal palmetto	6.35	11.44	
		1	Count
		11.44	Total
Cladium jamaicense	6.35	126.05	
Cladium jamaicense	6.35	34.05	
		2	Count
		160.10	Total
Juncus romerianus	6.35	62.59	
Juncus romerianus	6.35	100.88	

Juncus romerianus	6.35	42.95	
Juncus romerianus	6.35	2.67	
		4	Count
		209.09	Total
Spartina alterniflora	6.35	55.26	
Spartina alterniflora	6.35	71.38	
Spartina alterniflora	6.35	35.25	
Spartina alterniflora	6.35	25.45	
Spartina alterniflora	6.35	4.09	
Spartina alterniflora	6.35	16.45	
		6	Count
		207.88	Total
Ancient Reef Outcrops	6.45	61.75	
		1	Count
		61.75	Total
Bottomland Hardwood	6.45	44.19	
		1	Count
		44.19	Total
Typha domingensis	6.45	83.60	
		1	Count
		83.60	Total
Sabal palmetto	6.45	23.32	
Sabal palmetto	6.45	81.22	
		2	Count
		104.54	Total
Seawall	6.45	140.83	
Seawall	6.45	359.34	
		2	Count
		500.17	Total
Juncus romerianus	6.45	59.47	
Juncus romerianus	6.45	45.82	
Juncus romerianus	6.45	99.25	
Juncus romerianus	6.45	6.77	
Juncus romerianus	6.45	23.42	
Juncus romerianus	6.45	42.73	
Juncus romerianus	6.45	30.98	
Juncus romerianus	6.45	38.17	
		8	Count
		346.61	Total
Spartina alterniflora	6.45	11.27	
Spartina alterniflora	6.45	10.95	
Spartina alterniflora	6.45	70.94	
Spartina alterniflora	6.45	33.23	
Spartina alterniflora	6.45	12.59	
Spartina alterniflora	6.45	53.71	
Spartina alterniflora	6.45	30.12	
Spartina alterniflora	6.45	39.03	
		8	Count
		261.84	Total
Cladium jamaicense	6.45	35.75	
Cladium jamaicense	6.45	66.10	
Cladium jamaicense	6.45	133.33	
Cladium jamaicense	6.45	122.66	
Cladium jamaicense	6.45	22.56	
Cladium jamaicense	6.45	31.37	
Cladium jamaicense	6.45	186.96	
Cladium jamaicense	6.45	88.15	

Cladium jamaicense	6.45	146.74	
		9	Count
		833.62	Total
Juniperus silicicola	6.55	21.31	
		1	Count
		21.31	Total
Seawall	6.55	66.20	
		1	Count
		66.20	Total
Cladium jamaicense	6.55	28.69	
Cladium jamaicense	6.55	72.24	
		2	Count
		100.93	Total
Juncus romerianus	6.55	15.78	
Juncus romerianus	6.55	11.75	
		2	Count
		27.53	Total
Spartina alterniflora	6.55	25.22	
Spartina alterniflora	6.55	28.18	
Spartina alterniflora	6.55	12.72	
		3	Count
		66.13	Total
Cladium jamaicense	6.65	74.19	
		1	Count
		74.19	Total
Rip-Rap	6.65	53.58	
		1	Count
		53.58	Total
Sabal palmetto	6.65	12.90	
		1	Count
		12.90	Total
Spartina alterniflora	6.65	93.38	
		1	Count
		93.38	Total
Rip-Rap	6.75	20.33	
		1	Count
		20.33	Total
Spartina alterniflora	6.75	105.11	
		1	Count
		105.11	Total
Seawall	6.75	42.19	
Seawall	6.75	24.91	
		2	Count
		67.10	Total
Cladium jamaicense	6.85	25.41	
		1	Count
		25.41	Total
Juncus romerianus	6.85	47.33	
		1	Count
		47.33	Total
Seawall	6.85	2.12	
		1	Count
		2.12	Total
Spartina alterniflora	6.85	63.67	
Spartina alterniflora	6.85	42.18	

Spartina alterniflora	6.85	26.84	
Spartina alterniflora	6.85	12.96	
		4	Count
		145.65	Total
Juncus romerianus	6.95	39.03	
		1	Count
		39.03	Total
Spartina alterniflora	6.95	11.69	
Spartina alterniflora	6.95	66.57	
Spartina alterniflora	6.95	6.93	
Spartina alterniflora	6.95	32.22	
Spartina alterniflora	6.95	40.27	
Spartina alterniflora	6.95	34.86	
		6	Count
		192.54	Total
Beach	7.05	80.60	
		1	Count
		80.60	Total
Spartina alterniflora	7.05	14.38	
Spartina alterniflora	7.05	83.70	
Spartina alterniflora	7.05	15.46	
Spartina alterniflora	7.05	15.49	
		4	Count
		129.03	Total
Spartina alterniflora	7.15	99.76	
Spartina alterniflora	7.15	56.80	
Spartina alterniflora	7.15	55.97	
		3	Count
		212.53	Total
Cladium jamaicense	7.25	65.72	
Cladium jamaicense	7.25	13.50	
Cladium jamaicense	7.25	18.69	
		3	Count
		97.91	Total
Spartina alterniflora	7.25	29.15	
Spartina alterniflora	7.25	9.53	
Spartina alterniflora	7.25	27.93	
Spartina alterniflora	7.25	36.09	
Spartina alterniflora	7.25	31.23	
Spartina alterniflora	7.25	20.40	
		6	Count
		154.33	Total
Spartina alterniflora	7.35	12.42	
		1	Count
		12.42	Total
Cladium jamaicense	7.35	28.15	
Cladium jamaicense	7.35	12.61	
Cladium jamaicense	7.35	115.11	
Cladium jamaicense	7.35	52.98	
		4	Count
		208.85	Total
Sabal palmetto	7.45	15.09	
		1	Count

		15.09	Total
Seawall	7.45	93.85	
		1	Count
		93.85	Total
Cladium jamaicense	7.45	17.57	
Cladium jamaicense	7.45	23.40	
Cladium jamaicense	7.45	33.03	
Cladium jamaicense	7.45	27.06	
		4	
		101.06	
Seawall	7.55	196.58	
		1	Count
		196.58	Total
Cladium jamaicense	7.55	28.89	
Cladium jamaicense	7.55	8.27	
Cladium jamaicense	7.55	28.37	
		3	Count
		65.53	Total
Seawall	7.65	109.43	
		1	Count
		109.43	Total
Cladium jamaicense	7.65	32.36	
Cladium jamaicense	7.65	21.41	
		2	Count
		53.77	Total
Juniperus silicicola	7.65	42.24	
Juniperus silicicola	7.65	3.90	
		2	Count
		46.14	Total
Cladium jamaicense	7.75	33.59	
		1	Count
		33.59	Total
Juniperus silicicola	7.75	70.57	
		1	Count
		70.57	Total
Rip-Rap	7.75	43.52	
		1	Count
		43.52	Total
Seawall	7.75	33.57	
		1	Count
		33.57	Total
Beach	7.85	23.58	
		1	Count
		23.58	Total
Seawall	7.85	102.74	
		1	Count
		102.74	Total
Cladium jamaicense	7.85	68.54	
Cladium jamaicense	7.85	14.75	
		2	Count
		83.29	Total
Beach	7.95	7.13	
		1	Count
		7.13	Total

Rip-Rap	7.95	56.95	
		1	Count
		56.95	Total
Sabal palmetto	7.95	107.13	
		1	Count
		107.13	Total
Spartina alterniflora	7.95	16.74	
		1	Count
		16.74	Total
Sabal palmetto	8.05	37.59	
		1	Count
		37.59	Total
Seawall	8.05	39.75	
		1	Count
		39.75	Total
Spartina alterniflora	8.05	68.21	
		1	Count
		68.21	Total
Cladium jamaicense	8.05	75.02	
Cladium jamaicense	8.05	15.24	
		2	Count
		90.26	Total
Seawall	8.15	26.65	
Seawall	8.15	59.12	
		2	Count
		85.77	Total
Cladium jamaicense	8.15	77.23	
Cladium jamaicense	8.15	8.65	
Cladium jamaicense	8.15	38.38	
		3	Count
		124.26	Total
Seawall	8.25	28.20	
		1	Count
		28.20	Total
Cladium jamaicense	8.25	93.67	
Cladium jamaicense	8.25	109.20	
		2	Count
		202.87	Total
Typha domingensis	8.35	59.60	
		1	Count
		59.60	Total
Cladium jamaicense	8.35	41.59	
Cladium jamaicense	8.35	45.32	
Cladium jamaicense	8.35	129.35	
Cladium jamaicense	8.35	121.71	
		4	Count
		337.98	Total
Cladium jamaicense	8.45	68.60	
Cladium jamaicense	8.45	190.00	
		2	Count
		258.61	Total
Juniperus silicicola	8.55	22.11	
		1	Count

		22.11	Total
Cladium jamaicense	8.55	47.45	
Cladium jamaicense	8.55	121.74	
Cladium jamaicense	8.55	65.48	
		3	Count
		234.68	Total
Beach	8.65	69.85	
		1	Count
		69.85	Total
Bottomland Hardwood	8.65	44.55	
		1	Count
		44.55	Total
Cladium jamaicense	8.65	74.41	
Cladium jamaicense	8.65	76.67	
Cladium jamaicense	8.65	22.17	
Cladium jamaicense	8.65	40.19	
Cladium jamaicense	8.65	48.86	
Cladium jamaicense	8.65	29.44	
Cladium jamaicense	8.65	21.36	
		7	Count
		313.09	Total
Bottomland Hardwood	8.75	46.00	
		1	Count
		46.00	Total
Cladium jamaicense	8.75	57.30	
Cladium jamaicense	8.75	4.16	
Cladium jamaicense	8.75	12.86	
Cladium jamaicense	8.75	106.97	
		4	Count
		181.28	Total
Cladium jamaicense	8.85	144.37	
Cladium jamaicense	8.85	69.04	
		2	Count
		213.41	Total
Cladium jamaicense	8.95	102.47	
Cladium jamaicense	8.95	119.46	
		2	Count
		221.93	Total
Typha domingensis	9.05	38.53	
		1	Count
		38.53	Total
Cladium jamaicense	9.05	79.52	
Cladium jamaicense	9.05	85.84	
Cladium jamaicense	9.05	9.23	
		3	Count
		174.58	Total
Typha domingensis	9.15	36.08	
		1	Count
		36.08	Total
Cladium jamaicense	9.15	75.98	
Cladium jamaicense	9.15	109.81	
		2	Count
		185.79	Total

Cladium jamaicense	9.25	20.22	
Cladium jamaicense	9.25	75.73	
Cladium jamaicense	9.25	91.32	
Cladium jamaicense	9.25	14.38	
		4	Count
		201.65	Total
Beach	9.35	45.50	
		1	Count
		45.50	Total
Sabal palmetto	9.35	17.87	
		1	Count
		17.87	Total
Seawall	9.35	13.36	
		1	Count
		13.36	Total
Bottomland Hardwood	9.35	1.44	
Bottomland Hardwood	9.35	93.14	
		2	Count
		94.58	Total
Juniperus silicicola	9.35	36.74	
Juniperus silicicola	9.35	21.23	
Juniperus silicicola	9.35	110.41	
		3	Count
		168.38	Total
Cladium jamaicense	9.35	8.36	
Cladium jamaicense	9.35	59.88	
Cladium jamaicense	9.35	16.11	
Cladium jamaicense	9.35	46.47	
		4	Count
		130.82	Total
Seawall	9.45	247.39	
		1	Count
		247.39	Total
Bottomland Hardwood	9.45	8.00	
Bottomland Hardwood	9.45	109.00	
		2	Count
		117.00	Total
Bottomland Hardwood	9.55	25.65	
		1	Count
		25.65	Total
Seawall	9.55	191.62	
		1	Count
		191.62	Total
Typha domingensis	9.55	84.25	
		1	Count
		84.25	Total
Cladium jamaicense	9.65	23.73	
		1	Count
		23.73	Total
Seawall	9.65	110.90	
		1	Count
		110.90	Total
Typha domingensis	9.65	72.12	
Typha domingensis	9.65	26.38	

		2	Count
		98.50	Total
Bottomland Hardwood	9.75	61.34	
		1	Count
		61.34	Total
Seawall	9.75	149.93	
Seawall	9.75	117.52	
Seawall	9.75	29.37	
		3	Count
		296.82	Total
Typha domingensis	9.75	20.45	
Typha domingensis	9.75	18.61	
Typha domingensis	9.75	24.27	
		3	
		63.33	
Cladium jamaicense	9.75	28.22	
Cladium jamaicense	9.75	17.12	
Cladium jamaicense	9.75	23.43	
Cladium jamaicense	9.75	90.42	
		4	Count
		159.19	Total
Bottomland Hardwood	9.85	79.89	
		1	Count
		79.89	Total
Typha domingensis	9.85	20.89	
		1	Count
		20.89	Total
Cladium jamaicense	9.85	10.98	
Cladium jamaicense	9.85	28.12	
		2	Count
		39.10	Total
Rip-Rap	9.85	83.20	
Rip-Rap	9.85	32.14	
Rip-Rap	9.85	66.82	
Rip-Rap	9.85	20.52	
		4	Count
		202.68	Total
Seawall	9.85	8.15	
Seawall	9.85	156.38	
Seawall	9.85	85.58	
Seawall	9.85	314.90	
Seawall	9.85	204.46	
Seawall	9.85	253.40	
		6	Count
		1,022.87	Total
Rip-Rap	9.95	23.99	
Rip-Rap	9.95	7.39	
Rip-Rap	9.95	31.88	
Rip-Rap	9.95	25.72	
Rip-Rap	9.95	20.50	
		5	Count
		109.47	Total
Seawall	9.95	113.14	
Seawall	9.95	99.60	
Seawall	9.95	225.37	
Seawall	9.95	53.92	

Seawall	9.95	9.01	
Seawall	9.95	112.43	
Seawall	9.95	269.39	
		7	Count
		882.86	Total
Seawall	10.05	7.39	
Seawall	10.05	133.99	
Seawall	10.05	135.52	
		3	Count
		276.90	Total
Seawall	10.15	310.84	
Seawall	10.15	107.82	
Seawall	10.15	94.14	
		3	Count
		512.80	Total
Bottomland Hardwood	10.25	75.37	
		1	Count
		75.37	Total
Seawall	10.25	277.59	
Seawall	10.25	15.83	
Seawall	10.25	60.86	
		3	Count
		354.27	Total
Cyperus alternifolius	10.50	72.53	
Cyperus alternifolius	10.50	21.27	
		2	Count
		93.81	Total
Juniperus silicicola	10.50	155.60	
Juniperus silicicola	10.50	21.88	
Juniperus silicicola	10.50	51.60	
		3	Count
		229.08	Total
Beach	10.50	48.66	
Beach	10.50	59.05	
Beach	10.50	119.23	
Beach	10.50	19.68	
Beach	10.50	36.39	
Beach	10.50	213.66	
		6	Count
		496.67	Total
Rip-Rap	10.50	124.27	
Rip-Rap	10.50	126.11	
Rip-Rap	10.50	25.67	
Rip-Rap	10.50	158.81	
Rip-Rap	10.50	16.90	
Rip-Rap	10.50	98.85	
		6	Count
		550.61	Total
Sabal palmetto	10.50	26.85	
Sabal palmetto	10.50	40.18	
Sabal palmetto	10.50	19.46	
Sabal palmetto	10.50	51.54	
Sabal palmetto	10.50	229.29	
Sabal palmetto	10.50	87.97	
Sabal palmetto	10.50	62.16	

Sabal palmetto	10.50	320.17	
Sabal palmetto	10.50	105.99	
Sabal palmetto	10.50	12.45	
Sabal palmetto	10.50	277.63	
		11	Count
		1,233.71	Total
Bottomland Hardwood	10.50	234.85	
Bottomland Hardwood	10.50	206.10	
Bottomland Hardwood	10.50	44.36	
Bottomland Hardwood	10.50	121.74	
Bottomland Hardwood	10.50	72.38	
Bottomland Hardwood	10.50	158.19	
Bottomland Hardwood	10.50	111.80	
Bottomland Hardwood	10.50	389.19	
Bottomland Hardwood	10.50	51.52	
Bottomland Hardwood	10.50	180.88	
Bottomland Hardwood	10.50	72.07	
Bottomland Hardwood	10.50	26.36	
Bottomland Hardwood	10.50	84.48	
		13	Count
		1,753.93	Total
Cladium jamaicense	10.50	69.54	
Cladium jamaicense	10.50	227.96	
Cladium jamaicense	10.50	177.51	
Cladium jamaicense	10.50	23.08	
Cladium jamaicense	10.50	216.49	
Cladium jamaicense	10.50	25.54	
Cladium jamaicense	10.50	16.39	
Cladium jamaicense	10.50	173.10	
Cladium jamaicense	10.50	23.50	
Cladium jamaicense	10.50	46.02	
Cladium jamaicense	10.50	68.34	
Cladium jamaicense	10.50	191.00	
Cladium jamaicense	10.50	310.08	
		13	Count
		1,568.55	Total
Typha domingensis	10.50	41.80	
Typha domingensis	10.50	14.68	
Typha domingensis	10.50	50.73	
Typha domingensis	10.50	113.13	
Typha domingensis	10.50	88.71	
Typha domingensis	10.50	73.12	
Typha domingensis	10.50	118.20	
Typha domingensis	10.50	184.42	
Typha domingensis	10.50	85.14	
Typha domingensis	10.50	143.64	
Typha domingensis	10.50	128.17	
Typha domingensis	10.50	147.07	
Typha domingensis	10.50	303.61	
Typha domingensis	10.50	609.19	
Typha domingensis	10.50	77.23	
Typha domingensis	10.50	70.14	
Typha domingensis	10.50	80.42	
Typha domingensis	10.50	23.13	
Typha domingensis	10.50	124.14	
		19	Count
		2,476.67	Total
Seawall	10.50	34.96	

Seawall	10.50	56.26	
Seawall	10.50	217.49	
Seawall	10.50	36.43	
Seawall	10.50	27.30	
Seawall	10.50	78.05	
Seawall	10.50	183.44	
Seawall	10.50	123.75	
Seawall	10.50	299.08	
Seawall	10.50	221.88	
Seawall	10.50	1,015.69	
Seawall	10.50	95.95	
Seawall	10.50	472.88	
Seawall	10.50	278.86	
Seawall	10.50	276.27	
Seawall	10.50	411.81	
Seawall	10.50	97.57	
Seawall	10.50	49.36	
Seawall	10.50	897.60	
Seawall	10.50	59.02	
Seawall	10.50	2,004.98	
Seawall	10.50	315.48	
		22	Count
		7,254.12	Total
Rip-Rap	11.50	203.19	
Rip-Rap	11.50	52.50	
		2	Count
		255.70	Total
Sabal palmetto	11.50	26.31	
Sabal palmetto	11.50	75.20	
		2	Count
		101.52	Total
Beach	11.50	126.80	
Beach	11.50	11.76	
Beach	11.50	19.23	
		3	Count
		157.79	Total
Juniperus silicicola	11.50	36.52	
Juniperus silicicola	11.50	24.01	
Juniperus silicicola	11.50	86.80	
Juniperus silicicola	11.50	63.19	
		4	Count
		210.51	Total
Cyperus alternifolius	11.50	15.84	
Cyperus alternifolius	11.50	40.75	
Cyperus alternifolius	11.50	55.53	
Cyperus alternifolius	11.50	11.60	
Cyperus alternifolius	11.50	22.67	
		5	Count
		146.38	Total
Bottomland Hardwood	11.50	83.19	
Bottomland Hardwood	11.50	39.11	
Bottomland Hardwood	11.50	64.17	
Bottomland Hardwood	11.50	72.46	
Bottomland Hardwood	11.50	72.17	
Bottomland Hardwood	11.50	50.44	
Bottomland Hardwood	11.50	30.89	
Bottomland Hardwood	11.50	246.57	

Bottomland Hardwood	11.50	43.83	
Bottomland Hardwood	11.50	238.56	
Bottomland Hardwood	11.50	261.54	
Bottomland Hardwood	11.50	210.82	
Bottomland Hardwood	11.50	181.09	
Bottomland Hardwood	11.50	81.64	
Bottomland Hardwood	11.50	198.06	
Bottomland Hardwood	11.50	94.08	
Bottomland Hardwood	11.50	22.94	
Bottomland Hardwood	11.50	20.04	
Bottomland Hardwood	11.50	81.05	
Bottomland Hardwood	11.50	24.38	
Bottomland Hardwood	11.50	77.63	
Bottomland Hardwood	11.50	53.28	
Bottomland Hardwood	11.50	15.29	
Bottomland Hardwood	11.50	463.77	
Bottomland Hardwood	11.50	96.65	
Bottomland Hardwood	11.50	222.23	
		26	Count
		3,045.87	Total
Seawall	11.50	57.49	
Seawall	11.50	152.79	
Seawall	11.50	18.51	
Seawall	11.50	54.68	
Seawall	11.50	1,103.88	
Seawall	11.50	496.12	
Seawall	11.50	66.82	
Seawall	11.50	136.99	
Seawall	11.50	31.84	
Seawall	11.50	77.01	
Seawall	11.50	328.99	
Seawall	11.50	173.28	
Seawall	11.50	11.43	
Seawall	11.50	64.42	
Seawall	11.50	853.92	
Seawall	11.50	185.31	
Seawall	11.50	25.21	
Seawall	11.50	132.79	
Seawall	11.50	105.23	
Seawall	11.50	47.24	
Seawall	11.50	328.62	
Seawall	11.50	106.80	
Seawall	11.50	967.01	
Seawall	11.50	774.35	
Seawall	11.50	957.93	
Seawall	11.50	210.84	
Seawall	11.50	341.84	
Seawall	11.50	175.85	
Seawall	11.50	408.15	
		29	Count
		8,395.34	Total
Cladium jamaicense	11.50	74.68	
Cladium jamaicense	11.50	99.63	
Cladium jamaicense	11.50	51.09	
Cladium jamaicense	11.50	6.08	
Cladium jamaicense	11.50	241.17	
Cladium jamaicense	11.50	23.37	
Cladium jamaicense	11.50	27.79	

Cladium jamaicense	11.50	115.11	
Cladium jamaicense	11.50	26.62	
Cladium jamaicense	11.50	42.27	
Cladium jamaicense	11.50	77.62	
Cladium jamaicense	11.50	267.47	
Cladium jamaicense	11.50	360.13	
Cladium jamaicense	11.50	171.91	
Cladium jamaicense	11.50	20.37	
Cladium jamaicense	11.50	81.70	
Cladium jamaicense	11.50	60.60	
Cladium jamaicense	11.50	35.51	
Cladium jamaicense	11.50	32.14	
Cladium jamaicense	11.50	21.68	
Cladium jamaicense	11.50	111.50	
Cladium jamaicense	11.50	235.75	
Cladium jamaicense	11.50	73.19	
Cladium jamaicense	11.50	14.83	
Cladium jamaicense	11.50	196.45	
Cladium jamaicense	11.50	130.97	
Cladium jamaicense	11.50	119.64	
Cladium jamaicense	11.50	17.68	
Cladium jamaicense	11.50	279.91	
Cladium jamaicense	11.50	205.83	
		30	Count
		3,222.69	Total
Typha domingensis	11.50	280.07	
Typha domingensis	11.50	61.34	
Typha domingensis	11.50	79.04	
Typha domingensis	11.50	48.70	
Typha domingensis	11.50	37.56	
Typha domingensis	11.50	64.28	
Typha domingensis	11.50	31.19	
Typha domingensis	11.50	269.38	
Typha domingensis	11.50	127.60	
Typha domingensis	11.50	206.12	
Typha domingensis	11.50	123.23	
Typha domingensis	11.50	66.75	
Typha domingensis	11.50	25.07	
Typha domingensis	11.50	764.95	
Typha domingensis	11.50	23.25	
Typha domingensis	11.50	186.44	
Typha domingensis	11.50	64.67	
Typha domingensis	11.50	57.94	
Typha domingensis	11.50	92.55	
Typha domingensis	11.50	149.61	
Typha domingensis	11.50	369.37	
Typha domingensis	11.50	50.43	
Typha domingensis	11.50	46.15	
Typha domingensis	11.50	263.38	
Typha domingensis	11.50	87.78	
Typha domingensis	11.50	234.98	
Typha domingensis	11.50	59.12	
Typha domingensis	11.50	18.81	
Typha domingensis	11.50	25.87	
Typha domingensis	11.50	12.34	
Typha domingensis	11.50	55.38	
Typha domingensis	11.50	193.05	
Typha domingensis	11.50	91.48	

Typha domingensis	11.50	122.24	
Typha domingensis	11.50	38.25	
Typha domingensis	11.50	24.44	
Typha domingensis	11.50	338.99	
Typha domingensis	11.50	341.74	
Typha domingensis	11.50	231.61	
Typha domingensis	11.50	110.92	
Typha domingensis	11.50	264.95	
Typha domingensis	11.50	148.58	
Typha domingensis	11.50	1.71	
Typha domingensis	11.50	168.16	
Typha domingensis	11.50	73.09	
Typha domingensis	11.50	71.71	
Typha domingensis	11.50	118.85	
Typha domingensis	11.50	113.09	
Typha domingensis	11.50	77.75	
Typha domingensis	11.50	164.43	
Typha domingensis	11.50	31.26	
Typha domingensis	11.50	85.26	
Typha domingensis	11.50	40.72	
Typha domingensis	11.50	32.25	
Typha domingensis	11.50	133.84	
		55	Count
		7,001.73	Total
		901	
		70,860.54	

APPENDIX

Burghart, S.E. and Peebles, E.B. 2011. A comparison of spring-fed and surface-fed estuaries: zooplankton, ichthyoplankton, and hyperbenthos. University of South Florida College of Marine Science, St. Petersburg, Florida. Prepared for the Southwest Florida Water Management District, Brooksville, Florida.

Note: *This 2011 report includes previously reported discharge records for the U.S. Geological Survey (USGS) Crystal River at Bagley Cove, FL gage site that were revised by the USGS in November 2011, and also includes analyses based on the previously reported records.*

A COMPARISON OF SPRING-FED AND SURFACE-FED ESTUARIES: ZOOPLANKTON, ICHTHYOPLANKTON, AND HYPERBENTHOS

Prepared for
The Southwest Florida Water Management District
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Executive Summary

The objective of the analyses presented here was to use existing biological survey data to compare the zooplankton, ichthyoplankton, and hyperbenthos communities of four spring-fed and four surface-fed estuaries in west-central Florida. Between 8 and 14 sampling locations (stations) were positioned along each estuary's principal axis, extending from the estuaries' respective receiving basins (bay or gulf waters) upstream to the general area of permanent fresh water. Twelve months of data from each of the 8 estuaries were analyzed for difference in overall community structure, change in community structure along the salinity gradient, and identification of indicator taxa.

Although the lists of taxa encountered in the two types of estuaries were similar, there were substantial differences in the abundances and percent compositions of many taxa. Spring-fed estuaries were characterized by the prevalence of hyperbenthic crustaceans, especially peracarids, whereas surface-fed estuaries were characterized by a prevalence of pelagic zooplankton. In addition, community change along the salinity gradients of the two types of estuaries was different, with spring-fed estuaries having areas of more abrupt change that separated community structure into three groups: a spring/freshwater community type (0.3-1.0‰), a continuously varying estuarine community type (2-22‰), and a marine community type (23-30‰). The change in community structure along the salinity gradient of the surface-fed estuaries was marked by an inflection at around 8-13‰, which reflects the intersection between steep community gradients that form during low- and high-inflow periods, respectively. Biologically mediated discontinuities (phytoplankton blooms, hypoxia events) associated with interactions between inflow, water residence time, and geomorphology also tend to create community-level discontinuities within this salinity region.

Community distinctions between the two estuary types are based in differences in inflow related processes and water quality. The two types of estuaries have different light

environments, and differences in light environment lead to different sources of primary production, with phytoplankton being more prevalent in the surface-fed estuaries and benthic primary producers being more prevalent in the spring-fed estuaries. This distinction in primary producers is propagated into indicator consumers, which retain the pelagic-versus-benthic dichotomy.

The relatively constant inflows associated with the spring-fed estuaries do not allow phytoplankton blooms to form upstream, and the lack of extensive runoff from watersheds keeps concentrations of colored dissolved organic matter (CDOM) comparatively low. The relative absence of these two light-attenuating materials allows light to reach the bottom throughout the year in the spring-fed estuaries, which encourages benthic algal and submersed aquatic vegetation growth. The surface-fed estuaries, on the other hand, often experience phytoplankton blooms and seasonal periods of high CDOM concentration, both of which discourage benthic plant and algal growth.

Because anthropogenic additions of nutrients to the springs will not result in phytoplankton blooms unless local water residence times are long enough to allow blooms to form, water residence times in the spring-fed estuaries should be kept short enough to discourage such blooms. Should phytoplankton blooms become more prevalent in the future, a shift from hyperbenthic peracarid crustaceans to zooplanktonic organisms would be expected, causing many of the community-level differences documented here to diminish. The biological surveys that have been conducted to date in these estuaries are therefore useful as benchmarks for future comparisons. The present analysis documents the types of faunal changes that would be expected if future habitat degradation does occur.

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1 Introduction

West-central Florida is home to estuaries that primarily receive freshwater flows from surface runoff and others that are primarily supplied by groundwater flow from springs. Superficially, the two types of estuarine systems look quite different. Surface-fed estuaries often have highly colored waters and sandy or muddy bottoms, whereas spring-fed estuaries typically have clear waters with large beds of dense macrophytic and macroalgal growth on the bottom. Spring-fed estuaries are also noteworthy for the consistent nature of their flows, whereas surface-fed estuaries are more susceptible to large variations in flow due to a rapid response to chages in short-term and seasonal rainfall. While both types of estuaries have ecological, cultural and economic importance, Florida's spring-fed estuaries are distinctive ecosystems in that they are oligotrophic in their natural state. The relative regularity of the spring flows, along with consistent temperatures, is undoubtedly important to wildlife. Manatees and fishes, including many marine species, use springs as thermal refuges during the cold, winter months. Fossil evidence indicates the area's springs were important to prehistoric human cultures (Scott et al. 2002), and modern populations use them for a variety of recreational activities, including swimming, ecotourism, boating, fishing, diving and snorkeling. From an ecological standpoint, spring-fed estuaries are useful for community-level comparisons because so many ecosystem variables (e.g., freshwater inflow, temperature, nutrients, water clarity) are relatively constant (Knight and Notestein 2008).

Since 1980, the population of Florida has increased by 75%, making it the fastest growing U.S. state during that time period. This growth has been particularly intense near the coast. In 1960, 8.1% of the coast-dwelling U.S. population resided in Florida. This increased to 15.9% by 2008, with Florida absorbing the largest increase in coastal population of any state (Wilson and Fischetti 2010). Along the Gulf Coast of Florida, the population growth of some counties since 1960 has been explosive. Collier (1,901%), Hernando (1,432%), Citrus (1,426%), Pasco (1,181%) Charlotte (1,092%) and Lee (988%) counties have all seen population jumps of more than an order of magnitude (Wilson and Fischetti 2010). Population growth is expected to persist in the area (Crossett et al. 2004), and thus will continue to create challenges for policy makers and water managers, in particular.

Withdrawals of water along Florida’s west coast come from both surface and groundwater sources, meaning anthropogenic water withdrawals potentially impact both spring-fed and surface-fed estuarine systems. To make informed management decisions, it is important to understand the ecology of these two types of estuaries. Fundamental to that understanding is basic biological information pertaining to the similarities and differences between spring-fed and surface-fed estuaries. Here, we present the results of an examination of zooplankton, ichthyoplankton (the largely planktonic early stages of fish) and hyperbenthos (benthic invertebrates that rise into the water column, particularly at night) within eight estuaries, with four being spring-fed and four being surface-fed. Data used in this study were produced as a result of monitoring programs and studies commissioned by the Southwest Florida Water Management District (Matheson et al. 2005; Peebles 2005; Greenwood et al. 2006; Peebles et al. 2006; Peebles et al. 2009). The effectiveness of using these types of organisms to quantify ecosystem responses to freshwater inflow has been demonstrated in the past (Peebles et al. 2007; Tolley et al. 2010). Here, we use them to compare and contrast the two types of estuaries.

2 Materials and methods

2.1. Study sites

All eight estuaries in this study are located along the coast of west-central Florida (Figure 1), an area with a marked seasonality in rainfall, wherein more rain falls during the summer months (Figure 2). Five of the estuaries (Crystal, Homosassa, Chassahowitzka, Weeki Wachee and Anclote) are located within the Florida Springs

Coast basin (FDEP 2006), an area with well developed karst topography. The Upper Floridan Aquifer is the main source of water for all of the spring-fed estuaries along Florida's west coast. All four spring-fed estuaries in this study are fed by first order spring groups, discharging an average of 100 cfs or more (FDEP 2006) and water age analysis indicates discharged water is often on the order of a few decades or less in age (Katz 2004). The springs feeding the Crystal, Homosassa, Chassahowitzka, and Weeki Wachee estuaries are close enough to the coast to be impacted by the transition zone between fresh and saltwater within the aquifer, and thus some discharge is saline (Champion and Starks 2001).

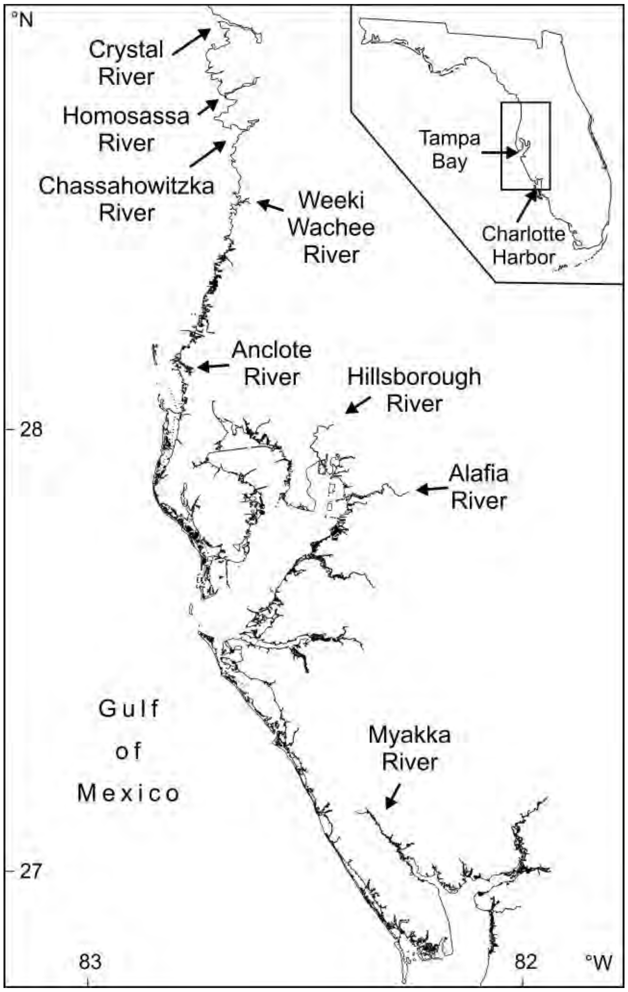


Figure 1: Location of estuaries included in the study.

Although the springshed area for spring-fed estuaries is difficult to estimate due to the complex nature of groundwater flow, source aquifers may have extensive recharge areas. Soils in recharge areas are sandy, porous, and often thin, meaning the source aquifer is vulnerable to contamination from anthropogenic sources. In terms of human impact, the Chassahowitzka is the least developed, while development along the Homosassa and Weeki Wachee estuaries is fairly extensive (Frazer et al. 2001; Frazer et al. 2006). Compared to the other two spring systems, submerged aquatic vegetation (SAV) in the Crystal and Homosassa estuaries is fairly sparse (Frazer et al. 2001; Frazer et al. 2006) though SAV was more abundant in previous decades (Flannery, pers. comm.). The Crystal estuary is the deepest of the spring-fed systems, and portions of its bottom habitats are consistently below the euphotic zone (Frazer et al. 2001). Reduced light environment and high salinities in the lower Homosassa and Crystal Estuaries are also less conducive to growth of benthic algae and SAV (Hoyer et al. 2004; Frazer et al. 2006). The Anclote, Hillsborough, Alafia and Myakka estuaries also receive a small portion of their inflows from springs, but none of these are first-order springs (Champion and Starks 2001; Scott et al. 2002). Flows from the Crystal, Homosassa, Chassahowitzka, Weeki Wachee and Anclote estuaries all empty into the Gulf of Mexico, while flows from the Hillsborough and Alafia empty into Tampa Bay and the Myakka River empties into Charlotte Harbor (Fig. 1).

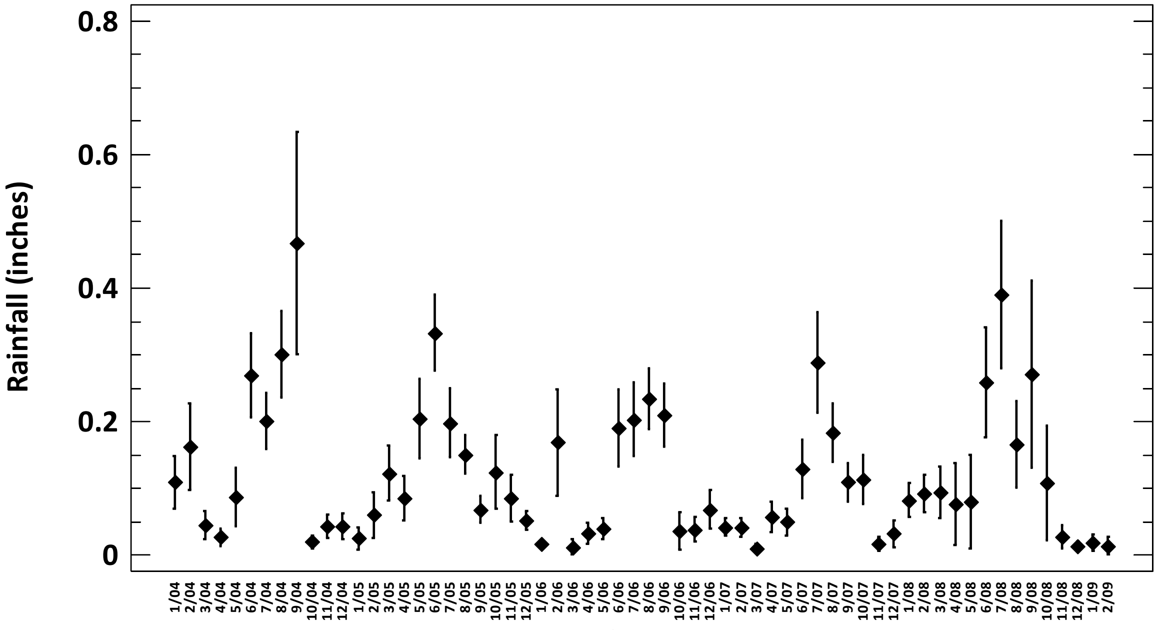


Figure 2: Average daily rainfall per month from three rain gauges on the west coast of Florida (Chassahowitzka 21033, Hillsborough 19436, Peace River 24573). Data are from the Southwest Florida Water Management District Water Management Information System and are presented as means and 95% confidence intervals. Five summer peaks in rainfall are visible in this figure.

2.2. Collection methods

Existing reports provide detailed methods and results for the biological surveys conducted in the eight estuaries considered here. Survey methods are repeated in this section for convenience. Each estuary was divided into 4-7 zones depending on length, with each zone containing two, fixed-location sampling stations. The first zone for each system began in the receiving basin (open Gulf of Mexico or bay) and the last zone was placed at the spring run or where the water column was fresh except during very dry periods. In consequence, the entire salinity gradient of each estuary was sampled.

Sampling was conducted monthly, at night, and on a flood tide. This timing allowed for characterization the vertically migrating hyperbenthos in addition to the zooplankton and ichthyoplankton assemblages. At two stations per zone, a conical plankton net (3:1) with a 0.5-m mouth diameter and a mesh size of 500 μm was towed from a 5 m boat with an outboard motor. The net was equipped with a 3-point bridle, a calibrated flow meter (General Oceanics model 2030R), a 1-liter plastic cod-end jar, and a 9-kg weight. Tow duration was five minutes, with tow time being divided equally among bottom, mid-water and surface depths. The fishing depth of the weighted net was controlled by adjusting the length of the tow line while using the boat’s tachometer readings to maintain a constant line angle. The tow line was attached to a winch located on the gunnel near the transom. All samples were preserved in 6-10% formalin in ambient water. At the end of each net deployment the water column was profiled at 1-m intervals for salinity, temperature, dissolved oxygen and pH using a YSI® 556 (YSI, Inc.) hand-held multi-parameter instrument.

The estuaries were sampled for more than twelve months, but for the sake of consistency in the comparisons, twelve collection months were selected from each estuary for analysis. Whenever possible, months were chosen so that there was exact temporal overlap between at least one spring-fed estuary and one surface-fed estuary (Table 1). Only in the cases of the Anclote (surface-fed) and the Chassahowitzka (spring-fed) was exact temporal pairing not possible.

Table 1: Sampling months for each river system. Spring-fed estuaries are shaded in blue, surface-fed estuaries are shaded in green.

	Alafia	Anclote	Chassahowitzka	Crystal	Hillborough	Homosassa	Myakka	Weeki Wachee
January-04							🟩	🟦
February-04							🟩	🟦
March-04							🟩	🟦
April-04							🟩	🟦
May-04							🟩	🟦
June-04							🟩	🟦
July-04							🟩	🟦
August-04							🟩	🟦
September-04							🟩	🟦
October-04		🟩					🟩	🟦
November-04		🟩					🟩	🟦
December-04		🟩					🟩	🟦
January-05		🟩						
February-05		🟩						
March-05		🟩						
April-05		🟩						
May-05		🟩						
June-05		🟩						
July-05		🟩						
August-05		🟩	🟦					
September-05		🟩	🟦					
October-05			🟦					
November-05			🟦					
December-05			🟦					
January-06			🟦					
February-06			🟦					
March-06			🟦					
April-06			🟦					
May-06			🟦					
June-06			🟦					
July-06			🟦					
August-06								
September-06								
October-06								
November-06								
December-06	🟩					🟦		
January-07	🟩					🟦		
February-07	🟩					🟦		
March-07	🟩					🟦		
April-07	🟩					🟦		
May-07	🟩					🟦		
June-07	🟩					🟦		
July-07	🟩					🟦		
August-07	🟩					🟦		
September-07	🟩					🟦		
October-07	🟩					🟦		
November-07	🟩					🟦		
December-07								
January-08								
February-08								
March-08								
April-08				🟦	🟩			
May-08				🟦	🟩			
June-08				🟦	🟩			
July-08				🟦	🟩			
August-08				🟦	🟩			
September-08				🟦	🟩			
October-08				🟦	🟩			
November-08				🟦	🟩			
December-08				🟦	🟩			
January-09				🟦	🟩			
February-09				🟦	🟩			
March-09				🟦	🟩			
April-09								
May-09								
June-09								
July-09								
August-09								
September-09								
October-09								
November-09								
December-09								

All aquatic taxa collected by the plankton net were identified and counted, except invertebrate eggs and organisms that were attached to debris (sessile stages of barnacles, bryozoans, sponges, tunicates and sessile coelenterates). During sorting, the data were entered directly into an electronic database via programmable keyboards that interfaced with a macro-driven spreadsheet. Although life-stage data was collected during enumeration, different stages of fish and crustacean taxa were grouped under a single taxonomic heading for this analysis. Life stage information is partially retained for some taxa due to changes in taxonomic resolution of identifications across life stages. For example, pre-flexion and flexion larvae of anchovies cannot be identified to species, meaning they appear in the database as *Anchoa* spp., while *Anchoa mitchilli* refers to the postflexion larva, juvenile and adult stages of the bay anchovy.

Most organisms collected by the plankton net fell within the size range of 0.5-50 mm. This size range spans three orders of magnitude, and includes mesozooplankton (0.2-20 mm) macrozooplankton/micronekton (>20 mm) and analogous sizes of hyperbenthos. To prevent larger objects from visually obscuring smaller ones during sample processing, all samples were separated into two size fractions using stacked sieves with mesh openings of 4 mm and 250 µm. The >4 mm fraction primarily consisted of juvenile and adult fishes, large macroinvertebrates and large particulate organic matter. In most cases, the fishes and macroinvertebrates in the >4 mm fraction could be identified and enumerated without the aid of microscopes.

A microscope magnification of 7-12X was used to enumerate organisms in the >250 µm fraction, with zoom magnifications as high as 90X being available for identifying individual specimens. The >250 µm fraction was usually sorted in two stages. In the first sorting stage, the entire sample was processed as 10-15 ml aliquots that were scanned in succession using a gridded petri dish. Only relatively uncommon taxa (n<50) were enumerated during this first stage. After the entire sample had been processed in this manner, the collective volume of the aliquots was recorded within a graduated mixing cylinder, the sample was inverted repeatedly, and then a single 30-60 ml aliquot was poured. The aliquot volume typically represented about 12-50% of the entire sample volume. The second sorting stage consisted of enumerating the relatively abundant taxa within this single aliquot. The second sorting stage was not required for all samples. The second stage was, however, sometimes extended to less abundant taxa (*n*<50) that were exceptionally small or were otherwise difficult to enumerate.

2.3. Analysis methods

Although all organisms were collected using plankton nets, many organisms have strong associations with the bottom. Taxa were subjectively classified as being either pelagic or hyperbenthic depending on the authors' perception of the strength of this benthic association. Some organisms occur in the water column on a sporadic and/or accidental basis (e.g., polychaetes and gastropods), some are diel vertical migrators (e.g., cumaceans and mysids), and some taxa are planktonic only as larvae or juveniles (e.g., pelecypods and larval stages of many crabs, shrimps and fishes).

2.3.1. Community analysis

A total of 316 taxa were present in 96 monthly-averaged collections. The number of samples that went into each monthly composite varied between 8 and 14, depending on the estuary, with each composite of samples representing the average catch per unit effort (CPUE) in an estuary-month combination, which will hereafter be referred to as a collection. Taxonomic abundance data were square-root transformed to down-weight the importance of the most abundant taxa (Clarke and Warwick 2001), and the Bray-Curtis metric (Faith et al. 1987) was used to construct a similarity matrix. The similarity matrix was the basis for nonmetric multidimensional scaling (MDS), using estuary as a classification factor.

For the purposes of determining indicator species and depicting abundance comparisons among indicator species, the abundance measures from individual stations were used (i.e., numbers were not averaged across an entire estuary to obtain a single monthly average). Indicator species for the *a priori* groups of spring-fed and surface-fed estuaries were identified via the method of Dûfrene and Legendre (1997), using PC-ORD (McCune and Mefford 2006). The method produces an indicator value

(IV) based on the abundance and frequency of a taxon in groups of sampling units. The values produced range between 0 and 100 with higher numbers meaning presence of the taxon points to a particular sample group. An indicator value (IV) of >50 was arbitrarily chosen as the level at which a taxon was labeled as a “strong” indicator; however, with one exception, only taxa with an IV >66.7 were used for Fisher’s LSD multiple range tests (when their variances between estuaries were equal).

2.3.2. Salinity Gradient

For the salinity gradient analysis, vertebrate taxa (primarily fish) were not included in the data set. This was done with the intention of eliminating early life history stages of fish species that were not locally spawned. In addition, individual stations were not averaged across an entire river over the course of a collection month, as described in section 2.3.1. Instead, methods followed Greenwood (2007), wherein individual samples were assigned to one of 38 salinity bins: 0-0.1, 0.11-0.2, 0.21-0.3, 0.31-0.4, 0.41-0.5, 0.51-1‰, and then at 1‰ intervals thereafter (1-2, 2.1-3, 3.1-4‰, etc.). The frequency of occurrence for each taxon within each salinity increment was calculated. Due to the low number of observations within each individual estuary, the data were pooled into spring-fed and surface-fed systems. The data where then square-root transformed, and Bray-Curtis similarities between salinity increments were calculated. The resulting matrix was used to generate an MDS plot (Clarke and Warwick 2001).

3. Results

3.1. Frequency

A total of 316 taxa were identified, sixty of which occurred in more than 50% of the collections overall (Appendix A1). The copepod *Acartia tonsa*, cumaceans, gammaridean amphipods, mysis stages of decapods, and the isopod *Edotia triloba* occurred in every collection. An additional 10 taxa occurred in more than 90% of the collections. Larval stages of decapods (zoea and crab megalopae) were among those taxa, as were polychaetes, developmental stages of dipterans, prosobranch gastropods, mysids belonging to the genus *Americamysis*, various life stages of *Anchoa mitchilli* and larval stages of the fish family Gobiidae.

Some taxa that were relatively common in one type of estuary were less common, or even rare, in another type of estuary. *Anchoa mitchilli* was found in 100% of the collections from surface-fed estuaries, but only 89.6% of collections from spring-fed estuaries. Similar patterns of higher catch frequency in surface-fed estuaries were seen for chaetognaths (97.9 vs. 75%), the isopod *Livoneca* sp. (93.8 vs. 73.1%), the ostracod *Parasterope pollex* (93.8 vs. 72.9%), the copepod *Labidocera aestiva* (91.7 vs. 43.8%), and the larvacean *Oikopleura dioica* (75 vs. 16.7%) (Appendix A1). Conversely, many peracarid crustaceans were very frequent in spring-fed collections, but were less frequently encountered in surface-fed estuaries. These included the isopod *Cassidinidea ovalis* (100 vs. 66.7%), the mysids *Bowmaniella dissimilis* (100 vs. 54.2%) and *Taphromysis bowmani* (95.8 vs. 54.2%), isopods of the genus *Erichsonella* (100 vs. 47.9%), the tanaid *Hargeria rapax* (100 vs. 45.8%), and the isopod *Harrieta faxoni* (97.9 vs. 39.6%). Other taxa frequently collected in spring-fed but less common in surface-fed estuaries included the daggerblade grass shrimp *Palaemonetes pugio* (91.7 vs. 62.5%), leeches (93.8 vs. 54.2%) and the rainwater killifish, *Lucania parva* (89.6 vs. 27.1%).

3.2. Density and Abundance

Decapod zoea and gammaridean amphipods were the first and second most abundant taxa in each estuary type (Appendix A2), although within surface-fed estuaries gammaridean amphipods only ranked in the top five for abundance in the Anclote River (Appendix A2). Cumaceans, similarly, ranked highly in both estuary types, but appeared to have their ranking in surface-fed estuaries bolstered by high abundances in the Alafia and Myakka. The larvacean *Oikopleura dioica* was equally abundant in both estuary types, but among spring-fed estuaries it was absent from the Chassahowitzka and Weeki Wachee and abundant only within the Crystal estuary (Appendix A2). Several taxa were much more abundant in surface-fed than in spring-fed estuaries, including percomorph eggs, *Acartia tonsa*, the ctenophore *Mnemiopsis leidyi,* the shrimp *Lucifer faxoni*, and the ostracod *Parasterope pollex* (Appendix A2). Conversely, juveniles of

Americamysis spp., as well as adults of *Americamysis almyra* and *Bowmaniella dissimilis*, ranked higher in abundance within spring-fed estuaries (Appendix A2).

3.3. Indicator taxa

Thirty-three taxa were strong indicators (IV $\geq$50, p <0.05) for at least one type of system (Appendix A3). Indicator values for taxa were generally higher for spring-fed compared to surface-fed estuaries. Average IVs for the top ten in each type were 86.1 and 78.8 respectively. The five taxa with the strongest IVs were all peracarid crustaceans, and four of these were indicators for spring-fed systems. Of the 13 strong indicators for surface-fed estuaries, 10 were classified as pelagic. These included a phylogenetically diverse array of organisms such as jellyfish (*Clytia* sp.), copepods (*Acartia tonsa* and *Labidocera aestiva*), a decapod (*Lucifer faxoni*), chaetognaths, chordates (*Oikopleura dioica*) and fish (*Anchoa mitchilli*). Hyperbenthic indicator taxa included only the isopods *Edotia triloba* and *Sphaeroma terebrans* and caprellid amphipods. In contrast, 20 taxa were strong indicators for spring-fed estuaries, and 17 of these were hyperbenthic (Appendix A3). Pelagic taxa included *L. parva,* dipteran pupae and the copepod *Eurytemora affinis*. Nine of the spring-fed indicators were peracarid crustaceans. It is important to note that some peracarid crustaceans, notably *Americamysis almyra*, *Bowmaniella dissimilis*, and *Edotia triloba* can also be exceedingly abundant in certain locations within surface-fed estuaries. In fact, *E. triloba* was the strongest indicator for surface-fed estuaries.

3.4. Community Analysis

Results from MDS showed polarization between spring-fed and surface-fed estuaries as well as higher similarity among spring-fed collections (Figure 3). With the exception of the Crystal estuary, spring-fed estuaries showed little overlap with surface-fed estuaries. Collections for the Crystal estuary were clearly mixed in among the Myakka and, to a lesser extent, the Anclote and Alafia. The Hillsborough River was the surface-fed system most unrelated to spring-fed estuaries. The estuaries plotted with spring-fed systems generally located in the lower left and surface-fed systems towards the upper right in roughly the following order: Chassahowitzka, Weeki Wachee, Homosassa, Crystal, Myakka, Anclote, Alafia and Hillsborough. The log transformed abundances of indicator taxa were compared between estuaries which are listed in Figures 4a and 4b in the same order that they apper in Figure 3. Surface-fed indicators tended to increase in abundance along the MDS gradient. For eight of the nine surface-fed indicator taxa IV's >66.7 the Chassahowitzka and Weeki Wachee estuaries grouped statistically with lowest abundance group while the Alafia or Hillborough grouped with the highest abundance group (Figure 4a). Spring-fed indicators tended to show the opposite trend of the Chassahowitzka or Weeki Wachee in the highest abundance group (5 of the 8 instances in with the taxa passed a variance check) and the Alafia or Hillsborough in the lowest abundance group (7 of 8) (Figure 4b).

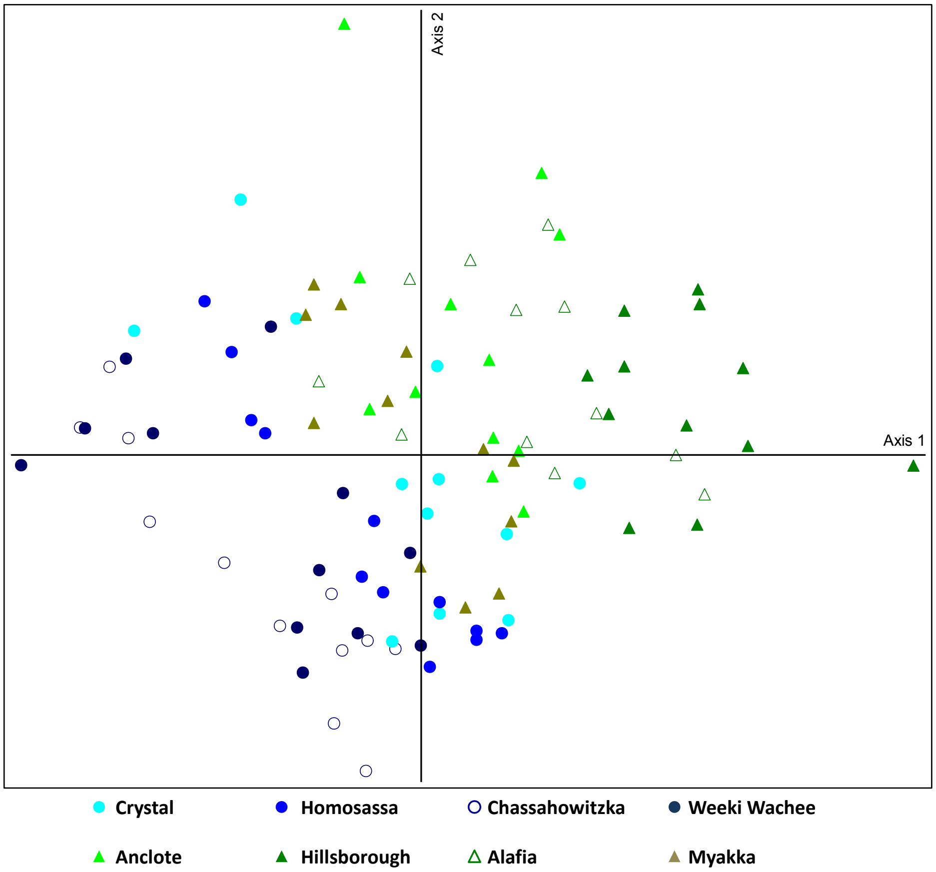
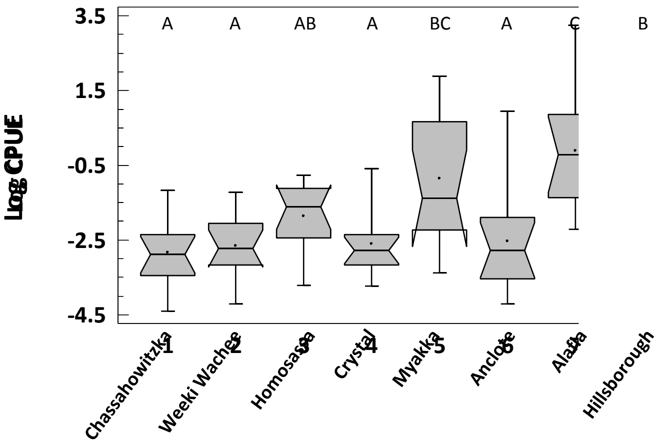
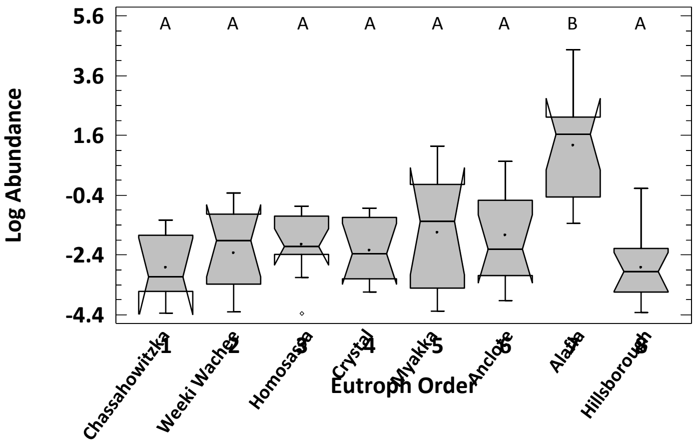


Figure 3: MDS plot based on plankton and hyperbenthos community composition. Each multidimensional scaling point represents a composite of 8-14 samples collected during one month (n = 12 for each estuary).

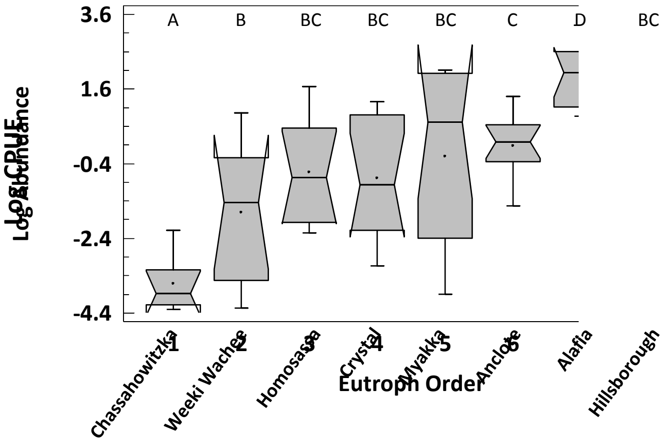
Edotia triloba



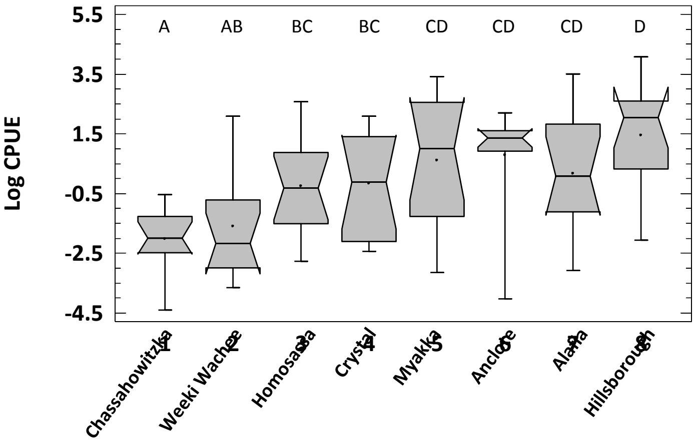
Parasterope pollex

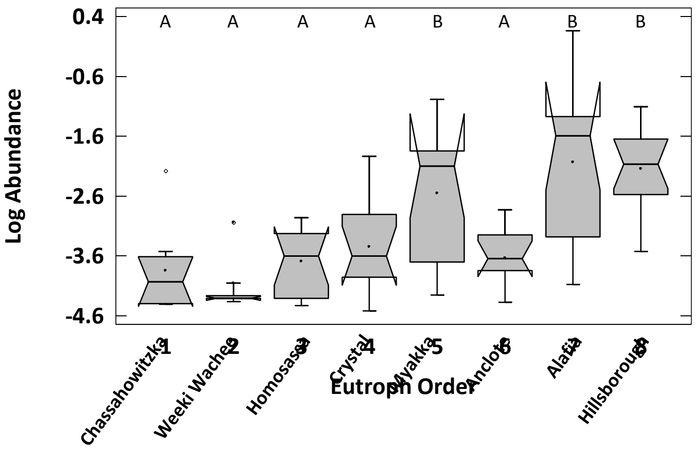


Chaetognaths

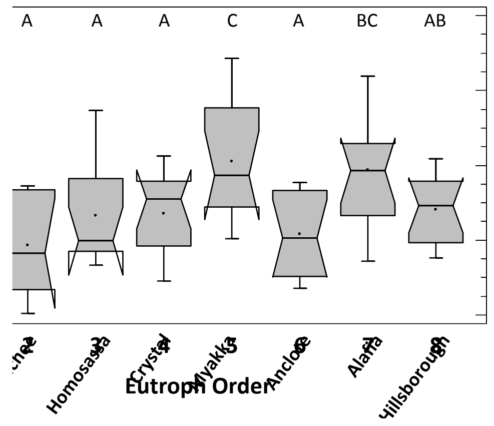


Acartia tonsa

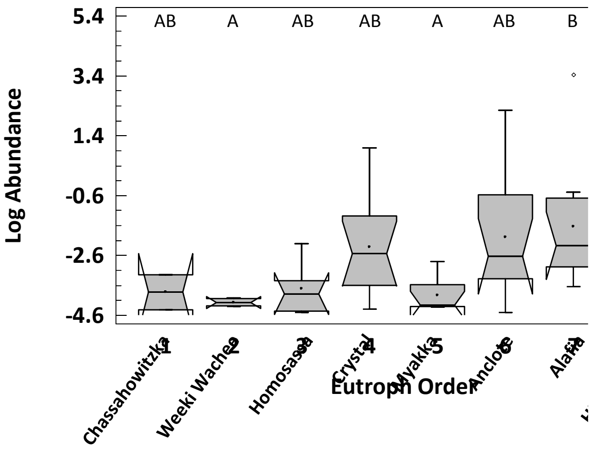




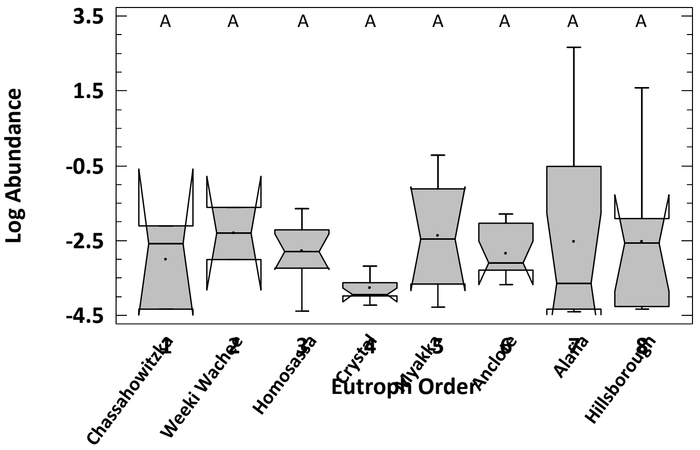
Livoneca sp.



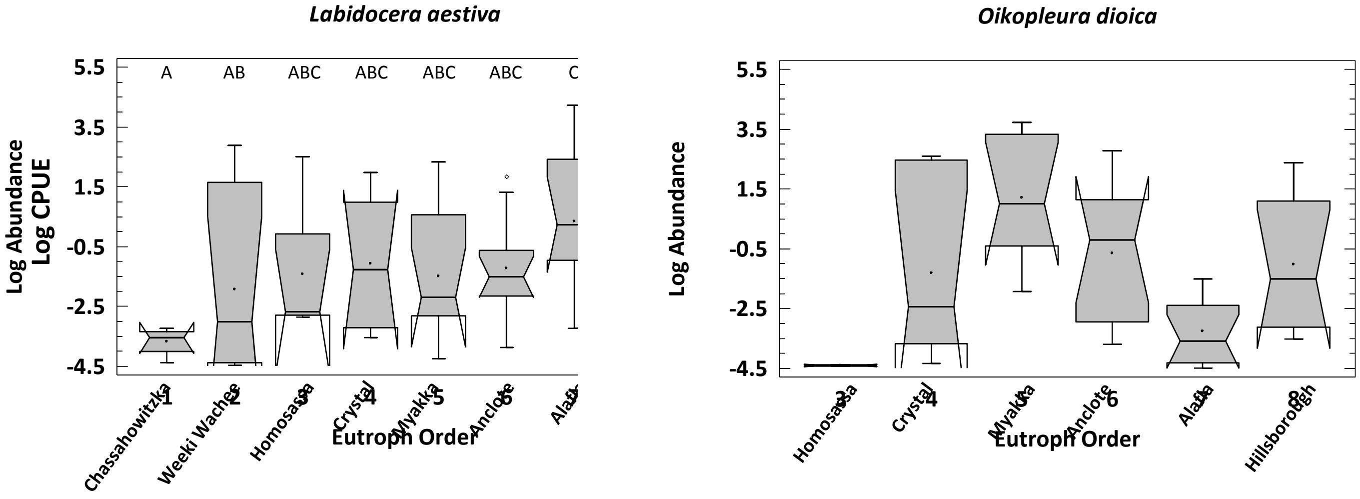
Anchoa mitchilli



Lucifer faxoni



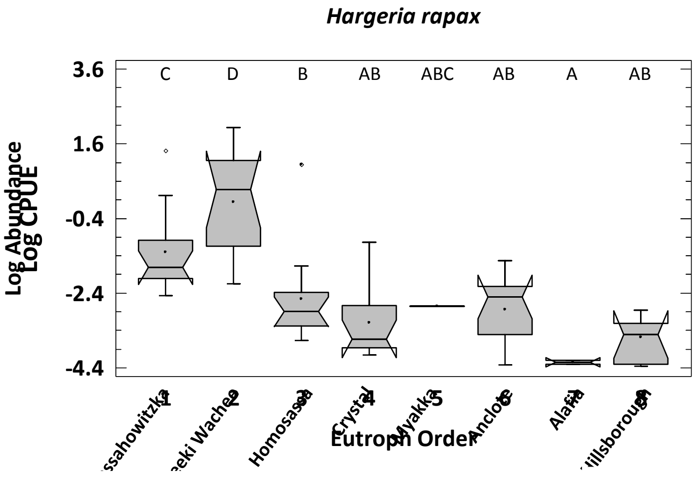
Caprellid amphipods

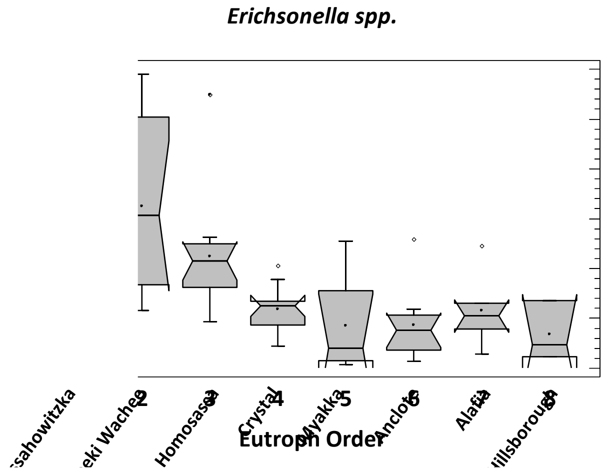


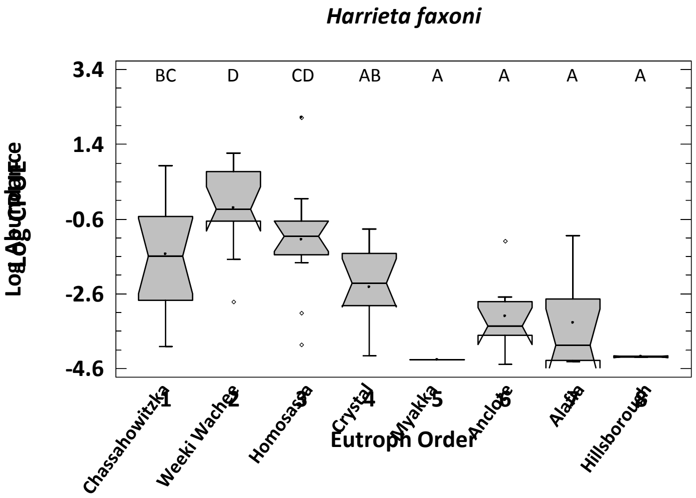
Labidocera aestiva

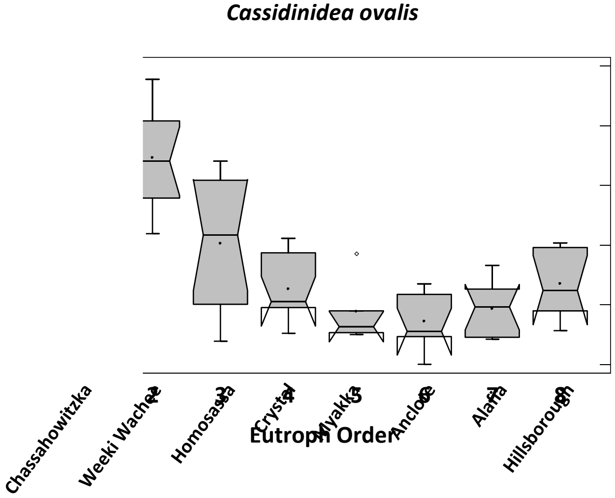
Oikopleura dioica

Figure 4a: Ln-transformed CPUE of surface-fed indicator taxa with IV >66.7 (except *O. dioica*) in each estuary. Boxes represent upper and lower quartiles, whiskers show ranges, points show the means and box dividers show the medians. For taxa that passed a variance check, multiple range tests were performed and the resulting groupings are represented by letters above the boxes.

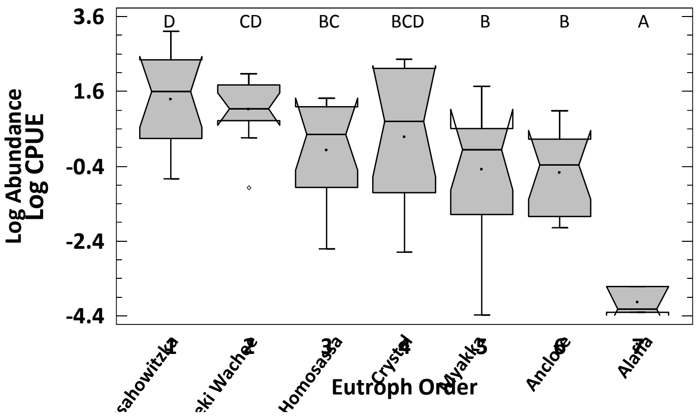

Hargeria rapax


Erichsonella spp.

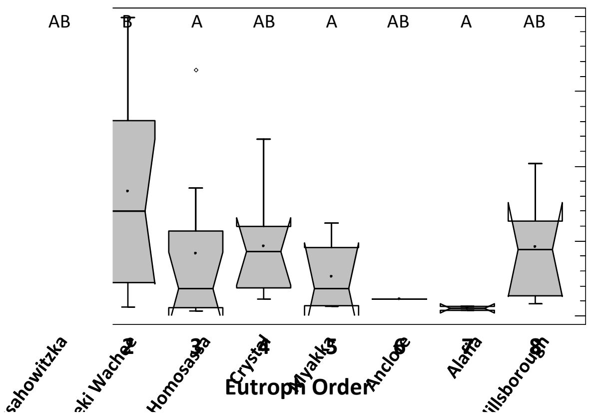

Harrieta faxoni


Cassidinidea ovalis

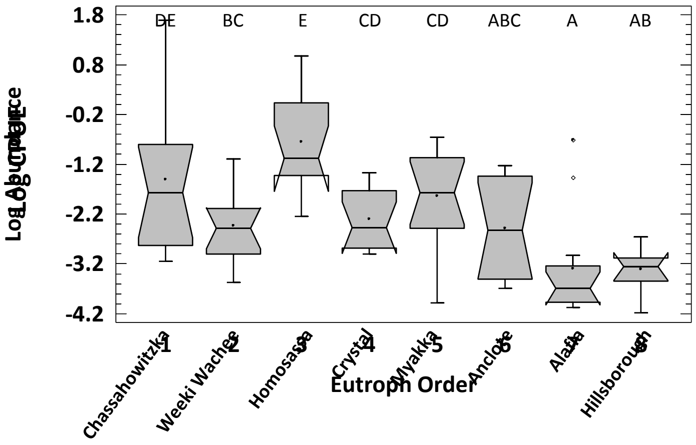
Bowmaniella dissimilis



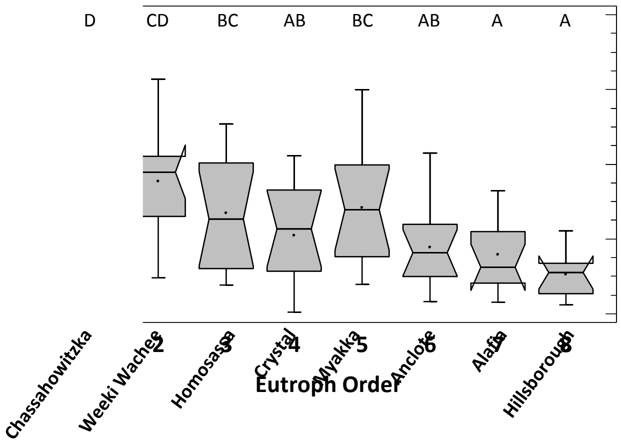
Lucania parva



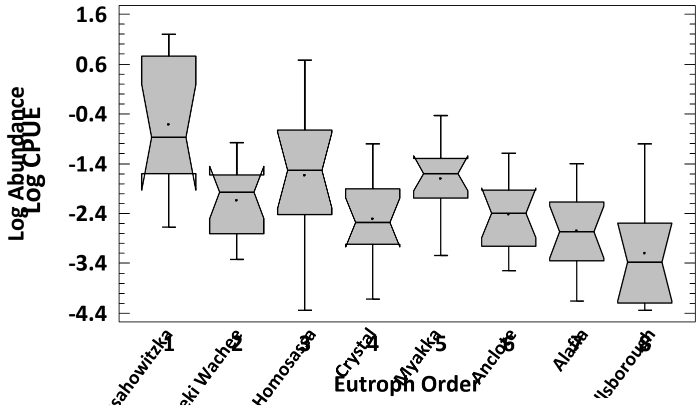
Dipteran pupae



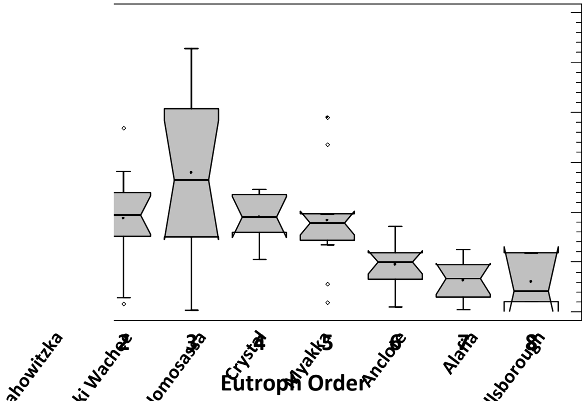
Prosobranch gastropods



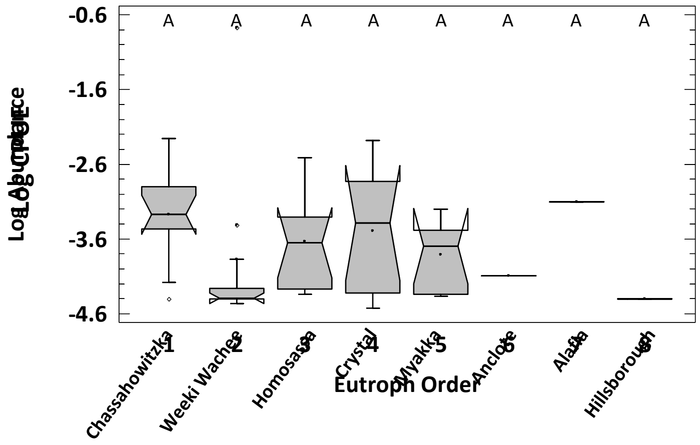
Chironomid larvae



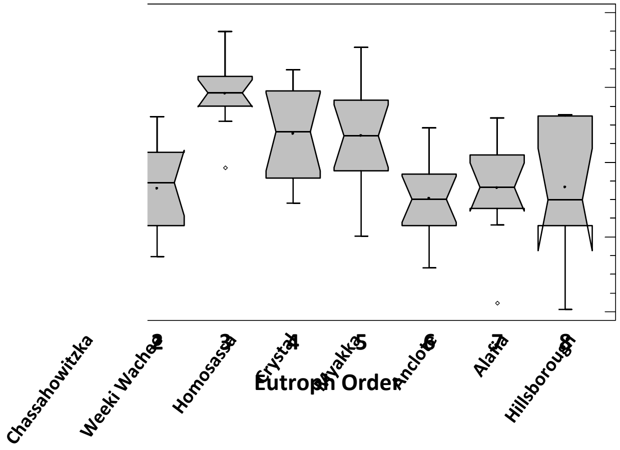
Podocopid ostracods



Ceratopogonid larvae



Americamysis juveniles



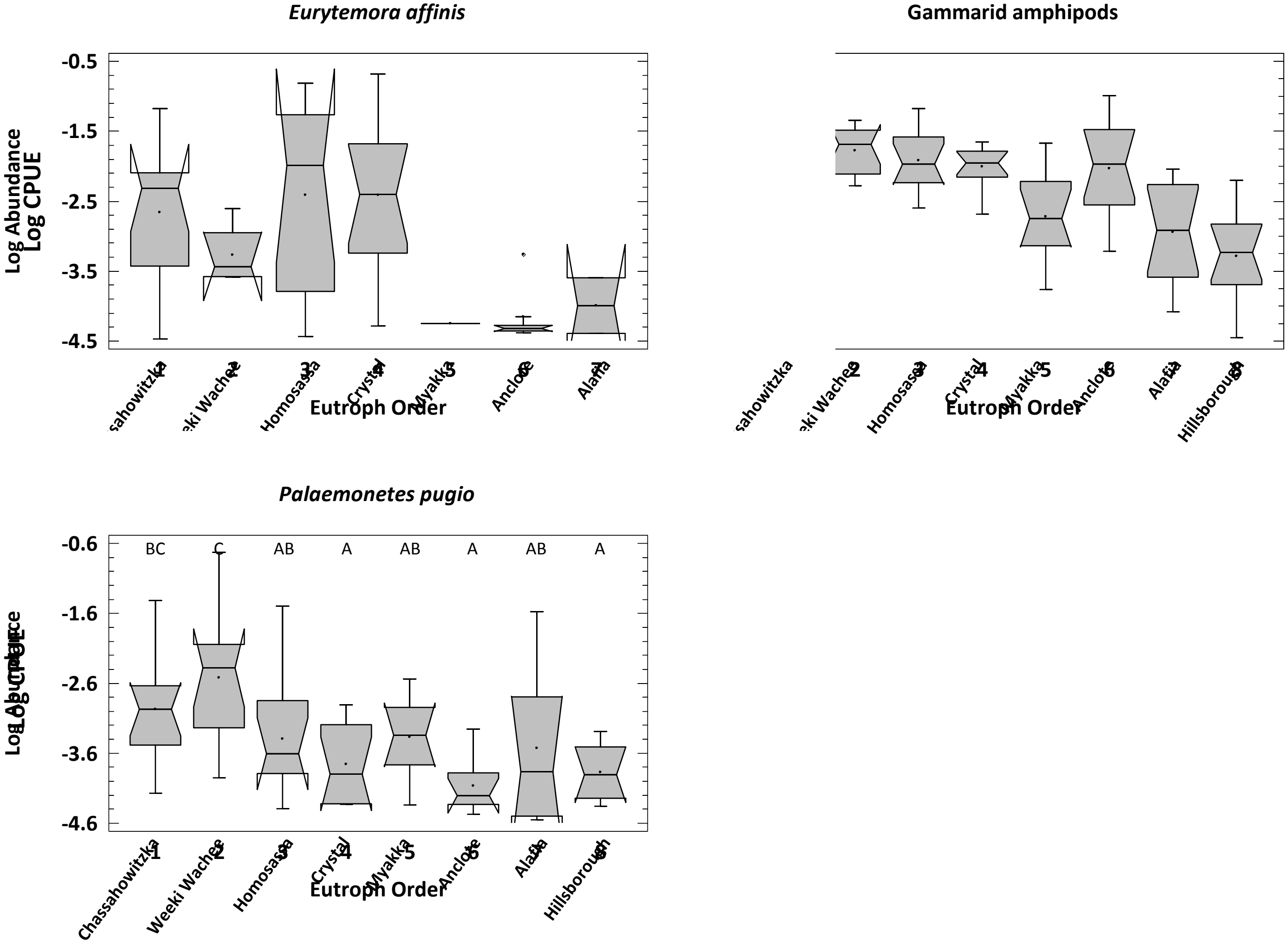


Figure 4b: Ln-transformed CPUE of spring-fed indicator taxa with IV >66.7 in each estuary. Boxes represent upper and lower quartiles, whiskers show ranges, points show the means and box dividers show the medians. For taxa that passed a variance check, multiple range tests were performed and the resulting groupings are represented by letters above the boxes.

3.5. Salinity Gradient

The number of observations per salinity increment was more evenly distributed within surface-fed than spring-fed estuaries (Figure 5), a reflection of the more constant flow within spring-fed estuaries. The lack of observations at high and low salinities within the spring-fed systems results from the lack of floods and droughts in those estuaries. The distance between points on the MDS plots (Figure 6) are related to the amount of change in community structure between increments. The surface-fed estuaries showed rapid change in community structure up until salinities greater than 1, at which point the rate of change was relatively constant. There was also an inflection point centered on salinities in the range of 8-13‰ (Figure 6). In contrast, the plot for spring-fed estuaries could be divided up into three distinct water masses based on community structure (Figure 6): salinities below 1‰ (freshwater/spring community), salinities of 23‰ and higher (marine community), and salinities from 2-22‰ (estuarine gradient community).

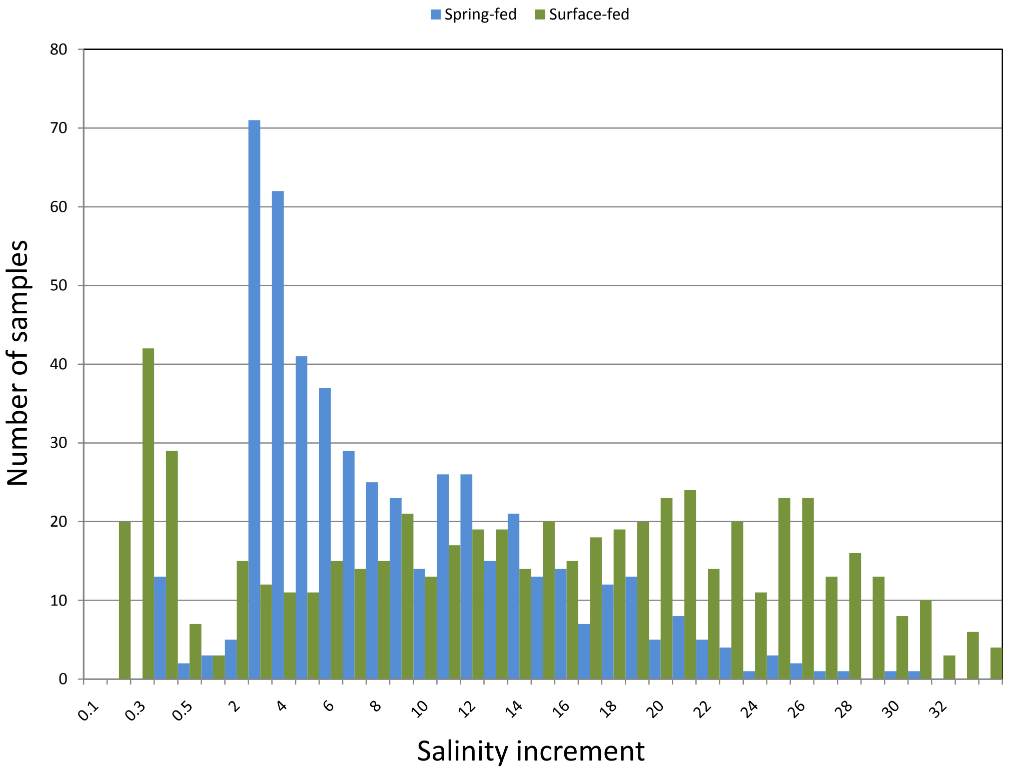


Figure 5: Distribution of sampling effort across salinity increments. Differences in number of samples per salinity bin reflect natural differences in the amount of variability between spring-fed and surface-fed inflow rates. High-inflow and low-inflow events created the left and right extremes in the surface-fed distribution, whereas the salinities associated with spring-fed estuaries collectively resemble a mixing (dilution) curve.

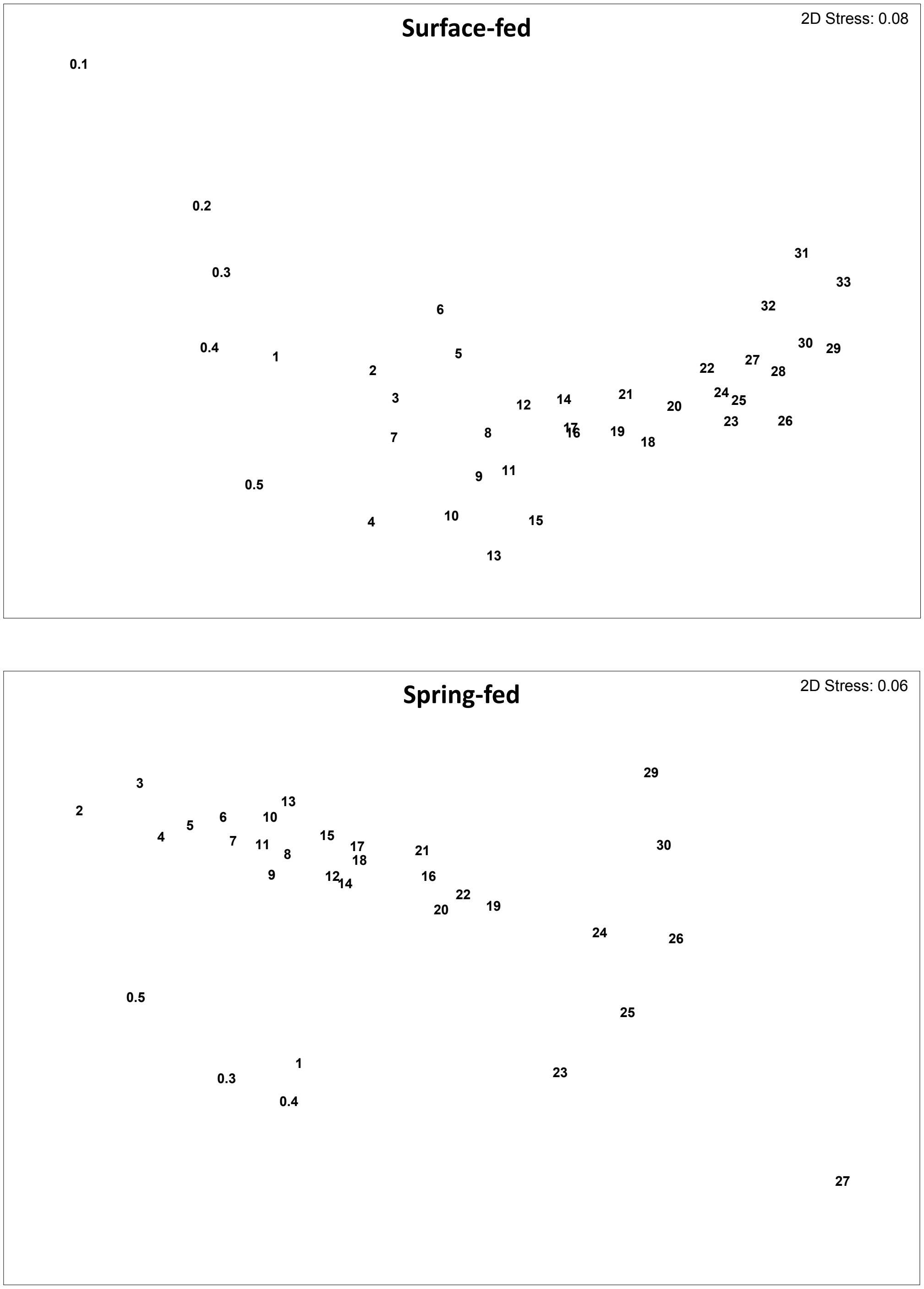


Figure 6: MDS plots of assemblage change in zooplankton and hyperbenthos along salinity bins in surface-fed and spring-fed estuaries (all estuaries and months included). In the surface-fed estuaries, note the inflection at around 8-13‰. In the spring-fed estuaries note the offset between the freshwater community (0.3-1.0‰), the continuously variable estuarine community (2-22‰), and the marine community (23-30‰).

4. Discussion

The results for salinity-based analysis suggest the two types of estuaries evaluated in this study are structured differently along the salinity-space gradient. Zooplankton assemblage changes in surface-fed estuaries are very similar to those found in nekton (Greenwood 2007). There was rapid change in community structure at low salinities followed by relatively constant change across the rest of the increments (Figure 6). Spring-fed systems were different in that there were different groupings of salinity increments (<1, 2-22 and >22) and no flexion point within the estuarine gradient portion of the plot (Figure 6). Flow patterns might be the driving factor behind the differences. The four surface-fed estuaries typically have many days of low flow and comparatively few days of high flow that are associated with heavy rainfall events (Figure 7). Such strong temporal differences in flow (flashiness) result in periods of very high or very low salinities over large portions of the estuary (Figure 5). This creates event-driven discontinuities that are likely disruptive to the formation of distinct assemblages (e.g., spatially discrete phytoplankton blooms or hypoxia events). Spring-fed systems, on the other hand, are characterized by relatively constant flow rates and very few periods where they experience disturbances caused by extremes in inflow or salinity (Figures 5 and 7). This allows a more temporally stable delineation between faunal groups to form and be maintained along the estuarine axis.

There were broad similarities in the faunas of the two types of estuaries. Decapod larvae, gammaridean amphipods, polychaetes and cumaceans were pervasive in all six estuaries. These groups, however, represent broad taxonomic categories and it is likely there are differences within these groups that are masked by the lack of higher taxonomic resolution. Even given these similarities, surface-fed and spring-fed estuaries appear to have fundamentally different faunas associated with them, at least in terms of zooplankton and hyperbenthos. The MDS plot in Figure 3 shows minimal intermingling between the two estuary types with the exception of the Crystal estuary. These differences were also clearly mirrored by the indicator taxa (Figures 4a, b). Although the order of presentation for estuaries is based on the MDS results in Figure 3, the selection of taxa for inclusion in Figures 4a and 4b was based on an independent method (Dufrêne and Legendre 1997) for identifying indicator taxa.

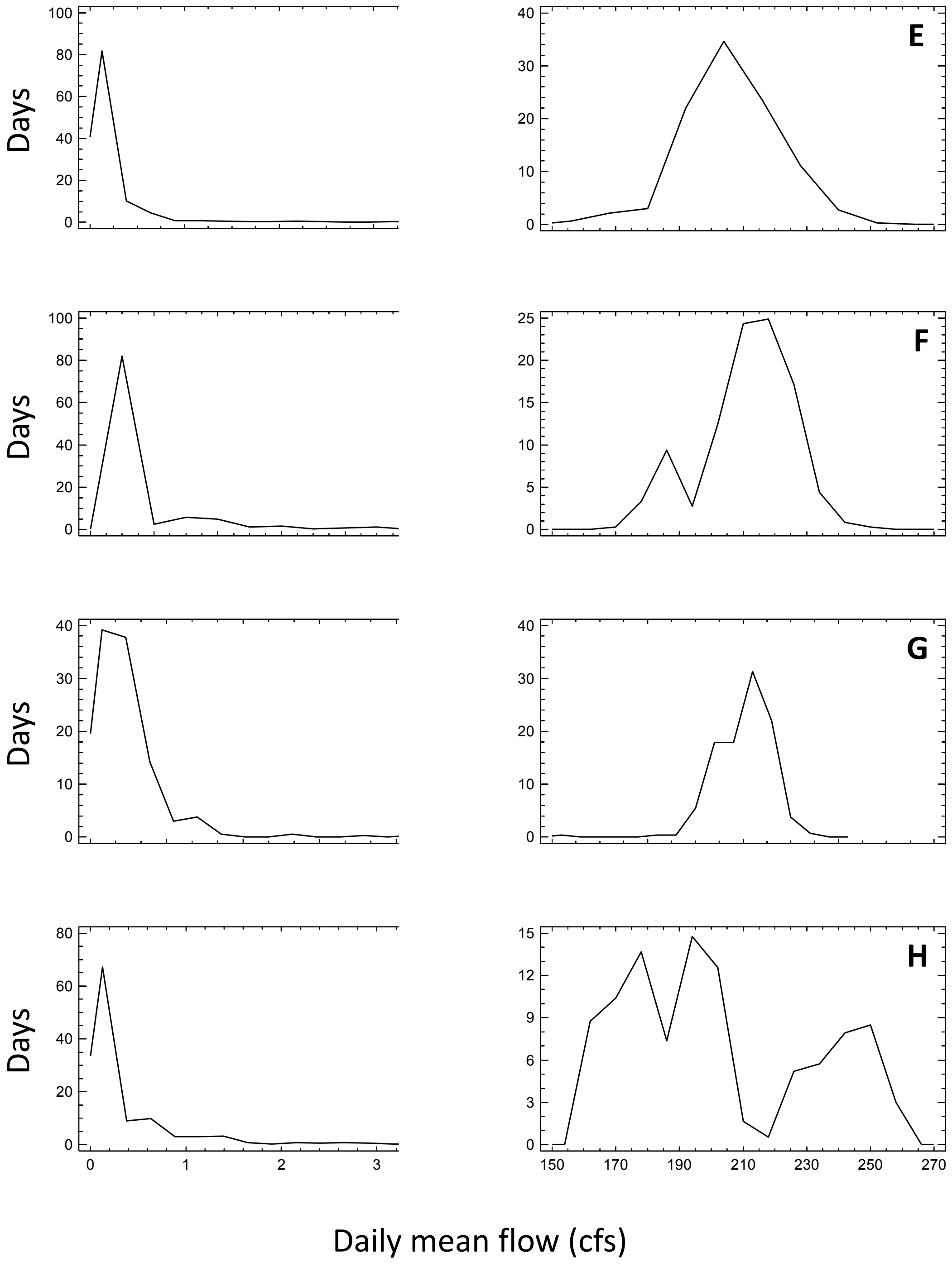


Figure 7: Flow distributions for the eight estuaries during the time period of the collections. (A) Anclote (B) Hillsborough (C) Alafia (D) Myakka (E) Crystal (F) Homosassa (G) Chassahowitzka (H) Weeki Wachee. Note the changes in scale of the y-axis.

The higher indicator values within spring-fed estuaries is likely related to the higher disparity between surface-fed estuaries compared to spring-fed estuaries. A taxon that was a good indicator for one spring-fed estuary was more likely to also be a good indicator for the other three. The higher degree of dissimilarity between surface-fed estuaries is also probably related to less consistent freshwater input as rainfall patterns produce a strong seasonal signal in inflow.

The indicator taxa for the two estuary types were markedly different in terms of their predominant habitat. Although all collections were made with plankton nets, and therefore all organisms were necessarily collected from the water column, many of the strongest indicator taxa live in close contact with the bottom during some or all of their life cycles. There was a clear tendency for spring-fed indicators to be benthic (e.g., prosobranch gastropods) or hyperbenthic organisms (e.g., isopods, *Bowmaniella dissimilis*), with most of these indicators being peracarid crustaceans. Conversely, indicator taxa for surface-fed estuaries were generally pelagic organisms that are directly (e.g., *Acartia tonsa* and *Oikopleura dioica*) or indirectly (e.g., chaetognaths and *Anchoa mitchilli*) dependent on phytoplankton.

As mentioned earlier, trends in the abundances of these indicator taxa mirrored the order the estuaries occurred in the MDS plot (Figures 3, 4a and 4b). *Oikopleura dioica* was included in Figure 4a because its IV approached 66.7 and the only spring-fed estuaries in which the species occurred at all were the Homosassa and Crystal estuaries (with especially high numbers in the latter), the two spring-fed estuaries that most closely resembled surface-fed estuaries. Likewise, the fifteen spring-fed indicator taxa with IVs >66.7 displayed the opposite trend, generally in an even more pronounced way. Spring-fed indicators often had the highest CPUE within the Chassahowitzka and Weeki Wachee estuaries. The Homosassa, Crystal, Myakka and Anclote estuaries were often intermediate, while the Alafia and Hillsborough estuaries were usually low (Figure 4b).

There are several differences in geomorphology, hydrology and water quality between spring-fed and surface-fed estuaries that could conceivably contribute to differences in community composition. The spring-fed estuaries are shorter than surface-fed estuaries and, and since their flow is derived primarily from springs, they are less impacted by short-term variations in freshwater supply from their watersheds. Their springsheds can be extensive, but groundwater flow is complex, causing rainfall to be temporally integrated and seasonal variations in flow much more subdued. Again, differences in flow patterns are likely to be a strong factor influencing community structure. Changes in freshwater inflow influence both the abundance and distribution of dominant organisms, but these responses are much more pronounced in surface-fed estuaries (Peebles et al. 1996; Tolley et al. 2005; Peebles et al. 2007; Tolley et al. 2010).

The two types of estuaries also exhibit differences in water clarity (Figure 8). EPA STORET data from spring-fed systems had higher Secchi disk depths and lower measures of color, turbidity, and chlorophyll a (Kolmogorov-Smirnov test, $p<0.05$)(EPA 2009), reflecting the greater reliance of surface-fed estuaries on productivity within the water column, which is, in turn, reflected in the taxonomic composition the estuarine communities. Strong indicator taxa for spring-fed estuaries were usually hyperbenthic crustaceans, especially peracarid crustaceans such as *Harrieta faxoni, Hargeria rapax, Erichsonella* spp., *Bowmaniella dissimilis* and *Cassidinidea ovalis*. It has been previously noted that the fauna in spring-fed systems tends to be dominated by benthic production and organisms (Jacoby et al. 2008). In contrast, strong indicator taxa for surface-fed estuaries were primarily pelagic zooplankton that were either directly dependant on water-column productivity (e.g. *Oikopleura dioica, Acartia tonsa*) or were predators on pelagic zooplankton (e.g. chaetognaths, *Anchoa mitchilli*). As mentioned earlier, the two spring-fed estuaries that most closely resembled surface-fed estuaries were the Homosassa and Crystal estuaries. Both have been shown to have less benthic macrophytes than the other two spring-fed estuaries (Frazer et al. 2001; Frazer et al. 2006). That is not to imply that benthic macrophytes are entering the planktonic food web since benthic microalgae is much more likely to be the trophically important source. It is, however a clear indicator of the location of the primary production. In the Crystal estuary, this partly results from greater depths placing the bottom below the euphotic zone (Frazer et al. 2001).

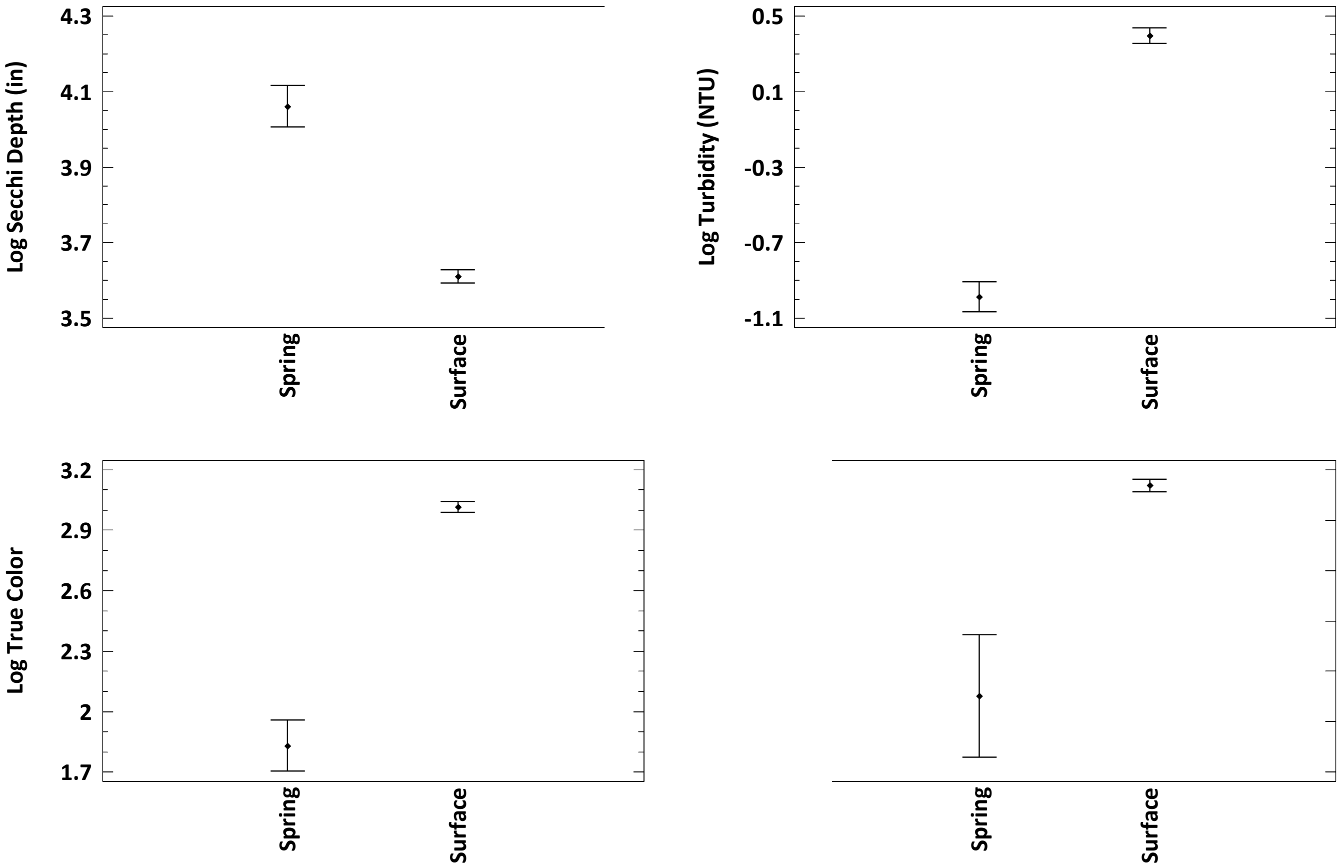


Figure 8: Water quality measures for the two estuary types (Ln-transformed data). Data are from the EPA STORET site (http://www.epa.gov/storet/).

Short stream lengths and short residence times of water moving through spring-fed estuaries will hinder the formation of phytoplankton blooms (Frazer et al. 2001). Nevertheless, although Florida's spring-fed estuaries would be considered to be oligotrophic estuaries in their natural state, agricultural activity and increasing residential/municipal development in the area has raised concerns about nutrient enrichment. Recent evidence suggests this is an increasing problem (Katz 2004; Brown et al. 2008; Harrington et al. 2010). Historic nitrate concentrations in Florida springs were typically less than 0.2 mg/L (Harrington et al. 2010). The Florida Department of Environmental Protection, in monitoring 49 springs between 2001 and 2006, found that 36 (73%) exceeded the established standard concentration of 0.35 mg/L for nitrate in clear-water streams, including three of the spring-fed estuaries considered here (Harrington et al. 2010). Frazer et al. (2006) found increases in nitrate and soluble reactive phosphate as well as decreases in SAV in all three systems they studied (Chassahowitzka, Homosassa and Weeki Wachee). Additionally, they recorded increased light attenuation and periphyton biomass in the Chassahowitzka and Homosassa estuaries. The Homosassa River has also been identified by the Florida Department of Environmental Protection as possibly impaired due to increased chlorophyll *a* (FDEP 2006). "In fact, the current view among many (if not all) scientists and resource managers is that plant and algal populations in Florida's spring-dominated ecosystems are undergoing major structural and functional changes, due, in large part, to increases in anthropogenic enrichment of nutrient levels in groundwater and the consequent nutrification of spring discharges" (Jacoby et al. 2008). Management of nutrient enrichment in spring-fed estuaries is complicated by the lag produced by transit time through the aquifer system (Katz et al. 2001; Katz 2004).

Although the data presented in this study span a period of almost five-and-a-half years, they do not represent a multi-year time series for any of the systems. It is therefore not possible to draw conclusions about temporal trends in eutrophication within any of the six estuaries. It is clear, at the very least, that the light environment within these estuaries plays a large role in determining the source of primary productivity. Clear water and short water residence times lead to increased benthic primary production and relatively low concentrations of holoplanktonic or pelagic taxa. Such estuaries are instead characterized by a predominance of hyperbenthic peracarid crustaceans. The data do, however, suggest there may be easily measurable ecological consequences of changes documented elsewhere (e.g., Frazer et al. 2006). If the spring-fed estuaries experience increases in episodic benthic hypoxia (as suggested for the Homosassa by Peebles et al. 2009) and/or a shifting of primary productivity from the benthos to the water column, then the faunal differences outlined here could result from a situation similar to that described for fisheries yields in semi-enclosed seas (Caddy 2000; Moreno et al. 2000). The conceptual models provided by Caddy (2000) detail how eutrophication leads to loss of benthic habitat and organisms via increased hypoxia and decreased water transparency followed by a shift to dominance by pelagic organisms. While this study represents only a snapshot of the current state of these systems, it does point to a dichotomy of benthic versus pelagic production among the estuaries and identifies which organisms are important indicators of changing trophic pathways within spring-fed estuaries.

The biological surveys that have been conducted to date are therefore useful as benchmarks for future comparisons. Community distinctions between the two estuary types are based on differences in inflow processes and water quality. The relatively constant inflows associated with the spring-fed estuaries do not allow phytoplankton blooms to form upstream, and the lack of extensive runoff from watersheds keeps concentrations of colored dissolved organic matter (CDOM) relatively low. The relative absence of these two light-attenuating materials allows light to reach the bottom throughout the year, which encourages benthic algal and vascular plant (SAV) growth. The surface-fed estuaries, on the other hand, often experience phytoplankton blooms and seasonal periods of high CDOM concentration, both of which discourage benthic plant growth, especially in the form of relatively long-lived SAV.

Because anthropogenic additions of nutrients to the springs will not result in phytoplankton blooms unless local water residence times are long enough to allow blooms to form, water residence times in the spring-fed estuaries should be kept short enough to discourage such blooms. Should phytoplankton blooms become more prevalent in the future, a shift from hyperbenthic peracarid crustaceans to zooplanktonic organism would be expected, causing many of the community-level differences documented here to diminish. The biological surveys that have been conducted to date are therefore useful as benchmarks for future comparisons. The present analyses document the types of faunal changes that would be expected if future degradation does occur.

5. Conclusions

Spring-fed and surface-fed estuaries in west-central Florida differ significantly in terms of water clarity, dominant benthic substrate, sources of freshwater and consistency of flow. These environmental differences translated into differences in the community composition of zooplankton, ichthyoplankton and hyperbenthos. Although both types of estuaries have similar taxa present within them, the relative organism abundances, percent occurrences and gradients of biological community change point to distinct community types.

Surface-fed estuaries, which have higher water-column productivity than their spring-fed counterparts, were characterized by the prevalence of pelagic organisms that are dependent on water-column productivity, such as *Acartia tonsa, Parasterope pollex,* chaetognaths, *Anchoa mitchilli, Lucifer faxoni, Labidocera aestiva,* and *Oikopleura dioica*. Spring-fed estuaries were characterized by the prevalence of hyperbenthic peracarids such as *Hargeria rapax, Erichsonella* spp., *Harrieta faxoni, Cassidinidea ovalis,* and *Bowmaniella dissimilis*. In addition, spring-fed estuaries appeared to have community-level breaks between 1 and 2‰ and between 22 and 23‰. The lack of such breaks in surface-fed estuaries may result from periodic disruptions in the community gradient caused by large variations in inflow.

We suggest the differences in community composition were largely a product of differences in the light environments in the two estuary types. Spring-fed estuaries have clear water and extensive communities of benthic primary producers. The prevalence of hyperbenthic taxa combined with the reduced prominence of pelagic herbivores and omnivores in these estuaries is evidence of community reliance on benthic primary productivity. The Crystal and Homosassa estuaries have been shown to have reduced amounts of benthic primary producers compared to the Chassahowitzka and Weeki Wachee estuaries. The similarity of their community compositions to those of the surface-fed estuaries suggests phytoplankton production plays a larger role in these two spring-fed estuaries. It is possible these differences were due to natural factors such as salinity intrusions or water depth; however, the evidence suggests eutrophication is a justified concern in spring-fed estuaries.

The relatively constant inflows into the spring-fed estuaries inhibit the formation of phytoplankton blooms, at least in upstream areas. This, along with relatively low colored dissolved organic matter (CDOM) concentrations, allows light to reach the bottom throughout the year. Benthic algal and vascular plant (SAV) growth is encouraged by this year-round light availability, whereas the surface-fed estuaries often experience phytoplankton blooms and seasonal periods of high CDOM concentration that discourage benthic plant growth, especially by long-lived SAV.

Anthropogenic additions of nutrients to the springs and their estuaries will not result in phytoplankton blooms unless local water residence times become long enough to allow blooms to form. For this reason, water residence times in the spring-fed estuaries should be kept short enough to discourage phytoplankton blooms. If phytoplankton blooms become more prevalent in the future, then a shift from hyperbenthic peracarid crustaceans to zooplanktonic organism would be expected, and many of the community-level differences documented here would become less apparent. The present study and the biological surveys that have been conducted to date are therefore likely to be useful benchmarks in future comparisons.

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7 Appendices

Appendix A 1. Percent occurrence of each taxon overall, for each estuary, and within each estuary type.

Taxon	Code	Overall	Chassahowitzka	Crystal	Homosassa	Weeki Wachee	Spring Total
Acartia tonsa	Atonsao	100.0	100.0	100.0	100.0	100.0	100.0
cumaceans	cumacn	100.0	100.0	100.0	100.0	100.0	100.0
Edotea triloba	Edotia	100.0	100.0	100.0	100.0	100.0	100.0
amphipods, gammaridean	gmmrd	100.0	100.0	100.0	100.0	100.0	100.0
decapod mysis	mysis	100.0	100.0	100.0	100.0	100.0	100.0
Unidentified Americamysis juveniles	AmysJUV	99.0	100.0	100.0	100.0	100.0	100.0
polychaetes	polych	99.0	100.0	100.0	100.0	91.7	97.9
decapod zoea	zoea	99.0	100.0	91.7	100.0	100.0	97.9
dipterans, chironomid larvae	chiron	97.9	100.0	100.0	100.0	100.0	100.0
Americamysis almyra	Aalmyra	96.9	100.0	100.0	100.0	100.0	100.0
Anchoa mitchilli	Amtch	94.8	100.0	100.0	91.7	66.7	89.6
gastropods, prosobranch	prosbrch	94.8	100.0	91.7	100.0	100.0	97.9
Unidentified gobiid larvae	gobiid	93.8	75.0	91.7	100.0	100.0	91.7
dipterans, pupae	pupae	93.8	100.0	100.0	100.0	100.0	100.0
decapod megalopae	megalop	90.6	75.0	91.7	100.0	91.7	89.6
pelecypods	plcypd	89.6	83.3	91.7	91.7	100.0	91.7
Pseudodiaptomus coronatus	Psdiap	89.6	83.3	100.0	100.0	66.7	87.5
chaetognaths	chaetog	86.5	50.0	100.0	83.3	66.7	75.0
Livoneca	cymthdA	85.4	75.0	91.7	100.0	41.7	77.1
Cassidinidea ovalis	Covalis	83.3	100.0	100.0	100.0	100.0	100.0
Microgobius spp.	Mcrgob	83.3	83.3	83.3	91.7	83.3	85.4
ostracods, podocopid	podocop	83.3	100.0	66.7	91.7	100.0	89.6
Parasterope pollex	ppollex	83.3	41.7	83.3	91.7	75.0	72.9
Menidia spp.	Mnidia	81.3	75.0	83.3	100.0	91.7	87.5
Palaemonetes spp.	Plmnts	81.3	66.7	66.7	83.3	75.0	72.9
Bowmaniella dissimilis	Bdissim	77.1	100.0	100.0	100.0	100.0	100.0
Palaemonetes pugio	Ppugio	77.1	100.0	91.7	83.3	91.7	91.7
Gobiosoma spp.	Gbsma	76.0	66.7	75.0	91.7	66.7	75.0
Taphromysis bowmani	Tbowman	75.0	100.0	100.0	83.3	100.0	95.8
Erichsonella spp.	Erchspp	74.0	100.0	100.0	100.0	100.0	100.0
hirudinoideans	hirud	74.0	100.0	83.3	91.7	100.0	93.8
Hargeria rapax	Hrapax	72.9	100.0	100.0	100.0	100.0	100.0
Munna reynoldsi	Uromunna	72.9	100.0	83.3	75.0	91.7	87.5
branchiurans, Argulus spp.	Argulus	71.9	75.0	75.0	58.3	83.3	72.9

Taxon	Code	Overall	Chassahowitzka	Crystal	Homosassa	Weeki Wachee	Spring Total
unidentified harpacticoids	hrpctcd	70.8	91.7	75.0	83.3	66.7	79.2
Hippolyte zostericola	Hzost	70.8	75.0	83.3	66.7	66.7	72.9
Harrieta faxoni	Hfaxoni	68.8	100.0	91.7	100.0	100.0	97.9
ephemeropteran larvae	ephmpt	67.7	100.0	75.0	75.0	100.0	87.5
Labidocera aestiva	Laestiva	67.7	33.3	50.0	33.3	58.3	43.8
amphipods, caprellid	cprlld	64.6	25.0	75.0	91.7	16.7	52.1
Gobiesox strumosus	Gbsx	64.6	33.3	75.0	75.0	75.0	64.6
acari	acari	63.5	100.0	91.7	41.7	83.3	79.2
Lucifer faxoni	Lucifer	62.5	16.7	91.7	41.7	33.3	45.8
Sarsiella zostericola	Szost	61.5	50.0	66.7	100.0	75.0	72.9
nematodes	nmtds	60.4	91.7	83.3	58.3	50.0	70.8
Sinelobus stanfordi	Sstnfrdi	59.4	50.0	75.0	75.0	100.0	75.0
Lucania parva	Lparv	58.3	100.0	66.7	91.7	100.0	89.6
oligochaetes	oligch	58.3	75.0	50.0	58.3	41.7	56.3
Unidentified alphaeids	Alph	57.3	50.0	66.7	66.7	41.7	56.3
gastropods, opisthobranch	opsbrch	57.3	91.7	41.7	58.3	66.7	64.6
Unidentified blenniid larvae	blniid	55.2	58.3	83.3	58.3	33.3	58.3
dipteran, Chaoborus punctipennis larvae	Cpncpnnd	55.2	33.3	8.3	83.3	83.3	52.1
trichopteran larvae	trichop	54.2	91.7	16.7	25.0	91.7	56.3
Trinectes maculatus	Trimac	54.2	41.7	50.0	33.3	33.3	39.6
Sphaeroma terebrans	Sphtrbs	53.1	50.0	41.7	16.7	41.7	37.5
Simocephalus vetulus	Svetelus	52.1	41.7	58.3	25.0	91.7	54.2
Syngnathus scovelli	Sygscv	52.1	83.3	75.0	33.3	91.7	70.8
Anchoa spp.	Anchoa	51.0	16.7	66.7	58.3	16.7	39.6
dipterans, ceratopogonid larvae	crtpgd	51.0	91.7	75.0	83.3	75.0	81.3
Brevoortia spp.	Brvtia	50.0	58.3	83.3	50.0	0.0	47.9
Clytia sp.	Clytia	49.0	25.0	16.7	33.3	41.7	29.2
Eurytemora affinis	Erytaff	45.8	91.7	100.0	66.7	33.3	72.9
appendicularian, Oikopleura dioica	Odioica	45.8	0.0	50.0	16.7	0.0	16.7
Temora turbinata	Tturb	45.8	58.3	75.0	83.3	41.7	64.6
siphonostomatids	caligoid	42.7	50.0	50.0	41.7	0.0	35.4
Cyathura polita	Cpolita	42.7	50.0	58.3	50.0	33.3	47.9
Macrocyclops albidus	Malbidus	42.7	50.0	50.0	58.3	33.3	47.9
fish eggs, percomorph	prcmph	41.7	16.7	41.7	50.0	16.7	31.3
Upogebia spp. postlarvae	Upgba	41.7	33.3	66.7	50.0	25.0	43.8
odonates, zygopteran larvae	zygptn	41.7	83.3	50.0	16.7	33.3	45.8
Mesocyclops edax	Medax	40.6	0.0	16.7	8.3	91.7	29.2
Anopsilana jonesi	Ajonesi	39.6	58.3	41.7	58.3	16.7	43.8
Sphaeroma quadridentata	Sphquad	39.6	16.7	33.3	0.0	66.7	29.2

Taxon	Code	Overall	Chassahowitzka	Crystal	Homosassa	Weeki Wachee	Spring Total
Callinectes sapidus	Csap	38.5	41.7	25.0	66.7	66.7	50.0
Apseudes sp.	Apseudes	36.5	75.0	66.7	66.7	50.0	64.6
foraminiferans	foram	36.5	91.7	16.7	8.3	91.7	52.1
Monstrilla sp.	Mnstrlla	36.5	0.0	66.7	58.3	25.0	37.5
hemipterans, gerrid adults	gerrid	34.4	50.0	25.0	16.7	50.0	35.4
Eucinostomus spp.	Eucin	32.3	33.3	66.7	50.0	58.3	52.1
Bathygobius soporator	Bthgob	31.3	16.7	50.0	25.0	16.7	27.1
Farfantepenaeus duorarum	Fduorm	31.3	33.3	50.0	25.0	50.0	39.6
Ambidexter symmetricus	Asymm	30.2	0.0	25.0	0.0	25.0	12.5
Membras martinica	Mmart	30.2	25.0	50.0	0.0	41.7	29.2
cirriped nauplii	crpdNaup	29.2	0.0	33.3	0.0	16.7	12.5
Orthocyclops modestus	Orthcyc	29.2	41.7	41.7	25.0	25.0	33.3
Xenanthura brevitelson	Xbrvtlsn	29.2	50.0	33.3	50.0	33.3	41.7
penaeid metamorphs	penmeta	28.1	0.0	41.7	50.0	25.0	29.2
Gobiosoma bosc	Gbsbsc	26.0	33.3	58.3	25.0	16.7	33.3
Microgobius gulosus	Mcgbgl	26.0	41.7	25.0	41.7	25.0	33.3
Sida crystallina	Scryst	26.0	8.3	8.3	0.0	75.0	22.9
Americamysis stucki	Astucki	25.0	8.3	33.3	0.0	8.3	12.5
Calanopia americana	Clanopia	25.0	8.3	41.7	25.0	16.7	22.9
turbellarians	trbllrns	25.0	75.0	0.0	25.0	8.3	27.1
Americamysis bahia	Abahia	24.0	8.3	66.7	16.7	25.0	29.2
Diaptomus spp.	Diaptmus	22.9	0.0	16.7	33.3	41.7	22.9
Lagodon rhomboides	Lrhom	21.9	41.7	0.0	25.0	41.7	27.1
Mnemiopsis leidyi	Mleidyi	21.9	0.0	0.0	25.0	0.0	6.3
Chasmodes saburrae	Chsab	20.8	25.0	25.0	33.3	25.0	27.1
hemipterans, corixid adults	corixid	20.8	50.0	0.0	0.0	8.3	14.6
Cynoscion arenarius	Cynar	20.8	0.0	25.0	0.0	0.0	6.3
coleopterans, elmid adults	elmid	20.8	0.0	0.0	16.7	25.0	10.4
Gambusia holbrooki juveniles	Ghlbk	20.8	8.3	8.3	16.7	25.0	14.6
Menticirrhus spp.	Mntcrr	20.8	16.7	8.3	8.3	16.7	12.5
Oithona spp.	Oithona	20.8	0.0	25.0	8.3	0.0	8.3
collembolas, podurid	podurid	20.8	0.0	8.3	41.7	25.0	18.8
Elops saurus	Esaur	19.8	8.3	16.7	16.7	0.0	10.4
Gobiosoma robustum	Gbsrob	19.8	33.3	0.0	8.3	50.0	22.9
penaeid postlarvae	penaeid	19.8	8.3	50.0	50.0	0.0	27.1
Cynoscion nebulosus	Cynneb	17.7	16.7	33.3	0.0	16.7	16.7
Fundulus spp.	Fndls	17.7	50.0	33.3	8.3	50.0	35.4
Syngnathus louisianae	Sygnls	17.7	8.3	8.3	0.0	0.0	4.2
cladocerans, Daphnia spp.	Daphnia	16.7	0.0	16.7	16.7	33.3	16.7
medusa sp. d	medspD	16.7	16.7	33.3	8.3	8.3	16.7
Periclimenes spp.	Prclmns	16.7	8.3	58.3	16.7	0.0	20.8

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Unidentified processids	procesd	16.7	0.0	16.7	8.3	0.0	6.3
Saphirella spp.	Sphrella	16.7	0.0	16.7	16.7	16.7	12.5
unidentified freshwater cyclopoids	UIDFWcop	16.7	8.3	25.0	25.0	25.0	20.8
coleopterans, gyrinid larvae	gyrinid	15.6	0.0	0.0	0.0	16.7	4.2
Limulus polyphemus larvae	Limulus	15.6	8.3	0.0	0.0	8.3	4.2
Mugil cephalus	Mcphls	15.6	8.3	25.0	16.7	0.0	12.5
medusa sp. e	medspE	15.6	33.3	16.7	0.0	0.0	12.5
Ogyrides alphaerostris	Ogyrds	15.6	8.3	50.0	8.3	16.7	20.8
Pseudevadne tergestina	Ptergstn	15.6	0.0	8.3	0.0	0.0	2.1
Ilyocryptus sp.	Ilycryp	14.6	0.0	8.3	0.0	8.3	4.2
Leiostomus xanthurus	Leixan	14.6	33.3	33.3	8.3	25.0	25.0
Lucania goodei	Lgood	14.6	66.7	0.0	0.0	33.3	25.0
Penilia avirostris	Pavrstrs	14.6	0.0	16.7	8.3	0.0	6.3
paguroid juveniles	pgurd	14.6	0.0	33.3	0.0	8.3	10.4
odonates, anisopteran larvae	ansptn	13.5	8.3	0.0	0.0	25.0	8.3
lepidopterans, pyralid larvae	lepidop	13.5	33.3	0.0	0.0	25.0	14.6
Lepomis spp.	Lepoms	13.5	16.7	16.7	41.7	0.0	18.8
Myrophis punctatus	Mpunc	13.5	25.0	0.0	16.7	16.7	14.6
Callianassa spp.	Clnssa	12.5	0.0	33.3	16.7	0.0	12.5
Lolliguncula brevis	Lllgbrvs	12.5	0.0	0.0	0.0	0.0	0.0
paracalanids	pracalnd	12.5	16.7	16.7	8.3	8.3	12.5
pycnogonids	pycgnd	12.5	0.0	16.7	33.3	0.0	12.5
Tozeuma carolinense	Tozma	12.5	0.0	8.3	0.0	0.0	2.1
Anchoa hepsetus	Ahepst	11.5	0.0	8.3	16.7	8.3	8.3
Latonopsis fasciculata	Lfsclta	11.5	0.0	0.0	0.0	25.0	6.3
coleopterans, noterid adults	notrid	11.5	0.0	8.3	0.0	25.0	8.3
Portunus sp.	Prtns	11.5	8.3	16.7	41.7	8.3	18.8
Syngnathus floridae	Sygnfl	11.5	33.3	8.3	8.3	0.0	12.5
Achirus lineatus	Achr	10.4	0.0	16.7	8.3	8.3	8.3
clupeid	clup	10.4	0.0	25.0	16.7	0.0	10.4
Centropages velificatus	Cvlfcts	10.4	0.0	16.7	0.0	0.0	4.2
Leydigia sp.	Leydigia	10.4	8.3	0.0	8.3	0.0	4.2
Notemigonus crysoleucas	Ncrysl	10.4	58.3	0.0	16.7	0.0	18.8
Petrolisthes armatus	Parm	10.4	0.0	8.3	0.0	16.7	6.3
Periclimenes longicaudatus	Plong	10.4	8.3	0.0	16.7	8.3	8.3
Pinnixa sayana	Psyna	10.4	0.0	0.0	0.0	0.0	0.0
Rhithropanopeus harrisii	Rhith	10.4	16.7	8.3	8.3	0.0	8.3
Bairdiella chrysoura	Brdcry	9.4	0.0	16.7	8.3	0.0	6.3
neuropterans, Climacia spp.	Climacia	9.4	0.0	8.3	0.0	0.0	2.1

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brachiopod, Glottidia pyramidata larvae	Gpyrmd	9.4	0.0	8.3	0.0	0.0	2.1
Heterandria formosa	Hform	9.4	0.0	0.0	8.3	8.3	4.2
Lupinoblennius nicholsi	Lupbl	9.4	8.3	25.0	8.3	16.7	14.6
Micropterus salmoides	Msalm	9.4	41.7	0.0	0.0	16.7	14.6
myodocopod sp. a	mydocopA	9.4	0.0	0.0	33.3	8.3	10.4
ophiuroidean juveniles	ophiurd	9.4	0.0	0.0	0.0	16.7	4.2
Palaemonetes vulgaris	Pvulg	9.4	0.0	25.0	0.0	41.7	16.7
Squilla empusa	Sqempsa	9.4	0.0	16.7	0.0	0.0	4.2
Unidentified callianassids	callian	8.3	8.3	16.7	25.0	0.0	12.5
coleopterans, dytiscid larvae	dystcid	8.3	8.3	0.0	0.0	25.0	8.3
Labidesthes sicculus	Lsicc	8.3	0.0	0.0	0.0	8.3	2.1
Liriope tetraphylla	Lttraphy	8.3	0.0	8.3	0.0	0.0	2.1
medusa sp. a	medspA	8.3	0.0	8.3	0.0	8.3	4.2
Osphranticum labronectum	Osphrntc	8.3	0.0	8.3	0.0	0.0	2.1
shrimps, unidentified juveniles	UIDshmp	8.3	0.0	8.3	0.0	0.0	2.1
Eucinostomus harengulus	Ecnhar	7.3	33.3	8.3	0.0	16.7	14.6
Latona setifera	Lsetifera	7.3	0.0	0.0	0.0	0.0	0.0
Leptochela serratorbita	Lsrtorb	7.3	0.0	0.0	0.0	0.0	0.0
Notropis spp.	Ntrps	7.3	8.3	0.0	16.7	0.0	6.3
Oligoplites saurus	Osaurs	7.3	0.0	0.0	0.0	0.0	0.0
xanthid juveniles	UIDxntd	7.3	16.7	0.0	8.3	8.3	8.3
Alteutha sp.	Alteutha	6.3	0.0	0.0	0.0	16.7	4.2
Brevoortia smithi juveniles	Bsmithi	6.3	0.0	8.3	16.7	0.0	6.3
Cyclops spp.	Cyclops	6.3	0.0	0.0	0.0	8.3	2.1
Eugerres plumieri	Eugrr	6.3	0.0	8.3	0.0	0.0	2.1
Hippocampus erectus	Herect	6.3	0.0	0.0	0.0	8.3	2.1
medusa, Obelia sp.	Obelia	6.3	8.3	16.7	0.0	0.0	6.3
dipterans, sciomyzid larvae	scmyz	6.3	0.0	0.0	0.0	0.0	0.0
Spelaeomysis sp.	Spelmys	6.3	0.0	0.0	33.3	8.3	10.4
Strongylura spp.	Stglra	6.3	8.3	8.3	0.0	0.0	4.2
dipterans, stratiomyid larvae	strtmyd	6.3	16.7	0.0	0.0	8.3	6.3
anuran larvae	tadpole	6.3	0.0	0.0	0.0	8.3	2.1
Centropages hamatus	Chmatus	5.2	0.0	0.0	0.0	0.0	0.0
coleopterans, curculionid	curcld	5.2	0.0	0.0	8.3	0.0	2.1
Fundulus grandis	Fgrnds	5.2	16.7	0.0	0.0	0.0	4.2
coleopterans, haliplid adults	halpld	5.2	0.0	0.0	0.0	8.3	2.1
Hypsoblennius spp.	Hypsbl	5.2	0.0	0.0	0.0	25.0	6.3
medusa sp. b	medspB	5.2	0.0	0.0	0.0	0.0	0.0
Opsanus beta	Obeta	5.2	25.0	8.3	8.3	0.0	10.4
Probopyrus	Probpyr	5.2	16.7	0.0	0.0	8.3	6.3

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Synodus foetens	Synft	5.2	8.3	16.7	0.0	0.0	6.3
unidentified flexion larvae	UIDfish	5.2	0.0	0.0	8.3	8.3	4.2
Archosargus probatocephalus	Arcprb	4.2	0.0	16.7	0.0	0.0	4.2
Alpheus viridari	Avirid	4.2	16.7	0.0	8.3	0.0	6.3
medusa, Bougainvillia sp.	Bgvlla	4.2	0.0	8.3	0.0	0.0	2.1
Chloroscombrus chrysurus	Cchry	4.2	0.0	0.0	0.0	0.0	0.0
Cyprinodon variegatus	Cvarg	4.2	0.0	8.3	0.0	16.7	6.3
Diaphanosoma sp.	Diphnsm	4.2	0.0	16.7	0.0	0.0	4.2
Dynamenella sp.	Dynmnlla	4.2	0.0	33.3	0.0	0.0	8.3
Euconchoecia chierchiae	Echierch	4.2	0.0	0.0	0.0	8.3	2.1
Eucinostomus gula	Ecngul	4.2	16.7	8.3	0.0	0.0	6.3
Euryalona occidentalis	Euryalona	4.2	0.0	0.0	0.0	0.0	0.0
medusa, Eutima sp.	Eutima	4.2	0.0	8.3	0.0	0.0	2.1
Grimaldina brazzai	Gbrzzai	4.2	0.0	0.0	0.0	0.0	0.0
Hyporhamphus unifasciatus	Hunif	4.2	0.0	0.0	0.0	8.3	2.1
Lepomis auritus	Laurts	4.2	16.7	0.0	0.0	0.0	4.2
Lepisosteus sp.	Lepis	4.2	0.0	8.3	16.7	0.0	6.3
hemipterans, pleid adults	pleid	4.2	0.0	0.0	0.0	0.0	0.0
Ameiurus catus	Acatus	3.1	0.0	0.0	0.0	0.0	0.0
hemipterans, belostomatids	blstmd	3.1	0.0	8.3	0.0	0.0	2.1
Beroe ovata	Bovata	3.1	0.0	0.0	0.0	0.0	0.0
Bunops sp.	Bunops	3.1	0.0	0.0	0.0	0.0	0.0
Ceridodaphnia sp.	Criodaph	3.1	0.0	0.0	0.0	8.3	2.1
cirriped cyprids	crpdCypr	3.1	0.0	25.0	0.0	0.0	6.3
Chilomycterus shoepfi	Cschpf	3.1	0.0	0.0	0.0	8.3	2.1
Euceramus praelongus	Eprael	3.1	0.0	8.3	0.0	0.0	2.1
Etheostoma fusiforme	Ethfus	3.1	0.0	0.0	0.0	0.0	0.0
Eucalanus sp.	Eucal	3.1	0.0	0.0	0.0	0.0	0.0
isopod sp. a	isopodA	3.1	0.0	0.0	0.0	0.0	0.0
Liposarcus spp.	Lposrc	3.1	0.0	0.0	0.0	0.0	0.0
Lepomis punctatus	Lpunc	3.1	16.7	0.0	0.0	0.0	4.2
Lutjanus griseus	Ltjgrs	3.1	8.3	0.0	8.3	0.0	4.2
medusa sp. c	medspC	3.1	0.0	0.0	0.0	0.0	0.0
Orthopristis chrysoptera	Orhcry	3.1	0.0	8.3	0.0	0.0	2.1
Palaemonetes intermedius	Pinter	3.1	0.0	0.0	0.0	25.0	6.3
Prionotus tribulus	Ptribls	3.1	0.0	8.3	0.0	0.0	2.1
Sciaenops ocellatus	Sciocl	3.1	8.3	0.0	0.0	8.3	4.2
coleopterans, scirtid larvae	scrtid	3.1	0.0	0.0	0.0	0.0	0.0
Strongylura marina	Smrina	3.1	8.3	0.0	0.0	0.0	2.1
Symphurus plagiusa	Symplg	3.1	0.0	8.3	8.3	0.0	4.2
dipterans, tabanid larvae	tbanid	3.1	8.3	0.0	0.0	0.0	2.1

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dipterans, tipulid larvae	tipulid	3.1	8.3	8.3	0.0	8.3	6.3
Ameiurus natalis	Anatlis	2.1	0.0	0.0	0.0	0.0	0.0
ascidiacean larvae	ascdacn	2.1	0.0	0.0	0.0	0.0	0.0
coleopterans	chrysmd	2.1	8.3	0.0	0.0	0.0	2.1
clinid prefelxion	clind	2.1	0.0	0.0	0.0	16.7	4.2
Dorosoma spp.	Doros	2.1	0.0	0.0	0.0	0.0	0.0
dipterans, ephydrid larvae	ephyd	2.1	8.3	0.0	0.0	0.0	2.1
Gobionellus boleosoma	Gbnlbl	2.1	0.0	0.0	0.0	0.0	0.0
Harengula jaguana	Hjgna	2.1	0.0	0.0	0.0	8.3	2.1
Hoplosternum littorale	Hlitt	2.1	0.0	0.0	0.0	0.0	0.0
Microgobius thalassinus	Mcrgbth	2.1	8.3	0.0	0.0	0.0	2.1
Mugil curema	Mcrma	2.1	0.0	0.0	0.0	0.0	0.0
Mysidopsis furca	Mfurca	2.1	0.0	16.7	0.0	0.0	4.2
dipterans, muscid larvae	muscid	2.1	0.0	8.3	0.0	0.0	2.1
Nebalia sp.	Nebalia	2.1	0.0	0.0	0.0	0.0	0.0
Noturus gyrinus	Ngyrns	2.1	0.0	0.0	0.0	0.0	0.0
nemerteans	nmrtns	2.1	0.0	0.0	0.0	0.0	0.0
Oncaea spp.	Oncaea	2.1	0.0	8.3	0.0	0.0	2.1
Opisthonema oglinum	Ooglnm	2.1	0.0	0.0	8.3	0.0	2.1
ophiopluteus larvae	ophioplt	2.1	0.0	0.0	0.0	0.0	0.0
Paracerceis caudata	Pcaudata	2.1	0.0	8.3	0.0	0.0	2.1
Palaemon floridanus	Pflrdn	2.1	0.0	8.3	0.0	0.0	2.1
Pinnixa sp. a juveniles	PnxaA	2.1	0.0	0.0	0.0	0.0	0.0
Monacanthus hispidus	Shisp	2.1	0.0	0.0	0.0	0.0	0.0
sipunculid	sipunc	2.1	0.0	0.0	0.0	0.0	0.0
Sphoeroides nephelus	Sphnph	2.1	0.0	0.0	8.3	8.3	4.2
Sphoeroides spp.	Sphr	2.1	16.7	0.0	0.0	0.0	4.2
dipterans, syrphid larvae	syrphid	2.1	8.3	0.0	0.0	0.0	2.1
Alpheus estuariensis	Aestrns	1.0	8.3	0.0	0.0	0.0	2.1
Acanthostrocion quadricornis	Aqdcrn	1.0	0.0	0.0	0.0	8.3	2.1
Albula vulpes	Avulpes	1.0	0.0	0.0	0.0	0.0	0.0
Branchiostoma floridae	Bflorid	1.0	0.0	0.0	0.0	0.0	0.0
Bagre marinus	Bmrins	1.0	0.0	0.0	0.0	0.0	0.0
Camptocercus rectirostris	Cmptcrc	1.0	0.0	0.0	0.0	0.0	0.0
megalopterans, corydalid larvae	crydld	1.0	0.0	0.0	0.0	0.0	0.0
cymothoid sp. B	cymthdB	1.0	0.0	0.0	0.0	0.0	0.0
dipterans, dolichopodid larvae	dolich	1.0	0.0	0.0	0.0	8.3	2.1
Dorosoma petenense	Dptnse	1.0	0.0	0.0	8.3	0.0	2.1
coleopterans, dryopid larvae	dryopid	1.0	0.0	0.0	0.0	0.0	0.0
Eurypanopeus depressus	Edeprss	1.0	0.0	0.0	0.0	8.3	2.1
Ergasilus sp.	Ergslus	1.0	0.0	0.0	0.0	0.0	0.0

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Erimyzon sucetta	Esctta	1.0	0.0	0.0	0.0	0.0	0.0
Fundulus seminolis	Fsmnls	1.0	0.0	0.0	0.0	0.0	0.0
Gobionellus spp.	Gbnell	1.0	0.0	0.0	0.0	0.0	0.0
Gobionellus oceanicus	Gbnloc	1.0	0.0	0.0	0.0	0.0	0.0
Isopod, Gnathia sp. (praniza larva)	Gnathia	1.0	0.0	8.3	0.0	0.0	2.1
Hoplomachus propinquus	Hplmchs	1.0	0.0	8.3	0.0	0.0	2.1
Hippocampus zosterae	Hppzst	1.0	0.0	0.0	0.0	0.0	0.0
Ictalurus punctatus	Ipunc	1.0	0.0	0.0	0.0	0.0	0.0
Kurzia longirostris	Kurzia	1.0	0.0	0.0	0.0	0.0	0.0
Lepomis microlophus	Lmcro	1.0	0.0	0.0	0.0	8.3	2.1
Lepisosteus platyrhincus	Lplaty	1.0	8.3	0.0	0.0	0.0	2.1
Latreutes parvulus	Ltparv	1.0	0.0	0.0	0.0	0.0	0.0
medusa sp. f	medspF	1.0	0.0	0.0	8.3	0.0	2.1
medusa sp. g	medspG	1.0	0.0	0.0	0.0	0.0	0.0
Mesocyclops leuckarti	Mescycl	1.0	8.3	0.0	0.0	0.0	2.1
Mysidopsis mortenseni	Mmortn	1.0	0.0	0.0	0.0	0.0	0.0
Menidia beryllina	Mnbryl	1.0	0.0	0.0	0.0	0.0	0.0
Moinadaphnia macleayii	Mnodaph	1.0	0.0	0.0	0.0	0.0	0.0
Menticirrhus americanus	Mntamr	1.0	0.0	0.0	0.0	0.0	0.0
Mysid sp. A	MysidA	1.0	0.0	0.0	0.0	0.0	0.0
hemipterans, naucorid adults	naucrd	1.0	0.0	0.0	0.0	0.0	0.0
hemipterans, nepid adults	nepid	1.0	0.0	0.0	0.0	0.0	0.0
Pseudosida bidentata	Pbdnta	1.0	0.0	0.0	0.0	0.0	0.0
Panopeus herbstii	Pherbs	1.0	0.0	0.0	0.0	0.0	0.0
Palaemonetes paludosus	Ppalud	1.0	8.3	0.0	0.0	0.0	2.1
Paralichthys spp.	Prlych	1.0	0.0	0.0	0.0	0.0	0.0
Prionotus spp.	Prnts	1.0	0.0	0.0	0.0	0.0	0.0
megalopterans, sialid larvae	sialid	1.0	0.0	0.0	0.0	8.3	2.1
Strongylura notata	Sntta	1.0	0.0	0.0	0.0	0.0	0.0
Sphoeroides parvus	Sphprv	1.0	0.0	0.0	8.3	0.0	2.1
Sphaeroma walkeri	Sphwlk	1.0	0.0	0.0	0.0	0.0	0.0
Monacanthus setifer	Ssetif	1.0	0.0	0.0	8.3	0.0	2.1
Tanaid sp. c	TanaidC	1.0	0.0	0.0	8.3	0.0	2.1
Thor sp.	Thor	1.0	0.0	0.0	0.0	0.0	0.0
Temora longicornis	Tlngcrn	1.0	0.0	8.3	0.0	0.0	2.1
Upogebia affinis	Uaffin	1.0	8.3	0.0	0.0	0.0	2.1
Uca spp.	Uca	1.0	0.0	8.3	0.0	0.0	2.1
unidentified calanoids	UIDcalnd	1.0	0.0	0.0	0.0	0.0	0.0
cladocerans, unidentified	UIDclad	1.0	0.0	0.0	0.0	0.0	0.0

Taxon	Code	Overall	Alafia	Anclote	Hillsborough	Myakka	Surface Total
Acartia tonsa	Atonsa	100.0	100.0	100.0	100.0	100.0	100.0
cumaceans	cumacn	100.0	100.0	100.0	100.0	100.0	100.0
Edotea triloba	Edotia	100.0	100.0	100.0	100.0	100.0	100.0
amphipods, gammaridean	gmmrd	100.0	100.0	100.0	100.0	100.0	100.0
decapod mysis	mysis	100.0	100.0	100.0	100.0	100.0	100.0
Unidentified Americamysis juveniles	AmysJUV	99.0	100.0	100.0	91.7	100.0	97.9
polychaetes	polych	99.0	100.0	100.0	100.0	100.0	100.0
decapod zoea	zoea	99.0	100.0	100.0	100.0	100.0	100.0
dipterans, chironomid larvae	chiron	97.9	100.0	100.0	83.3	100.0	95.8
Americamysis almyra	Aalmyra	96.9	91.7	100.0	83.3	100.0	93.8
Anchoa mitchilli	Amtch	94.8	100.0	100.0	100.0	100.0	100.0
gastropods, prosobranch	prosbrch	94.8	100.0	100.0	66.7	100.0	91.7
Unidentified gobiid larvae	gobiid	93.8	100.0	91.7	100.0	91.7	95.8
dipterans, pupae	pupae	93.8	100.0	91.7	58.3	100.0	87.5
decapod megalopae	megalop	90.6	91.7	83.3	100.0	91.7	91.7
pelecypods	plcypd	89.6	91.7	100.0	58.3	100.0	87.5
Pseudodiaptomus coronatus	Psdiap	89.6	91.7	100.0	100.0	75.0	91.7
chaetognaths	chaetog	86.5	100.0	100.0	100.0	91.7	97.9
Livoneca	cymthdA	85.4	100.0	83.3	100.0	91.7	93.8
Cassidinidea ovalis	Covalis	83.3	91.7	66.7	66.7	41.7	66.7
Microgobius spp.	Mcrgob	83.3	91.7	66.7	83.3	83.3	81.3
ostracods, podocopid	podocop	83.3	83.3	100.0	25.0	100.0	77.1
Parasterope pollex	ppollex	83.3	100.0	100.0	100.0	75.0	93.8
Menidia spp.	Mnidia	81.3	75.0	91.7	41.7	91.7	75.0
Palaemonetes spp.	Plmnts	81.3	91.7	75.0	91.7	100.0	89.6
Bowmaniella dissimilis	Bdissim	77.1	25.0	100.0	0.0	91.7	54.2
Palaemonetes pugio	Ppugio	77.1	50.0	66.7	66.7	66.7	62.5
Gobiosoma spp.	Gbsma	76.0	75.0	75.0	91.7	66.7	77.1
Taphromysis bowmani	Tbowman	75.0	50.0	75.0	0.0	91.7	54.2
Erichsonella spp.	Erchspp	74.0	50.0	83.3	25.0	33.3	47.9
hirudinoideans	hirud	74.0	83.3	25.0	33.3	75.0	54.2
Hargeria rapax	Hrapax	72.9	16.7	100.0	58.3	8.3	45.8
Munna reynoldsi	Uromunna	72.9	58.3	91.7	16.7	66.7	58.3
branchiurans, Argulus spp.	Argulus	71.9	50.0	91.7	41.7	100.0	70.8
unidentified harpacticoids	hrpctcd	70.8	58.3	91.7	66.7	33.3	62.5
Hippolyte zostericola	Hzost	70.8	16.7	100.0	100.0	58.3	68.8
Harrieta faxoni	Hfaxoni	68.8	58.3	66.7	16.7	16.7	39.6
ephemeropteran larvae	ephmpt	67.7	50.0	33.3	8.3	100.0	47.9

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Labidocera aestiva	Laestiva	67.7	91.7	100.0	91.7	83.3	91.7
amphipods, caprellid	cprlld	64.6	83.3	91.7	66.7	66.7	77.1
Gobiesox strumosus	Gbsx	64.6	41.7	83.3	66.7	66.7	64.6
acari	acari	63.5	25.0	50.0	16.7	100.0	47.9
Lucifer faxoni	Lucifer	62.5	83.3	100.0	83.3	50.0	79.2
Sarsiella zostericola	Szost	61.5	83.3	83.3	0.0	33.3	50.0
nematodes	nmtds	60.4	50.0	83.3	58.3	8.3	50.0
Sinelobus stanfordi	Sstnfrdi	59.4	16.7	75.0	41.7	41.7	43.8
Lucania parva	Lparv	58.3	16.7	8.3	50.0	33.3	27.1
oligochaetes	oligch	58.3	66.7	66.7	41.7	66.7	60.4
Unidentified alphaeids	Alph	57.3	50.0	66.7	58.3	58.3	58.3
gastropods, opisthobranch	opsbrch	57.3	25.0	100.0	25.0	50.0	50.0
Unidentified blenniid larvae	blniid	55.2	25.0	75.0	75.0	33.3	52.1
dipteran, Chaoborus punctipennis larvae	Cpncpnnd	55.2	41.7	50.0	41.7	100.0	58.3
trichopteran larvae	trichop	54.2	33.3	41.7	33.3	100.0	52.1
Trinectes maculatus	Trimac	54.2	66.7	66.7	50.0	91.7	68.8
Sphaeroma terebrans	Sphtrbs	53.1	83.3	66.7	33.3	91.7	68.8
Simocephalus vetulus	Svetelus	52.1	25.0	58.3	16.7	100.0	50.0
Syngnathus scovelli	Sygscv	52.1	25.0	33.3	33.3	41.7	33.3
Anchoa spp.	Anchoa	51.0	58.3	50.0	66.7	75.0	62.5
dipterans, ceratopogonid larvae	crtpgd	51.0	8.3	8.3	8.3	58.3	20.8
Brevoortia spp.	Brvtia	50.0	50.0	58.3	58.3	41.7	52.1
Clytia sp.	Clytia	49.0	75.0	58.3	83.3	58.3	68.8
Eurytemora affinis	Erytaff	45.8	16.7	50.0	0.0	8.3	18.8
appendicularian, Oikopleura dioica	Odioica	45.8	91.7	75.0	66.7	66.7	75.0
Temora turbinata	Tturb	45.8	0.0	50.0	25.0	33.3	27.1
siphonostomatids	caligoid	42.7	91.7	41.7	66.7	0.0	50.0
Cyathura polita	Cpolita	42.7	16.7	50.0	8.3	75.0	37.5
Macrocyclops albidus	Malbidus	42.7	8.3	50.0	33.3	58.3	37.5
fish eggs, percomorph	prcmph	41.7	50.0	75.0	33.3	50.0	52.1
Upogebia spp. postlarvae	Upgba	41.7	25.0	58.3	50.0	25.0	39.6
odonates, zygopteran larvae	zygptn	41.7	8.3	16.7	25.0	100.0	37.5
Mesocyclops edax	Medax	40.6	25.0	58.3	25.0	100.0	52.1
Anopsilana jonesi	Ajonesi	39.6	83.3	16.7	33.3	8.3	35.4
Sphaeroma quadridentata	Sphquad	39.6	25.0	50.0	25.0	100.0	50.0
Callinectes sapidus	Csap	38.5	0.0	66.7	0.0	41.7	27.1
Apseudes sp.	Apseudes	36.5	0.0	33.3	0.0	0.0	8.3
foraminiferans	foram	36.5	8.3	58.3	8.3	8.3	20.8
Monstrilla sp.	Mnstrlla	36.5	41.7	25.0	75.0	0.0	35.4

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hemipterans, gerrid adults	gerrid	34.4	66.7	16.7	0.0	50.0	33.3
Eucinostomus spp.	Eucin	32.3	8.3	33.3	0.0	8.3	12.5
Bathygobius soporator	Bthgob	31.3	25.0	25.0	50.0	41.7	35.4
Farfantepenaeus duorarum	Fduorm	31.3	16.7	25.0	0.0	50.0	22.9
Ambidexter symmetricus	Asymm	30.2	66.7	66.7	16.7	41.7	47.9
Membras martinica	Mmart	30.2	25.0	16.7	0.0	83.3	31.3
cirriped nauplii	crpdNaup	29.2	16.7	41.7	50.0	75.0	45.8
Orthocyclops modestus	Orthcyc	29.2	0.0	25.0	0.0	75.0	25.0
Xenanthura brevitelson	Xbrvtlsn	29.2	0.0	58.3	0.0	8.3	16.7
penaeid metamorphs	penmeta	28.1	25.0	58.3	0.0	25.0	27.1
Gobiosoma bosc	Gbsbsc	26.0	8.3	8.3	8.3	50.0	18.8
Microgobius gulosus	Mcgbgl	26.0	8.3	33.3	8.3	25.0	18.8
Sida crystallina	Scryst	26.0	0.0	33.3	16.7	66.7	29.2
Americamysis stucki	Astucki	25.0	58.3	33.3	8.3	50.0	37.5
Calanopia americana	Clanopia	25.0	25.0	66.7	8.3	8.3	27.1
turbellarians	trbllrns	25.0	33.3	25.0	0.0	33.3	22.9
Americamysis bahia	Abahia	24.0	33.3	8.3	0.0	33.3	18.8
Diaptomus spp.	Diaptmus	22.9	16.7	16.7	0.0	58.3	22.9
Lagodon rhomboides	Lrhom	21.9	0.0	41.7	16.7	8.3	16.7
Mnemiopsis leidyi	Mleidyi	21.9	25.0	16.7	25.0	83.3	37.5
Chasmodes saburrae	Chsab	20.8	8.3	0.0	33.3	16.7	14.6
hemipterans, corixid adults	corixid	20.8	0.0	8.3	33.3	66.7	27.1
Cynoscion arenarius	Cynar	20.8	33.3	8.3	41.7	58.3	35.4
coleopterans, elmid adults	elmid	20.8	0.0	25.0	16.7	83.3	31.3
Gambusia holbrooki juveniles	Ghlbk	20.8	8.3	8.3	33.3	58.3	27.1
Menticirrhus spp.	Mntcrr	20.8	16.7	41.7	25.0	33.3	29.2
Oithona spp.	Oithona	20.8	25.0	25.0	25.0	58.3	33.3
collembolas, podurid	podurid	20.8	16.7	16.7	41.7	16.7	22.9
Elops saurus	Esaur	19.8	33.3	33.3	16.7	33.3	29.2
Gobiosoma robustum	Gbsrob	19.8	16.7	16.7	0.0	33.3	16.7
penaeid postlarvae	penaeid	19.8	8.3	8.3	16.7	16.7	12.5
Cynoscion nebulosus	Cynneb	17.7	8.3	16.7	25.0	25.0	18.8
Fundulus spp.	Fndls	17.7	0.0	0.0	0.0	0.0	0.0
Syngnathus louisianae	Sygnls	17.7	58.3	8.3	25.0	33.3	31.3
cladocerans, Daphnia spp.	Daphnia	16.7	16.7	0.0	16.7	33.3	16.7
medusa sp. d	medspD	16.7	0.0	16.7	25.0	25.0	16.7
Periclimenes spp.	Prclmns	16.7	25.0	0.0	25.0	0.0	12.5
Unidentified processids	procesd	16.7	8.3	41.7	58.3	0.0	27.1
Saphirella spp.	Sphrella	16.7	8.3	66.7	8.3	0.0	20.8
unidentified freshwater cyclopoids	UIDFWcop	16.7	0.0	0.0	0.0	50.0	12.5

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coleopterans, gyrinid larvae	gyrinid	15.6	0.0	8.3	16.7	83.3	27.1
Limulus polyphemus larvae	Limulus	15.6	33.3	41.7	33.3	0.0	27.1
Mugil cephalus	Mcphls	15.6	0.0	25.0	33.3	16.7	18.8
medusa sp. e	medspE	15.6	0.0	25.0	50.0	0.0	18.8
Ogyrides alphaerostris	Ogyrds	15.6	0.0	0.0	8.3	33.3	10.4
Pseudevadne tergestina	Ptergstn	15.6	8.3	16.7	25.0	66.7	29.2
Ilyocryptus sp.	Ilycryp	14.6	8.3	25.0	8.3	58.3	25.0
Leiostomus xanthurus	Leixan	14.6	0.0	16.7	0.0	0.0	4.2
Lucania goodei	Lgood	14.6	0.0	0.0	0.0	16.7	4.2
Penilia avirostris	Pavrstrs	14.6	0.0	25.0	25.0	41.7	22.9
paguroid juveniles	pgurd	14.6	0.0	58.3	16.7	0.0	18.8
odonates, anisopteran larvae	ansptn	13.5	0.0	8.3	0.0	66.7	18.8
lepidopterans, pyralid larvae	lepidop	13.5	16.7	0.0	25.0	8.3	12.5
Lepomis spp.	Lepoms	13.5	0.0	8.3	0.0	25.0	8.3
Myrophis punctatus	Mpunc	13.5	0.0	16.7	0.0	33.3	12.5
Callianassa spp.	Clnssa	12.5	8.3	8.3	25.0	8.3	12.5
Lolliguncula brevis	Lllgbrvs	12.5	58.3	0.0	16.7	25.0	25.0
paracalanids	pracalnd	12.5	0.0	25.0	0.0	25.0	12.5
pycnogonids	pycgnd	12.5	0.0	33.3	16.7	0.0	12.5
Tozeuma carolinense	Tozma	12.5	25.0	50.0	16.7	0.0	22.9
Anchoa hepsetus	Ahepst	11.5	16.7	8.3	16.7	16.7	14.6
Latonopsis fasciculata	Lfsclta	11.5	0.0	16.7	8.3	41.7	16.7
coleopterans, noterid adults	notrid	11.5	0.0	0.0	0.0	58.3	14.6
Portunus sp.	Prtns	11.5	0.0	16.7	0.0	0.0	4.2
Syngnathus floridae	Sygnfl	11.5	0.0	41.7	0.0	0.0	10.4
Achirus lineatus	Achr	10.4	16.7	33.3	0.0	0.0	12.5
clupeid	clup	10.4	0.0	33.3	0.0	8.3	10.4
Centropages velificatus	Cvlfcts	10.4	0.0	41.7	16.7	8.3	16.7
Leydigia sp.	Leydigia	10.4	0.0	16.7	8.3	41.7	16.7
Notemigonus crysoleucas	Ncrysl	10.4	0.0	8.3	0.0	0.0	2.1
Petrolisthes armatus	Parm	10.4	50.0	0.0	0.0	8.3	14.6
Periclimenes longicaudatus	Plong	10.4	16.7	33.3	0.0	0.0	12.5
Pinnixa sayana	Psyna	10.4	50.0	16.7	16.7	0.0	20.8
Rhithropanopeus harrisii	Rhith	10.4	0.0	0.0	41.7	8.3	12.5
Bairdiella chrysoura	Brdcry	9.4	16.7	8.3	0.0	25.0	12.5
neuropterans, Climacia spp.	Climacia	9.4	0.0	0.0	0.0	66.7	16.7
brachiopod, Glottidia pyramidata larvae	Gpyrmd	9.4	16.7	25.0	8.3	16.7	16.7
Heterandria formosa	Hform	9.4	0.0	8.3	0.0	50.0	14.6
Lupinoblennius nicholsi	Lupbl	9.4	0.0	0.0	0.0	16.7	4.2
Micropterus salmoides	Msalm	9.4	0.0	0.0	0.0	16.7	4.2

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myodocopod sp. a	mydocopA	9.4	0.0	25.0	8.3	0.0	8.3
ophiuroidean juveniles	ophiurd	9.4	16.7	41.7	0.0	0.0	14.6
Palaemonetes vulgaris	Pvulg	9.4	0.0	8.3	0.0	0.0	2.1
Squilla empusa	Sqempsa	9.4	8.3	0.0	50.0	0.0	14.6
Unidentified callianassids	callian	8.3	0.0	0.0	8.3	8.3	4.2
coleopterans, dytiscid larvae	dystcid	8.3	0.0	8.3	0.0	25.0	8.3
Labidesthes sicculus	Lsicc	8.3	0.0	0.0	8.3	50.0	14.6
Liriope tetraphylla	Lttraphy	8.3	25.0	8.3	25.0	0.0	14.6
medusa sp. a	medspA	8.3	8.3	33.3	0.0	8.3	12.5
Osphranticum labronectum	Osphrntc	8.3	0.0	8.3	0.0	50.0	14.6
shrimps, unidentified juveniles	UIDshmp	8.3	41.7	16.7	0.0	0.0	14.6
Eucinostomus harengulus	Ecnhar	7.3	0.0	0.0	0.0	0.0	0.0
Latona setifera	Lsetifera	7.3	0.0	16.7	0.0	41.7	14.6
Leptochela serratorbita	Lsrtorb	7.3	33.3	0.0	16.7	8.3	14.6
Notropis spp.	Ntrps	7.3	0.0	0.0	0.0	33.3	8.3
Oligoplites saurus	Osaurs	7.3	16.7	25.0	8.3	8.3	14.6
xanthid juveniles	UIDxntd	7.3	25.0	0.0	0.0	0.0	6.3
Alteutha sp.	Alteutha	6.3	0.0	8.3	16.7	8.3	8.3
Brevoortia smithi juveniles	Bsmithi	6.3	8.3	0.0	16.7	0.0	6.3
Cyclops spp.	Cyclops	6.3	25.0	0.0	0.0	16.7	10.4
Eugerres plumieri	Eugrr	6.3	16.7	0.0	8.3	16.7	10.4
Hippocampus erectus	Herect	6.3	0.0	16.7	0.0	25.0	10.4
medusa, Obelia sp.	Obelia	6.3	0.0	25.0	0.0	0.0	6.3
dipterans, sciomyzid larvae	scmyz	6.3	0.0	8.3	0.0	41.7	12.5
Spelaeomysis sp.	Spelmys	6.3	0.0	0.0	0.0	8.3	2.1
Strongylura spp.	Stglra	6.3	16.7	0.0	0.0	16.7	8.3
dipterans, stratiomyid larvae	strtmyd	6.3	0.0	0.0	16.7	8.3	6.3
anuran larvae	tadpole	6.3	8.3	0.0	8.3	25.0	10.4
Centropages hamatus	Chmatus	5.2	0.0	33.3	0.0	8.3	10.4
coleopterans, curculionid	curcld	5.2	8.3	8.3	0.0	16.7	8.3
Fundulus grandis	Fgrnds	5.2	16.7	0.0	8.3	0.0	6.3
coleopterans, haliplid adults	halpld	5.2	16.7	0.0	0.0	16.7	8.3
Hypsoblennius spp.	Hypsbl	5.2	0.0	8.3	0.0	8.3	4.2
medusa sp. b	medspB	5.2	8.3	0.0	8.3	25.0	10.4
Opsanus beta	Obeta	5.2	0.0	0.0	0.0	0.0	0.0
Probopyrus	Probpyr	5.2	0.0	0.0	0.0	16.7	4.2
Synodus foetens	Synft	5.2	0.0	16.7	0.0	0.0	4.2
unidentified flexion larvae	UIDfish	5.2	0.0	8.3	0.0	16.7	6.3
Archosargus probatocephalus	Arcprb	4.2	0.0	8.3	8.3	0.0	4.2
Alpheus viridari	Avirid	4.2	0.0	8.3	0.0	0.0	2.1
medusa, Bougainvillia sp.	Bgvlla	4.2	0.0	25.0	0.0	0.0	6.3

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Chloroscombrus chrysurus	Cchry	4.2	0.0	0.0	25.0	8.3	8.3
Cyprinodon variegatus	Cvarg	4.2	0.0	0.0	0.0	8.3	2.1
Diaphanosoma sp.	Diphnsm	4.2	0.0	0.0	16.7	0.0	4.2
Dynamenella sp.	Dynmnlla	4.2	0.0	0.0	0.0	0.0	0.0
Euconchoecia chierchiae	Echierch	4.2	8.3	8.3	0.0	8.3	6.3
Eucinostomus gula	Ecngul	4.2	0.0	0.0	0.0	8.3	2.1
Euryalona occidentalis	Euryalona	4.2	0.0	8.3	0.0	25.0	8.3
medusa, Eutima sp.	Eutima	4.2	0.0	0.0	25.0	0.0	6.3
Grimaldina brazzai	Gbrzzai	4.2	0.0	8.3	0.0	25.0	8.3
Hyporhamphus unifasciatus	Hunif	4.2	0.0	0.0	0.0	25.0	6.3
Lepomis auritus	Laurts	4.2	8.3	0.0	0.0	8.3	4.2
Lepisosteus sp.	Lepis	4.2	0.0	0.0	0.0	8.3	2.1
hemipterans, pleid adults	pleid	4.2	0.0	0.0	8.3	25.0	8.3
Ameiurus catus	Acatus	3.1	0.0	0.0	0.0	25.0	6.3
hemipterans, belostomatids	blstmd	3.1	0.0	0.0	8.3	8.3	4.2
Beroe ovata	Bovata	3.1	0.0	8.3	0.0	16.7	6.3
Bunops sp.	Bunops	3.1	0.0	0.0	0.0	25.0	6.3
Ceridodaphnia sp.	Criodaph	3.1	0.0	0.0	0.0	16.7	4.2
cirriped cyprids	crpdCypr	3.1	0.0	0.0	0.0	0.0	0.0
Chilomycterus shoepfi	Cschpf	3.1	0.0	8.3	0.0	8.3	4.2
Euceramus praelongus	Eprael	3.1	16.7	0.0	0.0	0.0	4.2
Etheostoma fusiforme	Ethfus	3.1	0.0	0.0	0.0	25.0	6.3
Eucalanus sp.	Eucal	3.1	0.0	16.7	8.3	0.0	6.3
isopod sp. a	isopodA	3.1	16.7	0.0	8.3	0.0	6.3
Liposarcus spp.	Lposrc	3.1	8.3	0.0	0.0	16.7	6.3
Lepomis punctatus	Lpunc	3.1	0.0	0.0	0.0	8.3	2.1
Lutjanus griseus	Ltjgrs	3.1	0.0	0.0	0.0	8.3	2.1
medusa sp. c	medspC	3.1	8.3	16.7	0.0	0.0	6.3
Orthopristis chrysoptera	Orhcry	3.1	0.0	16.7	0.0	0.0	4.2
Palaemonetes intermedius	Pinter	3.1	0.0	0.0	0.0	0.0	0.0
Prionotus tribulus	Ptribls	3.1	0.0	8.3	0.0	8.3	4.2
Sciaenops ocellatus	Sciocl	3.1	0.0	8.3	0.0	0.0	2.1
coleopterans, scirtid larvae	scrtid	3.1	8.3	0.0	0.0	16.7	6.3
Strongylura marina	Smrina	3.1	0.0	0.0	0.0	16.7	4.2
Symphurus plagiusa	Symplg	3.1	8.3	0.0	0.0	0.0	2.1
dipterans, tabanid larvae	tbanid	3.1	0.0	0.0	16.7	0.0	4.2
dipterans, tipulid larvae	tipulid	3.1	0.0	0.0	0.0	0.0	0.0
Ameiurus natalis	Anatlis	2.1	0.0	0.0	0.0	16.7	4.2
ascidiacean larvae	ascdacn	2.1	0.0	16.7	0.0	0.0	4.2
coleopterans	chrysmd	2.1	0.0	0.0	8.3	0.0	2.1
clinid prefelxion	clind	2.1	0.0	0.0	0.0	0.0	0.0

Taxon	Code	Overall	Alafia	Anclote	Hillsborough	Myakka	Surface Total
Dorosoma spp.	Doros	2.1	0.0	0.0	0.0	16.7	4.2
dipterans, ephydrid larvae	ephyd	2.1	0.0	0.0	8.3	0.0	2.1
Gobionellus boleosoma	Gbnlbl	2.1	16.7	0.0	0.0	0.0	4.2
Harengula jaguana	Hjgna	2.1	0.0	8.3	0.0	0.0	2.1
Hoplosternum littorale	Hlitt	2.1	0.0	0.0	0.0	16.7	4.2
Microgobius thalassinus	Mcrgbth	2.1	8.3	0.0	0.0	0.0	2.1
Mugil curema	Mcrma	2.1	8.3	8.3	0.0	0.0	4.2
Mysidopsis furca	Mfurca	2.1	0.0	0.0	0.0	0.0	0.0
dipterans, muscid larvae	muscid	2.1	0.0	0.0	8.3	0.0	2.1
Nebalia sp.	Nebalia	2.1	16.7	0.0	0.0	0.0	4.2
Noturus gyrinus	Ngyrns	2.1	0.0	0.0	0.0	16.7	4.2
nemerteans	nmrtns	2.1	0.0	16.7	0.0	0.0	4.2
Oncaea spp.	Oncaea	2.1	0.0	0.0	0.0	8.3	2.1
Opisthonema oglinum	Ooglnm	2.1	0.0	8.3	0.0	0.0	2.1
ophiopluteus larvae	ophioplt	2.1	0.0	16.7	0.0	0.0	4.2
Paracerceis caudata	Pcaudata	2.1	0.0	8.3	0.0	0.0	2.1
Palaemon floridanus	Pflrdn	2.1	0.0	8.3	0.0	0.0	2.1
Pinnixa sp. a juveniles	PnxaA	2.1	0.0	8.3	8.3	0.0	4.2
Monacanthus hispidus	Shisp	2.1	0.0	16.7	0.0	0.0	4.2
sipunculid	sipunc	2.1	16.7	0.0	0.0	0.0	4.2
Sphoeroides nephelus	Sphnph	2.1	0.0	0.0	0.0	0.0	0.0
Sphoeroides spp.	Sphr	2.1	0.0	0.0	0.0	0.0	0.0
dipterans, syrphid larvae	syrphid	2.1	0.0	0.0	8.3	0.0	2.1
Alpheus estuariensis	Aestrns	1.0	0.0	0.0	0.0	0.0	0.0
Acanthostrocion quadricornis	Aqdcrn	1.0	0.0	0.0	0.0	0.0	0.0
Albula vulpes	Avulpes	1.0	0.0	0.0	8.3	0.0	2.1
Branchiostoma floridae	Bflorid	1.0	0.0	8.3	0.0	0.0	2.1
Bagre marinus	Bmrins	1.0	0.0	0.0	0.0	8.3	2.1
Camptocercus rectirostris	Cmptcrc	1.0	8.3	0.0	0.0	0.0	2.1
megalopterans, corydalid larvae	crydld	1.0	0.0	0.0	0.0	8.3	2.1
cymothoid sp. B	cymthdB	1.0	8.3	0.0	0.0	0.0	2.1
dipterans, dolichopodid larvae	dolich	1.0	0.0	0.0	0.0	0.0	0.0
Dorosoma petenense	Dptnse	1.0	0.0	0.0	0.0	0.0	0.0
coleopterans, dryopid larvae	dryopid	1.0	0.0	0.0	0.0	8.3	2.1
Eurypanopeus depressus	Edeprss	1.0	0.0	0.0	0.0	0.0	0.0
Ergasilus sp.	Ergslus	1.0	8.3	0.0	0.0	0.0	2.1
Erimyzon sucetta	Esctta	1.0	0.0	0.0	0.0	8.3	2.1
Fundulus seminolis	Fsmnls	1.0	8.3	0.0	0.0	0.0	2.1
Gobionellus spp.	Gbnell	1.0	0.0	8.3	0.0	0.0	2.1
Gobionellus oceanicus	Gbnloc	1.0	0.0	8.3	0.0	0.0	2.1

Taxon	Code	Overall	Alafia	Anclote	Hillsborough	Myakka	Surface Total
Isopod, Gnathia sp. (praniza larva)	Gnathia	1.0	0.0	0.0	0.0	0.0	0.0
Hoplomachus propinquus	Hplmchs	1.0	0.0	0.0	0.0	0.0	0.0
Hippocampus zosterae	Hppzst	1.0	0.0	8.3	0.0	0.0	2.1
Ictalurus punctatus	Ipunc	1.0	0.0	0.0	0.0	8.3	2.1
Kurzia longirostris	Kurzia	1.0	0.0	0.0	8.3	0.0	2.1
Lepomis microlophus	Lmcro	1.0	0.0	0.0	0.0	0.0	0.0
Lepisosteus platyrhincus	Lplaty	1.0	0.0	0.0	0.0	0.0	0.0
Latreutes parvulus	Ltparv	1.0	0.0	8.3	0.0	0.0	2.1
medusa sp. f	medspF	1.0	0.0	0.0	0.0	0.0	0.0
medusa sp. g	medspG	1.0	0.0	0.0	8.3	0.0	2.1
Mesocyclops leuckarti	Mescycl	1.0	0.0	0.0	0.0	0.0	0.0
Mysidopsis mortenseni	Mmortn	1.0	0.0	8.3	0.0	0.0	2.1
Menidia beryllina	Mnbryl	1.0	0.0	0.0	0.0	8.3	2.1
Moinadaphnia macleayii	Mnodaph	1.0	0.0	0.0	0.0	8.3	2.1
Menticirrhus americanus	Mntamr	1.0	0.0	0.0	0.0	8.3	2.1
Mysid sp. A	MysidA	1.0	0.0	0.0	8.3	0.0	2.1
hemipterans, naucorid adults	naucrd	1.0	8.3	0.0	0.0	0.0	2.1
hemipterans, nepid adults	nepid	1.0	0.0	0.0	0.0	8.3	2.1
Pseudosida bidentata	Pbdnta	1.0	0.0	0.0	0.0	8.3	2.1
Panopeus herbstii	Pherbs	1.0	0.0	8.3	0.0	0.0	2.1
Palaemonetes paludosus	Ppalud	1.0	0.0	0.0	0.0	0.0	0.0
Paralichthys spp.	Prlych	1.0	0.0	8.3	0.0	0.0	2.1
Prionotus spp.	Prnts	1.0	0.0	8.3	0.0	0.0	2.1
megalopterans, sialid larvae	sialid	1.0	0.0	0.0	0.0	0.0	0.0
Strongylura notata	Sntta	1.0	0.0	0.0	0.0	8.3	2.1
Sphoeroides parvus	Sphprv	1.0	0.0	0.0	0.0	0.0	0.0
Sphaeroma walkeri	Sphwlk	1.0	0.0	8.3	0.0	0.0	2.1
Monacanthus setifer	Ssetif	1.0	0.0	0.0	0.0	0.0	0.0
Tanaid sp. c	TanaidC	1.0	0.0	0.0	0.0	0.0	0.0
Thor sp.	Thor	1.0	0.0	8.3	0.0	0.0	2.1
Temora longicornis	Tlngcrn	1.0	0.0	0.0	0.0	0.0	0.0
Upogebia affinis	Uaffin	1.0	0.0	0.0	0.0	0.0	0.0
Uca spp.	Uca	1.0	0.0	0.0	0.0	0.0	0.0
unidentified calanoids	UIDcalnd	1.0	8.3	0.0	0.0	0.0	2.1
cladocerans, unidentified	UIDclad	1.0	0.0	0.0	0.0	8.3	2.1

Appendix A 2. CPUE for each taxon overall, in each estuary and within each estuary type.

Taxon	Code	Overall	Chassahowitzka	Crystal	Homosassa	Weeki Wachee	Spring Total
decapod zoea	zoea	3261.21	2508.55	5403.98	3848.25	2176.49	3443.47
amphipods, gammaridean	gmmrd	1474.73	2642.57	1381.15	1964.11	2289.74	2069.39
cumaceans	cumacn	751.36	1125.05	425.26	741.20	748.16	759.92
fish eggs, percomorph	prcmph	559.42	9.98	36.96	422.17	41.17	188.01
Acartia tonsa	Atonsa	441.38	19.95	233.06	282.32	138.13	168.37
Mnemiopsis leidyi	Mleidyi	435.11	0.00	0.00	51.77	0.00	51.77
appendicularian, Oikopleura dioica	Odioica	402.67	0.00	422.02	1.21	0.00	316.82
Americamysis almyra	Aalmyra	334.93	552.15	295.84	644.74	60.64	388.34
Labidocera aestiva	Laestiva	326.30	2.71	173.21	310.88	331.41	219.69
Bowmaniella dissimilis	Bdissim	311.77	719.31	410.30	186.42	387.43	425.86
cirriped nauplii	crpdNaup	273.25	0.00	59.12	0.00	1.36	39.87
Unidentified Americamysis juveniles	AmysJUV	267.61	383.26	304.85	723.88	80.17	373.04
chaetognaths	chaetog	260.69	3.68	117.72	123.86	63.29	88.32
Lucifer faxoni	Lucifer	258.07	2.53	53.16	3.65	1.55	27.92
decapod megalopae	megalop	246.25	399.46	82.64	404.55	194.12	267.30
Parasterope pollex	ppollex	228.20	10.87	16.41	18.35	20.77	17.35
decapod mysis	mysis	211.15	184.61	128.27	496.02	308.63	279.38
Americamysis bahia	Abahia	126.90	4.02	284.71	44.99	97.77	190.36
Taphromysis bowmani	Tbowman	111.91	72.98	16.12	15.20	215.49	82.76
polychaetes	polych	93.26	17.94	44.76	75.40	20.99	40.17
Oithona spp.	Oithona	92.78	0.00	2.97	1.37	0.00	2.57
Gobiosoma spp.	Gbsma	82.08	43.25	156.96	212.30	18.08	117.74
Edotea triloba	Edotia	79.36	8.90	10.97	21.20	9.98	12.76
nematodes	nmtds	76.07	122.86	4.80	6.93	3.01	43.12
Anchoa mitchilli	Amtch	72.63	30.79	29.80	56.49	16.03	34.34
Pseudevadne tergestina	Ptergstn	70.40	0.00	1.38	0.00	0.00	1.38
gastropods, prosobranch	prosbrch	66.05	238.22	19.08	47.65	99.05	102.75
penaeid postlarvae	penaeid	64.39	4.55	185.41	7.93	0.00	89.58
Clytia sp.	Clytia	64.14	80.74	3.07	2.50	15.22	23.89
Hargeria rapax	Hrapax	54.68	60.81	7.05	29.80	210.74	77.10
Unidentified gobiid larvae	gobiid	54.51	57.98	111.20	115.40	25.87	78.19
Harrieta faxoni	Hfaxoni	53.84	56.30	13.52	100.83	117.17	73.20
Americamysis stucki	Astucki	49.51	1.25	4.25	0.00	31.10	8.22
amphipods, caprellid	cprlld	40.69	6.92	2.45	7.87	12.33	6.16
Simocephalus vetulus	Svetelus	40.24	4.99	8.61	4.60	12.47	9.08
Erichsonella spp.	Erchspp	35.89	64.02	3.96	30.61	106.37	51.24
Munna reynoldsi	Uromunna	32.80	20.02	34.86	6.09	11.28	18.28

Taxon	**Code**	**Overall**	**Chassahowitzka**	**Crystal**	**Homosassa**	**Weeki Wachee**	**Spring Total**
Mesocyclops edax	Medax	32.42	0.00	3.07	4.03	36.08	29.08
Penilia avirostris	Pavrstrs	30.13	0.00	7.52	307.11	0.00	107.38
dipterans, chironomid larvae	chiron	28.86	111.83	11.49	38.67	15.07	44.26
dipterans, pupae	pupae	28.69	76.09	11.73	72.39	11.78	43.00
Hippolyte zostericola	Hzost	28.09	3.75	51.19	18.23	10.08	22.06
Apseudes sp.	Apseudes	26.24	74.97	6.46	16.73	7.26	29.16
Unidentified alphaeids	Alph	26.16	15.94	42.52	29.00	11.88	26.93
oligochaetes	oligch	24.78	3.99	22.45	44.84	13.77	20.49
ephemeropteran larvae	ephmpt	24.33	20.15	6.43	4.17	15.74	12.53
Upogebia spp. postlarvae	Upgba	23.85	5.26	82.72	15.44	2.62	37.30
paguroid juveniles	pgurd	23.09	0.00	5.55	0.00	10.98	6.63
Anchoa spp.	Anchoa	21.57	4.66	14.64	4.53	1.74	8.51
Microgobius thalassinus	Mcrgbth	18.31	35.15	0.00	0.00	0.00	35.15
Pseudodiaptomus coronatus	Psdiap	18.17	11.65	20.52	29.05	12.35	19.29
Ilyocryptus sp.	Ilycryp	17.17	0.00	8.48	0.00	2.75	5.61
Calanopia americana	Clanopia	16.66	8.05	13.24	40.23	1.98	18.08
Mysidopsis furca	Mfurca	16.22	0.00	16.22	0.00	0.00	16.22
ostracods, podocopid	podocop	15.98	30.61	8.13	46.19	10.84	24.90
pelecypods	plcypd	15.89	2.96	1.95	12.66	8.74	6.71
Temora longicornis	Tlngcrn	15.72	0.00	15.72	0.00	0.00	15.72
Palaemonetes spp.	Plmnts	15.57	25.95	18.30	18.37	16.12	19.51
Syngnathus scovelli	Sygscv	14.56	1.70	1.65	2.09	2.93	2.13
medusa sp. e	medspE	14.13	5.29	11.75	0.00	0.00	7.45
medusa, Eutima sp.	Eutima	14.01	0.00	34.92	0.00	0.00	34.92
Latonopsis fasciculata	Lfsclta	13.92	0.00	0.00	0.00	3.13	3.13
Palaemonetes paludosus	Ppalud	13.22	13.22	0.00	0.00	0.00	13.22
Cyclops spp.	Cyclops	13.13	0.00	0.00	0.00	1.17	1.17
foraminiferans	foram	12.63	14.57	1.86	2.57	21.83	16.27
clinid prefelxion	clind	12.16	0.00	0.00	0.00	12.16	12.16
Euconchoecia chierchiae	Echierch	12.13	0.00	0.00	0.00	22.46	22.46
Cassidinidea ovalis	Covalis	11.50	21.52	3.33	10.19	34.91	17.49
medusa sp. a	medspA	11.34	0.00	1.62	0.00	1.31	1.47
Pinnixa sayana	Psyna	11.24	0.00	0.00	0.00	0.00	0.00
Petrolisthes armatus	Parm	11.06	0.00	1.34	0.00	4.55	3.48
Sphaeroma quadridentata	Sphquad	11.05	1.22	2.64	0.00	2.59	2.41
Microgobius spp.	Mcrgob	10.98	17.10	8.28	23.80	8.15	14.56
Harengula jaguana	Hjgna	10.68	0.00	0.00	0.00	1.43	1.43
Eurytemora affinis	Erytaff	10.57	10.20	15.19	17.30	4.15	12.84
Sida crystallina	Scryst	10.56	13.27	1.28	0.00	6.17	6.37
Monstrilla sp.	Mnstrlla	10.45	0.00	15.65	14.83	11.34	14.61
hemipterans, gerrid adults	gerrid	10.19	11.96	1.84	2.11	3.95	6.19

Taxon	Code	Overall	Chassahowitzka	Crystal	Homosassa	Weeki Wachee	Spring Total
Tozeuma carolinense	Tozma	9.68	0.00	1.62	0.00	0.00	1.62
Livoneca	cymthdA	9.23	2.88	4.26	2.81	2.02	3.15
Macrocyclops albidus	Malbidus	9.19	4.36	3.19	3.21	1.91	3.28
Diaphanosoma sp.	Diphnsm	9.14	0.00	5.10	0.00	0.00	5.10
Periclimenes spp.	Prclmns	9.07	2.88	15.47	3.07	0.00	11.74
acari	acari	9.01	27.77	6.23	3.29	3.82	12.01
pycnogonids	pycgnd	8.52	0.00	1.89	1.99	0.00	1.95
Uca spp.	Uca	8.50	0.00	8.50	0.00	0.00	8.50
medusa, Obelia sp.	Obelia	8.44	3.21	20.37	0.00	0.00	14.65
Probopyrus	Probpyr	8.30	18.77	0.00	0.00	1.32	12.95
Unidentified processids	procesd	8.30	0.00	7.75	35.25	0.00	16.92
hemipterans, corixid adults	corixid	8.27	19.69	0.00	0.00	1.97	17.16
Notemigonus crysoleucas	Ncrysl	7.99	10.66	0.00	1.99	0.00	8.73
coleopterans, scirtid larvae	scrtid	7.94	0.00	0.00	0.00	0.00	0.00
Ambidexter symmetricus	Asymm	7.88	0.00	7.71	0.00	9.25	8.48
Latona setifera	Lsetifera	7.77	0.00	0.00	0.00	0.00	0.00
ophiopluteus larvae	ophioplt	7.68	0.00	0.00	0.00	0.00	0.00
dipteran, Chaoborus punctipennis larvae	Cpncpnnd	7.58	1.91	1.38	3.27	10.53	5.88
Lagodon rhomboides	Lrhom	7.48	2.92	0.00	15.75	11.67	9.25
coleopterans, gyrinid larvae	gyrinid	7.31	0.00	0.00	0.00	2.14	2.14
medusa sp. d	medspD	7.17	12.70	2.37	2.48	1.28	4.83
Callianassa spp.	Clnssa	6.91	0.00	4.52	20.52	0.00	9.85
clupeid	clup	6.70	0.00	7.13	4.07	0.00	5.91
Brevoortia spp.	Brvtia	6.67	3.32	5.20	1.80	0.00	3.74
cladocerans, Daphnia spp.	Daphnia	6.53	0.00	1.31	10.98	13.74	9.94
Dynamenella sp.	Dynmnlla	6.51	0.00	6.51	0.00	0.00	6.51
Micropterus salmoides	Msalm	6.45	9.55	0.00	0.00	2.52	7.54
Sarsiella zostericola	Szost	6.24	3.69	2.17	6.84	11.31	6.38
Leiostomus xanthurus	Leixan	6.19	2.98	3.75	1.33	10.44	4.96
trichopteran larvae	trichop	6.15	4.71	1.98	1.37	12.81	7.44
penaeid metamorphs	penmeta	6.08	0.00	6.41	5.41	15.04	7.83
Lucania parva	Lparv	6.07	5.64	3.62	4.82	13.12	7.14
Lepomis spp.	Lepoms	5.96	22.62	1.35	2.23	0.00	6.56
turbellarians	trbllrns	5.95	8.14	0.00	11.30	1.46	8.36
Temora turbinata	Tturb	5.95	8.06	5.91	5.03	6.34	6.18
Lepomis punctatus	Lpunc	5.82	8.16	0.00	0.00	0.00	8.16
Pinnixa sp. a juveniles	PnxaA	5.80	0.00	0.00	0.00	0.00	0.00
Gobiosoma robustum	Gbsrob	5.69	1.21	0.00	1.38	5.52	3.57
medusa sp. b	medspB	5.56	0.00	0.00	0.00	0.00	0.00
Unidentified blenniid larvae	blniid	5.32	8.54	2.83	4.93	17.47	6.87

Taxon	Code	Overall	Chassahowitzka	Crystal	Homosassa	Weeki Wachee	Spring Total
unidentified harpacticoids	hrpctcd	5.29	4.71	5.02	6.06	5.41	5.28
medusa, Bougainvillia sp.	Bgvlla	5.28	0.00	15.37	0.00	0.00	15.37
Palaemonetes pugio	Ppugio	5.24	6.82	2.66	5.05	11.67	6.59
shrimps, unidentified juveniles	UIDshmp	5.08	0.00	4.09	0.00	0.00	4.09
Grimaldina brazzai	Gbrzzai	4.97	0.00	0.00	0.00	0.00	0.00
Palaemonetes intermedius	Pinter	4.94	0.00	0.00	0.00	4.94	4.94
Lolliguncula brevis	Lllgbrvs	4.84	0.00	0.00	0.00	0.00	0.00
Liriope tetraphylla	Lttraphy	4.81	0.00	1.38	0.00	0.00	1.38
brachiopod, Glottidia pyramidata larvae	Gpyrmd	4.80	0.00	3.24	0.00	0.00	3.24
Ictalurus punctatus	Ipunc	4.75	0.00	0.00	0.00	0.00	0.00
Ogyrides alphaerostris	Ogyrds	4.75	16.41	5.56	1.40	1.33	5.39
Beroe ovata	Bovata	4.70	0.00	0.00	0.00	0.00	0.00
Hoplosternum littorale	Hlitt	4.64	0.00	0.00	0.00	0.00	0.00
Lucania goodei	Lgood	4.60	6.66	0.00	0.00	2.06	5.12
Bunops sp.	Bunops	4.57	0.00	0.00	0.00	0.00	0.00
Noturus gyrinus	Ngyrns	4.55	0.00	0.00	0.00	0.00	0.00
Limulus polyphemus larvae	Limulus	4.53	1.24	0.00	0.00	1.29	1.27
Gobiesox strumosus	Gbsx	4.47	2.10	3.09	2.69	7.22	4.05
Cynoscion arenarius	Cynar	4.40	0.00	2.08	0.00	0.00	2.08
Rhithropanopeus harrisii	Rhith	4.34	3.46	1.34	1.14	0.00	2.35
Unidentified callianassids	callian	4.34	9.25	4.69	4.34	0.00	5.28
Orthocyclops modestus	Orthcyc	4.32	4.65	2.91	2.72	1.75	3.20
gastropods, opisthobranch	opsbrch	4.31	4.77	1.52	1.84	9.36	4.77
Microgobius gulosus	Mcgbgl	4.25	4.83	2.18	1.69	5.33	3.44
Anopsilana jonesi	Ajonesi	4.18	7.18	1.90	4.21	2.31	4.47
Chasmodes saburrae	Chsab	4.13	5.93	2.15	3.81	7.40	4.74
paracalanids	pracalnd	4.11	3.56	2.71	1.36	2.57	2.75
Cyathura polita	Cpolita	4.11	2.86	4.50	2.29	4.01	3.41
dipterans, ceratopogonid larvae	crtpgd	4.09	4.41	4.31	3.08	6.46	4.52
Alpheus viridari	Avirid	4.03	5.35	0.00	4.33	0.00	5.01
Moinadaphnia macleayii	Mnodaph	4.03	0.00	0.00	0.00	0.00	0.00
Lepomis auritus	Laurts	3.97	6.59	0.00	0.00	0.00	6.59
Centropages velificatus	Cvlfcts	3.92	0.00	1.32	0.00	0.00	1.32
Eucinostomus spp.	Eucin	3.91	6.89	2.93	3.44	4.22	4.05
Sphaeroma terebrans	Sphtrbs	3.90	2.24	1.86	1.22	1.83	1.91
Squilla empusa	Sqempsa	3.89	0.00	2.19	0.00	0.00	2.19
medusa sp. c	medspC	3.88	0.00	0.00	0.00	0.00	0.00
Anchoa hepsetus	Ahepst	3.86	0.00	6.59	2.19	2.85	3.45
coleopterans, haliplid adults	halpld	3.81	0.00	0.00	0.00	2.13	2.13
Cyprinodon variegatus	Cvarg	3.80	0.00	1.36	0.00	6.27	4.63

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Diaptomus spp.	Diaptmus	3.79	0.00	2.03	3.74	7.43	5.11
siphonostomatids	caligoid	3.78	2.73	2.25	2.49	0.00	2.49
Paralichthys spp.	Prlych	3.74	0.00	0.00	0.00	0.00	0.00
Opsanus beta	Obeta	3.74	4.93	2.59	1.30	0.00	3.74
Euceramus praelongus	Eprael	3.70	0.00	2.73	0.00	0.00	2.73
coleopterans, noterid adults	notrid	3.68	0.00	1.28	0.00	1.95	1.79
Fundulus spp.	Fndls	3.64	3.11	1.67	1.36	5.87	3.64
Leptochela serratorbita	Lsrtorb	3.55	0.00	0.00	0.00	0.00	0.00
Menidia spp.	Mnidia	3.55	4.03	2.41	4.60	4.04	3.81
Menticirrhus spp.	Mntcrr	3.53	1.90	1.42	1.25	1.32	1.52
Sinelobus stanfordi	Sstnfrdi	3.53	2.37	2.74	2.19	7.17	4.02
Bathygobius soporator	Bthgob	3.47	1.90	6.25	1.72	1.33	3.78
Notropis spp.	Ntrps	3.29	12.06	0.00	2.09	0.00	5.41
coleopterans, elmid adults	elmid	3.25	0.00	0.00	1.35	2.25	1.89
Xenanthura brevitelson	Xbrvtlsn	3.24	1.84	1.31	4.22	7.22	3.52
Etheostoma fusiforme	Ethfus	3.24	0.00	0.00	0.00	0.00	0.00
Farfantepenaeus duorarum	Fduorm	3.24	4.35	1.31	2.48	6.15	3.66
Eugerres plumieri	Eugrr	3.19	0.00	4.19	0.00	0.00	4.19
Strongylura spp.	Stglra	3.19	1.25	6.55	0.00	0.00	3.90
Eucinostomus harengulus	Ecnhar	3.17	4.22	1.26	0.00	2.02	3.17
Saphirella spp.	Sphrella	3.16	0.00	2.30	2.64	8.68	4.54
unidentified flexion larvae	UIDfish	3.14	0.00	0.00	7.30	3.09	5.19
Myrophis punctatus	Mpunc	3.11	3.47	0.00	1.87	7.00	4.02
Leydigia sp.	Leydigia	3.10	1.30	0.00	1.24	0.00	1.27
unidentified freshwater cyclopoids	UIDFWcop	3.09	2.36	1.76	6.35	1.85	3.22
Orthopristis chrysoptera	Orhcry	3.04	0.00	4.36	0.00	0.00	4.36
Periclimenes longicaudatus	Plong	3.04	3.73	0.00	2.79	2.74	3.01
Hypsoblennius spp.	Hypsbl	2.98	0.00	0.00	0.00	2.79	2.79
Spelaeomysis sp.	Spelmys	2.98	0.00	0.00	2.20	2.80	2.32
Branchiostoma floridae	Bflorid	2.97	0.00	0.00	0.00	0.00	0.00
Achirus lineatus	Achr	2.95	0.00	3.28	2.57	2.76	2.98
coleopterans, dytiscid larvae	dystcid	2.93	1.32	0.00	0.00	3.16	2.70
Labidesthes sicculus	Lsicc	2.92	0.00	0.00	0.00	5.87	5.87
Chloroscombrus chrysurus	Cchry	2.91	0.00	0.00	0.00	0.00	0.00
Menidia beryllina	Mnbryl	2.89	0.00	0.00	0.00	0.00	0.00
Mysid sp. A	MysidA	2.89	0.00	0.00	0.00	0.00	0.00
Pseudosida bidentata	Pbdnta	2.87	0.00	0.00	0.00	0.00	0.00
Trinectes maculatus	Trimac	2.86	3.35	2.33	1.77	2.55	2.53
Callinectes sapidus	Csap	2.86	2.20	1.71	1.40	2.81	2.07
hirudinoideans	hirud	2.85	4.53	1.94	3.74	2.30	3.17

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odonates, anisopteran larvae	ansptn	2.82	2.64	0.00	0.00	2.72	2.70
Gobiosoma bosc	Gbsbsc	2.80	2.23	1.63	1.33	2.64	1.85
Gambusia holbrooki juveniles	Ghlbk	2.80	1.52	2.75	1.32	4.05	2.72
neuropterans, Climacia spp.	Climacia	2.78	0.00	1.22	0.00	0.00	1.22
megalopterans, sialid larvae	sialid	2.76	0.00	0.00	0.00	2.76	2.76
Palaemon floridanus	Pflrdn	2.73	0.00	4.19	0.00	0.00	4.19
Bairdiella chrysoura	Brdcry	2.71	0.00	1.64	1.76	0.00	1.68
odonates, zygopteran larvae	zygptn	2.68	3.79	1.35	1.23	2.11	2.59
unidentified calanoids	UIDcalnd	2.68	0.00	0.00	0.00	0.00	0.00
collembolas, podurid	podurid	2.66	0.00	10.66	2.91	1.94	3.45
coleopterans	chrysmd	2.61	1.33	0.00	0.00	0.00	1.33
Nebalia sp.	Nebalia	2.59	0.00	0.00	0.00	0.00	0.00
ophiuroidean juveniles	ophiurd	2.58	0.00	0.00	0.00	2.42	2.42
Euryalona occidentalis	Euryalona	2.57	0.00	0.00	0.00	0.00	0.00
Centropages hamatus	Chmatus	2.57	0.00	0.00	0.00	0.00	0.00
Alteutha sp.	Alteutha	2.57	0.00	0.00	0.00	1.30	1.30
branchiurans, Argulus spp.	Argulus	2.55	2.12	1.94	1.75	2.45	2.09
dipterans, syrphid larvae	syrphid	2.55	2.64	0.00	0.00	0.00	2.64
Elops saurus	Esaur	2.48	2.95	1.25	3.02	0.00	2.30
Syngnathus louisianae	Sygnls	2.46	5.02	1.62	0.00	0.00	3.32
Cynoscion nebulosus	Cynneb	2.45	1.27	2.03	0.00	2.96	2.07
Liposarcus spp.	Lposrc	2.44	0.00	0.00	0.00	0.00	0.00
myodocopod sp. a	mydocopA	2.43	0.00	0.00	1.60	1.34	1.55
Mysidopsis mortenseni	Mmortn	2.42	0.00	0.00	0.00	0.00	0.00
Palaemonetes vulgaris	Pvulg	2.36	0.00	1.66	0.00	2.94	2.46
cirriped cyprids	crpdCypr	2.35	0.00	2.35	0.00	0.00	2.35
dipterans, stratiomyid larvae	strtmyd	2.31	1.20	0.00	0.00	3.29	1.90
Osphranticum labronectum	Osphrntc	2.28	0.00	1.34	0.00	0.00	1.34
Membras martinica	Mmart	2.27	3.84	1.72	0.00	2.77	2.55
Strongylura marina	Smrina	2.26	1.23	0.00	0.00	0.00	1.23
Latreutes parvulus	Ltparv	2.21	0.00	0.00	0.00	0.00	0.00
Lutjanus griseus	Ltjgrs	2.21	1.25	0.00	1.30	0.00	1.28
isopod sp. a	isopodA	2.20	0.00	0.00	0.00	0.00	0.00
medusa sp. g	medspG	2.16	0.00	0.00	0.00	0.00	0.00
lepidopterans, pyralid larvae	lepidop	2.16	2.61	0.00	0.00	2.28	2.47
dipterans, ephydrid larvae	ephyd	2.14	1.39	0.00	0.00	0.00	1.39
dipterans, muscid larvae	muscid	2.12	0.00	2.78	0.00	0.00	2.78
sipunculid	sipunc	2.10	0.00	0.00	0.00	0.00	0.00
dipterans, tipulid larvae	tipulid	2.05	1.11	3.60	0.00	1.44	2.05
Mugil curema	Mcrma	2.03	0.00	0.00	0.00	0.00	0.00
Portunus sp.	Prtns	2.02	1.46	1.22	2.24	1.35	1.83

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Lepisosteus sp.	Lepis	2.02	0.00	2.50	2.02	0.00	2.18
dipterans, sciomyzid larvae	scmyz	2.00	0.00	0.00	0.00	0.00	0.00
Hippocampus erectus	Herect	1.96	0.00	0.00	0.00	1.18	1.18
Eucinostomus gula	Ecngul	1.95	2.05	1.35	0.00	0.00	1.82
Ceridodaphnia sp.	Criodaph	1.94	0.00	0.00	0.00	2.75	2.75
Syngnathus floridae	Sygnfl	1.93	2.41	1.30	2.83	0.00	2.29
Archosargus probatocephalus	Arcprb	1.90	0.00	1.21	0.00	0.00	1.21
Opisthonema oglinum	Ooglnm	1.88	0.00	0.00	2.27	0.00	2.27
Heterandria formosa	Hform	1.82	0.00	0.00	1.18	3.17	2.17
Eucalanus sp.	Eucal	1.82	0.00	0.00	0.00	0.00	0.00
coleopterans, curculionid	curcld	1.80	0.00	0.00	1.38	0.00	1.38
Mugil cephalus	Mcphls	1.78	1.43	1.24	1.28	0.00	1.29
Oligoplites saurus	Osaurs	1.75	0.00	0.00	0.00	0.00	0.00
dipterans, tabanid larvae	tbanid	1.72	2.21	0.00	0.00	0.00	2.21
xanthid juveniles	UIDxntd	1.68	1.84	0.00	2.77	1.31	1.94
Hippocampus zosterae	Hppzst	1.67	0.00	0.00	0.00	0.00	0.00
hemipterans, pleid adults	pleid	1.63	0.00	0.00	0.00	0.00	0.00
Monacanthus hispidus	Shisp	1.63	0.00	0.00	0.00	0.00	0.00
cladocerans, unidentified	UIDclad	1.62	0.00	0.00	0.00	0.00	0.00
Lupinoblennius nicholsi	Lupbl	1.58	1.28	1.87	1.25	1.63	1.63
Synodus foetens	Synft	1.58	2.54	1.36	0.00	0.00	1.75
Fundulus seminolis	Fsmnls	1.57	0.00	0.00	0.00	0.00	0.00
hemipterans, belostomatids	blstmd	1.56	0.00	1.31	0.00	0.00	1.31
Fundulus grandis	Fgrnds	1.54	1.95	0.00	0.00	0.00	1.95
Ergasilus sp.	Ergslus	1.53	0.00	0.00	0.00	0.00	0.00
Alpheus estuariensis	Aestrns	1.52	1.52	0.00	0.00	0.00	1.52
Sciaenops ocellatus	Sciocl	1.52	1.16	0.00	0.00	1.36	1.26
Panopeus herbstii	Pherbs	1.50	0.00	0.00	0.00	0.00	0.00
Thor sp.	Thor	1.48	0.00	0.00	0.00	0.00	0.00
Sphoeroides spp.	Sphr	1.46	1.46	0.00	0.00	0.00	1.46
cymothoid sp. B	cymthdB	1.45	0.00	0.00	0.00	0.00	0.00
Monacanthus setifer	Ssetif	1.44	0.00	0.00	1.44	0.00	1.44
Erimyzon sucetta	Esctta	1.41	0.00	0.00	0.00	0.00	0.00
Kurzia longirostris	Kurzia	1.40	0.00	0.00	0.00	0.00	0.00
Dorosoma petenense	Dptnse	1.40	0.00	0.00	1.40	0.00	1.40
Lepisosteus platyrhincus	Lplaty	1.39	1.39	0.00	0.00	0.00	1.39
Albula vulpes	Avulpes	1.39	0.00	0.00	0.00	0.00	0.00
Camptocercus rectirostris	Cmptcrc	1.38	0.00	0.00	0.00	0.00	0.00
Ameiurus natalis	Anatlis	1.37	0.00	0.00	0.00	0.00	0.00
Tanaid sp. c	TanaidC	1.37	0.00	0.00	1.37	0.00	1.37
medusa sp. f	medspF	1.37	0.00	0.00	1.37	0.00	1.37

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Hoplomachus propinquus	Hplmchs	1.36	0.00	1.36	0.00	0.00	1.36
Prionotus spp.	Prnts	1.35	0.00	0.00	0.00	0.00	0.00
Oncaea spp.	Oncaea	1.35	0.00	1.26	0.00	0.00	1.26
Dorosoma spp.	Doros	1.34	0.00	0.00	0.00	0.00	0.00
coleopterans, dryopid larvae	dryopid	1.34	0.00	0.00	0.00	0.00	0.00
Hyporhamphus unifasciatus	Hunif	1.34	0.00	0.00	0.00	1.38	1.38
Prionotus tribulus	Ptribls	1.34	0.00	1.22	0.00	0.00	1.22
Symphurus plagiusa	Symplg	1.33	0.00	1.33	1.39	0.00	1.36
ascidiacean larvae	ascdacn	1.33	0.00	0.00	0.00	0.00	0.00
hemipterans, nepid adults	nepid	1.33	0.00	0.00	0.00	0.00	0.00
Lepomis microlophus	Lmcro	1.32	0.00	0.00	0.00	1.32	1.32
Gobionellus spp.	Gbnell	1.32	0.00	0.00	0.00	0.00	0.00
nemerteans	nmrtns	1.32	0.00	0.00	0.00	0.00	0.00
Ameiurus catus	Acatus	1.31	0.00	0.00	0.00	0.00	0.00
Brevoortia smithi juveniles	Bsmithi	1.31	0.00	1.29	1.27	0.00	1.28
Sphoeroides parvus	Sphprv	1.30	0.00	0.00	1.30	0.00	1.30
anuran larvae	tadpole	1.30	0.00	0.00	0.00	1.26	1.26
Bagre marinus	Bmrins	1.29	0.00	0.00	0.00	0.00	0.00
Chilomycterus shoepfi	Cschpf	1.28	0.00	0.00	0.00	1.32	1.32
Eurypanopeus depressus	Edeprss	1.27	0.00	0.00	0.00	1.27	1.27
Paracerceis caudata	Pcaudata	1.27	0.00	1.20	0.00	0.00	1.20
megalopterans, corydalid larvae	crydld	1.27	0.00	0.00	0.00	0.00	0.00
Gobionellus oceanicus	Gbnloc	1.26	0.00	0.00	0.00	0.00	0.00
Sphoeroides nephelus	Sphnph	1.26	0.00	0.00	1.23	1.29	1.26
dipterans, dolichopodid larvae	dolich	1.26	0.00	0.00	0.00	1.26	1.26
Menticirrhus americanus	Mntamr	1.26	0.00	0.00	0.00	0.00	0.00
Acanthostrocion quadricornis	Aqdcrn	1.25	0.00	0.00	0.00	1.25	1.25
Sphaeroma walkeri	Sphwlk	1.23	0.00	0.00	0.00	0.00	0.00
Mesocyclops leuckarti	Mescycl	1.22	1.22	0.00	0.00	0.00	1.22
Isopod, Gnathia sp. (praniza larva)	Gnathia	1.21	0.00	1.21	0.00	0.00	1.21
Gobionellus boleosoma	Gbnlbl	1.20	0.00	0.00	0.00	0.00	0.00
Upogebia affinis	Uaffin	1.13	1.13	0.00	0.00	0.00	1.13
hemipterans, naucorid adults	naucrd	1.11	0.00	0.00	0.00	0.00	0.00
Strongylura notata	Sntta	1.07	0.00	0.00	0.00	0.00	0.00

Taxon	Code	Overall	Alafia	Anclote	Hillsborough	Myakka	Surface Total
decapod zoea	zoea	3261.21	2612.00	1224.55	6153.44	2340.96	3082.74
amphipods, gammaridean	gmmrd	1474.73	397.05	2302.16	190.25	630.81	880.07
cumaceans	cumacn	751.36	605.38	71.36	57.78	2236.70	742.81
fish eggs, percomorph	prcmph	559.42	951.21	403.15	203.05	1568.18	782.27
Acartia tonsa	Atonsa	441.38	539.93	378.77	1112.36	826.56	714.40
Mnemiopsis leidyi	Mleidyi	435.11	269.43	13.68	38.48	803.10	499.01
appendicularian, Oikopleura dioica	Odioica	402.67	6.07	280.19	273.12	1301.19	421.75
Americamysis almyra	Aalmyra	334.93	134.44	111.42	147.58	684.73	277.97
Labidocera aestiva	Laestiva	326.30	982.47	102.99	273.77	154.15	377.18
Bowmaniella dissimilis	Bdissim	311.77	1.83	92.72	0.00	137.43	101.15
cirriped nauplii	crpdNaup	273.25	1.41	7.83	3.74	816.37	336.90
Unidentified Americamysis juveniles	AmysJUV	267.61	70.44	48.21	115.07	402.32	159.94
chaetognaths	chaetog	260.69	940.90	139.60	172.67	310.89	392.72
Lucifer faxoni	Lucifer	258.07	326.85	100.36	1038.25	2.37	391.31
decapod megalopae	megalop	246.25	51.62	53.09	528.52	226.28	225.68
Parasterope pollex	ppollex	228.20	1355.63	48.24	13.22	71.56	392.20
decapod mysis	mysis	211.15	116.67	316.58	95.28	43.18	142.93
Americamysis bahia	Abahia	126.90	30.16	1.16	0.00	32.96	28.18
Taphromysis bowmani	Tbowman	111.91	4.10	9.79	0.00	376.13	163.47
polychaetes	polych	93.26	98.21	27.87	440.59	14.26	145.23
Oithona spp.	Oithona	92.78	2.68	6.66	6.81	256.68	115.33
Gobiosoma spp.	Gbsma	82.08	22.21	6.82	133.21	3.37	47.39
Edotea triloba	Edotia	79.36	326.83	29.28	71.92	155.83	145.96
nematodes	nmtds	76.07	2.57	5.39	410.76	1.44	122.75
Anchoa mitchilli	Amtch	72.63	157.77	17.35	28.82	223.77	106.93
Pseudevadne tergestina	Ptergstn	70.40	12.87	5.61	7.88	125.87	75.33
gastropods, prosobranch	prosbrch	66.05	9.72	14.15	4.22	71.76	26.85
penaeid postlarvae	penaeid	64.39	2.63	3.57	2.79	23.48	9.79
Clytia sp.	Clytia	64.14	178.73	15.60	92.38	5.53	81.22
Hargeria rapax	Hrapax	54.68	1.42	7.99	3.15	6.33	5.78
Unidentified gobiid larvae	gobiid	54.51	4.97	11.22	102.32	4.99	31.86
Harrieta faxoni	Hfaxoni	53.84	7.63	6.80	1.37	1.27	5.95
Americamysis stucki	Astucki	49.51	79.22	16.46	2.89	85.95	63.28
amphipods, caprellid	cprlld	40.69	157.68	7.19	67.00	22.09	64.02
Simocephalus vetulus	Svetelus	40.24	2.05	68.37	16.92	104.79	74.00
Erichsonella spp.	Erchspp	35.89	4.53	3.54	2.48	4.66	3.86
Munna reynoldsi	Uromunna	32.80	5.74	39.62	4.78	130.38	54.59
Mesocyclops edax	Medax	32.42	156.76	3.29	18.59	25.68	34.29
Penilia avirostris	Pavrstrs	30.13	0.00	5.79	3.51	14.36	9.06

Taxon	Code	Overall	Alafia	Anclote	Hillsborough	Myakka	Surface Total
dipterans, chironomid larvae	chiron	28.86	8.37	11.77	7.52	22.64	12.79
dipterans, pupae	pupae	28.69	8.07	11.98	3.99	21.80	12.33
Hippolyte zostericola	Hzost	28.09	2.59	75.35	9.15	16.97	34.49
Apseudes sp.	Apseudes	26.24	0.00	3.62	0.00	0.00	3.62
Unidentified alphaeids	Alph	26.16	17.35	9.10	25.43	50.98	25.42
oligochaetes	oligch	24.78	7.58	3.91	142.57	3.67	28.77
ephemeropteran larvae	ephmpt	24.33	2.90	7.30	9.27	83.30	45.89
Upogebia spp. postlarvae	Upgba	23.85	15.99	2.64	14.95	4.79	8.97
paguroid juveniles	pgurd	23.09	0.00	40.61	2.96	0.00	32.24
Anchoa spp.	Anchoa	21.57	17.30	5.57	31.77	54.07	29.84
Microgobius thalassinus	Mcrgbth	18.31	1.46	0.00	0.00	0.00	1.46
Pseudodiaptomus coronatus	Psdiap	18.17	10.70	5.46	12.63	46.45	17.11
Ilyocryptus sp.	Ilycryp	17.17	1.44	24.14	12.18	20.45	19.10
Calanopia americana	Clanopia	16.66	4.52	22.16	2.71	7.34	15.46
Mysidopsis furca	Mfurca	16.22	0.00	0.00	0.00	0.00	0.00
ostracods, podocopid	podocop	15.98	2.21	3.17	2.21	11.77	5.62
pelecypods	plcypd	15.89	7.51	13.95	30.07	50.88	25.50
Temora longicornis	Tlngcrn	15.72	0.00	0.00	0.00	0.00	0.00
Palaemonetes spp.	Plmnts	15.57	9.72	5.66	22.02	10.98	12.37
Syngnathus scovelli	Sygscv	14.56	1.25	2.48	2.86	126.07	40.96
medusa sp. e	medspE	14.13	0.00	8.04	23.86	0.00	18.58
medusa, Eutima sp.	Eutima	14.01	0.00	0.00	7.05	0.00	7.05
Latonopsis fasciculata	Lfsclta	13.92	0.00	9.70	3.04	24.26	17.97
Palaemonetes paludosus	Ppalud	13.22	0.00	0.00	0.00	0.00	0.00
Cyclops spp.	Cyclops	13.13	1.83	0.00	0.00	36.08	15.53
foraminiferans	foram	12.63	1.33	4.11	1.85	3.53	3.55
clinid prefelxion	clind	12.16	0.00	0.00	0.00	0.00	0.00
Euconchoecia chierchiae	Echierch	12.13	18.08	1.33	0.00	6.64	8.68
Cassidinidea ovalis	Covalis	11.50	2.26	1.84	3.63	2.32	2.51
medusa sp. a	medspA	11.34	1.90	21.11	0.00	1.47	14.64
Pinnixa sayana	Psyna	11.24	14.32	1.31	11.94	0.00	11.24
Petrolisthes armatus	Parm	11.06	16.11	0.00	0.00	3.51	14.31
Sphaeroma quadridentata	Sphquad	11.05	3.13	3.39	2.91	28.97	16.09
Microgobius spp.	Mcrgob	10.98	7.46	8.60	8.67	4.36	7.21
Harengula jaguana	Hjgna	10.68	0.00	19.94	0.00	0.00	19.94
Eurytemora affinis	Erytaff	10.57	1.99	1.73	0.00	1.42	1.75
Sida crystallina	Scryst	10.56	0.00	1.27	2.63	22.95	13.85
Monstrilla sp.	Mnstrlla	10.45	5.12	2.42	7.78	0.00	6.05
hemipterans, gerrid adults	gerrid	10.19	25.29	2.91	0.00	3.81	14.44
Tozeuma carolinense	Tozma	9.68	2.95	16.50	3.36	0.00	10.41
Livoneca	cymthdA	9.23	25.59	2.93	14.49	11.84	14.23

Taxon	**Code**	**Overall**	**Alafia**	**Anclote**	**Hillsborough**	**Myakka**	**Surface Total**
Macrocyclops albidus	Malbidus	9.19	1.38	2.65	42.16	16.53	16.76
Diaphanosoma sp.	Diphnsm	9.14	0.00	0.00	13.18	0.00	13.18
Periclimenes spp.	Prclmns	9.07	3.65	0.00	5.59	0.00	4.62
acari	acari	9.01	1.74	3.07	2.76	5.32	4.04
pycnogonids	pycgnd	8.52	0.00	21.48	2.30	0.00	15.09
Uca spp.	Uca	8.50	0.00	0.00	0.00	0.00	0.00
medusa, Obelia sp.	Obelia	8.44	0.00	2.23	0.00	0.00	2.23
Probopyrus	Probpyr	8.30	0.00	0.00	0.00	1.32	1.32
Unidentified processids	procesd	8.30	6.26	9.07	4.35	0.00	6.31
hemipterans, corixid adults	corixid	8.27	0.00	1.27	3.65	3.68	3.48
Notemigonus crysoleucas	Ncrysl	7.99	0.00	1.34	0.00	0.00	1.34
coleopterans, scirtid larvae	scrtid	7.94	1.13	0.00	0.00	11.35	7.94
Ambidexter symmetricus	Asymm	7.88	2.27	8.25	4.71	16.80	7.72
Latona setifera	Lsetifera	7.77	0.00	5.94	0.00	8.50	7.77
ophiopluteus larvae	ophioplt	7.68	0.00	7.68	0.00	0.00	7.68
dipteran, Chaoborus punctipennis larvae	Cpncpnnd	7.58	7.25	5.02	11.36	10.96	9.09
Lagodon rhomboides	Lrhom	7.48	0.00	6.15	2.36	1.41	4.61
coleopterans, gyrinid larvae	gyrinid	7.31	0.00	2.54	3.67	9.55	8.10
medusa sp. d	medspD	7.17	0.00	8.14	6.57	13.38	9.52
Callianassa spp.	Clnssa	6.91	1.56	1.29	4.92	6.16	3.96
clupeid	clup	6.70	0.00	7.98	0.00	5.58	7.50
Brevoortia spp.	Brvtia	6.67	4.90	2.21	19.02	11.26	9.37
cladocerans, Daphnia spp.	Daphnia	6.53	4.77	0.00	2.89	2.40	3.11
Dynamenella sp.	Dynmnlla	6.51	0.00	0.00	0.00	0.00	0.00
Micropterus salmoides	Msalm	6.45	0.00	0.00	0.00	2.63	2.63
Sarsiella zostericola	Szost	6.24	8.36	4.69	0.00	3.60	6.04
Leiostomus xanthurus	Leixan	6.19	0.00	13.55	0.00	0.00	13.55
trichopteran larvae	trichop	6.15	2.80	3.59	2.80	6.54	4.75
penaeid metamorphs	penmeta	6.08	2.89	5.54	0.00	2.39	4.20
Lucania parva	Lparv	6.07	1.23	1.39	3.42	2.09	2.52
Lepomis spp.	Lepoms	5.96	0.00	1.33	0.00	5.69	4.60
turbellarians	trbllrns	5.95	2.86	2.15	0.00	4.06	3.10
Temora turbinata	Tturb	5.95	0.00	5.61	4.11	6.01	5.39
Lepomis punctatus	Lpunc	5.82	0.00	0.00	0.00	1.12	1.12
Pinnixa sp. a juveniles	PnxaA	5.80	0.00	5.94	5.65	0.00	5.80
Gobiosoma robustum	Gbsrob	5.69	1.51	1.41	0.00	15.75	8.61
medusa sp. b	medspB	5.56	1.42	0.00	4.66	7.24	5.56
Unidentified blenniid larvae	blniid	5.32	2.75	3.51	3.90	3.63	3.58
unidentified harpacticoids	hrpctcd	5.29	2.74	7.45	5.06	4.29	5.29
medusa, Bougainvillia sp.	Bgvlla	5.28	0.00	1.92	0.00	0.00	1.92

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Palaemonetes pugio	Ppugio	5.24	5.57	1.85	2.24	3.94	3.26
shrimps, unidentified juveniles	UIDshmp	5.08	4.82	6.21	0.00	0.00	5.22
Grimaldina brazzai	Gbrzzai	4.97	0.00	1.22	0.00	6.22	4.97
Palaemonetes intermedius	Pinter	4.94	0.00	0.00	0.00	0.00	0.00
Lolliguncula brevis	Lllgbrvs	4.84	3.34	0.00	12.52	3.23	4.84
Liriope tetraphylla	Lttraphy	4.81	7.69	4.34	3.22	0.00	5.30
brachiopod, Glottidia pyramidata larvae	Gpyrmd	4.80	3.00	3.66	4.22	9.40	5.00
Ictalurus punctatus	Ipunc	4.75	0.00	0.00	0.00	4.75	4.75
Ogyrides alphaerostris	Ogyrds	4.75	0.00	0.00	1.28	4.01	3.47
Beroe ovata	Bovata	4.70	0.00	1.28	0.00	6.40	4.70
Hoplosternum littorale	Hlitt	4.64	0.00	0.00	0.00	4.64	4.64
Lucania goodei	Lgood	4.60	0.00	0.00	0.00	1.44	1.44
Bunops sp.	Bunops	4.57	0.00	0.00	0.00	4.57	4.57
Noturus gyrinus	Ngyrns	4.55	0.00	0.00	0.00	4.55	4.55
Limulus polyphemus larvae	Limulus	4.53	2.66	7.08	4.83	0.00	5.03
Gobiesox strumosus	Gbsx	4.47	1.50	4.79	8.15	3.84	4.88
Cynoscion arenarius	Cynar	4.40	3.64	1.81	5.79	5.19	4.80
Rhithropanopeus harrisii	Rhith	4.34	0.00	0.00	6.43	1.89	5.67
Unidentified callianassids	callian	4.34	0.00	0.00	1.39	1.69	1.54
Orthocyclops modestus	Orthcyc	4.32	0.00	1.62	0.00	7.21	5.81
gastropods, opisthobranch	opsbrch	4.31	1.89	3.53	2.62	5.54	3.71
Microgobius gulosus	Mcgbgl	4.25	1.42	9.59	1.28	3.36	5.68
Anopsilana jonesi	Ajonesi	4.18	3.71	1.31	5.99	1.26	3.82
Chasmodes saburrae	Chsab	4.13	1.12	0.00	4.02	1.90	3.00
paracalanids	pracalnd	4.11	0.00	8.89	0.00	2.05	5.47
Cyathura polita	Cpolita	4.11	6.25	3.88	1.30	5.87	5.00
dipterans, ceratopogonid larvae	crtpgd	4.09	4.46	1.67	1.22	2.38	2.40
Alpheus viridari	Avirid	4.03	0.00	1.11	0.00	0.00	1.11
Moinadaphnia macleayii	Mnodaph	4.03	0.00	0.00	0.00	4.03	4.03
Lepomis auritus	Laurts	3.97	1.16	0.00	0.00	1.55	1.35
Centropages velificatus	Cvlfcts	3.92	0.00	5.97	2.71	1.27	4.56
Eucinostomus spp.	Eucin	3.91	1.37	4.34	0.00	1.26	3.33
Sphaeroma terebrans	Sphtrbs	3.90	2.64	8.06	2.31	5.87	4.99
Squilla empusa	Sqempsa	3.89	1.41	0.00	4.87	0.00	4.38
medusa sp. c	medspC	3.88	2.39	4.62	0.00	0.00	3.88
Anchoa hepsetus	Ahepst	3.86	1.81	1.17	7.99	3.93	4.09
coleopterans, haliplid adults	halpld	3.81	1.36	0.00	0.00	7.09	4.23
Cyprinodon variegatus	Cvarg	3.80	0.00	0.00	0.00	1.30	1.30
Diaptomus spp.	Diaptmus	3.79	3.25	1.41	0.00	2.56	2.47
siphonostomatids	caligoid	3.78	3.86	8.13	3.71	0.00	4.70

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Paralichthys spp.	Prlych	3.74	0.00	3.74	0.00	0.00	3.74
Opsanus beta	Obeta	3.74	0.00	0.00	0.00	0.00	0.00
Euceramus praelongus	Eprael	3.70	4.19	0.00	0.00	0.00	4.19
coleopterans, noterid adults	notrid	3.68	0.00	0.00	0.00	4.76	4.76
Fundulus spp.	Fndls	3.64	0.00	0.00	0.00	0.00	0.00
Leptochela serratorbita	Lsrtorb	3.55	3.84	0.00	2.94	3.62	3.55
Menidia spp.	Mnidia	3.55	2.89	3.88	2.23	3.35	3.24
Menticirrhus spp.	Mntcrr	3.53	1.97	3.76	5.39	5.67	4.40
Sinelobus stanfordi	Sstnfrdi	3.53	1.74	2.25	3.72	2.83	2.69
Bathygobius soporator	Bthgob	3.47	1.22	1.42	2.97	5.86	3.24
Notropis spp.	Ntrps	3.29	0.00	0.00	0.00	1.69	1.69
coleopterans, elmid adults	elmid	3.25	0.00	3.40	2.78	3.97	3.70
Xenanthura brevitelson	Xbrvtlsn	3.24	0.00	2.70	0.00	1.45	2.54
Etheostoma fusiforme	Ethfus	3.24	0.00	0.00	0.00	3.24	3.24
Farfantepenaeus duorarum	Fduorm	3.24	1.41	2.43	0.00	2.89	2.49
Eugerres plumieri	Eugrr	3.19	3.36	0.00	4.44	1.90	2.99
Strongylura spp.	Stglra	3.19	1.26	0.00	0.00	4.41	2.83
Eucinostomus harengulus	Ecnhar	3.17	0.00	0.00	0.00	0.00	0.00
Saphirella spp.	Sphrella	3.16	1.25	2.59	1.45	0.00	2.34
unidentified flexion larvae	UIDfish	3.14	0.00	2.71	0.00	1.31	1.77
Myrophis punctatus	Mpunc	3.11	0.00	3.17	0.00	1.48	2.04
Leydigia sp.	Leydigia	3.10	0.00	1.33	5.21	4.13	3.56
unidentified freshwater cyclopoids	UIDFWcop	3.09	0.00	0.00	0.00	2.87	2.87
Orthopristis chrysoptera	Orhcry	3.04	0.00	2.37	0.00	0.00	2.37
Periclimenes longicaudatus	Plong	3.04	1.69	3.73	0.00	0.00	3.05
Hypsoblennius spp.	Hypsbl	2.98	0.00	1.43	0.00	5.12	3.28
Spelaeomysis sp.	Spelmys	2.98	0.00	0.00	0.00	6.28	6.28
Branchiostoma floridae	Bflorid	2.97	0.00	2.97	0.00	0.00	2.97
Achirus lineatus	Achr	2.95	1.51	3.65	0.00	0.00	2.94
coleopterans, dytiscid larvae	dystcid	2.93	0.00	1.44	0.00	3.72	3.15
Labidesthes sicculus	Lsicc	2.92	0.00	0.00	1.39	2.69	2.50
Chloroscombrus chrysurus	Cchry	2.91	0.00	0.00	3.39	1.46	2.91
Menidia beryllina	Mnbryl	2.89	0.00	0.00	0.00	2.89	2.89
Mysid sp. A	MysidA	2.89	0.00	0.00	2.89	0.00	2.89
Pseudosida bidentata	Pbdnta	2.87	0.00	0.00	0.00	2.87	2.87
Trinectes maculatus	Trimac	2.86	1.97	2.83	2.12	4.53	3.06
Callinectes sapidus	Csap	2.86	0.00	5.26	0.00	2.81	4.32
hirudinoideans	hirud	2.85	2.91	1.56	2.13	1.96	2.30
odonates, anisopteran larvae	ansptn	2.82	0.00	1.24	0.00	3.07	2.87
Gobiosoma bosc	Gbsbsc	2.80	1.20	2.82	1.36	5.84	4.49

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Gambusia holbrooki juveniles	Ghlbk	2.80	1.21	2.53	2.53	3.29	2.84
neuropterans, Climacia spp.	Climacia	2.78	0.00	0.00	0.00	2.97	2.97
megalopterans, sialid larvae	sialid	2.76	0.00	0.00	0.00	0.00	0.00
Palaemon floridanus	Pflrdn	2.73	0.00	1.27	0.00	0.00	1.27
Bairdiella chrysoura	Brdcry	2.71	1.37	1.16	0.00	5.15	3.22
odonates, zygopteran larvae	zygptn	2.68	1.26	2.96	3.31	2.76	2.79
unidentified calanoids	UIDcalnd	2.68	2.68	0.00	0.00	0.00	2.68
collembolas, podurid	podurid	2.66	1.31	1.29	2.46	2.33	2.02
coleopterans	chrysmd	2.61	0.00	0.00	3.89	0.00	3.89
Nebalia sp.	Nebalia	2.59	2.59	0.00	0.00	0.00	2.59
ophiuroidean juveniles	ophiurd	2.58	2.00	2.87	0.00	0.00	2.62
Euryalona occidentalis	Euryalona	2.57	0.00	5.01	0.00	1.76	2.57
Centropages hamatus	Chmatus	2.57	0.00	2.33	0.00	3.53	2.57
Alteutha sp.	Alteutha	2.57	0.00	1.38	5.03	1.37	3.20
branchiurans, Argulus spp.	Argulus	2.55	1.40	3.99	2.42	3.21	3.03
dipterans, syrphid larvae	syrphid	2.55	0.00	0.00	2.45	0.00	2.45
Elops saurus	Esaur	2.48	3.02	1.77	2.77	2.74	2.54
Syngnathus louisianae	Sygnls	2.46	1.90	6.24	1.56	2.73	2.34
Cynoscion nebulosus	Cynneb	2.45	1.46	1.39	2.48	4.46	2.79
Liposarcus spp.	Lposrc	2.44	3.24	0.00	0.00	2.05	2.44
myodocopod sp. a	mydocopA	2.43	0.00	3.87	2.54	0.00	3.54
Mysidopsis mortenseni	Mmortn	2.42	0.00	2.42	0.00	0.00	2.42
Palaemonetes vulgaris	Pvulg	2.36	0.00	1.51	0.00	0.00	1.51
cirriped cyprids	crpdCypr	2.35	0.00	0.00	0.00	0.00	0.00
dipterans, stratiomyid larvae	strtmyd	2.31	0.00	0.00	3.49	1.21	2.73
Osphranticum labronectum	Osphrntc	2.28	0.00	2.47	0.00	2.40	2.41
Membras martinica	Mmart	2.27	1.77	1.45	0.00	2.20	2.01
Strongylura marina	Smrina	2.26	0.00	0.00	0.00	2.78	2.78
Latreutes parvulus	Ltparv	2.21	0.00	2.21	0.00	0.00	2.21
Lutjanus griseus	Ltjgrs	2.21	0.00	0.00	0.00	4.08	4.08
isopod sp. a	isopodA	2.20	2.60	0.00	1.41	0.00	2.20
medusa sp. g	medspG	2.16	0.00	0.00	2.16	0.00	2.16
lepidopterans, pyralid larvae	lepidop	2.16	1.17	0.00	1.95	2.59	1.79
dipterans, ephydrid larvae	ephyd	2.14	0.00	0.00	2.89	0.00	2.89
dipterans, muscid larvae	muscid	2.12	0.00	0.00	1.46	0.00	1.46
sipunculid	sipunc	2.10	2.10	0.00	0.00	0.00	2.10
dipterans, tipulid larvae	tipulid	2.05	0.00	0.00	0.00	0.00	0.00
Mugil curema	Mcrma	2.03	1.30	2.76	0.00	0.00	2.03
Portunus sp.	Prtns	2.02	0.00	2.88	0.00	0.00	2.88
Lepisosteus sp.	Lepis	2.02	0.00	0.00	0.00	1.55	1.55
dipterans, sciomyzid larvae	scmyz	2.00	0.00	1.32	0.00	2.14	2.00

Taxon	Code	Overall	Alafia	Anclote	Hillsborough	Myakka	Surface Total
Hippocampus erectus	Herect	1.96	0.00	1.59	0.00	2.47	2.12
Eucinostomus gula	Ecngul	1.95	0.00	0.00	0.00	2.33	2.33
Ceridodaphnia sp.	Criodaph	1.94	0.00	0.00	0.00	1.54	1.54
Syngnathus floridae	Sygnfl	1.93	0.00	1.49	0.00	0.00	1.49
Archosargus probatocephalus	Arcprb	1.90	0.00	2.49	2.71	0.00	2.60
Opisthonema oglinum	Ooglnm	1.88	0.00	1.48	0.00	0.00	1.48
Heterandria formosa	Hform	1.82	0.00	1.27	0.00	1.79	1.72
Eucalanus sp.	Eucal	1.82	0.00	1.98	1.50	0.00	1.82
coleopterans, curculionid	curcld	1.80	2.47	1.41	0.00	1.87	1.91
Mugil cephalus	Mcphls	1.78	0.00	1.24	2.54	2.54	2.11
Oligoplites saurus	Osaurs	1.75	1.28	1.45	1.39	3.95	1.75
dipterans, tabanid larvae	tbanid	1.72	0.00	0.00	1.48	0.00	1.48
xanthid juveniles	UIDxntd	1.68	1.33	0.00	0.00	0.00	1.33
Hippocampus zosterae	Hppzst	1.67	0.00	1.67	0.00	0.00	1.67
hemipterans, pleid adults	pleid	1.63	0.00	0.00	1.49	1.68	1.63
Monacanthus hispidus	Shisp	1.63	0.00	1.63	0.00	0.00	1.63
cladocerans, unidentified	UIDclad	1.62	0.00	0.00	0.00	1.62	1.62
Lupinoblennius nicholsi	Lupbl	1.58	0.00	0.00	0.00	1.43	1.43
Synodus foetens	Synft	1.58	0.00	1.31	0.00	0.00	1.31
Fundulus seminolis	Fsmnls	1.57	1.57	0.00	0.00	0.00	1.57
hemipterans, belostomatids	blstmd	1.56	0.00	0.00	1.30	2.08	1.69
Fundulus grandis	Fgrnds	1.54	1.15	0.00	1.52	0.00	1.27
Ergasilus sp.	Ergslus	1.53	1.53	0.00	0.00	0.00	1.53
Alpheus estuariensis	Aestrns	1.52	0.00	0.00	0.00	0.00	0.00
Sciaenops ocellatus	Sciocl	1.52	0.00	2.02	0.00	0.00	2.02
Panopeus herbstii	Pherbs	1.50	0.00	1.50	0.00	0.00	1.50
Thor sp.	Thor	1.48	0.00	1.48	0.00	0.00	1.48
Sphoeroides spp.	Sphr	1.46	0.00	0.00	0.00	0.00	0.00
cymothoid sp. B	cymthdB	1.45	1.45	0.00	0.00	0.00	1.45
Monacanthus setifer	Ssetif	1.44	0.00	0.00	0.00	0.00	0.00
Erimyzon sucetta	Esctta	1.41	0.00	0.00	0.00	1.41	1.41
Kurzia longirostris	Kurzia	1.40	0.00	0.00	1.40	0.00	1.40
Dorosoma petenense	Dptnse	1.40	0.00	0.00	0.00	0.00	0.00
Lepisosteus platyrhincus	Lplaty	1.39	0.00	0.00	0.00	0.00	0.00
Albula vulpes	Avulpes	1.39	0.00	0.00	1.39	0.00	1.39
Camptocercus rectirostris	Cmptcrc	1.38	1.38	0.00	0.00	0.00	1.38
Ameiurus natalis	Anatlis	1.37	0.00	0.00	0.00	1.37	1.37
Tanaid sp. c	TanaidC	1.37	0.00	0.00	0.00	0.00	0.00
medusa sp. f	medspF	1.37	0.00	0.00	0.00	0.00	0.00
Hoplomachus propinquus	Hplmchs	1.36	0.00	0.00	0.00	0.00	0.00
Prionotus spp.	Prnts	1.35	0.00	1.35	0.00	0.00	1.35

Taxon	Code	Overall	Alafia	Anclote	Hillsborough	Myakka	Surface Total
Oncaea spp.	Oncaea	1.35	0.00	0.00	0.00	1.45	1.45
Dorosoma spp.	Doros	1.34	0.00	0.00	0.00	1.34	1.34
coleopterans, dryopid larvae	dryopid	1.34	0.00	0.00	0.00	1.34	1.34
Hyporhamphus unifasciatus	Hunif	1.34	0.00	0.00	0.00	1.32	1.32
Prionotus tribulus	Ptribls	1.34	0.00	1.35	0.00	1.44	1.39
Symphurus plagiusa	Symplg	1.33	1.28	0.00	0.00	0.00	1.28
ascidiacean larvae	ascdacn	1.33	0.00	1.33	0.00	0.00	1.33
hemipterans, nepid adults	nepid	1.33	0.00	0.00	0.00	1.33	1.33
Lepomis microlophus	Lmcro	1.32	0.00	0.00	0.00	0.00	0.00
Gobionellus spp.	Gbnell	1.32	0.00	1.32	0.00	0.00	1.32
nemerteans	nmrtns	1.32	0.00	1.32	0.00	0.00	1.32
Ameiurus catus	Acatus	1.31	0.00	0.00	0.00	1.31	1.31
Brevoortia smithi juveniles	Bsmithi	1.31	1.22	0.00	1.40	0.00	1.34
Sphoeroides parvus	Sphprv	1.30	0.00	0.00	0.00	0.00	0.00
anuran larvae	tadpole	1.30	1.19	0.00	1.33	1.34	1.31
Bagre marinus	Bmrins	1.29	0.00	0.00	0.00	1.29	1.29
Chilomycterus shoepfi	Cschpf	1.28	0.00	1.37	0.00	1.16	1.27
Eurypanopeus depressus	Edeprss	1.27	0.00	0.00	0.00	0.00	0.00
Paracerceis caudata	Pcaudata	1.27	0.00	1.34	0.00	0.00	1.34
megalopterans, corydalid larvae	crydld	1.27	0.00	0.00	0.00	1.27	1.27
Gobionellus oceanicus	Gbnloc	1.26	0.00	1.26	0.00	0.00	1.26
Sphoeroides nephelus	Sphnph	1.26	0.00	0.00	0.00	0.00	0.00
dipterans, dolichopodid larvae	dolich	1.26	0.00	0.00	0.00	0.00	0.00
Menticirrhus americanus	Mntamr	1.26	0.00	0.00	0.00	1.26	1.26
Acanthostrocion quadricornis	Aqdcrn	1.25	0.00	0.00	0.00	0.00	0.00
Sphaeroma walkeri	Sphwlk	1.23	0.00	1.23	0.00	0.00	1.23
Mesocyclops leuckarti	Mescycl	1.22	0.00	0.00	0.00	0.00	0.00
Isopod, Gnathia sp. (praniza larva)	Gnathia	1.21	0.00	0.00	0.00	0.00	0.00
Gobionellus boleosoma	Gbnlbl	1.20	1.20	0.00	0.00	0.00	1.20
Upogebia affinis	Uaffin	1.13	0.00	0.00	0.00	0.00	0.00
hemipterans, naucorid adults	naucrd	1.11	1.11	0.00	0.00	0.00	1.11
Strongylura notata	Sntta	1.07	0.00	0.00	0.00	1.07	1.07

Appendix A 3. Indicator statistics (see text for explanation). Indicators that were both strong (>50) and significant (p<0.05) are highlighted in blue for spring-fed and green for surface-fed estuaries.

Taxon	Code	Pelagic or Hyperbenthic	Max group	IV	Mean	Standard Deviation	p
Hargeria rapax	Hrapax	Hyperbenthic	Spring	96.7	45.8	6.92	0.0002
Erichsonella spp.	Erchspp	Hyperbenthic	Spring	96.5	46.6	7.19	0.0002
Harrieta faxoni	Hfaxoni	Hyperbenthic	Spring	94.8	43.2	6.22	0.0002
Edotea triloba	Edotia	Hyperbenthic	Surface	92	66.6	7.38	0.0002
Cassidinidea ovalis	Covalis	Hyperbenthic	Spring	91.3	48.5	5.24	0.0002
Parasterope pollex	ppollex	Pelagic	Surface	90.6	61.2	9.81	0.0002
Bowmaniella dissimilis	Bdissim	Hyperbenthic	Spring	88.6	44.5	4.65	0.0002
Chaetognaths	chaetog	Pelagic	Surface	83.5	50.5	5.4	0.0002
Lucania parva	Lparv	Pelagic	Spring	81	36	5.27	0.0002
Acartia tonsa	Atonsa	Pelagic	Surface	80.9	57.8	5.62	0.0002
dipterans, pupae	pupae	Pelagic	Spring	79.9	56.7	6.41	0.0002
Livoneca	cymthdA	Pelagic	Surface	79.3	49.8	5	0.0002
Polychaetes	polych	Hyperbenthic	Surface	78.7	67.5	7.61	0.0684
gastropods, prosobranch	prosbrch	Hyperbenthic	Spring	78.7	55.5	6.08	0.001
dipterans, chironomid larvae	chiron	Hyperbenthic	Spring	78.3	57.1	5.94	0.0006
Anchoa mitchilli	Amtch	pelagic	Surface	77.7	57	6.91	0.0038
Lucifer faxoni	Lucifer	pelagic	Surface	76	42.5	8.39	0.0002
ostracods, podocopid	podocop	Hyperbenthic	Spring	75	49.8	5.98	0.0004
amphipods, caprellid	cprlld	Hyperbenthic	Surface	72.4	50.8	8.06	0.0014
Labidocera aestiva	Laestiva	pelagic	Surface	71.7	45.2	6.95	0.0004
dipterans, ceratopogonid larvae	crtpgd	Hyperbenthic	Spring	71.5	32.3	4.9	0.0002
Unidentified Americamysis juveniles	AmysJUV	Hyperbenthic	Spring	70.4	55.8	4.62	0.0034
Eurytemora affinis	Erytaff	pelagic	Spring	70.4	28.5	4.43	0.0002
amphipods, gammaridean	gmmrd	Hyperbenthic	Spring	70.2	54.4	3.36	0.0002
Pelecypods	plcypd	Hyperbenthic	Surface	68.6	57.5	7.72	0.089
Palaemonetes pugio	Ppugio	Hyperbenthic	Spring	68.6	44.6	4.6	0.0002
decapod mysis	mysis	Hyperbenthic	Spring	66.2	57.1	5.3	0.0656
Hirudinoideans	hirud	Hyperbenthic	Spring	66	41.4	3.55	0.0002
Acari	acari	Hyperbenthic	Spring	65.8	41.1	5.84	0.0002
appendicularian, Oikopleura dioica	Odioica	pelagic	Surface	64.3	30.6	6.05	0.0002

Taxon	Code	Pelagic or Hyperbenthic	Max group	IV	Mean	Standard Deviation	p
Unidentified gobiid larvae	gobiid	Hyperbenthic	Spring	64.3	55.7	6.63	0.117
Apseudes sp.	Apseudes	Hyperbenthic	Spring	63.6	30.7	5.2	0.0002
Clytia sp.	Clytia	pelagic	Surface	61.1	36	7.56	0.0006
Americamysis almyra	Aalmyra	Hyperbenthic	Spring	59.8	53.9	4.16	0.0954
Microgobius spp.	Mcrgob	Hyperbenthic	Spring	58.1	48.1	4.83	0.0334
Sphaeroma terebrans	Sphtrbs	Hyperbenthic	Surface	56.9	33.2	5.16	0.0002
Sinelobus stanfordi	Sstnfrdi	Hyperbenthic	Spring	53.9	35.7	4.71	0.0018
Gobiosoma spp.	Gbsma	Hyperbenthic	Spring	53.1	47.3	6.84	0.2018
Anchoa spp.	Anchoa	pelagic	Surface	52.9	32.7	5.46	0.0018
decapod zoea	zoea	Hyperbenthic	Spring	51.2	54.1	3.55	0.7714
Cumaceans	cumacn	Hyperbenthic	Spring	50.6	56.3	4.64	0.944
Menidia spp.	Mnidia	pelagic	Spring	50.6	44.9	3.35	0.0678
decapod megalopae	megalop	Hyperbenthic	Spring	48.1	57	7.53	0.8814
Foraminiferans	foram	Hyperbenthic	Spring	47.9	23.5	4.25	0.0002
Temora turbinata	Tturb	pelagic	Spring	47.3	28	4.1	0.001
Trinectes maculatus	Trimac	Hyperbenthic	Surface	46.6	32	3.95	0.0026
Sphaeroma quadridentata	Sphquad	Hyperbenthic	Surface	46	30.6	6.5	0.0108
fish eggs, percomorph	prcmph	pelagic	Surface	45.5	27.4	5.33	0.0054
Pseudodiaptomus coronatus	Psdiap	Hyperbenthic	Spring	45.4	50.4	4.31	0.9336
Taphromysis bowmani	Tbowman	Hyperbenthic	Spring	45.3	46.8	7.02	0.5047
cirriped nauplii	crpdNaup	pelagic	Surface	44.4	21.9	5.65	0.0004
unidentified harpacticoids	hrpctcd	Hyperbenthic	Spring	44.2	40.4	3.91	0.1658
Sarsiella zostericola	Szost	pelagic	Spring	44.2	36.6	4.67	0.074
Simocephalus vetulus	Svetelus	pelagic	Surface	44.1	37.6	6.49	0.1668
Eucinostomus spp.	Eucin	pelagic	Spring	43.5	21	3.95	0.0002
branchiurans, Argulus spp.	Argulus	pelagic	Surface	41.4	40.5	3.65	0.3383
Hippolyte zostericola	Hzost	Hyperbenthic	Surface	41	42.8	5.76	0.5475
Palaemonetes spp.	Plmnts	Hyperbenthic	Spring	41	47.6	5.2	0.9596
gastropods, opisthobranch	opsbrch	Hyperbenthic	Spring	40.3	34.8	4.81	0.136
Unidentified blenniid larvae	blniid	Hyperbenthic	Spring	39.8	33.4	4.6	0.1046
Munna reynoldsi	Uromunna	Hyperbenthic	Surface	38.8	52.2	9	0.9304
Ambidexter symmetricus	Asymm	Hyperbenthic	Surface	37.2	20.1	4.11	0.001
dipteran, Chaoborus punctipennis larvae	Cpncpnnd	pelagic	Surface	37	34.4	5.22	0.2799
Mnemiopsis leidyi	Mleidyi	pelagic	Surface	36.9	18.2	4.42	0.0004
siphonostomatids	caligoid	pelagic	Surface	36.4	26.7	4.24	0.0324

Taxon	Code	Pelagic or Hyperbenthic	Max group	IV	Mean	Standard Deviation	p
oligochaetes	oligch	Hyperbenthic	Surface	36.3	43.8	6.43	0.8796
Americamysis stucki	Astucki	Hyperbenthic	Surface	35.9	18.6	4.76	0.0014
Upogebia spp. postlarvae	Upgba	Hyperbenthic	Spring	35.9	30	6.81	0.2174
Fundulus spp.	Fndls	pelagic	Spring	35.4	12.9	3.36	0.0002
Gobiesox strumosus	Gbsx	Hyperbenthic	Surface	35.3	37.4	3.98	0.6309
Mesocyclops edax	Medax	pelagic	Surface	35.3	28.4	5.39	0.116
trichopteran larvae	trichop	Hyperbenthic	Spring	35.3	33.4	4.96	0.3031
nematodes	nmtds	Hyperbenthic	Surface	33.4	50.1	7.26	0.9972
Oithona spp.	Oithona	pelagic	Surface	33.1	21.1	4.08	0.0012
Cynoscion arenarius	Cynar	Hyperbenthic	Surface	32.9	14.7	3.56	0.0004
Xenanthura brevitelson	Xbrvtlsn	Hyperbenthic	Spring	32.3	19.5	3.98	0.007
ephemeropteran larvae	ephmpt	Hyperbenthic	Surface	32	42.6	6.51	1
Syngnathus scovelli	Sygscv	Hyperbenthic	Surface	30	48.9	5.17	1
Macrocyclops albidus	Malbidus	pelagic	Surface	30	29.4	5.86	0.4103
Pseudevadne tergestina	Ptergstn	pelagic	Surface	29.1	14.9	3.71	0.0002
Unidentified alphaeids	Alph	pelagic	Surface	28.9	35.8	5.55	0.9686
Farfantepenaeus duorarum	Fduorm	Hyperbenthic	Spring	28.4	20.6	4.06	0.0522
Monstrilla sp.	Mnstrlla	pelagic	Spring	27	23.8	4.43	0.2118
coleopterans, elmid adults	elmid	Hyperbenthic	Surface	26.7	14.5	3.33	0.0054
Americamysis bahia	Abahia	Hyperbenthic	Spring	26.6	18.2	4.86	0.0598
Syngnathus louisianae	Sygnls	Hyperbenthic	Surface	26.3	12.6	3.06	0.0012
Limulus polyphemus larvae	Limulus	Hyperbenthic	Surface	26.1	12.1	3.39	0.0004
coleopterans, gyrinid larvae	gyrinid	pelagic	Surface	26	12.7	3.59	0.0008
Anopsilana jonesi	Ajonesi	Hyperbenthic	Spring	25.8	25.1	4.22	0.3649
penaeid postlarvae	penaeid	Hyperbenthic	Spring	25.8	18.5	4.1	0.0426
Menticirrhus spp.	Mntcrr	Hyperbenthic	Surface	25.4	14.6	3.49	0.0098
Lolliguncula brevis	Lllgbrvs	pelagic	Surface	25	10	3.03	0.0004
Brevoortia spp.	Brvtia	pelagic	Surface	24.4	22.7	4.71	0.3191
odonates, zygopteran larvae	zygptn	Hyperbenthic	Spring	24.3	25.5	3.72	0.5321
Lucania goodei	Lgood	pelagic	Spring	23.9	11.5	3.4	0.0022
Ilyocryptus sp.	Ilycryp	pelagic	Surface	23.8	11.4	3.45	0.004
Callinectes sapidus	Csap	Hyperbenthic	Spring	23.5	24.4	4.2	0.4939
Tozeuma carolinense	Tozma	Hyperbenthic	Surface	22.6	10.2	3.18	0.0014
Cyathura polita	Cpolita	Hyperbenthic	Spring	22.3	26.5	4.24	0.8642
Elops saurus	Esaur	pelagic	Surface	22	13.8	3.15	0.0216
Sida crystallina	Scryst	pelagic	Surface	21.4	18.5	4.51	0.236

Taxon	Code	Pelagic or Hyperbenthic	Max group	IV	Mean	Standard Deviation	p
Pinnixa sayana	Psyna	Hyperbenthic	Surface	20.8	9	2.97	0.0012
Lagodon rhomboides	Lrhom	Hyperbenthic	Spring	20.7	15.8	3.94	0.1272
turbellarians	trbllrns	Hyperbenthic	Spring	20.6	17.3	3.9	0.1876
Chasmodes saburrae	Chsab	Hyperbenthic	Spring	20.2	14.6	3.45	0.0752
penaeid metamorphs	penmeta	Hyperbenthic	Spring	19.5	18.7	3.84	0.3483
Bathygobius soporator	Bthgob	Hyperbenthic	Surface	18.7	21.4	4.41	0.6741
hemipterans, gerrid adults	gerrid	pelagic	Surface	18.6	20.9	4.44	0.6285
Notemigonus crysoleucas	Ncrysl	pelagic	Spring	18.4	8.7	2.88	0.0024
Gambusia holbrooki juveniles	Ghlbk	pelagic	Surface	17.9	14.5	3.37	0.1586
Microgobius gulosus	Mcgbgl	Hyperbenthic	Spring	17.3	18.2	4.14	0.5029
Leiostomus xanthurus	Leixan	Hyperbenthic	Spring	17.2	11.1	3.14	0.0534
Periclimenes spp.	Prclmns	Hyperbenthic	Spring	16.9	14.1	3.81	0.2302
paguroid juveniles	pgurd	Hyperbenthic	Surface	16.8	11.4	3.46	0.0856
Unidentified processids	procesd	Hyperbenthic	Surface	16.7	12.2	3.17	0.0964
neuropterans, Climacia spp.	Climacia	Hyperbenthic	Surface	15.9	7.6	2.47	0.0068
Membras martinica	Mmart	pelagic	Spring	15.8	19.5	3.64	0.8904
Ogyrides alphaerostris	Ogyrds	pelagic	Spring	15.8	11.8	3.32	0.1274
Latonopsis fasciculata	Lfsclta	pelagic	Surface	15.6	9.9	3.11	0.0442
Centropages velificatus	Cvlfcts	pelagic	Surface	15.5	8.5	2.71	0.0146
Palaemonetes vulgaris	Pvulg	Hyperbenthic	Spring	15.5	7.7	2.51	0.0184
brachiopod, Glottidia pyramidata larvae	Gpyrmd	pelagic	Surface	15.4	7.8	2.64	0.0122
Diaptomus spp.	Diaptmus	pelagic	Spring	15.4	15.9	3.65	0.4607
Leydigia sp.	Leydigia	pelagic	Surface	15.3	8.4	2.7	0.019
medusa sp. e	medspE	pelagic	Surface	14.8	12.5	3.6	0.2561
Oligoplites saurus	Osaurs	pelagic	Surface	14.6	6.3	2.32	0.0126
Leptochela serratorbita	Lsrtorb	Hyperbenthic	Surface	14.6	6.3	2.19	0.0116
Latona setifera	Lsetifer	pelagic	Surface	14.6	6.6	2.43	0.0104
Eucinostomus harengulus	Ecnhar	Hyperbenthic	Spring	14.6	6.5	2.46	0.0162
Orthocyclops modestus	Orthcyc	pelagic	Surface	14.4	19.7	4.2	0.989
Lepomis spp.	Lepoms	pelagic	Spring	14.3	11.6	3.49	0.2312
Liriope tetraphylla	Lttraphy	pelagic	Surface	14.1	7.5	2.62	0.0212
Gobiosoma bosc	Gbsbsc	Hyperbenthic	Spring	14.1	18.9	4.15	0.8834
Portunus sp.	Prtns	Hyperbenthic	Spring	13.9	9	2.71	0.053
Calanopia americana	Clanopia	pelagic	Surface	13.6	17.7	4.23	0.8384

Taxon	Code	Pelagic or Hyperbenthic	Max group	IV	Mean	Standard Deviation	p
unidentified freshwater cyclopoids	UIDFWcop	pelagic	Spring	13.6	12.1	3.07	0.2719
Osphranticum labronectum	Osphrntc	pelagic	Surface	13.5	7.1	2.39	0.0262
Mugil cephalus	Mcphls	pelagic	Surface	13.3	11.3	2.88	0.2006
Micropterus salmoides	Msalm	pelagic	Spring	13.3	7.9	2.71	0.0616
odonates, anisopteran larvae	ansptn	Hyperbenthic	Surface	13.2	10.2	2.83	0.1466
Petrolisthes armatus	Parm	Hyperbenthic	Surface	13.2	8.8	2.99	0.091
shrimps, unidentified juveniles	UIDshmp	Hyperbenthic	Surface	13.1	7.1	2.42	0.0382
Squilla empusa	Sqempsa	Hyperbenthic	Surface	12.8	7.7	2.45	0.0416
cladocerans, Daphnia spp.	Daphnia	pelagic	Spring	12.7	12.2	3.26	0.3585
dipterans, sciomyzid larvae	scmyz	Hyperbenthic	Surface	12.5	5.9	2.15	0.0268
medusa sp. a	medspA	pelagic	Surface	12.1	8.4	2.74	0.068
coleopterans, noterid adults	notrid	Hyperbenthic	Surface	12	9.3	2.89	0.1722
Lupinoblennius nicholsi	Lupbl	Hyperbenthic	Spring	11.7	7.6	2.53	0.1038
ophiuroidean juveniles	ophiurd	Hyperbenthic	Surface	11.5	7.6	2.49	0.0956
Unidentified callianassids	callian	pelagic	Spring	11.4	7.1	2.46	0.0676
Cynoscion nebulosus	Cynneb	Hyperbenthic	Surface	11.3	12.8	3.25	0.6089
medusa sp. d	medspD	pelagic	Surface	11.1	12.3	3.36	0.5525
pycnogonids	pycgnd	Hyperbenthic	Surface	11.1	12	3.28	0.5489
Labidesthes sicculus	Lsicc	pelagic	Surface	10.9	7.1	2.42	0.1014
collembolas, podurid	podurid	Hyperbenthic	Spring	10.9	14.5	3.37	0.893
Heterandria formosa	Hform	pelagic	Surface	10.7	7.6	2.42	0.1244
Gobiosoma robustum	Gbsrob	Hyperbenthic	Surface	10.6	15.9	4.1	0.9152
Centropages hamatus	Chmatus	pelagic	Surface	10.4	5	1.93	0.0576
medusa sp. b	medspB	pelagic	Surface	10.4	5.1	2.08	0.0566
Opsanus beta	Obeta	Hyperbenthic	Spring	10.4	5.3	2.12	0.0572
Cyclops spp.	Cyclops	pelagic	Surface	10.3	7	2.33	0.0524
Myrophis punctatus	Mpunc	pelagic	Spring	10.2	10.3	2.92	0.4201
Bairdiella chrysoura	Brdcry	pelagic	Surface	9.9	7.8	2.65	0.206
Anchoa hepsetus	Ahepst	pelagic	Surface	9.8	9.2	2.83	0.3509
Rhithropanopeus harrisii	Rhith	Hyperbenthic	Surface	9.8	8.7	2.82	0.2903
Saphirella spp.	Sphrella	pelagic	Surface	9.6	12.5	3.37	0.7758
Hippocampus erectus	Herect	Hyperbenthic	Surface	9.4	5.7	2.13	0.0576
lepidopterans, pyralid larvae	lepidop	Hyperbenthic	Spring	9	10.1	2.74	0.5667

Taxon	Code	Pelagic or Hyperbenthic	Max group	IV	Mean	Standard Deviation	p
Callianassa spp.	Clnssa	pelagic	Spring	8.9	9.9	2.98	0.5373
anuran larvae	tadpole	Hyperbenthic	Surface	8.7	5.5	2.2	0.1234
paracalanids	pracalnd	pelagic	Surface	8.3	9.8	2.97	0.6169
Chloroscombrus chrysurus	Cchry	pelagic	Surface	8.3	4.3	1.9	0.1228
Grimaldina brazzai	Gbrzzai	pelagic	Surface	8.3	4.6	1.89	0.1226
hemipterans, pleid adults	pleid	pelagic	Surface	8.3	4.2	1.88	0.1178
Euryalona occidentalis	Euryalon	pelagic	Surface	8.3	4.3	1.82	0.1136
Dynamenella sp.	Dynmnlla	Hyperbenthic	Spring	8.3	4.4	1.84	0.1136
Eugerres plumieri	Eugrr	Hyperbenthic	Surface	8.1	5.7	2.12	0.1398
Syngnathus floridae	Sygnfl	Hyperbenthic	Spring	8.1	8.9	2.68	0.5197
hemipterans, corixid adults	corixid	pelagic	Spring	7.6	14.1	3.77	0.9828
Achirus lineatus	Achr	Hyperbenthic	Surface	7.5	8.4	2.65	0.5607
Periclimenes longicaudatus	Plong	Hyperbenthic	Surface	7.5	8.3	2.58	0.5155
coleopterans, haliplid adults	halpld	Hyperbenthic	Surface	7.4	5.3	2.08	0.2963
coleopterans, curculionid	curcld	Hyperbenthic	Surface	7.1	5	1.97	0.1912
Alteutha sp.	Alteutha	pelagic	Surface	6.9	6	2.34	0.2104
Spelaeomysis sp.	Spelmys	Hyperbenthic	Spring	6.8	5.7	2.12	0.2276
medusa sp. c	medspC	pelagic	Surface	6.2	3.6	1.57	0.2507
Beroe ovata	Bovata	pelagic	Surface	6.2	3.6	1.72	0.2501
coleopterans, scirtid larvae	scrtid	pelagic	Surface	6.2	4	1.54	0.249
Ameiurus catus	Acatus	Hyperbenthic	Surface	6.2	3.6	1.5	0.2458
Etheostoma fusiforme	Ethfus	Hyperbenthic	Surface	6.2	3.7	1.66	0.245
Bunops sp.	Bunops	pelagic	Surface	6.2	3.6	1.55	0.2434
Eucalanus sp.	Eucal	pelagic	Surface	6.2	3.6	1.56	0.2432
Liposarcus spp.	Lposrc	Hyperbenthic	Surface	6.2	3.6	1.54	0.2354
isopod sp. a	isopodA	Hyperbenthic	Surface	6.2	3.6	1.62	0.2332
Palaemonetes intermedius	Pinter	Hyperbenthic	Spring	6.2	3.6	1.55	0.2498
cirriped cyprids	crpdCypr	pelagic	Spring	6.2	3.6	1.64	0.2452
dipterans, tipulid larvae	tipulid	Hyperbenthic	Spring	6.2	3.6	1.62	0.2422
Probopyrus	Probpyr	Hyperbenthic	Spring	5.9	5.8	2.13	0.4371
clupeid	clup	pelagic	Surface	5.8	8.4	2.69	0.7998
Alpheus viridari	Avirid	Hyperbenthic	Spring	5.8	4.5	1.89	0.2456
Cyprinodon variegatus	Cvarg	pelagic	Spring	5.7	4.7	1.93	0.2533
xanthid juveniles	UIDxntd	Hyperbenthic	Spring	5.5	6.4	2.22	0.6043
Penilia avirostris	Pavrstrs	pelagic	Surface	5.4	13.5	3.6	0.9986
myodocopod sp. a	mydocopA	pelagic	Surface	5.4	7.8	2.58	0.8094

Taxon	Code	Pelagic or Hyperbenthic	Max group	IV	Mean	Standard Deviation	p
medusa, Obelia sp.	Obelia	pelagic	Spring	5.4	6.6	2.35	0.6335
Lepisosteus sp.	Lepis	pelagic	Spring	5.1	4.1	1.87	0.2318
Strongylura spp.	Stglra	pelagic	Surface	4.9	5.8	2.33	0.6189
Hyporhamphus unifasciatus	Hunif	pelagic	Surface	4.6	4.2	1.97	0.6237
coleopterans, dytiscid larvae	dystcid	Hyperbenthic	Surface	4.5	7.2	2.5	0.9182
Notropis spp.	Ntrps	pelagic	Spring	4.4	6.6	2.38	0.6843
Eucinostomus gula	Ecngul	Hyperbenthic	Spring	4.4	4.3	1.88	0.5043
Dorosoma spp.	Doros	pelagic	Surface	4.2	2.6	1.55	0.5083
Nebalia sp.	Nebalia	Hyperbenthic	Surface	4.2	2.9	1.26	0.5065
Ameiurus natalis	Anatlis	Hyperbenthic	Surface	4.2	2.6	1.55	0.5021
Noturus gyrinus	Ngyrns	Hyperbenthic	Surface	4.2	3	1.2	0.5021
ophiopluteus larvae	ophioplt	Hyperbenthic	Surface	4.2	2.8	1.34	0.5015
nemerteans	nmrtns	Hyperbenthic	Surface	4.2	2.6	1.54	0.4999
sipunculid	sipunc	Hyperbenthic	Surface	4.2	2.8	1.4	0.4987
Mugil curema	Mcrma	pelagic	Surface	4.2	2.8	1.38	0.4935
ascidiacean larvae	ascdacn	pelagic	Surface	4.2	2.6	1.52	0.4931
Monacanthus hispidus	Shisp	pelagic	Surface	4.2	2.7	1.47	0.4897
Hoplosternum littorale	Hlitt	Hyperbenthic	Surface	4.2	2.8	1.32	0.4877
Gobionellus boleosoma	Gbnlbl	Hyperbenthic	Surface	4.2	2.6	1.53	0.4867
Pinnixa sp. a juveniles	PnxaA	Hyperbenthic	Surface	4.2	2.6	1.55	0.4857
Synodus foetens	Synft	pelagic	Spring	4.2	5.1	1.96	0.5625
Sphoeroides spp.	Sphr	pelagic	Spring	4.2	2.7	1.49	0.4947
Mysidopsis furca	Mfurca	Hyperbenthic	Spring	4.2	3	1.13	0.4921
Sphoeroides nephelus	Sphnph	pelagic	Spring	4.2	2.6	1.55	0.4869
clinid prefelxion	clind	Hyperbenthic	Spring	4.2	2.7	1.39	0.4835
Lepomis punctatus	Lpunc	Hyperbenthic	Spring	3.9	3.6	1.72	0.4965
dipterans, stratiomyid larvae	strtmyd	Hyperbenthic	Surface	3.7	5.7	2.14	0.835
Hypsoblennius spp.	Hypsbl	Hyperbenthic	Spring	3.5	5	1.97	0.7461
Lepomis auritus	Laurts	pelagic	Spring	3.5	4.6	1.9	0.6231
Euconchoecia chierchiae	Echierch	pelagic	Surface	3.4	4.4	1.92	0.7469
Strongylura marina	Smrina	pelagic	Surface	3.4	3.6	1.67	0.4911
Brevoortia smithi juveniles	Bsmithi	pelagic	Surface	3.2	5.6	2.19	0.8084
Fundulus grandis	Fgrnds	pelagic	Surface	3.1	4.9	1.94	0.9324
Euceramus praelongus	Eprael	pelagic	Surface	3.1	3.6	1.52	0.4905
Diaphanosoma sp.	Diphnsm	pelagic	Surface	3	4.6	1.91	0.872
hemipterans, belostomatids	blstmd	pelagic	Surface	3	3.6	1.52	0.7347

Taxon	Code	Pelagic or Hyperbenthic	Max group	IV	Mean	Standard Deviation	p
Prionotus tribulus	Ptribls	pelagic	Surface	2.9	3.6	1.49	0.5017
Archosargus probatocephalus	Arcprb	Hyperbenthic	Surface	2.8	4.2	1.92	0.7399
unidentified flexion larvae	UIDfish	unknown	Spring	2.8	5	2.03	0.9364
Symphurus plagiusa	Symplg	Hyperbenthic	Spring	2.8	3.6	1.5	0.5013
Chilomycterus shoepfi	Cschpf	pelagic	Surface	2.7	3.7	1.52	0.7479
medusa, Eutima sp.	Eutima	pelagic	Surface	2.4	4.5	1.91	1
dipterans, tabanid larvae	tbanid	pelagic	Surface	2.4	3.6	1.53	1
Sciaenops ocellatus	Sciocl	Hyperbenthic	Spring	2.3	3.7	1.54	1
Ceridodaphnia sp.	Criodaph	pelagic	Surface	2.2	3.6	1.52	1
Orthopristis chrysoptera	Orhcry	pelagic	Surface	2.2	3.6	1.58	1
Albula vulpes	Avulpes	Hyperbenthic	Surface	2.1	2.1	0.03	1
Branchiostoma floridae	Bflorid	Hyperbenthic	Surface	2.1	2.1	0.03	1
Bagre marinus	Bmrins	Hyperbenthic	Surface	2.1	2.1	0.03	1
Camptocercus rectirostris	Cmptcrc	pelagic	Surface	2.1	2.1	0.03	1
megalopterans, corydalid larvae	crydld	Hyperbenthic	Surface	2.1	2.1	0.03	1
cymothoid sp. B	cymthdB	pelagic	Surface	2.1	2.1	0.03	1
coleopterans, dryopid larvae	dryopid	Hyperbenthic	Surface	2.1	2.1	0.03	1
Ergasilus sp.	Ergslus	pelagic	Surface	2.1	2.1	0.03	1
Erimyzon sucetta	Esctta	Hyperbenthic	Surface	2.1	2.1	0.03	1
Fundulus seminolis	Fsmnls	pelagic	Surface	2.1	2.1	0.03	1
Gobionellus spp.	Gbnell	Hyperbenthic	Surface	2.1	2.1	0.03	1
Gobionellus oceanicus	Gbnloc	Hyperbenthic	Surface	2.1	2.1	0.03	1
Hippocampus zosterae	Hppzst	Hyperbenthic	Surface	2.1	2.1	0.03	1
Ictalurus punctatus	Ipunc	Hyperbenthic	Surface	2.1	2.1	0.03	1
Kurzia longirostris	Kurzia	pelagic	Surface	2.1	2.1	0.03	1
Latreutes parvulus	Ltparv	Hyperbenthic	Surface	2.1	2.1	0.03	1
medusa sp. g	medspG	pelagic	Surface	2.1	2.1	0.03	1
Mysidopsis mortenseni	Mmortn	Hyperbenthic	Surface	2.1	2.1	0.03	1
Menidia beryllina	Mnbryl	pelagic	Surface	2.1	2.1	0.03	1
Moinadaphnia macleayii	Mnodaph	pelagic	Surface	2.1	2.1	0.03	1
Menticirrhus americanus	Mntamr	Hyperbenthic	Surface	2.1	2.1	0.03	1
Mysid sp. A	MysidA	Hyperbenthic	Surface	2.1	2.1	0.03	1
hemipterans, naucorid adults	naucrd	Hyperbenthic	Surface	2.1	2.1	0.03	1

Taxon	Code	Pelagic or Hyperbenthic	Max group	IV	Mean	Standard Deviation	p
hemipterans, nepid adults	nepid	pelagic	Surface	2.1	2.1	0.03	1
Pseudosida bidentata	Pbdnta	pelagic	Surface	2.1	2.1	0.03	1
Panopeus herbstii	Pherbs	pelagic	Surface	2.1	2.1	0.03	1
Paralichthys spp.	Prlych	Hyperbenthic	Surface	2.1	2.1	0.03	1
Prionotus spp.	Prnts	pelagic	Surface	2.1	2.1	0.03	1
Strongylura notata	Sntta	pelagic	Surface	2.1	2.1	0.03	1
Sphaeroma walkeri	Sphwlk	Hyperbenthic	Surface	2.1	2.1	0.03	1
Thor sp.	Thor	Hyperbenthic	Surface	2.1	2.1	0.03	1
unidentified calanoids	UIDcalnd	pelagic	Surface	2.1	2.1	0.03	1
cladocerans, unidentified	UIDclad	pelagic	Surface	2.1	2.1	0.03	1
Alpheus estuariensis	Aestrns	Hyperbenthic	Spring	2.1	2.1	0.03	1
Acanthostrocion quadricornis	Aqdcrn	pelagic	Spring	2.1	2.1	0.03	1
dipterans, dolichopodid larvae	dolich	Hyperbenthic	Spring	2.1	2.1	0.03	1
Dorosoma petenense	Dptnse	pelagic	Spring	2.1	2.1	0.03	1
Eurypanopeus depressus	Edeprss	Hyperbenthic	Spring	2.1	2.1	0.03	1
Isopod, Gnathia sp. (praniza larva)	Gnathia	Hyperbenthic	Spring	2.1	2.1	0.03	1
Hoplomachus propinquus	Hplmchs	Hyperbenthic	Spring	2.1	2.1	0.03	1
Lepomis microlophus	Lmcro	Hyperbenthic	Spring	2.1	2.1	0.03	1
Lepisosteus platyrhincus	Lplaty	pelagic	Spring	2.1	2.1	0.03	1
medusa sp. f	medspF	pelagic	Spring	2.1	2.1	0.03	1
Mesocyclops leuckarti	Mescycl	pelagic	Spring	2.1	2.1	0.03	1
Palaemonetes paludosus	Ppalud	Hyperbenthic	Spring	2.1	2.1	0.03	1
megalopterans, sialid larvae	sialid	Hyperbenthic	Spring	2.1	2.1	0.03	1
Sphoeroides parvus	Sphprv	pelagic	Spring	2.1	2.1	0.03	1
Monacanthus setifer	Ssetif	pelagic	Spring	2.1	2.1	0.03	1
Tanaid sp. c	TanaidC	Hyperbenthic	Spring	2.1	2.1	0.03	1
Temora longicornis	Tlngcrn	pelagic	Spring	2.1	2.1	0.03	1
Upogebia affinis	Uaffin	Hyperbenthic	Spring	2.1	2.1	0.03	1
Uca spp.	Uca	Hyperbenthic	Spring	2.1	2.1	0.03	1
Microgobius thalassinus	Mcrgbth	Hyperbenthic	Spring	2	3.1	1.08	1
Harengula jaguana	Hjgna	pelagic	Surface	1.9	3	1.11	1
medusa, Bougainvillia sp.	Bgvlla	pelagic	Surface	1.7	4.6	1.92	1
coleopterans	chrysmd	Hyperbenthic	Surface	1.6	2.8	1.31	1

Taxon	Code	Pelagic or Hyperbenthic	Max group	IV	Mean	Standard Deviation	p
Lutjanus griseus	Ltjgrs	Hyperbenthic	Spring	1.6	3.7	1.65	1
Palaemon floridanus	Pflrdn	Hyperbenthic	Spring	1.6	2.8	1.28	1
dipterans, ephydrid larvae	ephyd	Hyperbenthic	Surface	1.4	2.8	1.38	1
dipterans, muscid larvae	muscid	Hyperbenthic	Spring	1.4	2.7	1.4	1
Opisthonema oglinum	Ooglnm	pelagic	Spring	1.3	2.7	1.45	1
Oncaea spp.	Oncaea	pelagic	Surface	1.1	2.6	1.53	1
Paracerceis caudata	Pcaudata	Hyperbenthic	Surface	1.1	2.7	1.53	1
dipterans, syrphid larvae	syrphid	Hyperbenthic	Spring	1.1	2.6	1.54	1

APPENDIX

Chen, X. 2016. Hindcasting submarine groundwater discharge to Kings Bay. Southwest Florida Water Management District, Brooksville, Florida.

Hindcasting Submarine Groundwater Discharge to Kings Bay

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December 2015 (First Draft)
August 2016 (Final Draft)

> *巧妇难为无米之炊*
> *(The cleverest housewife cannot cook a meal without rice)*
> *– A Chinese proverb (here rice refers to any food ingredients in general)*

Abstract

A method for hindcasting submarine groundwater discharge (SGD) to Crystal River/Kings Bay in west-central Florida is presented here. The main purpose of the SGD hindcasting is to synthesize historical flow data, which do not exist for Crystal River/Kings Bay.

The method involves the use of an empirical formula (Chen, 2014a) that relates the SGD with the water level (tides) in Kings Bay and the groundwater level in a nearby artesian well (ROMP TR21-3) to calculate flows out of all the spring vents at the bottom of the embayment at each time step in a hydrodynamic simulation of the Crystal River/Kings Bay estuary. The total SGD from all the vents was found to be linearly related to the head difference between the groundwater level in ROMP TR21-3 and the surface water level in Kings Bay after tidal signals were filtered out. In the analysis of the total SGD and the head difference, tidal signals were removed using 24-hour running average, daily average, and lunar-cycle running average, resulting in three different linear regressions between the total SGD and the head difference. All three linear regressions were used for the hindcasting of the total SGD with unknown surface water and groundwater levels.

The period of record of the water level data in Kings Bay started in November 2006, while the POR of the groundwater level data in ROMP TR21-3 started in May 1979. To generate a SGD record that is long enough for any meaningful studies of the Crystal River/Kings Bay system, an effort was made to first hindcast the water level in Kings Bay and the groundwater level in ROMP TR21-3 back to a time point that is as early as possible. An inventory study was conducted for the tidal data and the groundwater level data in the region, and it was included that the available data allow the water level in Kings Bay to be hindcasted back to October 1, 1969 and the groundwater level in ROMP TR21-3 back to May 1966. It was determined that tidal data at the downstream side of the Inglis Dam in the Withlacoochee River and at NOAA's Cedar Key station were most suitable for water level hindcasting in Kings Bay. A comparison of tidal data shows that Cedar Key tides lead Kings Bay tides by about 2.5 hours, while Withlacoochee River tides below the Inglis Dam lead Kings Bay tides by about 2 hours. Both Withlacoochee River tides and Cedar Key

tides are linearly correlated with Kings Bay tides. As such, linear regressions with the consideration of phase leads can be used for water level hindcasting in Kings Bay. For the groundwater level, data collected in Lecanto 7 were most suitable for hindcasting those in the ROMP TR21-3 well prior to May 1979.

With both the surface water level in Kings Bay and the groundwater level in ROMP TR21-3 being extended to 1969 and 1966, respectively, the total SGD entering the Crystal River/Kings Bay estuary was hindcasted back to November 1969. All three linear regressions yielded very similar daily total SGDs, which range roughly between -112 cfs and 960 cfs for the period November 1969 through October 2015. A negative SGD means that the flow direction is downward into the spring vent. The mean and median total SGDs during the 46 year period were about 374 cfs and 356 cfs, respectively.

1. Introduction

Crystal River/Kings Bay is spring-fed estuarine system located on the west-central coast of Florida peninsula. Freshwater input to the system comes mainly from discharges out of the numerous spring vents on the bottom of Kings Bay (Figure 1.) These submarine groundwater discharges are affected by the groundwater level in the region and tides in the bay. Based on an inventory of spring vents in Kings Bay conducted in 2008 and a well-designed field measurement of water level, SGD, and groundwater level during 2009, an empirical formula for SGD was obtained, which relates SGD with the surface water elevation (tides) in Kings Bay, the groundwater level in an Artesian well in the Upper Floridan Aquifer (Avon Park formation) named ROMP TR21-3, and the time derivative of the surface water elevation. Using this empirical formula, SGDs from all spring vents in Crystal River/Kings Bay can be calculated at each time step in a hydrodynamic simulation of the estuary. Summing up all the SGDs, the total SGD at each time step were output for analysis. After filtering out tidal signals, strong linear regressions between the total SGD and the head difference between the groundwater level in ROMP TR21-3 and the surface water level in Kings Bay were obtained. These regression formulas can be used to hindcast the total SGD back to a time point when both the tides and groundwater level data are available.

While the period of record for the groundwater level data at ROMP TR21-3 started on May 31, 1979, tidal data collection in Kings Bay didn't start till late 2006. This limits the SGD hindcasting to 2006, or back to a maximum of nine years ago from the current date (November 2015). For a sound management of water resources in the Crystal River/Kings Bay system, it is necessary to generate a SGD record for a period that is at least 30 - 40 years long. Based on an inventory study of measured tidal and groundwater level data in the region, it was found that available tidal data allow the surface water level in Kings Bay to be hindcasted back to 1969, while available groundwater level data allow those in ROMP TR21-3 to be hindcasted back to May 1966. The best suitable tidal stations for the water level hindcasting in Kings Bay include the Inglis Dam downstream stations by the Southwest Florida Water Management District (SWFWMD) and the U.S. Geological Survey (USGS) and the Cedar Key station by the National Oceanic and Atmospheric Administration (NOAA). The best suitable well for the groundwater level hindcasting in ROMP TR21-3 is the Lecanto 7 well.

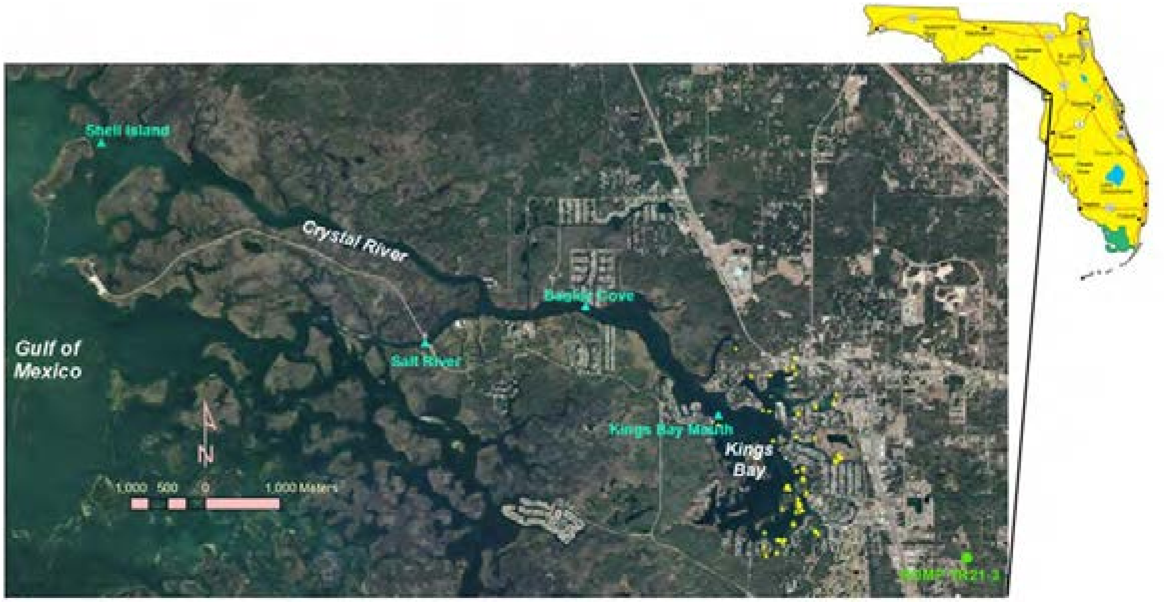

Figure 1. An Aerial photo of the Crystal River/Kings Bay system on the west-central coast of the Florida peninsula. Locations of USGS real-time measurement stations are marked with triangles and locations of identified spring vents are marked with asterisks. The solid circle at the bottom right shows the location of the well ROMP TR21-3.

In the following, Section 2 presents a procedure used for hindcasting tides in Kings Bay back to October 1, 1969, based on tidal data collected at the Inglis Dam downstream stations by the SWFWMD and the USGS and the NOAA station at Cedar Key. Section 3 explains how the groundwater level in ROMP TR21-3 was hindcasted based on data collected in the Lecanto 7 well. Section 4 describes details on how three regression formulas used for the SGD hindcasting were obtained. Results of hindcasted total SGDs using the three empirical formulas were presented and discussed in Section 5, which also compares the total SGD during for a 9-year period which will be used for scenario simulations in the MFL evaluation to the historical SGD. Conclusions of this effort of SGD hindcasting are presented in Section 6.

2. Hindcasting Tides in Kings Bay

Available Tidal Data in the Region

The USGS started tidal data collection the Mouth of Kings Bay station at 16:15, EST, on November 30, 2006. Almost at the same time, several other tidal stations in the Crystal River/Kings Bay system were also established and began operational in recording tides, salinity, and temperature. These stations include the Shell Island station at the mouth of Crystal River and the Salt River station. The Bagley Cove station in Crystal River was established a few years earlier and the USGS started the data collection at this station in August 2002. Although tides measured at the mouth of Crystal River, Salt River, and Bagley Cove are highly correlated with tides at the Mouth of Kings Bay station, they do not help much in the hindcasting of Kings Bay tides prior to November 30, 2006, because they are not available either. Nevertheless, these tidal data can be helpful in filling the gaps in tides measured at the Mouth of Kings Bay station for the period November 30, 2006.

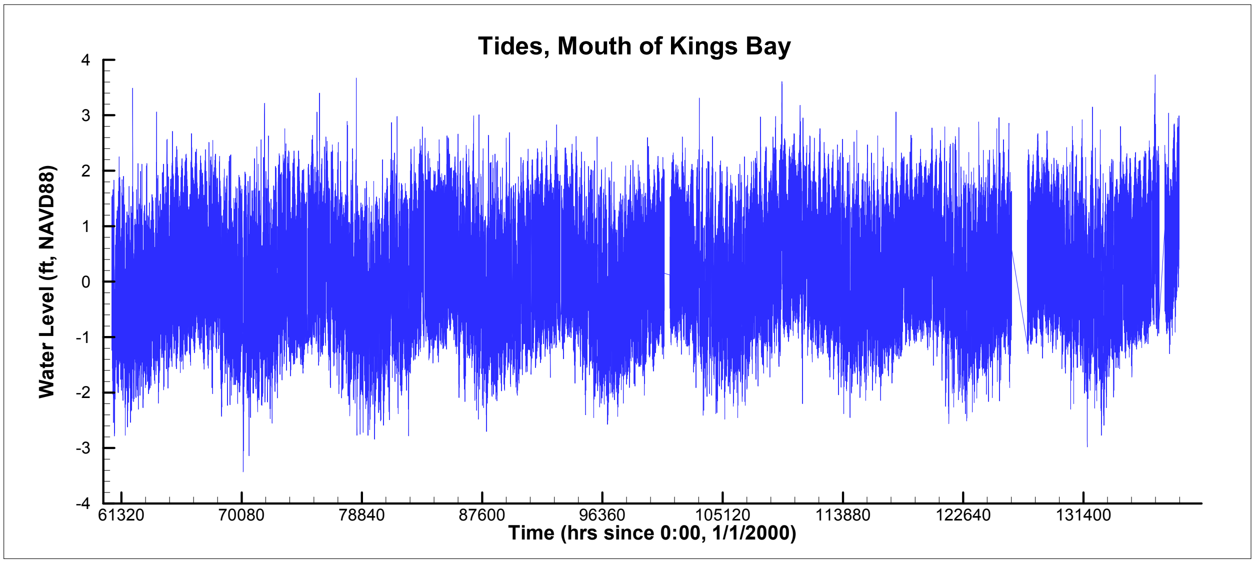

Figure 2. Time series of available USGS tidal data measured at the Mouth of Kings Bay station. The period of record is from November 30, 2006 to October 13, 2015.

Because tidal records for the Crystal River/Kings Bay system cannot be used to hindcast tides prior to November 30, 2006, an inventory study was conducted to evaluate the possibility of using other tidal stations in the region for the hindcasting. It was found that there are several tidal stations in the nearby estuarine systems that have longer periods of record. These stations include the Inglis Dam downstream station by the SWFWMD, the Inglis Dam Downstream station by the USGS, and Cedar Key station by the NOAA (Figure 3).

At the downstream side of the Inglis Dam in the Withlacoochee River, there are three tidal stations. One by the USGS and two by the SWFWMD. Both the SWFWMD and the USGS have a station called Inglis Dam downstream, which is about 13.5 km north of Kings Bay. The other SWFWMD station is called Inglis Bypass downstream, which is about 2.4 km northwest of the Inglis Dam. Both the Inglis Dam and the Inglis Bypass structure have no direct waterway connection with Kings Bay. The transit from Kings Bay to the Inglis Dam has to go through their common downstream water body, namely the Gulf of Mexico. This makes the waterway distance between Kings Bay and Inglis Dam or Inglis Bypass to be about 4 times longer than the direct distance between them. The SWFWMD Inglis Bypass downstream station is not discussed here, because it has similar tides as these at the Inglis Dam downstream stations by the SWFWMD and the USGS with a much shorter period of record than those at Inglis Dam downstream.

At the Inglis Dam downstream stations in the Withlacoochee River, both the SWFWMD and the USGS have installed sensors to measure the free surface elevation. While the SWFWMD calls the collected parameter "water level", the USGS calls their data "gauge height". They represent the same physical parameter but may have different values because the "water level" is referenced to the mean sea level, NGVD29, or NAVD88 but "gauge height" may be referenced to an arbitrary elevation.

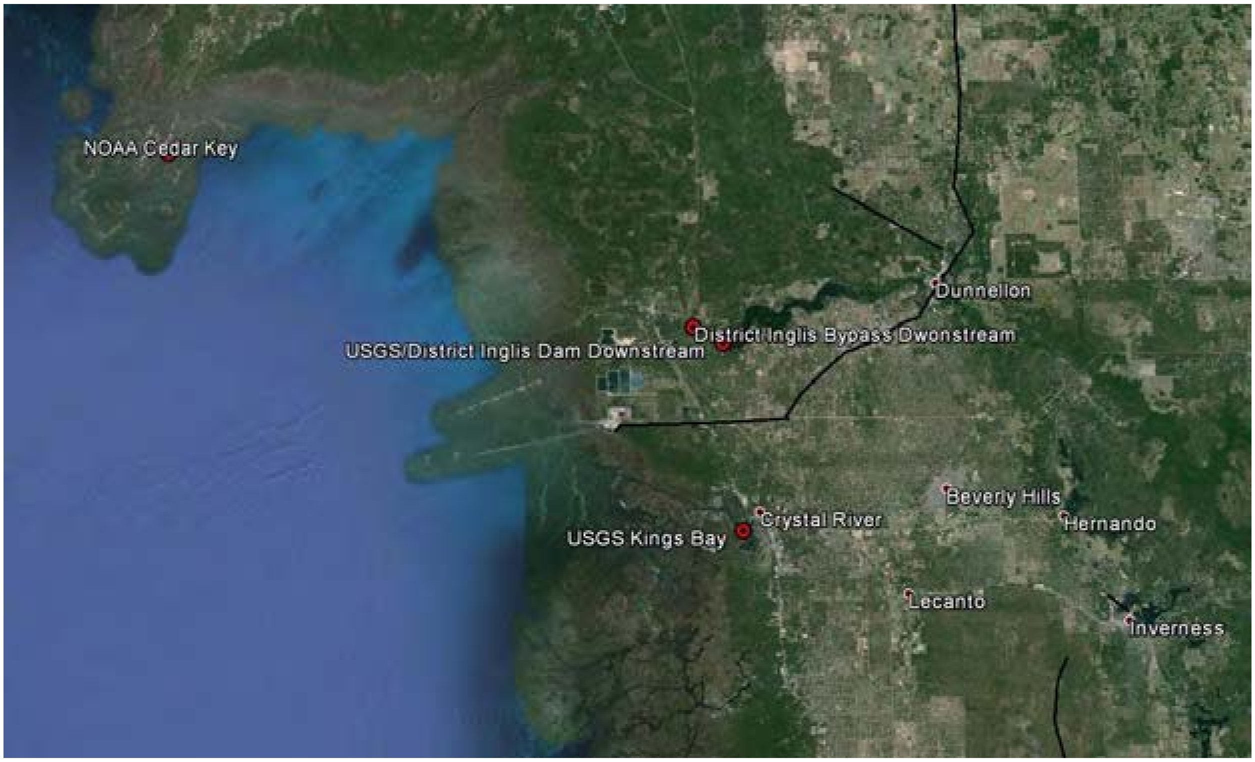

Figure 3 Tidal stations near in the Crystal River/Kings Bay region, where there are relatively longer periods of record.

At the Inglis Dam downstream station, the SWFWMD started to collect water level data on November 5, 1992, with daily values being recorded before May 31, 1993 and hourly values being recorded from May 31, 1993 on. The USGS started collecting gauge height data below the Inglis Dam since July 30, 1968. The USGS provides gauge height data at this station with a variable temporal resolution: monthly or quarterly gauge height during July 1968 – September 1969; daily gauge height during September 1969 – September 2007, and 15-minute gauge height during October 2007 - present. The USGS also provides daily gauge height since October 2007, with match perfectly with the daily averages of the 15-minute gauge height data. Therefore, it is believed that the USGS daily gauge height data prior to October 2007 were most likely obtained by taking the average of the 15-min data. An effort was made trying to find any 15-minute tidal data prior to October 1, 2007; however, according to USGS staff, there exist no real-time gauge height data prior to October 2007 on their system for this station.

Figure 4 shows measured tides by the SWFWMD and the USGS at the Inglis Dam downstream stations in the Withlacoochee River. The top panel in Figure 4 is a comparison between the SWFWMD hourly data with the USGS 15-minute data, while the bottom panel in the figure shows USGS daily gauge height from October 1, 1969 to present.

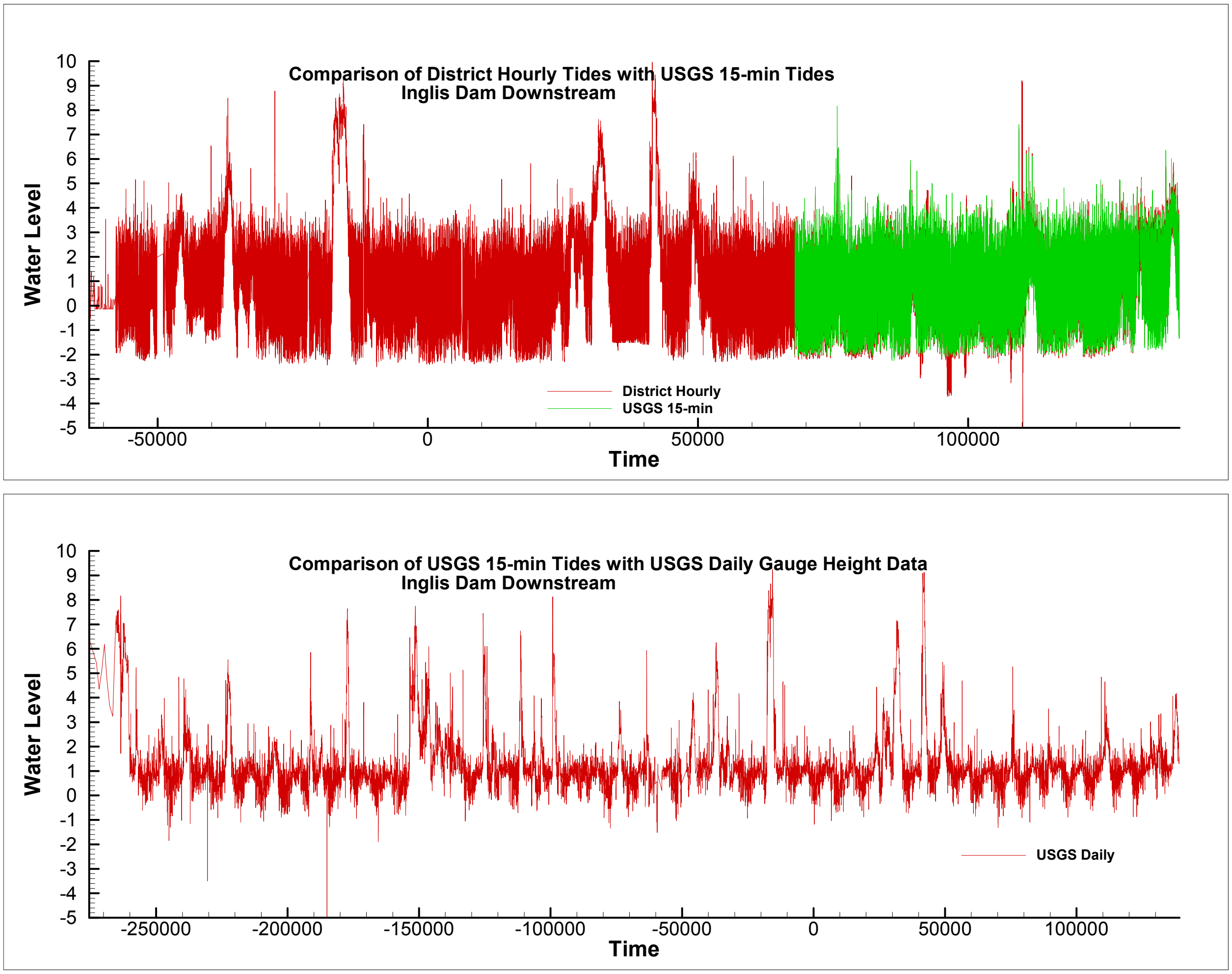

Figure 4. SWFWMD and USGS tidal data at the Inglis Dam Downstream station. Top panel: SWFWMD hourly tides (red line) and USGS 15-min tides (green line). The SWFWMD hourly tides started May 31, 1993, while the USGS 15-min tides started October 1, 2007. Bottom panel: USGS daily gauge height data from October 1, 1969 to present.

From the top panel of Figure 4, it can be seen that the SWFWMD hourly data have an overall very good agreement with the USGS 15-minite data. Both the SWFWMD hourly and USGS 15-min tidal data show that there were several time periods when the water level at the downstream side of the Inglis Dam had several noteworthy increases, which were not as pronounced at the Mouth of Kings Bay station (Figure 2). These more pronounced water level increases at the Inglis Dam Downstream station occurred during summer months and were most likely due to large water releases from the upstream reservoir through the Inglis Dam.

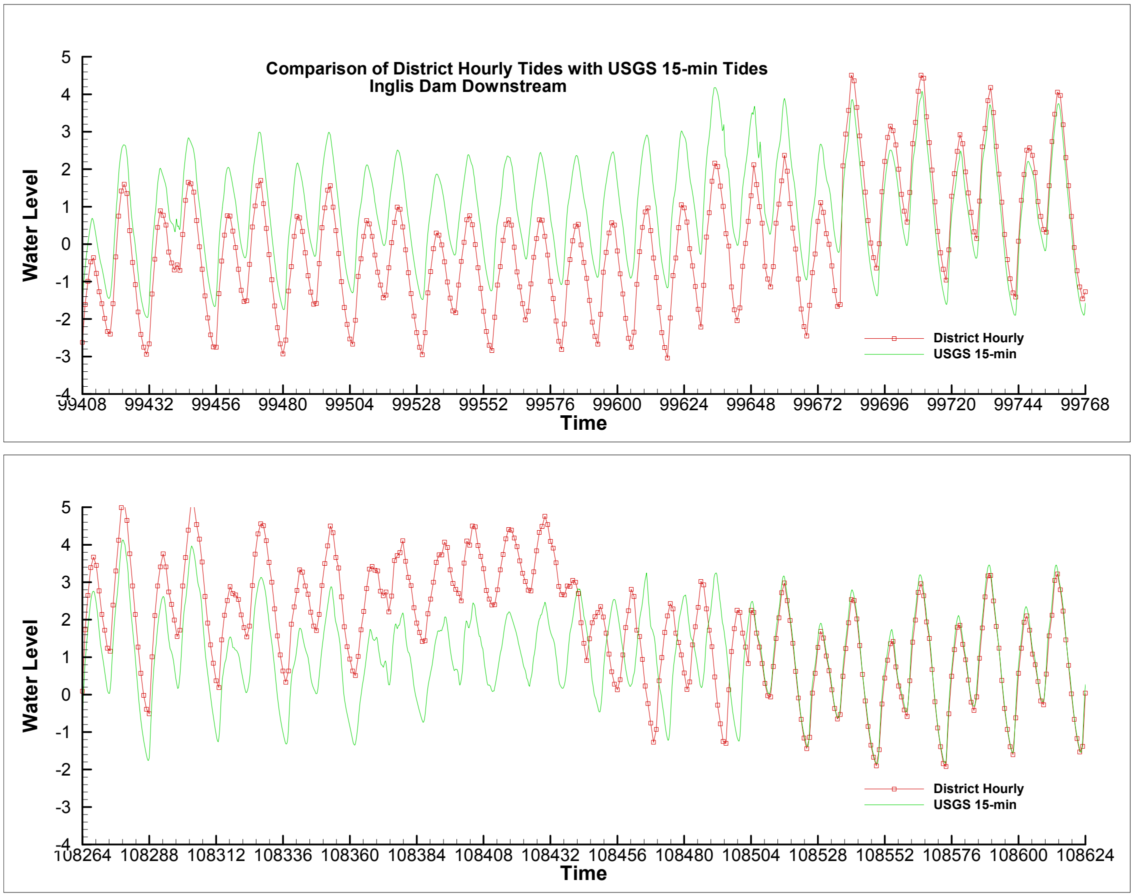

Figure 5. Comparison of the SWFWMD hourly tidal data (red line with small squares) with the USGS 15-min tidal data (green line). Occasional discrepancies between the two data sets can be seen, in both the water level and the tidal phase.

Although the SWFWMD tidal data and the USGS tidal data below the Inglis Dam match most of time, there exist some occasional discrepancies between the two. Figure 5 shows examples of the mismatches of the SWFWMD tidal data with the USGS tidal data. In the top panel of Figure 5, the SWFWMD data were lower than the USGS data, while the opposite can be seen in the bottom panel of Figure 5. In fact, a careful comparison of the SWFWMD and USGS tidal data shows that there was a drift of the SWFWMD tidal data between Hour 99219.0 and Hour 99680.0, during which the SWFWMD data continuously drifted from 0 to about -2 feet. In addition to the water level differences, sometimes, there were some phase differences between the SWFWMD and USGS tidal data (see the phase mismatch near Hour 108480.0 in the bottom panel of Figure 5.)

The NOAA Cedar Key station is located at about 50 km away from and about 56 degree to the northwest of Kings Bay. NOAA provides both predicted and verified tides with a 60-minute interval at this station starting on January 1, 1997. The predicted tides are model-predicted values, while the verified tides are gaged values. Although both predicted and verified tides match very well, they are not exactly the same. This project used NOAA verified data, as they are the actual tides measured at the Cedar Key station. Data gaps in the verified data are filled with predicted tides, which contains no data gaps. Figure 6 shown below is a plot of the verified tides (filled with predicted tides) at the NOAA Cedar Key station.

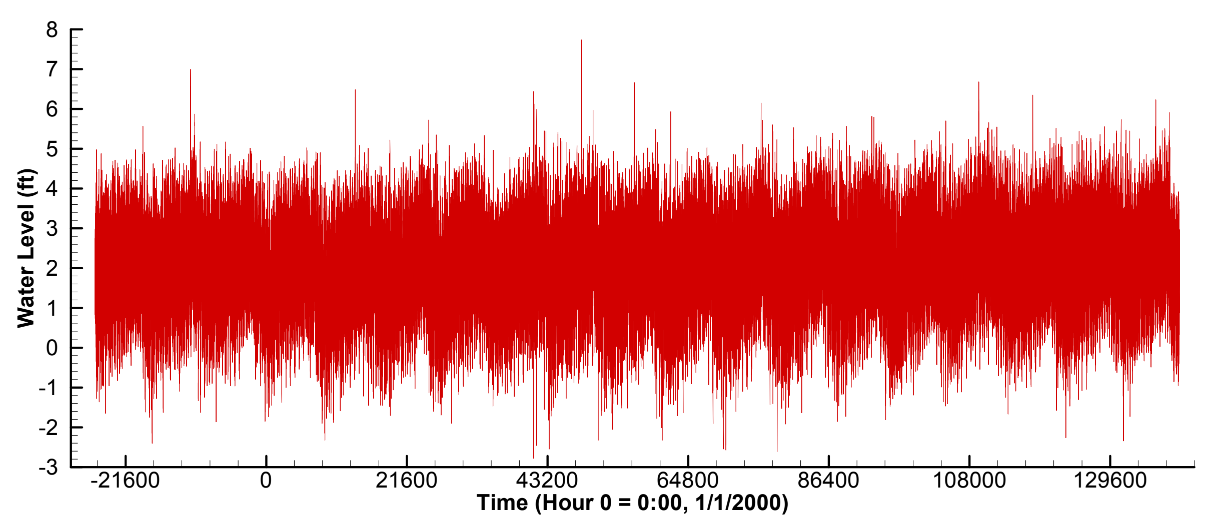

Figure 6. Hourly tidal data (verified tides filled with predicted tides) at NOAA Cedar Key station during January 1997 through December 2015.

Correlations among Tides at Different Stations

In order to determine the best tidal station for the estimation of tides in Kings Bay, measured tides at the USGS Mouth of Kings Bay station were first plotted against those at the SWFWMD Inglis Dam Downstream station, at the USGS Inglis Dam Downstream station, and at the NOAA Cedar Key station. Figure 7 is a scatter plot of measured water levels in Kings Bay versus those measured in the Withlacoochee River below the Inglis Dam by the SWFWMD. The linear regression line is also plotted in the figure and takes the following form

$$h_{kb}(t) = 0.661h_{dd}(t - 120) - 0.45 \qquad (1)$$

where t is time in minutes, $h_{kb}(t)$ denotes water elevation in Kings Bay at time = t and $h_{dd}(t - 120)$ is measured tides by the SWFWMD below the Inglis Dam 120 minutes before time = t.

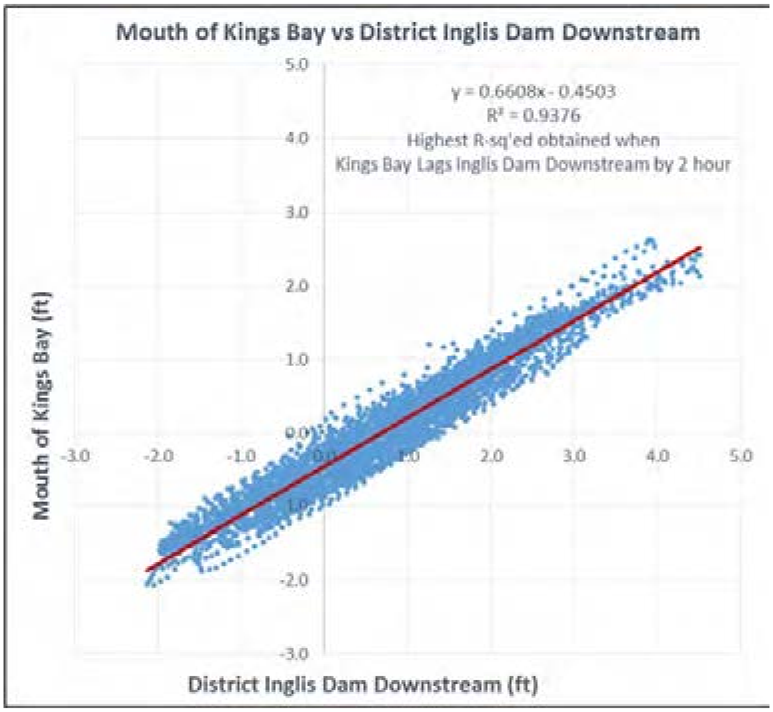

Figure 7. Scatter plot of measured water levels at the USGS Mouth of Kings Bay station vs those at the SWFWMD Inglis Dam Downstream station. The linear trend line is also plotted, with the equation and the R-squared value being included.

Due to the nature of tidal wave propagation, the correlation between Kings Bay tides and Withlacoochee River tides below the Inglis Dam involves a phase lead/lag, which needs to be determined before the correlation is calculated. However, without detailed information on tides and bathymetry in the region, it is impossible to determine the phase lead or phase lag between the two stations a priori. In this study, a trial and error method was used to estimate the phase lead/lag by calculating a series of R^2 values with a phase lead(or lag) of 15 minutes, 30 minutes, …, and so on. Because a wrong phase lead (or lag) will yield a low R^2 value, the best correlation is only possible when the phase lead (or lag) is at or close to the true phase lead (or lag). As thus, the true phase lead (or lag) can be estimated by finding the one that yields the highest R^2 value. The estimated phase lead (or lag) has an uncertainty of 7.5 minutes or less. For the correlation between Kings Bay tides and Withlacoochee River tides below the Inglis Dam, the highest R^2 value is obtained when Kings Bay tides lags Withlacoochee River tides below the dam by 2 hours, with R^2 = 0.94.

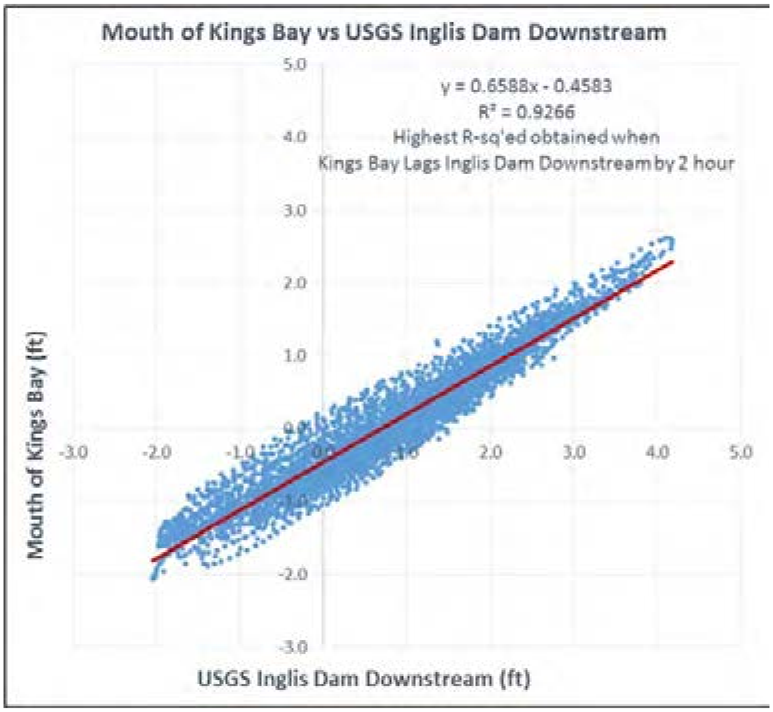

Figure 8. Scatter plot of measured water levels at the USGS Mouth of Kings Bay station vs those at the USGS Inglis Dam Downstream station. The linear trend line is also plotted, with the equation and the R-squared value being included.

Figure 8 is a scatter plot of measured water levels at the USGS Mouth of Kings Bay station versus those at the USGS Inglis Dam Downstream station. Because the USGS Inglis Dam Downstream station is located at the same place as the SWFWMD Inglis Dam Downstream station, tides measured by both the USGS and the SWFWMD have the same phase lead of 2 hours over the Kings Bay tides. Because the USGS data match the SWFWMD data very well most of time, the correlation between Kings Bay tides and USGS Inglis Dam Downstream tides is similar to that between Kings Bay tides and SWFWMD Inglis Dam Downstream tides. The linear regression equation takes the following form

$$h_{kb}(t) = 0.659h_{dg}(t - 120) - 0.46 \tag{2}$$

where $h_{dg}(t - 120)$ is measured gauge height by the USGS below the Inglis Dam 120 minutes before time = t. The R^2 value for the above linear regression is 0.93.

In Figure 9, USGS water level data at the Mouth of Kings Bay station are plotted against NOAA Cedar Key verified water level data. Similar to Figures 7 and 8, a trial and error method was used to determine the phase lead/lag between Kings Bay tides and Cedar key tides. It is found that the highest R^2 value was obtained when the Cedar Key tides lead Kings Bay tides by 2.5 hours. The linear regression equation is as follows

$$h_{kb}(t) = 0.713h_{ck}(t - 150) - 1.50 \tag{3}$$

where $h_{ck}(t-150)$ is verified tides at the NOAA Cedar Key station 150 minutes before time = t. The R2 value between Kings Bay tides and Cedar Key tides is 0.85.

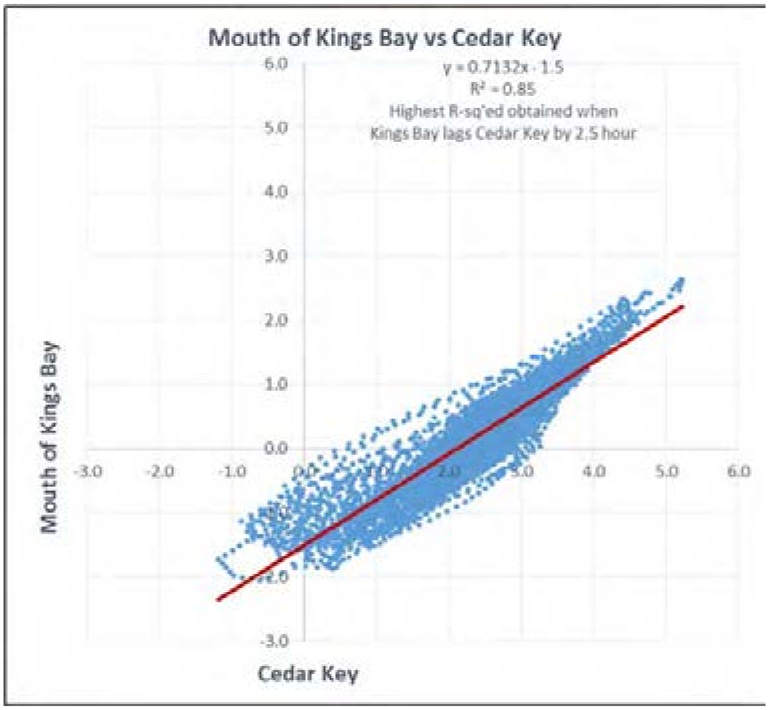

Figure 9. Scatter plot of measured water levels at the USGS Mouth of Kings Bay station vs those at the NOAA Cedar Key station. The linear trend line is also plotted, with the equation and the R-squared value being included.

Figure 10 is a scatter plot of USGS 15-min tides at Inglis Dam Downstream versus NOAA Cedar Key tides. The phase lead/lag was obtained in the same trial and error method described above. The highest R^2 value between the two tidal datasets was found to be 0.95, with Cedar Key tides leading Inglis Dam Downstream tides by 30 minutes. The linear regression equation relating Cedar Key tides and USGS Inglis Dam Downstream tides takes the following form

$$h_{dg}(t) = 1.099h_{ck}(t-30) - 1.62 \tag{4}$$

Figures 7 – 10 were created with data collected between Hour 99000 and Hour 100075, during this period no impact of high water release from the upstream reservoir through the Inglis Dam can be observed. Because the SWFWMD tides at the Inglis Dam Downstream and NOAA tides at Cedar Key were recorded with a time interval of 60 minutes while tides at the USGS stations in Kings Bay and at Inglis Dam Downstream were recorded at a time interval of 15 minutes, hourly tidal data at the former two stations were converted to 15-minute tidal through linear interpolation.

Because the SWFWMD-measured tides and the USGS-measured tides are not exactly the same all the time at the downstream side of the Inglis Dam in the Withlacoochee River, their respective R^2 values with Kings Bay tides are not exactly the same, though the two R^2 value is only off by 0.01. With a R^2 of 0.93 – 0.94, the correlation between tides in Kings Bay are highly correlated with these at Inglis Dam Downstream. As such, either the SWFWMD- or USGS-measured tides at Inglis Dam Downstream can be used to estimate tides in Kings Bay using Equation (1) or (2).

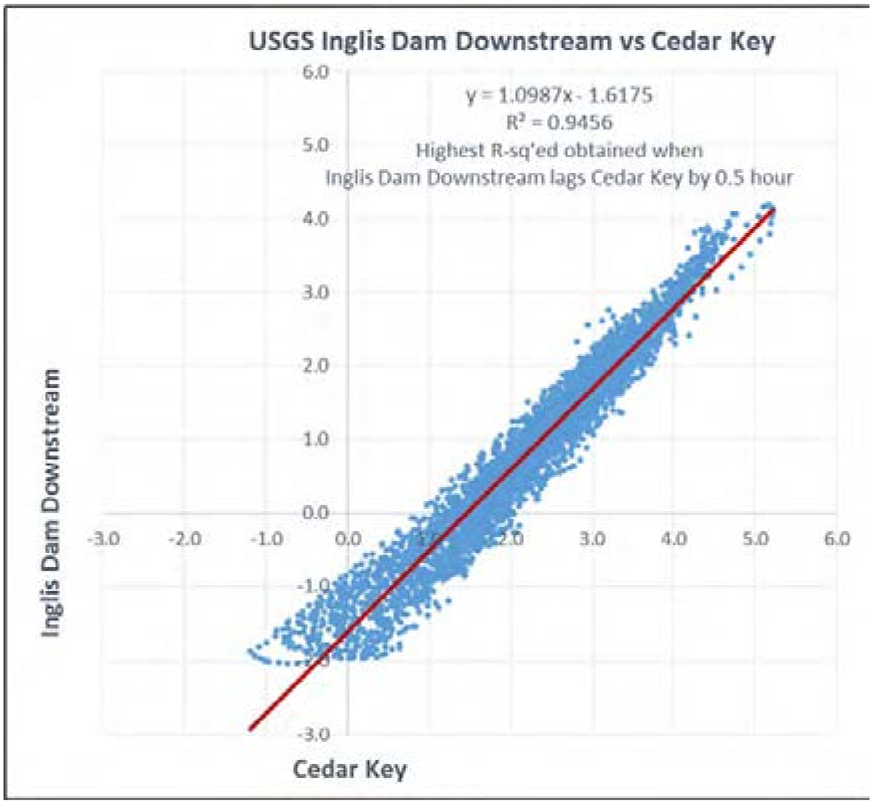

Figure 10. Scatter plot of measured water levels at the USGS Inglis Dam Downstream station vs those at the NOAA Cedar Key station. The linear trend line is also plotted, with the equation and the R-squared value being included.

Although a R^2 value of 0.85 is little lower than a R^2 value of 0.93 (or 0.94) for the correlation between Inglis Dam Downstream tides and Kings Bay tides, Cedar Key tides should also be considered to have a good correlation with the Kings Bay tides. In the case when no data are available below the Inglis Dam, Cedar Key tides can be used to estimate Kings Bay tides using Equation (3).

Equation (4), in combination with Equation (2), can also be used to estimate the water level elevation in Kings Bay. Substituting $h_{dg}(t)$ in Equation (2) with the right hand side of Equation (4), the combined equation is as follows

$$h_{kb}(t) = 0.724h_{ck}(t - 150) - 1.52 \tag{5}$$

The above equation is similar to Equation (3), which is obtained by directly correlating Kings Bay tides with Cedar Key tides. However, because Equation (5) involves one more layer of regression than Equation (3) does, it may contain a larger uncertainty than the latter does.

Extending Period of Record of Tidal Data in Kings Bay

Based on the above analysis of existing tides in the region of Crystal River/Kings Bay, the following steps were used in extending the period of record of tides in Kings Bay:

1. For the period of November 30, 2006 through present, measured tides at the mouth of Crystal River and Salt River stations were used to fill the gaps of the measured tides in Kings Bay.
2. If there are still data gaps after Step 1 for the period from October 1, 2007 to present, Equation (2) is used to fill the gap in Kings Bay tidal data based on USGS 15-min gauge height data measured at the Inglis Dam Downstream station. This step is skipped during events when a large amount of water was released through the Inglis Dam.
3. From May 31, 1993 to November 30, 2006, Equation (1) is used to estimate hourly water levels in Kings Bay based on measured hourly tidal data by the SWFWMD in the Withlacoochee River below the Inglis Dam. During May 31, 1993 through December 31, 1996, adjust hourly tidal data below the dam during high release events by comparing tides before and after the release before the use of Equation (1). During January 1997 – November 30, 2006, this step is skipped during events when a large amount of water was released through the Inglis Dam.
4. For the period of January 1997 – present, Equation (3) is used to fill the gaps after Step 3.
5. For the period between October 1, 1969 and May 30, 1993, first adjust the USGS daily gauge height below the dam during high release days by comparing gauge heights before and after the release. Then, use Equation (2) to estimate daily water levels in Kings Bay.

Figure 11 shows extended stage data at the Mouth of Kings Bay station, which combine measured 15-minute tides with hindcasted daily and hourly water levels using the above procedure. Results from 10/1/1969 to 5/30/1993 were daily water levels, while those from 5/31/1993 to 11/30/2006 were hourly water levels. Although a direct comparison of measured and estimated water levels is impossible for these daily and hourly data, it is expected that at least 85% of the variances of the water level data at the mouth of Kings Bay are correctly predicted in the hindcasted water levels, as indicated in R^2 values shown in Figures 7 – 10.

The availability of measured water level data at the mouth of Kings Bay since 11/30/2006 allows a comparison of estimated water levels with measured ones. Applying Equations (1) – (3) for November 30, 2006 to present, three sets of water level data at the mouth of Kings Bay could be obtained. Figure 12 shows plots of measured and estimated water levels using available tidal data at the SWFWMD and USGS Inglis Dam stations and at the Cedar Key station. As can be seen from the figure, tides predicted using Equations (1) – (3) all match well with measured tides.

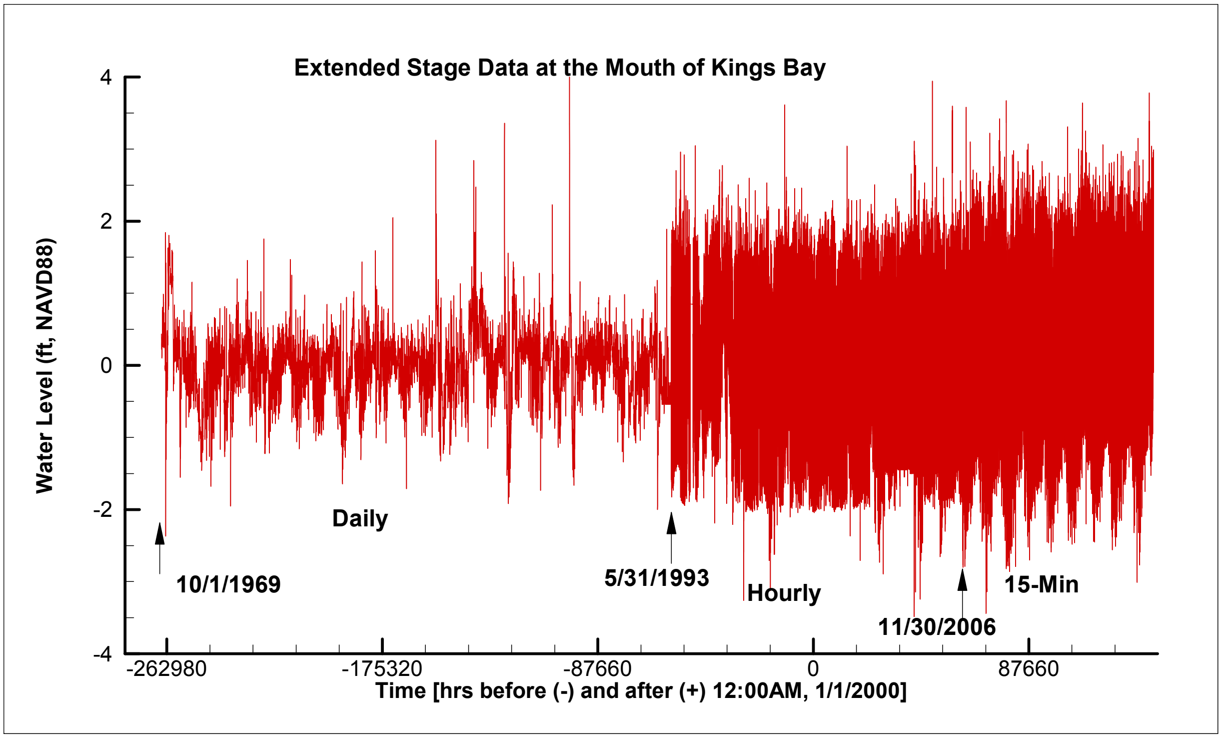

Figure 11 Extended stage data at the mouth of Kings Bay.

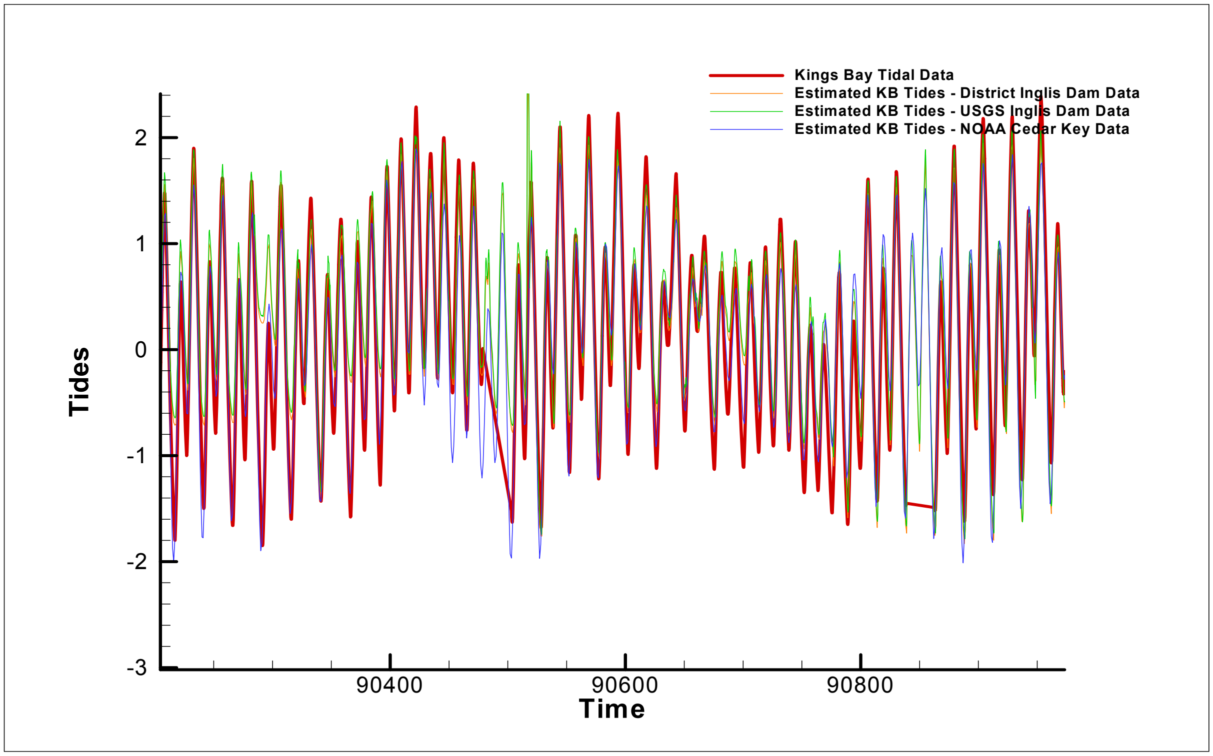

Figure 12 Comparison of hindcasted tides using Equations (1) – (3) with measured data.

3. Hindcasting Groundwater Level in ROMP TR21-3

The collection of groundwater level in the ROMP TR21-3 well started on May 31, 1979, with a frequency of one reading a day between May 31, 1979 and September 30, 1989 and monthly reading between October 1989 and September 2000. Since October 2000, groundwater level data were collected. To hindcast the total SGD entering Crystal River/Kings Bay to 1969, it is necessarily to hindcast ROMP TR21-3 groundwater levels prior to 1969 or earlier. The nearest well that can be used for the estimation is the Lecanto 7 well, in which groundwater level data was collected starting May 5, 1966. Comparing to the ROMP TR21-3 well, groundwater level data collected in in the Lecanto 7 well has a much lower and more inconsistent frequency. In early years, prior to September 1980, groundwater level data were collected roughly every other month in Lecanto 7, but the data collection frequency was increased to about once a month well since September 1980.

Similar to the hindcasting of the water level data at the mouth of Kings Bay, a correlation relationship between groundwater levels measured in the ROMP R21-3 well and those measured in the Lecanto 7 well can be obtained. The linear correlation has a coefficient of determination of 0.623, which is understandably lower than those among surface water levels shown in Figures 7 - 9. Nevertheless, groundwater levels collected in Lecanto 7 are still the best source for hindcasting groundwater levels in ROMP TR21-3 prior to May 31, 1979. Applying the correlation relationship for the entire period of record of the Lecanto 7 well, predicted groundwater levels in ROMP TR21-3 since May 5, 1966 were obtained, which were plotted in Figure 13. Measured groundwater levels in the ROMP TR21-3 well were also plotted in the figure for comparison. The blue line represents measured groundwater level, while the red line represents the estimated groundwater level in ROMP TR21-3. Clearly, the estimated groundwater levels match well with measured data, as both have the same long-term variabilities. It is thereby reasonable to use estimated data for the hindcasting of groundwater levels prior to May 31, 1979 in ROMP TR21-3.

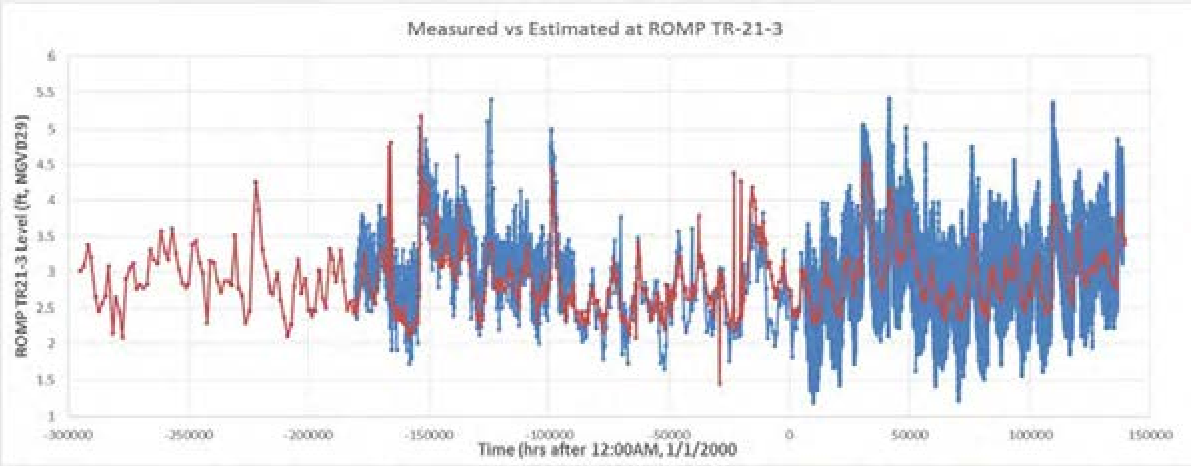

Figure 13 Comparison of measured and estimated groundwater levels in the ROMP TR21-3 well.

4. SGD Formulas for the Total SGD

The empirical formulas that were used for the SGD hindcasting were obtained from the model output of the total SGD to Crystal River/Kings Bay, which was computed as a summation of all SGDs from all the spring vents at each time step of the model run. The SGD estimation for each spring vent at each time step was done in the model using the following formula (Chen, 2014a and 2014b):

$$Q = Q_0\left[1 + C_1(G - G_0 - \eta) + C_2\frac{\partial \eta}{\partial t}\right] \tag{6}$$

where Q and Q_0 are respectively estimated spring flow and long-term mean of measured spring flow; G and G_0 are groundwater level at the well station and the long-term mean of the head difference between the well station and Kings Bay, respectively; η is the surface water level in Kings Bay; and C_1 and C_2 are coefficients. Q_0, G_0, C_1, and C_2 can be determined from field data.

Details on how the Equation (6) was used in the model can be found in Chen (2014b). Adding all the SGDs from all the spring vents, including the 70 vents that were identified during an inventory study in 2008 – 2009 in Crystal River/Kings Bay and 40 assumed small vents that were randomly distributed in Kings Bay to represent countless hairline fractures and diffuse fluxes. Adding estimated SGDs from all these vents, a time series of the total SGD that the estuary system received can be obtained. Figure 14(a) is the time series of the total SGD entering Crystal River/Kings Bay. For comparison, time series of measured water levels in Kings Bay and in the ROMP TR21-3 well are plotted in Figure (b). As can be seen from Figure 14, tidal signals are strong not only in measured water levels in Kings Bay but also in the groundwater level data and in estimated total SGD.

For the management purpose of the water body, it is desirable to remove these high frequency tidal signals from the total SGD. The simplest and most practical way to do it is to calculate 24-hour running averages or to calculate daily averages of SGDs. As a result of these calculations, the 24-hour running average or the daily average of the time derivative term in Equation (6) become negligible and the average total SGD will mainly be a function of the head difference between the groundwater level in ROMP TR21-3 and the surface water level in Kings Bay.

Figure 15(a) are plots of 24-hour running averages of SGD and head difference between the groundwater level in ROMP TR21-3 and the surface water level in Kings Bay, while Figure 15(b) are daily averages of SGD and head difference. Because Figure 15(a) was plotted with an hourly interval, 24-running averages of SGD and head difference contain more variabilities than daily averages shown in Figure 15(b), which is just a sub-set of SGD and head difference shown in Figure 15(b).

Although a majority of the tidal signals have been filtered out in the 24-hour running averages or daily averages, there are still some insignificant tidal variabilities remaining in these averaged values, because tidal constituents in Kings Bay include mainly M2, S2, K1, and O1, with tidal periods of 12.42, 12.0, 23.93, and 25.82 hours, respectively. Nevertheless, SGD and head difference have a strong linear correlation, for both 24-hour running averages and daily averages.

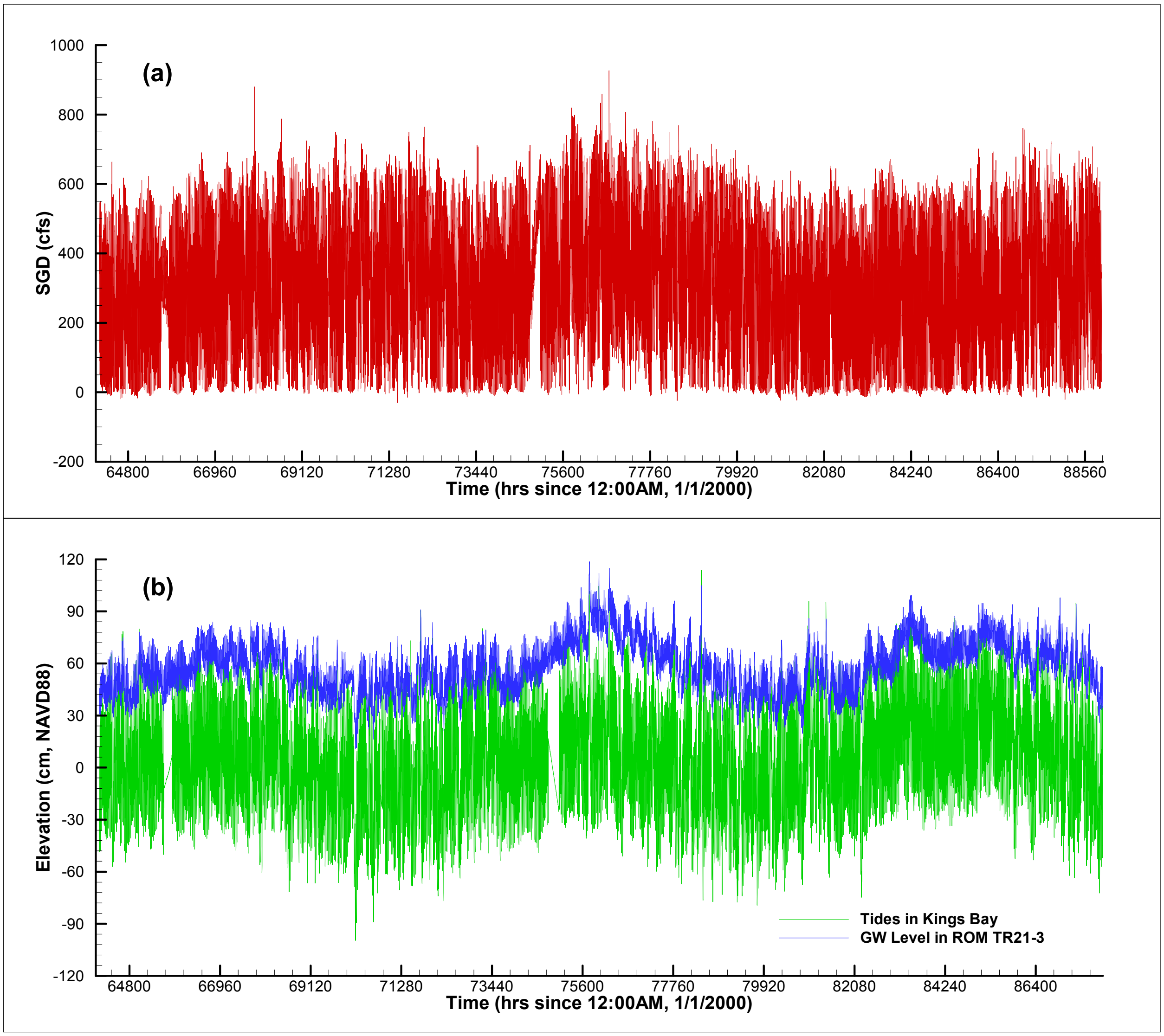

Figure 14 Time series of total SGD entering Crystal River/Kings Bay (a) and tides and groundwater level in ROMP TR21-3 (b).

Figures 16(a) shows a scatter plot of 24-hour running averages of the total SGD entering Crystal River/Kings Bay versus the head difference between groundwater and surface water levels. The red dashed line is the linear regression between them, which has a R^2 of 0.983 and takes the following form

$$\overline{Q} = 6.7766\Delta\overline{h} - 64.895 \qquad (7)$$

where $\overline{Q}$ (in cfs) is the 24-hour running average of SGD and $\Delta\overline{h}$ is the 24-hour running average of the head difference between groundwater level in ROMP TR21-3 and surface water level in Kings Bay.

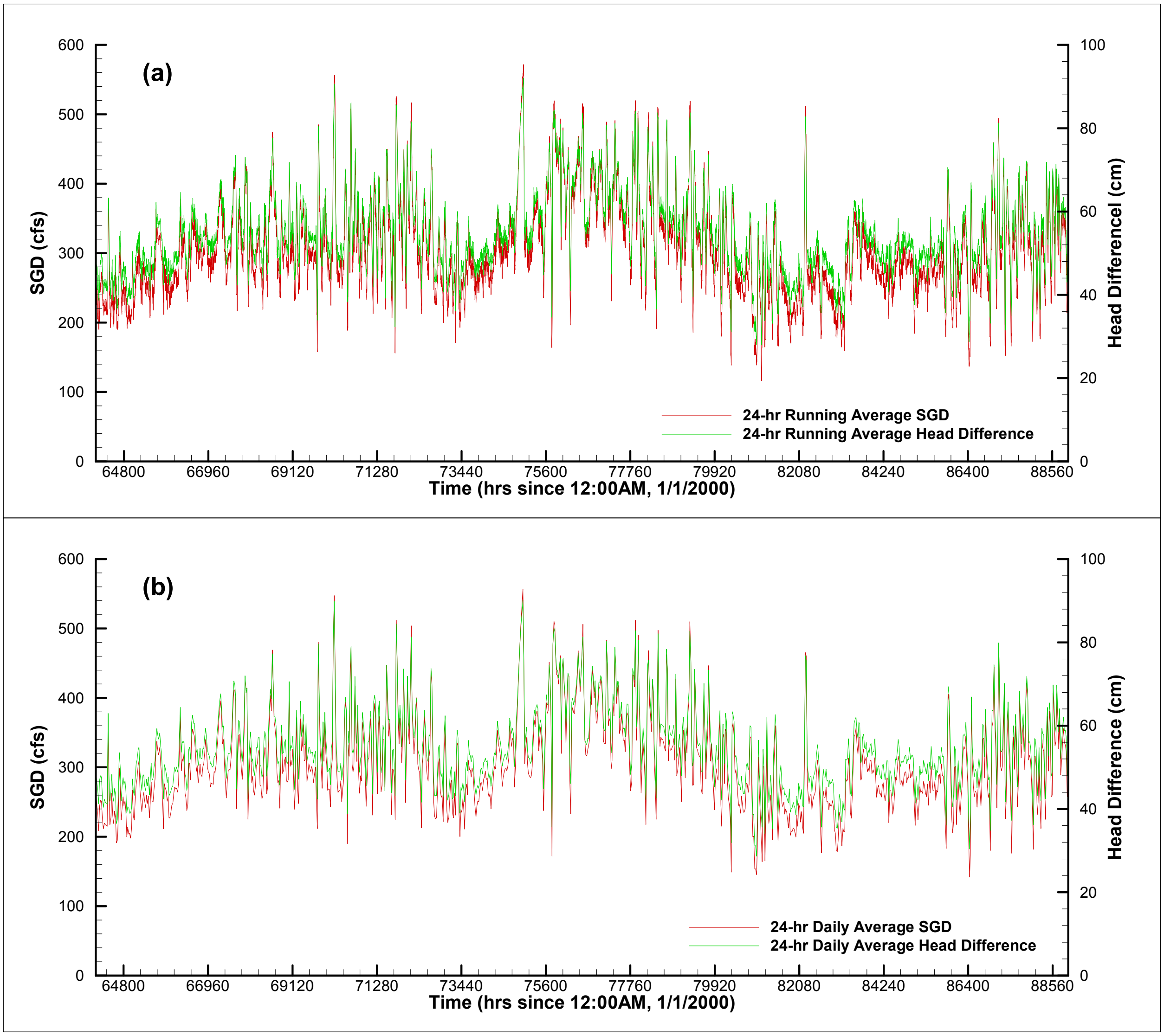

Figure 15 Time series of 24-hour running averages of SGD and head difference, plotted with an hourly interval (a) and daily averages of SGD and head difference (b).

A scatter plot of the daily average SGD versus daily average head difference is shown in Figure 16(b). Similarly, the linear regression was obtained to take the following form

$$\widetilde{Q} = 6.8938\Delta\widetilde{h} - 71.319 \tag{8}$$

where $\widetilde{Q}$ (in cfs) is the daily average of SGD and $\Delta\widetilde{h}$ is the daily average of the head difference between groundwater level in ROMP TR21-3 and surface water level in Kings Bay. The above linear regression has a R^2 of 0.9944.

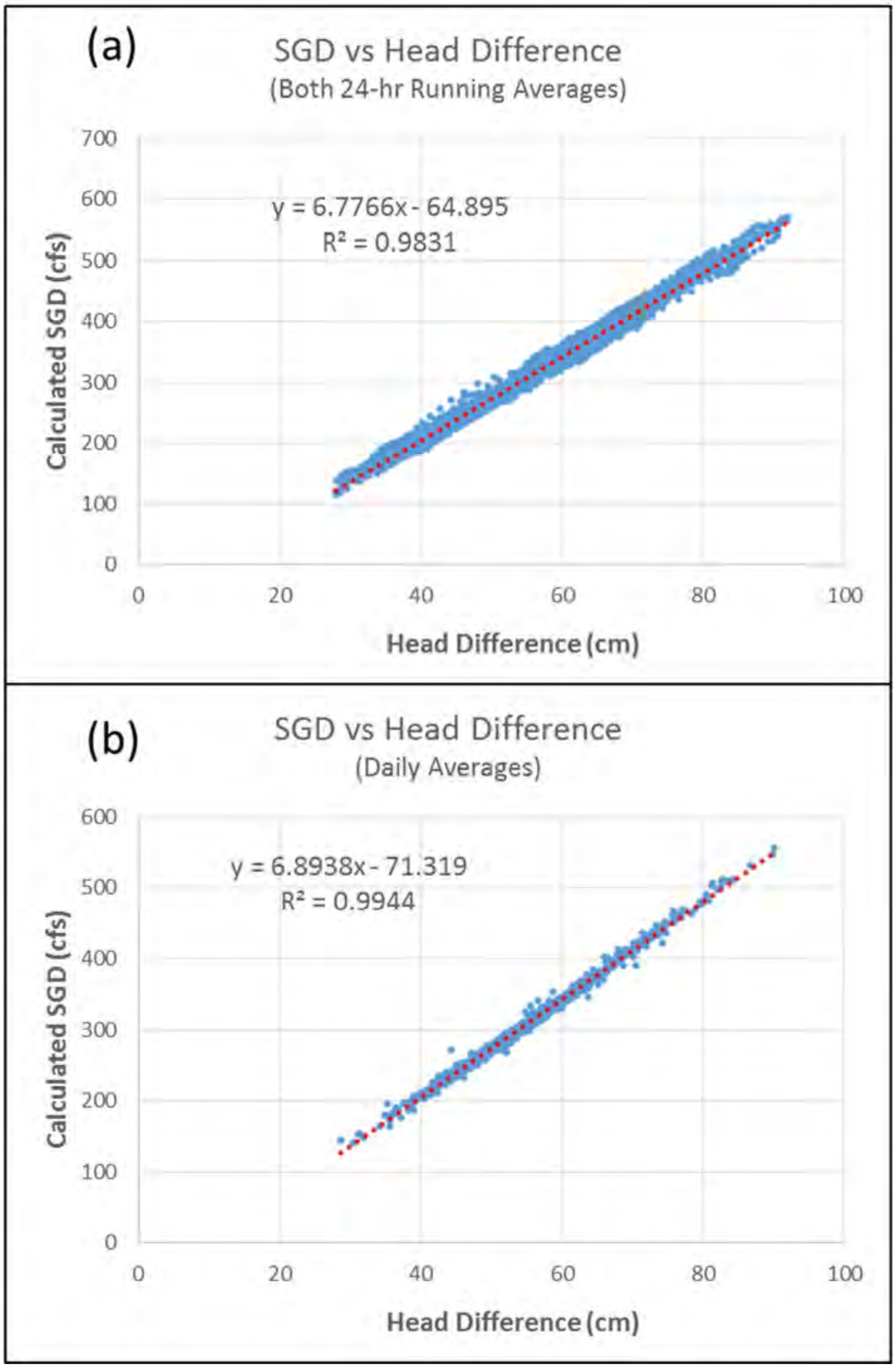

Figure 16 Scatter plots of 24-hour running average of SGD versus 24-hour running average of head difference (a) and daily average of SGD versus daily average of head difference (b).

Both the daily and 24-hour running averages contain some tidal signals with timescales longer than 24 hours. The 24-running average also contains variabilities with sub-diurnal timescales, resulting a slightly lower R^2 value for Equation (7) than for Equation (8). To further remove tidal signals, running averages with the lunar cycle (about 29.5306 days) were calculated. Figure 17 shows lunar-cycle running averages of the total SGD and the head difference, and Figure

18 shows the scatter plot of the lunar-cycle running average of SGD versus that of head difference. The linear regression takes the following form

$$\widehat{Q} = 6.8649\Delta\widehat{h} - 69.297 \tag{9}$$

where $\widehat{Q}$ (in cfs) is the lunar-cycle running average of SGD and $\Delta\widehat{h}$ is the lunar-cycle running average of the head difference between groundwater level in ROMP TR21-3 and surface water level in Kings Bay. The above linear regression has a R^2 of 0.9944 (Figure 18). It should be noted that the lunar-cycle running average not only effectively removes the tidal signals but also smooths out other variable with timescales shorter than 29.53 days. As such, many peaks shown in Figure 15, which could be caused by wind variations or storm events, do not appear in Figure 17.

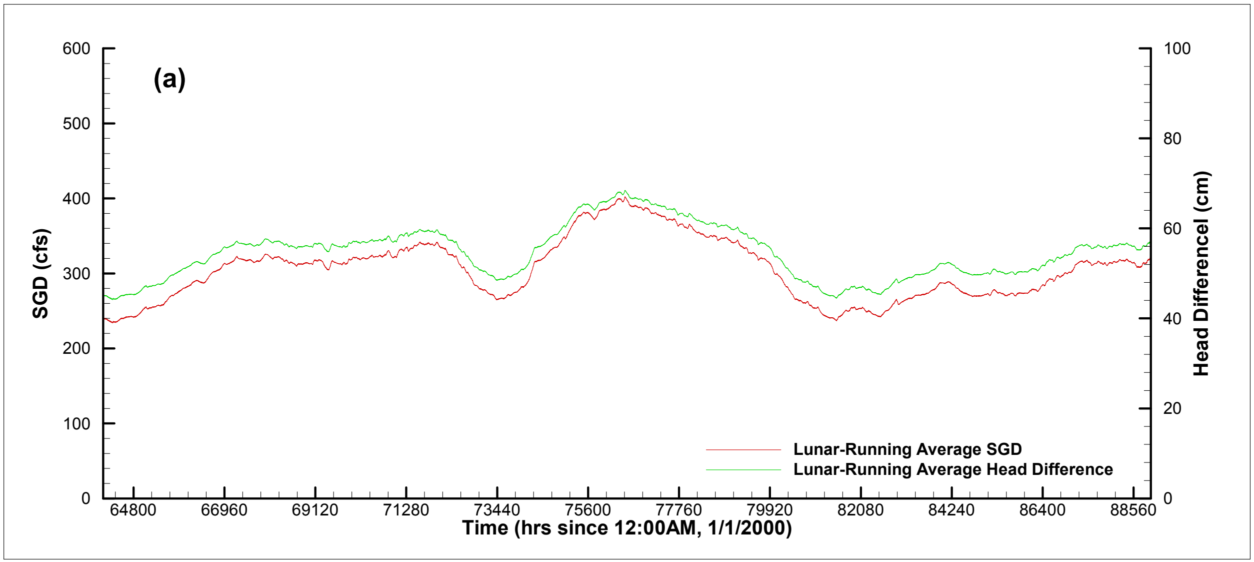

Figure 17 Time series of 29.53–day (lunar cycle) running averages of SGD and head difference, plotted with an hourly interval.

5. Results of SGD Hindcasting

With the groundwater level and surface water level being hindcasted back to November 1969, any one of the three formulas shown in Equations (7) – (9) can be used to hindcast the total SGD back to November 1969. For comparison, all three formulas are used here. Because surface water level data in Kings Bay and groundwater level data in ROMP TR21-3 were collected with different temporal resolutions, daily averages of the surface water and groundwater levels were first calculated before they were used to hindcast daily total SGDs. To reduce uncertainty, daily SGDs were calculated only on days when both the daily surface water and groundwater levels were available.

Hindcasted daily SGDs using three different formulas are presented in Figure 19. It can be seen from the figure that all three formulas give almost the same SGD estimate, except that the peaks in SGDs using Equation (9) are slightly lower than those using Equations (7) and (8). The total SGD varies roughly in the range of -112 – 960 cfs, with tidal signals being almost filtered out. The 46-year averages of total SGD entering the Crystal River/Kings Bay system are 372.65 cfs, 373.79 cfs, and 373.94 cfs, respectively, while the median SGDs are 354.99 cfs, 355.83cfs, and 356.06 cfs, respectively using Equations (7), (8), and (9).

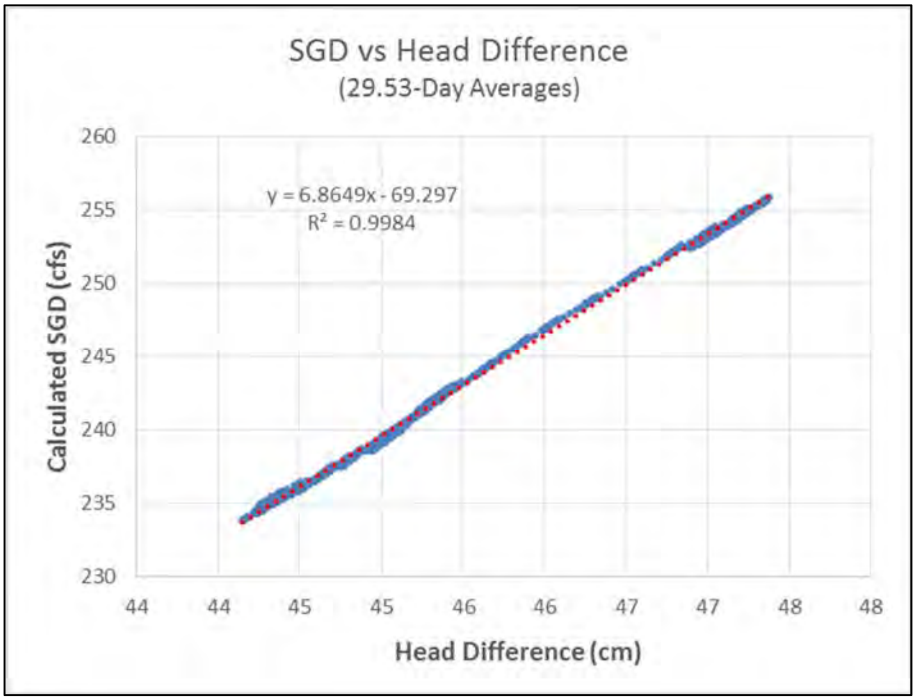

Figure 18 A scatter plot of lunar-cycle running averages of SGD vs. head difference.

Table 1 provides more details on the statistics of the daily SGDs hindcasted using the three formulas derived from 24-hour running averages, daily averages, and Lunar-cycle running averages of the total SGD and head difference between the groundwater level in ROMP TR21-3 and the surface water level in Kings Bay. Figure 20 compares cumulative distribution functions of the daily SGDs hindcasted using equations (7) – (9). Both Table 1 and Figure 20 show that daily SGDs hindcasted using the three different formulas are almost the same using different formulas.

Table 1 Statistics of daily SGDs hindcasted using formulas derived from 24-hour running averages, daily averages, and Lunar-cycle running averages of the total SGD and head difference between the groundwater level in ROMP TR21-3 and the surface water level in Kings Bay.

	Hindcasted Daily SGDs (cfs) using formulas derived from		
	24-hr running avgs	Daily averages	Lunar-cycle running avgs
Minimum	-105.20	-112.32	-110.13
5th Percentile	232.72	231.45	232.20
10th Percentile	260.24	259.44	260.08
25th Percentile	304.34	304.31	304.75
50th Percentile	354.99	355.83	356.06
75th Percentile	418.54	420.48	420.44

90th Percentile	506.11	509.56	509.15
95th Percentile	583.23	588.02	587.28
Maximum	948.83	959.94	957.64
Average	372.65	373.79	373.94

Although signals of long-term variabilities in the timescale of 20 years or longer were generally weak in the total SGD, it did vary significantly with a timescale 4 – 6 years. Consequently, it is possible that the 9-year simulation period between November 2006 and October 2015, which will be used for MFL scenario runs, was not representative of the historical SGD entering Crystal River/Kings Bay.

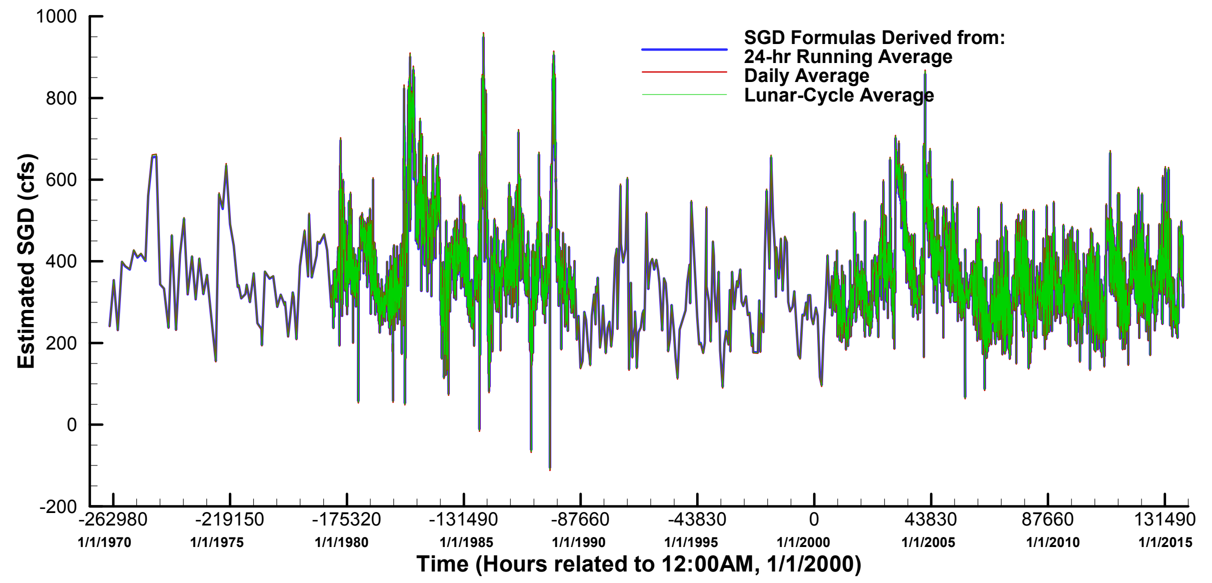

Figure 19 Results of daily SGDs hindcasted using three formulas as shown in Equations (7) – (9).

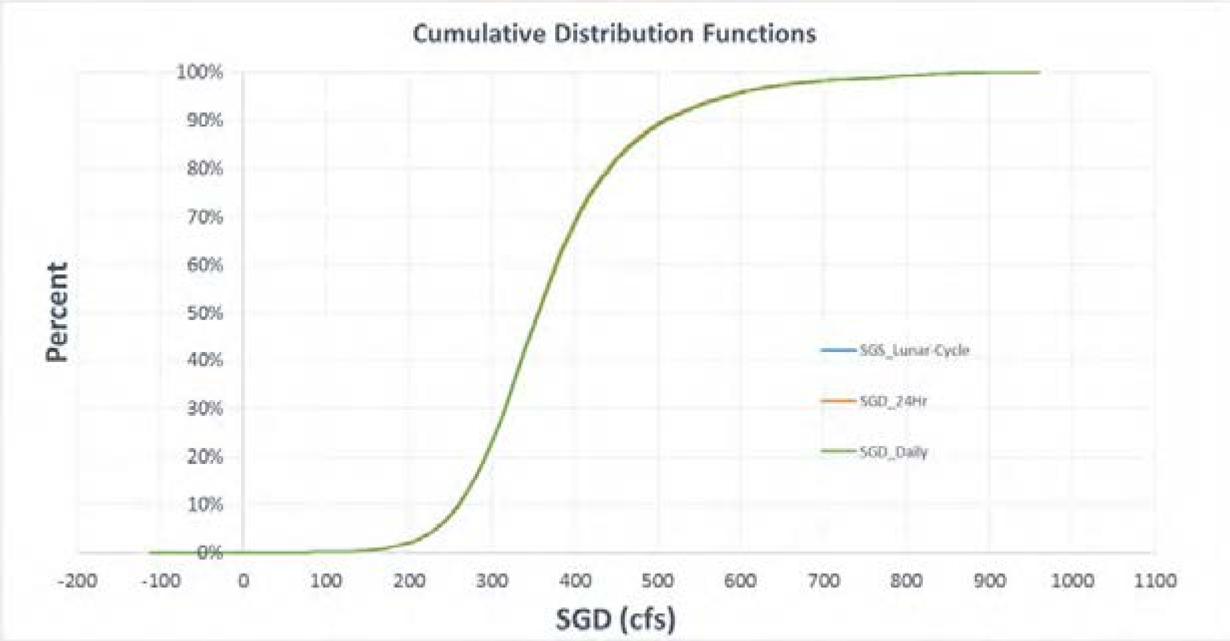

Figure 20 Cumulative distribution functions of daily hindcasted using three formulas as shown in Equations (7) – (9).

To gain some insight on how the 9-year period represented the historical total SGD data, cumulative distribution functions of the total SGD during different time frames were computed and shown in Figures 21 - 23. Figure 21 depicts CDFs of the total SGD hindcasted using the empirical formula derived from the 24-hour running averages, Equation (7), for various time periods, including 11/5/1969 – 10/13/2015, 11/1/2006 – 10/13/2015, 11/5/1969 – 10/31/2006, 1/1/1989 – 10/13/2015, and 11/1/2006 – 10/31/2010. Figures 22 and 23 depict CDFs of SGD hindcasted using Equations (8) and (9), respectively for the same time periods.

Consistent with Figure 19, Figures 21 – 23 are all similar. It can be seen from these figures that the total SGD during the 9-year period (red lines) was lower than that during the period of record, 11/5/1969 – 10/13/2015 (dashed blue lines). The lower-than-normal 9-year SGD was mainly due to low SGDs during the first five years between 11/1/2006 and 10/31/2010 (green lines). The overall total SGD prior to November 2006 (gray lines) was substantially higher than that during the 9-year period after November 2006, which was more close to that during 1/1/1989 – 10/13/2015 (dotted yellow lines).

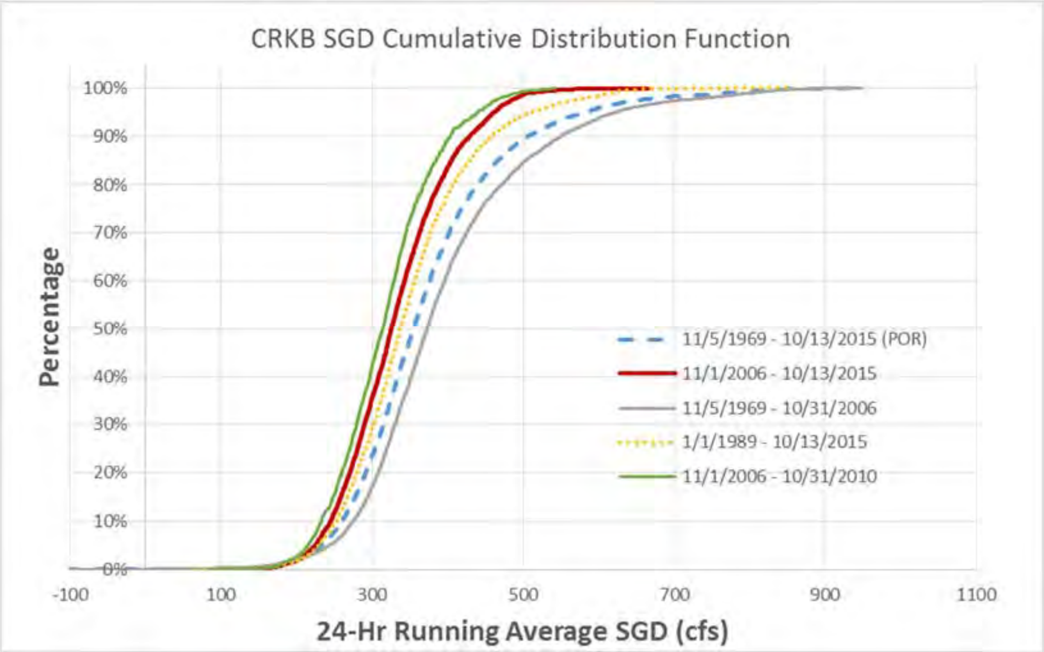

Figure 21 Cumulative distribution functions of 24-hour running averages of the total SGD for periods during 11/5/1969 – 10/13/2015, 11/1/2006 – 10/13/2015, 11/5/1969 – 10/31/2006, 1/1/1989 – 10/13/2015, and 11/1/2006 – 10/31/2010.

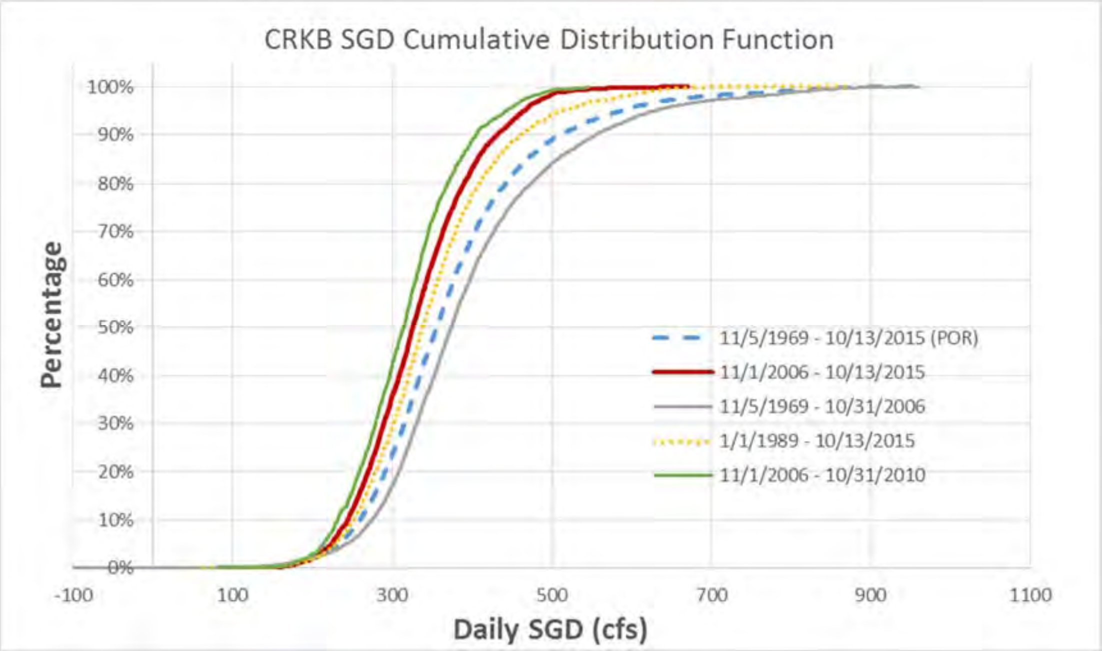

Figure 22 Cumulative distribution functions of daily averages of the total SGD for periods during 11/5/1969 – 10/13/2015, 11/1/2006 – 10/13/2015, 11/5/1969 – 10/31/2006, 1/1/1989 – 10/13/2015, and 11/1/2006 – 10/31/2010.

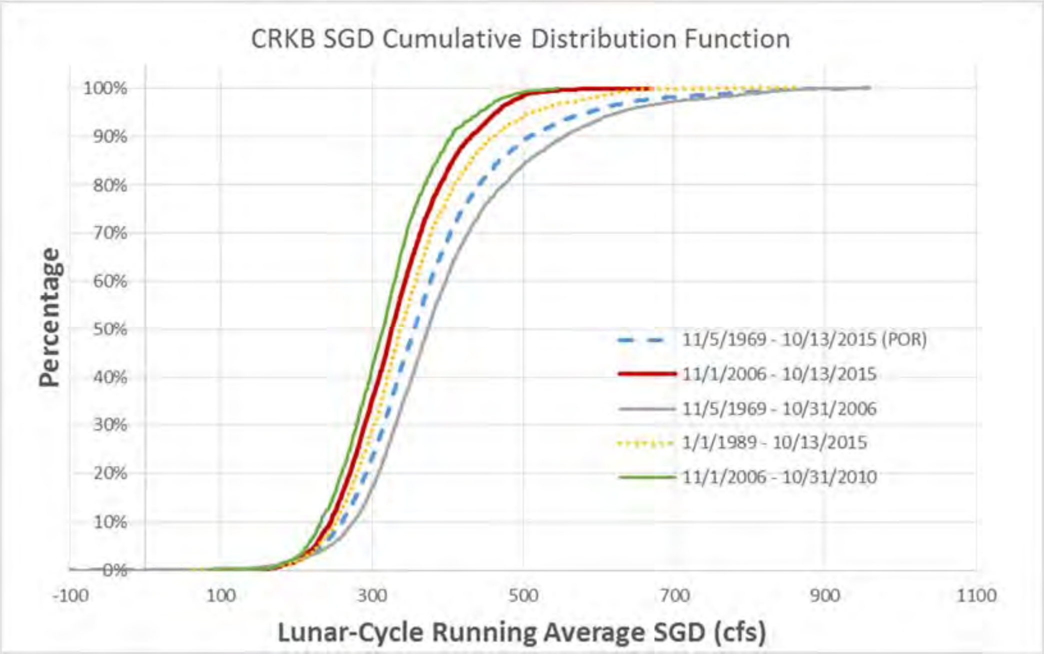

Figure 23 Cumulative distribution functions of lunar-cycle running averages of the total SGD for periods during 11/5/1969 – 10/13/2015, 11/1/2006 – 10/13/2015, 11/5/1969 – 10/31/2006, 1/1/1989 – 10/13/2015, and 11/1/2006 – 10/31/2010.

6. Conclusion

For a sound management of the water resources in Crystal River/Kings Bay, a regulatory minimum flow needs to be established; however, to set a minimum flow, a flow record of the system need to be known beforehand. Just like that the cleverest housewife cannot cook without rice, it is impossible to manage flow to Crystal River/Kings Bay without any knowledge of the flow rate to the system.

Unfortunately, Crystal River/Kings Bay is such an estuary for which a reliable flow data record does not exist. As such, it is necessary to synthesize flow entering the water body, of which over 99% are SGDs from the numerous spring vents on the bottom of Kings Bay. Based on field measurement of fluxes at two controlling cross sections in Kings Bay, an empirical formula relating the SGD with the surface water level in Kings Bay and the groundwater level in ROMP TR21-3 was obtained. This empirical formula was used to estimate real-time SGDs from all spring vents in a hydrodynamic model that simulated circulation, salinity transport processes, and thermodynamics in Crystal River/Kings Bay for a 34-month period. From the total SGD output of the model simulation, empirical formulas relating the total SGD with the head difference between the groundwater and surface water levels were derived. These empirical formulas were used here to hindcast the total SGD back to November 1969.

Because of the lack of water level data in Kings Bay prior to November 2006 and groundwater level data in ROMP TR21-3 prior to May 1979, it is necessary to first hindcast both the surface water land groundwater levels back to November 1969. The former was done using available tidal data at the Inglis Dam downstream stations by the SWFWMD and the USGS as well the Cedar Key station by the NOAA, while th elater was done using available groundwater level data at the Lecanto 7 well. An analysis of available tidal data shows that tides in Kings Bay in Kings Bay are linearly correlated with tides two hour earlier at the downstream side of the Inglis Dam in the Withlacoochee River with a R^2 value of about 0.93, while they are linearly correlated with tides 2.5 hours earlier at the NOAA Cedar Key station with a R^2 value of about 0.85. A linear regression between the groundwater level in ROMP TR21-3 and that in Lecanto 7 was found to have a R^2 value of 0.623.

Using extended surface water level data in Kings Bay and groundwater level data in ROMP TR21-3, total SGDs are hindcasted back to November 1969 using three empirical formulas that are derived from 24-hour running averages, daily averages, and lunar-cycle running averages of modelled total SGD and the head difference. Comparisons of the hindcasted daily SGD results show that the three formulas generate almost the same hindcasting. The hindcasted daily SGD varied roughly between -112 cfs to 960 cfs, with an average of about 374 cfs and a median of about 356 cfs. Comparisons of CDF plots of the daily SGD during the 9-year period between November 2006 and October 2015 with those of the entire 46-year period show that the overall SGD during the 9-year period was lower than the 46-year average but more close to that of the 26-year period between 1989 and 2015.

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Chen, X., 2014b. Estimate Submarine Groundwater Discharge to Crystal River/Kings Bay in Florida with the Help of a Hydrodynamic Model, *Journal of Marine Science and Engineering*, 2014, **2**: 66-80; doi:10.3390/jmse2010066.

APPENDIX

Chen, X. 2017. An evaluation of effects of flow reduction on salinity and thermal habitats and transport time scales in Crystal River/Kings Bay. Southwest Florida Water Management District, Brooksville, Florida.

An Evaluation of Effects of Flow Reduction on Salinity and Thermal Habitats and Transport Time Scales in Crystal River/Kings Bay

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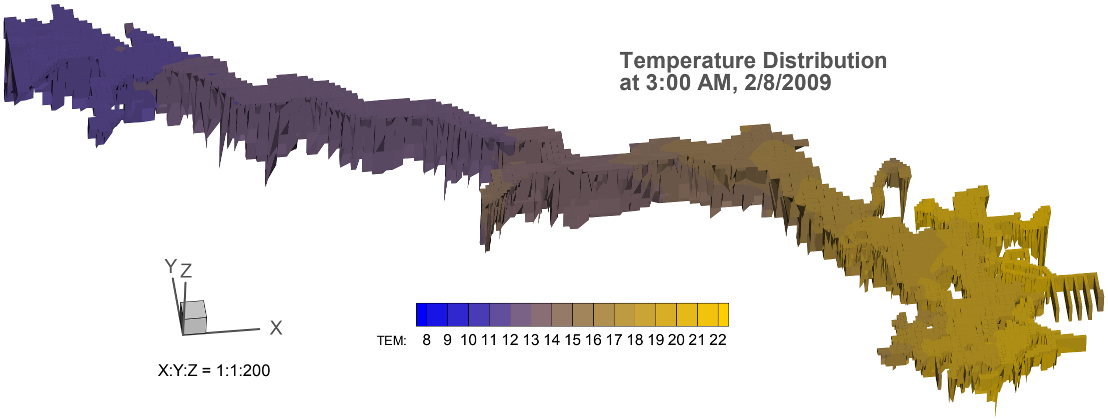

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October 2016 (First Draft)
April 2017 (Revised)

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Summary

Crystal River/Kings Bay (CRKB) is a spring-fed estuary on the Gulf coast of central Florida. In order to evaluate minimum flows and levels (MFLs) for this relatively small but complex system, a three-dimensional hydrodynamic model named UnLESS3D has been developed to study how groundwater flow variation would affect salinity and thermal conditions and transport time scales in the estuary. UnLESS3D is an unstructured Cartesian grid, z-level, cut-cell model that solves flux-based finite difference equations using a free-surface correction method, which is a very efficient numerical scheme because it is unconditionally stable with respect to gravity waves, wind and bottom shear stresses, and vertical eddy viscosity terms.

The simulation domain extends from the mouth of Crystal River to the most south part of Kings Bay, which is about 12 kilometers from the mouth of Crystal River. Hydrological loadings to the estuary consist of mainly submarine groundwater discharges (SGDs) from numerous spring vents, which are distributed at the bottom of roughly eastern half of Kings Bay. Less than 1% of hydrological loadings are from surface water runoff. Because no long-term field measurements of SGDs exists for Crystal River/Kings Bay, a reliable estimate of SGDs is crucial for a successful simulation of circulations, salinity transport processes and thermal dynamics in the estuary. The SGD estimate in Kings Bay was carried out by using an empirical formula that relates SGDs with the head difference between groundwater and surface water levels and the time derivative of tides. This empirical formula is obtained from a careful analysis of available real-time flow data collected at two controlled cross sections which are located at the downstream sides of their respective spring groups during roughly a three-week period in 2009 and verified against those measured at the same locations for almost the same length of time period in 2012.

The UnLESS3D model was calibrated and verified against measured real-time data of water level, salinity and temperature measured in Crystal River/Kings Bay during a 34-month period from April 2007 to February 2010. Simulated water elevations, salinities, temperatures, and cross-sectional flux all match well or very well with measured real-time field data. Because SGDs play a very important role in circulations, salinity transport processes, and thermal dynamics in Crystal River/Kings Bay, the success of the hydrodynamic modeling of in the estuarine system suggests that the use of the empirical formula, which relates the spring discharge with the water level in Kings Bay and the groundwater level measured in a nearby well, in the model is reasonable, despite the fact that there could be some unidentified uncertainties in quantifying long-term flow rates from the spring vents and salinity and temperature variations in spring flows.

Following UnLESS3D calibration and verification, the model was used to simulate hydrodynamics, salinity transport, and thermal dynamics in the estuary for nine years, from October 2006 to October 2015, to evaluate effects of the SGD reduction to salinity and thermal habitats and to transport time scales in Crystal River/Kings Bay. A series of model runs were conducted to simulate salinity and temperature in the estuary for various flow reduction scenarios

and various sea level change forecasts. These model results were processed and analyzed for salinity, water volumes, bottom areas, and shoreline lengths for salinities less than or equal to 0.5, 1, 2, 3, 5, 10, 15 psu were calculated based on model results and known bathymetry. For temperature, water volumes and surface area for temperature ≤ 15 ºC, 15 – 20 ºC, and ≥ 20 ºC were calculated. When calculating water volume and surface area ≥ 20 ºC, a constraint of a minimum of 3.8 ft (1.158 m) warm water (≥ 20 ºC) layer was imposed, i.e., grids with warm water layers less than 1.158 m thick were excluded in the calculation.

Processed results of salinity habitats (water volumes, bottom areas and shoreline lengths for ≤ 0.5, 1, 2, 3, 5, 10, 15 psu) and temperature habitats (water volume and surface area for ≤ 15 ºC, 15 ºC – 20 ºC, and ≥ 20 ºC) were further analyzed to generate a list of allowable flow reduction percentages based on a criterion that favorable salinity and thermal habitats should not suffer a loss of 15% or more from their baseline conditions due to a flow reduction. Details on why a 15% loss of favorable habitats is critical for protecting the estuarine system are beyond the scope of this report and not discussed here.

1. Introduction

Crystal River/Kings Bay is a spring-fed estuary on the Gulf coast of central Florida (Figure 1). It is a relatively small estuarine system, which includes the 2.43 km^2 Kings Bay as its head water and the 10-km long Crystal River that joins Kings Bay with the Gulf of Mexico (SWFWMD, 2000). Crystal River/Kings Bay is a first magnitude spring system, which is defined as having a discharge rate of 2.83 m^{3}sec^{-1} (100 cubic feet per second) or greater (Meinzer, 1927). It is one of the largest spring systems in Florida with a tidally-influenced discharge averaged at about 14 m^{3}sec^{-1}. The system has a very small runoff basin, as spring flows from numerous spring vents and countless hairline fractures at the bottom of Kings Bay account for 99% of the total hydrologic loading to the estuary.

Similar to some other estuaries along the Gulf coast of Florida, Crystal River/Kings Bay estuary is generally well or partially mixed. The system is ecologically very important for some marine species particularly manatees, because a large amount of spring water with a relatively constant temperature of about 22.2 ^{o}C flows to the Kings Bay on a daily basis, attracting many manatees to the area in winter. With approximately 350 manatees inhabiting the spring-fed estuary during the coldest days in winter, it is believed that Crystal River/Kings Bay is the largest natural refuge for manatees in the United States. In order to protect this ecologically valuable springs/estuarine system, a regulatory minimum spring water flow rate needs to be determined and established. For the purpose of minimum flow evaluation of the estuary, circulations, salt transport processes, and thermodynamics need to be simulated.

Because the Crystal River portion of the estuary is relatively narrow and simple (Figure 1), it normally exhibits a vertically two-dimensional circulation pattern, which is typical for narrow estuaries (Prandle, 1985; Jay and Smith, 1990; Chen, 2004a). On the other hand, the Kings Bay portion of the estuary has a distinct three-dimensional flow pattern because of the complexity of the topographic characteristics and the spring flows entering vertically to the bay. Three-dimensional estuarine circulations are mainly caused by the topographic variation, barotropic and baroclinic forces, Coriolis effect, wind, buoyancy, tides, freshwater inflows, and turbulence mixing (Pritchard, D.W., 1989; Dyer, 1997), and submarine groundwater discharges generally play a relatively less important role in shaping the 3D flow patterns in most estuaries; however, Kings Bay is an exception, with its 3D circulation pattern being essentially determined by a relatively large amount of SGDs out of the many spring vents and hairline fractures at the bottom of the bay. The hydrologic loading to Crystal River/Kings Bay is almost entirely from SGDs, which transfer ground water from the Floridian aquifer to the estuary, with different levels of salt, temperature, nutrients, and other biochemical contents. The influence of SGDs on hydrodynamics, salinity transport processes, thermodynamics, and biogeochemical processes in Crystal River/Kings Bay is much more pronounced than those in most other estuaries in Florida.

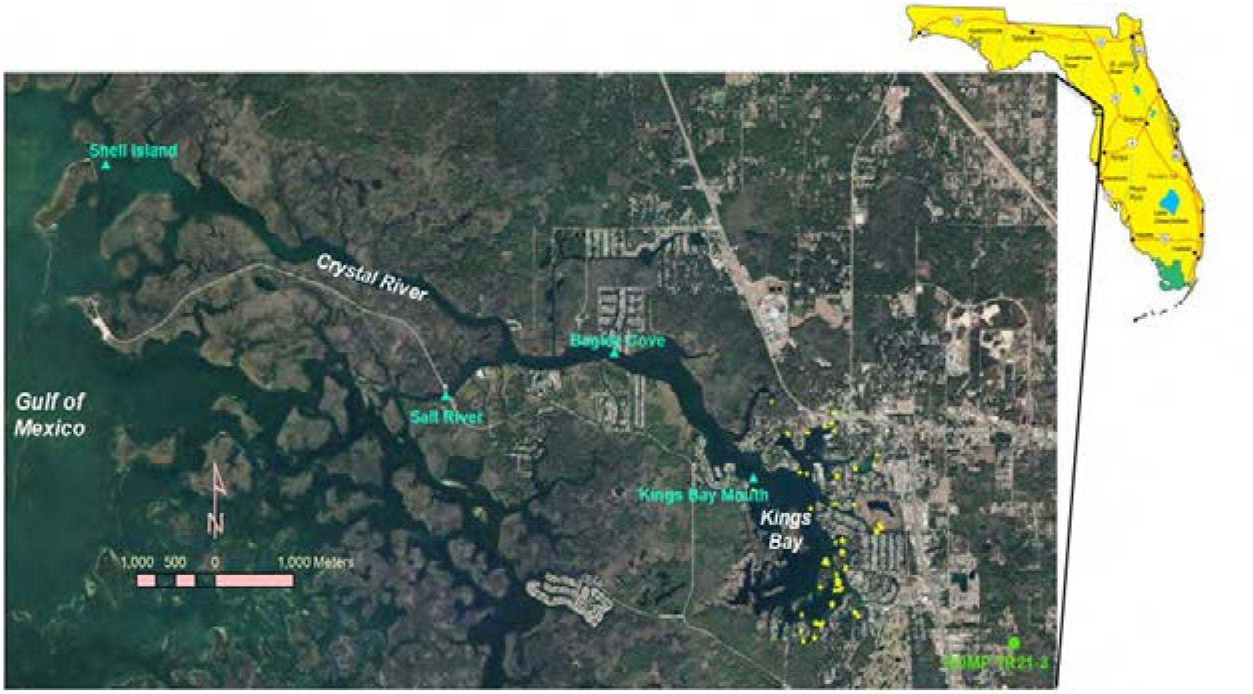

Figure 1 The Crystal River/Kings Bay estuarine system on the Gulf coast of central Florida. The solid triangles indicate USGS stations where water levels, salinities, and temperatures are measured. Asterisks in the eastern part of Kings Bay denote locations of detected spring vents. The solid circle in the bottom right of the photo is the location of the ROMP TR21-3, where groundwater level is measured.

Most previous coastal and estuarine hydrodynamic modeling studies did not consider effects of SGDs (Johnson et al, 1991; Blumberg and Kim, 2000), partly because SGDs are much lower than river flows and precipitations for these estuaries and partly because SGDs are very difficult to quantify in many cases. In an effort to set minimum flow for Blue Spring, Florida, Sucsy et al. (1998) simulated hydrodynamics in the spring run and a short segment of the St. Johns River estuary using the 3D EFDC model by Hamrick (1992). Ganju et al. (2011) applied the 3D model ROMS (Warmer et al., 2008) to West Falmouth Harbor, Massachusetts to verify their tidal and groundwater flux estimates to the estuary based on velocity and salinity measurements. Hammett et al. (1996) performed a hydrodynamic simulation using SIMSYS2D, a horizontal two-dimensional model by Leedertse and Gritton (1971), to study circulation and flushing characteristics of Kings Bay.

Because of the three-dimensional circulation pattern in Kings Bay, a 3D hydrodynamic model needs to be developed for the Crystal River/Kings Bay in the minimum flow evaluation process for the estuary. Considering the complex geometry of Kings Bay, a three-dimensional unstructured Cartesian grid hydrodynamic model (Chen, 2011) has been developed for the Crystal River/Kings Bay system. The source code of the unstructured Cartesian grid model is named UnLESS3D, because many numerical features (e.g., the use of cut cells, etc.) involved in the unstructured Cartesian grid model are similar to the previously developed, structured Cartesian grid model LESS3D (Chen, 2003a, 2003b).

Like LESS3D, the UnLESS3D model is a flux-based finite difference model that uses a hybrid grid approach to fit the bottom topography and shorelines and, at the same time, has the flexibility of discretizing complex geometries with Cartesian grids that can be arbitrarily downsized in the two horizontal directions simultaneously. The hybrid grid approach involves a cut-cell method (Chen, 2004b), which uses rectangular grids for the inner domain and cut-cell grids with bilinear interpolation for the boundary areas. The cut-cell method can effectively fit the bottom bathymetry and dynamically track the shoreline position.

Due to its ability of arbitrarily splitting grids in the two horizontal directions simultaneously without any orthogonality constrain imposed on the grids, UnLESS3D provides better flexibility on the arrangement of the computational mesh than other existing unstructured grid models (e.g., Casulli and Zanolli, 1998; Chen et al., 2003; Zhang et al., 2004). The nonexistence of the orthogonality constrain on grids greatly abates the grid generation difficulty that often occurs in applying other unstructured grid models. Because of the use of Cartesian grids, grid generation for UnLESS3D becomes a very simple task in practical applications of the model and can be easily carried out with the help of a geographic information system.

As mentioned in Chen (2011), the term "Cartesian grid" is used in a mathematically less strict way here, as it simply means that the elements are regular rectangles (in 2D) or bricks (in 3D) and not necessarily have to be uniform squares or cubes, which are mathematically strict Cartesian grids. Literature reviews on various popular structured and unstructured hydrodynamic models and their applications to different water bodies have been provided in previous publications (e.g., Chen, 2007 and 2011).

In the following, a brief description of the UnLESS3D model is provided in Section 2, followed by a discussion of the physical characteristics of the Crystal River/Kings Bay estuary in Section 3, which also contains available field data collected in the estuary. Section 4 describes model calibration and verification, including comparisons of modeled water levels, salinities, temperatures, and cross-sectional flux to measured real-time data. Section 5 presents scenario simulations and analyses of model results of these scenario runs. Section 6 considers effects of the sea level rise on the MFL evaluation results. Conclusions of this modeling effort for the MFL evaluation of Crystal River/Kings Bay are summarized at the end of the report in Section 7.

2. The UnLESS3D Model

This section is a brief description of the UnLESS3D model used in the MFL evaluation for the Crystal River/Kings Bay system. A more detailed description of the model can be found in Chen (2011).

2.1 Governing Equations

The three-dimensional unstructured Cartesian grid model solves the Reynolds Averaged Navier-Stokes (RANS) equations for free surface flows in lakes, rivers, estuaries, and coastal waters. Using the hydrostatic pressure assumption and the Boussinesq approximation, governing equations for shallow waters include the following continuity, momentum, and transport equations:

$$\frac{\partial u}{\partial x}+\frac{\partial v}{\partial y}+\frac{\partial w}{\partial z}=0 \tag{1}$$

$$\frac{du}{dt}=-fv-\frac{1}{\rho_o}\frac{\partial p}{\partial x}+\frac{\partial}{\partial x}(A_h\frac{\partial u}{\partial x})+\frac{\partial}{\partial y}(A_h\frac{\partial u}{\partial y})+\frac{\partial}{\partial z}(A_v\frac{\partial u}{\partial z}) \tag{2}$$

$$\frac{dv}{dt}=fu-\frac{1}{\rho_o}\frac{\partial p}{\partial y}+\frac{\partial}{\partial x}(A_h\frac{\partial v}{\partial x})+\frac{\partial}{\partial y}(A_h\frac{\partial v}{\partial y})+\frac{\partial}{\partial z}(A_v\frac{\partial v}{\partial z}) \tag{3}$$

$$p=g\int_z^\eta \rho d\xi \tag{4}$$

$$\frac{dc}{dt}=\frac{\partial}{\partial x}(B_h\frac{\partial c}{\partial x})+\frac{\partial}{\partial y}(B_h\frac{\partial c}{\partial y})+\frac{\partial}{\partial z}(B_v\frac{\partial c}{\partial z})+S_s+R \tag{5}$$

where t is time; p is pressure; x, y, and z represent the Cartesian coordinates in the eastward, northward, and upward directions, respectively; u, v, and w are the velocity components in x-, y-, and z-directions, respectively; ρ is density which is a function of temperature and salinity (UNESCO,1983); ρ_o is the reference density; η, f, and g are respectively the free surface elevation, the Coriolis parameter, and the gravitational acceleration of the Earth; c denotes concentration and can be temperature, salinity, suspended sediment concentrations, nutrient concentrations, etc.; S_s and R represent the sink/source terms and the reaction terms, respectively; A_h and B_h are horizontal eddy viscosity and diffusivity, respectively; A_v and B_v are vertical eddy viscosity and diffusivity, and d/dt represents the material derivative.

If the concentration simulated involves settling, w in the advective term in Equation (5) includes the settling velocity of the material. Equation (1) is the continuity equation and can be integrated over the water depth, leading to an equation for the free surface

$$\frac{\partial \eta}{\partial t} + \frac{\partial}{\partial x}\left(\int_{h_o}^{\eta} u dz\right) + \frac{\partial}{\partial y}\left(\int_{h_o}^{\eta} v dz\right) = r + q \tag{6}$$

where h_o is the bottom elevation, r is the net rain intensity (precipitation minus evaporation), and q represents the flux through the bed.

Boundary conditions in the horizontal directions are specified with either free surface elevations or velocities for open boundaries. At solid boundary, normal velocity is set to zero and the pressure gradient in the normal direction is set to zero. Boundary conditions at the free surface and at the bottom are implicitly specified by wind and bottom shear stresses, respectively. Details on specifying boundary conditions in the model can be found in Chen (2003a and 2003b).

3.2 Numerical Scheme

The use of the unstructured Cartesian grids allows the grid size to be varied in two horizontal directions simultaneously. The horizontal view of the model mesh generally has a pavement-like pattern, with each brick (or box) being cut by the bottom and/or shoreline (Figure 2). Same as in the LESS3D model (Chen 2003a, 2003b, 2004b), a colocated arrangement of model variables was used, where all variables (velocity components, concentrations, pressure, and density, etc.) are placed at the center of the grid cell. The treatment of grid cells that involve the bottom and the shoreline is also the same as that in LESS3D (Chen, 2004b), with the bottom face being determined using a bi-linear interpolation from the given bottom elevations at the four corners of the rectangular grid.

The UnLESS3D model solves Equations (1) through (3) using flux-based finite difference equations for control volumes (called computational cells), instead of the Cartesian grid cells plotted with dotted lines in Figure 2. Internal cells are all computational cells; however, a computational cell is not always necessarily the same as a Cartesian grid cell. For example, the multiple-faced control volume ABCD1D2A'B'C' shown in Figure 2 is a computational cell. Unlike a Cartesian grid cell that is always a brick (or box) in 3D, a computational cell could be a multiple-faced cell for which the model solves the governing equations.

The model uses a semi-implicit scheme based on the free surface correction (FSC) method (Chen, 2003a), which involves a predictor-corrector procedure. The FSC method is unconditionally stable with respect to gravity waves, wind and bottom shear stresses, and vertical eddy viscosity terms, making UnLESS3D a very efficient free-surface hydrodynamic model. The convective terms are solved employing a semi-Lagrangian approach, with which the water particle at the centroid of the cell at the new time step is tracked back to its original location at the old time point before its original velocity is interpolated from the velocity field at the old time point.

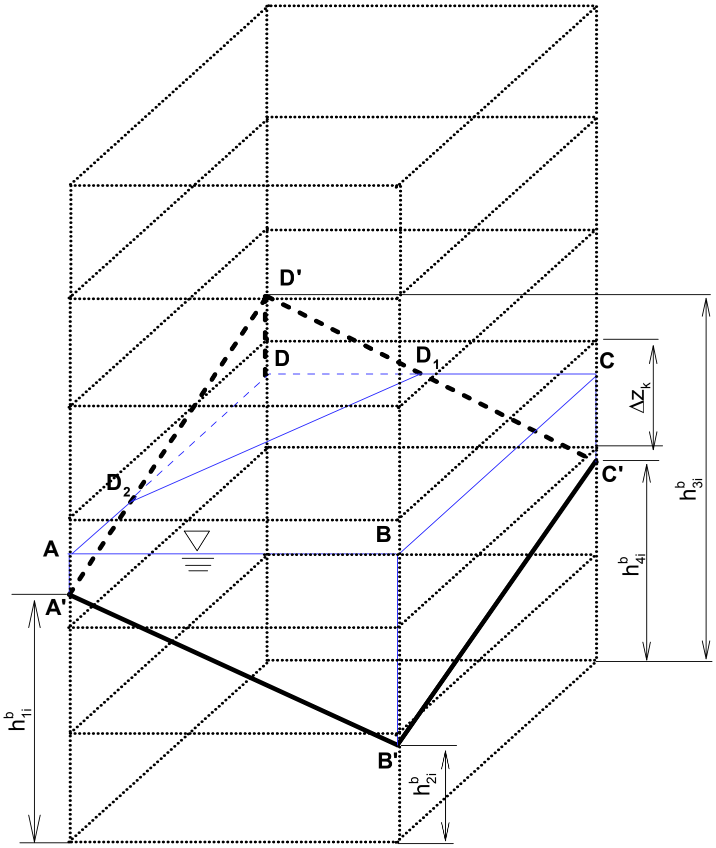

Figure 2. A boundary grid with one corner emerged and three corners submerged. ABCD and A’B’C’D’ represent the water surface and the bottom face, respectively, while $\mathbf{h}^{\mathbf{b}}_{\mathbf{1i}}$, $\mathbf{h}^{\mathbf{b}}_{\mathbf{2i}}$, $\mathbf{h}^{\mathbf{b}}_{\mathbf{3i}}$, and $\mathbf{h}^{\mathbf{b}}_{\mathbf{4i}}$ denote bottom elevations at Points A’, B’, C’, and D’, respectively.

By treating each computational cell as a control volume, the flux-based finite difference equations are derived from the mass and momentum balances of the computational cell. Using *i* and *k* as the index of the unstructured grids in the horizontal plane and the index of the vertical layer, respectively, the flux-based finite difference equations for the momentum equations for the predictor step are as follows

$$\begin{aligned}\frac{u_{cc}^{n+1}-\tilde{u}_{i,k}^{n}}{\Delta t} &= -fv_i^n - \frac{\theta_1}{\rho \mathcal{V}_{i,k}^n}\oiiint_{\mathcal{V}}\left(\frac{\partial p}{\partial x}\right)_i^{n+1} d\mathcal{V} - \frac{1-\theta_1}{\rho \mathcal{V}_{i,k}^n}\oiiint_{\mathcal{V}}\left(\frac{\partial p}{\partial x}\right)_i^{n} d\mathcal{V} + H(u) \\ &+ \frac{1}{V_{i,k}^n}[a_{31i,k}^n(A_v\frac{\partial u}{\partial z})_{31i,k}^{n+1} - a_{30i,k}^n(A_v\frac{\partial u}{\partial z})_{30i,k}^{n+1}]\end{aligned} \tag{7}$$

$$\begin{aligned}\frac{v_{cc}^{n+1}-\tilde{v}_{i,k}^{n}}{\Delta t}&=fu_i^n-\frac{\theta_1}{\rho \not{V}_{i,k}^{n}}\oiiint_{\not{V}}\left(\frac{\partial p}{\partial y}\right)_i^{n+1}d\not{V}-\frac{1-\theta_1}{\rho \not{V}_{i,k}^{n}}\oiiint_{\not{V}}\left(\frac{\partial p}{\partial y}\right)_i^{n}d\not{V}+H(v)\\&+\frac{1}{\not{V}_{i,k}^{n}}[a_{31i,k}^{n}(A_v\frac{\partial v}{\partial z})_{31i,k}^{n+1}-a_{30i,k}^{n}(A_v\frac{\partial v}{\partial z})_{30i,k}^{n+1}]\end{aligned}\tag{8}$$

where superscripts n and n+1 denote values at n-th and n+1-th time steps, respectively; subscript cc denotes the centroid of the computational cell; u_{cc}^{n+1} and v_{cc}^{n+1} are u- and v-velocities of the water particle located at the centroid of the computational cell at the new time step, while $\tilde{u}_{i,k}^{n}$ and $\tilde{v}_{i,k}^{n}$ are the velocity components of the same water particle at the previous (n-th) time step; θ_1 is an implicit parameter for momentum equations; $\not{V}$ is the volume of the computational cell; a is the area of the side face of the computational cell ($a_{30i,k}^{n}$ and $a_{31i,k}^{n}$ are areas of the bottom and top faces, respectively); and $H(\ )$ is an operator representing the explicit treatment of the horizontal eddy viscosity terms

$$H(\,)=\frac{1}{\not{V}_{i,k}^{n}}\{[a(A_h\frac{\partial}{\partial x})]_{11i,k}^{n}-[a(A_h\frac{\partial}{\partial x})]_{10i,k}^{n}+[a(A_h\frac{\partial}{\partial y})]_{21i,k}^{n}-[a(A_h\frac{\partial}{\partial y})]_{20i,k}^{n}\}\tag{9}$$

where subscript groups (11i,k), (10i,k), (21i,k), and (20i,k) represent the east, west, north , and south faces of the grid cell. Because of the variation of the surface elevation, $\not{V}$- and a-values at each time point need to be calculated for the surface cells.

In using the FSC method to solve Equations (7) and (8), an intermediate velocity field, denoted as $u_{i,k}^{n+*}$ and $v_{i,k}^{n+*}$, is first solved by setting $\theta_1 = 0$:

$$\frac{u_{cc}^{n+*}-\tilde{u}_{i,k}^{n}}{\Delta t}=-fv_i^n-\frac{1}{\rho \not{V}_{i,k}^{n}}\oiiint_{\not{V}}\left(\frac{\partial p}{\partial x}\right)_i^{n}d\not{V}+H(u)+\frac{1}{V_{i,k}^{n}}[a_{31i,k}^{n}(A_v\frac{\partial u}{\partial z})_{31i,k}^{n+1}-a_{30i,k}^{n}(A_v\frac{\partial u}{\partial z})_{30i,k}^{n+1}]\tag{10}$$

$$\frac{v_{cc}^{n+*}-\tilde{v}_{i,k}^{n}}{\Delta t}=fu_i^n-\frac{1}{\rho \not{V}_{i,k}^{n}}\oiiint_{\not{V}}\left(\frac{\partial p}{\partial y}\right)_i^{n}d\not{V}+H(v)+\frac{1}{\not{V}_{i,k}^{n}}[a_{31i,k}^{n}(A_v\frac{\partial v}{\partial z})_{31i,k}^{n+1}-a_{30i,k}^{n}(A_v\frac{\partial v}{\partial z})_{30i,k}^{n+1}]\tag{11}$$

Subtracting Equations (10) and (11) from Equations (7) and (8) yields the following two equations for the difference between the final velocity field (with a non-zero θ_1) and the intermediate velocity field (with a zero θ_1):

$$\frac{u_{cc}^{n+1}-u_{cc}^{n+*}}{\Delta t}=-g\theta_1\frac{\partial(\Delta\eta)}{\partial x}+\frac{\partial}{\partial z}[A_v\frac{\partial(u^{n+1}-u^{n+*})}{\partial z}]\tag{12}$$

$$\frac{v_{cc}^{n+1}-v_{cc}^{n+*}}{\Delta t}=-g\theta_1\frac{\partial(\Delta\eta)}{\partial y}+\frac{\partial}{\partial z}[A_v\frac{\partial(v^{n+1}-v^{n+*})}{\partial z}] \tag{13}$$

where $\Delta\eta\ (=\eta^{n+1}-\eta^{n})$ is the increment of the free surface over the time span Δt; η^nandη^{n+1} are respectively free surface locations at the n- and n+1-the time steps.

Combining the above two equations with Equation (6), a two-dimensional Poisson equation for the free surface increment can be obtained

$$\eta_i^{n+1}-\eta_i^{n+*}=\frac{g\Delta t^2\theta_1\theta_2}{a_i^{\tau}}[\left[\varsigma\frac{\partial(\Delta\eta)}{\partial x}\right]_{11i}-\left[\varsigma\frac{\partial(\Delta\eta)}{\partial x}\right]_{10i}+\left[\varsigma\frac{\partial(\Delta\eta)}{\partial y}\right]_{21i}-\left[\varsigma\frac{\partial(\Delta\eta)}{\partial y}\right]_{20i}] \tag{14}$$

where superscripts 11i, 10i, 21i, and 20i represent the east, west, north, and south sides of the horizontal grid i; a_i^{τ} is the instantaneous wetted surface area for the horizontal grid i; ς is the sum of the side face areas of all the grid cells of the water column in a certain direction, θ_2 represents the implicitness for the continuity equation; and η_i^{n+*} is an intermediate free surface, which is calculated from the intermediate velocity field using Equation (6).

After solving the Poisson equation for the free surface increment, the final free surface is found. The final velocity field at the n+1-th time step is then calculated from Equations (12) and (13) with known intermediate velocity and the free surface increment.

For the transport equation, the flux-based finite difference equation takes the following form

$$\begin{aligned}\frac{\not{V}_{i,k}^{n+1}c_{i,k}^{n+1}-\not{V}_{i,k}^{n}c_{i,k}^{n}}{\Delta t}&=\mathbf{F}_{10i,k}^{n}-\mathbf{F}_{11i,k}^{n}+\mathbf{F}_{20i,k}^{n}-\mathbf{F}_{21i,k}^{n}+\mathbf{F}_{30i,k}^{n}-\mathbf{F}_{31i,k}^{n}\\&+a_{11i,k}^{n}(B_h\frac{\partial c}{\partial x_1})_{11i,k}^{n}-a_{10i,k}^{n}(B_h\frac{\partial c}{\partial x_1})_{10i,k}^{n}+a_{21i,k}^{n}(B_h\frac{\partial c}{\partial x_2})_{21i,k}^{n}\\&-a_{20i,k}^{n}(B_h\frac{\partial c}{\partial x_2})_{20i,k}^{n}+a_{31i,k}^{n}(A_v\frac{\partial c}{\partial x_3})_{31i,k}^{n+1}-a_{30i,k}^{n}(A_v\frac{\partial c}{\partial x_3})_{30i,k}^{n+1}+S_s+R\end{aligned} \tag{15}$$

where $\mathbf{F}_{11i,k}$, $\mathbf{F}_{21i,k}$ and $\mathbf{F}_{31i,k}$ are advective fluxes of the material flowing out of the cell through the east, north, and top faces, respectively, and $\mathbf{F}_{10i,k}$, $\mathbf{F}_{20i,k}$ and $\mathbf{F}_{30i,k}$ are advective fluxes of the material entering the cell through the west, south, and bottom faces, respectively.

3. Physical Characteristics of CRKB and Field Data

3.1 Physical characteristics of Crystal River/Kings Bay

Kings Bay (Figure 1) is a small embayment located on the west coast of Florida with a surface area of less than 2.5 km^2. It receives only insignificant amount of surface water runoff from a watershed of about 178 km^2. About 99% of its freshwater resource comes from numerous spring vents at the bottom of Kings Bay or around the bay through spring runs.

Spring flows exit Kings Bay at its northwestern corner to the Gulf of Mexico through Crystal River, which is about 10 km long and runs northwestward to connect Kings Bay with the Gulf of Mexico. Crystal River has a relatively simple shape with a typical depth of 2.5 – 4 m. At about two third from its mouth, the Crystal River is connected to the Salt River, which provides a short cut to the Gulf of Mexico for the Crystal River (Figure 1).

While the Crystal River is a relatively simple riverine system, the small Kings Bay is a quite complex water body because it involves several islands, spring runs, finger channels, a tidal flat, about 70 detectable spring vents, and countless hairline fractures that contribute an unidentified fraction of spring water to the system. The springshed of the Crystal River/Kings Bay system covers an area of around 640 km^2, which is much larger than the surface area of Crystal River/Kings Bay. The average depth of Kings Bay is about of 2.44 m, but the southwestern portion of the bay is a shallow tidal flat which can be exposed to air during low tides (Hammett et al., 1996). Since about 50 years ago, the area around Kings Bay has been undergoing significant urbanization. Extensive dredge-and-fill activities have altered much of Kings Bay and portions of the Crystal River shorelines. Sea walls and canal systems were built to provide residential and commercial boat access and to create waterfront residential lots. Dead-end channels were dredged around the bay except for the area near the shallow tidal flat. Most noticeably are the five finger channels on the east side of the bay, which are about 23 m wide, 380 – 440 m long, and 1.83 m deep. All these developments have changed water circulations in Kings Bay and reduced the total acreage of the natural wetland.

3.2 Field data

Available field data for the hydrodynamic modeling of the Crystal River/Kings Bay system using UnLESS3D included real-time data of water elevation, salinity, and temperature at four United States Geological Survey (USGS) stations in the estuary. Financially supported by the Southwest Florida Water Management District (SWFWMD), the USGS installed measurement instruments at the Shell Island station near the mouth of the Crystal River, the Salt River station at County Road 44, the Bagley Cove station near the town also called Crystal River, and the mouth of Kings Bay station to record these data with a time interval of 15 minutes. Locations of the four USGS stations are marked with solid triangles on the aerial photo in Figure 1. At the Bagley Cove station, real-time data are available since August 2002, while at the other three stations, real-time data are available since around October 2006.

Salinity and temperature data were collected at the top and bottom layers at the mouth of Kings Bay and Salt River stations, while at the Shell Island station these data were collected at three water depths (top, middle, and bottom). At Bagley Cove where the USGS started to collected real-time data about four years earlier, only bottom layer salinity and temperature data were recorded.

Table 1 lists elevations of the salinity/temperature sensors, in cm, NAVD 88, at the four USGS stations. Despite the fact that there are a few missing data periods and some problematic data points in the dataset, these USGS data are overall of good quality and appropriate for a successful application of the UnLESS3D model to Crystal River/Kings Bay.

Table 1 Elevations of salinity/temperature sensor (in cm, NAVD 88) at the four USGS stations in Cryatsl River/Kings Bay. N/A stands for not available here.

	Shell Island	**Salt River**	**Bagley Cove**	**Mouth of Kings Bay**
Top-layer sensor	-113.08	-48.77	N/A	-120.40
Middle-layer sensor	-161.85	N/A	N/A	N/A
Bottom-layer sensor	-234.70	-213.36	-246.89	-303.28

For simplicity and clarity, only two months of real-time field data measured during August 2 – October 1, 2007 are presented here, as those measured parameters have similar patterns during other periods of time. Plots of field data for other periods are presented in Appendix A. Figure 3-Figure 6 show measured water levels, salinities, and temperatures at the Shell Island, Salt River, Bagley Cove and the mouth of Kings Bay stations, respectively during August 2 – October 1, 2007. At the Bagley Cove station, the USGS also maintained an Acoustic Doppler Current Profile (ADCP) sensor to obtain the real-time cross-sectional flux in the Crystal River at the site. Time series of USGS cross-sectional flux at Bagley Cove during August 2 – October 1, 2007 are plotted in Figure 7.

From the real-time data shown in Figure 3 - Figure 6, it can be seen that tidal signals are evident in water level, salinity, temperature, and cross-sectional flux data in the estuarine system. The high-frequency tidal variability includes both diurnal and semi-diurnal variations. Non-tidal variability with much lower frequencies can be seen in these figures, too. These low-frequency signals are mainly influenced by meteorological and hydrological characteristics of the region, with a distinctive seasonal and inter-annual variability (see later in this section for more discussions on the climatology of the region). Disturbances caused by episodic storm events can also be seen in water level, salinity, and water temperature data measured in Crystal River/Kings Bay. For example, a storm event moved to the region on September 20, 2007 (around Hour 67680). As a result, noticeable increases in water level and salinity and a decrease of nearly 5 ^{o}C in water temperature can clearly be seen in measured data all over the estuarine system.

Similar to other estuaries along the Gulf coast of central Florida, tides in Crystal River/Kings are micromareal. The Shell Island station, which is near the mouth of Crystal River, has the largest tidal range of about 100 cm for the entire Crystal River/Kings Bay system. During October 2006 – February 2010, tides at this station typically range between a mean lower low water (MLLW) of -48.6 cm, NAVD 88 to a mean higher high water (MHHW) of 51.4 cm, NAVD 88. On the other hand, the Salt River station at CR 44 has the smallest tidal range of about 86 cm among the four USGS stations, with the MLLW and MHHW being respectively -41.4 cm and 44.7 cm, NAVD 88 during October 2006 – February 2010. The Bagley Cove and the mouth of Kings Bay stations have tidal ranges of 87.1 cm and 90.5 cm, respectively during the same time period. The MLLW and MHHW at the Bagley Cove station are -41.6 cm and 45.5 cm, NAVD 88, respectively, while they are -42.6 cm and 47.9 cm, NAVD 88 at the mouth of Kings Bay station.

Salinity data measured in Crystal River/Kings Bay exhibit dramatic variations, both spatially and temporally. At the Shell Island station, salinity generally has a 15-psu range of variation during a 24-hour period, while at the Salt River station this daily variation range is about 10 psu. Salinity at the mouth of Kings Bay station typically varies between 2 psu to 5 psu most of the time, with its peak values generally being larger than 5 psu during spring tides and lower than 5 psu during neap tides. Spring and neap tidal signals are also evident in measured salinity at the Bagley Cove station, where during spring tides, daily salinity maximum reaches 15 psu or higher, but during neap tides, daily salinity maximum normally stays about 10 psu or lower.

Occasionally, salinity at the mouth of Kings Bay station can reach 15 psu or higher during storm events when saltier water from the Gulf is pushed further upstream to Kings Bay, resulting in the sudden death of submerged aquatic plants which are normally found in freshwater or brackish water environments such as Kings Bay (SWFWMD, 2000). The decomposing tissues of aquatic plants can release nutrients and be easily suspended in the water column, often causing reduced water clarity in Kings Bay. Field observations have shown that major storm events were generally followed by reductions of submerged aquatic vegetation, increases of chlorophyll concentrations and reduced water clarity in Kings Bay

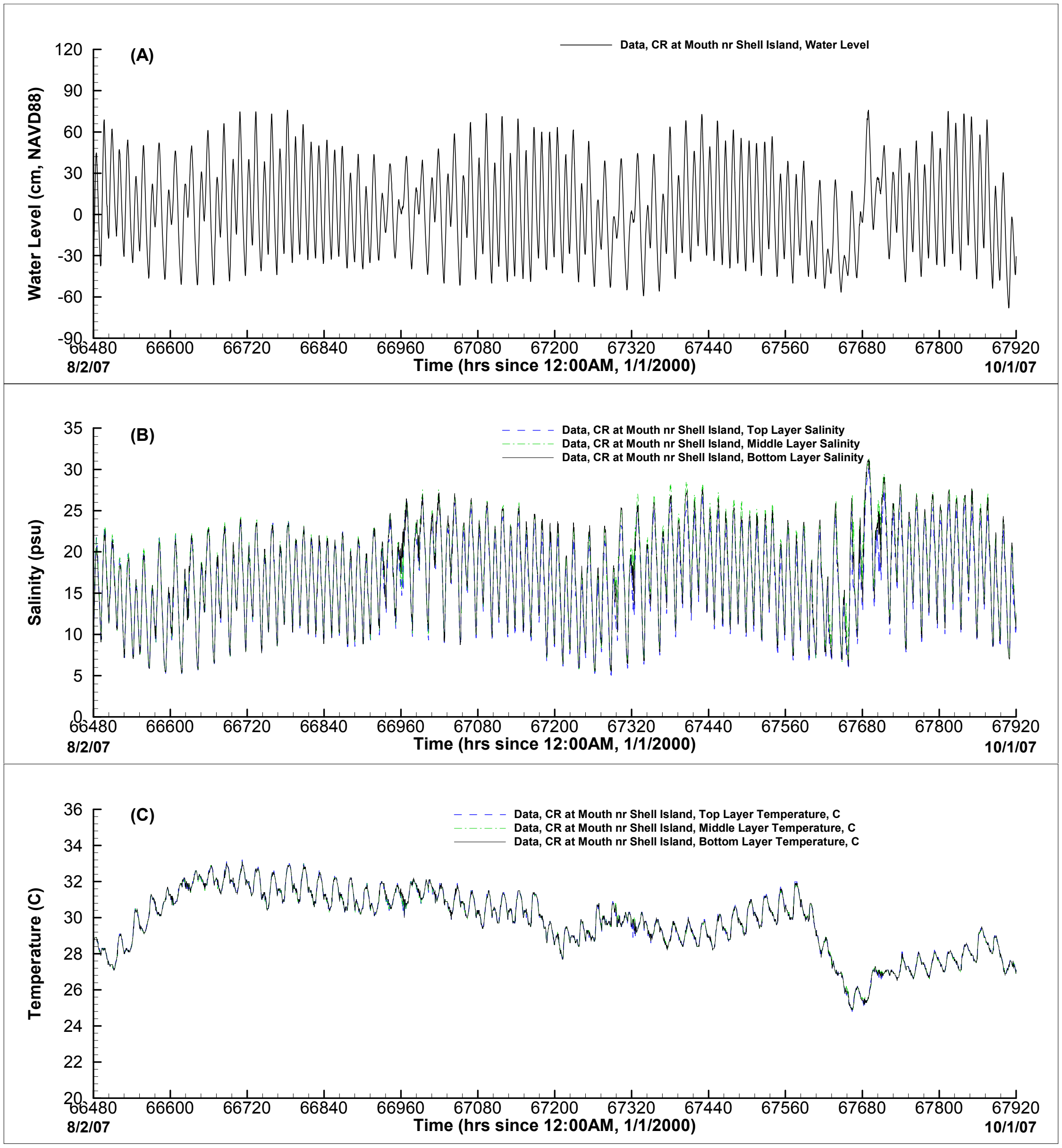

Figure 3 Time series of measured water level (A), salinities at three depths (B), and temperatures at three depths (C) at the USGS Crystal River near Shell Island station during August 2 – October 1, 2007.

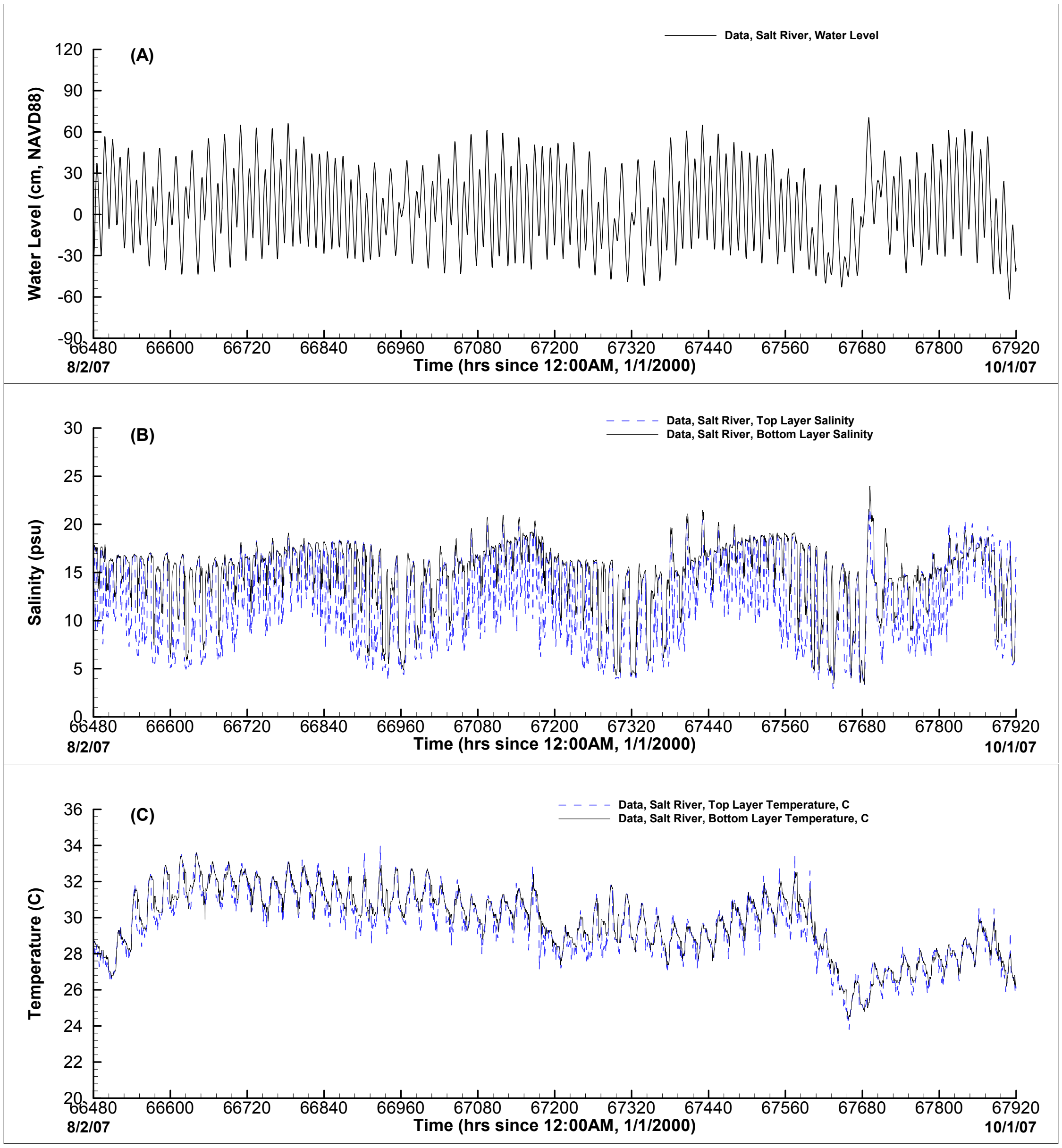

Figure 4 Time series of measured water level (A), salinities at two depths (B), and temperatures at two depths (C) at the USGS Salt River station during August 2 – October 1, 2007.

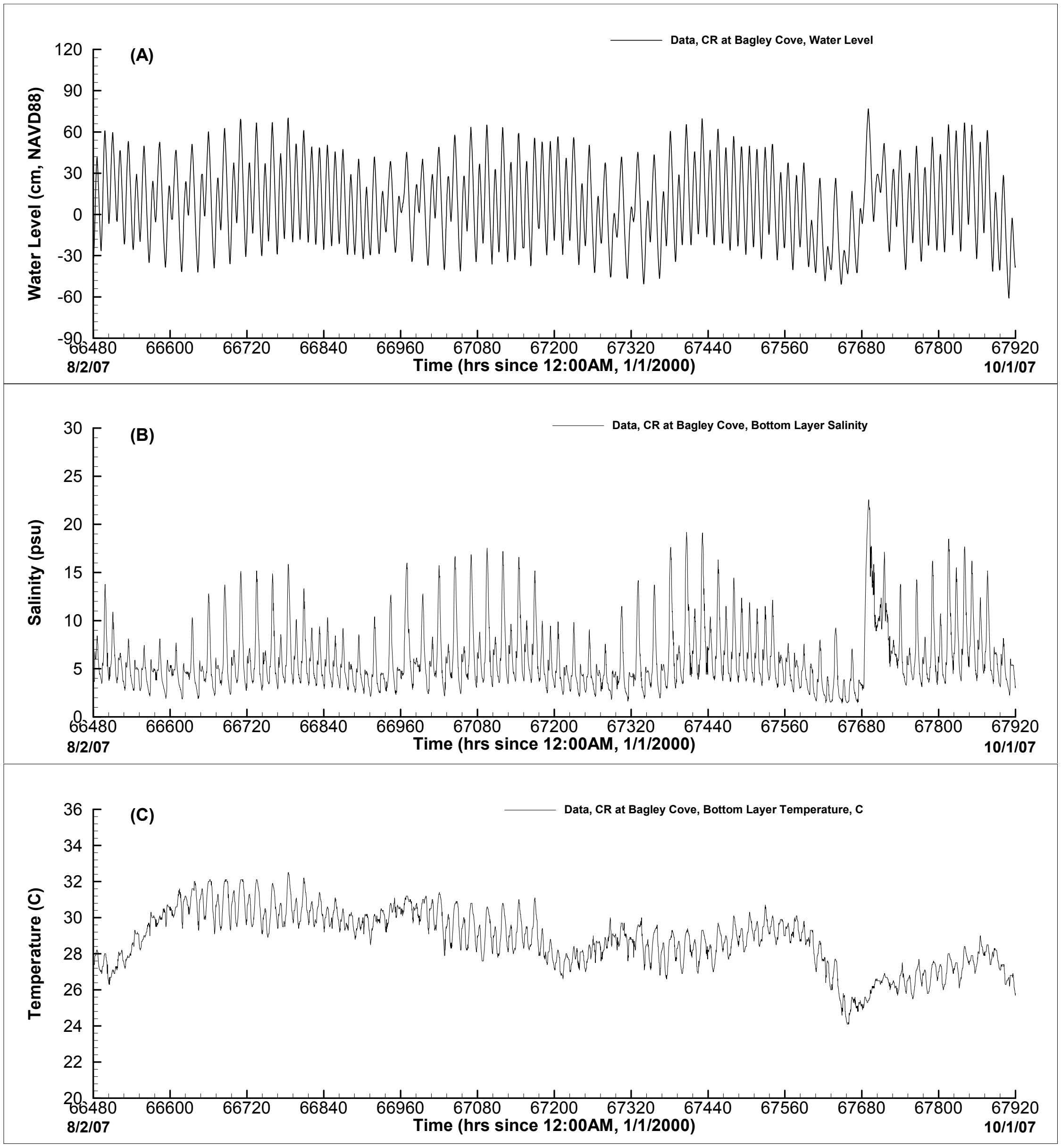

Figure 5 Time series of measured water level (A), bottom-layer salinity (B), bottom-layer temperature (C), and (D) cross-sectional flux at the USGS Bagley Cove station during August 2 – October 1, 2007.

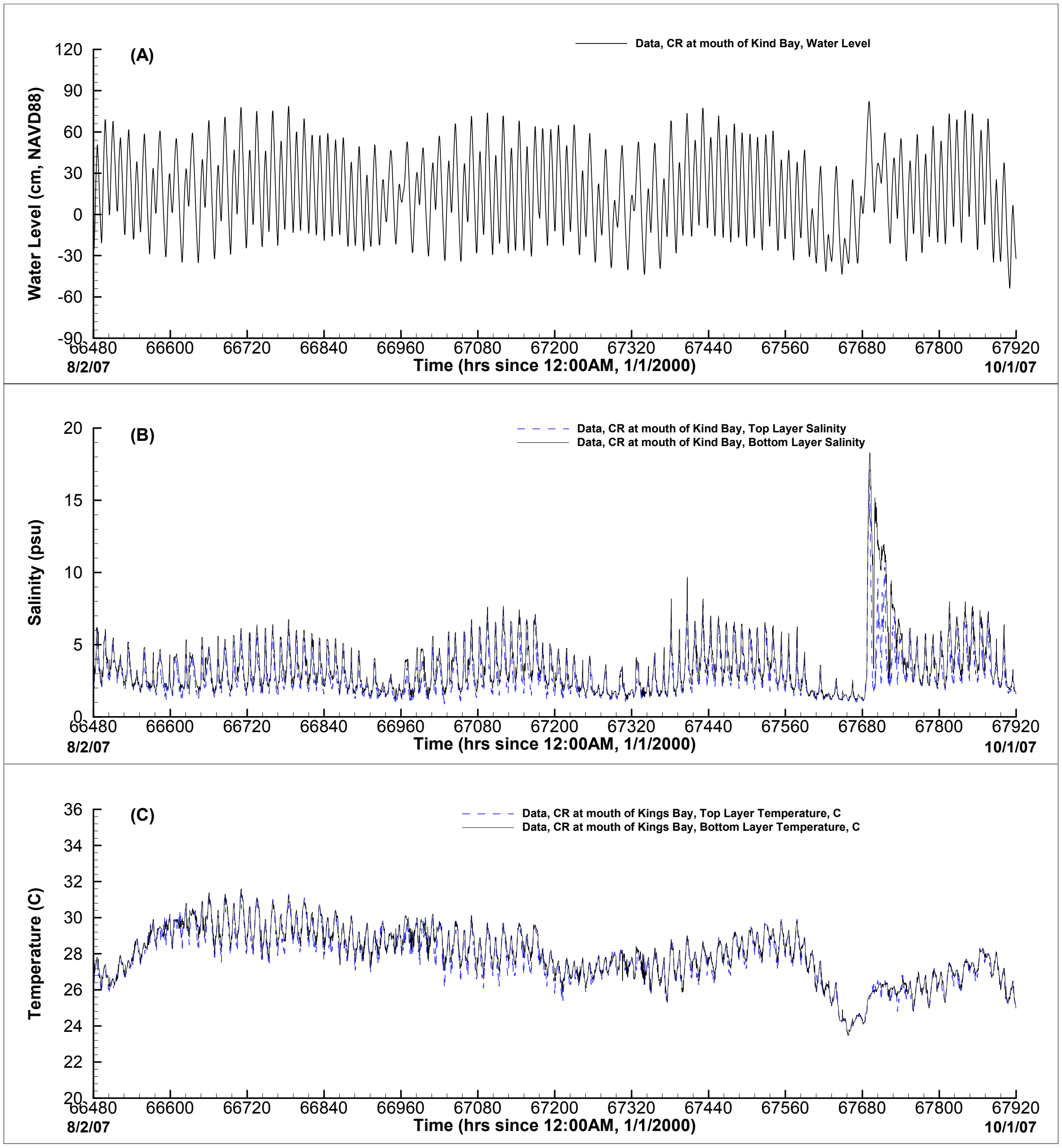

Figure 6 Time series of measured water level (A), salinities at two depths (B), and temperatures at two depths (C) at the USGS Mouth of Kings Bay station during August 2 – October 1, 2007.

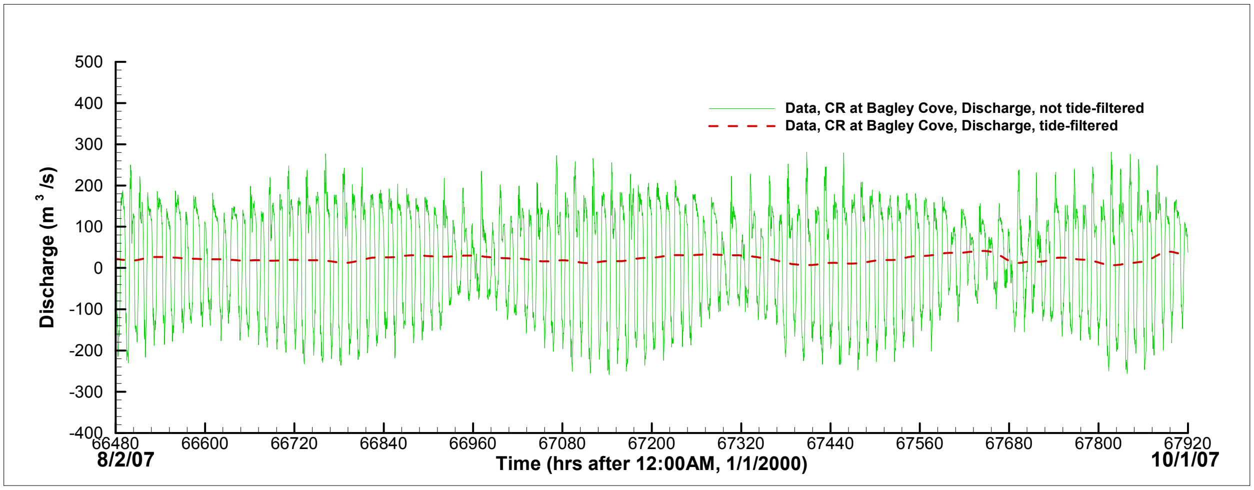

Figure 7 Time series of measured cross-sectional discharge at Bagley Cove during August 2 – October 1, 2007.

Meteorological data (wind speed, wind direction, air temperature, air humidity, and solar radiation) used for this modeling study were hourly readings at a station near Inglis, Florida, which is about 13 km north of the Crystal River/Kings Bay system. The climatology in the region has distinct winter and summer patterns. Winter is characterized by frequent frontal incursions and extratropical cyclones that can produce large shifts in wind speed and wind direction in response to rapidly changing atmospheric pressure and thermal gradients. Summer is generally characterized by light and variable winds originating from the northeast trade wind circulation. Sea/land breezes are typical due to the strong differential heating of the land and adjacent waters along the coast during the summer months. Occasional tropical storms can move to the area during summer, causing a temporal but sometimes intense modification to the meteorological conditions of the region. Although meteorological parameters are important driving forces controlling hydrodynamics and thermodynamics in the Crystal River/Kings Bay system, detailed discussion on these parameters is omitted here, as the main focus of the report is on using the model to evaluate MFLs for the Crystal River/Kings Bay system.

One of the most important pieces of field data for a successful hydrodynamic simulation of the Crystal River/Kings Bay estuary is the freshwater input to the system, of which 99% comes from the spring vents mainly distributed in and along eastern portion of Kings Bay. Historically, there were only limited field measurements of spring flows from the entirety of Kings Bay, which appear to be quite inconsistent. For example, based on limited measurements, an earlier study by Yobbi and Knochenmus (1989) estimated the average total spring discharge during 1965 - 1977 to be about 27.59 m^3sec^{-1} (or 975 cfs), while a June 1990 USGS survey recorded an average total spring discharge of 20.80 m^3sec^{-1} (735 cfs) (Hammett et al, 1996). Nevertheless, based on the water balance in the region, it is believed that it is impossible for the springshed to yield more than

14.15 m^3sec^{-1} (500 cfs) of groundwater discharge to the estuarine system (Ron Basso, personal communication, November 2011).

For a better understanding of the factors controlling the spring flow discharge to the Crystal River/Kings Bay system, a field study was completed by the SWFWMD during 2008 – 2009 to conduct a spring vent inventory to identify detectable spring vents and to measure the flow rate through each of the identified spring vents. Besides the 28 vents listed in Hammett et al. (1996), which was compiled mainly based on information contained in Rosenau et al. (1977), this recent study identified 42 additional spring vents in Kings Bay. One or more field trips were made to each of the 70 detectable spring vents to measure discharges from them. It was found that the flow rate varies significantly, depending on the location of the spring vent, its dimension, and the time when the measurement was done. The average total spring flow was found to be about 13.87 m^3sec^{-1} (490 cfs) during July – October 2009. Although this time period is during the wet season of 2009 for the region, the measured total spring flow is much lower than previously recorded or estimated total spring flow by the USGS.

One component of this field study was to use two ADCP sensors to measure real-time fluxes through two spring runs, each conveying flows from multiple spring vents. The ADCP measurements was conducted during a 25-day period in summer 2009, during which both surface water level data in Kings Bay and groundwater level data at a nearby well were available. The GW well station is called ROMP TR21-3 and located roughly 2.5 km southeast of the center of Kings Bay.

Based on newly collected spring flows, tides, and groundwater levels, the following empirical formula was found to fit the ADCP data very well.

$$Q = Q_0\left[1 + C_1(G - G_0 - \eta) + C_2\frac{\partial \eta}{\partial t}\right] \tag{16}$$

where Q and Q_0 are respectively estimated spring flow and long-term mean of measured spring flow; G and G_0 are groundwater level at the well station and the long-term mean of the head difference between the well station and Kings Bay, respectively; η is the surface water level in Kings Bay; and C_1 and C_2 are coefficients. Q_0, G_0, C_1, and C_2 can be determined from field data.

Equation (16) shows that the variation in spring flow is proportional to the difference between groundwater and surface water levels, or the head difference between the two. It is also proportional to the time derivative of tides. It is not a surprise that spring flows in coastal areas such as Kings Bay are controlled by the combined effect of groundwater and surface water levels, with the former being a positive force and the latter being the negative force. Nevertheless, the head difference alone does not allow estimated flow to match the phase and higher mode oscillation signals in measured spring flow data. By including the time derivative to the equation, a much better match between estimated and measured spring flow rates can be achieved, suggesting that tidal signals propagate into the spring vents.

Equation (16) was used to estimate flows from each spring vents in Kings Bay at each time step of the model run. Details on how the above equation was obtained and how it was used in the model application are described in Chen (2014).

In addition to the flow rate, salinity in the spring flow also varies with space and tides. Spring flows out of the vents in the northeastern portion of Kings Bay are close to fresh with salinity generally less than 1.0 psu, while spring flows out of the vents in the southern portion of Kings Bay are saltier with salinity varying from about 1.0 psu to up to 7 psu or above.

4. Model Calibration and Verification

4.1 Model Setup

When applying the UnLESS3D model described in Section 2 and in Chen (2011) to the Crystal River/Kings Bay system, 3030 Cartesian grids were used in the horizontal plan. The grid size varies between 15m×15m (225 m^2) to 120m×120m (14,400 m^2), though the longest length of a few rectangle grids was 140m. In the vertical direction, a total of 12 layers were used, with the layer thickness varying between 0.4m and 2.5m. Because of the cut-cell feature used in UnLESS3D, the actual smallest computational cell used in the simulation could be as small as 7.5m×7.5m×0.2m. A variable time step between 48 and 75 sec was used in model runs, with Δt = 75 sec being used 92% of the simulation time period. This means that the model was run with a Courant number larger than 15 for the complicated estuarine system of Crystal River/Kings Bay.

Figure 8 shows the unstructured Cartesian grid mesh used to simulate hydrodynamics in the Crystal River/Kings Bay system. Real-time data measured at the Shell Island and Salt River stations were used for open boundary conditions, while those measured at the Bagley Cove and the mouth of Kings Bay stations were used for model calibration and verification. The total simulation period was a 34-months period (1037 days), from April 24, 2007 to February 23, 2010. The model was calibrated against real-time data of water level, salinity and temperature for a 150-day period during December 28, 2007 – May 26, 2008 after a spin-up run for 25 days. It was then verified for the remaining days before and after the 150-day calibration period.

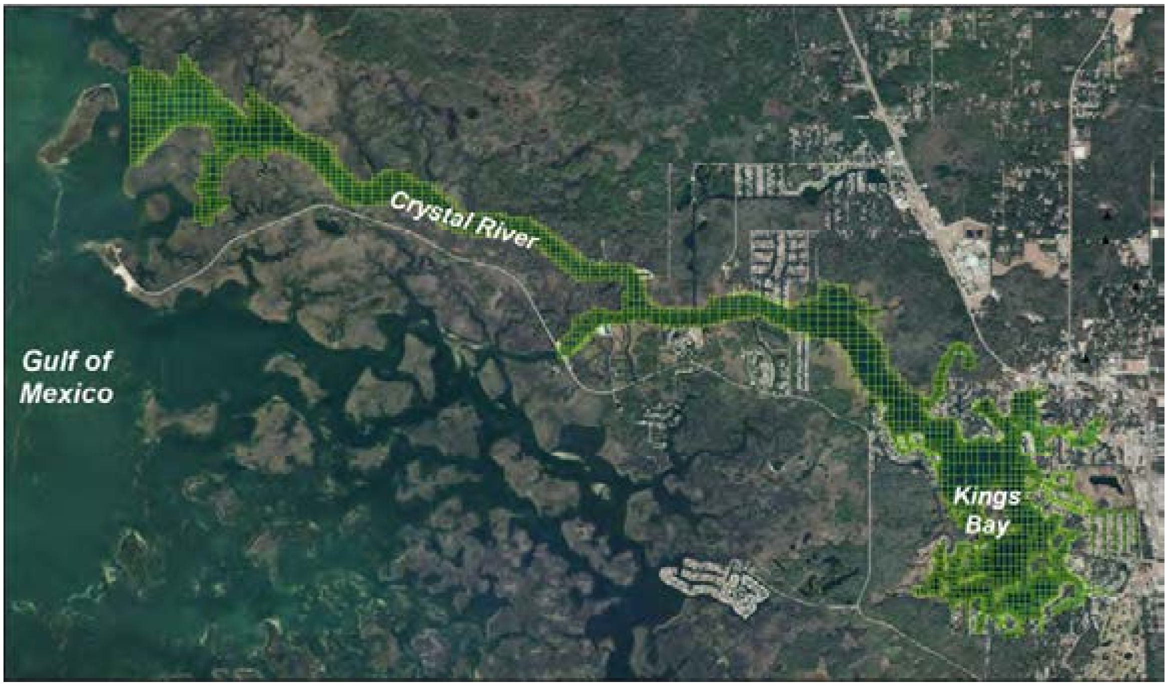

Figure 8 Unstructured Cartesian grid mesh used in the model application to the Crystal River/Kings Bay system.

Only limited input parameters had to be tuned in the calibration process, including the bottom roughness, ambient vertical eddy viscosity and diffusivity, and ranges of salinity variation in spring discharges. An additional spring flow that also varies with tides and groundwater level according to Equation (16) was added to Kings Bay to represent SGDs out of the many hairline fractures that cannot be identified by practical field investigation. Without any specific knowledge of where these hairline fractures are located and what flow rate each of them contributes to the system, this additional spring flow was assumed to be randomly distributed among 40 locations that are evenly spread on the bay bottom and its long-term mean, Q_0 in Equation (16), was adjusted in model calibration. In using Equation (16) for estimating spring flows out of the hairline fractures, G_0, C_1, and C_2 were interpolated from known values at the 70 detectable spring vents using the inverse distance weighting method. These 40 randomly distributed vents also represent diffuse flow at the bottom of Kings Bay. Based on model calibration, it was estimated that the hairline fractures in Kings Bay contribute about 7.4% of the total spring flows to the estuarine system.

4.2 Comparisons of Model Results with Data

Comparisons of model results with measured field data at the two measurement stations inside the simulation domain (Bagley Cove and the mouth of Kings Bay) are presented in Figure 9 - Figure 12. For simplicity and clarity, only a two-month period between Hour 66480 and Hour 67920 (August 2 – October 1, 2007) are shown here to demonstrate how model results compare with measured field data. It should be noted that the choice of these two-month period is arbitrary (and thus the two-month period shown in Figure 3 - Figure 6.) Comparisons of model results with field data during other periods are similar to these during August 2 – October 1, 2007 and are shown in Figures A1 through E11 in Appendixes B - E

Figure 9 shows and compares simulated and measured water levels at the two measurement stations. The top panel of the figure is for the Bagley Cove station, and the bottom panel is for the mouth of Kings Bay station. Dashed lines are measured water level data, while solid lines are simulated water level results by the UnLESS3D model. An excellent match of modeled water levels with measured data shown in the figure indicates that the UnLESS3D model performs very well in simulating circulations and tidal wave propagations in the Crystal River/Kings Bay system. Both short-term and long-term characteristics of the tides are appropriately modeled.

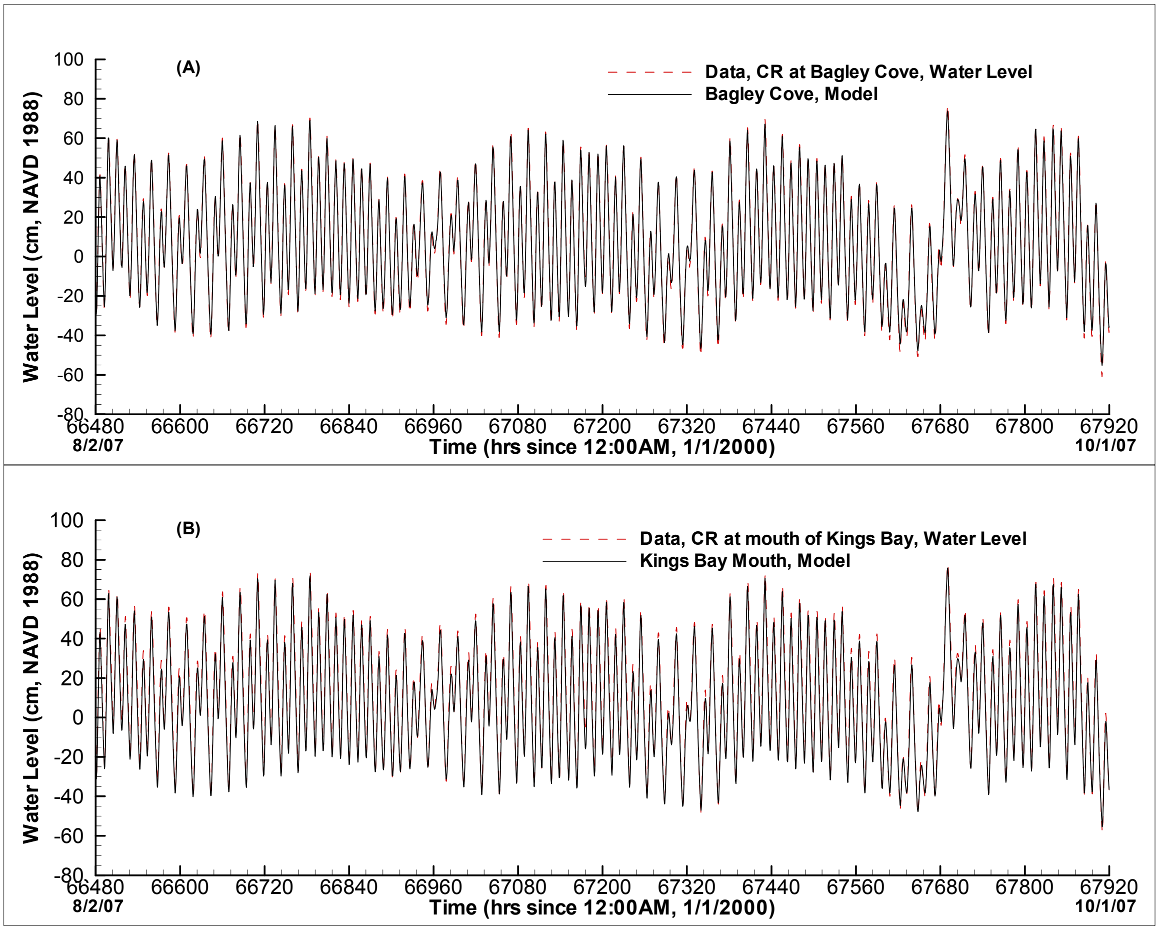

Figure 9 Comparison of measured and simulated water levels at the Bagley Cove station (A) and the mouth of Kings Bay station (B) during August 2 – October 1, 2007.

Figure 10 shows and compares simulated and measured salinities. The top panel is for the bottom layer at the Bagley Cove station (salinity and temperature were only measured near the bottom at this station), while the middle and bottom panels are for the top and bottom layers, respectively at the mouth of Kings Bay station. Again, dashed lines are measured field data and solid lines are model results. It can be seen from Figure 10 that during August 2 – October 1, 2007, the UnLESS3D model over-predicts salinity peaks at the Bagley Cove station but under-predicts some peaks at the mouth of Kings Bay station. Even so, the model generally works well in simulating salinity transport processes in Crystal River/Kings Bay, as it properly simulates both the high- and low- frequency variations of salinity in the estuarine system. Similar salinity variability characteristics associated with tides and climatic patterns in the region can clearly be seen in both simulated and measured salinities shown in Figure 10.

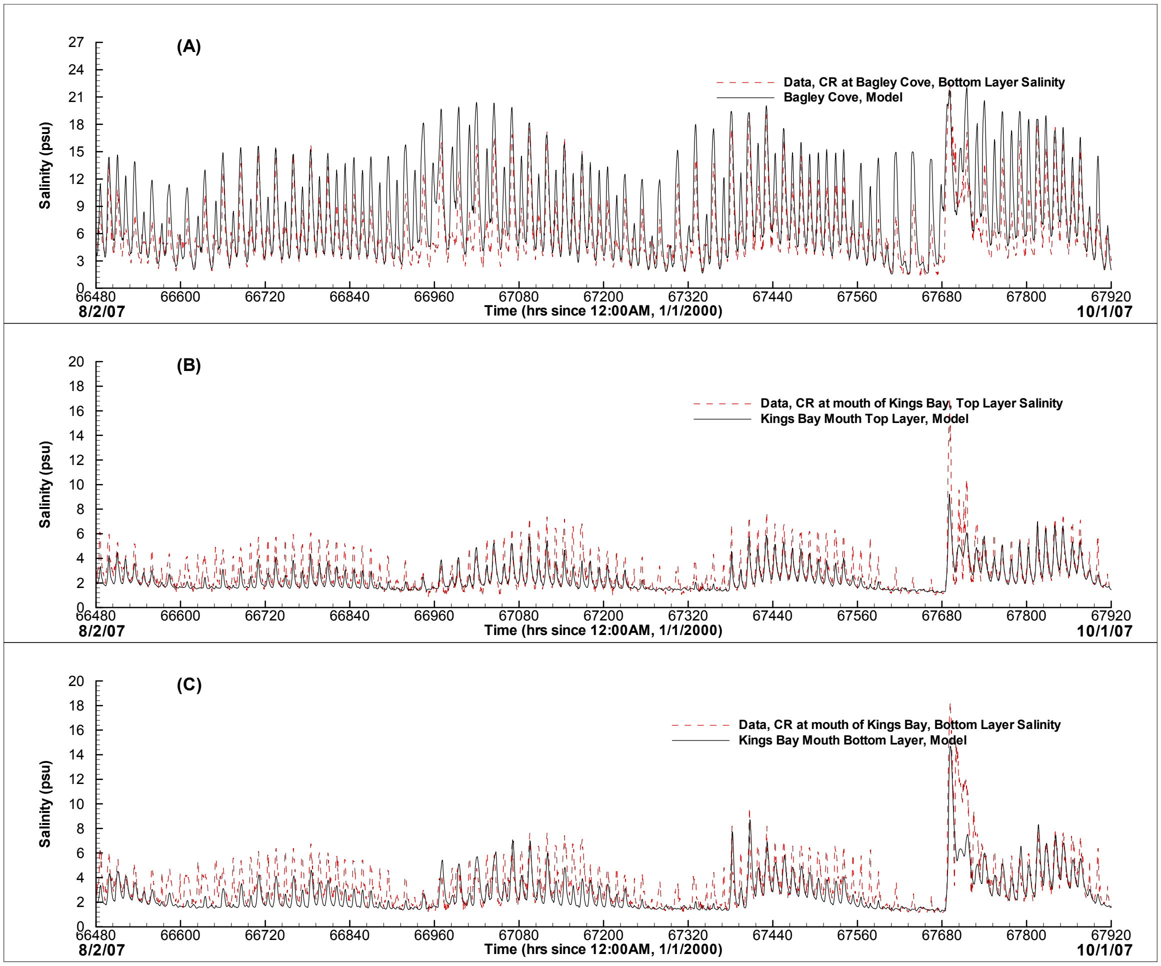

Figure 10 Comparison of measured and simulated salinities near the bottom at the Bagley Cove station (A), in the top layer at the mouth of Kings Bay station (B), and in the bottom layer at the mouth of Kings Bay station (C) during August 2 – October 1, 2007.

In Figure 11, simulated and measured temperatures at Bagley Cove and the mouth of Kings Bay are shown and compared in the same manner as that in Figure 10, with dashed lines being field data and solid lines being model results. Figure 11 demonstrates that the UnLESS3D model properly simulates thermodynamics in the Crystal River/Kings Bay estuarine system in terms of both short-term and long-term variations. As mentioned earlier, because of its large spring discharges with relatively constant temperature of about 22.2 ºC (with a small seasonal variation), Crystal River/Kings Bay is a very important natural refuge for manatees in cold days in winter. It is thus critical to ensure that the estuary receives enough spring discharges so that a certain volume of a warm water pool can be maintained in the Crystal River/Kings Bay system. Clearly, UnLESS3D provides a reliable tool for determining the minimum spring flow rate the estuary needs to maintain the size of the warm water pool.

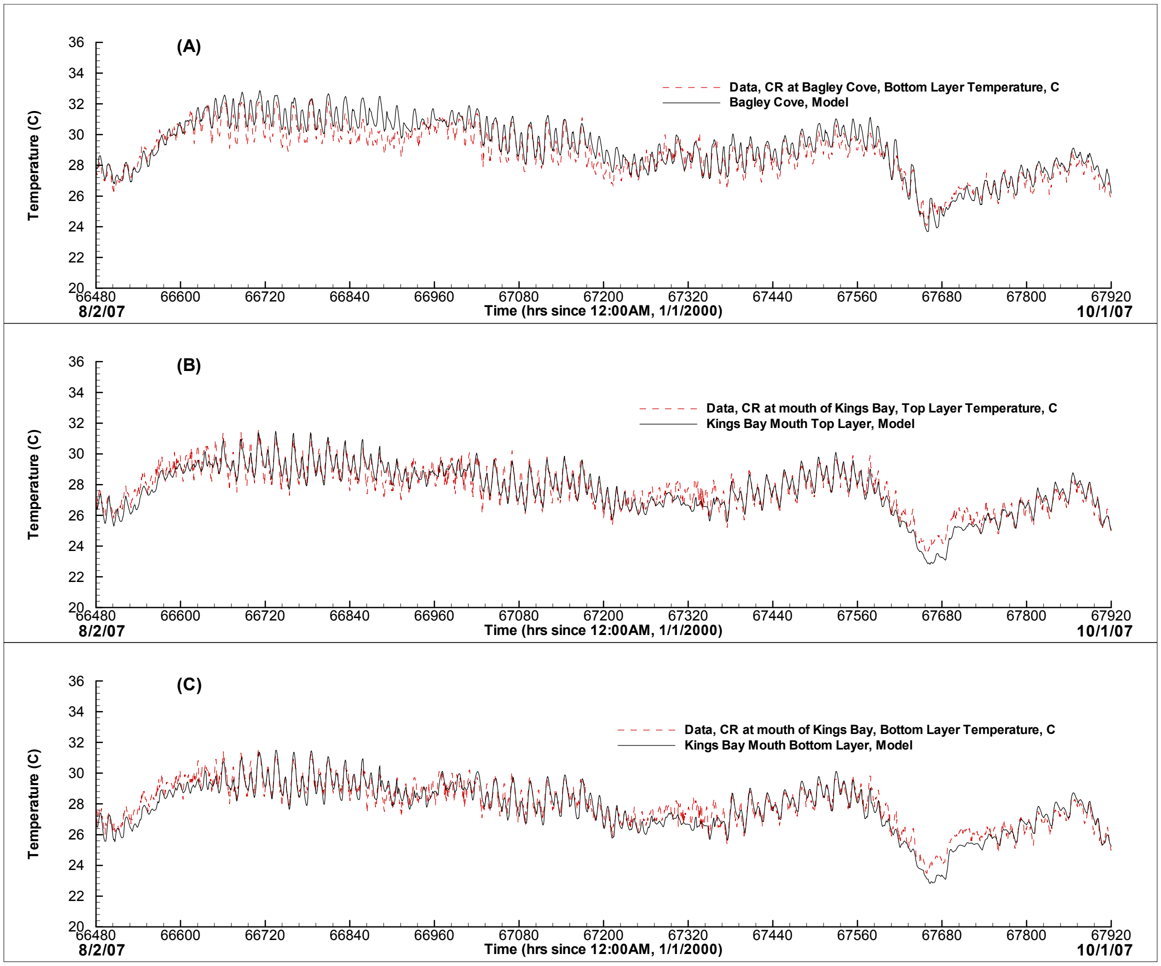

Figure 11 Comparison of measured and simulated temperatures near the bottom at the Bagley Cove station (A), in the top layer at the mouth of Kings Bay station (B), and in the bottom layer at the mouth of Kings Bay station (C) during August 2 – October 1, 2007.

Figure 12 presents the comparison of simulated and measured cross-sectional flux through the river cross section at Bagley Cove. As can be seen from the figure, modeled cross-sectional flux at Bagley Cove matches with ADCP results most of time except for the positive (flooding) and negative (ebbing) peaks. Because the ADCP not only gauges the spring flows but also the tidal prism upstream of the Bagley Cove station, a possible explanation of the mismatch of these positive and negative peaks is that some of the finger channels, small creaks, and portions of the tidal flat either not included or not accurately represented in the model domain. As a result, water volumes flowing into or out of these areas were not counted in the model, resulting in smaller magnitudes of the peaks in modeled cross-sectional flux.

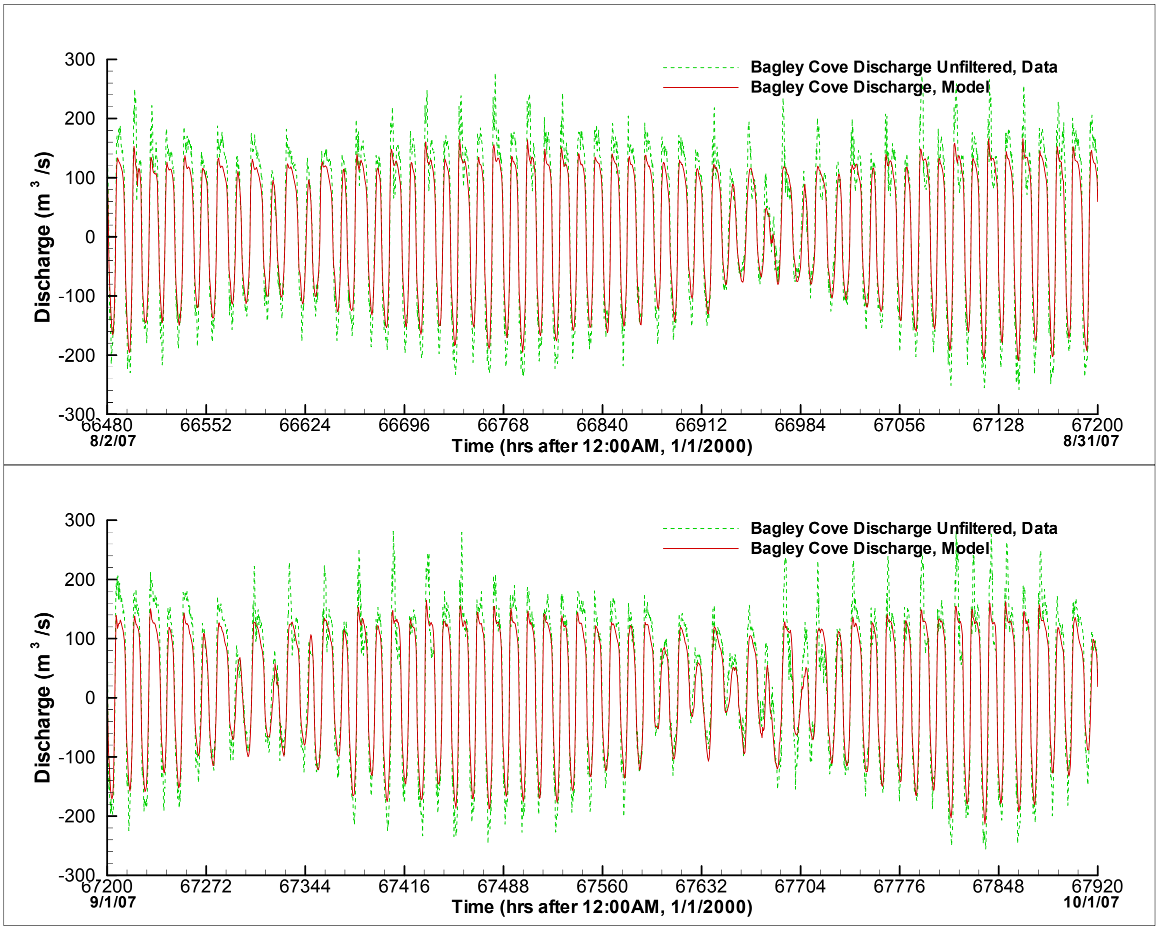

Figure 12 Comparison of measured and simulated cross-sectional fluxes at the Bagley Cove station during August 2 – October 1, 2007.

4.3 Model Performance Metrics

The coefficient of determination (R^2) is frequently used in quantifying the agreement between modeled results and field data. For modeled water levels at both stations, R^2 is 0.995 for the Bagley Cove station and 0.994 for the mouth of Kings Bay station. The R^2 value for salinity at the bottom layer at the Bagley Cove station is 0.714, while R^2 values for salinities at the top and bottom layers at the mouth of Kings Bay station are 0.732 and 0.657, respectively. The average R^2 value for simulated and measured salinities at the Bagley Cove and the mouth of Kings Bay stations is 0.701. Although these R^2 values are not as high as those for the water level results, they are normally considered as satisfactory in simulating a complex estuarine system such as Crystal River/Kings Bay. For temperature, model results have a R^2 ranging between 0.892 and 0.919 at the two measurement stations. The average R^2 value is 0.903 for simulated and measured temperatures.

In additional to the R^2 values, a skill assessment parameter introduced by Willmott (1981) can be used to quantitatively judge the agreement between model results and measured data as well. This skill assessment parameter was used by Warner et al. (2005) to assess the performance of a hydrodynamic model for the Hudson River estuary. It also was used by the author to examine performances of a laterally averaged model for the Lower Alafia River estuary and a multi-block, dynamically coupled 3D-2DV model for the lower Peace River – Lower Myakka River – Upper Charlotte Harbor estuarine system (Chen, 2005 and 2010). This skill assessment parameter takes the following form

$$S_k = 1 - \frac{\sum (y^M - y^D)^2}{\sum (|y^M - \overline{y^D}| + |y^D - \overline{y^D}|)^2} \tag{17}$$

where S_k is the skill assessment parameter (or simply the skill); y^M and y^D represent simulated and measured variables (water level, salinity, etc.); and $\overline{y^D}$ is the expectation of y^D. S_k in the above equation varies between 0 and 1, with one being a perfect agreement and zero being a complete disagreement between simulated results and measured data.

Table 2 - Table 4 show skills and R^2 values for simulated water levels, salinities, and temperatures, respectively at the Bagley Cove and the mouth of Kings Bay stations for the entire 34-month simulation period. Mean errors and mean absolute errors are also included in these tables. The bottom rows in Table 2 - Table 4 are arithmetic averages of R^2, the mean error, the mean absolute error, and the skill for the respective model variables. From Table 2 - Table 4, it can be seen that while the skill assessment parameter for salinity is between 0.7 and 0.8, skills for water level and temperature are all equal to or higher than 0.98. Statistics for measuring the agreement between simulated discharge with real-time field data at Bagley Cove were also calculated, and they are -9.28 m^3sec^{-1}, 29.14 m^3sec^{-1}, 0.92, and 0.97 for the mean error, the mean absolute error, R^2 value, and the skill, respectively.

Table 2 R^2 values, mean errors, mean absolute errors, and skill assessment parameters for simulated water levels in comparison with real-time field data measured at the Bagley Cove and the mouth of Kings Bay stations in Crystal River/Kings Bay.

	R^2	**Mean Error (cm)**	**Mean Abs Error (cm)**	**Skill**
Bagley Cove	0.995	1.01	3.21	0.99
Mouth of Kings Bay	0.994	0.79	4.51	0.99
Average	0.995	0.90	3.86	0.99

Table 3 R^2 values, mean errors, mean absolute errors, and skill assessment parameters for simulated salinities in comparison with real-time field data measured at the Bagley Cove and the mouth of Kings Bay stations in Crystal River/Kings Bay.

	R^2	Mean Error (psu)	Mean Abs Error (psu)	Skill
Bagley Cove	0.714	1.15	2.41	0.80
Mouth of Kings Bay - Top	0.732	-0.48	0.86	0.76
Mouth of Kings Bay - Bottom	0.657	-0.85	1.35	0.70
Average	0.701	-0.06	1.54	0.75

With an arithmetic average of 0.75 for the skill assessment parameter for salinity, it can be concluded that the overall match of simulated salinity by the UnLESS3D model with field data measured in the Crystal River/Kings Bay system is good. The skill of the model for simulating salinity transport processes in the spring-fed estuarine system is expected to be improved if more reliable data on discharge and salinity out of the spring vents become available. For water level, temperature, and cross-sectional flux, simulated results match with field data with average skills being equal to or higher than 0.97, which can be categorized as very good or even excellent.

Table 4 R^2 values, mean errors, mean absolute errors, and skill assessment parameters for simulated temperatures in comparison with real-time field data measured at the Bagley Cove and the mouth of Kings Bay stations in Crystal River/Kings Bay.

	R^2	Mean Error (°C)	Mean Abs Error (°C)	Skill
Bagley Cove	0.919	0.15	0.73	0.99
Mouth of Kings Bay - Top	0.892	-0.04	0.70	0.98
Mouth of Kings Bay - Bottom	0.897	-0.02	0.77	0.98
Average	0.903	0.03	0.73	0.98

Comparisons of model results with field data shown in Figure 9 - Figure 11 as well as the model performance metrics presented in Table 2 - Table 4 suggest that the UnLESS3D model is sophisticated enough to properly simulate major physical processes in the Crystal River/Kings Bay estuarine system, including the tidal propagation, tide- and wind-driven circulations, salinity transport processes, heat exchange at the water surface, thermodynamics, buoyancy effects, turbulence mixing, and additional mixing due to the groundwater discharge at the bottom of Kings Bay. With proper boundary conditions as input data to drive the model, UnLESS3D appropriately reproduces both the high-frequency variability caused by tides and the low-frequency variability caused by seasonal and inter-annual variations of both the meteorological condition in the region and the hydrological loading to the estuarine system. Effects of episodic storm events to circulations, salinity transport processes, and thermodynamics in Crystal River/Kings Bay are simulated with a reasonable response of the model output.

5. Scenario Simulations

5.1 Scenarios

The UnLESS3D model that was calibrated and verified for Crystal River/Kings Bay was run for various flow reduction conditions during a 9-year period from October 6, 2006 to October 13, 2015, based on available boundary conditions at the time these scenario runs were performed. Because of the lack of historical SGD data in CRKB, it is impossible to have a direct comparison of the characteristics of the hydrologic loadings to the estuary during this 9-year period with those of historical flow condition. To gain some insights on how SGDs in these 9 years would represent the historical hydrologic loadings, an effort was made to hindcast the total SGD to the estuary back to November 1969 based on tides and groundwater levels, which were also hindcasted. Results of hindcasted tides, groundwater levels, and SGDs are presented in Chen (2015), which also discusses how the SGD hindcast was conducted.

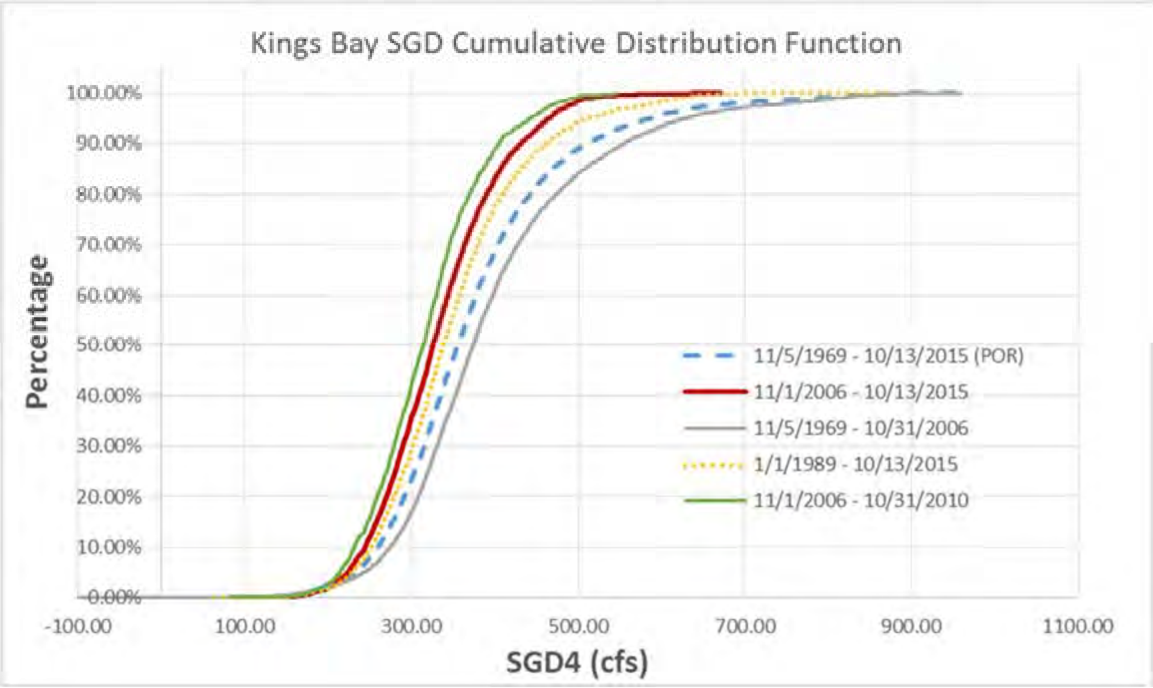

Figure 13 Comparison of SGD CDFs for different periods.

Figure 13 shows a comparison of cumulative distribution functions (CDFs) of SGDs hindcasted for different periods of time. The blue dashed line is for the period of record (POR), from November 5 to October 13, 2015, and the red solid line is for the 9-year period used for scenario simulations. CDFs of SGD for 11/5/1969 – 10/31/2006 (gray solid line), 1/1/1989 – 10/31/2015 (yellow dashed line), and 11/1/2006 – 10/31/2010 (green solid line) are also presented in Figure 13. All the five CDF lines have a similar shape, suggesting that they have a similar temporal variability; however their SGD averages over different periods are different. During the 9-year period used for scenario simulations, the average SGD entering Kings Bay is lower than the POR. While the estuary received more SGDs prior to 2006, it received much less SGDs between November 2006 and October 2010, during which it was relative dry. These relatively dry 5 years caused an overall low average of SGD for the 9-year simulation period. Nevertheless, the 9-year simulation period is a good representation of the 27-year period between 1/1/1989 and 10/31/2015 as far as SGD is concerned, even though it represents the POR poorly.

A total of 14 flow scenarios were simulated and analyzed, including the baseline flow condition, the existing flow condition, and 2.5%, 5%, 7.5%, 10%, 12.5%, 15%, 17.5%. 20%, 22.5%, 25%, 27.5%, and 30% reductions from the baseline flow condition. The baseline flow condition is an imaginary flow condition that would exist if no ground water were withdrawn in the springshed. It is estimated that the existing withdrawal causes about 2% reduction of SGDs in Kings Bay (Basso & Leeper, personal communication, 2016). As such, the baseline flow is obtained by dividing the existing SGDs by 0.98. The existing flow condition is calculated at each time step based on measured (or simulated, as they match very well) water levels in Kings Bay and measured hourly groundwater level in ROMP TR21-3 at each time step. Table 5 lists details on how flow is calculated for each flow scenarios.

Table 5 Flow scenarios conducted in the Crystal River/Kings Bay MFL evaluation.

Scenario No.	**Scenario Name**	**Flow Calculation**
1	Baseline	(No. 2 SGDs)/0.98, or 1.0204×(No. 2 SGDs)
2	Existing	Calculated from water levels in King Bay & ROMP TR21-3 using Equation (16)
3	2.5%	0.975×(No. 1 SGDs), or 0.9949×(No. 2 SGDs)
4	5%	0.95×(No. 1 SGDs), or 0.9694×(No. 2 SGDs)
5	7.5%	0.925×(No. 1 SGDs), or 0.9439×(No. 2 SGDs)
6	10%	0.9×(No. 1 SGDs), or 0.9184×(No. 2 SGDs)
7	12.5%	0.875×(No. 1 SGDs), or 0.8929×(No. 2 SGDs)
8	15%	0.85×(No. 1 SGDs), or 0.8673×(No. 2 SGDs)
9	17.5%	0.825×(No. 1 SGDs), or 0.8418×(No. 2 SGDs)
10	20%	0.8×(No. 1 SGDs), or 0.8163×(No. 2 SGDs)
11	22.5%	0.775×(No. 1 SGDs), or 0.7908×(No. 2 SGDs)
12	25%	0.75×(No. 1 SGDs), or 0.7653×(No. 2 SGDs)
13	27.5%	0.775×(No. 1 SGDs), or 0.7398×(No. 2 SGDs)
14	30%	0.7×(No. 1 SGDs), or 0.7143×(No. 2 SGDs)

Simulated salinities and temperatures at the centers of all grid cells were written out to output files with an interval of 30 minutes for all 14 scenarios. These model results were processed to calculate volumes, bottom areas, and shoreline lengths for various salinity ranges and volumes and surface areas of various temperature ranges at each time point. Salinity and thermal habitats calculated and analyzed are listed in Table 6 below.

Table 6 Salinity and temperature ranges used in the post-processes of model results of the scenario runs.

	Ranges	Habitats
Salinity	1. ≤ 0.5 psu 2. ≤ 1 psu 3. ≤ 2 psu 4. ≤ 3 psu 5. ≤ 5 psu 6. ≤ 10 psu 7. ≤ 15 psu 8. ≤ 20 psu	Salinity habitats calculated: 1. Water volume, 2. Bottom area, and 3. Shoreline length.
Temperature	1. ≤ 15 °C 2. Between 15 °C and 20 °C (exclusive) 3. ≥ 20 °C	Thermal habitats calculated are water volume and surface area. For ≥ 20 °C habitats, a minimum of 1.158 m (3.8 feet) of water layer is required.

5.2. Results of Salinity Habitats

For salinity, instead of directly analyzing the 30-minute results of water volume, bottom area, and shoreline length, daily mean values were typically analyzed in the MFL evaluation. Figure 14 - Figure 21 show daily mean volumes, bottom area, and shoreline lengths for salinity ≤ 0.5, 1, 2, 3, 5, 10, 15, and 20 psu, respectively. The *x*-axis range of these figures are from Day 1 (11/1/2006) to Day 3269 (11/12/2015). The first 26 days of the scenario simulations (10/6/2006 – 10/31/2006) were considered as a spin-up period and model results were not used in the MFL evaluation and thus not included in Figure 14 - Figure 21. Because the simulations didn't include the entire 24 hours of the last day (11/13/2015), results on that day were not included in Figure 14 - Figure 21 either. Due to the overlapping graphs, only the daily results for scenarios of the baseline, existing, 5%, 10%, 20%, and 30% flow reduction conditions are plotted in the figures.

Effects of SGD reduction to salinity habitats can be seen in Figure 14 - Figure 21, especially to low salinity habitats. The ≤ 2 psu volume, bottom area, and shoreline length have the highest temporally variability, and effects of a flow reduction on these salinity habitats are most significant.

Eyeballing the daily mean plots of salinity volume, bottom area, and shoreline length shown in Figure 14 - Figure 21, it was found that the freshwater (≤ 0.5 psu) volume, bottom area, and shoreline length approximated 0.29×10^6 m^3, 0.22×10^6 m^2, and 7.29 km, respectively for the baseline scenario. Because the average total volume, bottom area, and shoreline length are about 10.4 $\times 10^6$ m^3, 5.5$\times 10^6$ m^2, and 32.1 km, respectively for the entire estuary, freshwater volume is about 2.8% of CRKB, while freshwater bottom area and freshwater shoreline are about 4.0% and 22.7%, respectively of total bottom area and shoreline of CRKB. As mentioned before, SGDs from spring vents in Kings Bay contain a variety of salinity ranging from < 0.5 psu to > 7 psu. Freshwater SGDs come mostly from the northern spring vents of Kings Bay. Correspondingly, freshwater volume and bottom area exist mainly in areas close to northern spring vents of Kings Bay. Fresh water out of these northern vents can also be transported to the top layer of other areas, resulting in a higher percentage for freshwater shoreline in comparison with those for freshwater volume and freshwater bottom area in the overall CRKB estuary.

Water volume, bottom area, and shoreline length for salinity ≤ 20 psu approximated 10.0$\times 10^6$ m^3, 5.3$\times 10^6$ m^2, and 31.5 km m, respectively for the baseline scenario. For the 2006 through 2015 simulation period, the 9-year averages of > 20 psu volume, bottom area, and shoreline length were approximately 0.4 $\times 10^6$ m^3, 0.2$\times 10^6$ m^2, and 0.6 km, respectively, or about 3.8%, 3.6%, and 1.9%, respectively, of the total volume, bottom area, and shoreline length of the estuary. These high salinity habitats exist near the mouth of Crystal River.

The ≤ 1 psu salinity volume, bottom area, and shoreline length approximated 0.44$\times 10^6$ m^3, 0.33$\times 10^6$ m^2, and 8.29 km, respectively for the baseline scenario, equivalent to 4.2%, 6.0%, and 25.8% of the total CRKB volume, bottom area, and shoreline, respectively. The ≤ 2 psu salinity volume, bottom area, and shoreline length approximated 2.45$\times 10^6$ m^3, 1,41 $\times 10^6$ m^2, and 13.42 km, respectively under the baseline flow condition, equivalent to about 23.6%, 25.6%, and 41.8% of the total Kings Bay volume, bottom area, and shoreline, respectively.

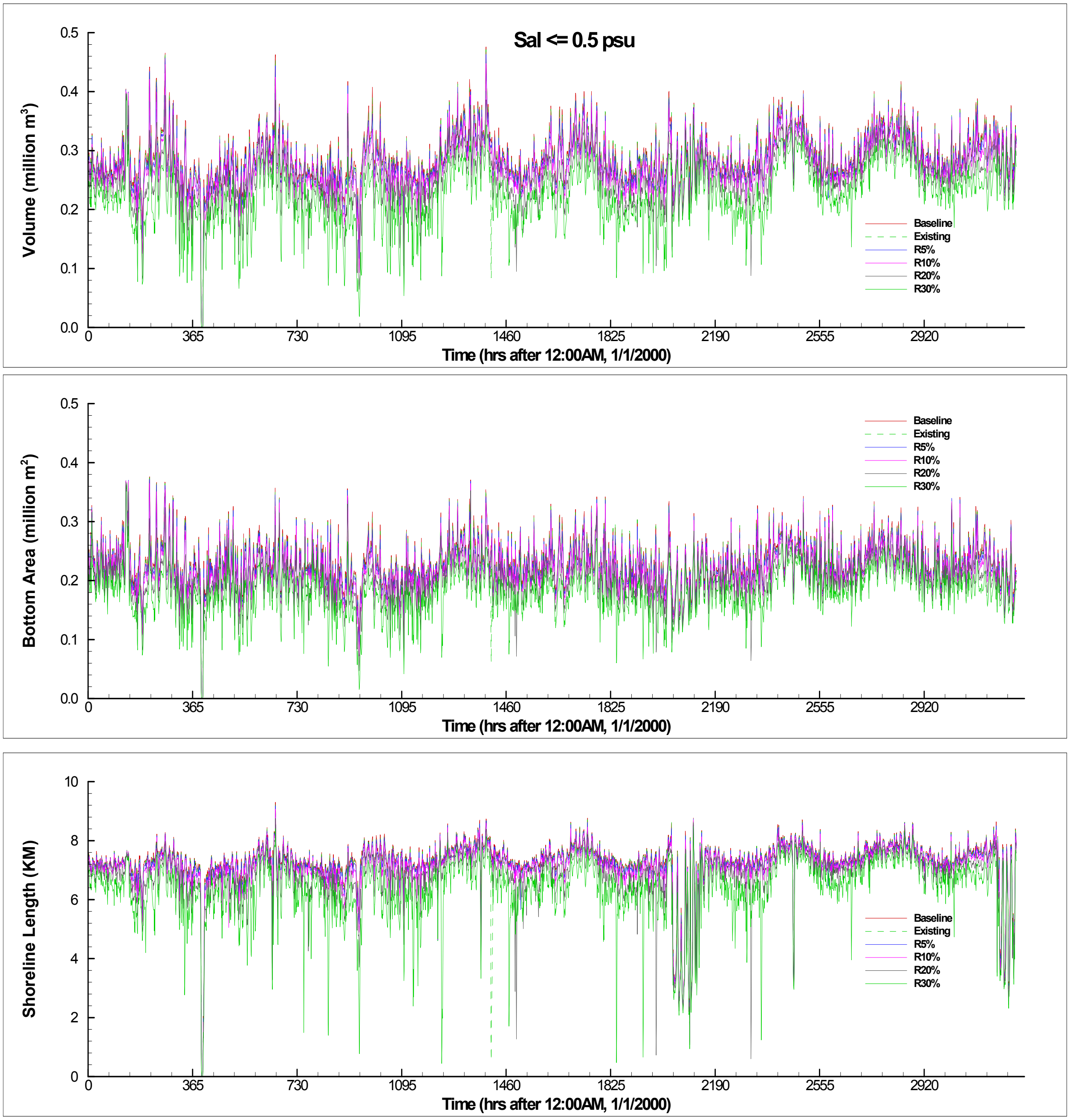

Figure 14 Daily mean water volumes, bottom areas, and shoreline lengths for salinity ≤ 0.5 psu under the baseline, existing, 5% flow reduction, 10% flow reduction, 20% flow reduction, and 30% flow reduction conditions.

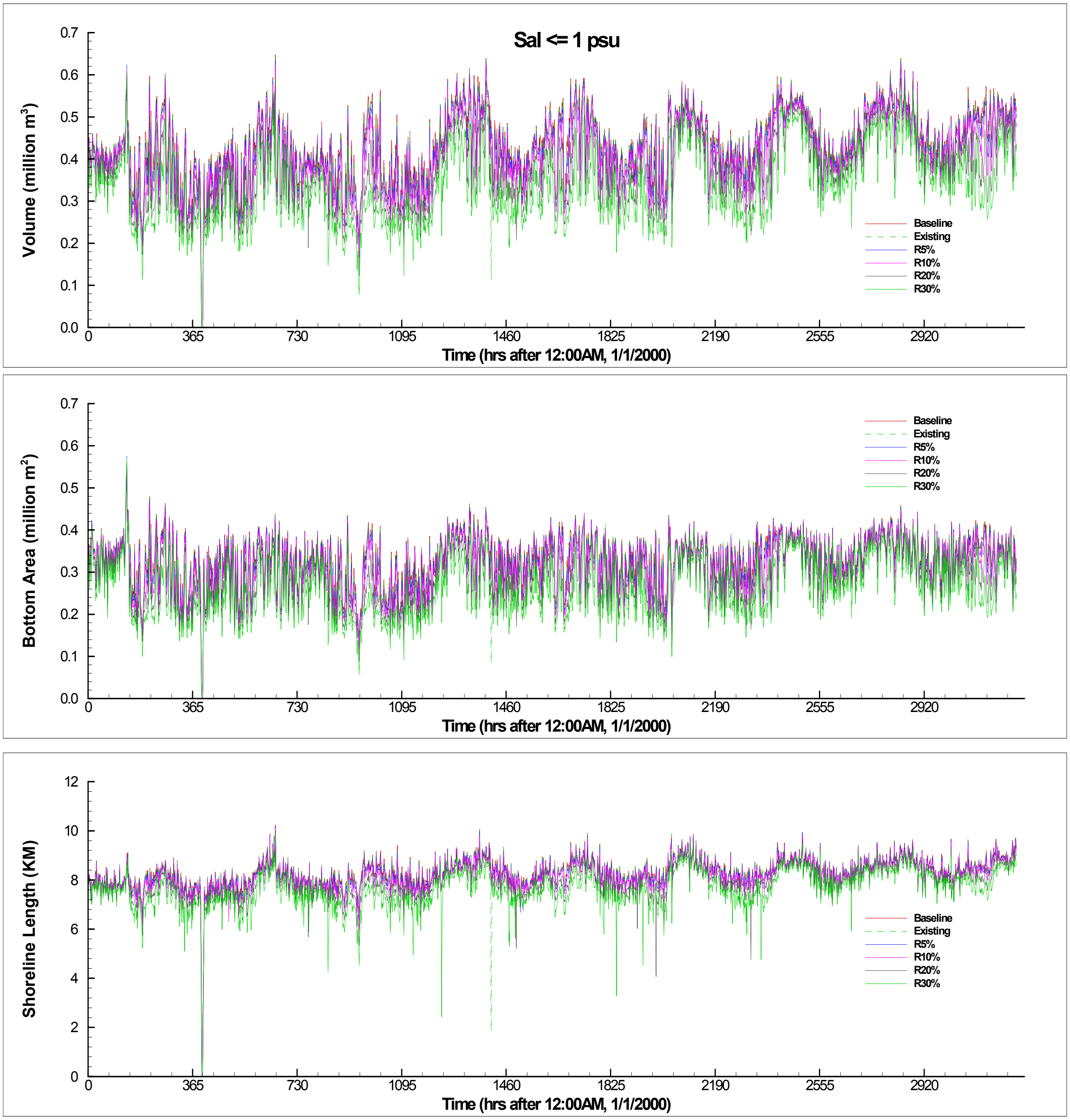

Figure 15 Daily mean water volumes, bottom areas, and shoreline lengths for salinity ≤ 1psu under the baseline, existing, 5% flow reduction, 10% flow reduction, 20% flow reduction, and 30% flow reduction conditions.

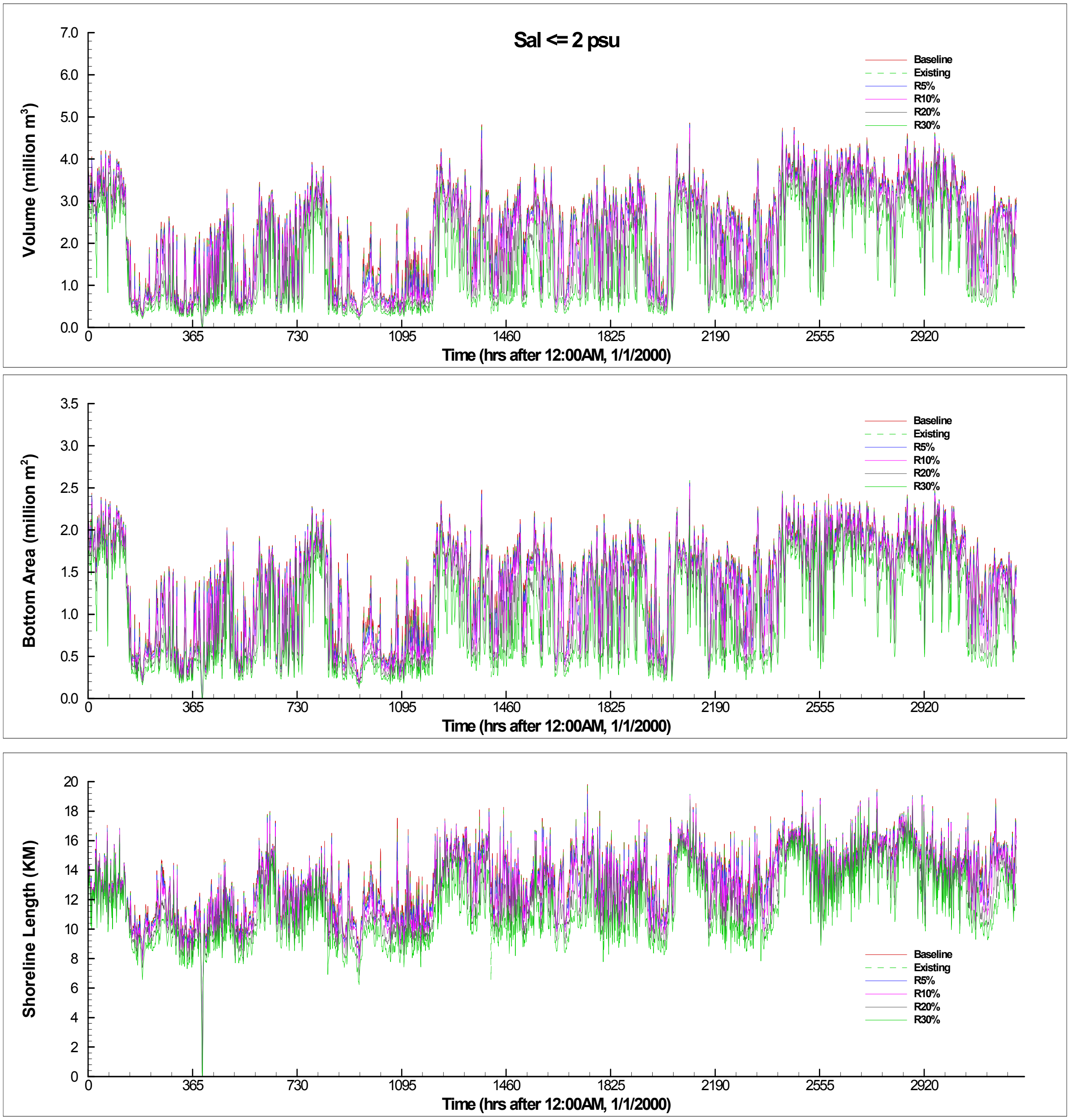

Figure 16 Daily mean water volumes, bottom areas, and shoreline lengths for salinity ≤ 2 psu under the baseline, existing, 5% flow reduction, 10% flow reduction, 20% flow reduction, and 30% flow reduction conditions.

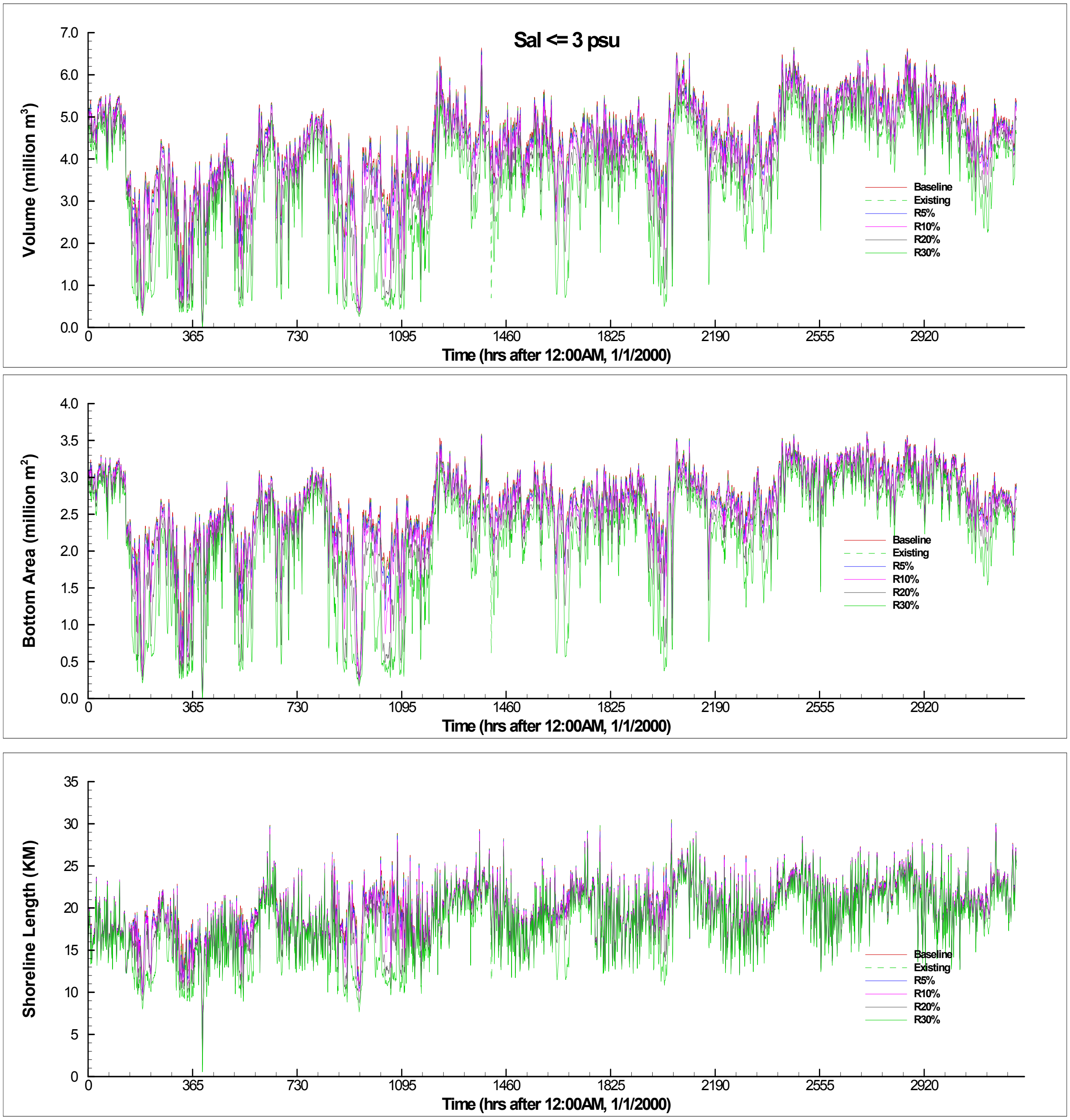

Figure 17 Daily mean water volumes, bottom areas, and shoreline lengths for salinity ≤ 3 psu under the baseline, existing, 5% flow reduction, 10% flow reduction, 20% flow reduction, and 30% flow reduction conditions.

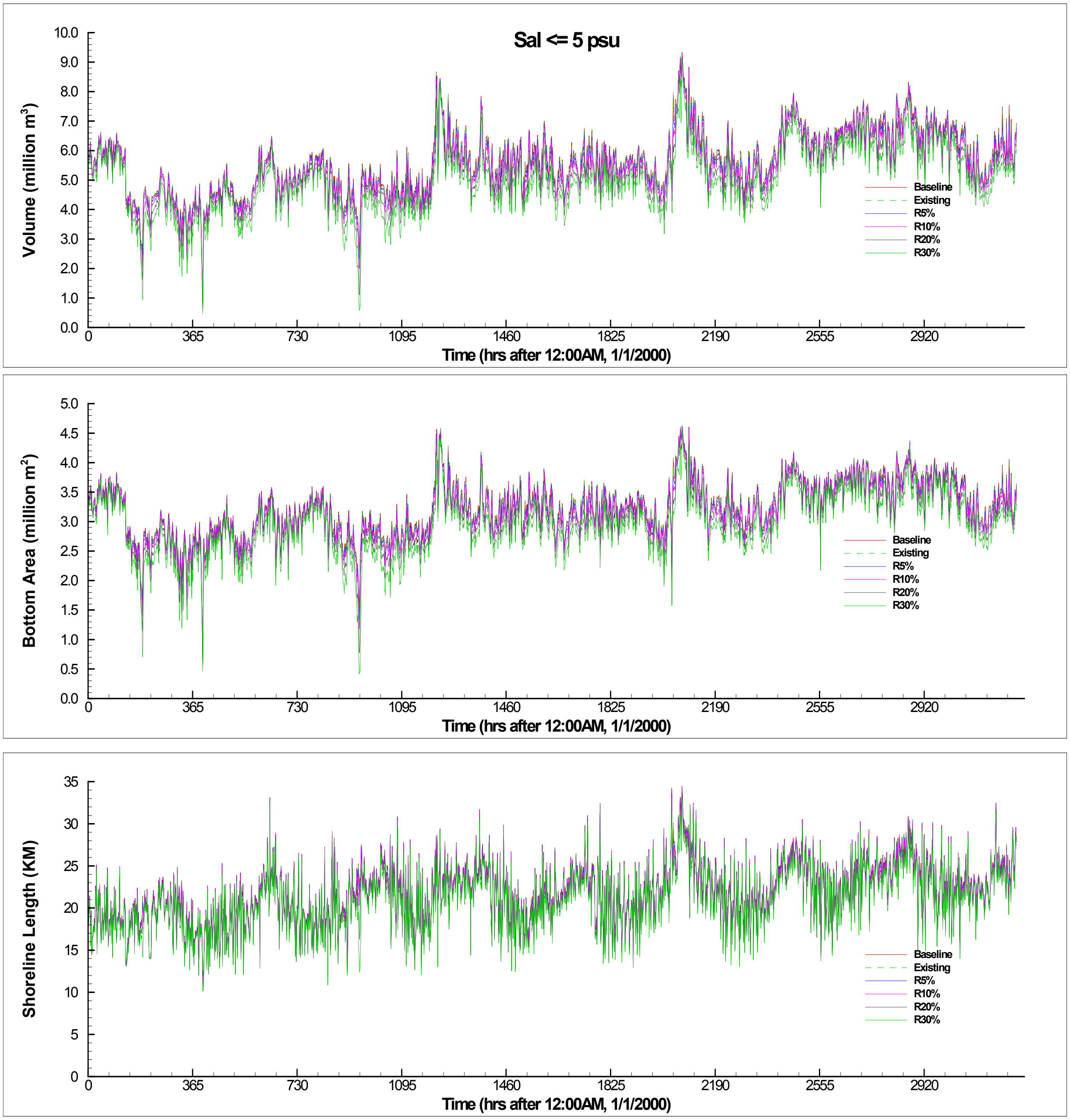

Figure 18 Daily mean water volumes, bottom areas, and shoreline lengths for salinity ≤ 5 psu under the baseline, existing, 5% flow reduction, 10% flow reduction, 20% flow reduction, and 30% flow reduction conditions.

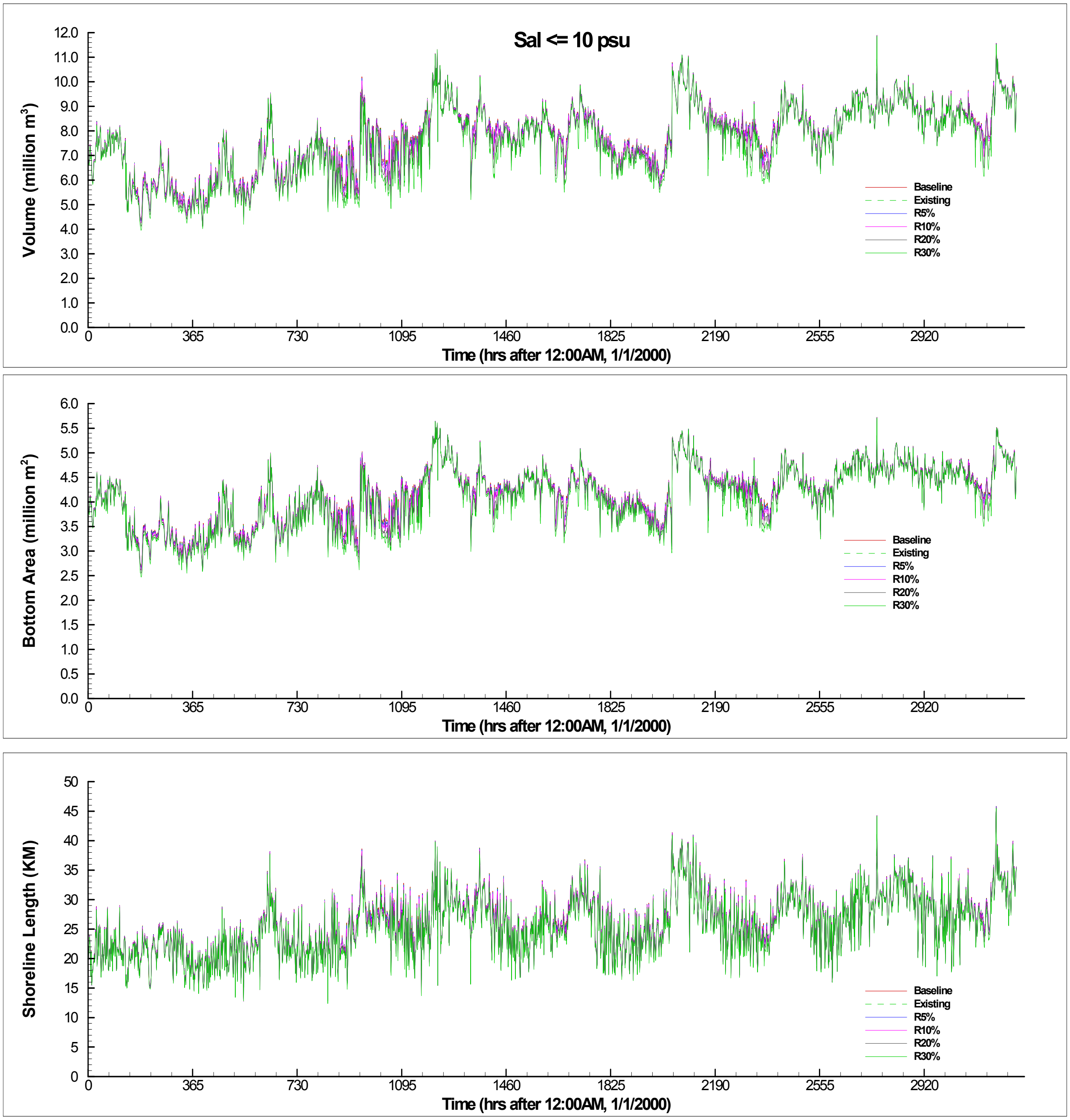

Figure 19 Daily mean water volumes, bottom areas, and shoreline lengths for salinity ≤ 10 psu under the baseline, existing, 5% flow reduction, 10% flow reduction, 20% flow reduction, and 30% flow reduction conditions.

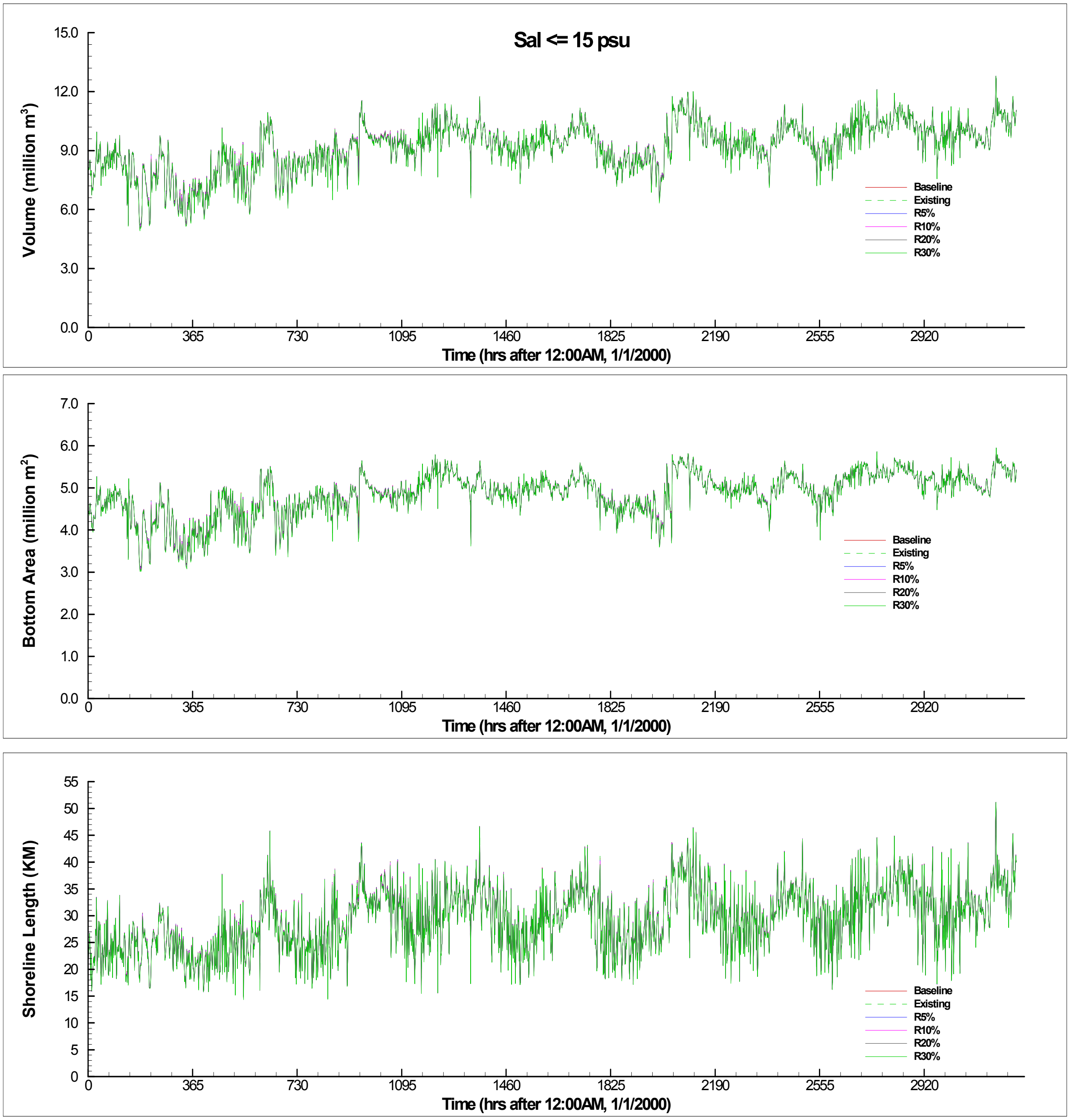

Figure 20 Daily mean water volumes, bottom areas, and shoreline lengths for salinity ≤ 15 psu under the baseline, existing, 5% flow reduction, 10% flow reduction, 20% flow reduction, and 30% flow reduction conditions.

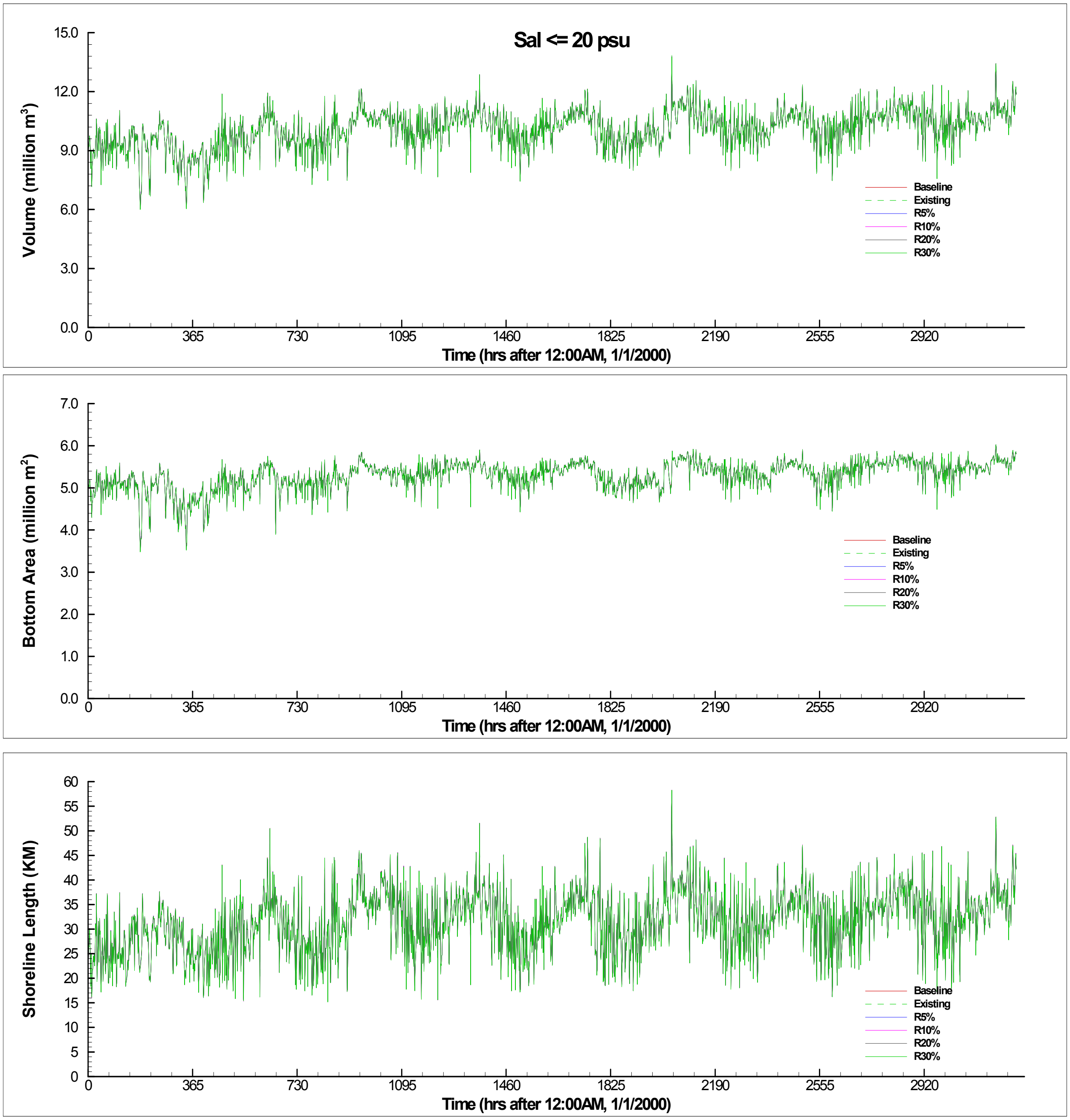

Figure 21 Daily mean water volumes, bottom areas, and shoreline lengths for salinity ≤ 20 psu under the baseline, existing, 5% flow reduction, 10% flow reduction, 20% flow reduction, and 30% flow reduction conditions.

As the upper bound of the salinity range increase, the temporal variations of volume, bottom area, and shoreline approach those caused mainly by tides. When the upper bound of the salinity range becomes 10 psu or more, the relative changes of water volume, bottom area, and shoreline due to the flow reduction become less significant.

One easy way to visualize the relative changes of water volume, bottom area, and shoreline caused by a flow reduction is to plot the daily results in the form of cumulative distribution function (CDF). Figure 22 - Figure 24 show CDF plots of water volume, bottom area, and shoreline length, respectively, for various salinity ranges under different flow reduction conditions. Due to the overlapping of graphs, only the baseline, existing, 5%, 10%, 15%, 20%, 25%, and 30% flow reduction scenarios are included in the figures. Because ≤ 15 psu and ≤ 20 psu habitats only have very small relative changes when SGDs are reduced, their CDF plots are not included in Figure 22 - Figure 24.

Examining Figure 22 - Figure 24, it is apparent that the ≤ 2 psu habitats exhibit the highest relative changes caused by flow reduction. In other words, the ≤ 2 psu habitats are most sensitive to a SGD reduction in the estuarine system. This is true not only for ≤ 2 psu water volume, but also for ≤ 2 psu bottom area and shoreline length. To quantify the relative changes of ≤ 2 psu habitats caused by flow reduction, average water volume, bottom area, and shoreline length for salinity ≤ 2 psu have been calculated, which are graphically areas between the *y*-axis and CDF curves in the figures. Based on these average values, the relative changes against the baseline scenario for ≤ 2 psu water volume can be found to be 2.09%, 6.06%, 12.59%, 19.55%, 27.02%, 34.78%, and 42.86%, respectively for existing, 5%, 10%, 15%, 20%, 25%,and 30% flow reduction scenarios.

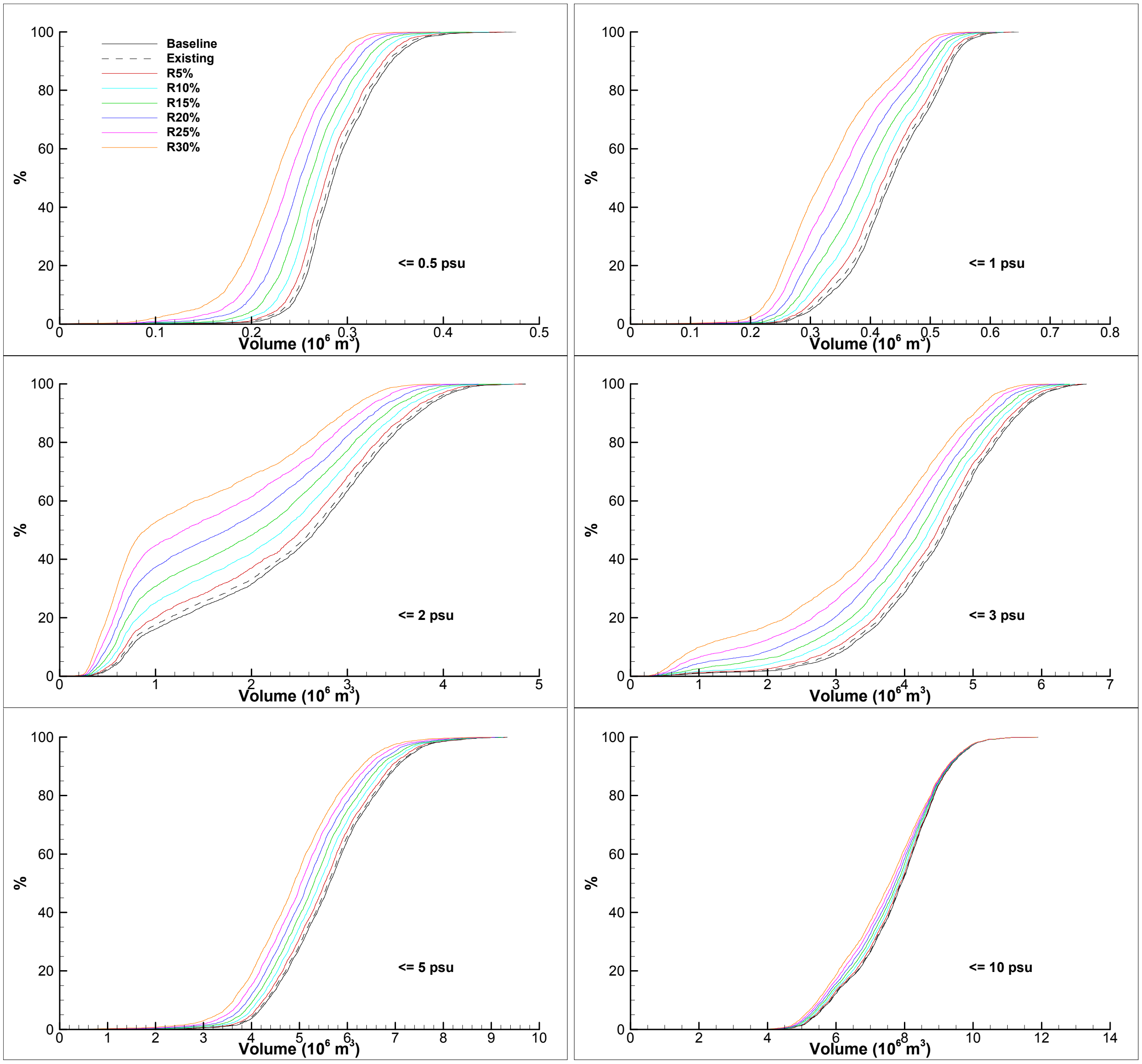

Figure 22 Cumulative distribution functions of water volumes for ≤ 0.5, 1, 2, 3, 5, and 10 psu under eight flow conditions (baseline, existing, and 5%, 10%, 15%, 20%, 25%, and 30% reductions from the baseline.)

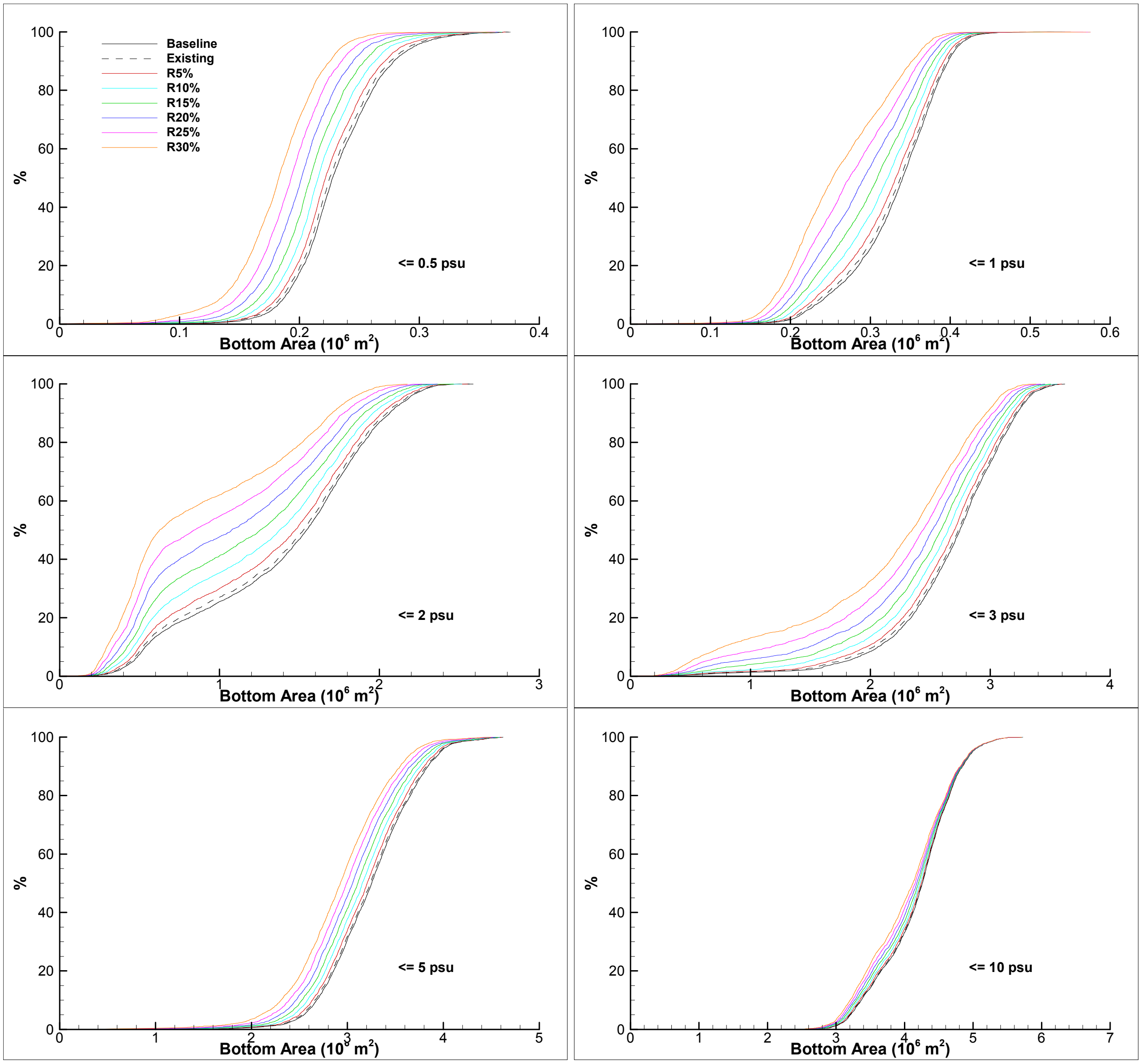

Figure 23 Cumulative distribution functions of bottom areas for ≤ 0.5, 1, 2, 3, 5, and 10 psu under eight flow conditions (baseline, existing, and 5%, 10%, 15%, 20%, 25%, and 30% reductions from the baseline.)

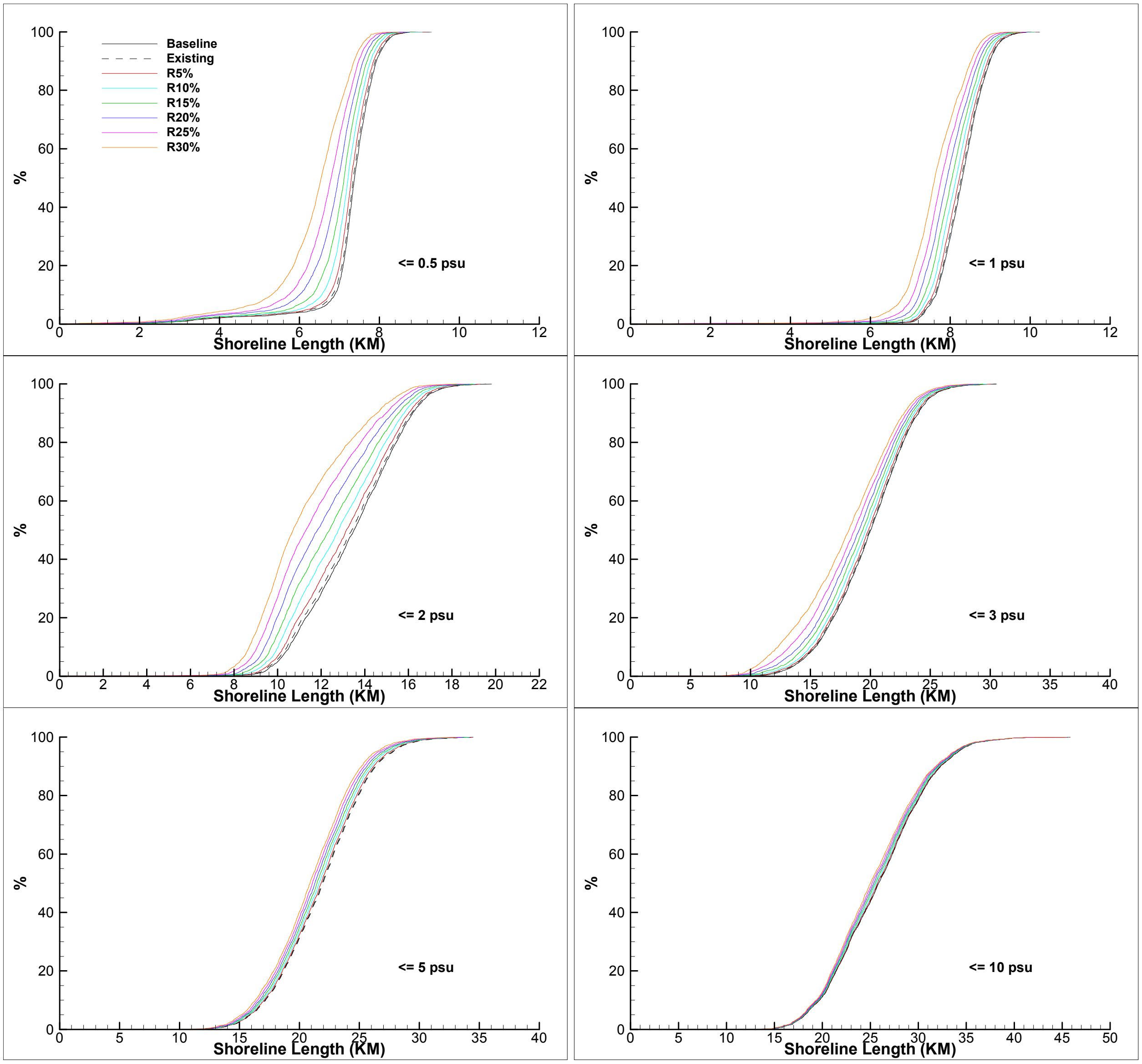

Figure 24 Cumulative distribution functions of shoreline lengths for ≤ 0.5, 1, 2, 3, 5, and 10 psu under eight flow conditions (baseline, existing, and 5%, 10%, 15%, 20%, 25%, and 30% reductions from the baseline.)

Table 7 provides more details on relative changes caused by different SGD reductions for water volumes of various salinity ranges. The last row in Table 7 lists the percentage reductions that would trigger a 15% water volume reduction for various salinity ranges. From the table, it is can be seen that an 11.78% SGD reduction would trigger a 15% reduction of ≤ 2 psu water volume. The percentages of the SGD reduction that would trigger 15% reductions of ≤ 0.5 psu, ≤ 1 psu, and ≤ 3 psu water volumes are 21.88%, 20.56%, and 21.58%, respectively. Higher salinity volumes are generally located in the downstream portion of CRKB and are less sensitive to the SGD reduction. Table 7 shows that a SGD reduction of 30% is not large enough to cause a 15% (or more) of water volume reduction for salinity ≤ 5 psu, ≤ 10 psu, and ≤ 15 psu. For example, a 30% SGD reduction only causes a 3.99% reduction of water volume for salinity ≤ 10 psu.

Similar to Table 7, Table 8 and Table 9 provide details of relative changes of bottom areas and shoreline lengths, respectively for various salinity ranges caused by different flow reduction scenarios. From Tables 7 – 9, it is clear that bottom area is less sensitive to SGD reduction than water volume is and shoreline length is less sensitive to SGD reduction than bottom area is. The percentage reductions of SGD that trigger a 15% reduction of bottom areas of ≤ 0.5 psu, ≤ 1 psu, ≤ 2 psu, and ≤ 3 psu are respectively 22.64%, 22.82%, 13.48%, and 24.90%. A 30% reduction of SGD is not enough to cause a 15% reduction of bottom areas of ≤ 5 psu, ≤ 10 psu, and ≤ 15 psu. For shoreline length, a 30% SGD reduction is not enough to cause a 15% shoreline length reduction for all salinity ranges except for ≤ 2 psu, which will be reduced by 15% with a 27.75% SGD reduction.

Table 7 Relative changes of water volume for various salinity ranges under different SGD reduction scenarios.

Reduction Scenario	**Relative Change (Water Volume)**						
	Sal ≤ 0.5	*≤ 1*	*≤ 2*	*≤ 3*	*≤ 5*	*≤ 10*	*≤ 15*
Existing	1.15%	1.15%	2.09%	1.02%	0.64%	0.17%	0.02%
2.5%	1.40%	1.51%	2.99%	1.36%	0.89%	0.24%	0.04%
5.0%	2.87%	3.08%	6.06%	2.78%	1.82%	0.49%	0.08%
7.5%	4.39%	4.75%	9.27%	4.28%	2.77%	0.75%	0.12%
10.0%	6.00%	6.50%	12.59%	5.91%	3.76%	1.03%	0.16%
12.5%	7.65%	8.33%	15.97%	7.64%	4.77%	1.32%	0.19%
15.0%	9.48%	10.29%	19.55%	9.53%	5.84%	1.65%	0.24%
17.5%	11.06%	12.00%	22.69%	11.07%	6.79%	1.92%	0.27%
20.0%	13.47%	14.50%	27.02%	13.58%	8.09%	2.33%	0.32%
22.5%	15.51%	16.71%	30.82%	15.83%	9.30%	2.72%	0.36%
25.0%	17.80%	19.03%	34.78%	18.31%	10.56%	3.12%	0.40%
27.5%	20.19%	21.39%	38.69%	20.83%	11.89%	3.54%	0.45%
30.0%	23.03%	24.00%	42.86%	23.68%	13.30%	3.99%	0.50%
Trigger (%)	***21.88%***	***20.56%***	***11.78%***	***21.58%***	***>30%***	***>30%***	***>30%***

Table 8 Relative changes of bottom area for various salinity ranges under different SGD reduction scenarios.

Reduction Scenario	**Relative Change (Bottom Area)**						
	Sal ≤ 0.5	*≤ 1*	*≤ 2*	*≤ 3*	*≤ 5*	*≤ 10*	*≤ 15*
Existing	1.13%	0.98%	1.75%	0.80%	0.48%	0.14%	0.01%
2.5%	1.37%	1.30%	2.55%	1.04%	0.67%	0.19%	0.03%
5.0%	2.79%	2.65%	5.17%	2.14%	1.37%	0.39%	0.06%
7.5%	4.28%	4.09%	7.95%	3.32%	2.09%	0.60%	0.09%
10.0%	5.83%	5.62%	10.83%	4.62%	2.84%	0.82%	0.12%
12.5%	7.42%	7.21%	13.77%	6.04%	3.61%	1.04%	0.15%
15.0%	9.16%	8.95%	16.91%	7.61%	4.43%	1.30%	0.18%
17.5%	10.71%	10.45%	19.62%	8.82%	5.15%	1.51%	0.20%
20.0%	12.97%	12.73%	23.54%	11.00%	6.17%	1.84%	0.24%
22.5%	14.88%	14.73%	26.94%	12.95%	7.12%	2.14%	0.28%
25.0%	17.02%	16.85%	30.49%	15.09%	8.11%	2.45%	0.31%
27.5%	19.21%	19.02%	34.07%	17.33%	9.15%	2.78%	0.34%
30.0%	21.85%	21.46%	37.91%	19.92%	10.27%	3.13%	0.38%
Trigger (%)	***22.64%***	***22.82%***	***13.48%***	***24.90%***	***>30%***	***>30%***	***>30%***

Table 9 Relative changes of shoreline length for various salinity ranges under different SGD reduction scenarios.

Reduction Scenario	**Relative Change (Shoreline Length)**						
	Sal ≤ 0.5	*≤ 1*	*≤ 2*	*≤ 3*	*≤ 5*	*≤ 10*	*≤ 15*
Existing	0.78%	0.59%	1.07%	0.35%	0.48%	0.32%	0.25%
2.5%	0.60%	0.40%	1.03%	0.45%	0.33%	0.15%	0.04%
5.0%	1.25%	0.83%	2.11%	0.92%	0.67%	0.31%	0.09%
7.5%	1.96%	1.30%	3.26%	1.43%	1.01%	0.48%	0.13%
10.0%	2.73%	1.80%	4.47%	2.02%	1.37%	0.65%	0.17%
12.5%	3.55%	2.35%	5.73%	2.70%	1.72%	0.83%	0.21%
15.0%	4.50%	2.97%	7.09%	3.46%	2.10%	1.02%	0.26%
17.5%	5.36%	3.50%	8.26%	3.99%	2.43%	1.18%	0.29%
20.0%	6.81%	4.38%	10.01%	5.11%	2.89%	1.43%	0.35%
22.5%	7.88%	5.12%	11.53%	6.11%	3.30%	1.65%	0.40%
25.0%	9.34%	6.05%	13.18%	7.24%	3.77%	1.89%	0.45%
27.5%	10.76%	6.89%	14.81%	8.42%	4.20%	2.12%	0.49%
30.0%	12.84%	8.04%	16.65%	9.84%	4.69%	2.37%	0.54%
Trigger (%)	***>30%***	***>30%***	***27.75%***	***>30%***	***>30%***	***>30%***	***>30%***

5.3. Results of Thermal Habitats

The purpose for considering thermal habitats (water volume and surface area of certain temperature ranges) is to protect manatees during the coldest days in winter, so that the warm-water refuge in Kings Bay won't be significantly reduced as a result of SGD reduction. Manatees cannot survive in water colder than 20 °C for a prolonged period of time, because of their inability to increase their metabolic rates in cold water to compensate the increased rate of body heat loss, as they have a high thermal conductance, or poor insulation (Worthy et al., 2000). As mentioned in Section 1, SGDs in Kings Bay have a relatively stable temperature at around 22.2 °C and provide a quite big area of warm-water refuge for manatees in winter when water temperature in the Gulf dips to 20 °C or lower.

Following the similar MFL-evaluation procedure used for other spring-fed estuaries in the District (e.g. Weeki Wachee River, Homosassa River, and Chassahowitzka River), water volumes and surface areas of three temperature ranges, namely ≤ 15 °C, between 15 and 20 °C (exclusive), and ≥ 20 °C, were calculated for various flow reduction scenarios. Figure 25 shows time series (30-minute interval) plots of water volume for temperature ≤ 15 °C, ≥ 20 °C, and between 15 and 20 °C (exclusive), while Figure 26 presents plots of time series of surface area for the same temperature ranges. For clarity, only results for the baseline, existing, 5%, 10%, 15%, 20%, 25%, and 30% flow reduction scenarios are plotted in these two figures. It should be noted that the computation of ≥ 20 °C volume and surface area only includes grids containing at least one continuous warm water (≥ 20 °C) layer with a thickness of 1.158 m (3.8 feet) or more in the water column. This 1.158 m thickness constrain for the warm water layer is determined from the size of an adult manatee to ensure that the animal is fully enclosed in warm water. Any grids that do not meet the 1.158 m criterion for the warm water layer are excluded from the computation of ≥ 20 °C volume and surface area.

As expected, during the warm months of the year, water temperature in Crystal River/Kings Bay is ≥ 20 °C and there exist no water volume and surface area that are < 20 °C. During the manatee season, which is defined as November – March in this MFL evaluation, water temperature in Crystal River/Kings Bay can drop to below 10 °C, a significant amount of < 15 °C water volume and surface area exist in the estuary. A careful exam of the plots reveals that during the coldest days of the year, it is possible that ≥ 20 °C volume and surface area can temporally vanish. This may sound contradictory to the statement that spring flow in Kings Bay is about 22.2 °C, with a small seasonal variation, all year around. The reason for this contradiction stems from the fact that the 1.158 m warm layer limitation. In grids containing spring vents, there will be a certain amount of warm water volume near the bottom, but the warm water thickness is less than 1.158 m thick and cannot be considered as a usable warm water refuge for manatees.

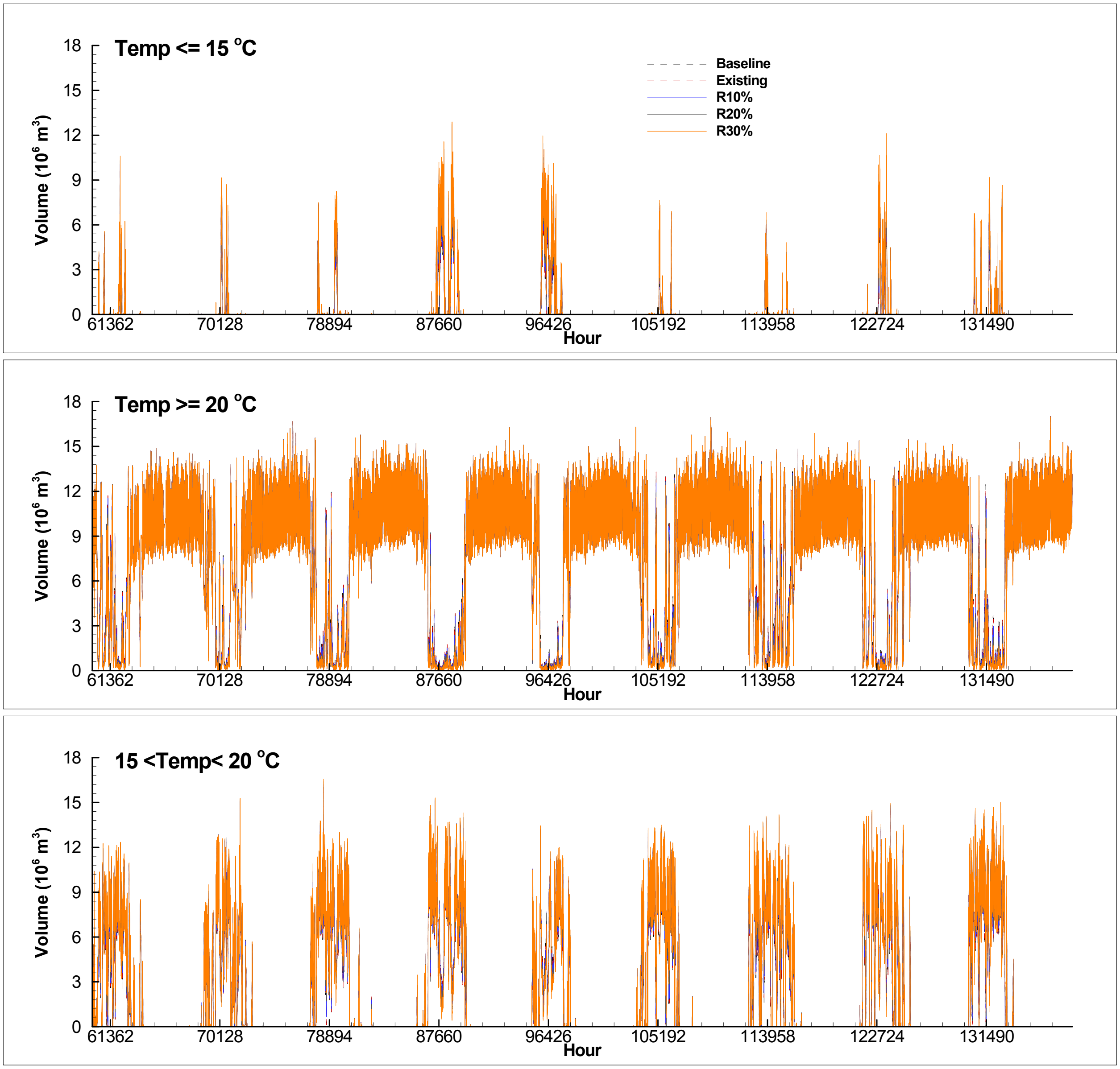

Figure 25 Real-time water volumes for temperature ≤ 15 ºC, between 15 and 20 ºC (exclusive), and ≥ 20 ºC for the baseline, existing, and 10% flow reduction, 20% flow reduction, and 30% flow reduction scenarios in Crystal River/Kings Bay.

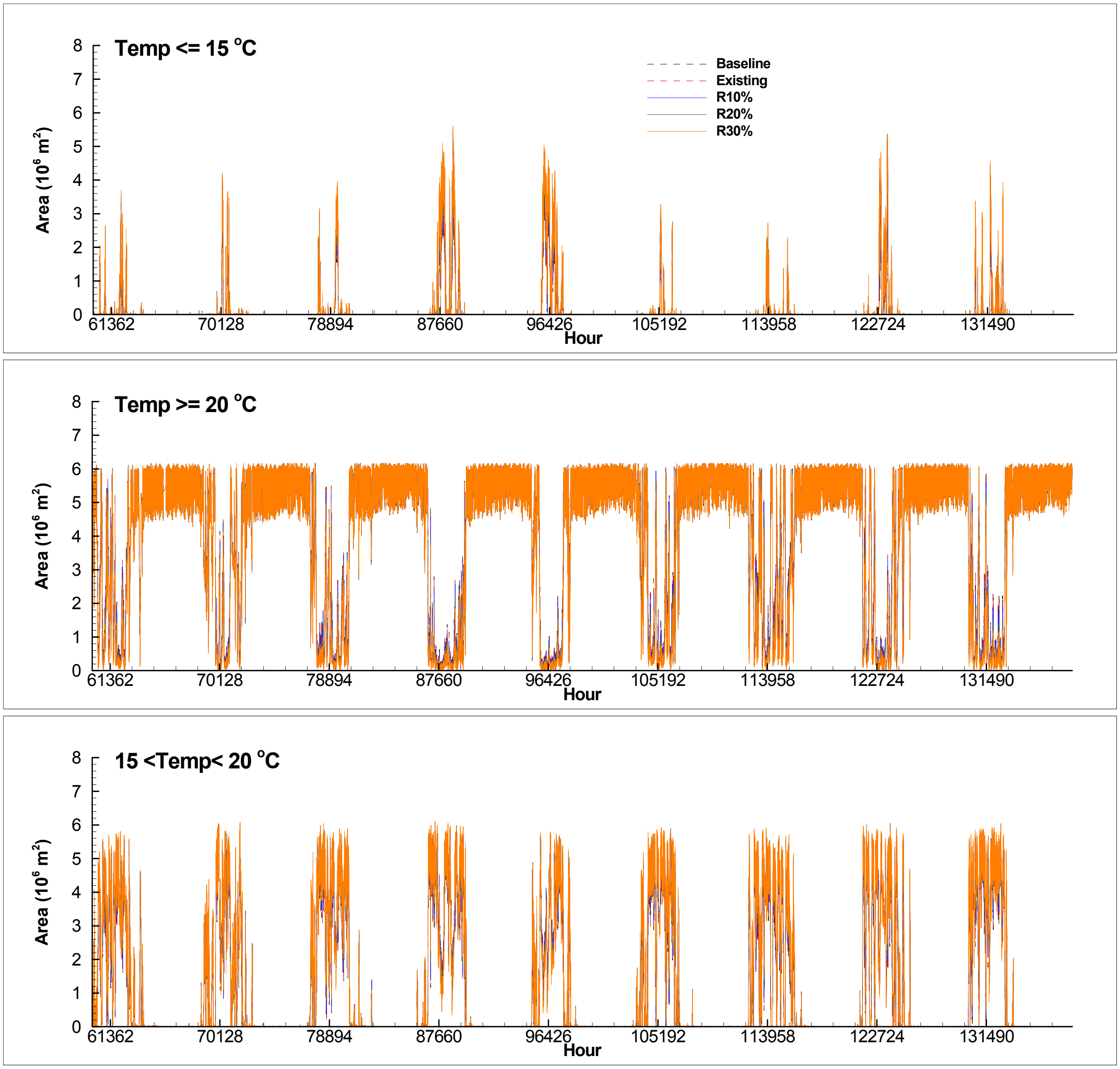

Figure 26 Real-time surface areas for temperature ≤ 15 ºC, between 15 and 20 ºC (exclusive), and ≥ 20 ºC for the baseline, existing, and 10% flow reduction, 20% flow reduction, and 30% flow reduction scenarios in Crystal River/Kings Bay.

Figure 27 shows an example of the cold time period when usable ≥ 20 ºC volume was not available for manatees. Between Hours 88705.5 - 88712.5 (1:30 AM – 8:30 AM, 2/13/2010), the usable warm water volume was zero for five hours under the baseline flow condition. As the flow is further reduced, the duration of the lack of usable warm water become longer. When the SGD was reduced by 30%, the zero warm water hours increased to 9.5 hours, from Hour 88704.5 to Hour 88714.0. The 2/13/2010 event was the coldest in 2010 but lasted only for a couple of days. About a month earlier, there was a prolonged period of cold event that lasted about 12 days, from January 4, 2010 to January 15, 2010, when the daily low of air temperature in the region dipped to below 0 °C every day. The lowest daily low air temperature measured at a nearby weather station at Inverness during this 12 days was -7.8 °C, which although not the lowest low for the year of 2010, caused the least available thermal habitats for manatee in Crystal River/Kings Bay due to the longevity of the cold event.

Based on available air temperature data measured at the Inverness station, which started in 1948, the daily low of -7.8 °C has a return period of about 15 years. However, if a 3-day moving average is taken before the return period is calculated, the second lowest 3-day moving average for the 69 years of period of record occurred during the 12-day cold event and has a return period of 35 – 46 years, depending on the type of formula used in calculating the return period. Furthermore, if a 5-day moving average is taken before the return period is calculated, the lowest 5-day moving average for the 69 years of period of record did occur during the 12-day cold event and has a return period of 70 - 138 years. Smith (2000) recommended that the protection of the preferred manatee habitats from a cold event should be at a frequency (or return period) that is consistent with the lifespan of manatees, which is on the order of 50 years or longer. Based on the POR air temperature data, the coldest 3-day average in January 2010 would happen to a manatee, on average, one or two times in its lifespan, but the coldest 5-day average in January 2010 would statistically happen no more than one time in its lifespan.

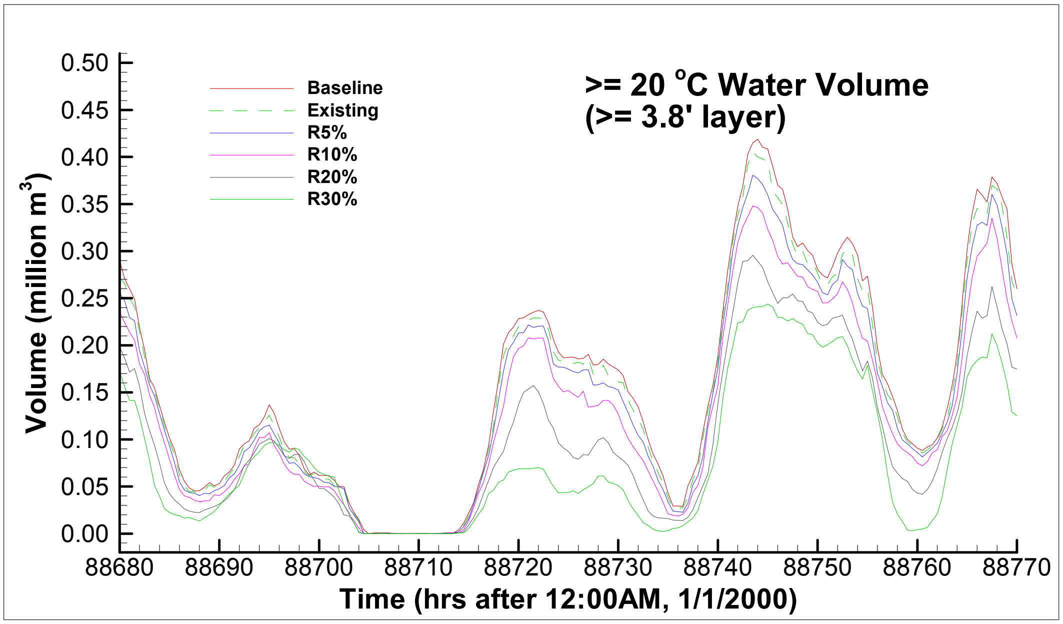

Figure 27 Time series of ≥ 20 °C water volume during the coldest days in 2010, within which there was a period for about 10 hours, during which none of warm water volumes is thick enough for manatee to use as a refuge.

Figure 28 - Figure 29 are CDF plots of various thermal habitats for different flow reduction scenarios. Once again, for clarity, only the baseline, existing, 5%, 10%, 15%, 20%, 25%, and 30%

flow reductions are plotted in the figures. These CDFs plots include only model results during the manatee season (November – March). It is clear that even during the cold months, the overall thermal habitats are not sensitive to SGD reduction. Long-term averages of water volume and surface areas over the 45 months (5 manatee months for 9 yeras) for temperature ≤ 15 ºC, ≥ 20 ºC, and between 15 and 20 ºC (exclusive) were only slightly reduced with a SGD reduction. This should not be a surprise because the Gulf water during the manatee season generally varies between 15 – 25 ºC most of the time, except for days when sever cold fronts come in, during which Gulf water could drop to a couple of degrees below 10 ºC. When the Gulf water is only a few degrees warmer or colder than the spring flow temperature, reducing spring flow won't have much an effect on thermal habitats. As such, the only time period when thermal habitats are sensitive to SGD reduction would be during the cold days when the Gulf water is much colder than spring flows out of the vents.

For the protection of thermal habitats for manatees, it is necessary to examine how sensitive thermal habitats are to the flow reduction during short-term cold events. Because of their inability to survive in cold environment, exposure to water below 20 ºC for longer than 4 – 7 days could result in disastrous losses to the manatee population (Rouhani et al., 2007). Therefore, less than 4 days should be the time scale in analyzing sensitivities of thermal habitats to flow reduction in Crystal River/Kings Bay during short-term cold events. For the sake of conservatism, St. Johns River Water Management District further reduced the time scale to 3 days in their evaluation of a minimum flow regime for the Blue Spring (Rouhani et al., 2007).

This 3-day time scale was also used by SWFWMD in analyzing thermal habitats in the Weeki Wachee River (Janicki Environmental and Applied Technology & Management, 2007), the Chassahowtizka River (Dynamic Solutions, 2009), and the Homosassa River (HSW Engineering, 2011). For example, during the MFL evaluation for the Homosassa River, a 3-day window was chosen for the thermal analysis based on available data of air temperature and tides, during which the least favorable thermal conditions for manatees were supposed to occur in the spring-fed estuary. To protect manatees, ≥ 20 ºC water volume and surface area during these critical 3 days are supposed to be not reduced by more than 15% due to flow reduction.

In addition to the 3-day time scale, SWFWMD also considered an acute condition that requires a much shorter time scale: when water temperature is further drops to below 15 ºC, manatees cannot withstand the cold for more than 4 hours (Janicki Environmental and Applied Technology & Management, 2007). Relative to the 4-hour period of the acute condition, a three-day period of cold condition is considered as chronic in the thermal analysis.

Although the coldest single day in 2010 did not occur in January 2010, the prolonged cold event for consecutive 12 days in January appears to be a very rare occurrence. Considering the fact that the lowest 5-day moving average of air temperature within the 12-day period has a return period of 70 – 138 years, the return period for the 12-day cold event is certainly longer. Although water temperature in Crystal River is highly correlated with air temperature measured in Inverness, water temperature generally lags air temperature, as it takes time for water to respond to climatic changes. Water temperature variation in Crystal River/Kings Bays is a result of convolution of the thermal transport process, SGDs, temperature of SGDs, and the heat flux at the free surface, which is related to the air temperature, air humidity, solar radiation, etc. Therefore, a single day of low air temperature does not necessarily reduce temperature in Crystal River significantly; however, the cumulative effect of a prolonged period of cold air temperature definitely results in a substantial reduction of preferred thermal habitats. As such, we consider these 12 days as most critical to manatees. Out of this consideration, it is reasonable to select a 3-day period within the 12-day cold event for the thermal analysis for the chronic condition.

There are several ways to select the 3-day period for thermal analysis of the chronic condition and each will result in a different 3-day window. For example, from the hourly air temperature data collected at the Inverness station, the lowest 3-day (or more precisely, 72-hour) moving average of the air temperature within the 12-day period can be found to be between Hours 87873 – 87945. From measured water temperature data (with 15-minute interval) collected in Crystal River/Kings Bay, the lowest 72-hour water temperature at the mouth of Crystal River can be found to be between Hours 87894.5 – 87966.5, while the lowest 72-hour water temperature at the mouth of Kings Bay was between Hours 97897.25 – 97969.25. For the Crystal River as a whole, the lowest 72-hour water temperature during the 12-day period was found to be between Hours 87896 – 87968.

Apparently, the last 72-hour window, Hours 87896 – 87968, is most suitable for the thermal habitat analysis under the chronic condition, because our analysis considers favorable thermal habitats for the CRKB system as a whole. Average water volumes and surface areas for temperature ≥ 20 ^{o}C under various flow reduction scenarios can be calculated during this 72-hour period. Relative changes of ≥ 20 ^{o}C thermal habitats caused by the flow reduction can then be calculated under the chronic condition. Results of the analysis are listed in Table 10, which shows that a 15.49% flow reduction will cause a 15% reduction of ≥ 20 ^{o}C water volume and a 15.22% flow reduction will cause a 15% reduction of ≥ 20 ^{o}C water surface area in Crystal River/Kings Bay during the critical 72-hour period.

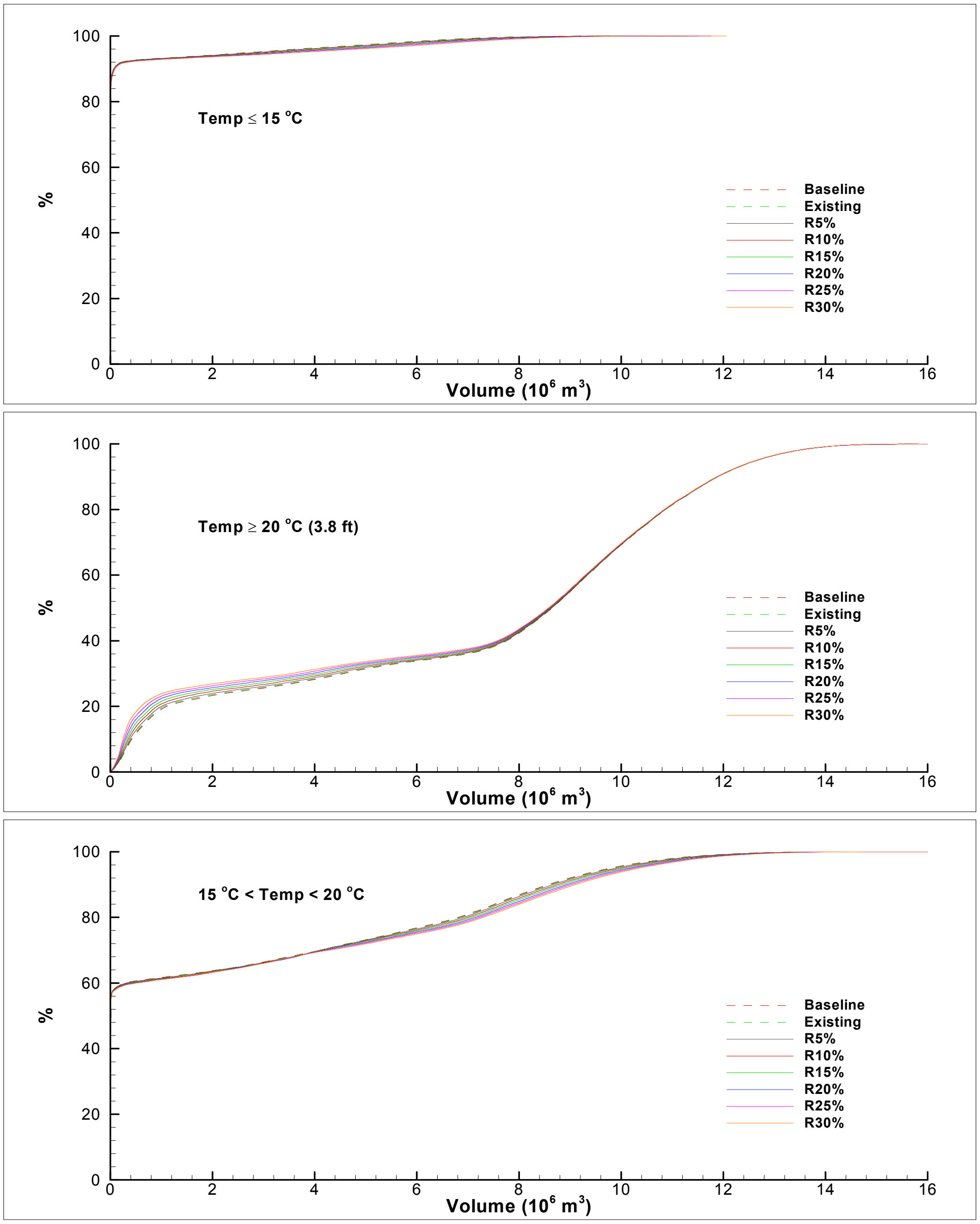

Figure 28 Cumulative distribution functions of water volumes for various temperature ranges, including ≤ 15 °C, between 15 and 20 °C (exclusive), ≥ 20 °C (with 3.8' limit), and more.

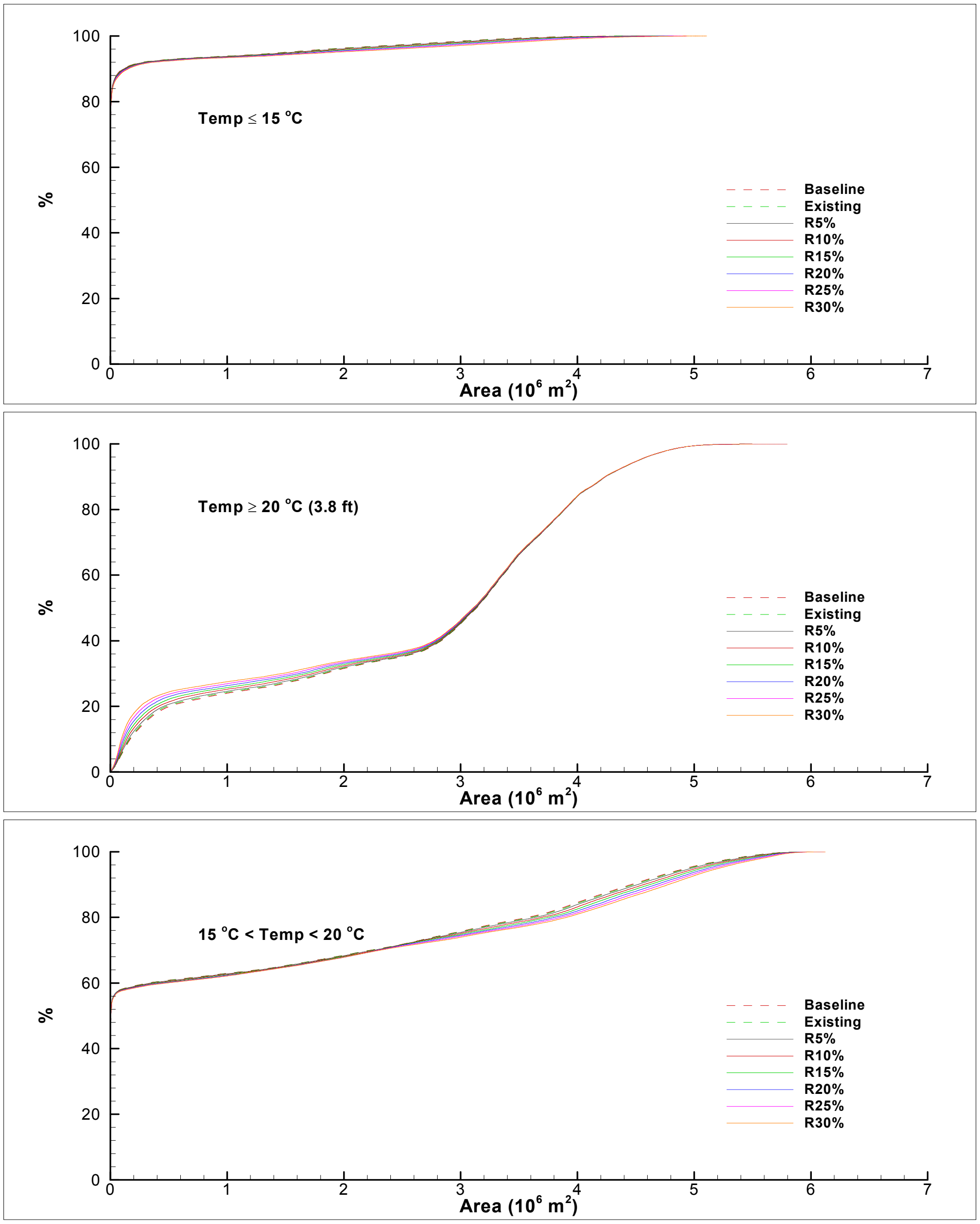

Figure 29 Cumulative distribution functions of surface areas for various temperature ranges, including ≤ 15 ºC, between 15 and 20 ºC (exclusive), ≥ 20 ºC (with 3.8' limit), and more.

Table 10 Water volumes and surface areas for temperature ≥ 20 °C and their relative changes during the chronic 72-hour period in Crystal River/Kings Bay.

Flow Scenario	**Volume (m^3)**	**Volume Reduction**	**Area (m^2)**	**Area Reduction**
Baseline	142012		50227	
Existing	139353	1.87%	48859	2.72%
2.5%	138320	2.60%	48648	3.14%
5.0%	137291	3.32%	48287	3.86%
7.5%	134229	5.48%	47198	6.03%
10.0%	131833	7.17%	46235	7.95%
12.5%	127542	10.19%	44667	11.07%
15.0%	122937	13.43%	43079	14.23%
17.5%	111620	21.40%	38732	22.89%
20.0%	114946	19.06%	40082	20.20%
22.5%	110170	22.42%	38528	23.29%
25.0%	104175	26.64%	36083	28.16%
27.5%	99498	29.94%	34569	31.17%
30.0%	92079	35.16%	32043	36.20%
Trigger (%)		15.49%		15.22%

As stated above, when water temperature drops to ≤ 15 °C, the condition for manatees becomes very server, as manatees can withstand cold water lower than 15 °C no more than four hours. Naturally, manatees try to avoid ≤ 15 °C habitats and find warmer habitats to survive in these acute conditions. As such, the existence and extension of > 15 °C habitats are critical and the analysis of thermal habitats under the acute condition becomes the analysis of thermal habitats > 15 °C, which are not supposed to be reduced more than 15% in the 4-hour period. This approach is consistent with analyses of salinity and thermal habitats in our previous MFL evaluations, as we focus on reductions of favorable habitats, not on the increases of unfavorable habitats.

Similar to the way that thermal habitats ≤ 15 °C, between 15 and 20 °C (exclusive), and ≥ 20 °C habitats were calculated in the post-process, water volumes and surface areas for temperature > 15 °C (with a continuous layer of 1.158 m or thicker) can be calculated and shown in Figure 30 - Figure 31. A close exam of the time series of > 15 °C habitats confirms that > 15 °C always existed during the 9-year simulation period and there was no single time point that > 15 °C water volume or surface area was reduced to zero, even during the prolonged period of cold event in 2010. Under the baseline flow condition, the minimum > 15 °C water volume was 894,823 m^3, which occurred at Hour 88712.5. The minimum > 15 °C surface area was 664,877 m^2, which occurred at Hour 88712. If a 4-hour moving average is conducted, the minimum > 15 °C volume still occurred at Hour 88712.5 with a value of 932,014 m^3, but the minimum 4-hour average surface area occurred at Hour 88710.5 with the minimum value of 687,473 m^2.

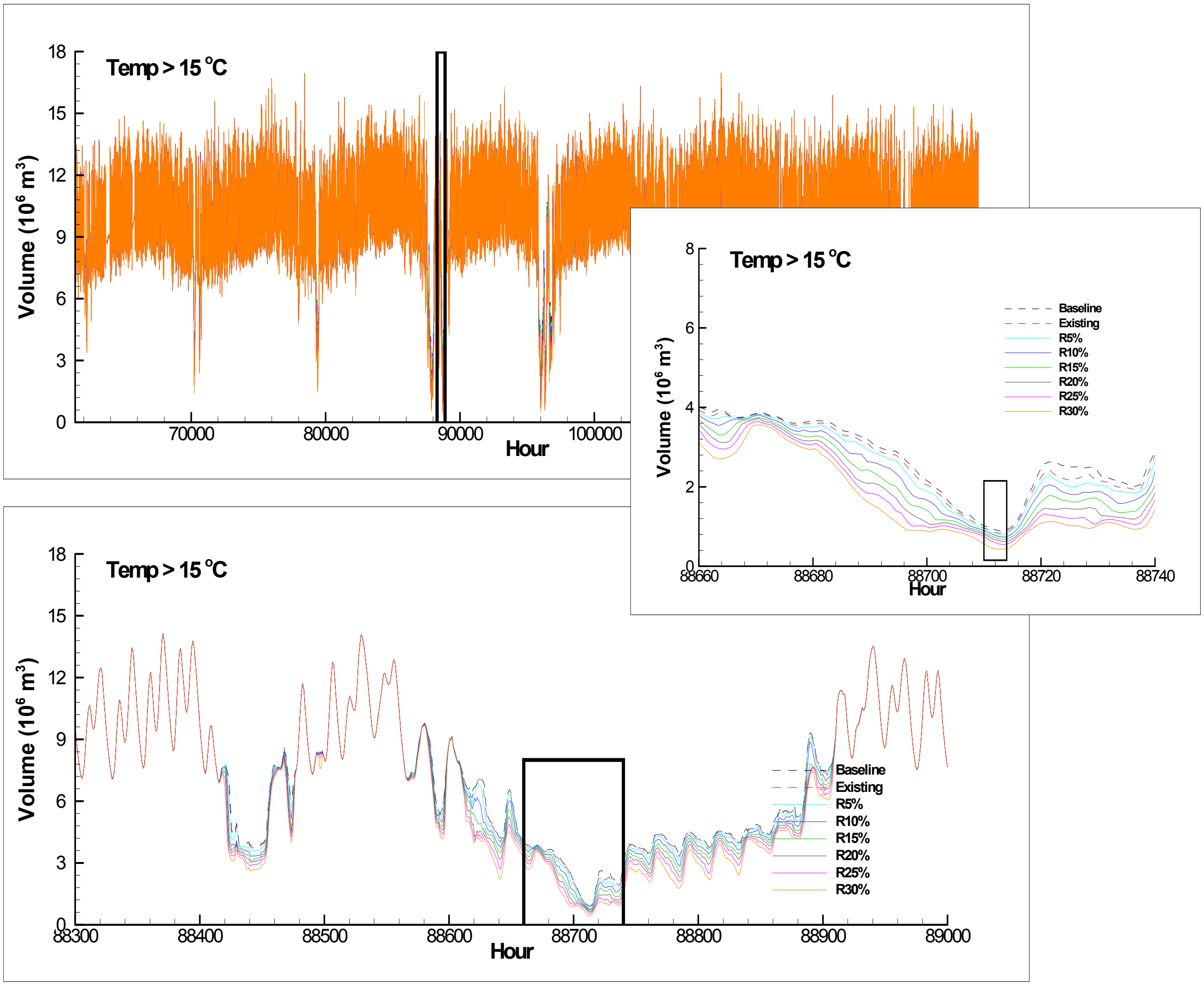

Figure 30 Time series of >15 ºC water volume in Crystal River/Kings Bay during the 9-year simulation period.

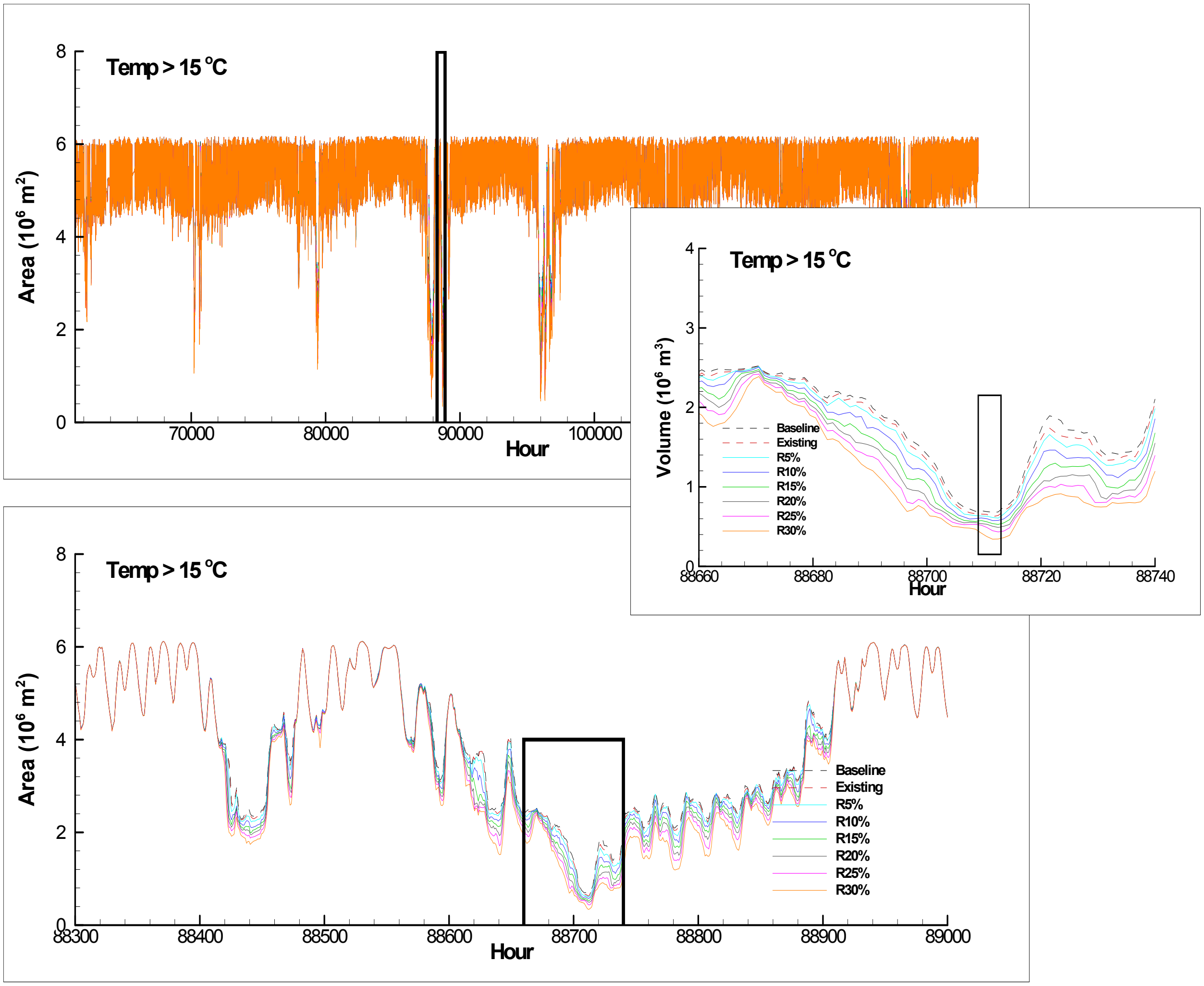

Figure 31 Time series of >15 °C surface area in Crystal River/Kings Bay during the 9-year simulation period.

Table 11 lists results of minima of 4-hour moving averages of > 15 °C water volume and surface area for all flow reduction scenarios. The relative changes with respect to results of the baseline flow scenario are also included in the table. From the table, it can be seen that the 15% threshold for > 15 °C volume and surface area under the acute condition is respectively crossed by 8.61% and 10.68% flow reductions.

Table 11 Minima of water volume and surface area for temperature > 15 °C in Crystal River/Kings Bay and their relative reduction from the baseline flow scenario.

Flow Scenario	**Volume (m^3)**	**Volume Reduction**	**Area (m^2)**	**Area Reduction**
Baseline	932,014		687,473	
Existing	872,502	6.39%	648,734	5.64%
2.5%	886,366	4.90%	657,912	4.30%
5.0%	835,109	10.40%	625,807	8.97%
7.5%	807,625	13.35%	608,539	11.48%
10.0%	772,836	17.08%	589,303	14.28%
12.5%	749,550	19.58%	570,982	16.94%
15.0%	713,703	23.42%	544,189	20.84%
17.5%	694,350	25.50%	529,798	22.94%
20.0%	658,998	29.29%	508,350	26.06%
22.5%	623,328	33.12%	477,878	30.49%
25.0%	587,281	36.99%	455,435	33.75%
27.5%	527,987	43.35%	412,790	39.96%
30.0%	452,171	51.48%	358,707	47.82%
Trigger (%)		***8.61%***		***10.68%***

5.4 Results of Residence Times

One important concern is that flow reduction would increase the residence time in Kings Bay and thereby affect water quality in the embayment. It is thus necessary to estimate residence times in the MFL evaluation for the Crystal River/Kings Bay system. This sub-section describes how the estuary residence time (ERT) was calculated for Kings Bay.

The estuary residence time for Kings Bay is defined as the time needed for conservative tracers that are evenly distributed at an initial time to be flushed out the water body. Because the reduction of conservative tracer in estuaries generally follows a curve that has an asymptote of zero concentration as the time increases, ERT could be infinite. In practice, a cutoff at 95% is used in determining the ERT. In other words, the ERT is the time needed for 95% of the original conservative tracer mass to be removed from the waterbody by the advective-diffusive transport.

Because the transport time scale in Kings Bay is affected not only by SGDs but also by tides and the volume of Kings Bay, a number of simulation periods were selected to include various tidal, SGD, and volume condition in the ERT runs. Table 12 lists all the ERT simulation periods. These simulation periods are also shown in Figure 32, along with time series plots of tides (red line) at the mouth of Kings Bay, groundwater level in ROMP TR21-3 (green line), and the total SGD (brown line). For each ERT simulation period, 14 flow scenarios were run, including the baseline, existing, and various flow reduction scenarios, resulting 126 ERT simulations. As can be seen in the following discussion, ERT for Kings Bay is roughly in the time scale of 1 – 4 weeks. Therefore, it was deemed appropriate to simulate conservative tracer concentration for about 30 days after tracers are released to Kings Bay, with a 30-day spin-up run conducted beforehand.

Table 12 Nine ERT simulation periods, for the consideration of different tidal, SGD, and Kings Bay volume conditions.

ERT Run Period	Tides	SGD	KB Volume	Simulation Period (Hrs)
1	Spring	Low	Average	116698.0 – 117288.0
2	Neap	Low	Average	116871.0 – 117510.0
3	Average	High	High MMSL	76206.0 – 76560.0
4	Average	Average	Low MMSL	70133.5 – 70512.0
5	Neap	Average	Average	125666.0 – 126264.0
6	Average	5th Percentile	Average	80856.0 – 81576.0
7	Neap	10th Percentile	Above Avg.	81576.0 – 82296.0
8	Neap	50th Percentile	High MMSL	119304.0 – 120024.0
9	Spring	90th Percentile	High MMSL	110832.5 – 111552.0

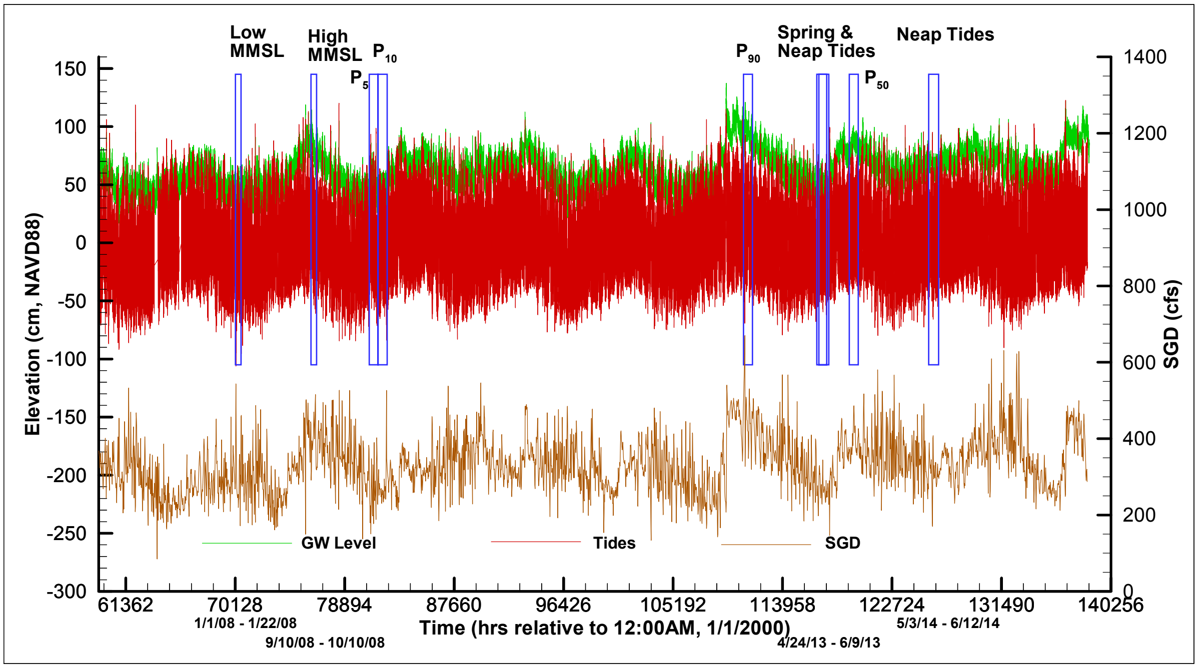

Figure 32 Simulation periods for ERT runs (blue boxes) and time series of tides, groundwater level, and total SGD.

Some of the factors controlling the transport time scale in Kings Bay have a much shorter time scale than ERTs. For example, the spring-neap tidal cycle is about 14 days and spring (neap) tides last about 3 - 4 days, which won't cover the entire length of the ERT. The tidal and SGD conditions listed in Table 12 were actually conditions during the first 3 days of each ERT simulation period. Simulation periods No.6 – 9 were obtained by first conducting a 7-day moving average of total SGD results for the baseline scenario and then finding the 5^{th}, 10^{th}, 50^{th}, and 90^{th} percentiles of the 7-day moving average of total SGD and the corresponding time points of these flow percentiles. The starting time points of Periods 6 – 9 were set to be 3.5 day (84 hours) earlier than these corresponding time points of the flow percentiles and the ending time points would be ≥ 720 hours later from the starting time points. The logic for taking the 7-day average of SGD came from the consideration of the length of ERT in Kings Bay.

Figure 33 - Figure 41 are time series of the mass of conservative tracer remaining in Kings Bay (red lines) and in the entire Crystal River/Kings Bay (blue lines). Clearly, these time series contain tidal signals, which can be filtered out with a low-pass filter. We used the Demerliac filter (Demerliac, 1974), which involves 71 symmetric weighting factors that are bell-shaped. The filtered time series of remaining tracer mass in Kings Bay and CRKB are depicted in Figure 33 - Figure 41 with green and black lines, respectively. Again, for clarity, not all the flow scenarios are included in these figures.

Using the 5% criterion for the remaining mass, ERTs for Kings Bay can be found from the filtered time series (green lines) shown in Figure 33 - Figure 41 for various flow scenarios in all 9 simulation periods. Similarly, transit times for Kings Bay water to pass through Crystal River can be obtained from the filtered time series of mass remaining in CRKB (black lines) shown in Figure 33 - Figure 41. As can be seen from the blue (or black) lines shown in the figures, the total mass of conservative tracer didn't start to leave the simulation domain till about 20 – 80 hours after the tracers were released, as it takes time for tracer particles to be transported to the nearest open boundary of the domain, which is the one on the Salt River (see Figure 8 for the simulation domain.)

Numerical values of ERTs for different simulation periods under various flow conditions are listed in Table 13. Model results shown in Figure 33 - Figure 41 and Table 13 confirms our general understanding of the transport time scale in Kings Bay. A reduction in SGD will cause an increase of ERT in Kings Bay. ERT in Kings Bay is highly correlated with the water volume of the water body. During the period of low monthly mean sea level, water volume of Kings Bay is small and ERT is much shorter than that during the period of high monthly mean sea level. The shortened ERT during low MMSL is not only due to a smaller water volume of the water body but also due to high spring flows, as low water level in Kings Bay causes high SGDs. ERT results for spring and neap tides do not lead to definitive conclusion, mainly because the duration of spring (or neap) tides is generally much shorter than ERT, during which both spring and neap tides occur (the tidal conditions listed in Table 12 were just for the first 3 days of the simulation period.)

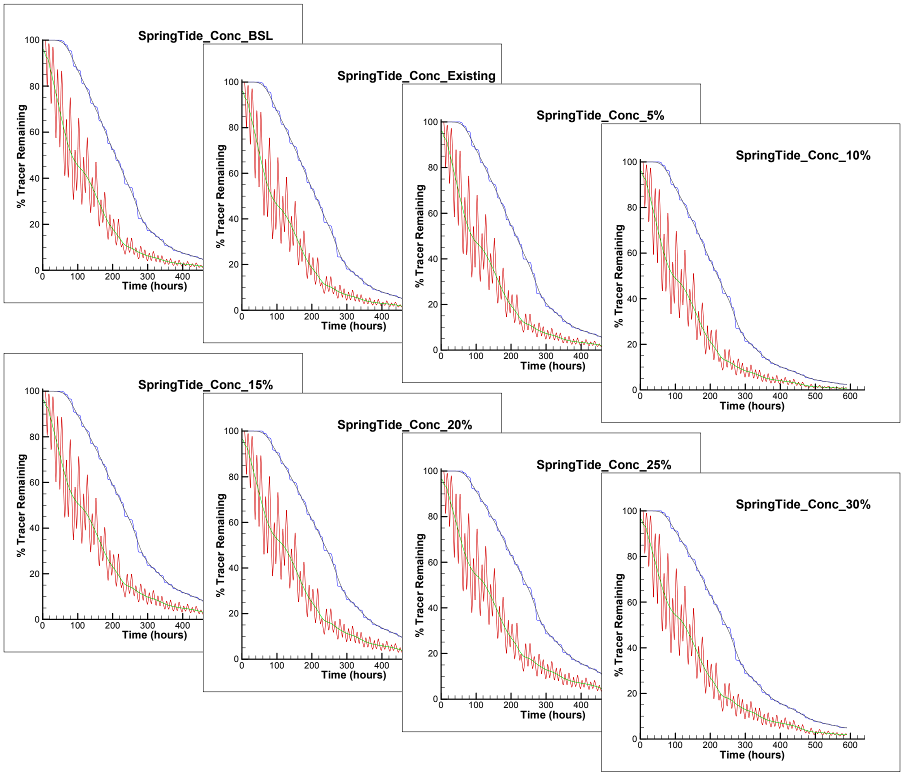

Figure 33 Time series of conservative tracer mass remaining in KB (red lines) and CRKB (blue lines) for various flow scenarios during Period 1.

Table 13 Simulated ERTs of Kings Bays for various flow scenarios during different periods.

Flow Scenario	**ERT for Kings Bay (hours)**									
	Period 1	**Per 2**	**Per 3**	**Per 4**	**Per 5**	**Per 6**	**Per 7**	**Per 8**	**Per 9**	**Average**
BSL	331.56	298.38	220.90	144.17	307.56	372.66	327.23	263.42	170.22	282.82
Existing	337.10	301.64	223.74	149.86	310.95	375.24	334.07	269.12	173.84	286.85
2.5%	338.38	302.47	224.46	152.18	311.71	376.09	335.69	270.56	174.78	287.98
5.0%	345.16	306.86	228.39	161.00	315.48	379.27	344.43	278.56	179.22	293.23
7.5%	352.46	312.18	232.81	170.84	319.03	382.48	353.92	286.57	183.74	298.88
10.0%	361.16	319.34	237.41	180.48	322.53	386.30	364.64	294.89	188.68	305.20
12.5%	372.64	330.34	242.37	192.14	326.15	390.70	373.09	303.39	193.70	312.43
15.0%	386.86	344.84	247.49	199.97	330.19	396.90	382.61	312.30	198.71	320.50
17.5%	405.34	359.30	252.75	206.72	334.53	411.15	394.84	320.82	204.13	331.10
20.0%	426.60	372.37	258.92	218.39	339.56	431.58	408.30	328.83	210.10	344.16
22.5%	436.92	383.75	266.59	231.41	345.70	452.42	419.37	336.54	216.73	356.15
25.0%	446.68	394.84	276.07	246.14	354.45	464.64	428.93	343.83	224.17	366.73
27.5%	454.80	409.65	284.90	260.30	374.57	474.70	439.71	351.25	233.14	378.50
30.0%	461.50	425.30	292.08	271.58	398.56	483.98	453.22	358.50	244.04	390.47

Table 14 Percentage increases of ERTs for various flow reduction scenarios and the trigger percentages that will cause 15% increases of ERTs for different ERT simulation periods.

Flow Scenario	**Relative ERT Increase (%)**									
	Period 1	**Per 2**	**Per 3**	**Per 4**	**Per 5**	**Per 6**	**Per 7**	**Per 8**	**Per 9**	**Average**
Existing	1.67	1.09	1.29	3.95	1.10	0.69	2.09	2.16	2.13	1.62
2.5%	2.06	1.37	1.61	5.56	1.35	0.92	2.59	2.71	2.68	2.06
5.0%	4.10	2.84	3.39	11.67	2.58	1.77	5.26	5.75	5.29	4.20
7.5%	6.30	4.62	5.39	18.50	3.73	2.64	8.16	8.79	7.94	6.48
10.0%	8.93	7.02	7.47	25.19	4.87	3.66	11.43	11.95	10.84	9.00
12.5%	12.39	10.71	9.72	33.27	6.04	4.84	14.01	15.17	13.79	11.84
15.0%	16.68	15.57	12.04	38.70	7.36	6.50	16.92	18.56	16.74	14.93
17.5%	22.25	20.42	14.42	43.39	8.77	10.33	20.66	21.79	19.92	18.61
20.0%	28.66	24.80	17.21	51.48	10.40	15.81	24.77	24.83	23.43	22.93
22.5%	31.78	28.61	20.68	60.51	12.40	21.40	28.16	27.76	27.32	26.82
25.0%	34.72	32.33	24.98	70.73	15.25	24.68	31.08	30.53	31.69	30.53
27.5%	37.17	37.29	28.97	80.55	21.79	27.38	34.37	33.34	36.96	34.77
30.0%	39.19	42.54	32.22	88.37	29.59	29.87	38.50	36.09	43.37	39.11
Trigger	***14.02***	***14.71***	***18.02***	***6.22***	***24.78***	***19.63***	***13.35***	***12.37***	***13.52***	***15.05***

The shortest ERT is about 144.17 hours, roughly 6 days, and occurred during simulation period No. 4 (a low monthly MSL period) under the baseline condition. The longest ERT is about 483.98 hours, roughly 20 days, and occurred during simulation period No. 6 (5 percentile of SGD, a period with very low SGD) of the 30% flow reduction scenario.

Taking the average of ERT crossing all nine ERT simulation periods, an average ERT can be calculated, which hopefully can be used as an estimate of the overall ERT for the entire 9-year simulation period. These average ERTs for different flow scenarios are given in the last column of Table 13. Relative increases of ERT caused by different flow reductions for the 9 simulation periods are depicted in Table 14. The percentage reduction of SGDs that would trigger a 15% ERT increase for each ERT simulation period is shown in the last row of Table 14. It can be seen that a 15.05% flow reduction will cause the average ERT to be increased by 15%.

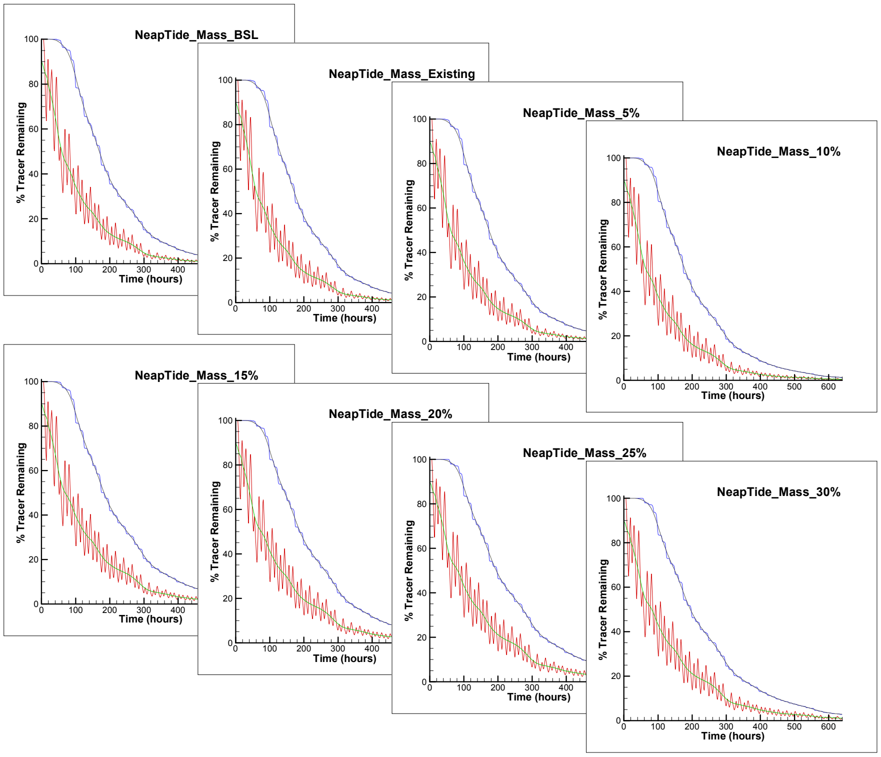

Figure 34 Time series of conservative tracer mass remaining in KB (red lines) and CRKB (blue lines) for various flow scenarios during Period 2.

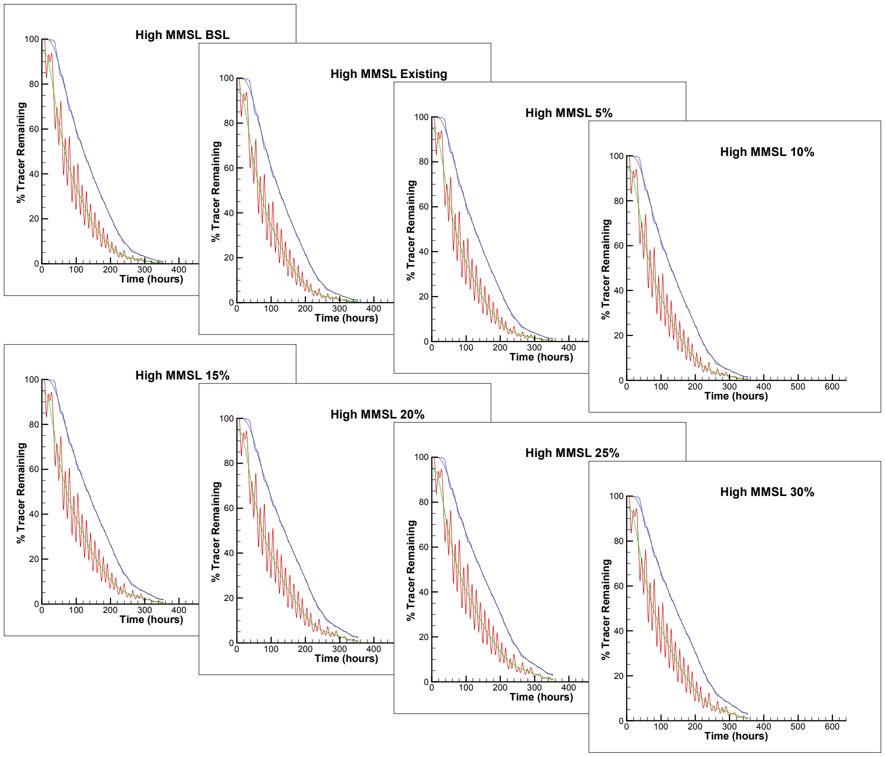

Figure 35 Time series of conservative tracer mass remaining in KB (red lines) and CRKB (blue lines) for various flow scenarios during Period 3.

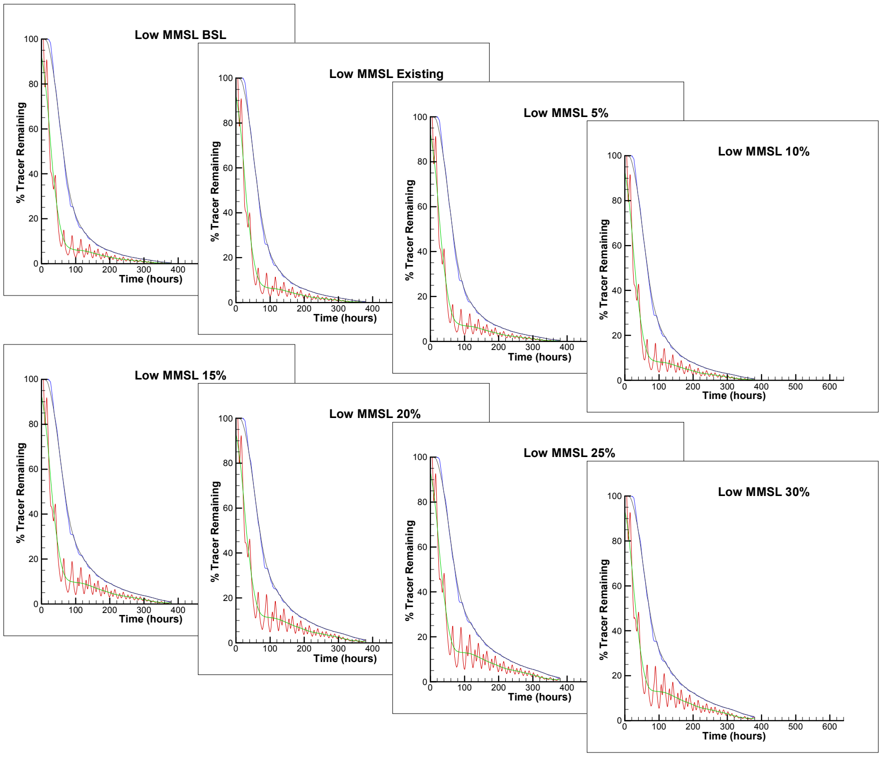

Figure 36 Time series of conservative tracer mass remaining in KB (red lines) and CRKB (blue lines) for various flow scenarios during Period 4.

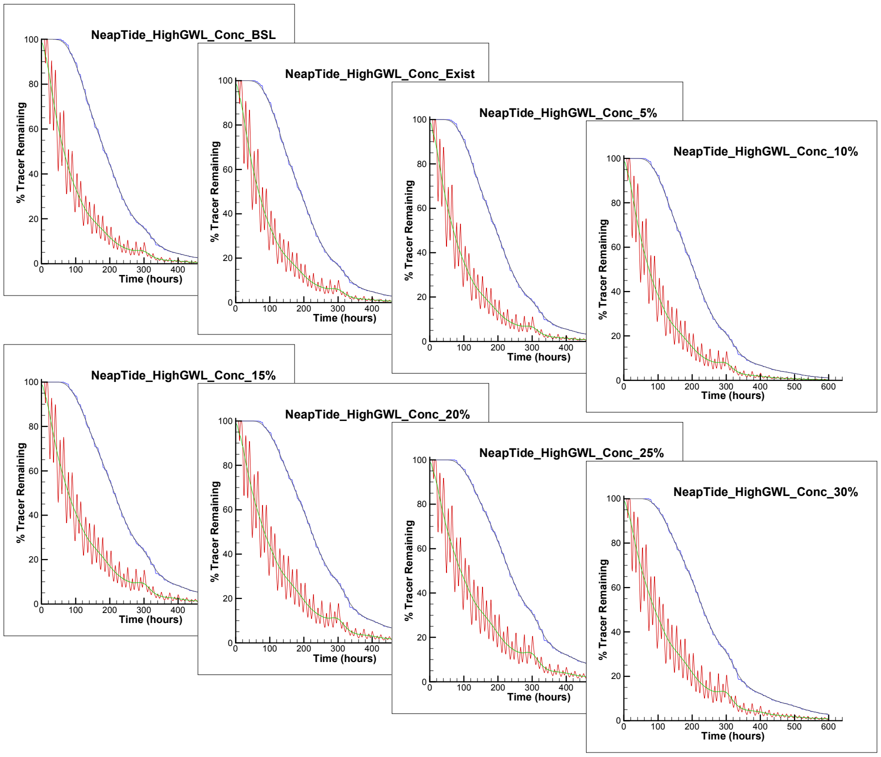

Figure 37 Time series of conservative tracer mass remaining in KB (red lines) and CRKB (blue lines) for various flow scenarios during Period 5.

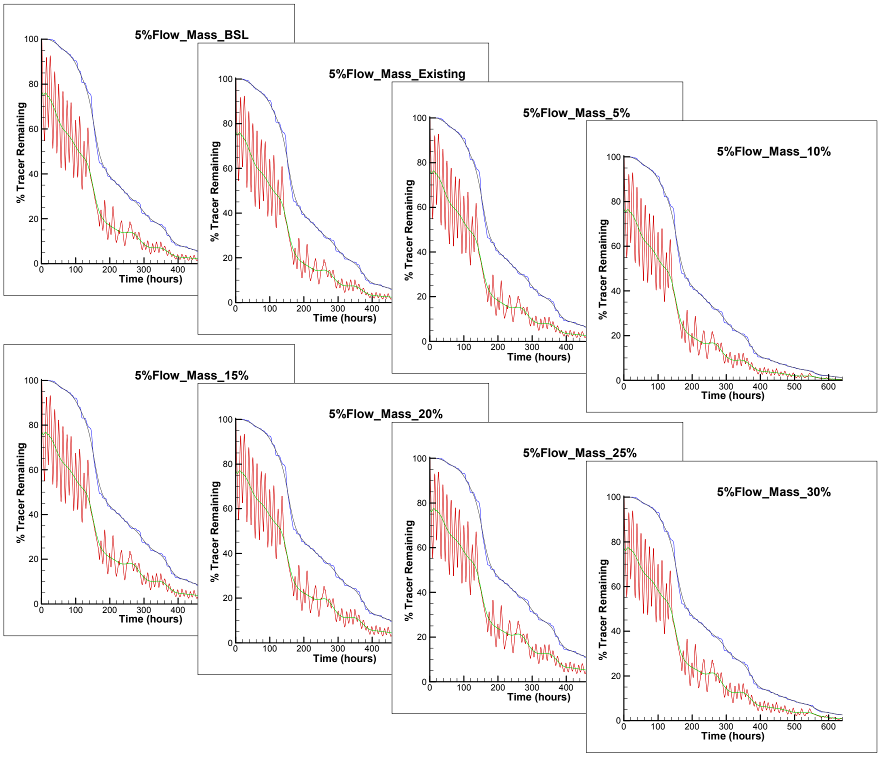

Figure 38 Time series of conservative tracer mass remaining in KB (red lines) and CRKB (blue lines) for various flow scenarios during Period 6.

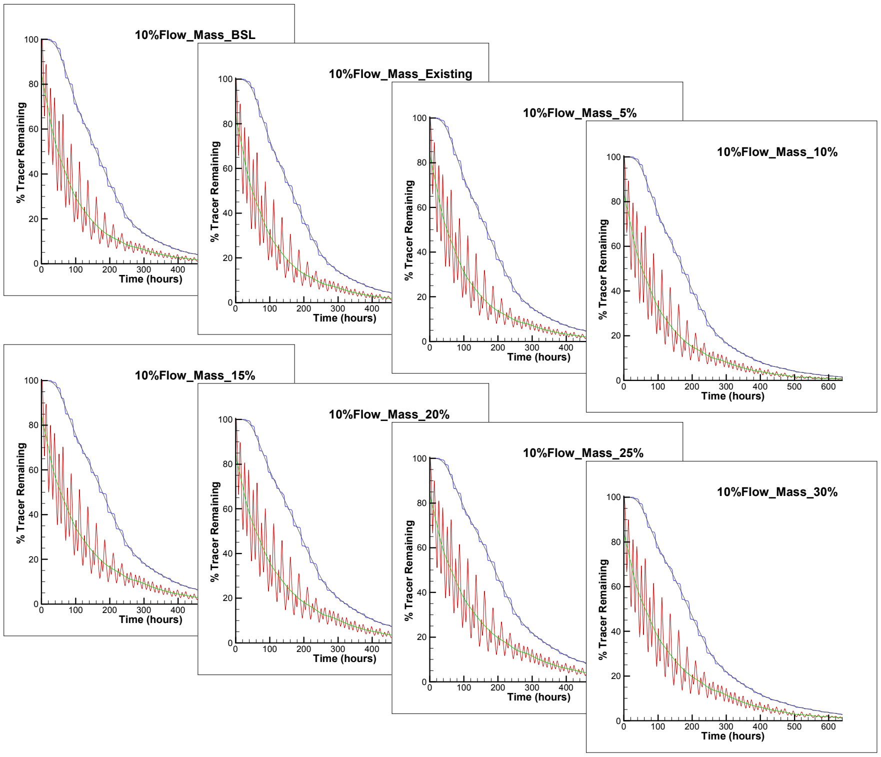

Figure 39 Time series of conservative tracer mass remaining in KB (red lines) and CRKB (blue lines) for various flow scenarios during Period 7.

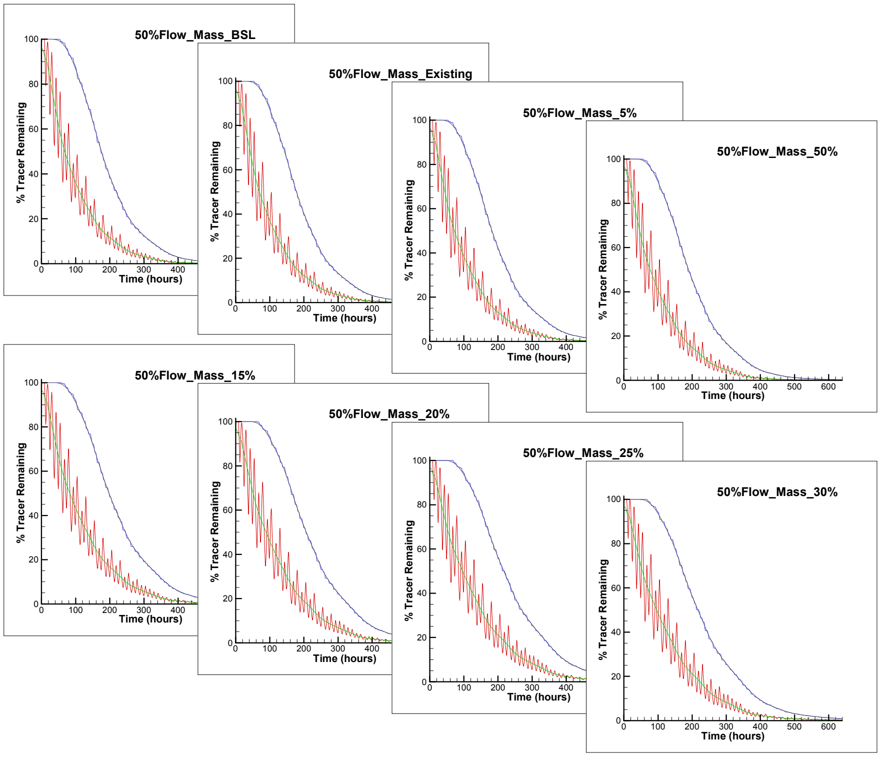

Figure 40 Time series of conservative tracer mass remaining in KB (red lines) and CRKB (blue lines) for various flow scenarios during Period 8.

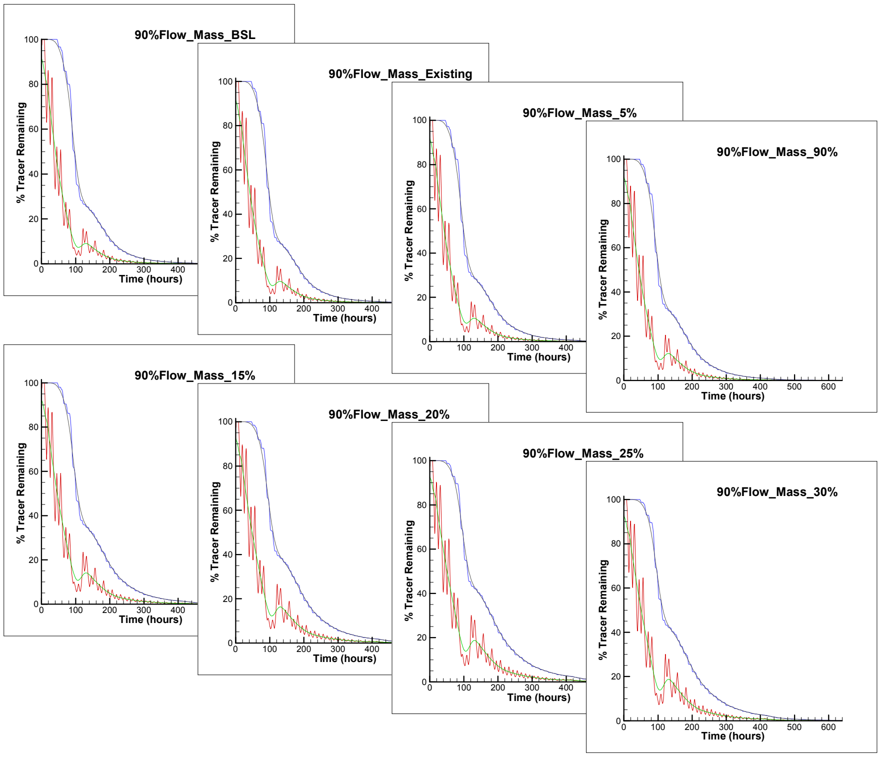

Figure 41 Time series of conservative tracer mass remaining in KB (red lines) and CRKB (blue lines) for various flow scenarios during Period 9.

5.5 A Summary of Model Results of Scenario Runs

As described above, percentages of flow reduction that would trigger a 15% reduction of salinity and thermal habitats in Crystal River/Kings Bay or a 15% increase of estuarine residence time for Kings Bay have been obtained through a series of model simulations for various flow reduction scenarios. Table 15 is a summary of the triggering percentages of the flow reduction that would cause significant harms to the Crystal River/Kings Bay system.

From Table 15, it can be seen that salinity volume is more sensitive to flow reduction than salinity bottom area, which is more sensitive to flow reduction than salinity shoreline length. The 15% reduction threshold won't be crossed for salinity habitats of 5 psu or above with a flow reduction 30% or less. The most sensitive salinity habitats to flow reduction are ≤ 2 psu volume, bottom area, and shoreline length. For the thermal habitats, > 15 °C volume is more sensitive to flow reduction than > 15 °C surface area under an acute condition in 4 consecutive hours. Under the chronic condition in 72 consecutive hours, ≥ 20 °C surface area is slightly more sensitive to flow reduction than ≥ 20 °C volume.

Table 15 A summary of percentages of flow reduction which would trigger a 15% reduction of salinity and thermal habitats in CRKB or a 15% increase of ERT for Kings Bay

	Salinity Habitats					
Salinity (psu) ≤	*0.5*	*1*	*2*	*3*	*5*	*10*
Volume	21.88%	20.56%	11.78%	21.58%	>30%	>30%
Bottom Area	22.64%	22.82%	13.48%	24.90%	> 30%	> 30%
Shoreline Length	>30%	> 30%	27.75%	>30%	> 30%	> 30%
	Thermal Habitats					
Thermal Conditions	*Acute*	*Chronic*				
Volume	8.61%	15.49%				
Surface Area	10.68%	15.22%				
	Estuarine Residence Time (Kings Bay)					
Overall ERT	15.05%					

Except for > 15 °C volume under the acute condition, all other habitats or parameters have a triggering percentage of flow reduction larger than 10%. The 8.61% flow reduction for > 15 °C volume under the acute condition could become a controlling factor in deciding the MFL for the Crystal River/Kings Bay estuarine system. Nevertheless, even with a 30% SGD reduction, the Crystal River/Kings Bay system still has 452,171 m^3 of > 15 °C water, which is big enough to hold more than 10 times of all the manatees found in Florida during the acute condition. Therefore, it is debatable whether the 8.61% flow reduction is the real controlling factor for the MFL establishment. A more realistic allowable flow reduction seems to be 11.78%, which would cause a 15% reduction of ≤ 2 psu volume.

6. Consideration of Sea Level Rises

This section describes how sea level rises are considered in the hydrodynamic modeling of CRKB and how SLRs would affect salinity and thermal habitat in the spring-fed estuary. In the following discussion, the baseline or existing flow condition without considering SLRs are still called the baseline or existing flow condition. The baseline flow condition with consideration of a SLR will be called the baseline with a SLR.

6.1 Sea Level Rise Estimates

Scenarios considering sea level rises were included in the MFL evaluation for the Crystal River/Kings Bay estuary to examine how SLRs would affect salinity and thermal habitats and whether a MFL will be violated under a future sea level condition many years later. To be consistent with the District's regional water supply planning horizon, sea level conditions in 2035 are evaluated. The United States Army Corps of Engineers (USACE) provides SLR estimates at their web site, http://www.corpsclimate.us/ccaceslcurves.cfm, where three types of the SLR can be obtained at several NOAA stations along the Florida Gulf coast: a low estimate, an intermediate estimate, and a high estimate. The closest are Stations 8726724 (Clearwater Beach FL) and 8727520 (Cedar Key FL), with the Clearwater Beach station being about 105,813 m south - southwest of mouth of Crystal River and the Cedar Key station about 40,064 m northwest of the mouth of Crystal River, respectively. The St. Petersburg station is further south from the mouth of Crystal River with a distance of about 128,076 m but has a longer period of record of water level data than the Clearwater Beach station does. As such, the St. Petersburg station is considered as a better station for the SLR estimation than the Clearwater Beach station. Based on this consideration, the low, intermediate, and high sea level rise estimates at the mouth of Crystal River in 2035 were calculated from those at the St. Petersburg and Cedar Key stations using an inverse distance weighting method.

Table 16 lists the low, intermediate, and high SLRs from 2011 to 2015 at the St. Petersburg, Cedar Key stations, and at the mouth of Crystal River. Because 2011 is the middle year of the scenario simulation period, during which there was also sea level rise, adding the same sea level rise estimates to the water level data at the mouth of Crystal River during 2007 – 2014 is reasonable, as there will be sea level rises 24 years later, from 2031 to 2039.

Table 16 Sea level rise estimates at St. Petersburg, Cedar Key, and the mouth of Kings Bay. SLRs at the St. Petersburg and Cedar Key stations were obtained from a USACE website, while SLRs at the mouth of Crystal River were estimated based on those at the former two stations.

SLR Estimates (cm)	***St. Petersburg***	***Cedar Key***	***Crystal River***
Low	6.096	4.572	4.938
Intermediate	10.363	8.230	8.748
High	23.165	21.031	21.549

6.2 Model Results for SLR Scenarios

In the SLR model runs, 4.938, 8.748, and 21.549 cm were added to the water level data measured at the open boundaries for the entire 9-year simulation period for the low, intermediate and high SLR estimates, respectively. The added layer of water is assumed to have the same salinity and temperature values as measured top-layer salinity and temperature during the 9-year simulation period. The modified boundary conditions at these open boundaries were used to drive the model to simulate effects of low, intermediate, and high SLR estimates on salinity, and temperature in the system. The added SLR not only increases the average depth of the estuary and thereby the volume of the estuary, but also causes more Gulf water to be transported to the system and reduces SGDs to Kings Bay.

It should be acknowledged that the above treatment of the SLR in the model is far from perfect when considering its effects on hydrodynamics and salinity and thermal transport processes in Crystal River/Kings Bay, because a SLR could modify several factors controlling physical processes in the estuary. For example, the rainfall pattern in the region could be altered by the SLR, the salinity and temperature characteristics in the Gulf could be quite different with or without a SLR, and the potentiometric surface in the coastal region could be pushed upward by a SLR. As a result of the SLR and the potentiometric surface rise, SGDs to the Crystal River/Kings Bay system would likely be reduced to a certain degree. Clearly, our treatment only considered the direct effect of the SLR on the estuary and didn't consider other consequences caused by the SLR, which are virtually unknown to us because of the lack of data or research on the topics for the region.

The SLR runs were conducted for the baseline flow scenario (baseline with SLRs) and the two MFL flow scenarios, one with an 8.61% flow reduction (MFL1) and the other 11.78% (MFL2). For simplify, time series plots of daily means of simulated salinity habitats similar to Figure 14 - Figure 21 and thermal habitat plots similar to Figure 25 - Figure 27 and Figure 30 - Figure 31 are omitted here, and only the CDF plots are presented in the following discussion.

Cumulative distribution functions for water volumes, bottom areas, and shoreline lengths are depicted in Figure 42, Figure 43, and Figure 44, respectively for salinity ≤ 0.5, 1, 2, 3, 5, and 10 psu for the baseline and existing flow conditions (dashed red and green lines) and for baseline with SLRs (high, intermediate, and low estimates). It can be seen from these figures that the shape of CDFs has been greatly modified by SLR. The biggest change of the CDF shapes is for <1, <2, and < 3 psu water volumes and bottom areas, indicating that SLR has a significant effect on the temporal and spatial variations for salinity between 0.5 – 5 psu. For shoreline length, the biggest change of CDF shape is for < 3 psu, indicating the greatest effect of SLR for salinity between 2 – 5 psu.

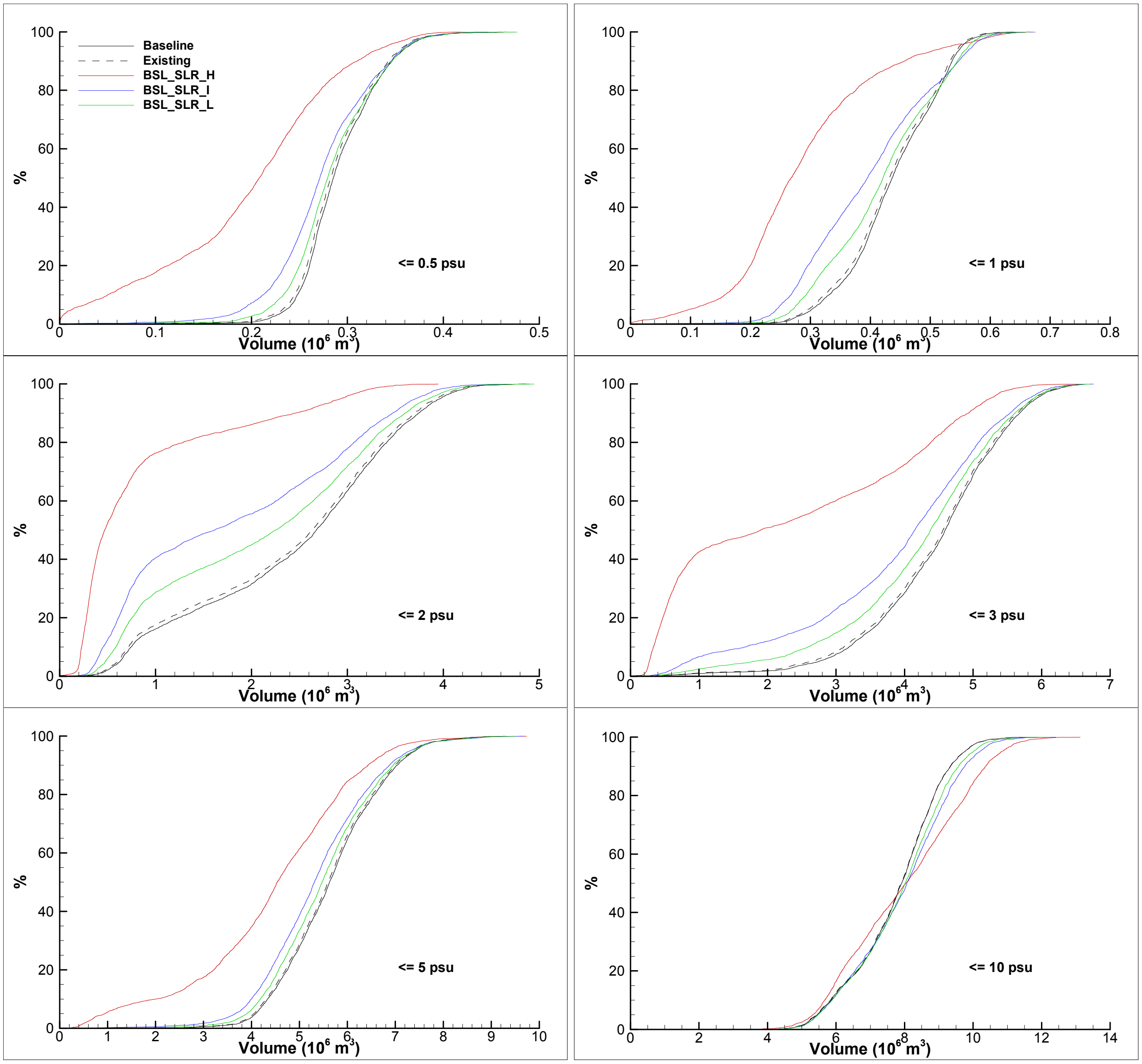

Figure 42 CDFs of water volumes for salinity ≤ 0.5, 1, 2, 3, 5, and 10 psu for the baseline and existing flow conditions (solid and dashed black lines) and for the baseline with the high SLR (red solid lines), the intermediate SLR (blue solid lines), and low SLR , and green solid lines) in Crystal River/Kings Bay.

As mentioned before, the area between the *y*-axis and the CDF curve numerically represents the average value of the variable for the given sample used to generate the CDF curve. Effects of SLR on salinity habitats can be clearly seen in Figure 42 - Figure 44, especially on low salinity habitats such as ≤ 0.5, 1, 2, and 3 psu volumes, bottom areas, and shoreline lengths with the high SLR estimate. While low salinity habitats are reduced by SLRs, high salinity habitats are increased. For salinity ≤ 10 psu, the average water volume and bottom area are roughly the same as those of the baseline and existing flow conditions without SLRs, indicating that the decrease of low salinity habitats, say ≤ 3 psu, is roughly equal to the increases of salinity habitats between 3 psu (exclusive) and 10 psu (inclusive). In other words, below 10 psu, it is almost a wash and salinity volumes and bottom areas are redistributed by SLR. Above 10 psu (not shown in Figure 42 - Figure 44), salinity volumes and bottom areas increase steadily as sea level rises. For shoreline length, it is almost a wash at a salinity between < 3 psu to < 5 psu, depending on SLR. Shoreline length for salinity > 5 psu increases considerably.

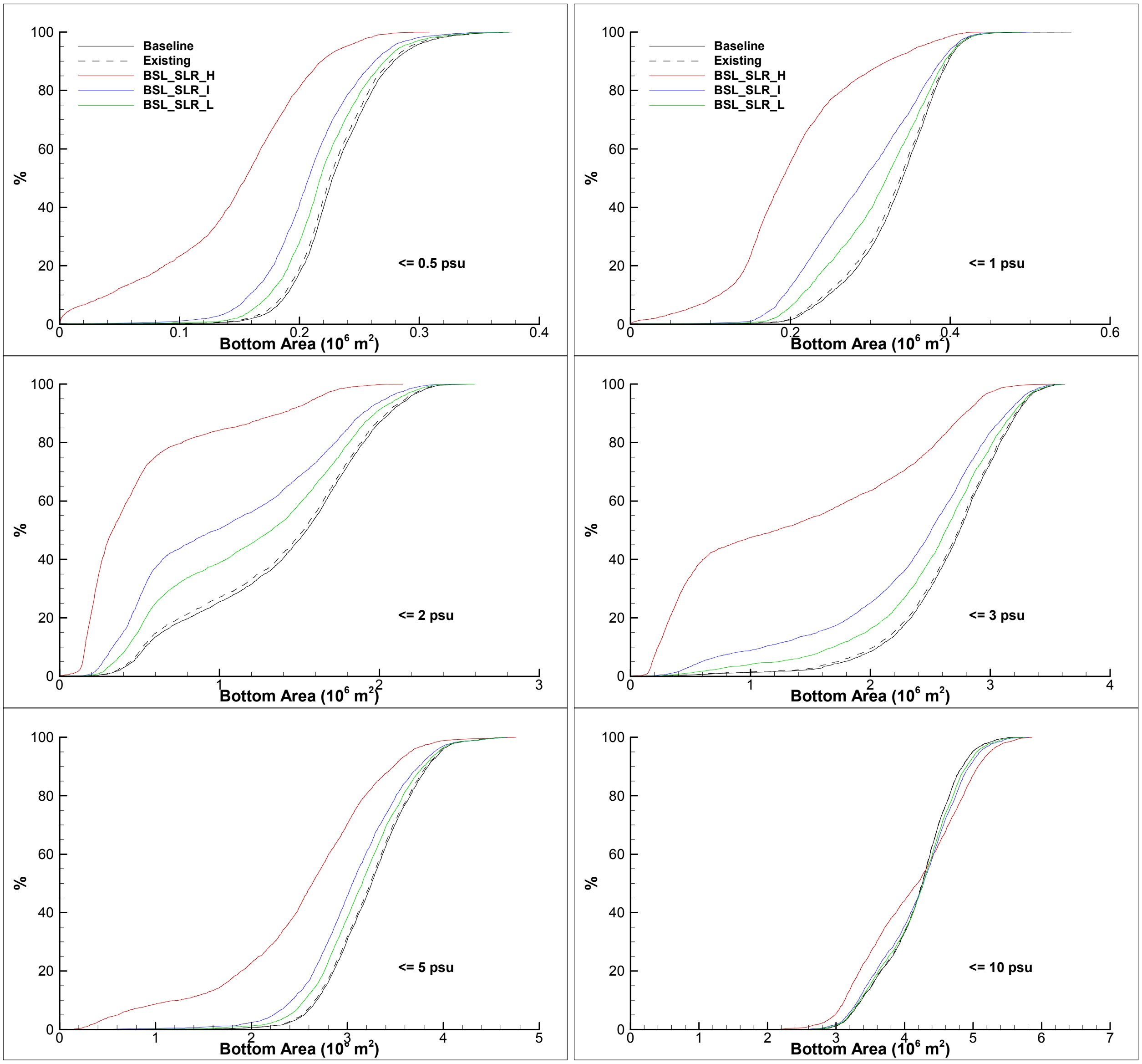

Figure 43 CDFs of bottom areas for salinity ≤ 0.5, 1, 2, 3, 5, and 10 psu for baseline and existing flow conditions (solid and dashed black lines) and for baseline with SLRs (red, blue, and green solid lines) in Crystal River/Kings Bay.

Figure 45 shows comparisons of CDFs among the baseline flow condition, baseline with SLRs, MFL1 with SLRs, and MFL2 with SLRs for water volumes of salinity ≤ 0.5, 1, 2, 3, 5, and

10 psu. Salinity volume CDFs for the baseline flow condition are plotted with black solid lines, baseline with SLRs are plotted with red lines, MFL1 with SLRs are plotted with blue lines, and MFL2 with SLRs are plotted with green lines. In the figure, solid, dashed, and dotted lines are for the high, intermediate, and low SLRs, respectively. Similar to Figure 45, Figure 46 and Figure 47 are comparisons of CDFs for bottom areas and shoreline lengths, respectively of salinity ≤ 0.5, 1, 2, 3, 5, and 10 psu.

Tables 17 – 19 show relative changes of various salinity habitats for different SLR estimates for the baseline, MFL1 (8.61%), and MFL2 (11.78%) flow conditions. These changes were relative to the results of the baseline flow condition without a SLR. From the tables, it can be seen that ≤ 2 psu water volume is still the most sensitive salinity habitat to SLRs and to flow reductions with SLRs. For example, the ≤ 2 psu water volume under baseline with an intermediate SLR will be reduced by 26.38% from that of the baseline flow condition. This is more than twice the percentage loss of the second most sensitive salinity habitat, ≤ 3 psu water volume, which suffers a 12.88% reduction. Under the MFL1 and MFL2 flow conditions and with the intermediate SLR, the losses of ≤ 2 psu water volume are further increased to 37.23% and 41.18%, respectively. In other words, MFL1 will cause an additional 10.85% loss of the ≤ 2 psu water volume, while MFL2 will cause an additional 14.80% loss comparing to that caused by the intermediate SLR.

Table 20 **-** Table 22 show relative changes of water volumes, bottom areas, and shorelines of various salinity ranges for MFL1 with SLRs and MFL2 with SLRs in comparison with those of baseline with SLRs. An 8.61% (MFL1) flow reduction from the baseline with high, intermediate, and low SLRs will cause the most sensitive salinity habitat, the ≤ 2 psu water volume, to be reduced by 19.27%, 14.74%, and 13.00%, respectively, while an 11.78% (MFL2) flow reduction from the baseline with high, intermediate, and low SLRs will cause the ≤ 2 psu water volume to be reduced by 27.84%, 20.10%, and 17.99%, respectively. Effects of MFL1 and MFL2 with SLRs on salinity bottom areas are similar to but slightly less server than their effects on salinity volumes; however, effects of MFL1 and MFL2 with SLRs on salinity shoreline lengths are quite different from those on salinity volumes and bottom areas. None of shoreline length reduction caused by MFL1 and MFL2 with SLRs is more than 13.38%, which occurs to ≤ 0.5 psu shoreline length under MFL2 with the high SLR.

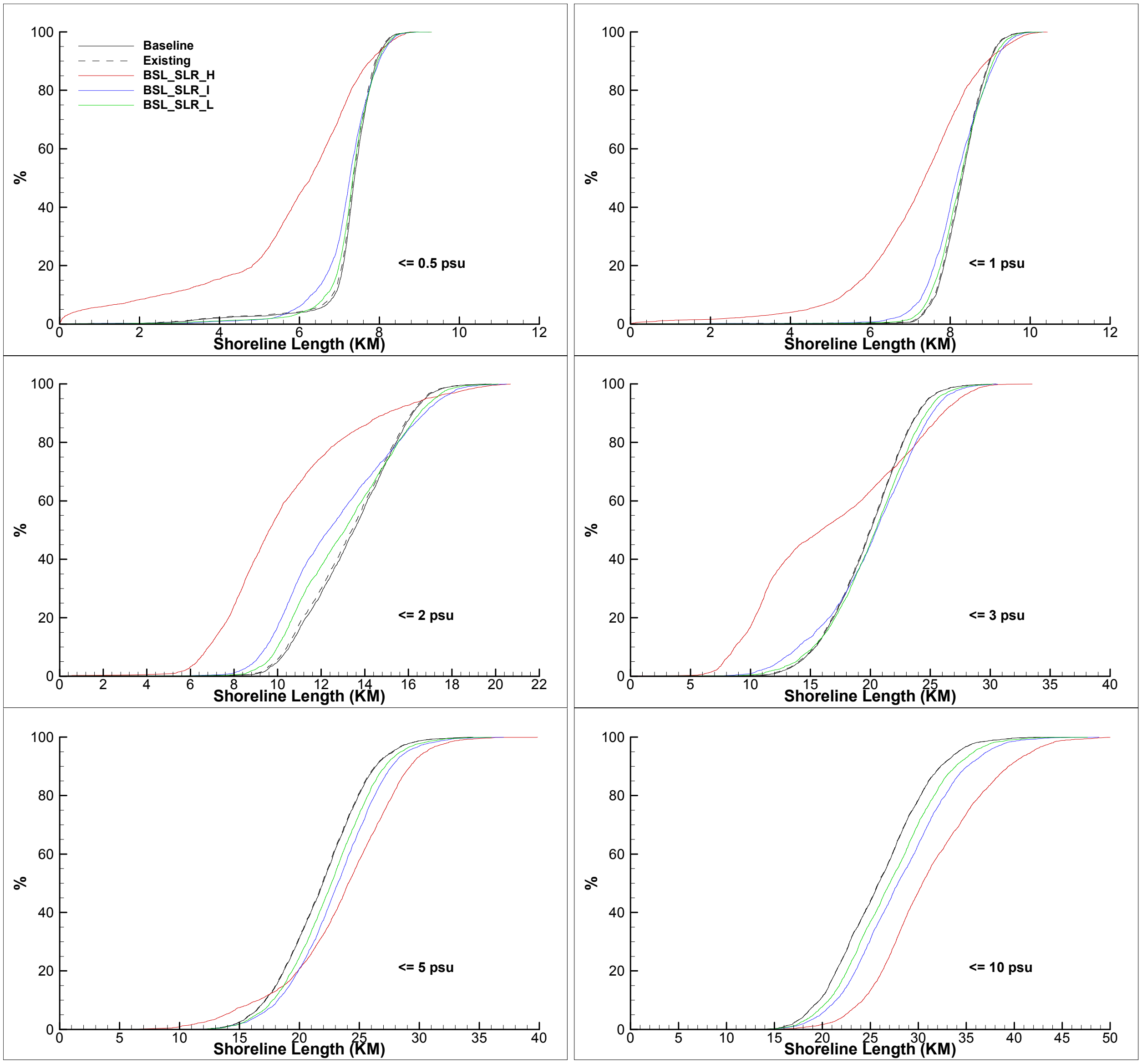

Figure 44 CDFs of shoreline lengths for salinity ≤ 0.5, 1, 2, 3, 5, and 10 psu for baseline and existing flow conditions (solid and dashed black lines) and for baseline with SLRs (red, blue, and green solid lines) in Crystal River/Kings Bay.

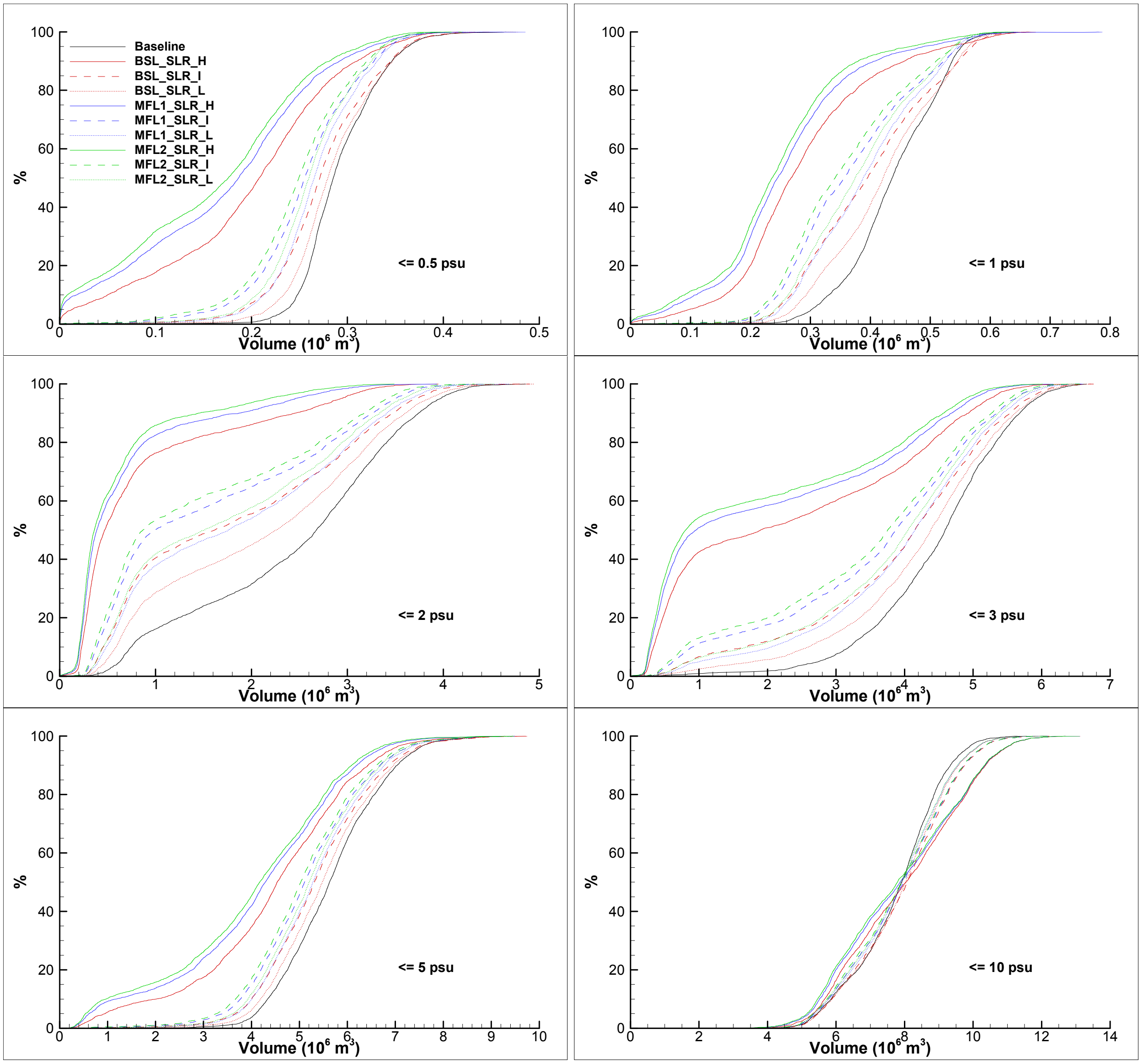

Figure 45 CDFs of water volumes for salinity ≤ 0.5, 1, 2, 3, 5, and 10 psu for baseline flow condition (black solid lines), baseline with SLRs (red lines), MFL1 with SLRs (blue lines), and MFL2 with SLRs (green lines) in Crystal River/Kings Bay.

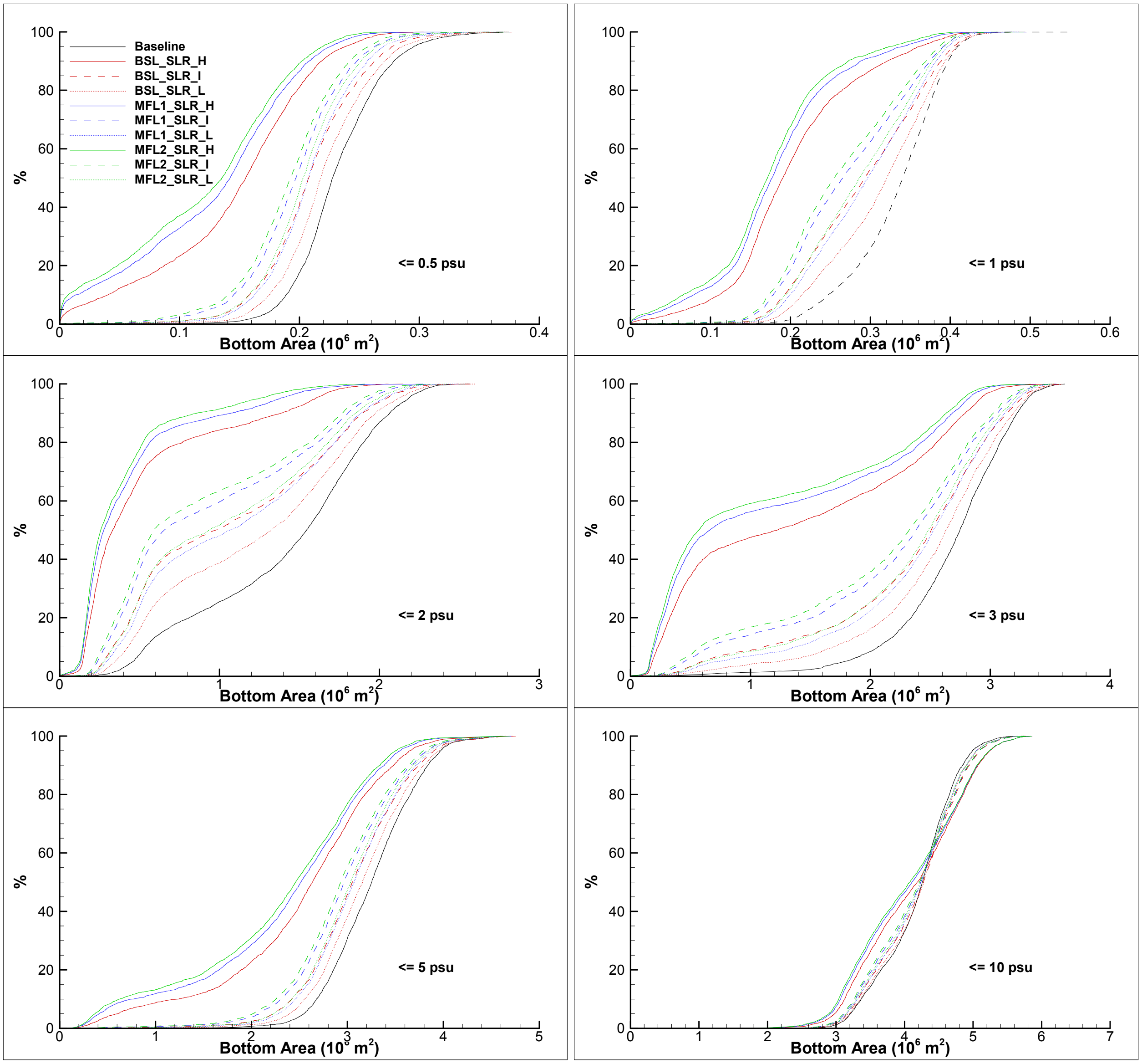

Figure 46 CDFs of bottom areas for salinity ≤ 0.5, 1, 2, 3, 5, and 10 psu for baseline flow condition (black solid lines), baseline with SLRs (red lines), MFL1 with SLRs (blue lines), and MFL2 with SLRs (green lines) in Crystal River/Kings Bay.

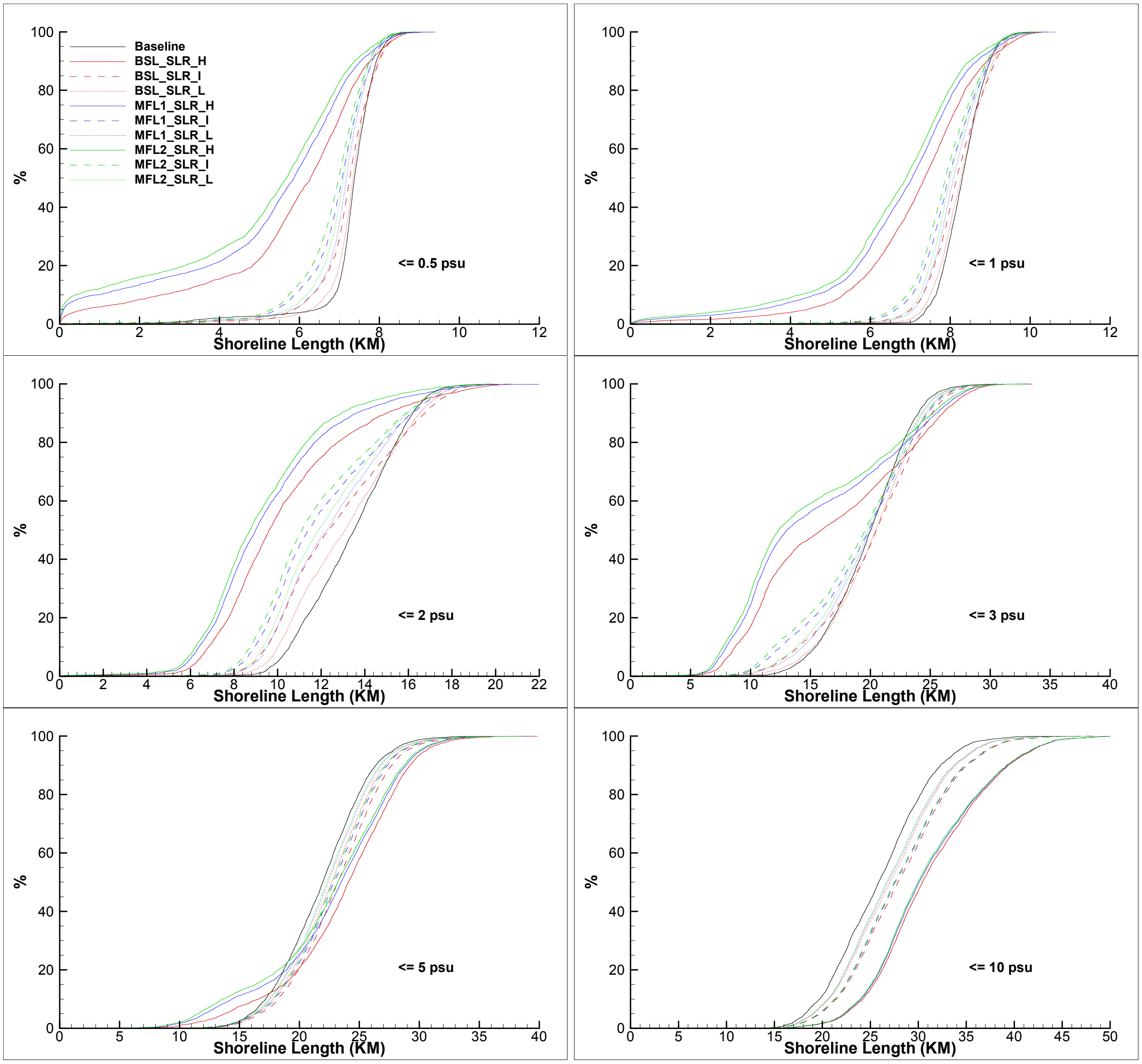

Figure 47 CDFs of shoreline lengths for salinity ≤ 0.5, 1, 2, 3, 5, and 10 psu for baseline flow condition (black solid lines), baseline with SLRs (red lines), MFL1 with SLRs (blue lines), and MFL2 with SLRs (green lines) in Crystal River/Kings Bay.

Table 17 Percentage reductions of water volume of various salinity ranges for baseline with SLRs, MFL with SLRs, and MFL2 with SLRs relative to those of the baseline flow condition. Negative percentage means increase.

Flow Scenario	**SLR Estimate**	**Relative Water Volume Reduction (%)**						
		Sal ≤ 0.5	***≤ 1***	***≤ 2***	***≤ 3***	***≤ 5***	***≤ 10***	***≤ 15***
Baseline	**High**	32.84	34.54	65.04	47.99	21.86	-3.21	-11.81
	Intermediate	6.11	9.03	26.38	12.88	5.19	-2.31	-4.76
	Low	2.48	4.04	14.25	5.99	2.55	-1.47	-2.70
MFL1	**High**	41.37	41.26	71.78	55.29	27.26	-1.68	-11.69
	Intermediate	12.47	15.95	37.23	20.17	8.92	-1.16	-4.64
	Low	8.23	10.57	25.40	12.29	6.00	-0.43	-2.58
MFL2	**High**	45.25	44.37	74.77	58.20	29.57	-1.03	-11.64
	Intermediate	15.00	18.54	41.18	23.14	10.44	-0.68	-4.59
	Low	10.56	13.14	29.67	14.95	7.40	-0.01	-2.53

Table 18 Percentage reductions of bottom area of various salinity ranges for baseline with SLRs, MFL with SLRs, and MFL2 with SLRs relative to those of the baseline flow condition. Negative percentage means increase.

Flow Scenario	**SLR Estimate**	**Relative Bottom Area Reduction (%)**						
		Sal ≤ 0.5	***≤ 1***	***≤ 2***	***≤ 3***	***≤ 5***	***≤ 10***	***≤ 15***
Baseline	**High**	37.87	39.34	63.21	48.24	23.03	1.53	-5.30
	Intermediate	9.75	12.25	25.29	12.87	5.79	-0.31	-2.33
	Low	4.74	6.05	13.64	5.97	2.91	-0.33	-1.36
MFL1	**High**	45.17	45.09	69.48	55.11	27.74	2.71	-5.21
	Intermediate	15.44	18.21	34.96	19.26	8.73	0.57	-2.24
	Low	10.10	11.69	23.41	11.24	5.58	0.48	-1.27
MFL2	**High**	48.48	47.72	72.28	57.81	29.77	3.22	-5.18
	Intermediate	17.65	20.47	38.52	21.90	9.94	0.94	-2.21
	Low	12.22	13.94	27.21	13.54	6.66	0.80	-1.24

Table 19 Percentage reductions of shoreline length of various salinity ranges for baseline with SLRs, MFL with SLRs, and MFL2 with SLRs relative to those of the baseline flow condition. Negative percentage means increase.

Flow Scenario	**SLR Estimate**	**Relative Shoreline Length Reduction (%)**						
		Sal ≤0.5	***≤ 1***	***≤ 2***	***≤ 3***	***≤ 5***	***≤ 10***	***≤ 15***
Baseline	**High**	21.01	13.81	23.11	15.39	-7.78	-20.35	-26.67
	Intermediate	1.59	1.39	5.06	-1.30	-5.70	-8.48	-10.37
	Low	0.24	0.38	2.20	-1.66	-3.29	-4.78	-5.75
MFL1	**High**	28.19	18.69	28.57	21.76	-4.23	-19.45	-26.54
	Intermediate	5.01	3.95	10.17	2.61	-4.26	-7.77	-10.23
	Low	3.09	2.44	6.81	1.09	-2.01	-4.14	-5.61
MFL2	**High**	31.58	20.98	31.11	24.29	-2.66	-19.07	-26.48
	Intermediate	6.37	4.96	12.16	4.23	-3.67	-7.48	-10.18
	Low	4.27	3.31	8.64	2.36	-1.50	-3.88	-5.56

It should be noted that a comparison of the percentage reductions listed in Tables 20 – 22 is reasonable only when the same base is used, and care needs to be taken when analyzing the percentages shown in these tables. For example, the 19.27% reduction of ≤ 2 psu water volume caused by MFL1 with the high SLR was relative to that caused by baseline with the high SLR; however, the 14.74% reduction of ≤ 2 psu water volume caused by MFL1 with the intermediate SLR was relative to that caused by baseline with the intermediate SLR, not by baseline with the high SLR.

Table 20 Percentage reductions of water volume of various salinity ranges for MFL1 with SLRs and MFL2 with SLRs relative to those of the baseline with SLRs.

Flow Scenario	**SLR Estimate**	**Relative Water Volume Reduction (%)**						
		Sal ≤ 0.5	***≤ 1***	***≤ 2***	***≤ 3***	***≤ 5***	***≤ 10***	***≤ 15***
MFL1	**High**	12.71	10.27	19.27	14.04	6.91	1.48	0.10
	Intermediate	6.77	7.60	14.74	8.37	3.94	1.12	0.12
	Low	5.90	6.80	13.00	6.70	3.55	1.02	0.12
MFL2	**High**	18.49	15.02	27.84	19.62	9.87	2.11	0.15
	Intermediate	9.47	10.46	20.10	11.78	5.54	1.58	0.16
	Low	8.29	9.48	17.99	9.54	4.97	1.44	0.16

Table 21 Percentage reductions of bottom area of various salinity ranges for MFL1 with SLRs and MFL2 with SLRs relative to those of the baseline with SLRs.

Flow Scenario	**SLR Estimate**	**Relative Bottom Area Reduction (%)**						
		Sal ≤ 0.5	***≤ 1***	***≤ 2***	***≤ 3***	***≤ 5***	***≤ 10***	***≤ 15***
MFL1	**High**	11.75	9.48	17.04	13.28	6.12	1.20	0.08
	Intermediate	6.30	6.80	12.95	7.34	3.12	0.88	0.09
	Low	5.62	6.00	11.31	5.61	2.75	0.80	0.09
MFL2	**High**	17.07	13.82	24.65	18.49	8.76	1.72	0.12
	Intermediate	8.75	9.37	17.71	10.37	4.40	1.25	0.12
	Low	7.85	8.40	15.71	8.05	3.86	1.13	0.12

Table 22 Percentage reductions of shoreline length of various salinity ranges for MFL1 with SLRs and MFL2 with SLRs relative to those of the baseline with SLRs.

Flow Scenario	**SLR Estimate**	**Relative Shoreline Length Reduction (%)**						
		Sal ≤ 0.5	***≤ 1***	***≤ 2***	***≤ 3***	***≤ 5***	***≤ 10***	***≤ 15***
MFL1	**High**	9.09	5.66	7.10	7.53	3.29	0.75	0.11
	Intermediat	3.47	2.60	5.38	3.86	1.35	0.66	0.13
	Low	2.85	2.07	4.72	2.71	1.24	0.62	0.13
MFL2	**High**	13.38	8.31	10.41	10.52	4.75	1.07	0.15
	Intermediat	4.85	3.62	7.48	5.46	1.92	0.92	0.17
	Low	4.04	2.94	6.59	3.96	1.73	0.86	0.18

Table 23 shows averages of ≥ 20 °C water volume and surface area during the coldest 72 hours for baseline with SLRs, MFL with SLRs, and MFL2 with SLRs. Percentage reductions relative to results under the baseline flow condition are also listed in the table. The ≥ 20 °C water volume during the coldest 72 hours has the biggest loss at 59.04% which is caused by a flow reduction of 11.78% and the high SLR estimate.

Table 24 shows averages of > 15 °C water volume and surface area during four hours of the acute condition in Crystal River/Kings Bay for baseline with SLRs, MFL1 with SLRs, and MFL2 with SLRs. Percentage reductions relative to results for the baseline flow condition are also listed in the table. The biggest percentage loss of the thermal habitat during the acute period is > 15 °C area, which will be reduced to about 24% of that of the baseline flow condition with an11.78% flow reduction and a SLR of 21.549 cm.

Table 23 Average volumes and surface areas for temperature ≥ 20 ºC in Crystal River/Kings Bay during the coldest 72 hours for baseline with SLRs, MFL1 with SLRs, and MFL2 with SLRs. Reductions are relative to those for the baseline flow condition.

Flow Scenario	SLR Estimate	≥ 20 ºC Volume (m^3)	≥ 20 ºC Volume Reduction	≥ 20 ºC Area (m^2)	≥ 20 ºC Area Reduction
Baseline	**High**	69,328	51.18%	27,403	45.44%
	Intermediate	118,175	16.79%	43,259	13.87%
	Low	128,513	9.51%	46,485	7.45%
MFL1	**High**	62,107	56.27%	24,313	51.59%
	Intermediate	108,042	23.92%	39,633	21.09%
	Low	121,001	14.80%	43,546	13.30%
MFL2	**High**	58,174	59.04%	22,867	54.47%
	Intermediate	105,049	26.03%	38,624	23.10%
	Low	115,153	18.91%	41,302	17.77%

Table 24 Average water volumes and surface areas for temperature > 15 ºC in Crystal River/Kings Bay during four hours of the acute condition in Crystal River/Kings Bay for baseline with SLRs, MFL1 with SLRs, and MFL2 with SLRs and their percentage reductions relative to those for the baseline flow condition.

Flow Scenario	SLR Estimate	>15 ºC Volume (m^3)	>15 ºC Volume Reduction	>15 ºC Area (m^2)	>15 ºC Area Reduction
Baseline	**High**	287,283	69.18%	208,388	69.69%
	Intermediate	702,023	24.68%	527,032	23.34%
	Low	783,612	15.92%	586,558	14.68%
MFL1	**High**	248,054	73.39%	177,852	74.13%
	Intermediate	549,799	41.01%	423,892	38.34%
	Low	688,990	26.08%	522,000	24.07%
MFL2	**High**	227,536	75.59%	165,328	75.95%
	Intermediate	471,782	49.38%	368,042	46.46%
	Low	651,331	30.12%	495,286	27.96%

Table 25 are percentage reductions of ≥ 20 ºC water volume and surface area in Crystal River/Kings Bay during the coldest 72 hours for MFL1 with SLRs and MFL2 with SLRs relative to those for the baseline with SLRs. The biggest loss of the thermal habitat under the chronic condition is ≥ 20 ºC area. An 11.78% flow reduction combined with a 21.549 cm SLR will cause a 16.55% reduction of ≥ 20 ºC area during the 72 hours of the chronic condition relative to that of the baseline with the high SLR.

Table 25 Percentage reductions of ≥ 20 °C water volume and surface area in Crystal River/Kings Bay during the coldest 72 hours for MFL1 with SLRs and MFL2 with SLRs relative to those for baseline with SLRs.

Flow Scenario	SLR Estimate	≥ 20 °C Volume Reduction (%)	≥ 20 °C Area Reduction (%)
MFL1	**High**	10.42	11.28
	Intermediate	8.57	8.38
	Low	5.85	6.32
MFL2	**High**	16.09	16.55
	Intermediate	11.11	10.71
	Low	10.40	11.15

Table 26 are percentage reductions of > 15 °C water volume and surface area in Crystal River/Kings Bay during four hours of the acute condition for MFL1 with SLRs and MFL2 with SLRs relative to those for the baseline with SLRs. The biggest loss of the thermal habitat under the chronic condition is the > 15 °C volume caused by MFL2 with an intermediate SLR. An 11.78% flow reduction combined with an 8.748 cm SLR will cause a 32.80% reduction of > 15 °C volume in the four hours of the acute condition relative to that of the baseline with the intermediate SLR.

Table 26 Percentage reductions of > 15 °C water volume and surface area during four hours of the acute condition in Crystal River/Kings Bay for MFL1 with SLRs and MFL2 with SLRs relative to those for baseline with SLRs.

Flow Scenario	SLR Estimate	> 15 °C Volume Reduction (%)	> 15 °C Area Reduction (%)
MFL1	**High**	13.66	14.65
	Intermediate	21.68	19.57
	Low	12.08	11.01
MFL2	**High**	20.80	20.66
	Intermediate	32.80	30.17
	Low	16.88	15.56

Again, it should be noted that the percentage reductions shown in Table 25 and Table **26** are obtained relative to thermal habitats for baseline with different SLR estimates.

7. Conclusions

The unstructured Cartesian grid model (UnLESS3D) presented in Chen (2011) was used to simulate circulations and salinity and thermal transport processes in Crystal River/Kings Bay, a spring-fed estuary on the Gulf coast of Florida. Although it is a relatively small estuary, Crystal River/Kings Bay possesses all the complexities normally found in other large estuaries, such as islands, finger channels, a tidal flat, et cetera. Additionally, the estuarine system is further complicated by numerous spring vents at the bottom of Kings Bay, with their discharge rates and salinities being dependent on tides and groundwater level. Based on available ADCP measurements of fluxes through two spring runs, it was found that the spring discharges to Kings Bay vary linearly with both the head difference between groundwater and surface water levels and the time derivative of tides.

In the model application, 3030 Cartesian grids in the horizontal plane and 12 layers in the vertical directions were used to discretize the simulation domain, with the size of the Cartesian grid varying between 225 m^2 and 14,400 m^2 and the vertical layer thickness varied between 0.4 m and 2.5 m. The model was calibrated and verified against measured real-time data of water level, salinity, and temperature in Crystal River/Kings Bay during a 34-months period, from April 24, 2007 to February 23, 2010.

The application of UnLESS3D to the Crystal River/Kings Bay estuary was a success. Model results of water level, temperature, and cross-sectional flux agree very well with real-time field data with their skill assessment parameters being 0.97 or higher and their R^2 values being 0.89 or higher. Simulated salinities by the UnLESS3D model match well with real-time field data with an overall skill of 0.75 and an overall R^2 of 0.70, despite the fact that there are some unidentified uncertainties associated with spring flows and the salinity values in these spring flows.

After the hydrodynamic model was calibrated and verified, it was used to conduct a series of flow scenario runs in the evaluation of MFL for Crystal River/Kinga Bay, including the baseline and existing flow conditions and 2.5% – 30% flow reductions with a 2.5% increment. The scenario simulations period was about nine years, from October 6, 2006 to October 13, 2015. Model results, including salinities and temperatures at each grid cell over the entire 9-year period, were analyzed. Different salinity and thermal habitats were calculated based on simulated salinity and temperature results and bathymetry data using a post-process program. These salinity and thermal habitats include water volumes, bottom areas, and shoreline lengths for salinity $\leq$ 0.5, 1, 2, 3, 5, 10, 15, and 20 psu and water volume and surface areas for temperature $\leq 15\ ^{o}C$, between 15 and 20 (exclusive), $\geq 20\ ^{o}C$, and $> 15\ ^{o}C$.

Calculated salinity and thermal habitats were analyzed to examine how flow reductions affect the availabilities of the habitats and at what percentage of flow reduction would a significant harm occur to the habitats. It was found that the most sensitive salinity habitat to flow reduction is $\leq$ 2 psu water volume, which will be reduced by 15% with an 11.8% reduction of SGD. The most sensitive thermal habitats to flow reduction is > 15 °C volume for the acute condition, which would be reduced by 15% with an 8.61% reduction of SGD.

The UnLESS3D model was also run for ERT for Kings Bay for nine periods, which include various SGD, tides, and bay water volume conditions. For each ERT simulation period, all 14 flow scenarios were run, resulting in 126 ERT runs. Calculated ERTs are roughly within a range of 6 - 20 days. Averaged over the 9 ERT simulation periods, a mean ERT for each flow scenario can be computed, which can be used to represent the overall ERT of Kings Bay under a particular flow condition. A 15.05% SGD reduction to Kings Bay would cause a 15% increase of the overall ERT for Kings Bay.

Sea level rises in 2035 relative to 2011, the middle of the 9-year scenario simulation period, at the mouth of Crystal River were estimated based on those obtained from the USACE web site http://www.corpsclimate.us/ccaceslcurves.cfm for the NOAA St. Petersburg and Cedar Key stations by the inverse distance weighting method. The low, intermediate, and high SLRs were estimated to be 4.938, 8.748, and 21.549 cm, respectively over the 24-year span. These SLRs were added to open boundaries at the mouth of Crystal River and in Salt River to drive the hydrodynamic model in simulating the baseline flow condition and the 8.61% and 11.78% flow reduction scenarios. Because SGDs in Kings Bay is affected by tides, effects of a SLR on Crystal River/Kings Bay is at least twofold: it will cause more Gulf water to be transported to the estuary and it will suppress SGDs to the estuary. Many other factors associated with a SLR were not included in the simulations, including the groundwater level rise that could be caused by the SLR. Therefore, SGDs in the SLR runs could be under-estimated, making the evaluation more conservative.

The purpose of the consideration of SLRs in the MFL evaluation is to see if a proposed MFL is still valid when there is a SLR in the future. In consistence with the District planning horizon, we would like to see if the MFL established using the 9-year period between 2007 and 2015 would be violated 24 years later if a 9-year period between 2031 and 2039 were used in the analysis, assuming that the baseline conditions during the two 9-year periods were the same except for the sea level rise. Therefore, the relative changes of salinity and thermal habitats caused by a MFL with a SLR should be compared with those for the baseline condition with the same SLR.

Model results have shown that a sea level rise could significantly change salinity and thermal characteristics in Crystal River/Kings Bay. While low salinity habitats would become considerably less available, high and intermediate salinity habitats would be substantially increased. Using the 15% criteria to define a significant harm, both the 8.61% reduction and the 11.78% reduction of SGDs would cross the threshold for salinity habitats with the high SLR estimate. With the intermediate and low SLRs, the 15% threshold for salinity habitats will be crossed by MFL2 (11.78% flow reduction) but not by MFL1 (8.61% flow reduction).

For thermal habitats under the 72-hour chronic condition, MFL1 is still valid for all SLRs. MFL2 is valid for the intermediate and low SLRs, but not for the high SLR. For thermal habitats under the 4-hour acute condition, an 11.78% flow reduction would cause the crossing of the 15% threshold for all SLRs, but an 8.61% flow reduction only causes the crossing of the 15% threshold for the intermediate SLR only.

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Appendix A

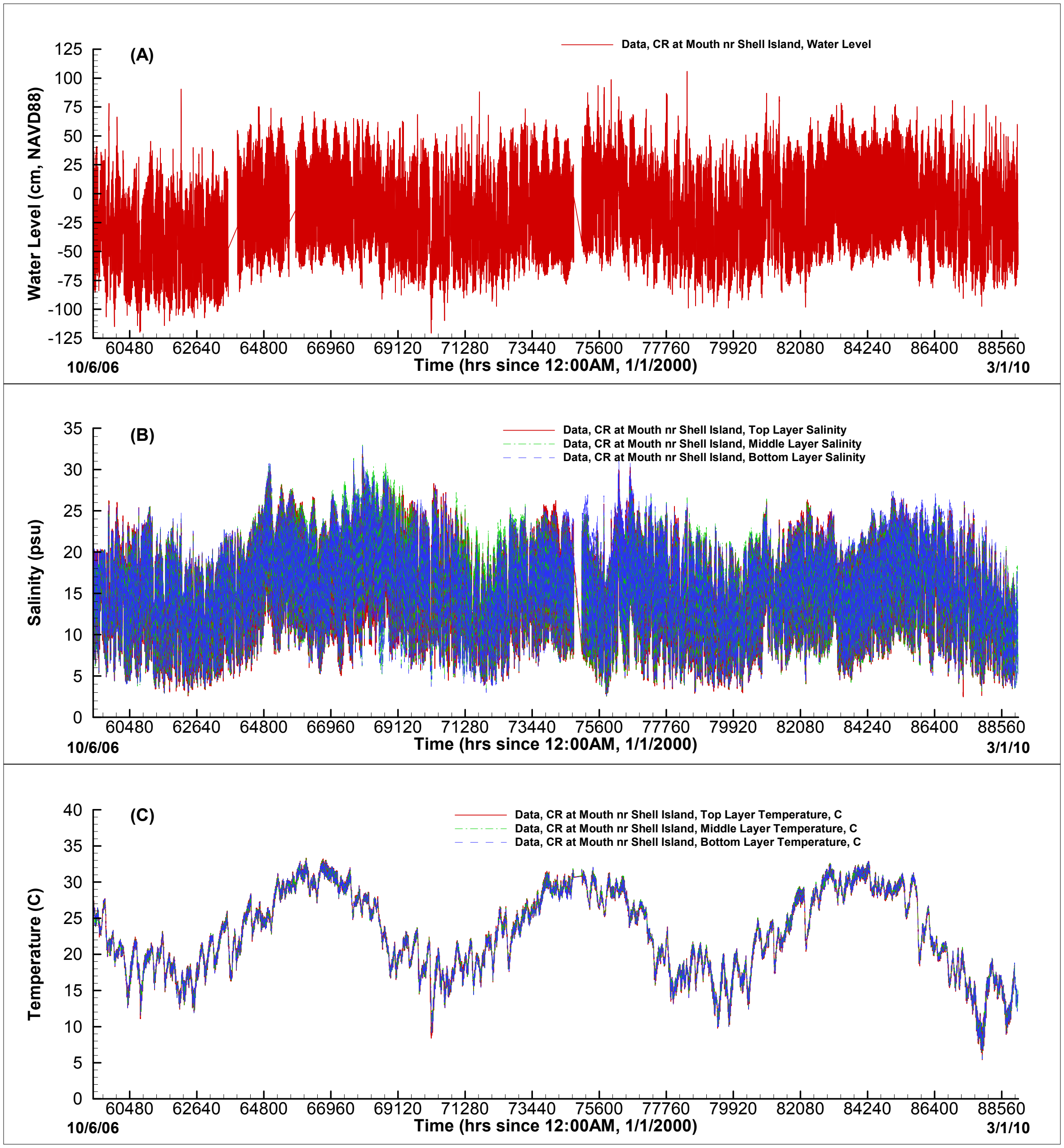

Figure A - 1 Time series of measured water level (A), salinities at three depths (B), and temperatures at three depths (C) at the USGS Crystal River near Shell Island station during October 6, 2006 – March 1, 2010.

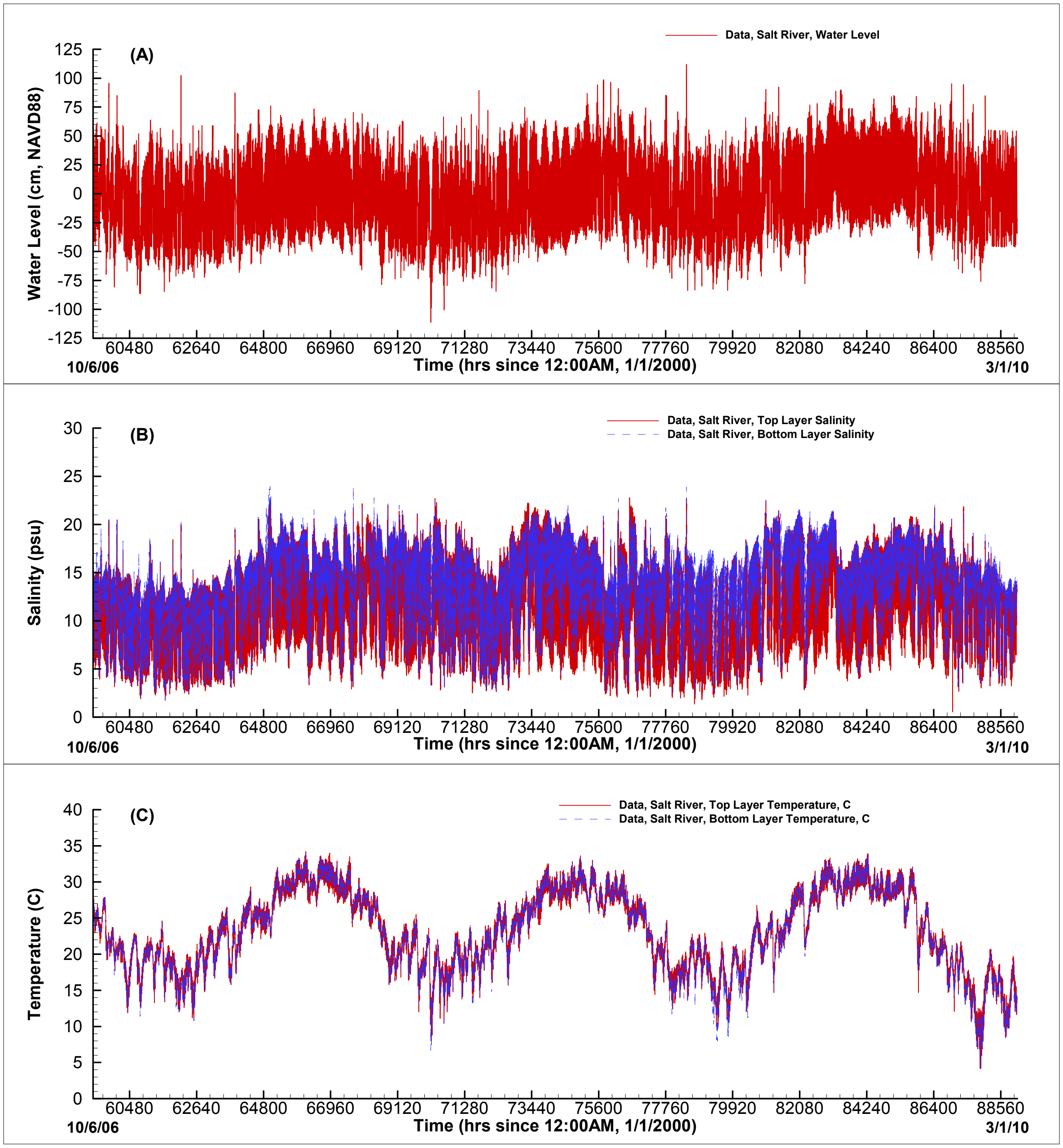

Figure A - 2 Time series of measured water level (A), salinities at the top and bottom depths (B), and temperatures at the top and bottom depths (C) at the USGS Salt River station during October 6, 2006 – March 1, 2010.

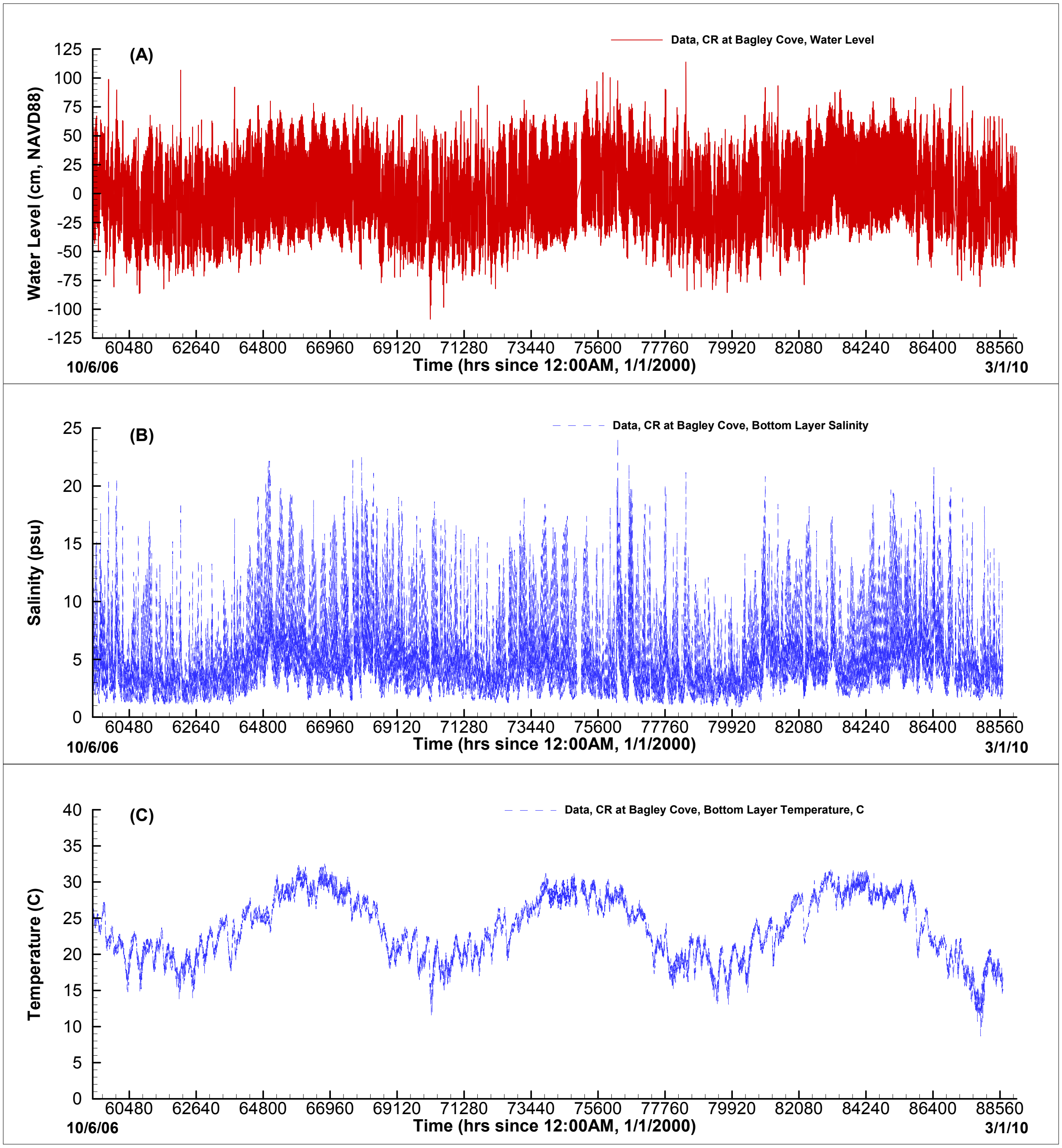

Figure A - 3 Time series of measured water level (A), salinity at the bottom depth (B), and temperature at the bottom depth (C) at the USGS Crystal River at Bayley Cove station during October 6, 2006 – March 1, 2010.

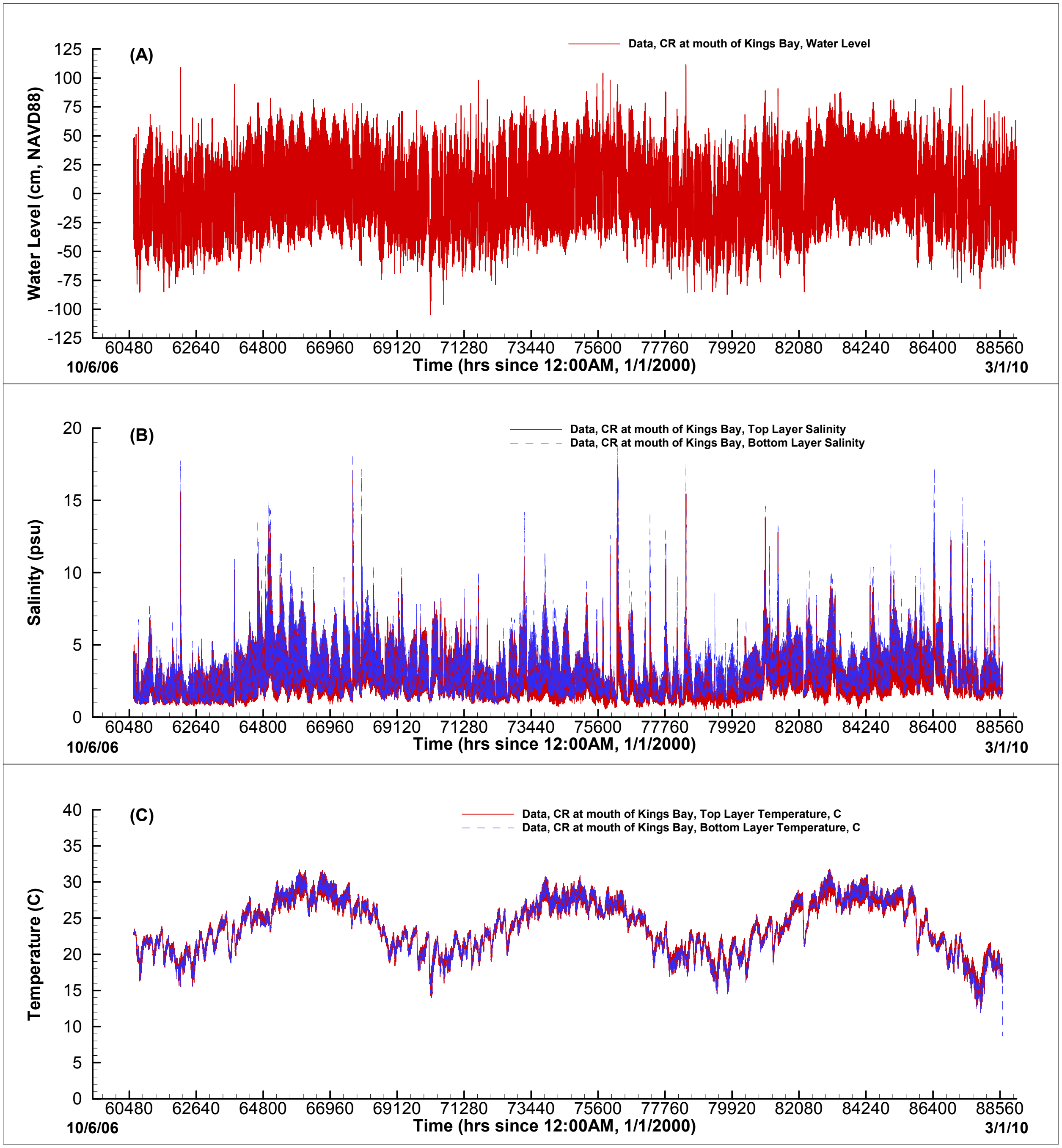

Figure A - 4 Time series of measured water level (A), salinities at the top and bottom depths (B), and temperatures at the top and bottom depths (C) at the USGS Mouth of Kings Bay station on during October 6, 2006 – March 1, 2010.

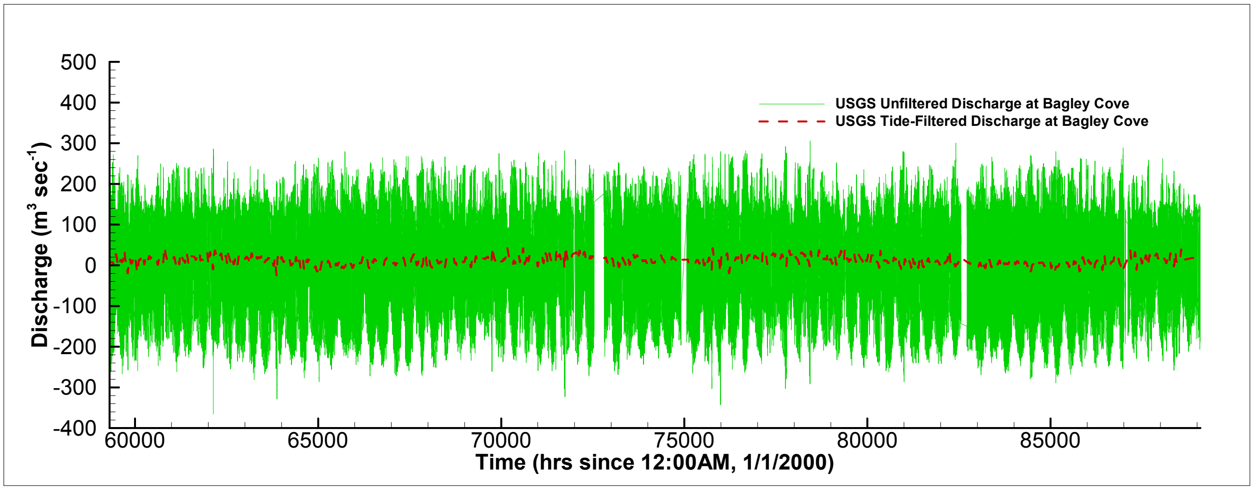

Figure A - 5 Time series of measured cross-sectional discharge at Bagley Cove during October 6, 2006 – March 1, 2010.

Appendix B

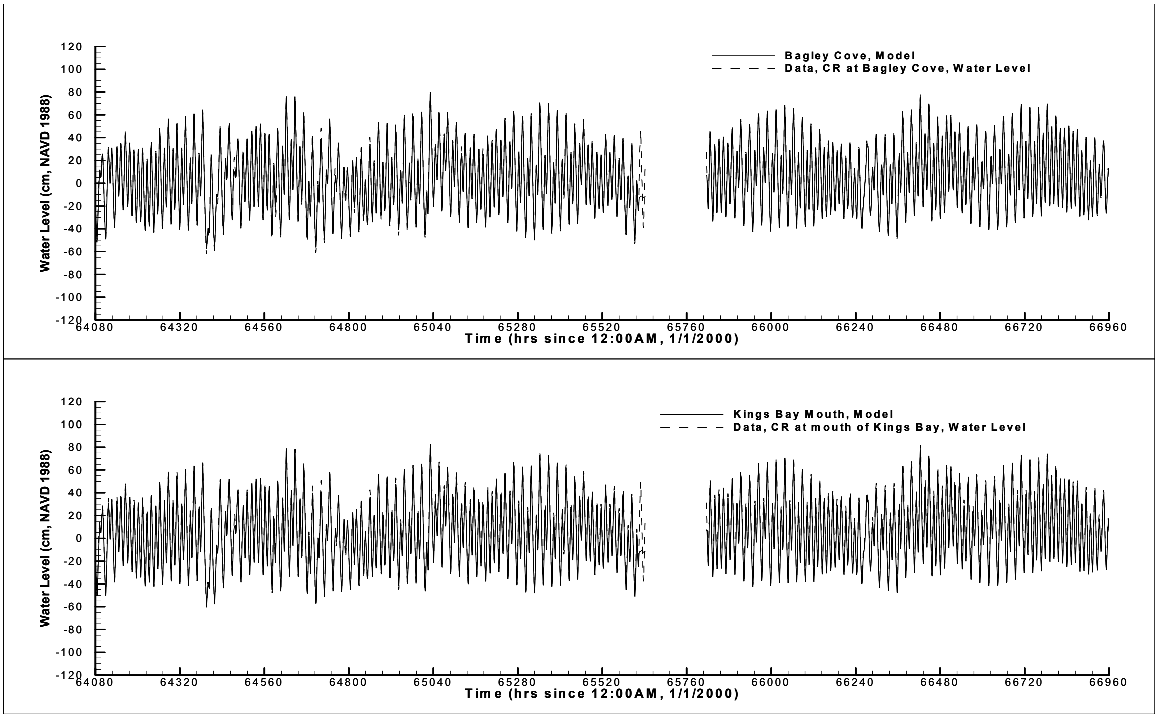

Figure B - 1 Comparison of simulated and measured water levels at the Bagley Cove station and the mouth of Kings Bay station during Hours 64080 - 66960.

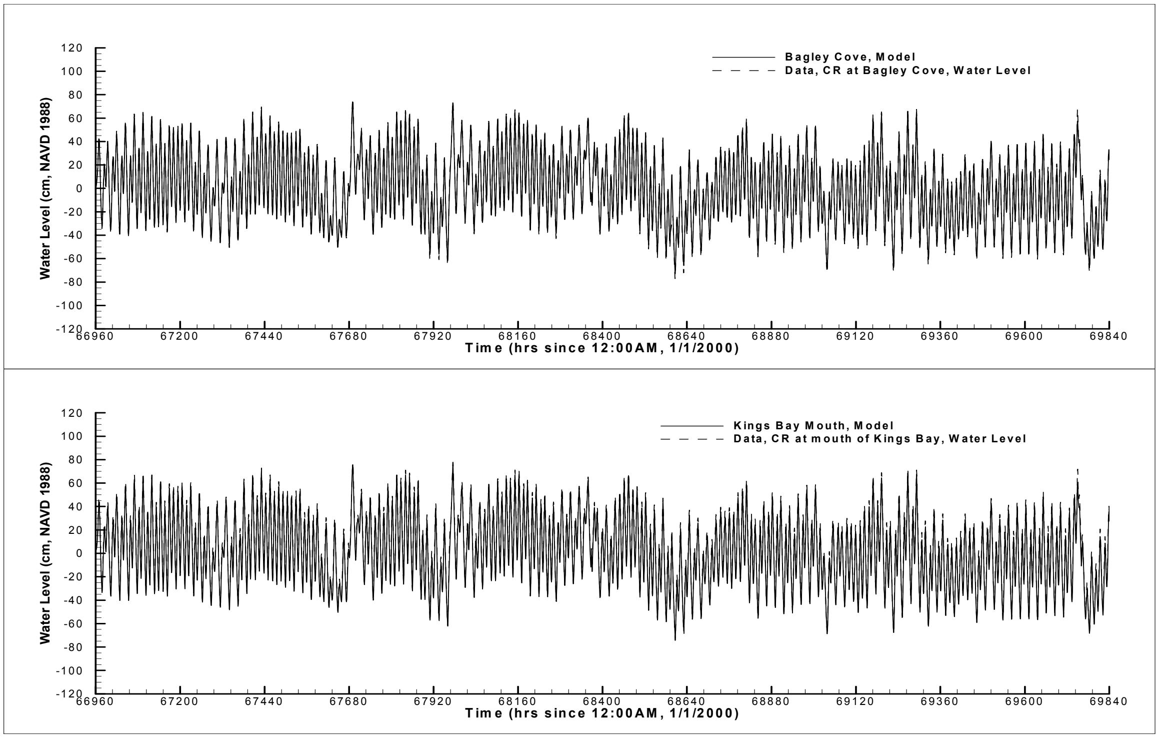

Figure B - 2 Comparison of simulated and measured water levels at the Bagley Cove station and the mouth of Kings Bay station during Hours 64080 - 66960.

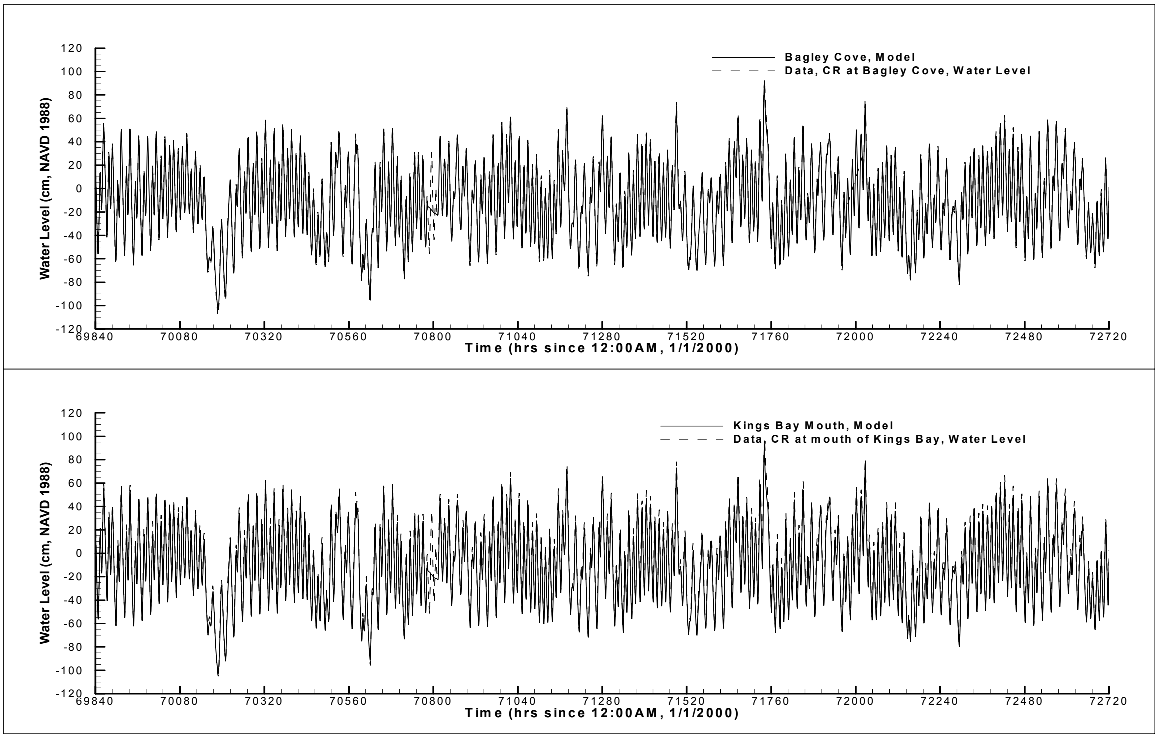

Figure B - 3 Comparison of simulated and measured water levels at the Bagley Cove station and the mouth of Kings Bay station during Hours 66960 - 72720.

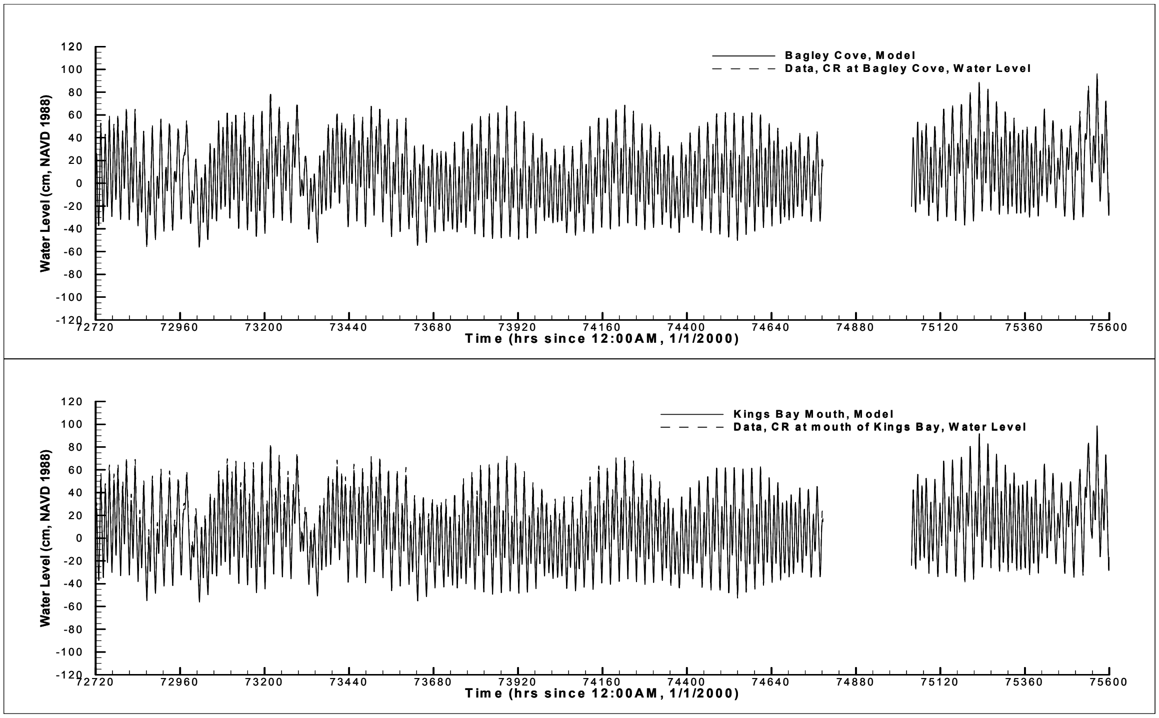

Figure B - 4 Comparison of simulated and measured water levels at the Bagley Cove station and the mouth of Kings Bay station during Hours 72720 - 75600.

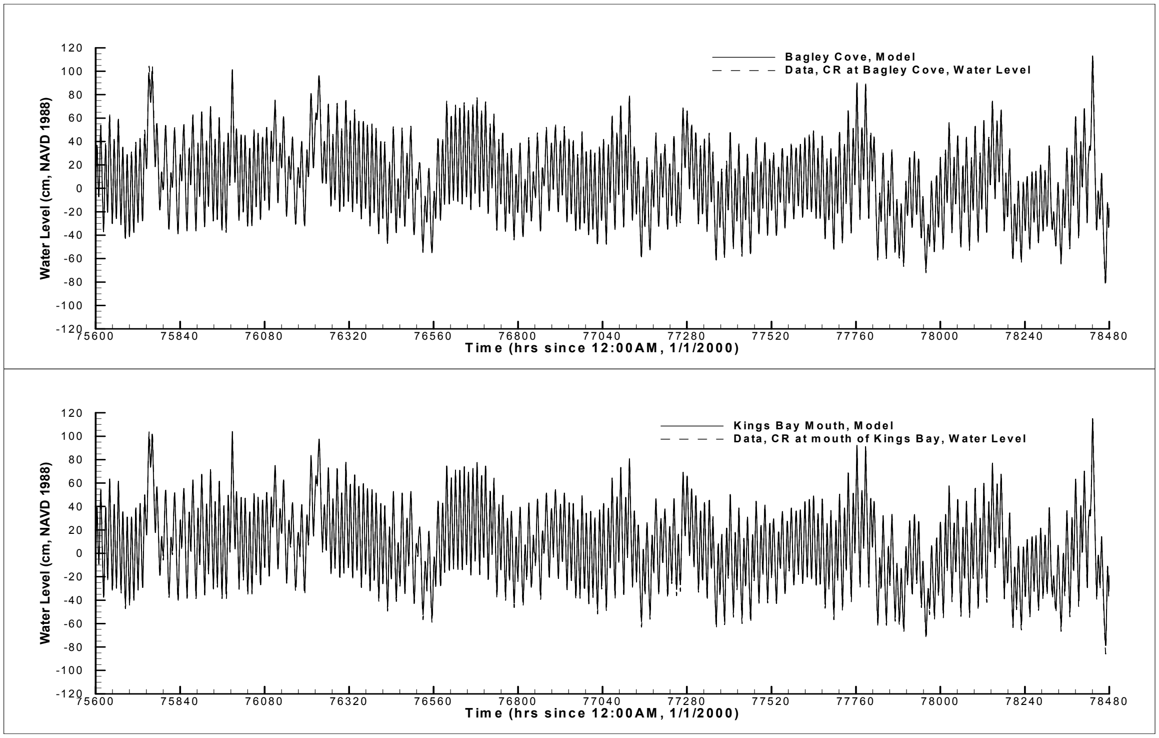

Figure B - 5 Comparison of simulated and measured water levels at the Bagley Cove station and the mouth of Kings Bay station during Hours 75600 - 78480.

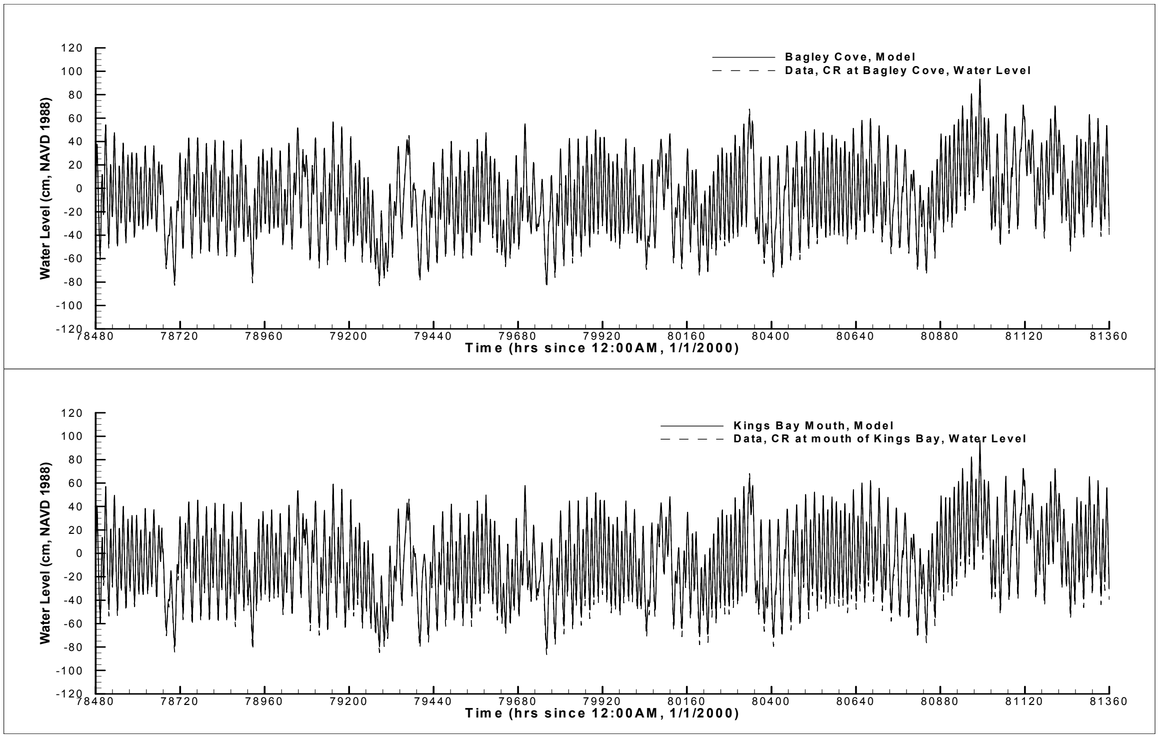

Figure B - 6 Comparison of simulated and measured water levels at the Bagley Cove station and the mouth of Kings Bay station during Hours 78480 - 81360.

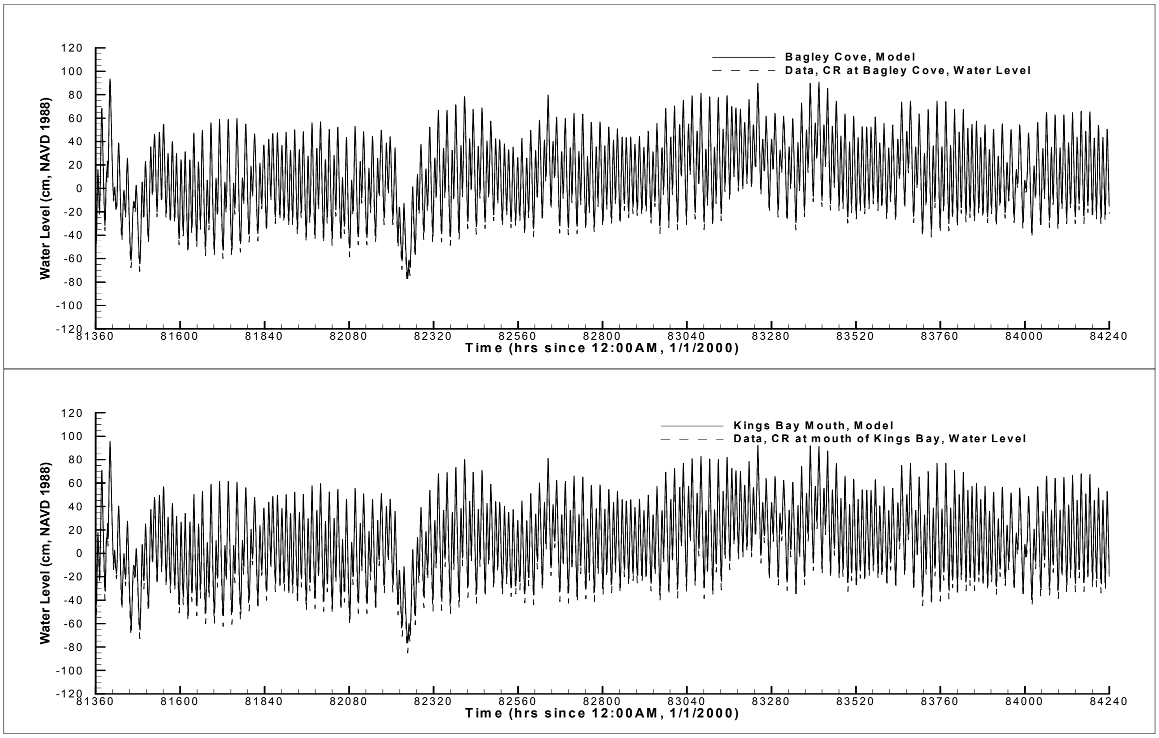

Figure B - 7 Comparison of simulated and measured water levels at the Bagley Cove station and the mouth of Kings Bay station during Hours 81360 - 84240.

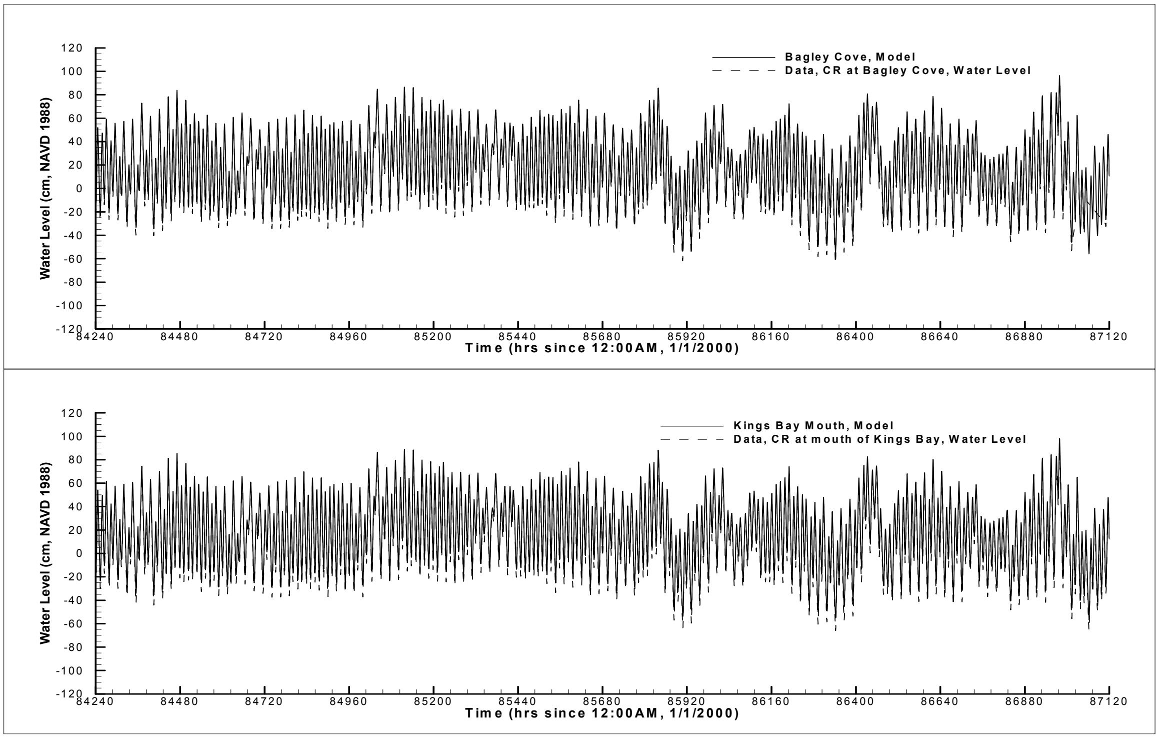

Figure B - 8 Comparison of simulated and measured water levels at the Bagley Cove station and the mouth of Kings Bay station during Hours 84240 - 87120.

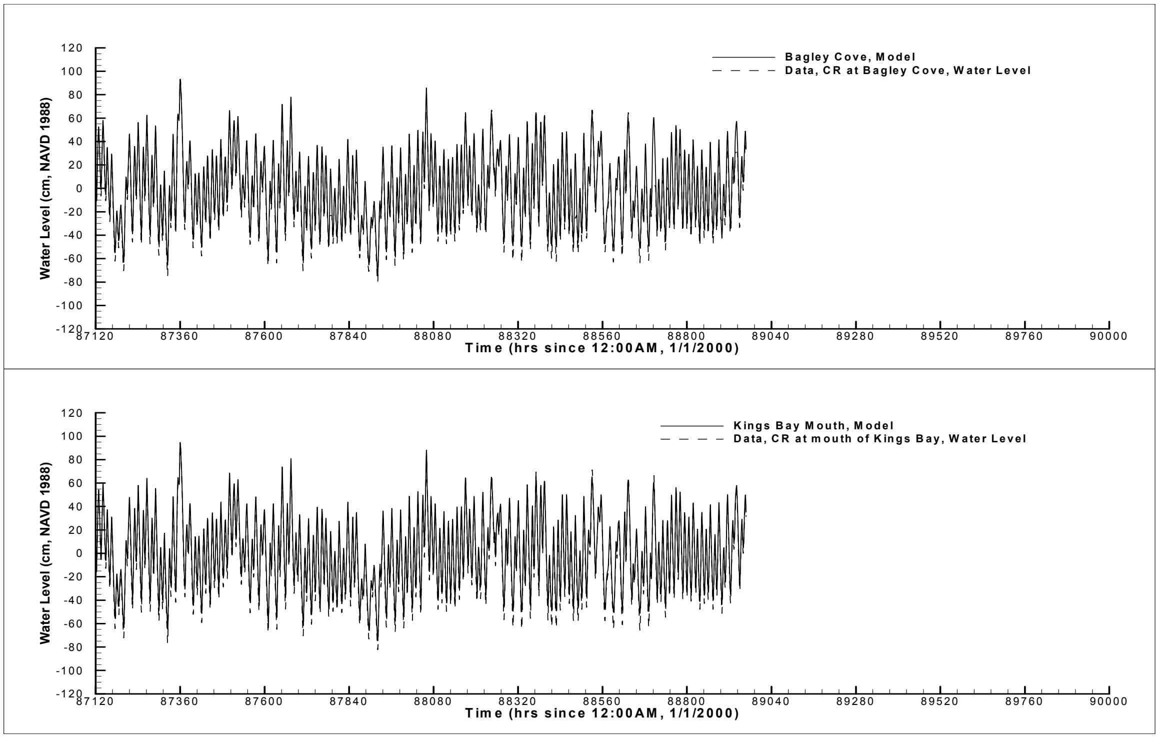

Figure B - 9 Comparison of simulated and measured water levels at the Bagley Cove station and the mouth of Kings Bay station during Hours 87120 - 90000.

Appendix C

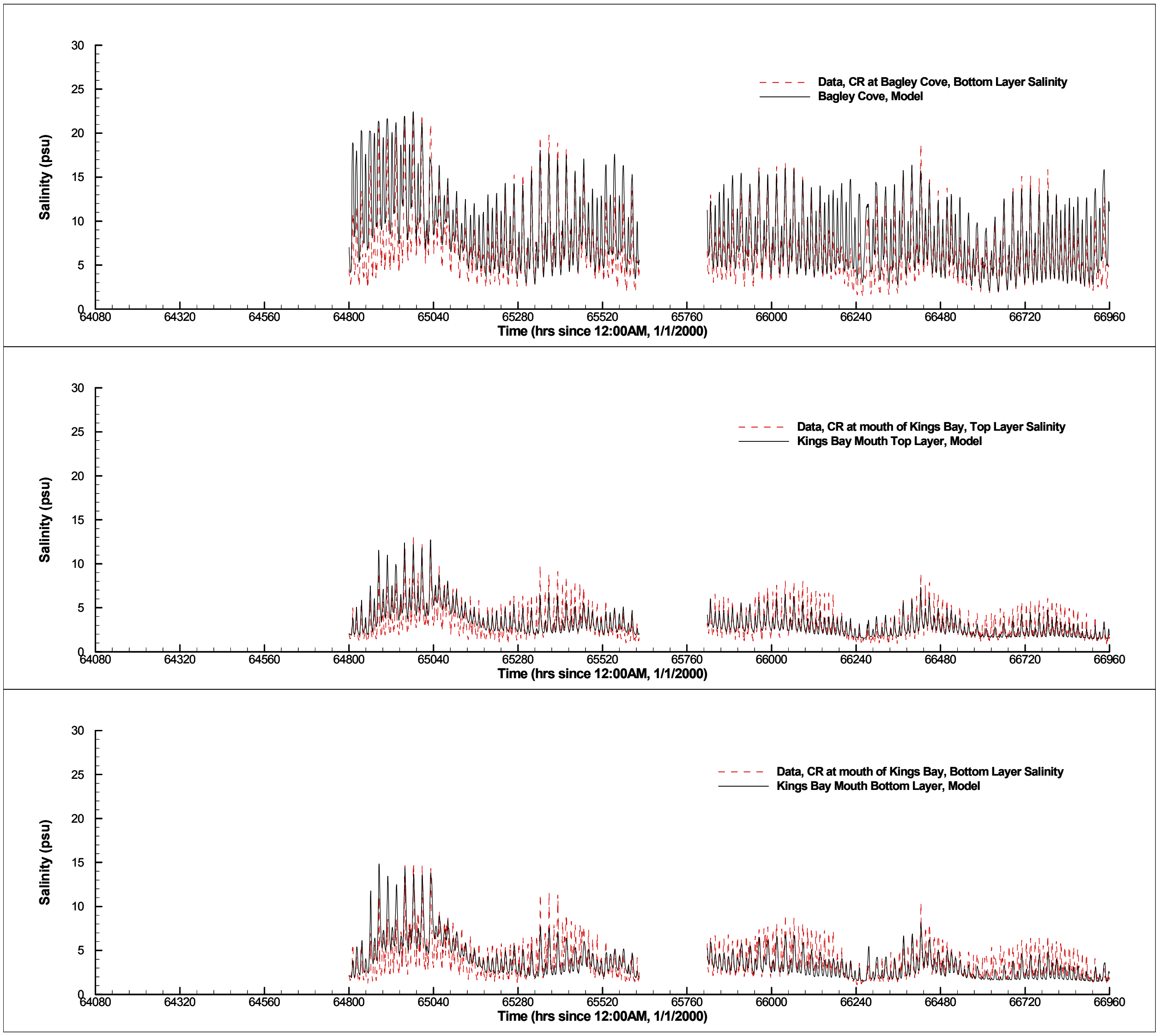

Figure C - 1 Comparison of simulated and measured salinities at the bottom layer of the Bagley Cove station and the top and bottom layers of the mouth of Kings Bay station during Hours 64080 - 66960.

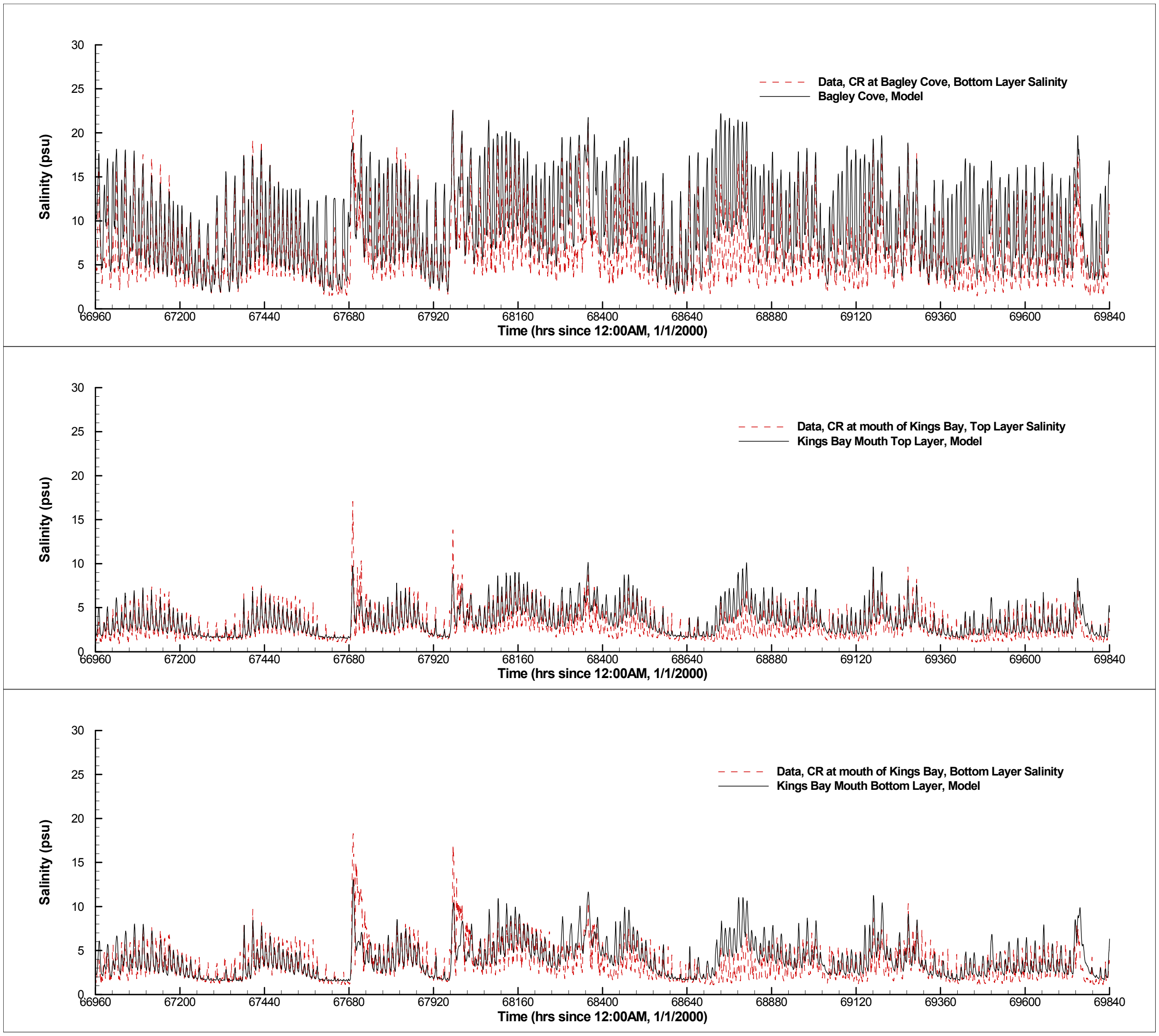

Figure C - 2 Comparison of simulated and measured salinities at the bottom layer of the Bagley Cove station and the top and bottom layers of the mouth of Kings Bay station during Hours 66960 - 69840.

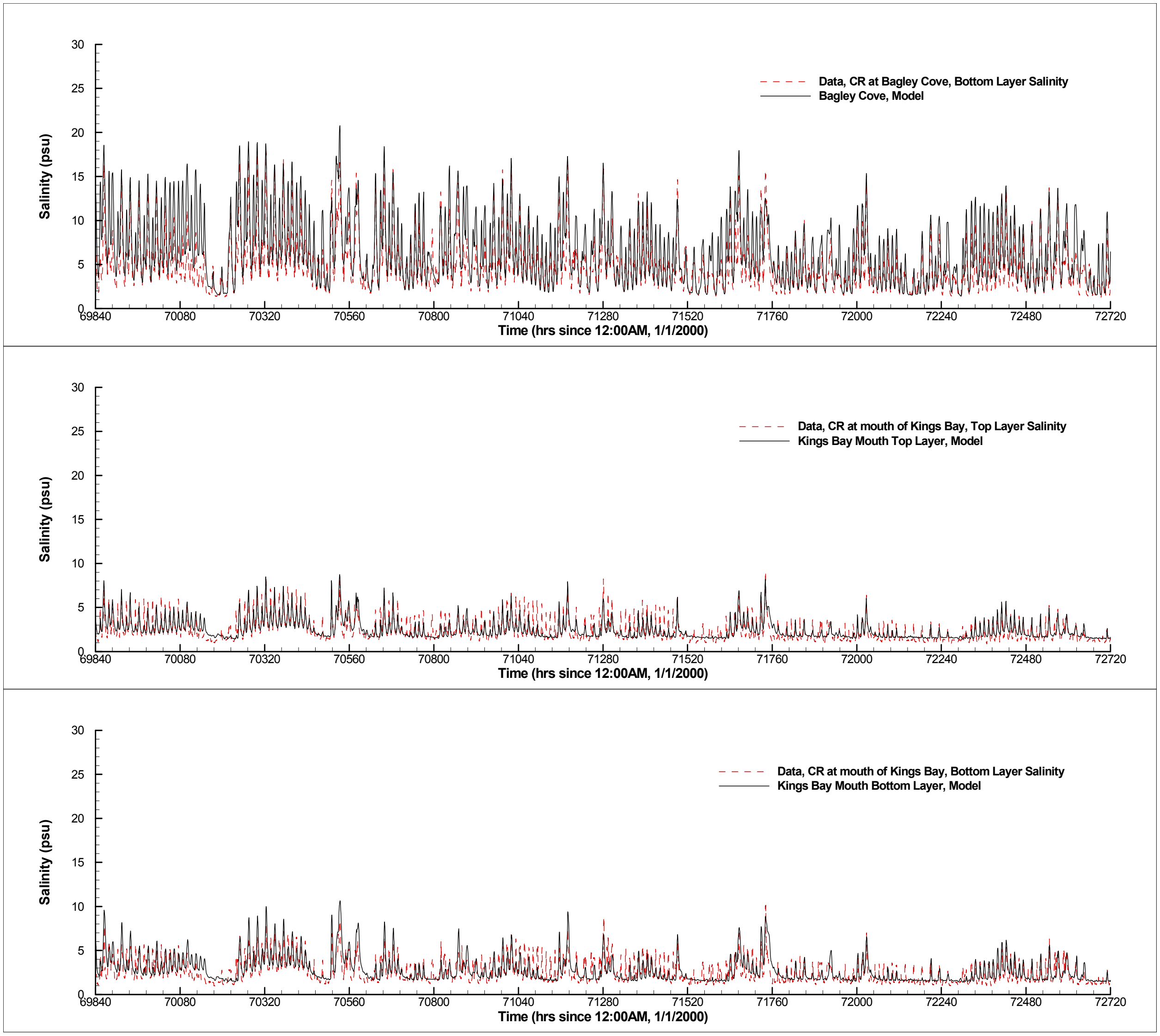

Figure C - 3 Comparison of simulated and measured salinities at the bottom layer of the Bagley Cove station and the top and bottom layers of the mouth of Kings Bay station during Hours 66960 - 69840.

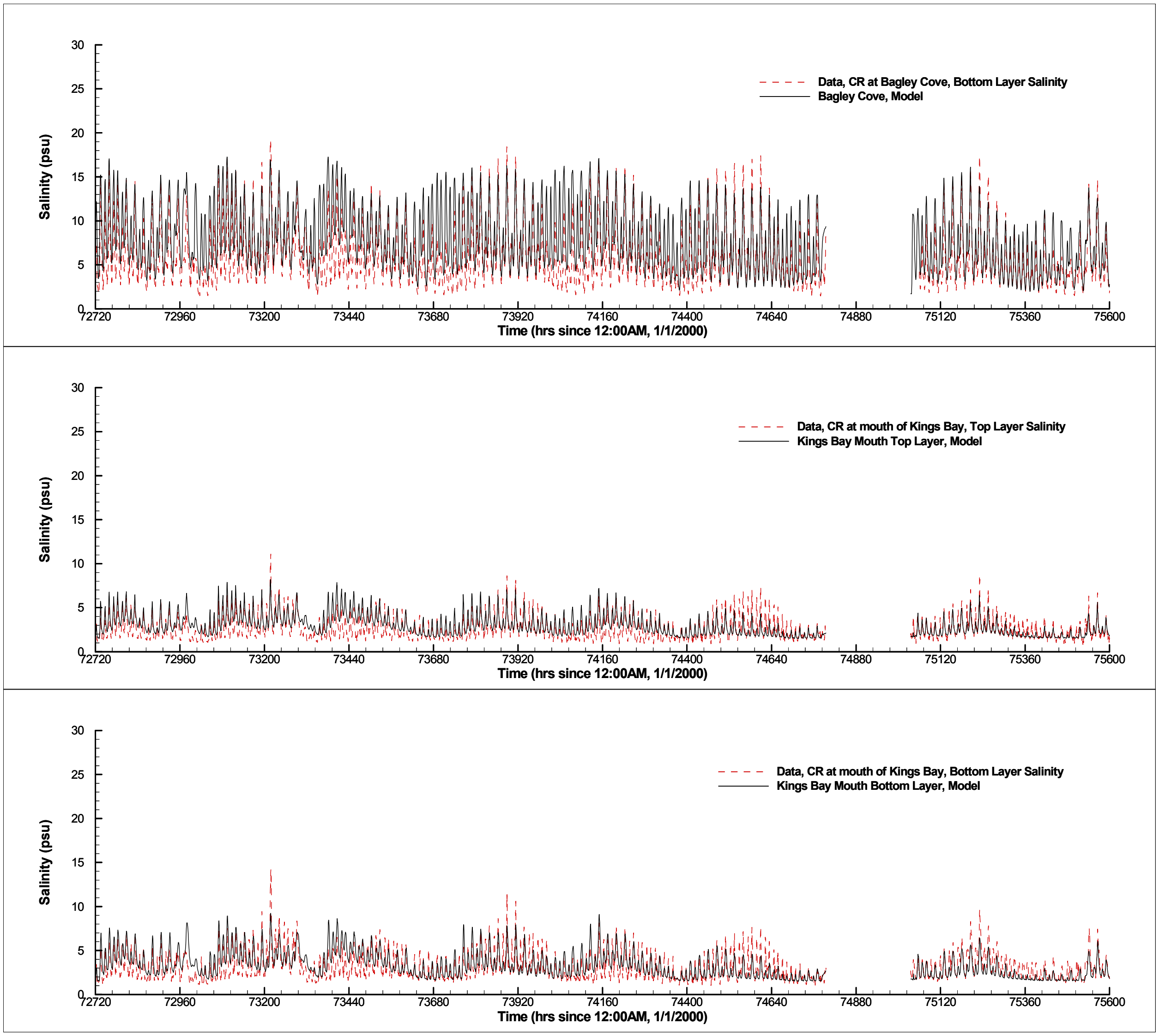

Figure C - 4 Comparison of simulated and measured salinities at the bottom layer of the Bagley Cove station and the top and bottom layers of the mouth of Kings Bay station during Hours 72720 - 75600.

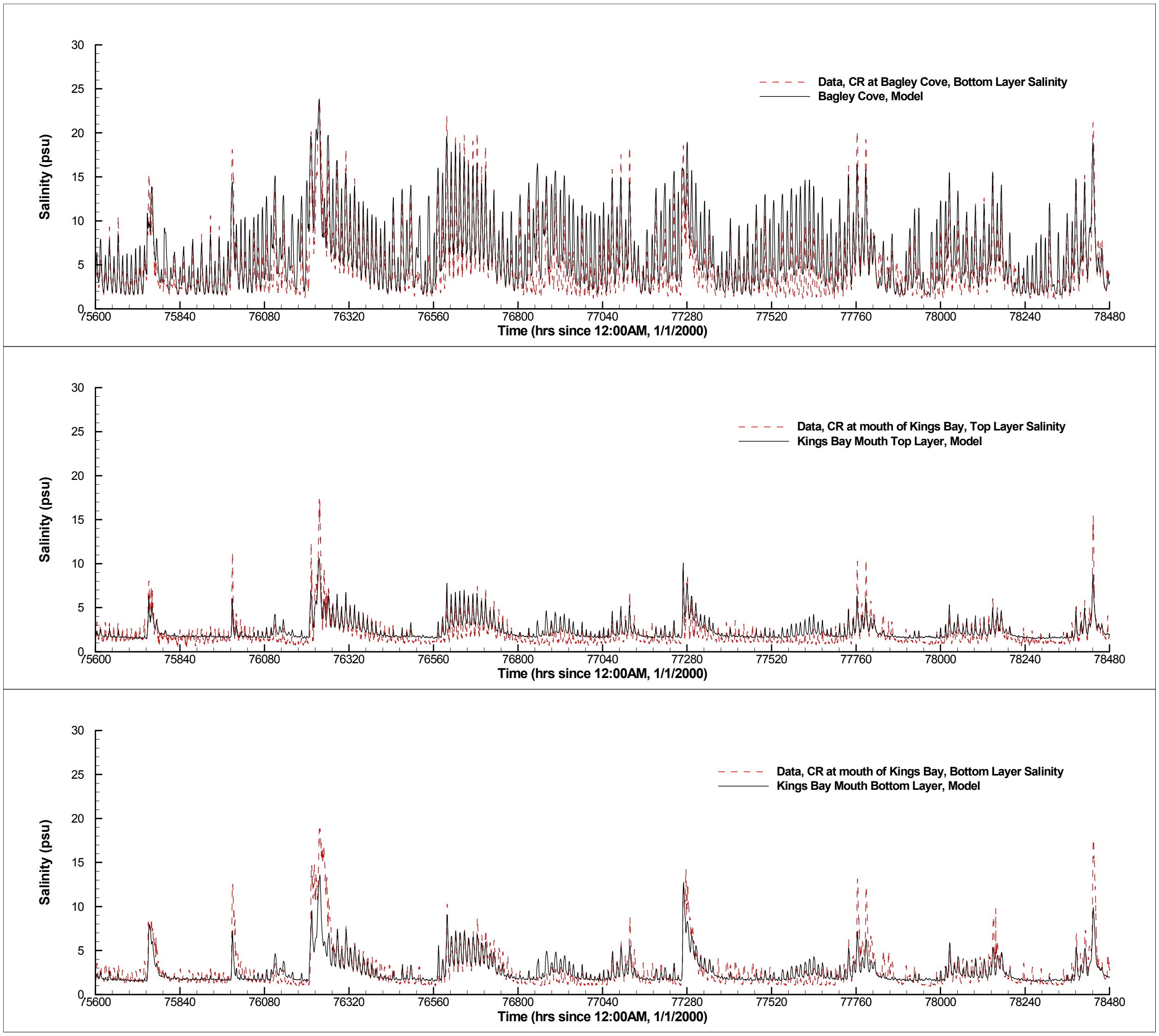

Figure C - 5 Comparison of simulated and measured salinities at the bottom layer of the Bagley Cove station and the top and bottom layers of the mouth of Kings Bay station during Hours 75600 - 78480.

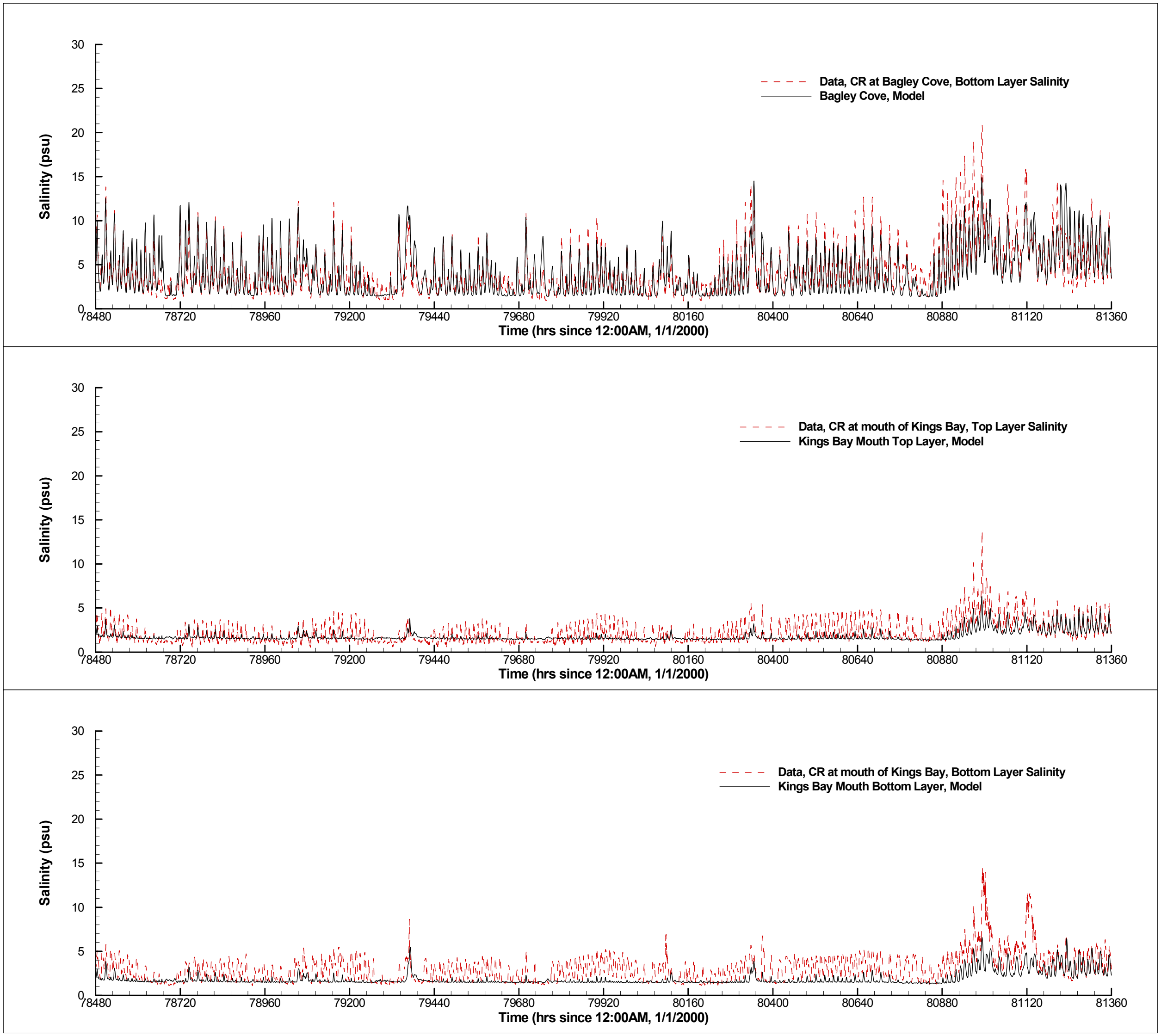

Figure C - 6 Comparison of simulated and measured salinities at the bottom layer of the Bagley Cove station and the top and bottom layers of the mouth of Kings Bay station during Hours 78480 - 81360.

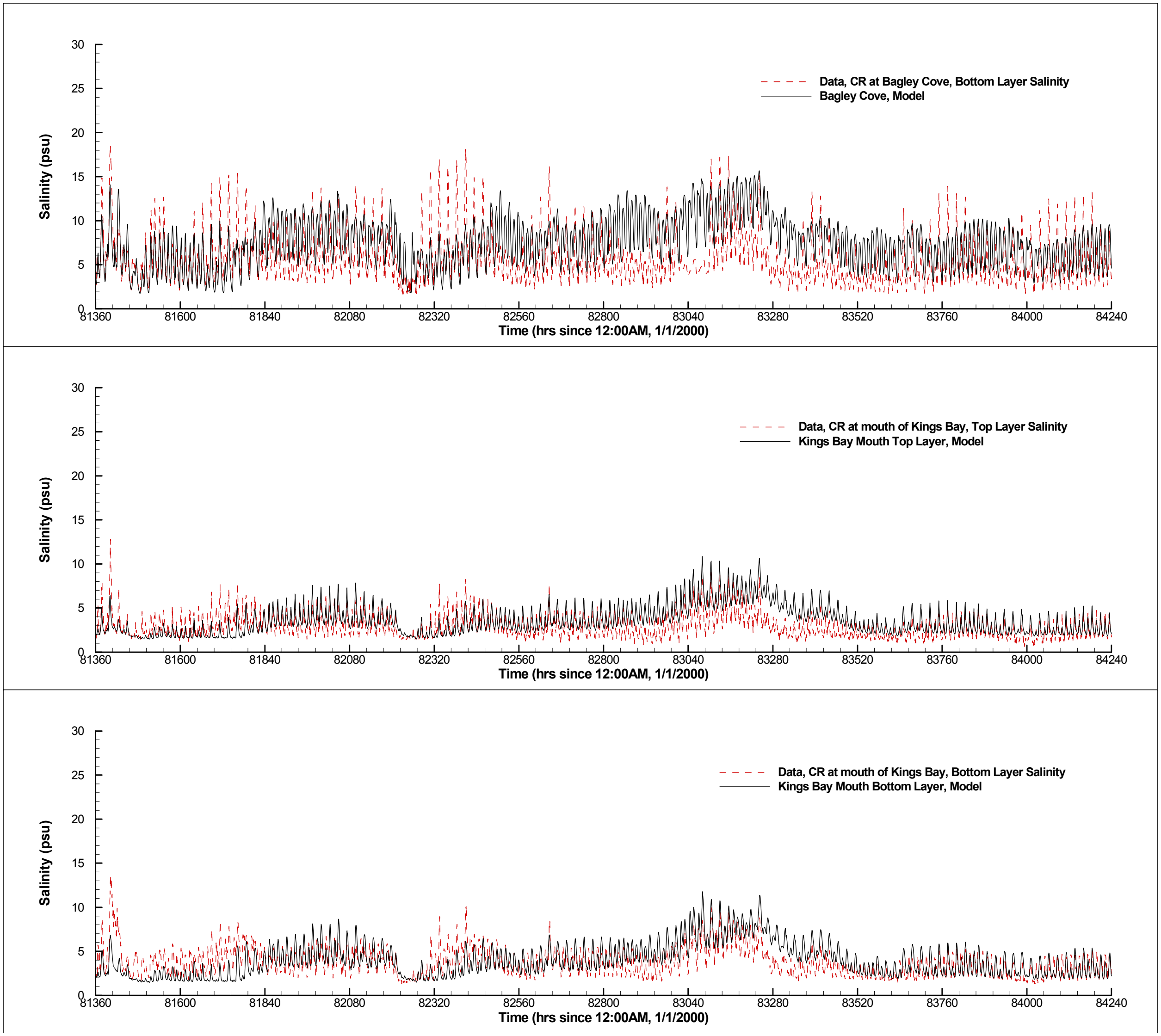

Figure C - 7 Comparison of simulated and measured salinities at the bottom layer of the Bagley Cove station and the top and bottom layers of the mouth of Kings Bay station during Hours 81360 - 84240.

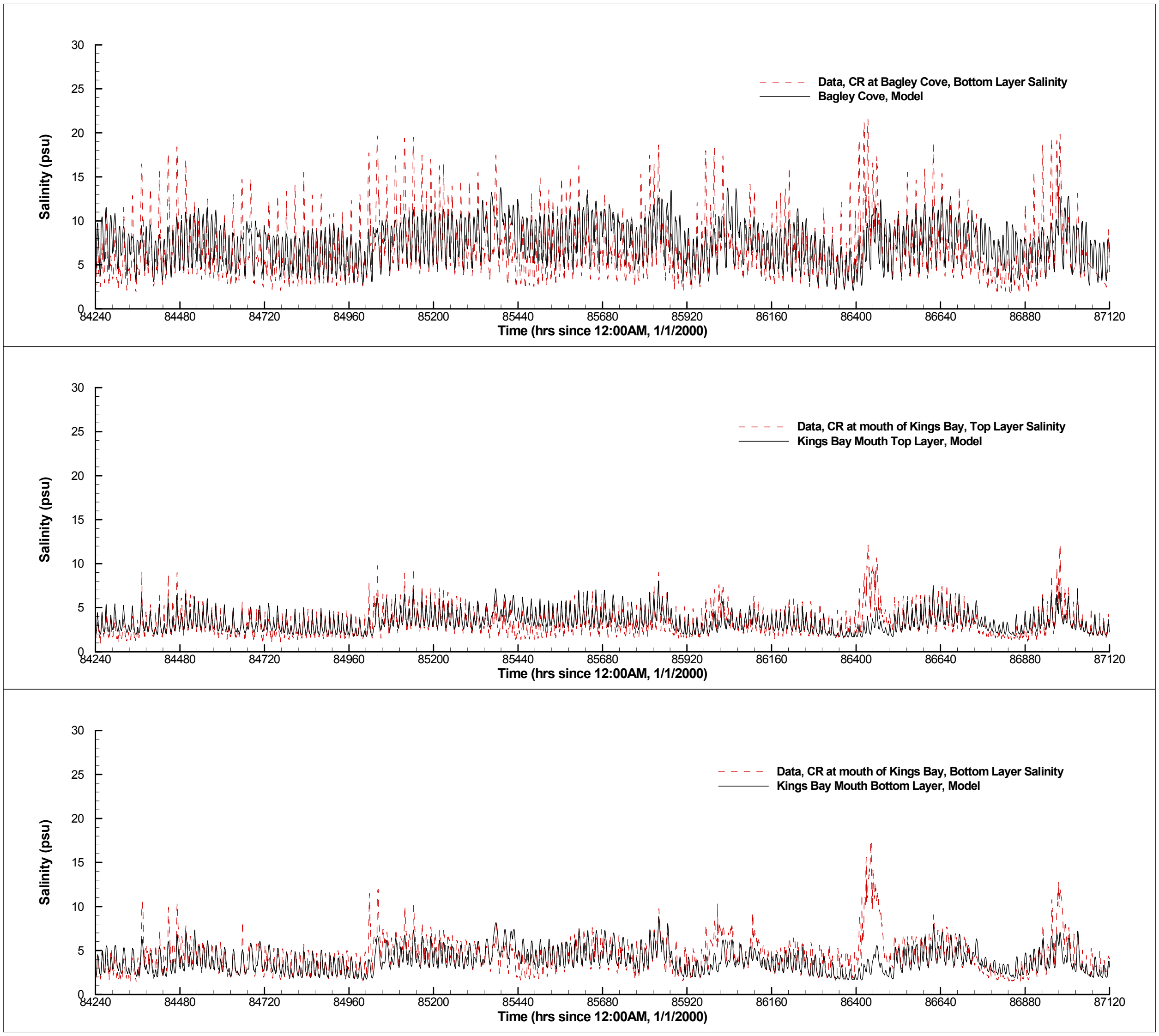

Figure C - 8 Comparison of simulated and measured salinities at the bottom layer of the Bagley Cove station and the top and bottom layers of the mouth of Kings Bay station during Hours 84240 - 87120.

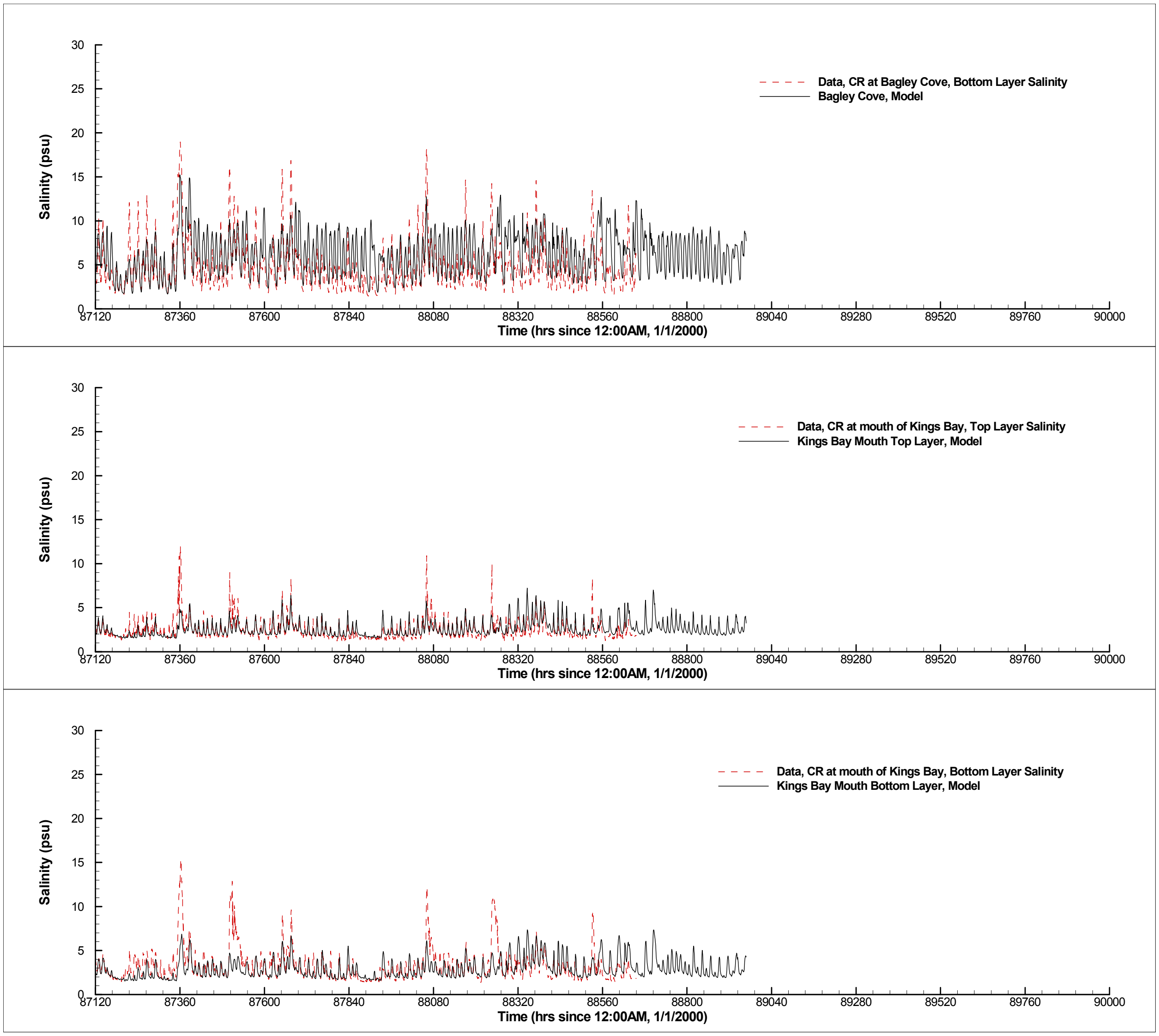

Figure C - 9 Comparison of simulated and measured salinities at the bottom layer of the Bagley Cove station and the top and bottom layers of the mouth of Kings Bay station during Hours 87120 - 90000.

Appendix D

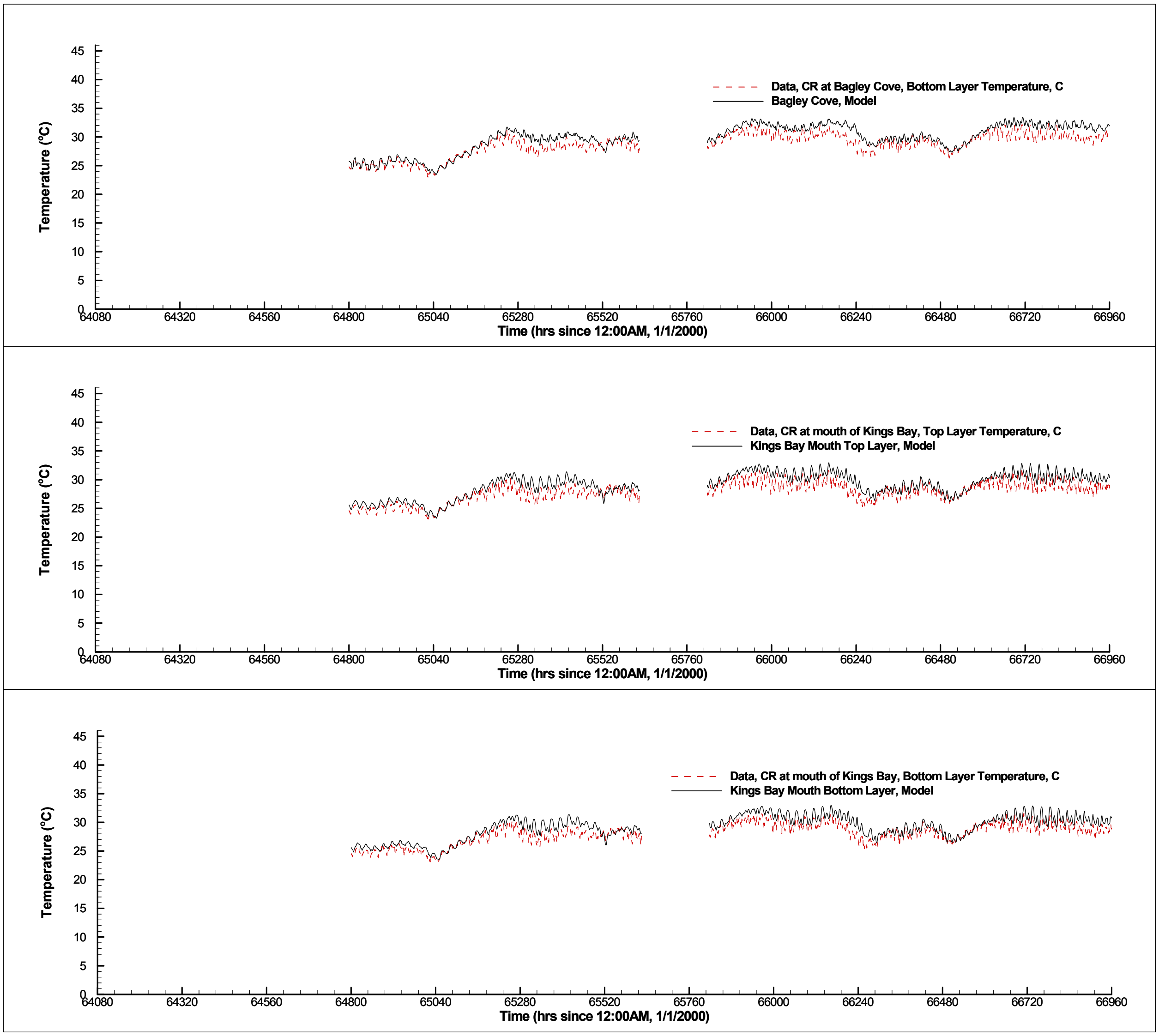

Figure D - 1 Comparison of simulated and measured temperatures at the bottom layer of the Bagley Cove station and the top and bottom layers of the mouth of Kings Bay station during Hours 64080 - 66960.

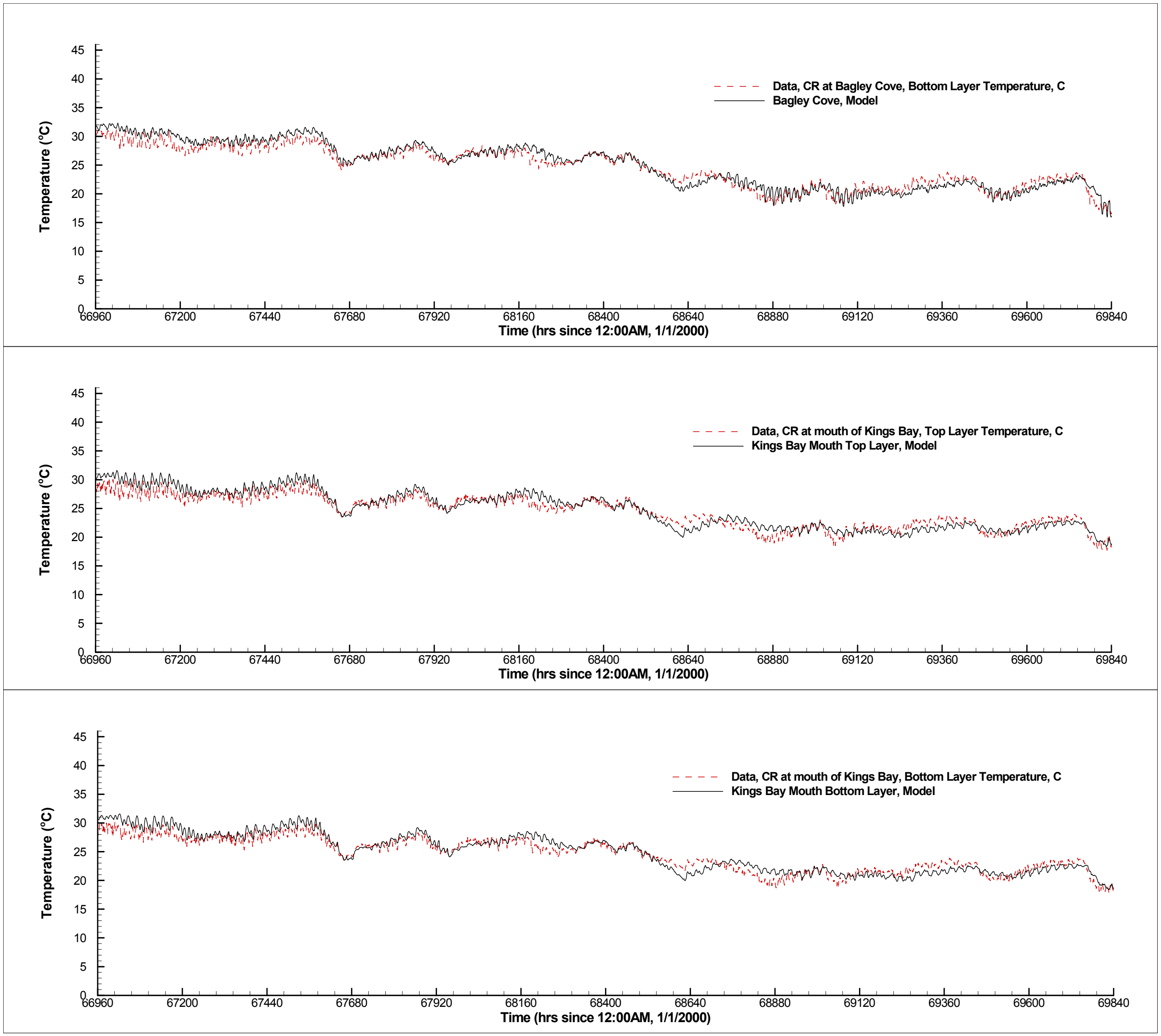

Figure D - 2 Comparison of simulated and measured temperatures at the bottom layer of the Bagley Cove station and the top and bottom layers of the mouth of Kings Bay station during Hours 66960 - 69840.

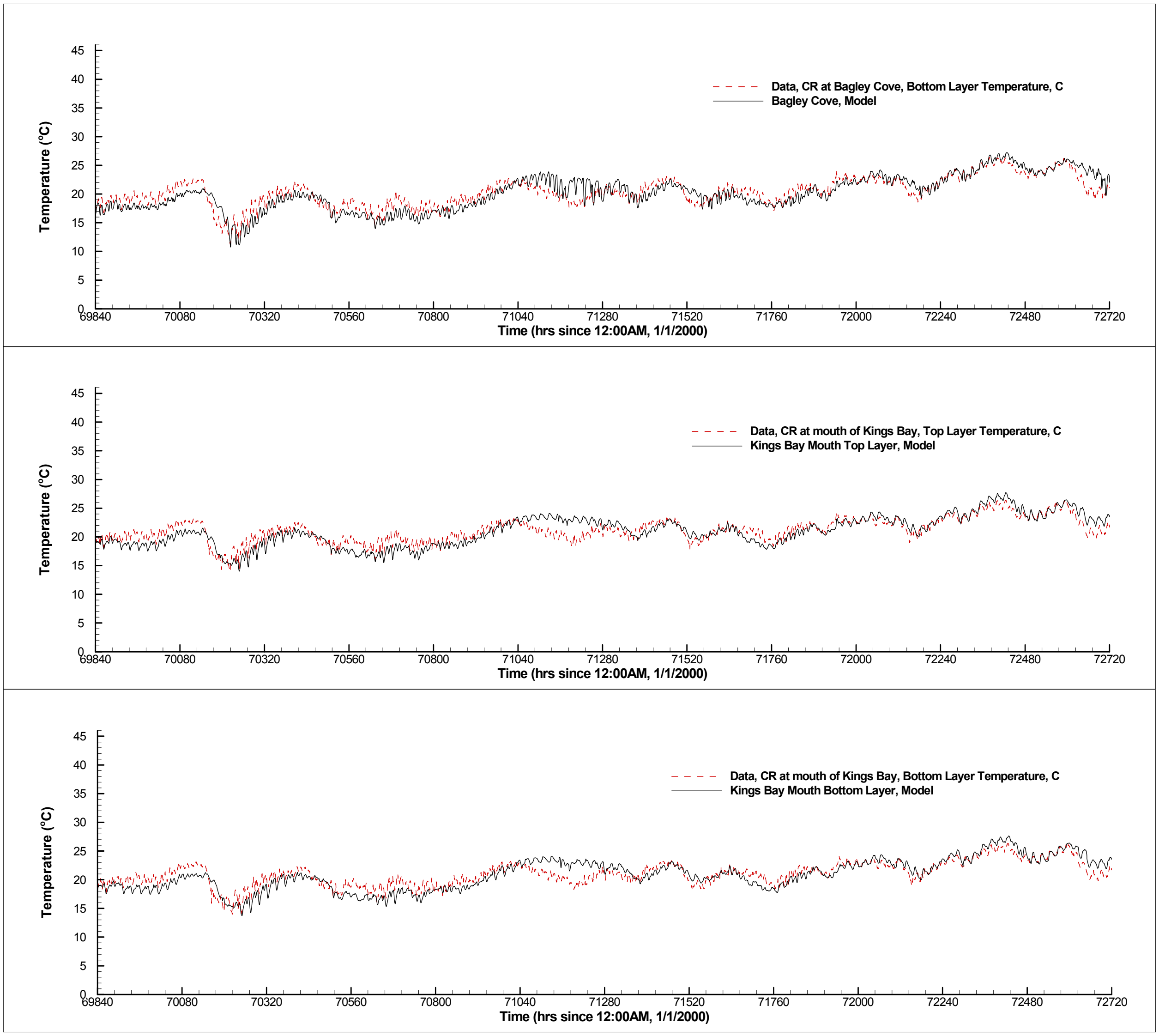

Figure D - 3 Comparison of simulated and measured temperatures at the bottom layer of the Bagley Cove station and the top and bottom layers of the mouth of Kings Bay station during Hours 69840 - 72720.

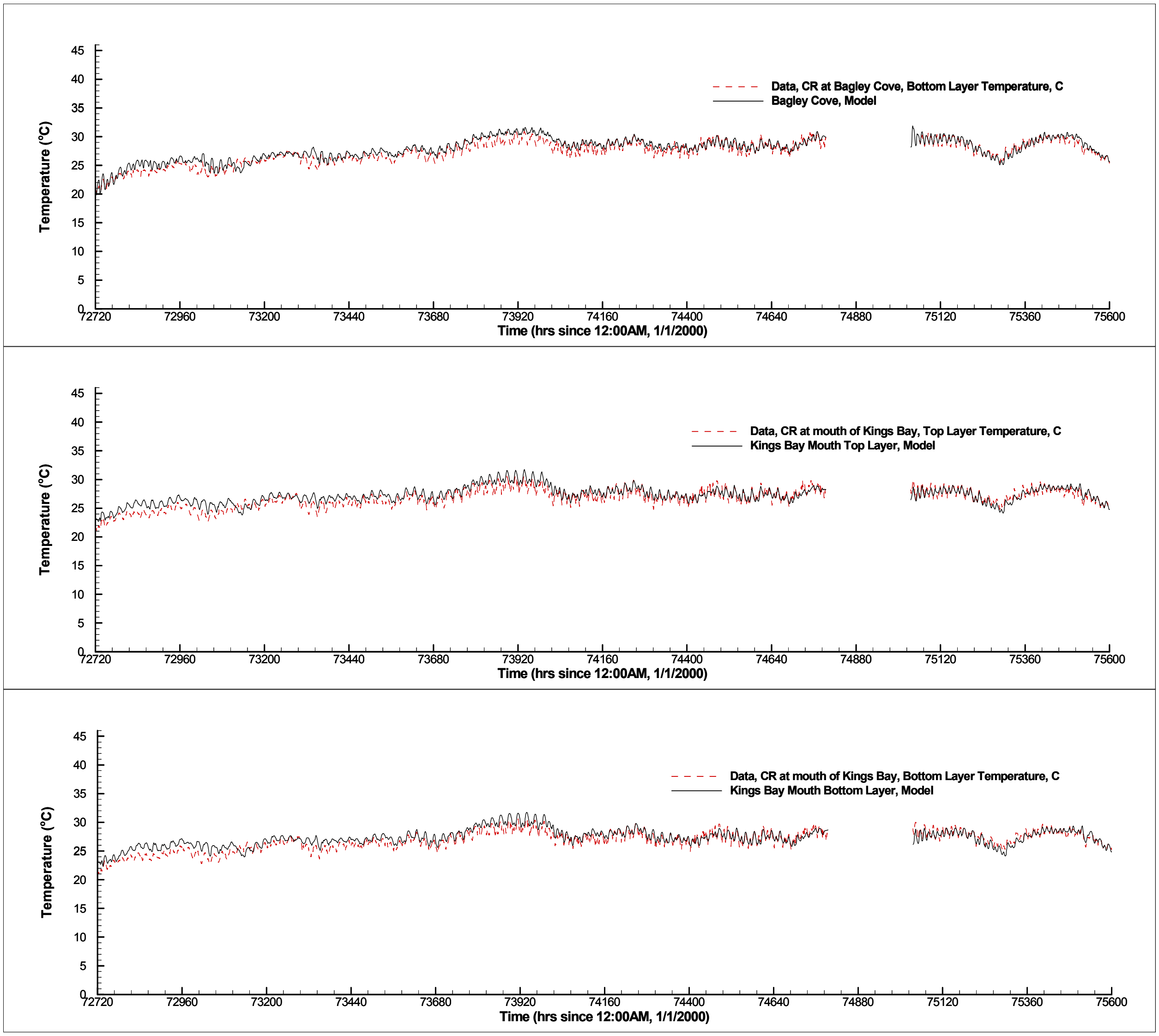

Figure D - 4 Comparison of simulated and measured temperatures at the bottom layer of the Bagley Cove station and the top and bottom layers of the mouth of Kings Bay station during Hours 72720 - 75600.

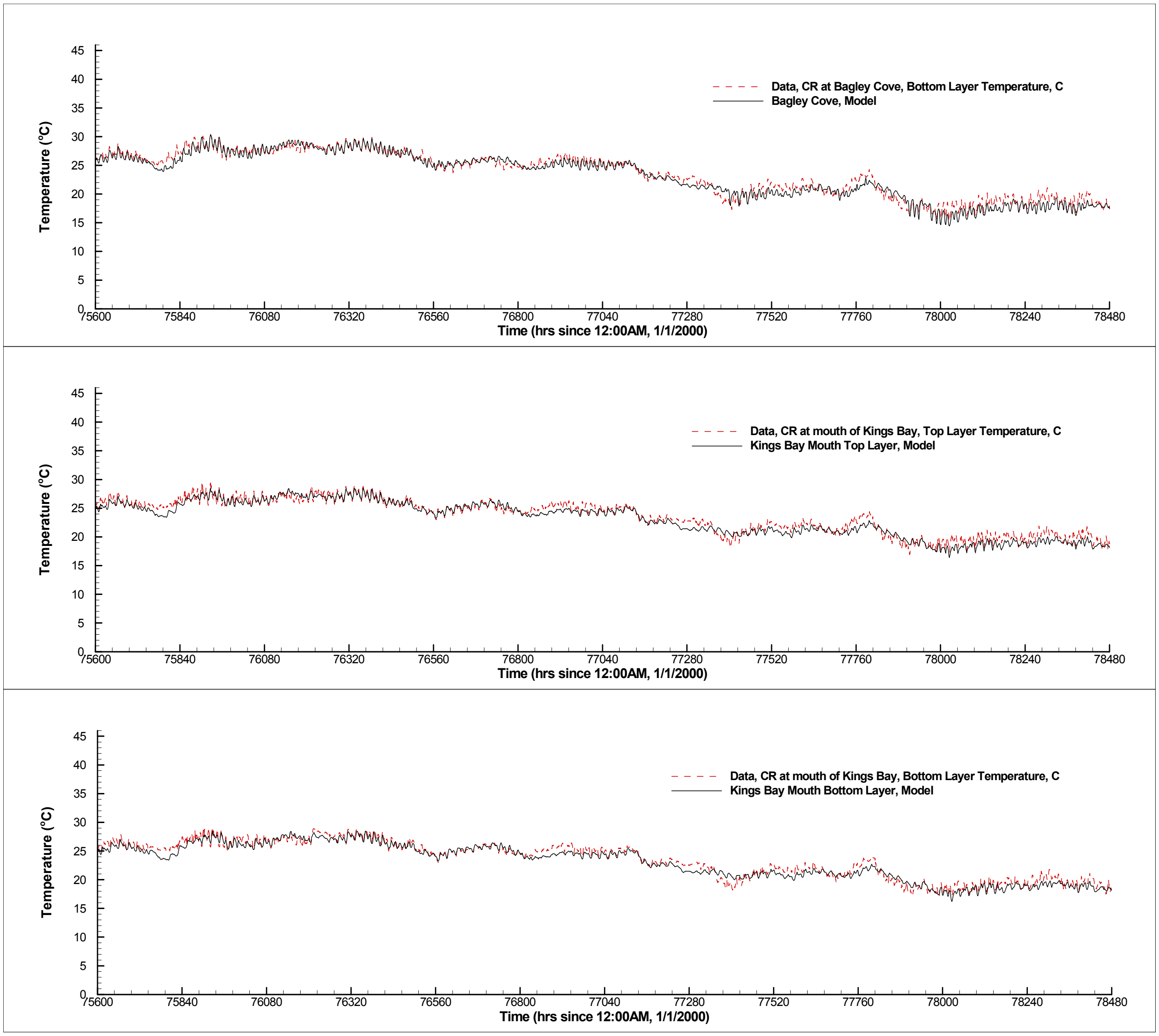

Figure D - 5 Comparison of simulated and measured temperatures at the bottom layer of the Bagley Cove station and the top and bottom layers of the mouth of Kings Bay station during Hours 75600 -78480.

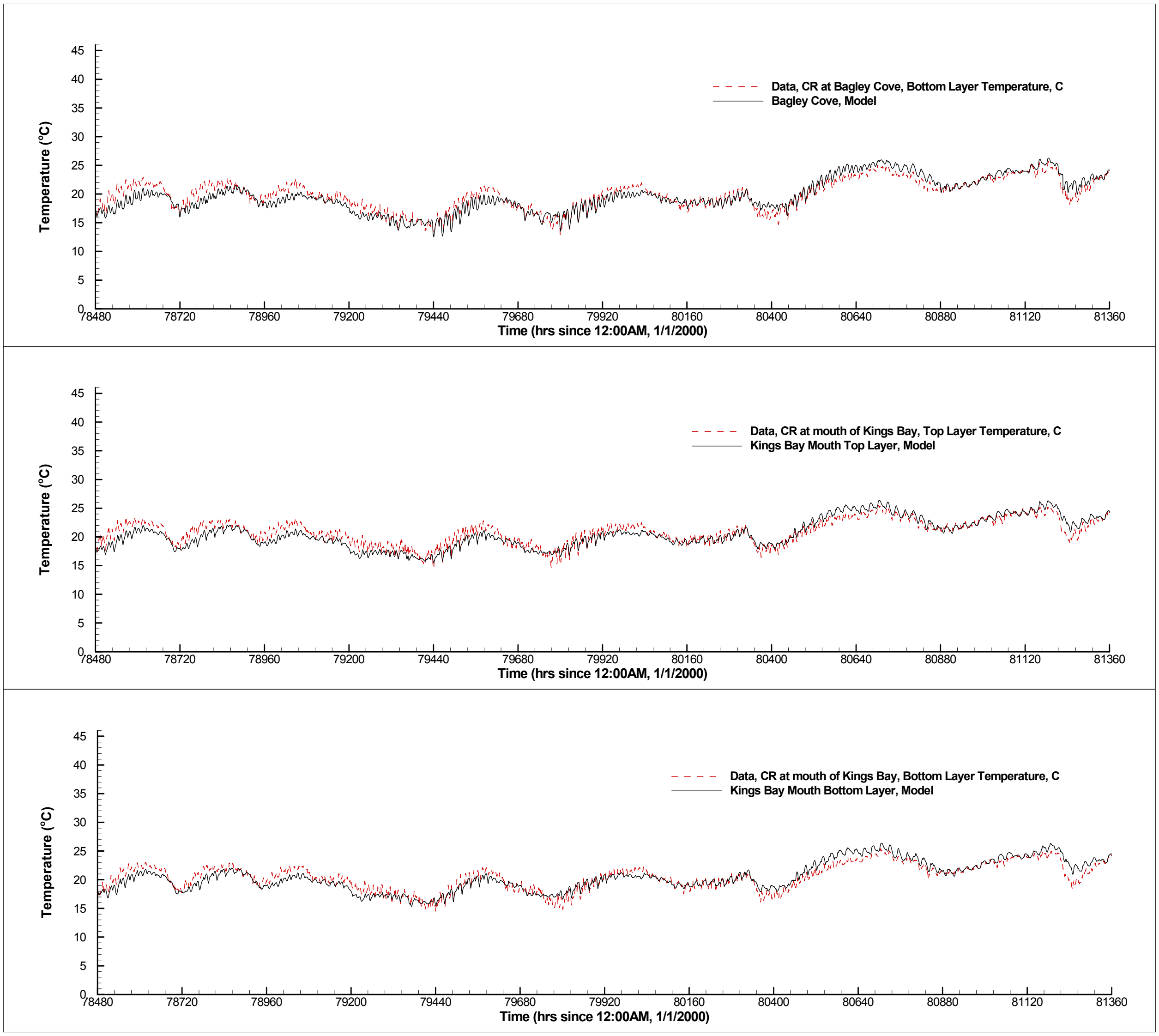

Figure D - 6 Comparison of simulated and measured temperatures at the bottom layer of the Bagley Cove station and the top and bottom layers of the mouth of Kings Bay station during Hours 78480 - 81360.

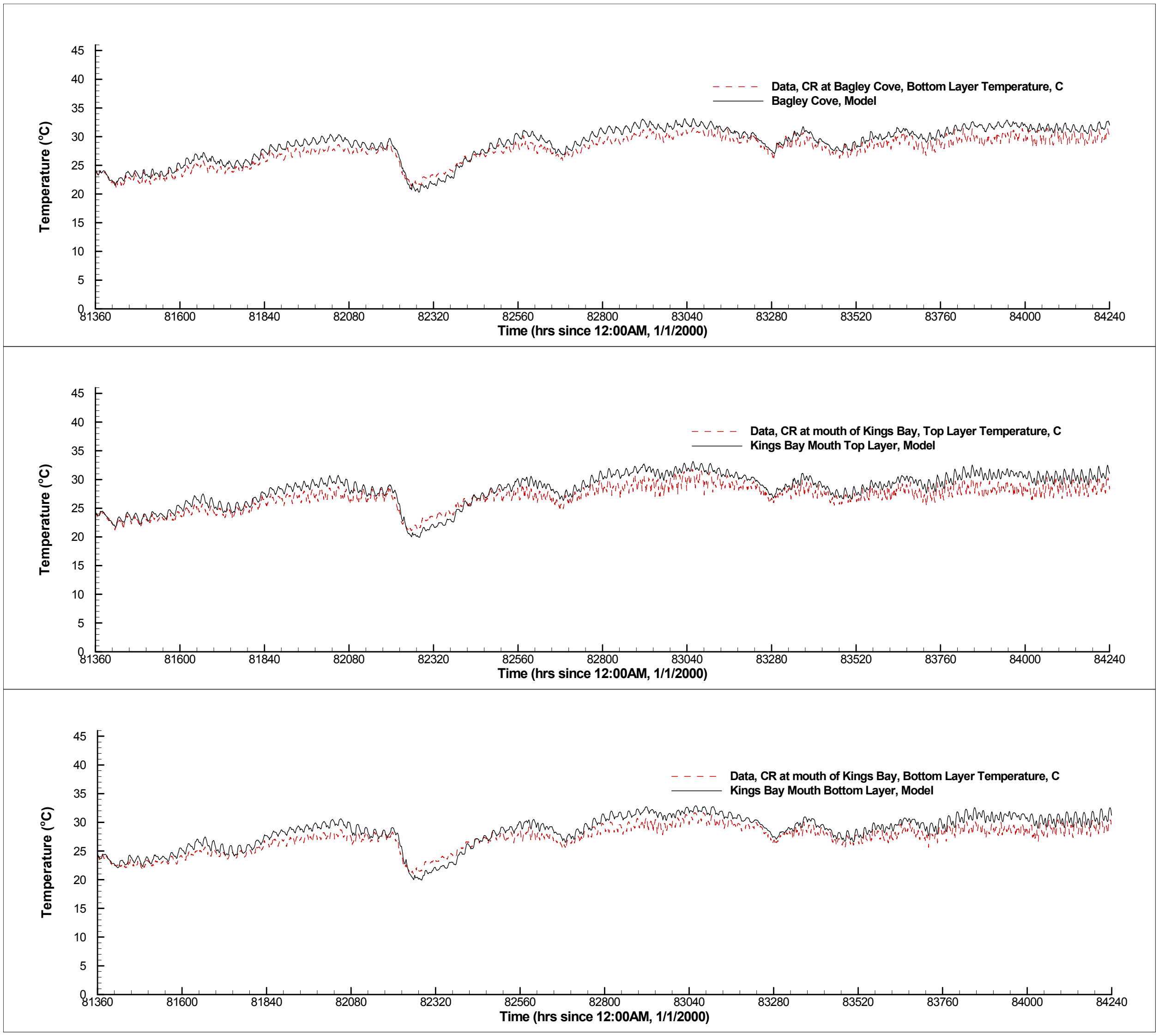

Figure D - 7 Comparison of simulated and measured temperatures at the bottom layer of the Bagley Cove station and the top and bottom layers of the mouth of Kings Bay station during Hours 81360 - 84240.

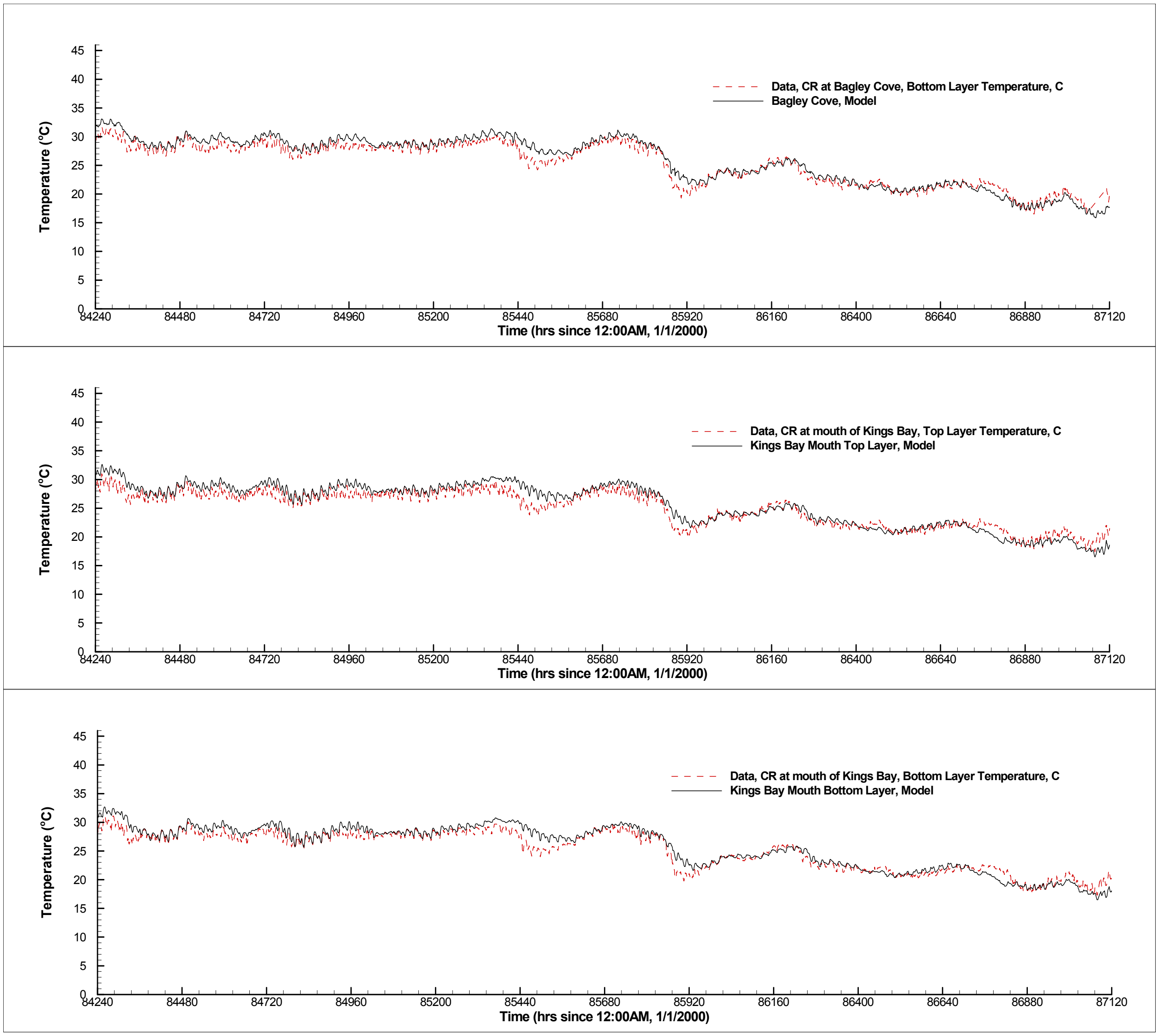

Figure D - 8 Comparison of simulated and measured temperatures at the bottom layer of the Bagley Cove station and the top and bottom layers of the mouth of Kings Bay station during Hours 84240 - 87120.

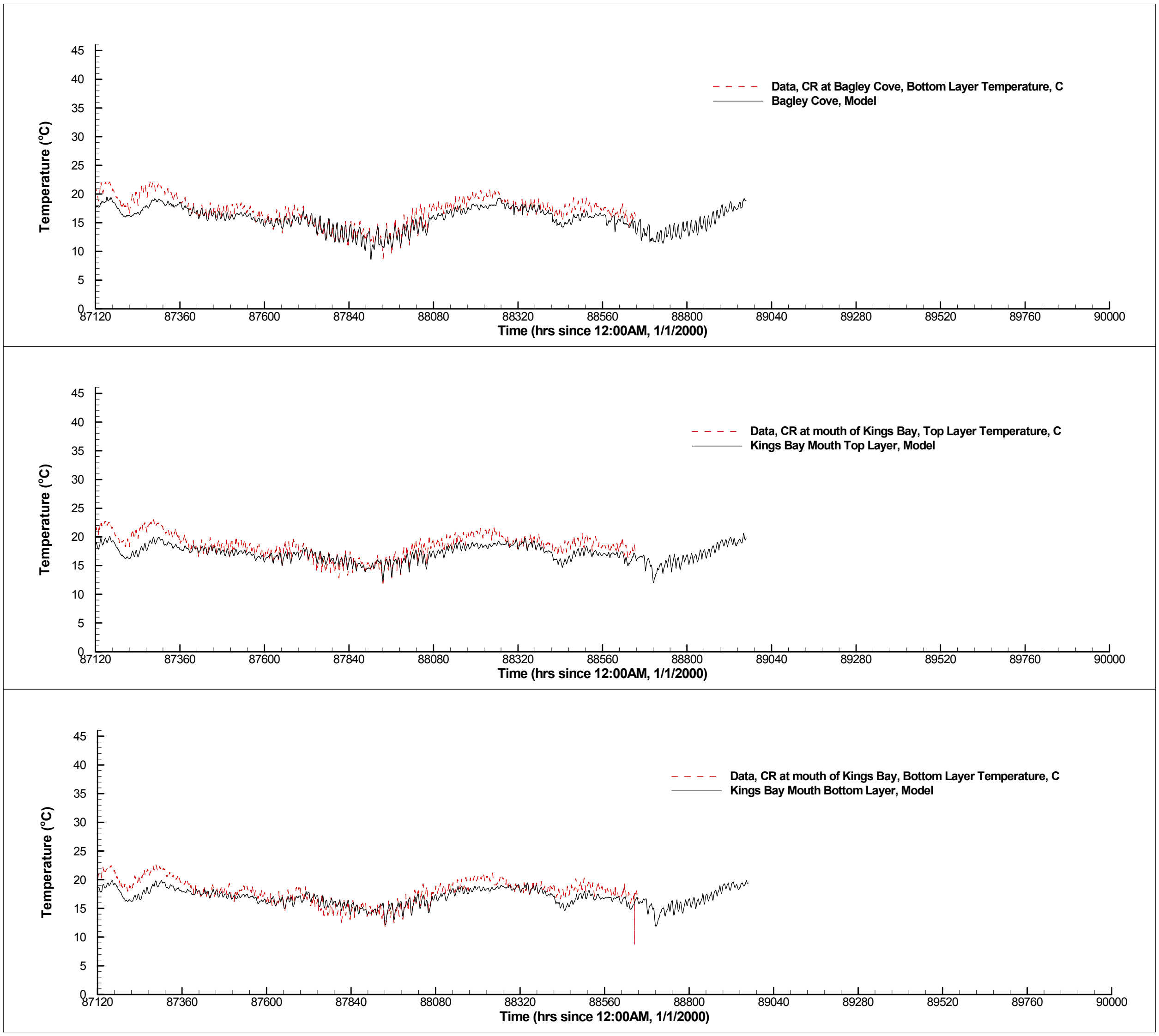

Figure D - 9 Comparison of simulated and measured temperatures at the bottom layer of the Bagley Cove station and the top and bottom layers of the mouth of Kings Bay station during Hours 87120 - 90000.

Appendix E

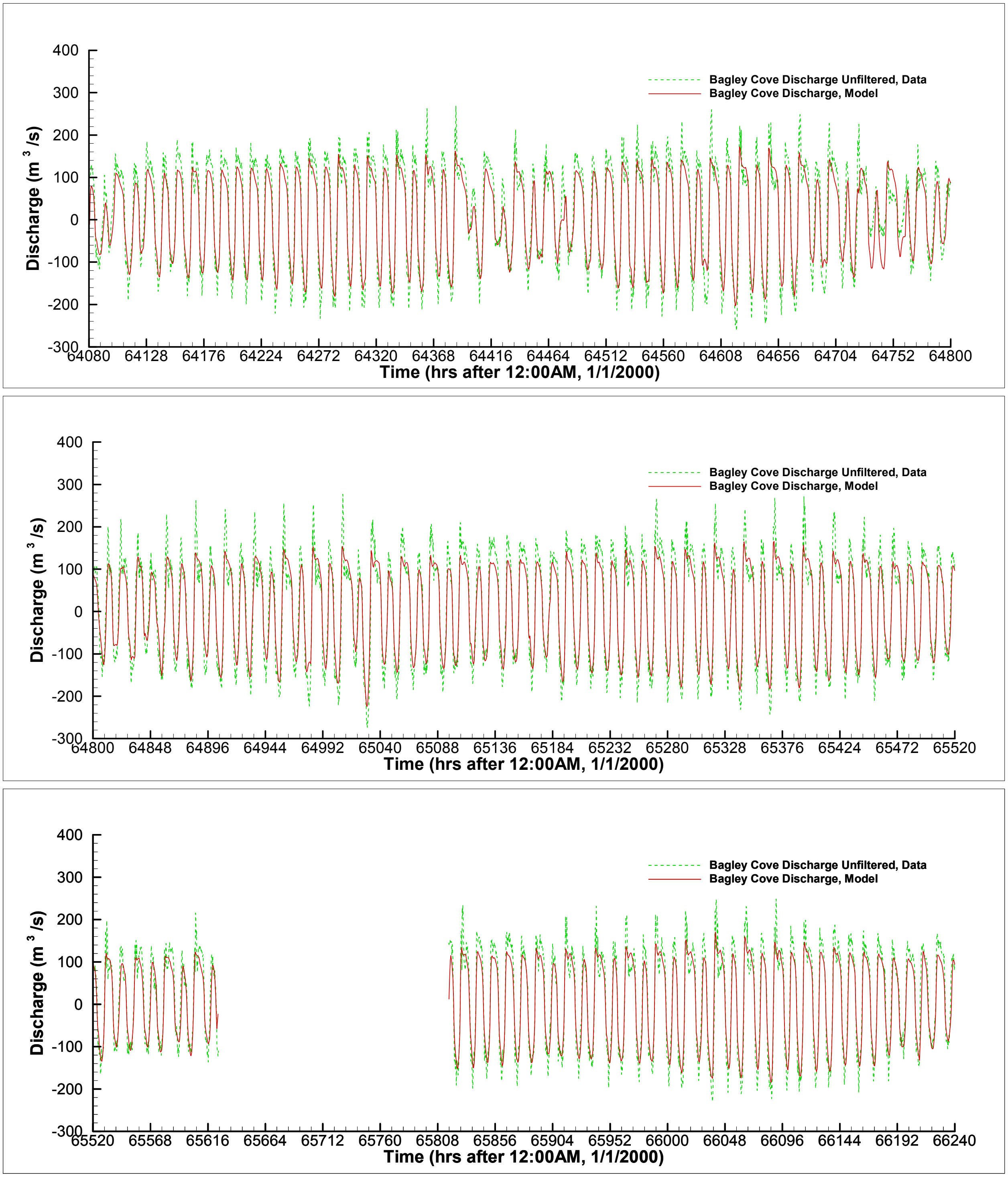

Figure E - 1 Comparison of simulated and measured cross-sectional discharges at Bagley Cove in Crystal River during Hours 64080 – 66240.

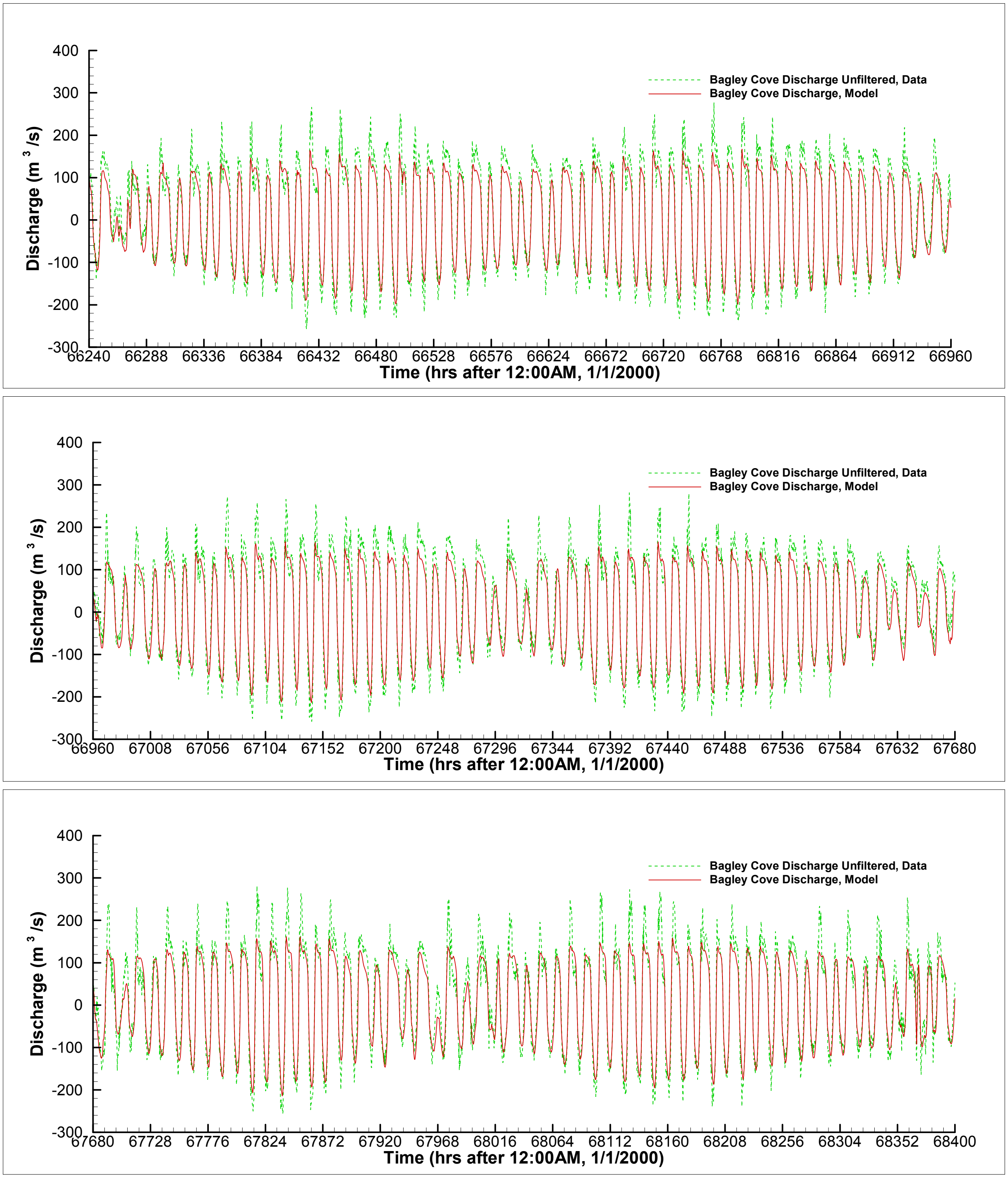

Figure E - 2 Comparison of simulated and measured cross-sectional discharges at Bagley Cove in Crystal River during Hours 66240 - 68400.

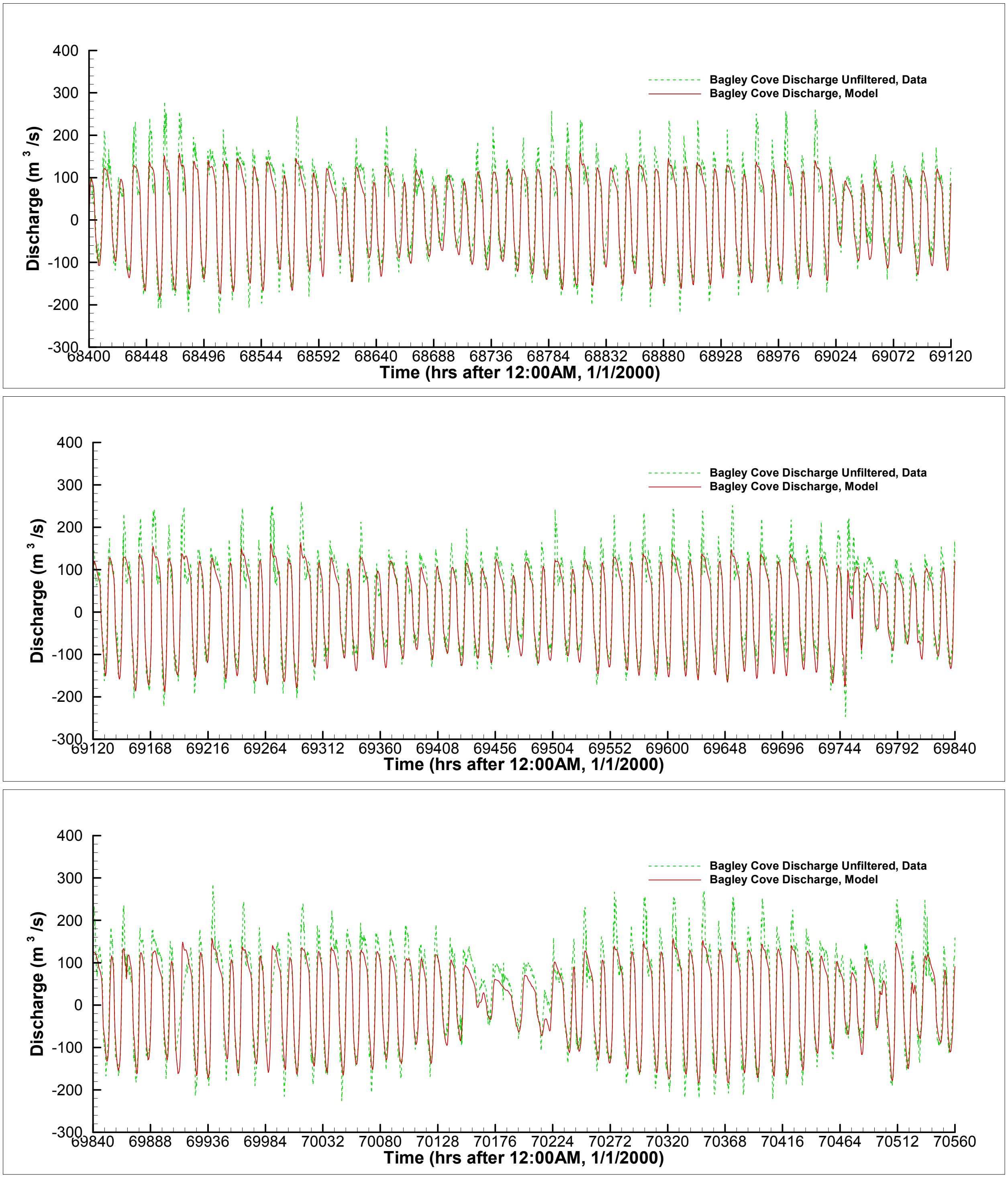

Figure E - 3 Comparison of simulated and measured cross-sectional discharges at Bagley Cove in Crystal River during Hours 68400 - 70560.

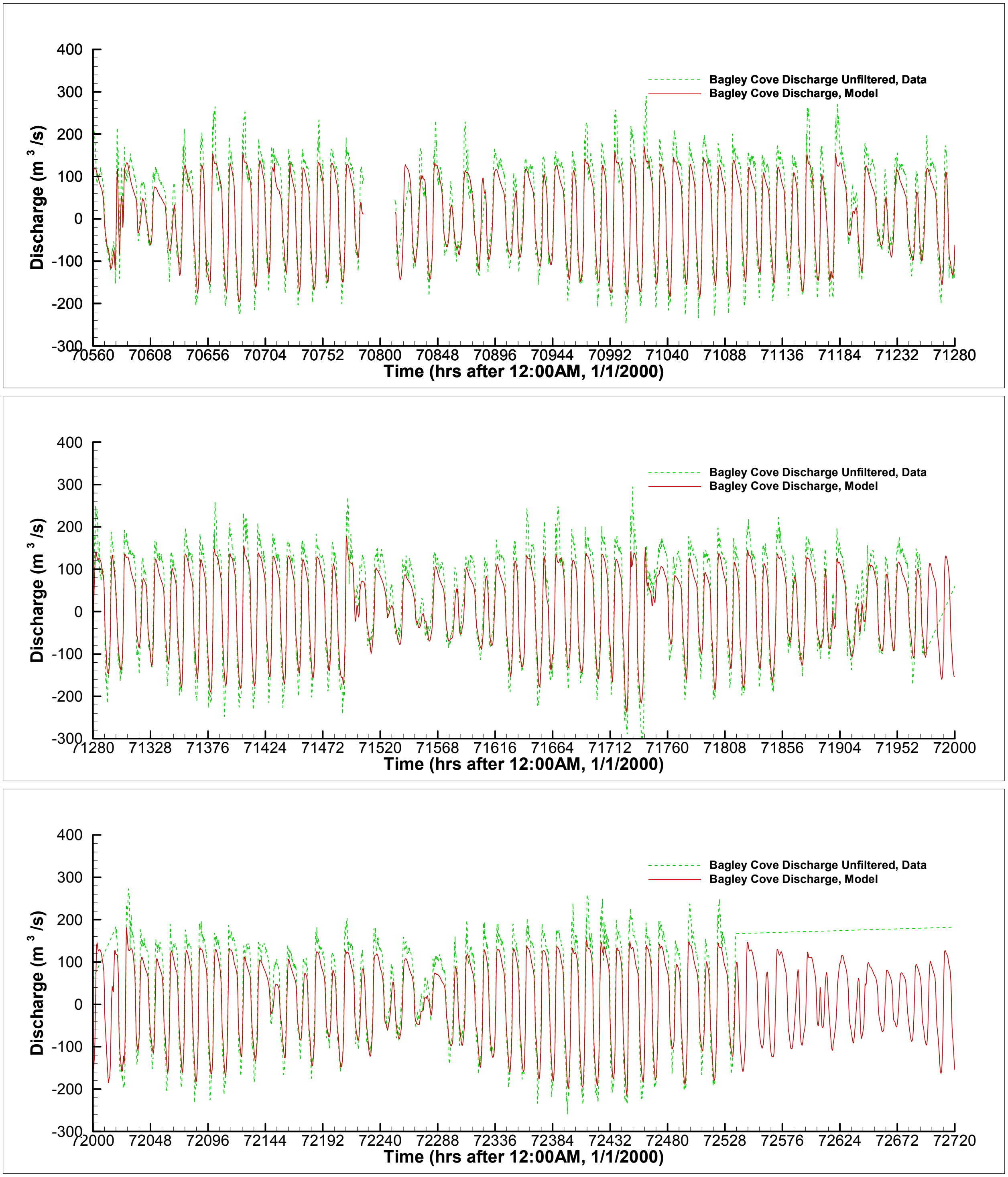

Figure E - 4 Comparison of simulated and measured cross-sectional discharges at Bagley Cove in Crystal River during Hours 70560 - 72720.

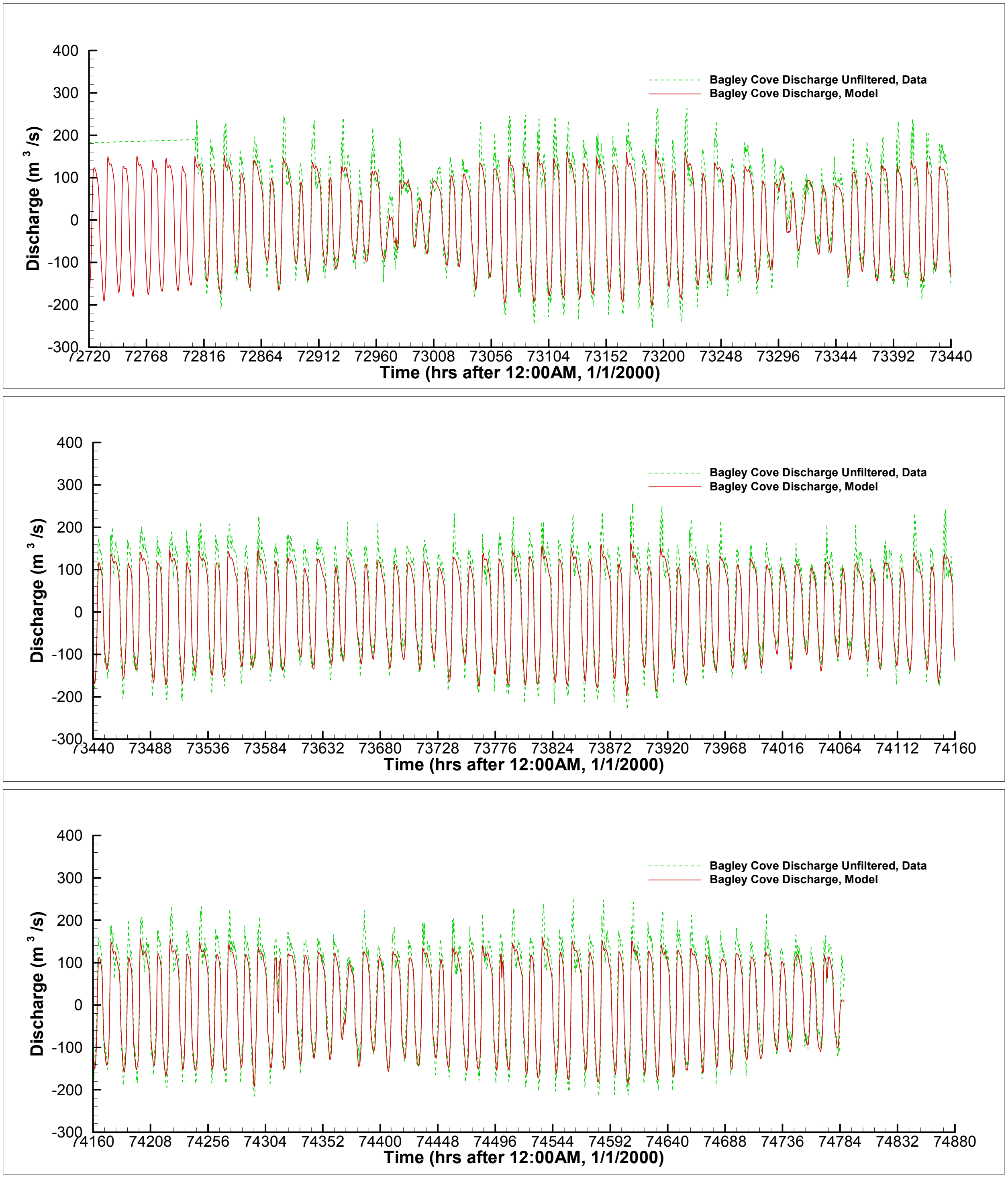

Figure E - 5 Comparison of simulated and measured cross-sectional discharges at Bagley Cove in Crystal River during Hours 70560 - 74880.

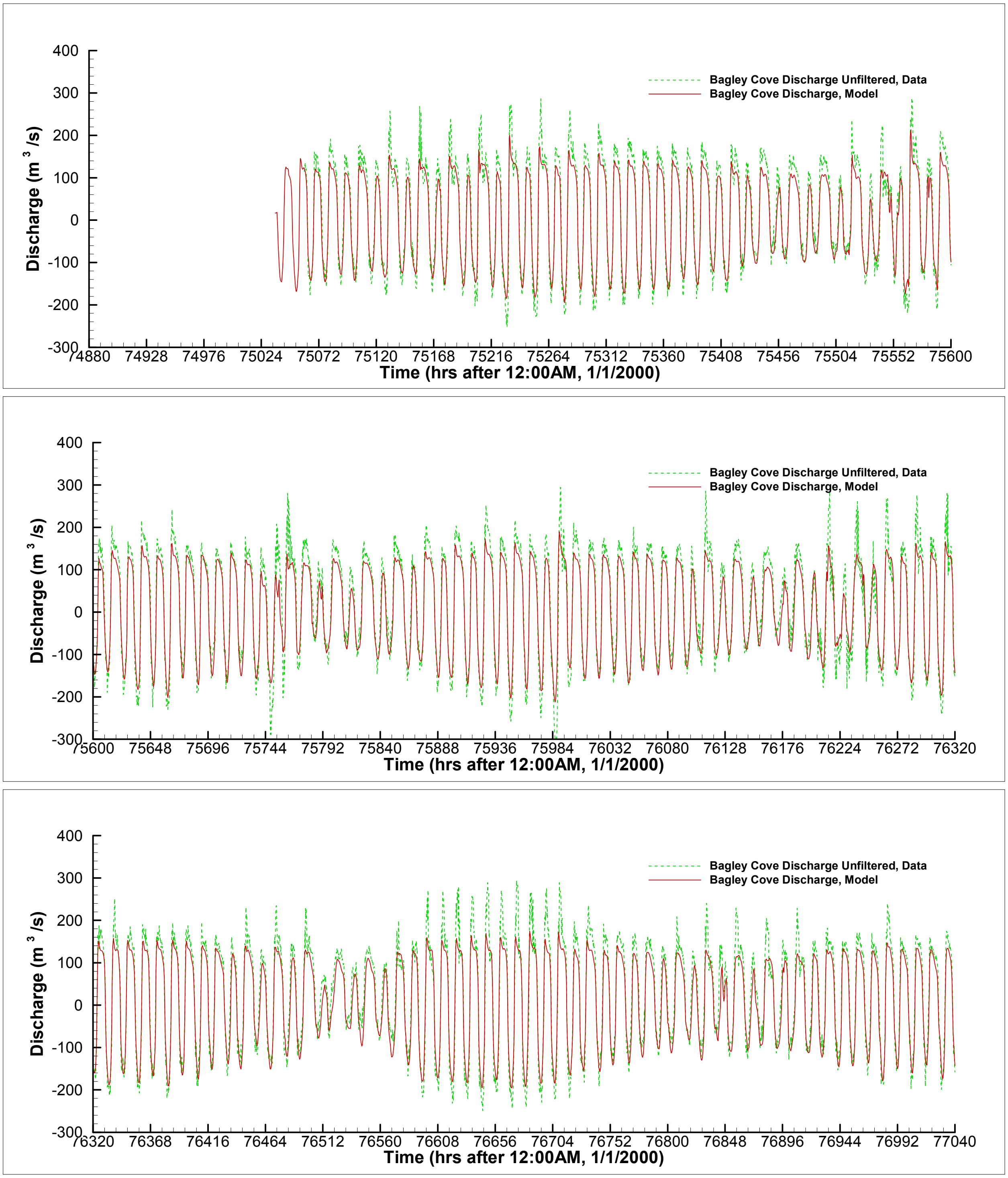

Figure E - 6 Comparison of simulated and measured cross-sectional discharges at Bagley Cove in Crystal River during Hours 74880 - 77040.

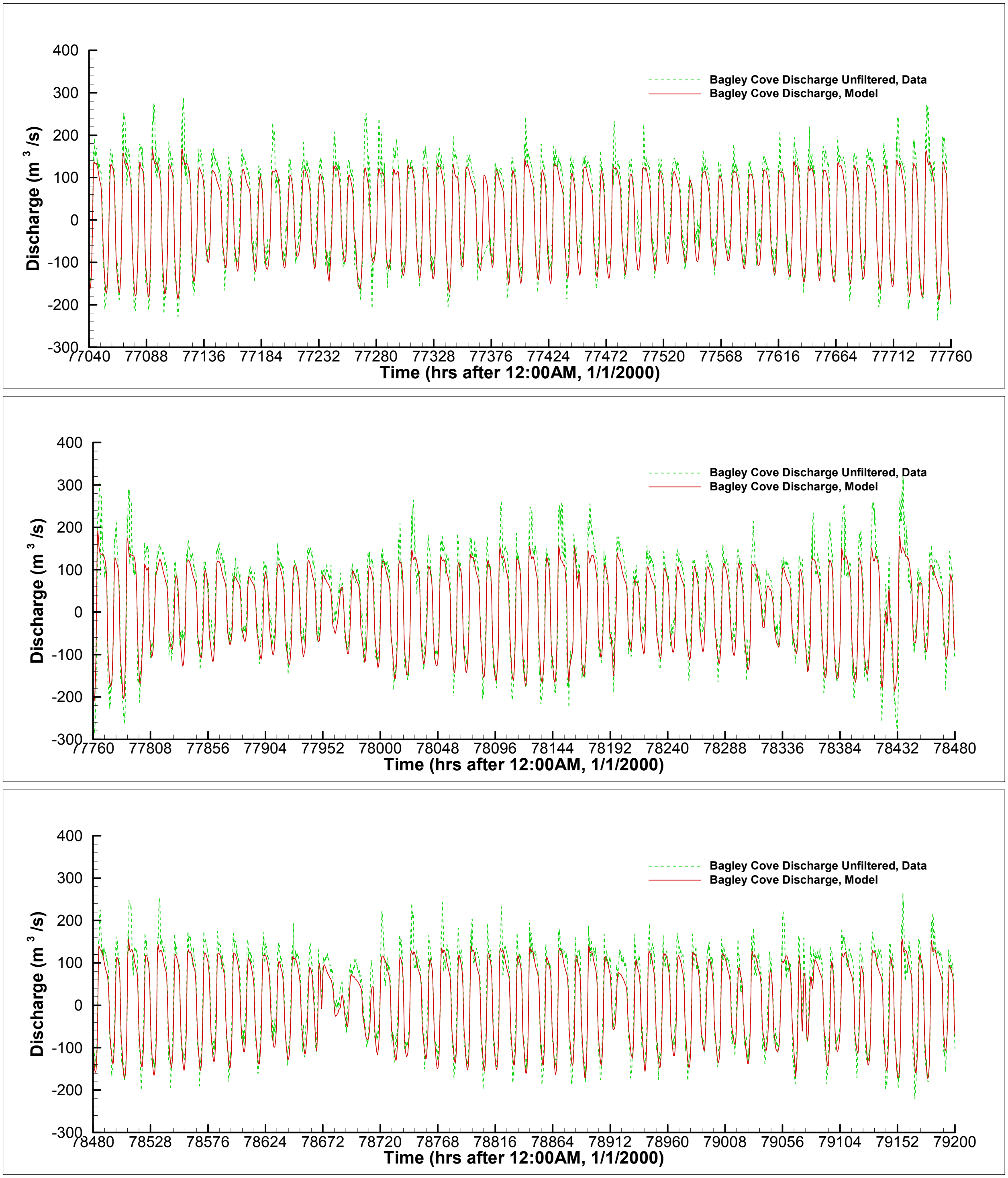

Figure E - 7 Comparison of simulated and measured cross-sectional discharges at Bagley Cove in Crystal River during Hours 77040 - 79200.

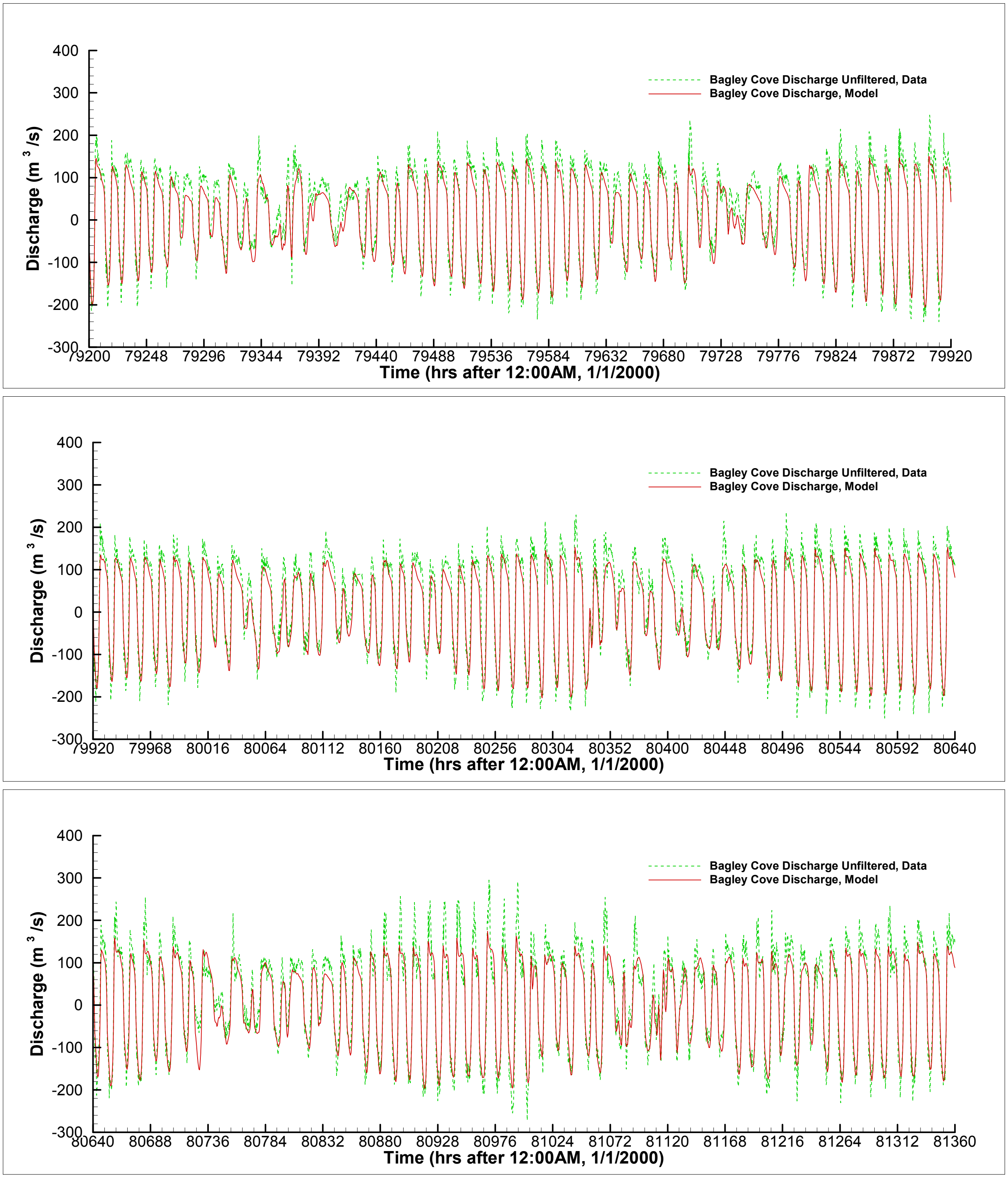

Figure E - 8 Comparison of simulated and measured cross-sectional discharges at Bagley Cove in Crystal River during Hours 79200 - 81360.

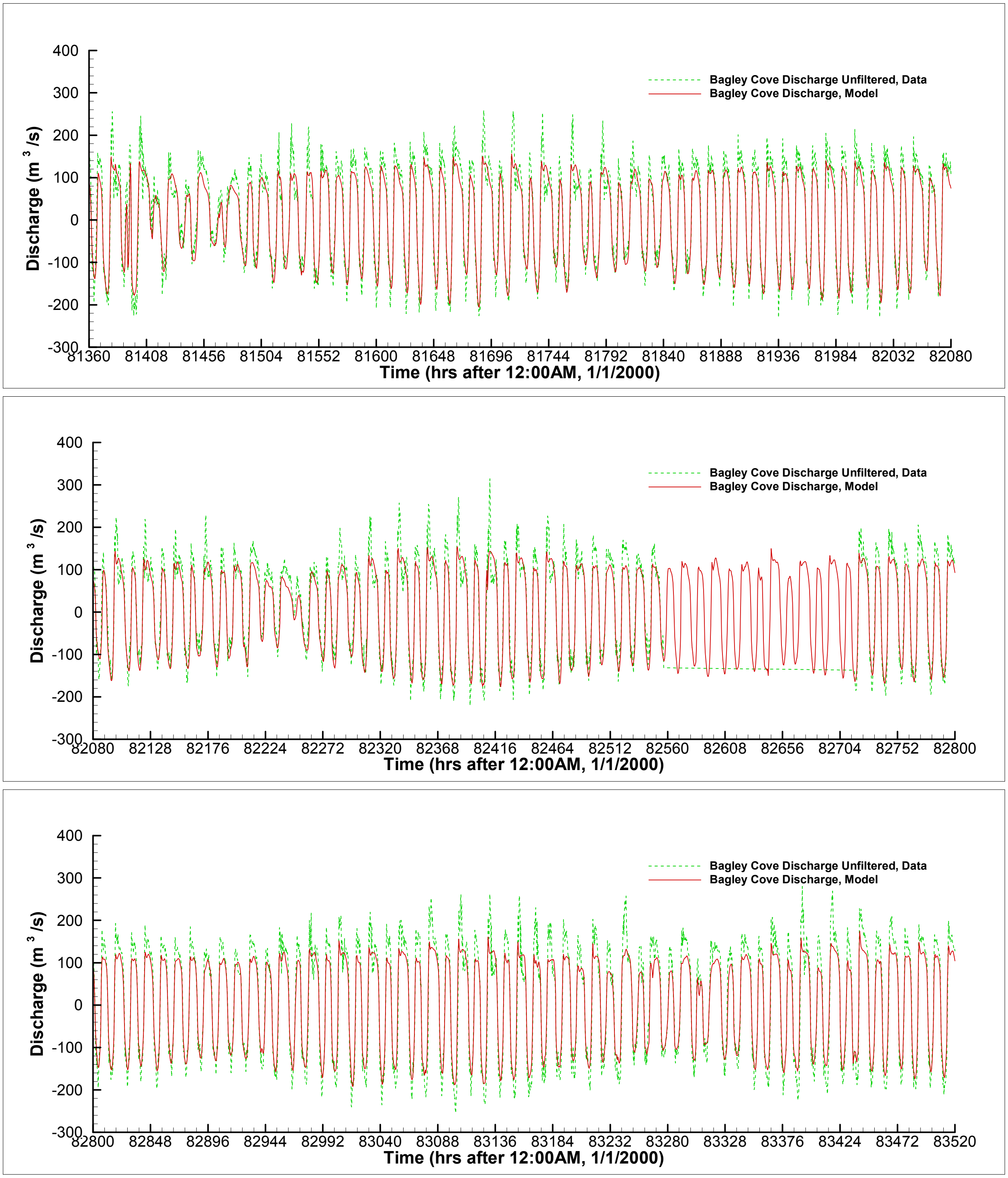

Figure E - 9 Comparison of simulated and measured cross-sectional discharges at Bagley Cove in Crystal River during Hours 81360 - 83520.

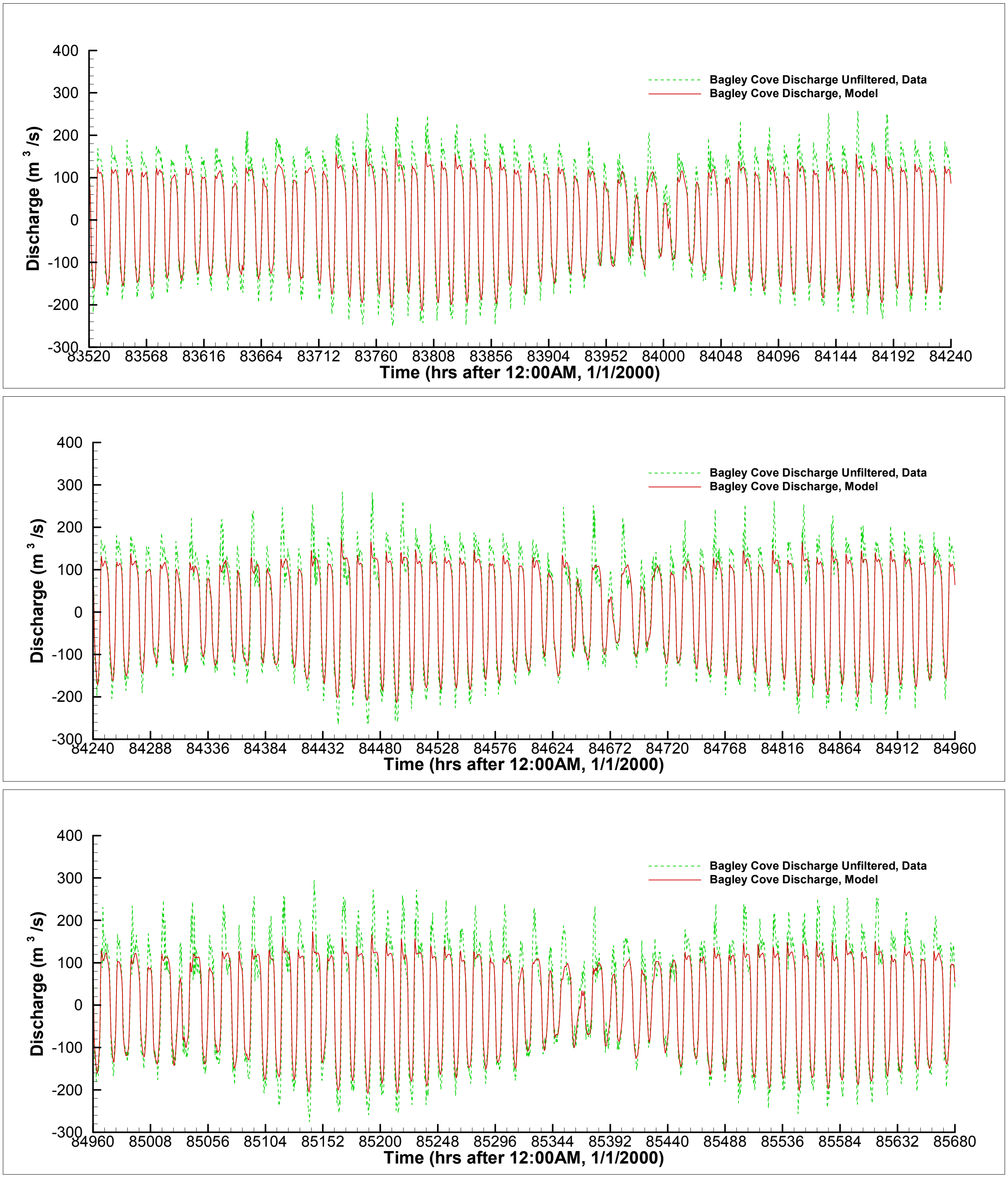

Figure E - 10 Comparison of simulated and measured cross-sectional discharges at Bagley Cove in Crystal River during Hours 83520 - 85680.

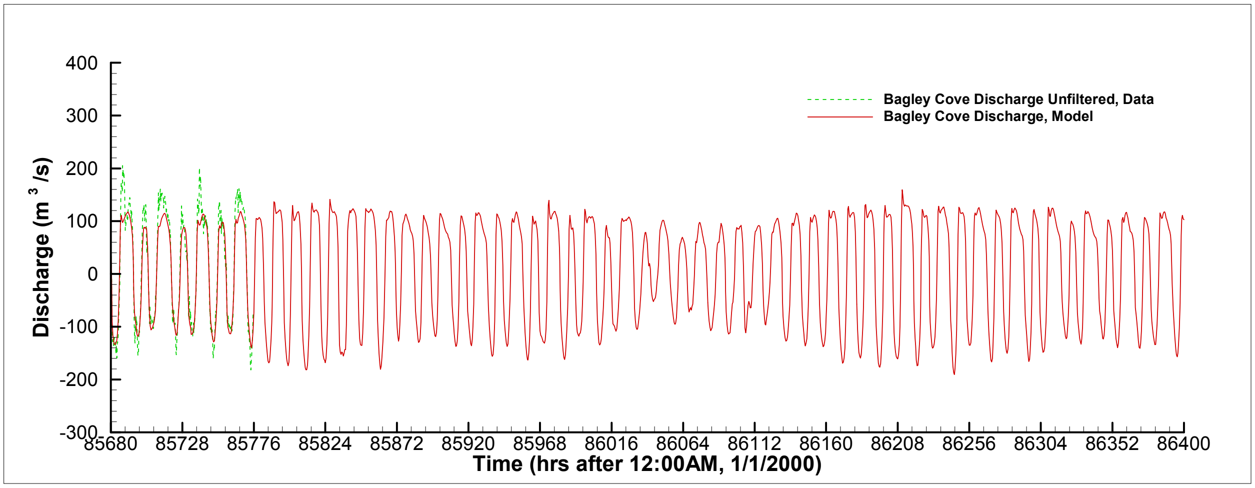

Figure E - 11 Comparison of simulated and measured cross-sectional discharges at Bagley Cove in Crystal River during Hours 85680 – 86400.

APPENDIX

Chen, X. 2017. Response to major comments by the MFL Peer Review Panel on the hydrodynamic modeling of Crystal River/Kings Bay. Southwest Florida Water Management District, Brooksville, Florida.

Response to Major Comments by the MFL Peer Review Panel on the Hydrodynamic Modeling of Crystal River/Kings Bay

XinJian Chen, Ph.D., P.E.

April 2017

1. *Consideration of salinity increases at the downstream open boundaries caused by flow reductions.*

To estimate average salinity increases at the mouth of Crystal River and Salt River, let's first look at the increase of average salinity at Bagley Cove for different flow reduction scenarios. From the modeled salinity results of the original 9-year scenario simulations, average salinities at the top and bottom layers at Bagley Cove were calculated for the baseline (0% flow reduction) and the 12 flow reduction scenarios. Salinity increases relative to the baseline scenario were then calculated for each flow reduction scenario. Table 1 shows increases of average salinity in the top and bottom layers at Bagley Cove with the 12 flow reductions. Both the top and bottom layers have almost the same salinity increase for the same flow reduction, with the bottom-layer salinity increasing a few thousandth psu more than the top-layer salinity does. The depth-averaged salinity increases shown in the table were calculated as the arithmetic means of salinity increases at the top and bottom layers.

Table 1. Increases in average salinity in the top- and bottom-layers and increase in depth-averaged salinity (Dep_Avg) at Bagley Cove for various flow reductions over the 9-year simulation period from October 6, 2006 to October 13, 2015.

Flow Reduction (%)	Average Salinity Increase (psu)		
	Top_Layer	Bottom_Layer	Dep_Avg
0.0	0.000	0.000	0.000
2.5	0.088	0.090	0.089
5.0	0.179	0.182	0.181
7.5	0.273	0.277	0.275
10.0	0.372	0.378	0.375
12.5	0.472	0.478	0.475
15.0	0.578	0.586	0.582
17.5	0.675	0.683	0.679
20.0	0.803	0.810	0.807
22.5	0.922	0.929	0.926
25.0	1.045	1.050	1.048
27.5	1.171	1.176	1.174
30.0	1.304	1.307	1.306

Figure 1 shows relationships between the salinity increase and flow reduction for the top and bottom layers at Bagley Cove. As can be seen from the figure, average salinity steadily increases at Bagley Cove as groundwater flow is reduced. Although the relationships are almost linear for both the top and bottom layers, they are best fitted with second degree polynomials.

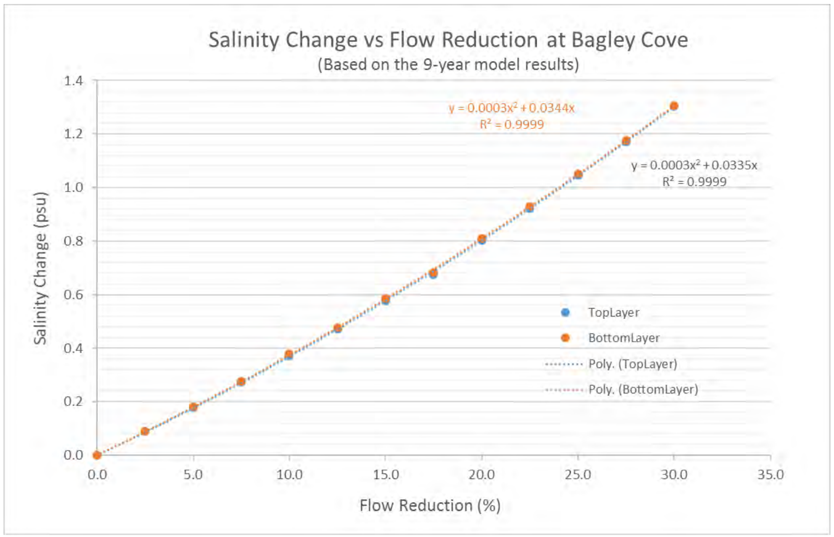

Figure 1. Relationships of salinity increase versus flow reduction at Bagley Cove.

Bagley Cove is about 7 KM upstream of Shell Island, which is at the mouth of Crystal River. It is reasonable to assume that Kings Bay spring flow has undetectable effects on salinity several kilometers offshore from the mouth of Crystal River. It is also reasonable to assume that the salinity change due to flow reduction roughly linearly increases from offshore to Bagley Cove.

To be conservative, let's assume that the salinity increase due to flow reduction in Kings Bay linearly increases from 10 KM offshore to Bagley Cove. Then, salinity change at Shell Island due to flow reduction can be estimated by multiplying the salinity change at Bagley Cove by a factor 10/17. Table 2 is an estimate of average salinity increase at Shell Island.

Table 2. Estimated salinity increase at Shell Island caused by flow reduction in Kings Bay.

Flow Reduction (%)	Sal Increase at Shell Island (psu)
0.0	0.000
2.5	0.052
5.0	0.106
7.5	0.162
10.0	0.221
12.5	0.279
15.0	0.342
17.5	0.399
20.0	0.474
22.5	0.544

25.0	0.616
27.5	0.690
30.0	0.768

The original scenario simulations used for the minimum flow analyses were re-run, with the salinity boundary conditions at the Shell Island being adjusted per the estimated salinity increases listed in Table 2 for different flow reductions. Although the Salt River is closer to Bagley Cove than Shell Island, average salinity increase due to flow reduction is negligible because the Salt River is much smaller than the Crystal River, and only a very small portion of the spring flow originating in Kings Bay reaches the Gulf through the Salt River. Since the salinity increase at the mouth of Crystal River is slightly over-estimated because of the linear increase assumption, effects of a very small salinity increase in the Salt River are being included in the adjustment of the salinity boundary condition at the mouth of Crystal River.

Tables 3, 4 and 5 show simulated water volumes, bottom areas, and shoreline lengths, respectively for salinity ranges of ≤ 0.5, 1, 2, 3, 4, 10, and psu under different flow conditions, including the baseline condition, the existing condition, and 12 reduction scenarios ranging from 2.5% to 30 % reduction from the baseline scenario.

Table 3. Simulated average water volumes for various salinity ranges under different flow reduction conditions.

Reduction Scenario	**Water Volume (million m^3)**						
	Sal ≤ 0.5	*≤ 1*	*≤ 2*	*≤ 3*	*≤ 5*	*≤ 10*	*≤ 15*
Baseline	0.291	0.437	2.445	4.469	5.656	7.770	9.191
Existing	0.288	0.432	2.395	4.424	5.619	7.756	9.189
2.5%	0.287	0.430	2.371	4.406	5.601	7.740	9.176
5.0%	0.283	0.423	2.296	4.343	5.547	7.710	9.160
7.5%	0.278	0.416	2.213	4.270	5.487	7.678	9.145
10.0%	0.274	0.408	2.130	4.194	5.427	7.644	9.128
12.5%	0.269	0.400	2.045	4.112	5.366	7.608	9.110
15.0%	0.264	0.393	1.961	4.025	5.303	7.570	9.093
17.5%	0.259	0.384	1.878	3.950	5.244	7.536	9.076
20.0%	0.251	0.372	1.767	3.833	5.166	7.488	9.055
22.5%	0.246	0.363	1.674	3.728	5.094	7.443	9.035
25.0%	0.239	0.352	1.577	3.614	5.016	7.395	9.011
27.5%	0.233	0.345	1.490	3.495	4.939	7.347	8.990
30.0%	0.223	0.330	1.380	3.366	4.854	7.294	8.966

Table 4. Simulated average bottom areas for various salinity ranges under different flow reduction conditions.

Reduction Scenario	**Bottom Area (million m^2)**						
	Sal ≤ 0.5	*≤ 1*	*≤ 2*	*≤ 3*	*≤ 5*	*≤ 10*	*≤ 15*
Baseline	0.232	0.332	1.414	2.672	3.248	4.185	4.860
Existing	0.229	0.329	1.389	2.650	3.232	4.179	4.859
2.5%	0.228	0.327	1.377	2.642	3.224	4.172	4.853
5.0%	0.225	0.323	1.340	2.613	3.201	4.158	4.845
7.5%	0.221	0.318	1.298	2.578	3.174	4.144	4.838
10.0%	0.218	0.313	1.257	2.542	3.148	4.129	4.831
12.5%	0.214	0.307	1.214	2.501	3.121	4.113	4.822
15.0%	0.211	0.302	1.172	2.458	3.093	4.097	4.814
17.5%	0.206	0.296	1.129	2.422	3.067	4.081	4.807
20.0%	0.201	0.288	1.071	2.360	3.032	4.061	4.797
22.5%	0.197	0.282	1.023	2.306	2.999	4.041	4.787
25.0%	0.192	0.275	0.972	2.246	2.964	4.020	4.776
27.5%	0.187	0.269	0.927	2.182	2.929	3.999	4.767
30.0%	0.180	0.259	0.868	2.112	2.889	3.976	4.755

Table 5. Simulated average shoreline lengths for various salinity ranges under different flow reduction conditions.

Reduction Scenario	**Shoreline Length (KM)**						
	Sal ≤ 0.5	*≤ 1*	*≤ 2*	*≤ 3*	*≤ 5*	*≤ 10*	*≤ 15*
Baseline	7.293	8.290	13.422	19.859	21.892	25.975	29.316
Existing	7.251	8.260	13.323	19.790	21.843	25.948	29.313
2.5%	7.249	8.256	13.281	19.766	21.814	25.913	29.275
5.0%	7.203	8.221	13.138	19.673	21.735	25.846	29.231
7.5%	7.148	8.180	12.974	19.560	21.651	25.777	29.188
10.0%	7.093	8.138	12.810	19.438	21.567	25.703	29.147
12.5%	7.028	8.090	12.634	19.291	21.482	25.628	29.099
15.0%	6.962	8.042	12.459	19.135	21.394	25.548	29.051
17.5%	6.898	7.994	12.289	19.011	21.315	25.479	29.009
20.0%	6.764	7.909	12.039	18.774	21.206	25.379	28.950
22.5%	6.709	7.856	11.837	18.568	21.109	25.290	28.896
25.0%	6.610	7.785	11.618	18.333	21.003	25.193	28.837
27.5%	6.479	7.705	11.417	18.069	20.897	25.099	28.780
30.0%	6.346	7.607	11.145	17.789	20.781	24.992	28.714

Tables 6 – 8 provide details of relative changes caused by different flow reductions for water volumes, bottom areas, and shoreline lengths, respectively of various salinity ranges. These tables are updates of Tables 7 – 9 in the original modeling report entitled "An Evaluation of Effects of Flow Reduction on Salinity and Thermal Habitats and Transport Time Scales in Crystal River/Kings Bay."

Table 6. Relative changes of water volume for various salinity ranges under different flow reduction scenarios.

Reduction Scenario	**Relative Change (Water Volume)**						
	Sal ≤ 0.5	*≤ 1*	*≤ 2*	*≤ 3*	*≤ 5*	*≤ 10*	*≤ 15*
Existing	1.14%	1.14%	2.08%	1.02%	0.64%	0.17%	0.02%
2.5%	1.41%	1.54%	3.05%	1.41%	0.96%	0.38%	0.16%
5.0%	2.85%	3.09%	6.10%	2.83%	1.92%	0.78%	0.34%
7.5%	4.44%	4.84%	9.51%	4.47%	2.98%	1.18%	0.50%
10.0%	6.05%	6.61%	12.88%	6.17%	4.03%	1.62%	0.69%
12.5%	7.78%	8.50%	16.38%	8.00%	5.12%	2.08%	0.88%
15.0%	9.32%	10.10%	19.79%	9.94%	6.23%	2.57%	1.07%
17.5%	11.22%	12.21%	23.19%	11.62%	7.27%	3.02%	1.25%
20.0%	13.83%	14.89%	27.74%	14.25%	8.66%	3.63%	1.48%
22.5%	15.72%	17.00%	31.55%	16.58%	9.94%	4.20%	1.70%
25.0%	18.02%	19.33%	35.51%	19.13%	11.30%	4.82%	1.95%
27.5%	20.00%	20.95%	39.06%	21.79%	12.67%	5.44%	2.19%
30.0%	23.32%	24.36%	43.56%	24.69%	14.18%	6.12%	2.45%
Trigger (%)	***21.55%***	***20.14%***	***11.52%***	***20.80%***	***>30%***	***>30%***	***>30%***

Table 7. Relative changes of bottom area for various salinity ranges under different flow reduction scenarios.

Reduction Scenario	**Relative Change (Bottom Area)**						
	Sal ≤ 0.5	*≤ 1*	*≤ 2*	*≤ 3*	*≤ 5*	*≤ 10*	*≤ 15*
Existing	1.13%	0.98%	1.75%	0.80%	0.48%	0.14%	0.01%
2.5%	1.38%	1.33%	2.61%	1.09%	0.72%	0.31%	0.14%
5.0%	2.79%	2.66%	5.21%	2.19%	1.45%	0.64%	0.30%
7.5%	4.34%	4.18%	8.18%	3.49%	2.26%	0.97%	0.44%
10.0%	5.89%	5.72%	11.09%	4.85%	3.06%	1.33%	0.60%
12.5%	7.55%	7.38%	14.14%	6.37%	3.90%	1.71%	0.77%
15.0%	9.05%	8.85%	17.12%	7.99%	4.76%	2.11%	0.94%
17.5%	10.86%	10.68%	20.10%	9.35%	5.55%	2.47%	1.10%

20.0%	13.39%	13.12%	24.23%	11.65%	6.66%	2.97%	1.30%
22.5%	15.10%	15.03%	27.64%	13.67%	7.65%	3.43%	1.49%
25.0%	17.21%	17.14%	31.21%	15.93%	8.73%	3.93%	1.72%
27.5%	19.23%	18.84%	34.41%	18.33%	9.82%	4.43%	1.92%
30.0%	22.11%	21.84%	38.62%	20.94%	11.04%	4.98%	2.15%
Trigger (%)	***22.35%***	***22.47%***	***13.22%***	***23.97%***	***>30%***	***>30%***	***>30%***

Table 8. Relative changes of shoreline length for various salinity ranges under different flow reduction scenarios.

Reduction Scenario	**Relative Change (Shoreline Length)**						
	Sal ≤ 0.5	*≤ 1*	*≤ 2*	*≤ 3*	*≤ 5*	*≤ 10*	*≤ 15*
Existing	0.58%	0.36%	0.74%	0.35%	0.23%	0.10%	0.01%
2.5%	0.61%	0.41%	1.05%	0.47%	0.36%	0.24%	0.14%
5.0%	1.24%	0.83%	2.11%	0.94%	0.72%	0.50%	0.29%
7.5%	1.98%	1.33%	3.34%	1.50%	1.10%	0.76%	0.44%
10.0%	2.74%	1.83%	4.56%	2.12%	1.48%	1.04%	0.58%
12.5%	3.63%	2.41%	5.88%	2.86%	1.88%	1.34%	0.74%
15.0%	4.53%	2.99%	7.18%	3.65%	2.28%	1.64%	0.90%
17.5%	5.42%	3.57%	8.44%	4.27%	2.64%	1.91%	1.05%
20.0%	7.26%	4.60%	10.31%	5.47%	3.13%	2.29%	1.25%
22.5%	8.01%	5.24%	11.81%	6.50%	3.58%	2.64%	1.43%
25.0%	9.37%	6.09%	13.44%	7.69%	4.06%	3.01%	1.64%
27.5%	11.15%	7.05%	14.94%	9.01%	4.55%	3.37%	1.83%
30.0%	12.98%	8.23%	16.97%	10.42%	5.07%	3.78%	2.05%
Trigger (%)	***>30%***	***>30%***	***27.58%***	***>30%***	***>30%***	***>30%***	***>30%***

Comparing Table 6 – 8 with Tables 7 – 9 in the original modeling report, it can be concluded that the adjustment of the salinity boundary condition has an insignificant effect on the model results. The flow reduction percentage that triggers a 15% loss of the most sensitive salinity habitat (< 2psu volume) is reduced from 11.78% to 11.52%.

The above response was presented to the peer review panel, which found that the salinity boundary condition issue was suitably addressed after the salinity at the downstream open boundaries were adjusted according the method described here.

2. *Consideration of effects of flow reduction on different types of shoreline*

In response to one of the reviewers' comment that the District should consider effects of flow reductions on various types of shoreline, available data of shoreline type for Crystal River/Kings

Bay were analyzed. Figure 2 shows the shoreline map that was generated from the available shoreline data. As can be seen from the figure, the shoreline of the Crystal River/Kings Bay system was disaggregated into three types, namely altered shore, natural shore, and vegetation. Although shoreline data are available for a majority of the system, there is an area near the Three Sisters Springs, including the nearby finger channels, where shoreline data do not exist.

Figure 2 Available shoreline types: altered, natural, and vegetation shores in Crystal River/Kings Bay.

Tables 9, 10 and 11 respectively show results of altered, natural, and vegetation shoreline lengths for salinity ranges of ≤ 0.5, 1, 2, 3, 4, 10, and psu under different flow conditions, including the baseline condition, the existing condition, and 12 reduction scenarios ranging from 2.5% to 30 % reduction from the baseline scenario.

Table 9. Simulated averaged altered shoreline lengths for various salinity ranges under different flow reduction conditions.

Reduction Scenario	**Altered Shoreline Length (KM)**						
	Sal ≤ 0.5	*≤ 1*	*≤ 2*	*≤ 3*	*≤ 5*	*≤ 10*	*≤ 15*
Baseline	3.939	5.343	13.695	19.032	21.128	22.262	22.514
Existing	3.905	5.305	13.562	18.965	21.106	22.257	22.514
2.5%	3.895	5.291	13.508	18.944	21.096	22.253	22.513
5.0%	3.852	5.238	13.313	18.854	21.062	22.244	22.511
7.5%	3.806	5.177	13.090	18.739	21.022	22.234	22.509

10.0%	3.760	5.115	12.863	18.617	20.981	22.224	22.507
12.5%	3.712	5.048	12.618	18.474	20.936	22.213	22.505
15.0%	3.672	4.987	12.369	18.315	20.887	22.201	22.502
17.5%	3.618	4.912	12.121	18.179	20.842	22.191	22.500
20.0%	3.555	4.815	11.770	17.931	20.770	22.176	22.497
22.5%	3.501	4.731	11.467	17.721	20.704	22.162	22.495
25.0%	3.439	4.640	11.141	17.480	20.627	22.146	22.492
27.5%	3.377	4.557	10.827	17.223	20.544	22.131	22.489
30.0%	3.293	4.440	10.432	16.924	20.447	22.113	22.486

Table 10 Simulated average natural shoreline lengths for various salinity ranges under different flow reduction conditions.

Reduction Scenario	**Natural Shoreline Length (KM)**						
	Sal ≤ 0.5	*≤ 1*	*≤ 2*	*≤ 3*	*≤ 5*	*≤ 10*	*≤ 15*
Baseline	0.058	0.142	0.526	0.838	1.114	1.855	2.441
Existing	0.057	0.139	0.517	0.830	1.105	1.851	2.441
2.5%	0.057	0.137	0.513	0.826	1.099	1.847	2.435
5.0%	0.054	0.133	0.500	0.814	1.084	1.837	2.428
7.5%	0.052	0.128	0.486	0.802	1.068	1.826	2.421
10.0%	0.050	0.123	0.471	0.789	1.052	1.814	2.418
12.5%	0.048	0.118	0.456	0.776	1.036	1.802	2.410
15.0%	0.046	0.113	0.440	0.762	1.020	1.790	2.403
17.5%	0.043	0.108	0.427	0.750	1.005	1.779	2.395
20.0%	0.040	0.101	0.405	0.732	0.986	1.764	2.387
22.5%	0.038	0.096	0.388	0.717	0.969	1.749	2.379
25.0%	0.035	0.090	0.370	0.699	0.951	1.734	2.371
27.5%	0.033	0.085	0.352	0.680	0.934	1.719	2.362
30.0%	0.030	0.078	0.331	0.660	0.915	1.700	2.350

Table 11. Simulated average vegetation shoreline lengths for various salinity ranges under different flow reduction conditions.

Reduction Scenario	**Vegetation Shoreline Length (KM)**						
	Sal ≤ 0.5	*≤ 1*	*≤ 2*	*≤ 3*	*≤ 5*	*≤ 10*	*≤ 15*
Baseline	1.5125	2.6129	9.4397	23.74	28.3246	37.498	42.5137
Existing	1.4756	2.5853	9.2756	23.5804	28.1936	37.4443	42.5103
2.5%	1.4652	2.5745	9.2006	23.5266	28.1239	37.382	42.4705
5.0%	1.4177	2.537	8.9665	23.3148	27.9215	37.2603	42.4219
7.5%	1.3657	2.4906	8.6967	23.0712	27.7033	37.1342	42.375

10.0%	1.3143	2.4427	8.4365	22.8071	27.4877	36.9981	42.3257
12.5%	1.2609	2.3893	8.1651	22.4941	27.2673	36.8561	42.2728
15.0%	1.2112	2.3356	7.9133	22.167	27.0446	36.705	42.219
17.5%	1.1535	2.2806	7.6333	21.8921	26.8312	36.5701	42.1685
20.0%	1.0849	2.1954	7.2786	21.4331	26.5588	36.3778	42.1028
22.5%	1.0272	2.1244	6.9844	21.0136	26.3089	36.2009	42.0384
25.0%	0.9685	2.044	6.6802	20.5324	26.0464	36.0102	41.9664
27.5%	0.9139	1.9715	6.4256	20.0008	25.7864	35.8193	41.9002
30.0%	0.8424	1.8632	6.0272	19.4508	25.4987	35.6065	41.8243

Tables 6 – 9 are relative changes of shoreline length for altered shore, natural shore, and vegetation shore, respectively for various salinity ranges under different flow reduction conditions. Results presented in the tables were obtained through an analysis of the observed shoreline data and modeled salinity results for different flow reduction scenarios, in which the salinity boundary condition at the downstream open boundary were adjusted per Table 2.

Table 12. Relative changes of the length of altered shore for various salinity ranges under different flow reduction scenarios.

Reduction Scenario	**Relative Change (Altered Shoreline Length)**						
	Sal ≤ 0.5	*≤ 1*	*≤ 2*	*≤ 3*	*≤ 5*	*≤ 10*	*≤ 15*
Existing	0.9%	0.7%	1.0%	0.4%	0.1%	0.0%	0.0%
2.5%	1.1%	1.0%	1.4%	0.5%	0.2%	0.0%	0.0%
5.0%	2.2%	2.0%	2.8%	0.9%	0.3%	0.1%	0.0%
7.5%	3.4%	3.1%	4.4%	1.5%	0.5%	0.1%	0.0%
10.0%	4.5%	4.3%	6.1%	2.2%	0.7%	0.2%	0.0%
12.5%	5.8%	5.5%	7.9%	2.9%	0.9%	0.2%	0.0%
15.0%	6.8%	6.7%	9.7%	3.8%	1.1%	0.3%	0.1%
17.5%	8.1%	8.1%	11.5%	4.5%	1.4%	0.3%	0.1%
20.0%	9.8%	9.9%	14.1%	5.8%	1.7%	0.4%	0.1%
22.5%	11.1%	11.4%	16.3%	6.9%	2.0%	0.4%	0.1%
25.0%	12.7%	13.2%	18.7%	8.2%	2.4%	0.5%	0.1%
27.5%	14.3%	14.7%	20.9%	9.5%	2.8%	0.6%	0.1%
30.0%	16.4%	16.9%	23.8%	11.1%	3.2%	0.7%	0.1%
Trigger (%)	***28.36%***	***27.97%***	***21.06%***	***>30%***	***>30%***	***>30%***	***>30%***

Table 13 Relative changes of the length of natural shore for various salinity ranges under different flow reduction scenarios.

Reduction Scenario	**Relative Change (Natural Shoreline Length)**						
	Sal ≤ 0.5	*≤ 1*	*≤ 2*	*≤ 3*	*≤ 5*	*≤ 10*	*≤ 15*
Existing	2.6%	1.9%	1.6%	1.0%	0.8%	0.2%	0.0%

2.5%	3.3%	3.1%	2.4%	1.4%	1.3%	0.4%	0.3%
5.0%	6.8%	6.2%	4.8%	2.8%	2.7%	1.0%	0.6%
7.5%	10.6%	9.9%	7.6%	4.3%	4.1%	1.6%	0.8%
10.0%	14.4%	13.3%	10.4%	5.8%	5.6%	2.2%	1.0%
12.5%	18.3%	16.9%	13.3%	7.3%	7.0%	2.8%	1.3%
15.0%	22.1%	20.3%	16.2%	9.0%	8.4%	3.5%	1.6%
17.5%	26.0%	23.8%	18.8%	10.4%	9.8%	4.1%	1.9%
20.0%	31.0%	28.7%	22.9%	12.6%	11.5%	4.9%	2.2%
22.5%	35.4%	32.6%	26.2%	14.4%	13.0%	5.7%	2.5%
25.0%	39.7%	36.5%	29.6%	16.6%	14.7%	6.5%	2.9%
27.5%	42.8%	39.7%	33.0%	18.8%	16.2%	7.3%	3.2%
30.0%	49.0%	44.8%	37.1%	21.2%	17.9%	8.4%	3.7%
Trigger (%)	***10.39%***	***11.18%***	***13.95%***	***23.15%***	***25.57%***	***>30%***	***>30%***

Table 14 Relative changes of the length of vegetation shore for various salinity ranges under different flow reduction scenarios.

Reduction Scenario	**Relative Change (Vegetation Shoreline Length)**						
	Sal ≤ 0.5	*≤ 1*	*≤ 2*	*≤ 3*	*≤ 5*	*≤ 10*	*≤ 15*
Existing	2.4%	1.1%	1.7%	0.7%	0.5%	0.1%	0.0%
2.5%	3.1%	1.5%	2.5%	0.9%	0.7%	0.3%	0.1%
5.0%	6.3%	2.9%	5.0%	1.8%	1.4%	0.6%	0.2%
7.5%	9.7%	4.7%	7.9%	2.8%	2.2%	1.0%	0.3%
10.0%	13.1%	6.5%	10.6%	3.9%	3.0%	1.3%	0.4%
12.5%	16.6%	8.6%	13.5%	5.2%	3.7%	1.7%	0.6%
15.0%	19.9%	10.6%	16.2%	6.6%	4.5%	2.1%	0.7%
17.5%	23.7%	12.7%	19.1%	7.8%	5.3%	2.5%	0.8%
20.0%	28.3%	16.0%	22.9%	9.7%	6.2%	3.0%	1.0%
22.5%	32.1%	18.7%	26.0%	11.5%	7.1%	3.5%	1.1%
25.0%	36.0%	21.8%	29.2%	13.5%	8.0%	4.0%	1.3%
27.5%	39.6%	24.5%	31.9%	15.8%	9.0%	4.5%	1.4%
30.0%	44.3%	28.7%	36.2%	18.1%	10.0%	5.0%	1.6%
Trigger (%)	***11.34%***	***19.25%***	***13.90%***	***26.66%***	***>30%***	***>30%***	***>30%***

It should be noted that the shoreline length in the original minimum flow analysis for Crystal River King Bay System was calculated from the bathymetry data read by the model. Any meandering features with a length scale that is smaller than the length scale of the model grid cell was considered as a straight line; however, in the new analysis using observed shoreline data, these small-scale curvatures were considered and included in the calculation. Thus, the total shoreline length in the new analysis is much longer than the one originally calculated, if all three types of shoreline length are summed up.

Another thing that should be noted is that the low salinity (< 0.5 psu and <1 psu) shore can only be found near the northern springs where groundwater discharges are low in salinity. As can been in Figure 2, the shore type in this part of Kings Bay is mostly altered shore, with only a very small portion of it being vegetation and natural shores. As a result, low salinity vegetation and natural shores are more sensitive to flow reduction than the altered shore is.

3. *How well do average tidally filtered flows (or unfiltered over longer time periods) at Bagley Cove correlate with rainfall, perhaps based on weekly, monthly, or annual averages?*

It is possible that measured Bagley Cove flow has certain degree of correlation with rainfall data in forms of seasonal or annual averages; nevertheless, this kind of correlation should be weak, because the measured discharge at Bagley Cove is a combination of many factors, including submarine groundwater discharge, tidal flow, storm surge, wind and barometric pressure effects, etc., to which Bagley Cove discharge responds with various time scales. Generally, the longer the time scale is, the higher the correlation could be. Yet, one should not expect to use a single factor such as rainfall to explain the variability of Bagley Cove discharge, even on an annual time scale.

Because a weekly time scale is too short for Bagley Cove discharge to respond, the correlation between rainfall and discharge on a weekly time scale is not discussed here. To find correlations between rainfall and Bagley Cove discharge on monthly, seasonal, and annual time scales, monthly statistics of the Bagley Cove discharge data were downloaded from the USGS website and daily rainfall data at three rainfall stations (Chassahowitzka, Lecanto Government Complex, and ROMP TR 21-2 Ozello) in the region were downloaded from the SWFWMD Water Management Information System. Daily rainfalls at the three stations were first averaged before the monthly, seasonal and annual rain totals were calculated.

Figure 3 shows time series of monthly average Bagley Cove discharge and monthly rain total for Crystal River/Kings Bay from 2003 – 2016, while Figure 4 shows the scatter plot of the two variables. It can be seen from Figure 4 that on a monthly time scale, rainfall and Bagley Cove discharge are poorly correlated.

Figure 5 shows time series of seasonal average Bagley Cove discharge and seasonal rain total for Crystal River/Kings Bay from 2003 – 2016, while Figure 6 shows the scatter plot of the two variables. From Figure 6, one can see that on a seasonal time scale, rainfall and Bagley Cove discharge are also poorly correlated.

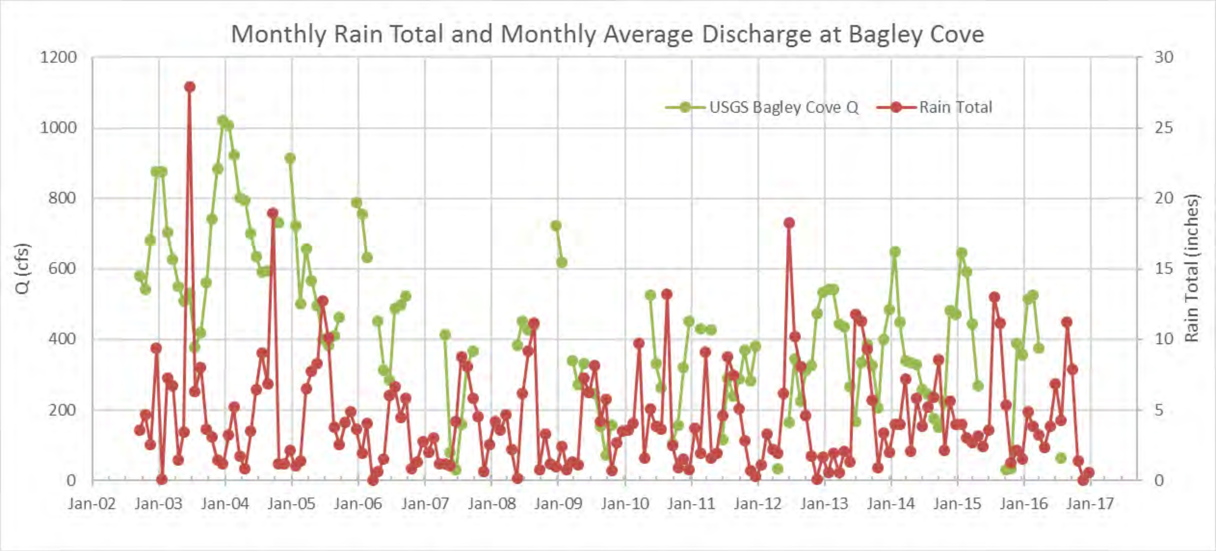

Figure 3. Monthly rain total and monthly average Bagley Cove discharge.

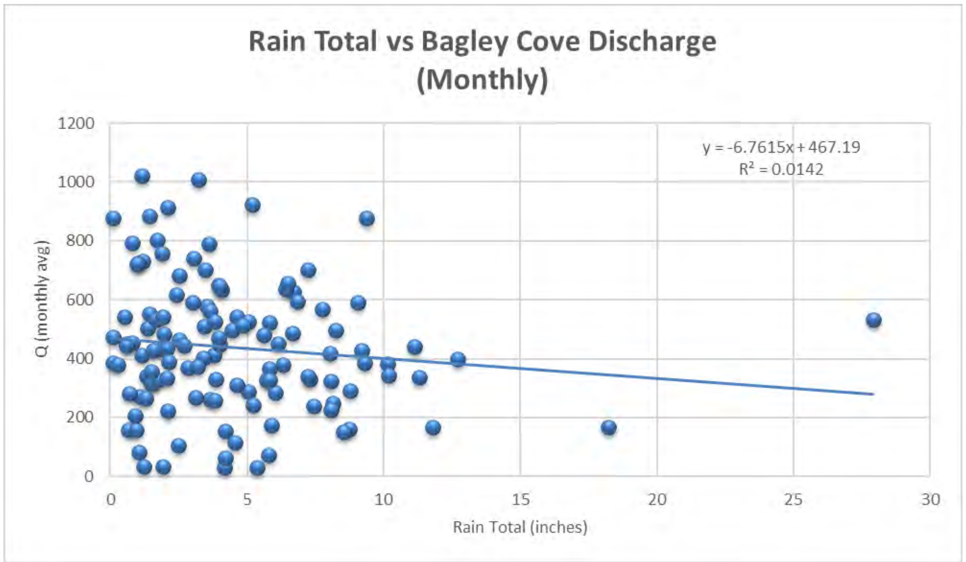

Figure 4. Monthly average Bagley Cove discharge versus monthly rain total.

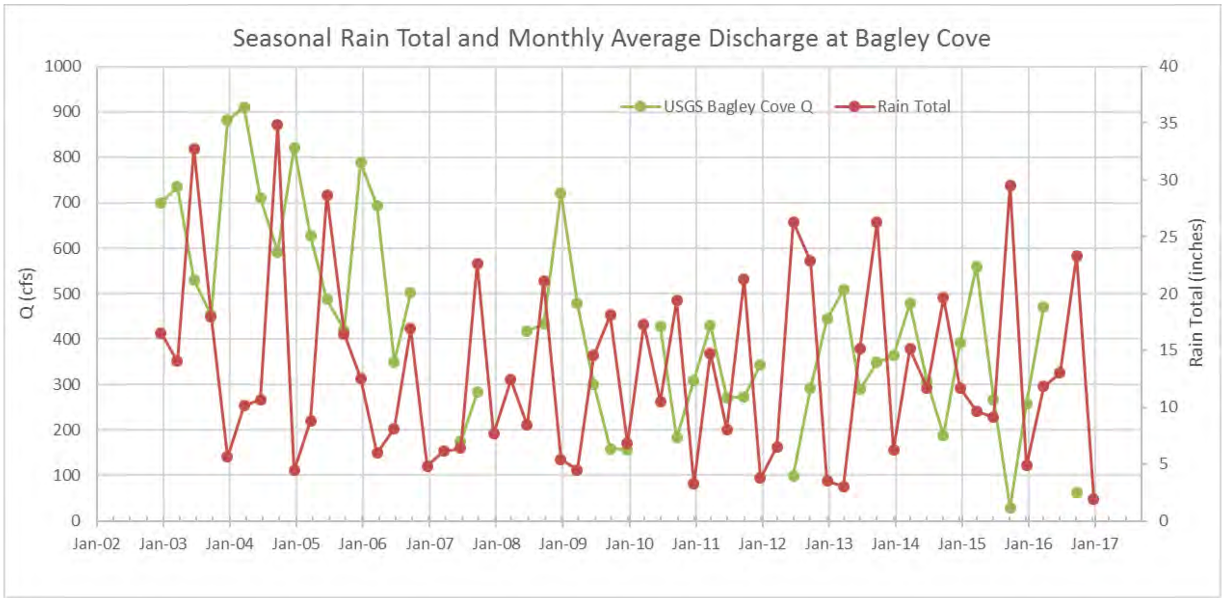

Figure 5. Seasonal rain total and monthly average Bagley Cove discharge.

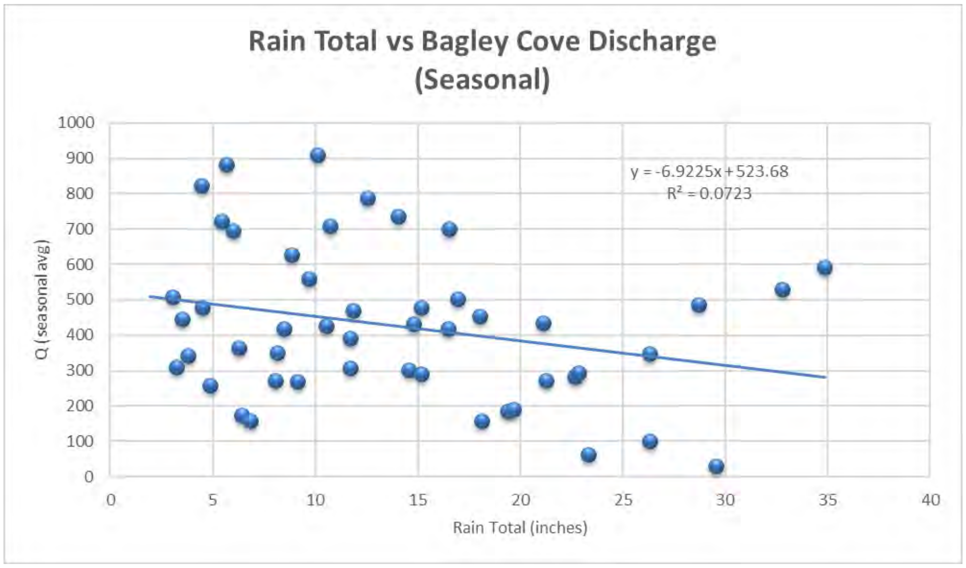

Figure 6. Seasonal average Bagley Cove discharge versus monthly rain total.

Figure 7 shows time series of annual average Bagley Cove discharge and annual rain total for Crystal River/Kings Bay from 2003 – 2016, while Figure 8 shows the scatter plot of the two variables. On an annual time scale, the Bagley Cove discharge is positively correlated with rainfall, with a low R^2 value of 0.26. In other words, the annual rain total is able to explain about 26% of the variability seen in the annual average of measured discharge at Bagley Cove.

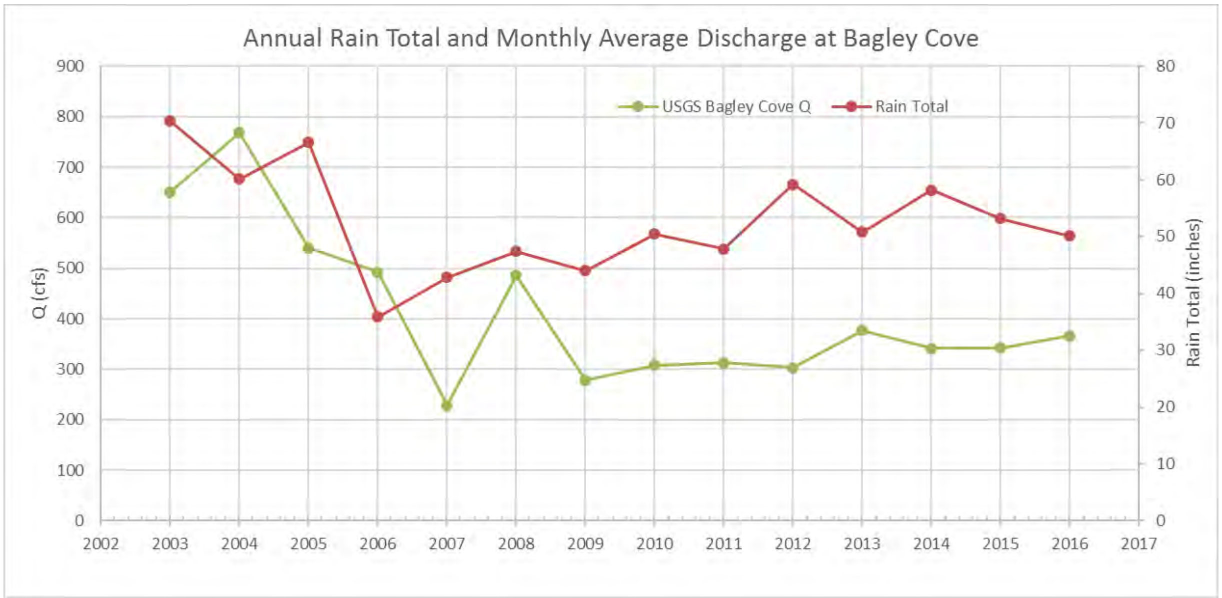

Figure 7. Annual rain total and monthly average Bagley Cove discharge.

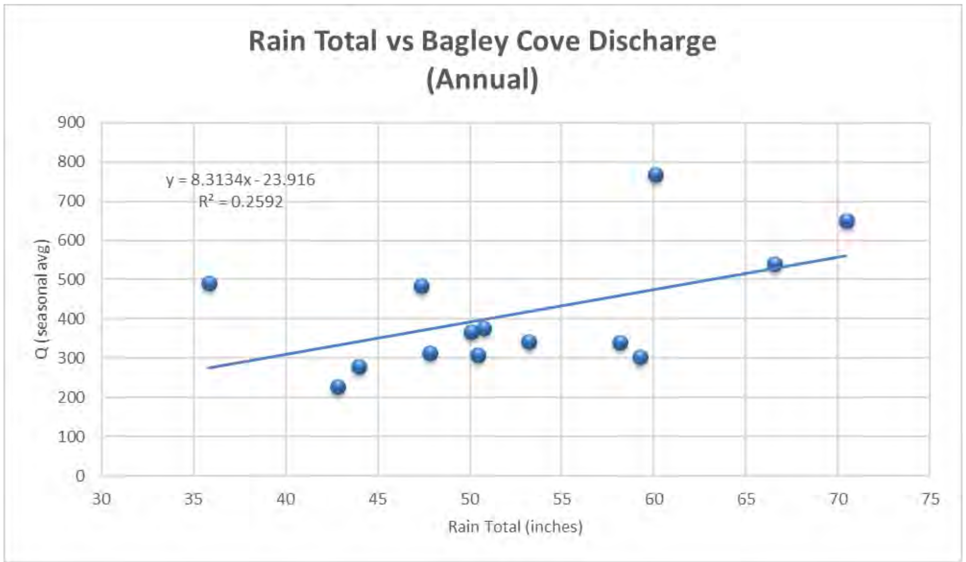

Figure 8. Seasonal average Bagley Cove discharge versus monthly rain total.

APPENDIX

Culter, J.K. 2010. Evaluation of the spatial extent, density and growth rates of barnacles in the Crystal, Homosassa and Withlacoochee Rivers, Florida. Mote Marine Laboratory, Sarasota, Florida. Prepared for the Southwest Florida Water Management District, Brooksville, Florida.

EVALUATION OF THE SPATIAL EXTENT, DENSITY, AND GROWTH RATES OF BARNACLES IN THE CRYSTAL, HOMOSASSA AND WITHLACOOCHEE RIVERS, FLORIDA

Technical Report Submitted to:

Southwest Florida Water Management District
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Brooksville, FL. 34604-6899

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Photo. Balanus and a polychaete worm tube on an artificial substrate.

Photo. Balanus illustration by Darwin.

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I. INTRODUCTION

Early naturalists considered barnacles to be members of the Phylum Mollusca. It wasn't until 1819 that the Cirripedia were determined to be crustaceans. Charles Darwin produced a monograph on the Balanidae (the sessile Cirripedes) which was published in 1884. In the Introduction of this volume Darwin comments that there is considerable variation in the barnacle shell lamenting that "*...I have enlarged on this subject and have shown that there is scarcely a single external character which is not highly variable in most of the species."* The morphological plasticity of the barnacle seems to emulate the physiological tolerance of wide salinity ranges. Within the arthropods the thoracic Cirripedia (barnacles) are quite unique comprising one of only three arthropod groups that have developed the ability to retain and build up portions of the exoskeleton of the carapace while frequently molting the exoskeleton of the rest of the body (Newman et al. 1965).

The Southwest Florida Water Management District (District) had been receiving complaints of barnacle infestation on boats and pilings within the Homosassa and Crystal Rivers. This provided an opportunity to document distributional changes in the fouling community of the tidal portions of three river systems with differing source waters, i.e., springs versus drainage basin. The Withlacoochee River was added as a drainage basin river although it does receive a level of base flow from upstream springs primarily Rainbow Springs and Lake Panasoffkee (Estevez et al. 1990). A long period of below-average precipitation and runoff and reduced spring discharges, were believed to be the most likely proximate causes of the barnacle invasion owing to the strong influence of springs on river circulation and salinity. Other factors may also be involved such as the increase of man-made fixed hard substrate, such as seawalls, pilings, floating docks, drainage culverts and boat hulls, which offer ideal colonization substrate for planktonic barnacle spat. Naturally occurring hard-substrate is limited to rock outcroppings and deadfall from trees growing along the river banks.

An increase in the prevalence of barnacles suggests a hypothesis that the freshwater flows of the river systems may no longer adequate to prevent colonization of estuarine fauna from areas that were historically tidal freshwater environments. Any effect of reduced freshwater flows would also be exacerbated by sea level rise which would enable salt wedges to travel farther upstream. Beyond concerns for alterations of the natural systems, the reaction of boaters to barnacle fouling of hulls is to apply biocides in the form of antifouling paint coatings. Such coatings are known to release toxic compounds into the water. The war against biofouling has a history as old as ships. Innumerable benign and highly toxic compounds have been tried over the centuries. Copper has been the traditional compound used as a biocide in antifouling paints. In the 1970s, organotin copolymer anti-fouling paints were developed that provided five or more years of protection for ships and were considered environmentally safe. Organotins released from anti-fouling paints were subsequently found to be environmentally damaging with TBT (tributyltin), the most commonly used organotin anti-fouling agent, claimed to be the most toxic compound ever intentionally introduced into the marine environment. Consequently, an unexpected indirect effect of large and permanent barnacle populations may be an increasing threat of chemical contamination in relatively small but highly important habitats.

The Crystal and Homosassa / Halls River systems are relatively short and are entirely contained within the low coastal plain. The main springs of both the Crystal and Homosassa River are approximately 10 to 12 kilometers, respectively, upstream of the rivers' confluence with the Gulf of Mexico. In Crystal River the multiple headsprings area known as Kings Bay has been heavily developed with housing and recreational boating facilities. Canal systems and seawall hardened shorelines are prevalent on the east and south sides of Kings Bay with the southwest and west areas bordered by marshland. The Homosassa River system is similarly developed with riverside housing and commercial resort facilities along much of the upper sections of river. The Halls River which flows into the Homosassa River is largely undeveloped with the exception of housing in the vicinity of Highway 19. Extensive marshes border much of the Halls River, and extensive tidal marshes adjoin both Crystal and Homosassa Rivers in their downstream reaches, which are much less developed than the upstream areas of those rivers.

In contrast to the Crystal and Homosassa systems, the Withlacoochee is a much longer combination black water and spring-fed river with it origin in the Green Swamp in west central Florida. Approximately 138 kilometers long (86 miles), the Withlacoochee winds through the sandhill area as it moves northwest and is bordered by hardwood forests with an understory of cabbage palm and saw palmetto. As the river nears the coast it flows through lush swampland with cypress, gum and maple. Much of the river flows through the Withlacoochee State Forest, but there are scattered residential areas along the river. The Withlacoochee also receives a significant base flow of water from the spring-fed tributary the Rainbow River. The Rainbow Springs system is the fourth largest spring in Florida. There are two Withlacoochee(ie) Rivers in Florida. This project investigated the Withlacoochee River that flows into the Gulf of Mexico at Yankeetown. A second spring-fed Withlacoochee (also often spelled with-"ie") River is a tributary to the Suwannee River.

The fouling communities of tidal rivers progress from high diversity in polyhaline zones to low diversity in areas that are more oligohaline. The barnacle fauna of the Florida west coast is relatively species depauperate, especially across low salinity gradients. Some species of *Balanus*, for example, do especially well in waters that are nearly freshup to 16 ppt (Poirrier and Partridge, 1979) or may be able to tolerate fresh water for part of the year (Kaplan 1988), a tolerance also pointed out by Darwin (1854). Poirrier and Partridge noted that *B. subalbidus* appears to occur in a lower salinity zone than *B. improvisus* and suspected *B. subalbidus* has probably been confused with *B. improvisus* because it has been assumed that *B. improvisus* was the only barnacle which extends into oligohaline waters in Atlantic coast and Gulf of Mexico estuaries. As was lamented by Darwin barnacle species show considerable environmentally induced variation in skeleton structure. More recently phenotypic plasticity was observed in *Chthamalus fissus* from the California coast that developed significantly narrower opercula in the presence of predatory snails as compared to a control group.

A study of *Balanus amphitrite* in Japan showed significant detrimental effects on survival and development at salinity ≤10 PSU but showed no stress in the salinity range of 15 to 35 PSU. Notably there seemed to be accommodation of larvae that as embryos were exposed to salinities of 10 PSU which as larvae survivorship and length of development were independent of the salinity that the embryo had experienced. For larvae cultured at 15 and 35 PSU, exposing embryos to 10 PSU resulted in lower larval survival and longer larval development time. When cypris larvae were exposed to 10 PSU juvenile growth was not altered but it did result in lower survivorship. The authors concluded that osmotic stress experienced in one life-stage can be passed over to the next life-stage (Qiu and Qian 1999).

A study of Caspian Sea *Balanus improvisus* showed larval size decrease with increasing salinity for development from nauplius II larva to cypris larva. Larval survival was highest at 12 PSU and lowest at 36 PSU (Nasrolahi et al 2006).

The most common Florida species of barnacles are within the genera of *Balanus* and *Chthamalus.* A river reconnaissance on March 18, 2009 resulted in the collection and preliminary identification of two species of *Balanus* and verified the presence of live barnacles within low salinity areas of all three rivers. Examination of specimens identified the majority of specimens as *Balanus subalbidus* with specimens of *Balanus amphitrite* being recovered only from the lower Withlacoochee River. Specimens of *B. subalbidus* contained eggs/sperm as well as larval stages indicating that the low salinity in these areas does not inhibit reproduction.

Balanus amphitrite, an exotic species in the U.S, is very common and is one of the most broadly distributed and abundant coastal and estuarine biofouling organisms found in warm and temperate waters worldwide (Desai et al. 2006). It is found on almost any natural or man-made hard surface. The native range of *B. amphitrite* is uncertain but is considered to be the Indian Ocean to the southwestern Pacific, based on its presence in the Pleistocene fossil record (Cohen 2005).

The United States Geological Survey (USGS) list of nonindigenous aquatic species list describes *B. amphitrite* as established in Florida coastal waters by 1975 (Henry and McLaughlin 1975, Carlton and Ruckelshaus 1997), but the initial introduction most likely occurred much earlier and the first reports of the species in Florida date to at least the 1940s. It may be possible other species are present in the systems particularly in the downstream sections of the Withlacoochee River. However, it was not feasible to dissect all of the barnacles collected for this project. *B. amphitrite* is recognizable by the presence of pink or purplish stripes and was infrequent in occurrence for this survey

Other similar in appearance barnacles may occur in this area. *Balanus improvisus*, the white bay barnacle, is a common species and is often confused with *B. eburneus*, the ivory barnacle. *B. improvisus* is usually smaller than *B. eburneus*, but definitive identification between species this similar in external appearance usually requires examination of the shape of the terga and scuta through dissection. We examined a fairly large number of specimens and all appeared to be *Balanus subalbidus*. However, considerable age dependent variation in the terga was also observed.

It is of considerable importance that *B. eburneus* is known to be capable of self-fertilization (Furman and Yulea 1990). Hermaphroditism is universal in sessile barnacles, but only a few species are known to be facultative self-fertilizers. The ability to self-fertilize is advantageous for individuals of a species such as *B. improvisus*, which often has sparse and isolated populations. Such a reproductive mechanism may offer an advantage when colonizing areas such as a tidal river where an influx of new planktonic recruits may be intermittent and hindered by seasonal changes in river flow.

As for the occurrence of barnacles in the upper estuarine zones, according to Southward and Crisp (1987, p. 127), Darwin "noted that *Balanus improvisus* was found in a small stream in the estuary of La Plata, near Monte Video, where at high water specimens apparently were covered by the brackish and occasionally almost fresh waters of the estuaries." Branscomb (1976) reported that a population in the Chesapeake Bay "appeared unaffected by unusually high freshwater run-off in June which lowered salinities in the bay for 1972."

There are few studies of rates of barnacle growth for tropical and subtropical regions where settlement and subsequent growth is rapid. Studies at Mote Marine Laboratory, Sarasota, showed that under favorable conditions species of *Balanus* can grow to 1 centimeter basal diameter within 30 days post-settlement and become reproductive within 15 days post-settlement (Culter 1996).

II. MATERIALS AND METHODS

Site visits were made to the study rivers on three occasions. A field reconnaissance that included the placement of artificial substrates at six sites in the rivers was conducted on March 18, 2009. These artificial substrates were collected on May 14th and processed in the laboratory. Artificial substrates were placed at thirty-five sites on May 14 and 15, including redeployment at four sites from the first sampling effort. A final trip was made from June 29 to July 2 to retrieve the artificial substrates from the second deployment, make in-situ measurements, and collect field scrape samples of barnacles from hard substrates (e.g. pilings) that occur in the rivers.

The reconnaissance survey in March was for the purpose of locating existing barnacle habitats and determination of the most upriver extent of barnacles. Information on salinity distributions within the tidal sections of these rivers was provided by the District which served as the basis to determine the reconnaissance survey areas. Along the chosen sections of each river fixed hard substrates were examined for evidence of barnacle growth. Suitable barnacle substrate consisted primarily of channel markers, dock pilings, metal sign posts and PVC pipes. Deadwood snags and submerged rocks were also examined in areas where these were present.

After deliberation of the field reconnaissance information, it was decided there would be two main components of the study; field measurements on available hard substrates in the rivers, and monitoring barnacle growth on artificial substrates placed in close proximity to the field sites. Field measurements would provide information on the local extent of barnacle populations on existing surfaces, while the artificial substrate incubations would allow for determination of late spring colonization and growth rates. It is difficult to quantify colonization rates by examination of natural communities. There are numerous variables present in a natural fouling community, including; substrate type and age, tidal position (depth), orientation of substrate, water flow, etc. The deployment of artificial substrates was intended to reduce the potential number of variables for evaluation of the relative rate of colonization within salinity zones of each river system.

Sampling site nomenclature for the Homosassa and Withlacoochee Rivers was based on a river kilometer (Rkm) system provided by the District, with river kilometer zero (Rkm 0) located at the designated mouth of the river. Sampling sites within Kings Bay were not based on a linear system. Sampling sites were distributed to provide a broad representation of the system.

Locations of the barnacle sampling sites in the rivers are shown in **Figures 1, 2 and 3** (pages 6 - 8). Unless specified otherwise, the same sites were used for the examination of barnacles on existing hard substrates in the rivers and the placement of artificial substrates for barnacle growth measurements.

II.1. Barnacle Sampling and Measurement on Existing Hard Substrates

The objectives of the field sampling of barnacles on existing hard substrates is the rivers were to:

1) Identify barnacle species,
2) Determine the relative proportion of live to dead,
3) Determine the size range, based on basal diameter.
4) Determine the farthest upriver extent of live / dead barnacles.
5) Apply items 1-4 to a river kilometer system for Homosassa and Withlacoochee Rivers and salinity strata for Kings Bay in Crystal River.

The intention of the field survey was to identify in-situ both living and dead barnacles with respect to species and basal diameter. However, when conducting the field work, limited water visibility, color, and heavy epiphytic growth of algae, tube dwelling amphipods and other organisms prevented quantitative observation of living versus dead barnacles for most locations. The March site reconnaissance showed that the predominant fixed position hard substrata were channel markers and dock pilings. These substrates proved to be the most utilitarian structures on which to base field measurements and collections. As will be described in Section II.2, artificial substrates were also placed at these same structures.

Sampling sites were spatially distributed to reflect that the Homosassa and Withlacoochee Rivers have horizontal salinity gradients that are generally linear, with salinity values increasing upstream. A different sampling design was employed in the Kings Bay area of Crystal River, where the large headspring area has a more complex circulation and salinity structure due to multiple spring vents, small islands, canals and creeks.

In Florida estuaries, barnacles are usually found in greatest abundance within the intertidal zone with the greatest abundance typically at or near mean low water. Near-surface waters are generally high in plankton abundance and are well circulated both of which seem to enhance barnacle growth. In the Homosassa and Withlacoochee Rivers, the most upstream barnacles were exclusively limited to the deep mid-zone or near-bottom zone, reflecting the upstream most extent of the tidal salinity wedge. These deep barnacles were not initially planned for in the survey and the upstream-most settling plates, located in the deep tidal zone, did not always exhibit colonization as a result of the influence of the freshwater flows at those depths.

Figures 1, 2, and 3 and associated text on the following pages.

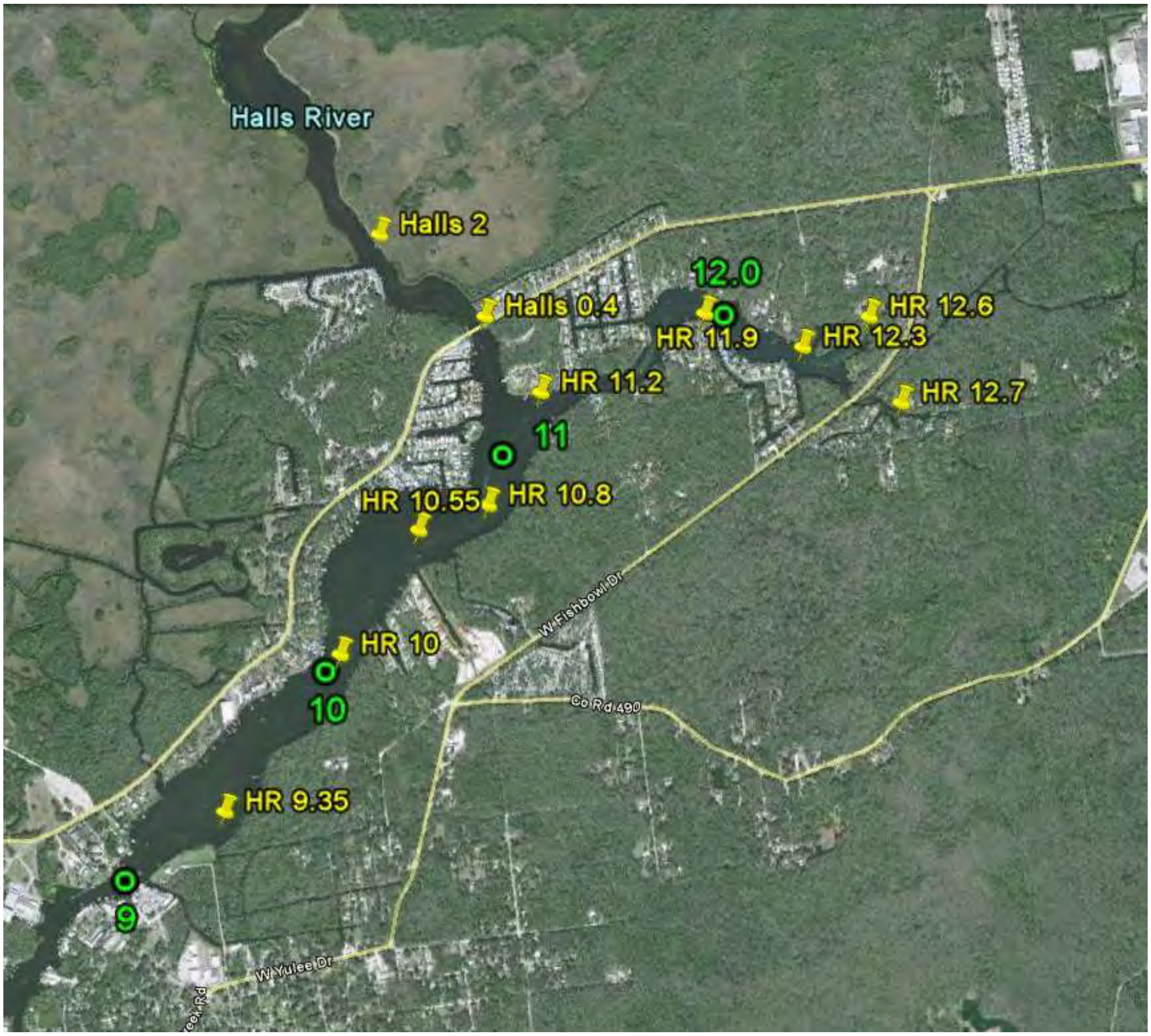


Figure 1. Sampling sites marked as river kilometer positions in the Homosassa River with river kilometer distances also shown as green numbers and circles. Sampling at each site included both the scraping of barnacles from hard substrates and the placement of artificial substrates.

The Homosassa River does have some lateral salinity gradients that warranted examination due to different salinity values in the Halls River and the Southeast Fork compared to the main stem of the river. Sampling in the Homosassa River consisted of 10 stations arranged along the longitudinal axis of the river upstream of McRae's Fish Camp, near river kilometer 9, as shown in **Figure 1**. Sampling at these sites consisted of steps 1 through 5 on page 5. Three of these sampling sites were associated with the Halls River at the W. Halls River Road Bridge, the Homosassa main spring, and the Southeast Fork. In these three areas, transects were also visually reconnoitered to qualitatively classify the distribution of barnacles across river. However, cross river transects did not provide much useful information due to the lack of uniform cross-river hard substrates. The sampling design was dependent on the availability of uniform hard substrate which generally consisted of channel marker and dock pilings. In areas were cross-river investigations were made there did not appear to be differences in the fouling community.

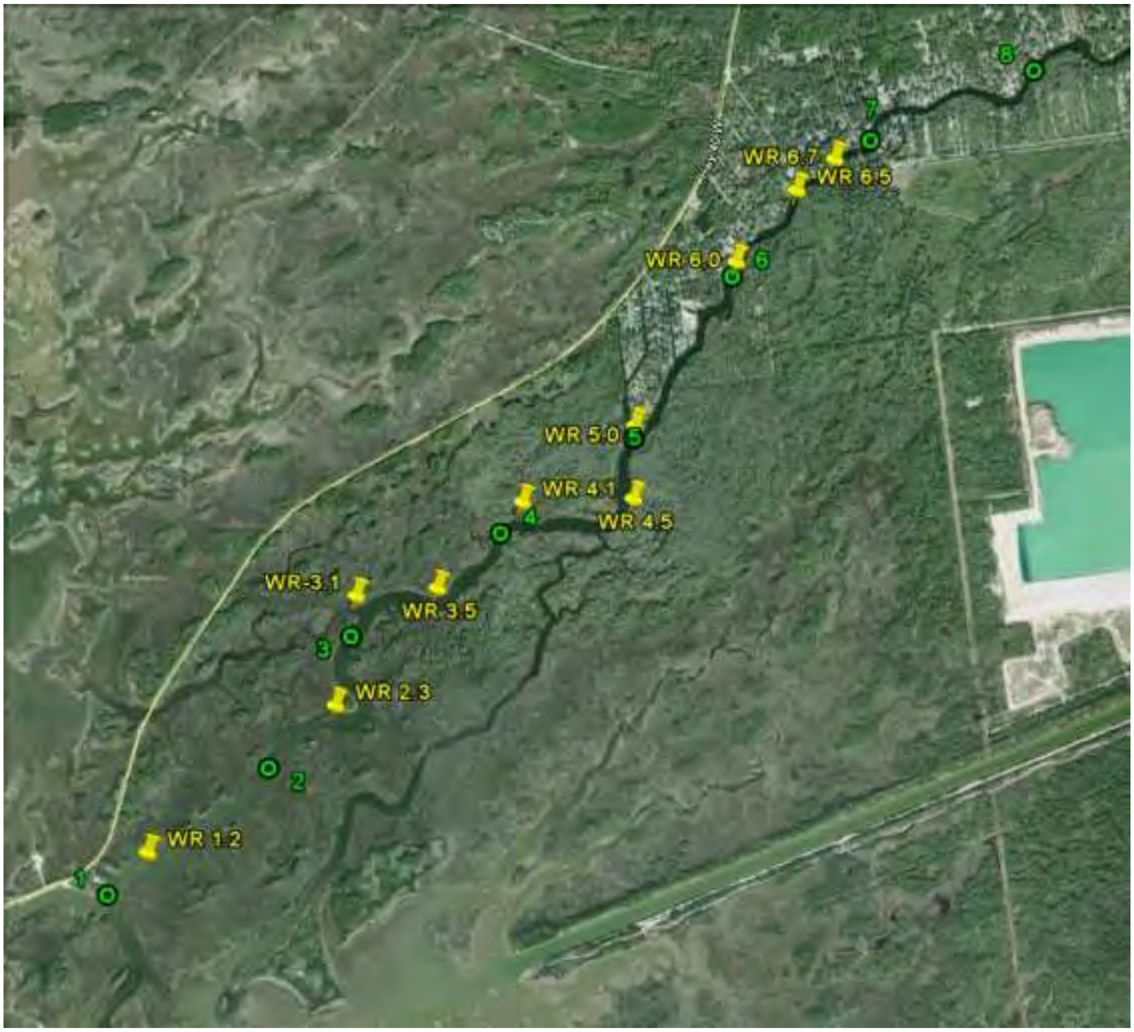


Figure 2. Sampling sites marked as river kilometer positions in the Withlacoochee River with river kilometer distances also shown as green numbers and circles. Sampling at each site included both the scraping of barnacles from hard substrates and the placement of artificial substrates.

The Withlacoochee River was evaluated on a river kilometer basis with sampling intervals targeted to include an approximate 6.0 kilometer survey distance **(Figure 2)**. For the Withlacoochee, tasks 1-5 (described on page 5) were completed at each of 10 locations exhibiting barnacles. For much of the length of the survey area the Withlacoochee River exhibits a deeply incised channel with limestone rock exposed on portions of the banks and riverbed. This deep channel allows for salinity stratification. The barnacles located farthest upriver were found near the bottom, a reversal of the normal barnacle occupancy of the intertidal zone.

Figure 3. Sampling sites in Kings Bay (Crystal River). Sampling at each site included both the scraping of barnacles from hard substrates and the placement of artificial substrates.

For Crystal River the focus was on Kings Bay, the broad area that contains the headsprings of the river. Data provided by the District illustrated that there were subtle salinity gradients within Kings Bay due to spring flow from numerous vents. Based on salinity data provided by the District, thirteen sampling sites were selected within Kings Bay, with one site (KB-1) located in the river channel approximately one kilometer downstream of Kings Bay (**Figure 3)**. Other areas were also visually reconnoitered to qualitatively classify the distribution of barnacles, but the lack of uniform hard substrate generally limited the utility of the observational data.

Where barnacles were present, field measurements of basal diameter were made at each survey site. At each sampling the largest, densest, or most developed barnacle community on the existing hard substrate was sampled. At some sampling sites such as in the Withlacoochee River, the number of barnacles was sparse and all barnacles at the site were measured. Salinity, pH, water temperature and dissolved oxygen profiles were measured at each barnacle survey site.

Removal of barnacles from the substrate is usually very destructive, resulting in many broken barnacle fragments. Therefore at each site, the feasibility of identifying live versus dead barnacles in situ was also evaluated. For many sites it was not possible to identify live versus dead barnacles due to water color, turbidity, and the growth of epiphytic algae and other organisms among the barnacles. If the substrate was intertidal, such as a piling, the range of the colony from the uppermost to the lowermost dead and live barnacles was measured. After in situ characterization, the area of greatest barnacle density in a 10 x 10 cm^2 area was measured in place or collected by scraping from the substrate into a net. A minimum of 25 barnacles or all of the barnacles that could be found at a site were examined and measured. The material scraped from the substrate was placed in a jar and preserved with 10% Formalin™ solution.

In the laboratory the scrape samples were sorted and barnacles were identified as either *Balanus subalbidus* Darwin 1854 or *Balanus amphitrite* Darwin 1854 (striped barnacle) and were noted as live or dead. Since measurements were taken in the field, no additional measurements were made in the laboratory as most of the shells were broken in the removal process.

II.2. Artificial Substrates

Artificial settling plates were first deployed in the river on March 18, 2009 at six sites listed in **Table 6** (page 26). These substrates were retrieved and data for barnacle growth at these sites were measured on May 14th, yielding a 57 day incubation period. Artificial substrates were also placed at thirty-five sites on May 14th and 15th, including redeployment at four sites from the previous sampling effort. These substrates were retrieved between June 29 and July 2, yielding incubation periods between 46 to 48 days. These thirty-five sites were deployed at the same locations and structures as the hard substrate sampling effort (**Figures 1-3**).

Artificial substrates were constructed of square gray PVC plates that measured 15 cm x 15 cm. The sites from the second deployment were visited again to collect and process the settlement plates and conduct the field survey to delineate the distribution of barnacles. Latitude / longitude positions were recorded for each survey location. The objectives of the artificial substrate survey were to provide measures of barnacle settlement and growth for each river and location. The following metrics were measured for each artificial substrate panel.

1) Deploy artificial substrates (15cm x 15cm) for comparison of barnacle colonization rates between locations.
2) Measure the number of barnacles per unit area.
3) Measure basal diameters of 25 barnacles per plate from randomly selected 4 cm^2 grid blocks up to a count of 25 barnacles.
4) Measure the basal diameter of the largest and smallest barnacle on each plate.
5) Measure barnacle biomass as wet weight and dry weight, grams per unit area.

III. RESULTS

The results are presented sequentially with the first sections presenting the data for salinity for the current field work, as well as District records for each river (sections III.1 to III.3). This is followed by discussion of the data for the field observations of the barnacle distribution within the rivers (III.4) and the colonization and size data for the artificial substrates (III.5).

To successfully colonize an area, barnacles need hard or firm fixed substrate in addition to favorable salinity and water quality. Hard substrate is limited throughout most of the natural areas of each river. Rock outcrops are present in all three rivers, but the overall areal extent of natural rock is small in comparison to the sand, muddy sand and marsh dominated shorelines and river bottom. The barnacle fouling problem as a boat nuisance may be, in-part, exacerbated by coastal development. Development of these rivers has resulted in the increase of hard substrate available to fouling organisms. The presence of seawalls, bridge pilings, channel markers, information signs, boats, and mooring structures have dramatically increased the "hard bottom" areas compared to pre-development conditions. This is particularly true for the intertidal areas favored by barnacles.

For the period June 29 - July 2 there were abnormally high tides in all three rivers due to the weather patterns in the Gulf of Mexico. **Figure 4** illustrates the tide level at the Withlacoochee River boat ramp (RK 7.1) on June 30. The high tides enabled documentation of salinity incursions that were significantly greater than average conditions.

Figure 4. Withlacoochee River boat ramp on June 30, illustrating the unusually high tide.

III.1 Stations and Salinity -Homosassa and Halls Rivers

Table 1 presents salinity and depth data for the sampling locations in each river system for the dates of sampling June 29 - July 2, 2009. Data are arranged from highest to lowest surface salinity for each river. The unusually high tides during this period contributed to pronounced tidally induced salinity stratification in all three rivers. Average and maximum salinity values in the top meter and bottom waters at nearby stations in the three rivers sampled by the District are also listed in **Table 1.** The District data for the Homosassa and Halls Rivers were collected on nine dates between February 2008 and March 2009.

Average and maximum salinity values for the District data are also graphically displayed for the three rivers in **Figures 5, 6, and 7**. To aid the comparison between rivers, top meter salinity values are shown for the Homosassa and Crystal Rivers, as barnacles are abundant in the intertidal zones of those rivers and the bottom depths of the sites vary considerably. Near bottom salinity values are shown for the Withlacoochee River, as barnacles are typically most abundant at deeper depths in that river due to more pronounced vertical salinity stratification.

Table 1. Surface and near bottom salinity values for the three river systems sampled June 29 - July 2, 2009 ranked by decreasing surface salinity along with average and maximum salinity values from nearby stations sampled by the District.

	Overall*		Salinity (PSU)		District Data Salinity (PSU)			
Location	Depth (m)	River ** Kilometer	Surface (0.5m)	Near Bottom	Top Meter Average	Top Meter Maximum	Nr. Bottom Average	Nr. Bottom Maximum
HR-9.35	2.8	9.35	10.7	13.4	3.9	7.1	4.6	10
HR-10	3.7	10.0	8.2	14.0				
HR-10.55	2.9	10.55	5.9	11.7				
HR-10.8	2.8	10.8	5.4	7.9	2.8	4.8	3.1	5.8
HR-11.2	3.9	11.2	2.4	9.7				
Halls 0.4	2.8	0.4	5.9	6.4	2.9	4.4	2.9	4.4
HR-11.9	4.3	11.9	1.8	8.8				
HR-12.3	3.9	12.3	1.2	6.8	1.6	2.0	2.4	2.9
HR-12.6	3.6	12.6	1.0	2.4				
HR-12.7	0.8	12.7	0.6	0.7	0.5	0.6	0.5	0.6

	Overall	River **	Salinity (PSU)		District Data Salinity (PSU)			
Location	Depth (m)	Kilometer	Surface (0.5m)	Nr. Bottom	Top Meter Average	Top Meter Maximum	Nr. Bottom Average	Nr. Bottom Maximum
WR-1.2	2.4	1.2	8.1	9.1	13.7	20.8	18.0	25.7
WR-2.3	4.7	2.3	6.5	8.2	11.0	20.3	19.0	25.8
WR-3.1	1.1	3.1	4.7	5.2	4.7	8.1	14.0	24.3
WR-3.5	4.0	3.5	3.6	12.5	4.2	8.0	14.5	23.5
WR-4.1	5.1	4.1	2.5	15.7	2.5	5.5	12.1	23.0
WR-4.5	4.1	4.5	2.0	14.2	1.8	4.5	11.1	22.3
WR-5.0	5.1	5.0	1.4	14.5	1.0	3.0	12.9	26.7
WR-6.0	5.5	6.0	0.2	12.2	0.8	3.0	6.5	19.9
WR-6.5	4.8	6.5	0.2	10.7	0.5	1.8	5.8	19.1
WR-6.7	6.5	6.7	0.2	9.2	---	---	---	---

	Overall	River **	Salinity (PSU)		District Data Salinity (PSU)			
Location	Depth (m)	Kilometer	Surface (0.5m)	Nr. Bottom	Top Meter Average	Top Meter Maximum	Nr. Bottom Average	Nr. Bottom Maximum
KB-1	4.0	na	4.8	6.1	4.0	6.6	5.1	7.8
KB-10	0.7	na	2.9	2.9	1.9	2.7	2.0	2.8
KB-9	1.0	na	2.7	2.8	2.1	2.5	2.2	2.6
KB-4	1.2	na	2.6	3.7	2.1	3.4	2.9	6.8
KB-5	1.8	na	2.5	3.6	2.1	3.4	2.9	6.8
KB-14	1.5	na	2.4	3.7	2.0	2.6	2.3	3.3
KB-11	1.3	na	2.0	2.5	1.7	2.6	2.3	3.5
KB-12	2.4	na	1.8	2.7	0.9	1.5	0.9	1.5
KB-15	1.7	na	1.8	2.9	1.8	2.5	2.5	3.5
KB-13	2.1	na	1.6	2.6	1.1	1.7	1.2	2.0
KB-6	2.3	na	0.9	3.4	1.4	2.5	1.7	3.5
KB-3	1.5	na	0.6	1.7	0.6	1.8	0.9	2.3
KB-8	1.9	na	0.5	0.8	---	---	---	---
KB-2	1.2	na	0.5	2.2	0.7	1.7	0.9	2.4
KB-7	1.1	na	0.2	0.2	0.6	1.4	0.7	1.8

Footnotes: * Overall depth = at site of salinity reading. **river kilometer of barnacle site, not assigned for Kings bay. HR-12.6 reading taken at no entry signs downstream of spring.

The salinity values at the Halls River station recorded during the barnacle survey were greater than nearby stations in the Homosassa River. Furthermore, the bottom salinity values in both rivers were greater than the surface salinities at most locations, possibly due to strong salinity incursions during the very high tide on that sampling day. The average top-meter and bottom salinity values from the District data indicate less vertical stratification. Also, the surface salinity readings taken on June 29, 2009 were generally greater than the average top-meter values recorded by the District. However, the maximum values recorded by the District over the preceding period were more similar to the values recorded during the barnacle survey.

On June 29, the surface and bottom readings observed at the no entry signs of the Homosassa headspring were 1.0 and 2.4 PSU respectively. There were no barnacles present within the run from the headsprings and no barnacles were present on the "No Entry" sign pilings. A few small barnacles (~5mm basal diameter) were found on the pilings at the park gazebo approximately 5 feet below the water line and 2-3 ft off the bottom. No barnacles were present in the small bay to the south, HR-12.7, nor were there barnacles present on the concrete bridge structure for West Fishbowl Drive. Surface and bottom salinity at HR-12.7 were 0.6 and 0.7 PSU respectively at the time of sampling, Table 1. At HR-12.3 there was a well developed fouling community on the lower portion of the marker piling (near the south shore at a canal junction) which extended from near bottom to ~1.25 meters above the bottom. Overall water depth at this location was ~2.14 meters. Surface salinity at HR-12.3 was 1.6 PSU and the bottom salinity was 6.8 PSU. The District average top-meter salinity in this vicinity was 1.6 PSU (**Figure 5**), with an average bottom value of 2.4 PSU (**Table 1**) The barnacle community at this location appears dependent on the incursion of the saltwater wedge along the river bottom.

At location HR-11.9 there was a barnacle-mussel community that extended from the bottom to 1.14 meters above the bottom. Overall depth at this location was ~2.5 meters. Due to low light levels and a coating of algae it was not possible to tell live from dead barnacles, although most barnacles appeared to be living. For the sampling date surface salinity at this location was 1.8 PSU and bottom salinity 8.8 PSU.

At location HR-11.2 near the confluence of the Homosassa and Halls River surface salinity was 2.4 PSU and bottom salinity 9.7 PSU. Mussels were more numerous than barnacles at this location. Overall depth was approximately 1.5 meters with the barnacle / mussel community extending from near the bottom to approximately 0.3 meters below the surface of the water. For normal tides the barnacle community is present throughout the intertidal range.

Station Halls-0.4 was located in Halls River at the bridge for West Halls River Road. Surface and bottom salinities at this location were 5.9 and 6.4 PSU respectively. Barnacles on the concrete bridge pilings dominated the fouling community. Visibility was very poor due to highly colored tannic water from the Halls River. Barnacles were present over the entire depth of the location, 0.9 meters.

Location HR-10.8 also exhibited poor visibility due to the tannins from Halls River. Surface and bottom salinity values were 5.4 and 7.9 PSU respectively. The bottom salinity was slightly less than that of site HR-11.2 possibly due to increased surface to bottom mixing in this portion of the river. Overall depth of this site was 2.8 meters and barnacles were present from the bottom to a depth of 1.5 meters.

Figure 5. Average (yellow) and maximum (orange) salinity values recorded in the top meter of water at in the Homosassa and Halls Rivers sampled by the District between February 2008 and March 2009. River kilometers shown as green circles.

Location HR-10.55 exhibited barnacles throughout the entire depth range of 2.9 meters with the exception of the near surface zone (~0.25 meters) covered by the exceptional high tide. Surface salinity for this location was 5.9 PSU and bottom salinity 11.7 PSU.

At location HR-10 the piling used for a scrape sample was located slightly up-river of the artificial substrate location. Barnacles occurred throughout the entire depth range of ~2.1 meters with the exception of the near surface zone (~0.25 meters) which was covered by the exceptional high tide. Surface salinity for this location was 8.2 PSU and bottom salinity 14.0 PSU.

Location HR-9.35 was at the green "3" navigation marker Barnacles occurred throughout the entire depth range of ~1.0 meter with the exception of the near surface zone (~0.1 meters). Salinity readings in the deeper channel showed a surface value of 10.7 PSU and bottom salinity of 13.4 PSU at 2.77 meters depth.

From HR-12.3 downstream barnacles were present at all locations. Mussels were a dominant fauna at station HR-11.9 and HR-11.2. Salinity conditions for the benthos of the Homosassa River downstream and including station HR-12.3 for the June - July sampling were upper estuarine ranging in salinity from 6.4 to 14.0 PSU. **Figure 6** illustrates the surface and bottom salinity readings for the sampling sites on the Homosassa River arranged by distance upstream (kilometers) for the sampling in June (top graph) as compared to average salinity values for top meter and bottom waters based on District data (bottom graph).

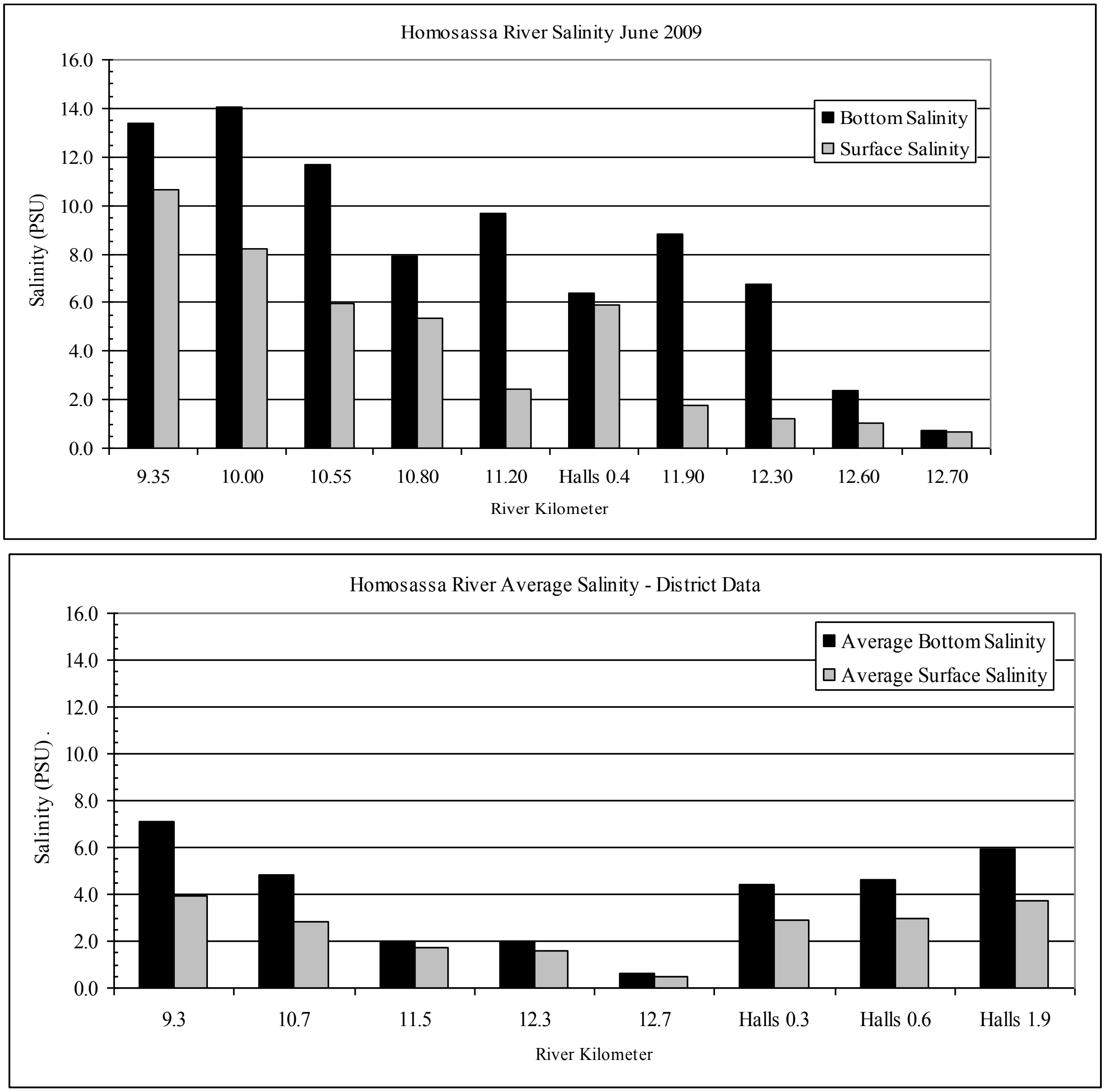


Figure 6. Surface and bottom salinity for Homosassa River stations for June 29, 2009 (top) and average values for the top meter and bottom waters from District data (bottom).

III.2 Stations and Salinity - Kings Bay, Crystal River

Historic data for Kings Bay at the head of Crystal River have shown the bay does not exhibit a simple linear salinity gradient. Multiple spring vents and irregular spring flows coupled with tides create a complex salinity regime within the bay. **Figure 7** illustrates the barnacle sampling sites in Kings Bay with average and maximum top-meter salinity values based on District sampling on six dates between July 2008 and June 2009. Locations KB-1 through KB-14 included artificial substrate samples and natural substrate barnacle collections.

During the field days of this study, spring flows were low and brackish water was observed in most areas of the bay. Salinity values for the field sampling of June 29 to July 2, 2009 are shown in **Table 1** and plotted as **Figure 8**. Surface salinity in Kings Bay ranged from 0.2 to 4.8 PSU and bottom salinity ranged from 0.2 to 6.1 PSU. Only two locations KB-7 and KB-8 exhibited bottom salinities of less than 1.0 PSU for the days of sampling in July. At location KB-15, salinity measurements were made and an observational dive was made into the large spring vent at this site. Barnacles growing on the limestone walls of the spring vent were measured and sampled.

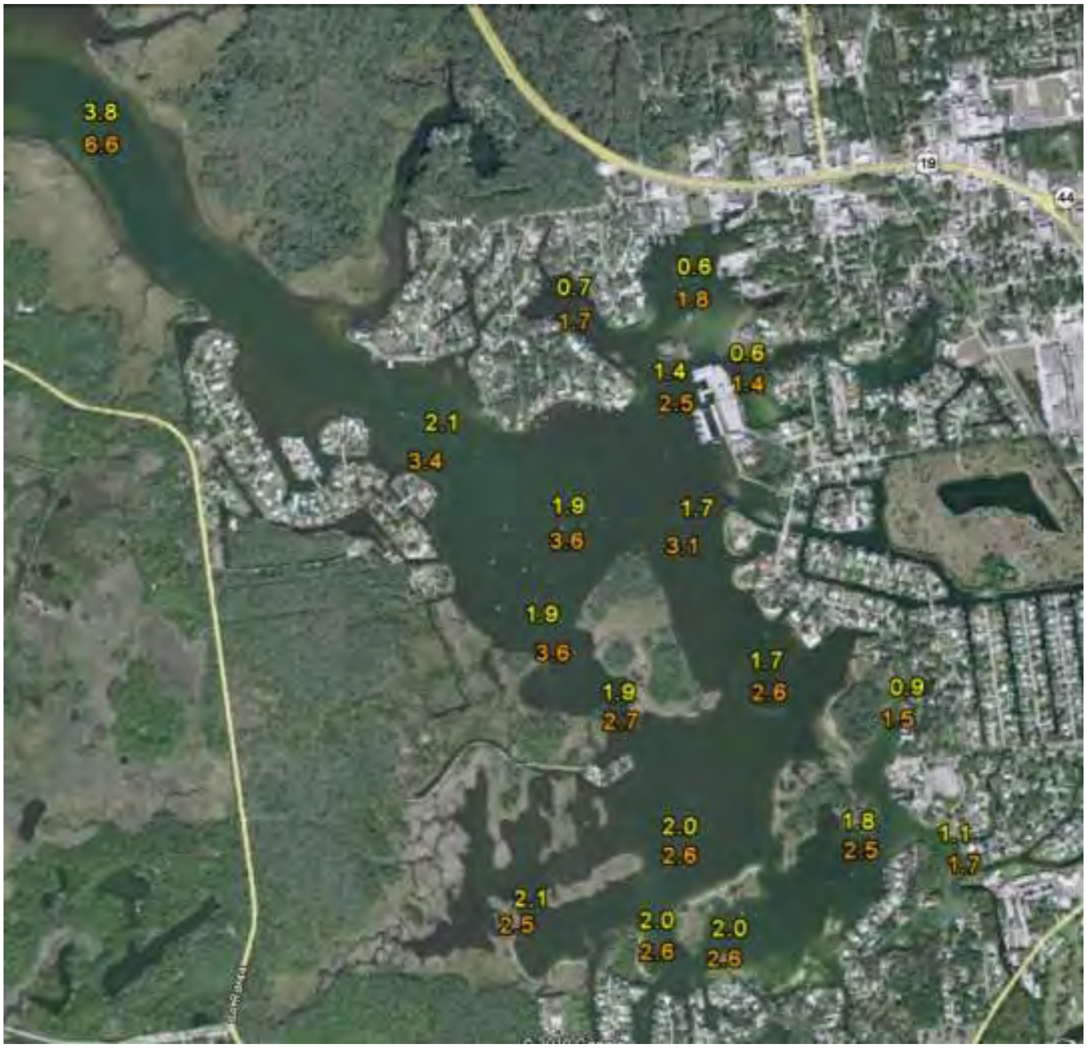


Figure 7. Average (yellow) and maximum (orange) salinity values recorded in the top meter of water in Crystal River / Kings Bay sampled by the District between July 2008 and June 2009.

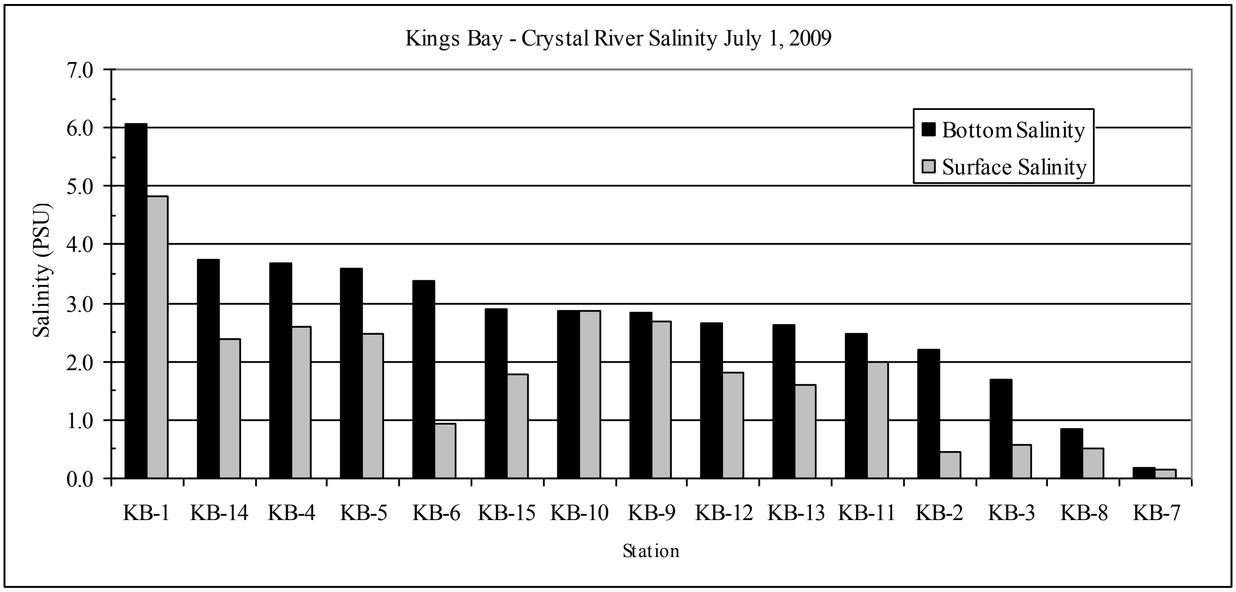


Figure 8. Surface and bottom salinity for Kings Bay stations for July 1 and 2, 2009, with stations shown in rank order of highest to lowest bottom salinity.

Figure 9 illustrates the average and maximum top meter salinity values for 17 locations in Kings Bay and one in the river measured by the District. The data illustrate that there were four areas of the bay with average salinity values below 1.0 PSU, twelve areas representing a gradual gradient between 1.0 and 2.0 PSU and three sites that averaged above 2.0 PSU, with the highest salinity recorded at KB 1, a site in Crystal River, approximately 1.7 kilometers downstream of Kings Bay proper.

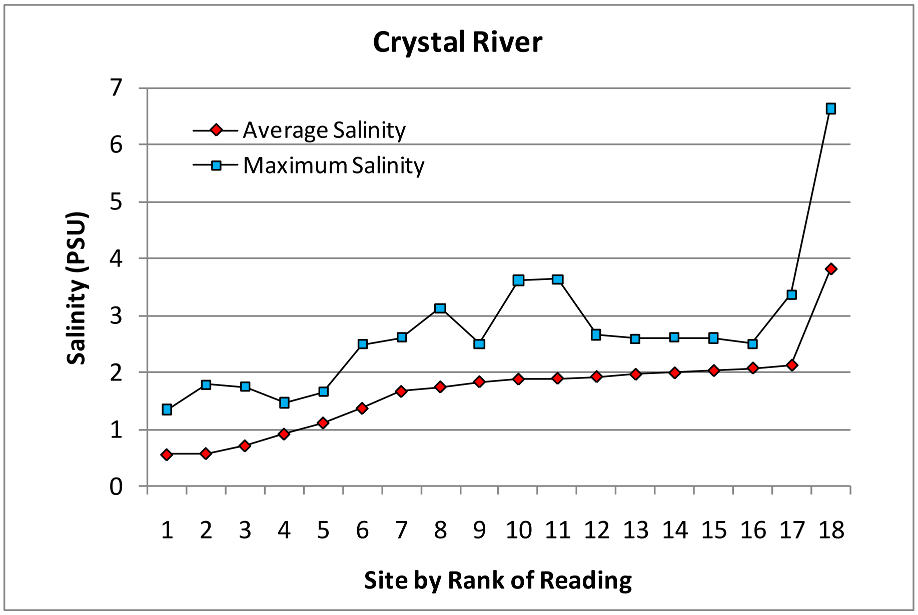


Figure 9. Rank order of average and maximum values for top meter salinity for stations in Kings Bay and one in Crystal River measured by the District.

III.3 Stations and Salinity - Withlacoochee River

Barnacle sampling sites in the Withlacoochee River are shown in **Figure 10**, along with average and maximum top-meter and bottom salinity values based on District sampling between October 2008 and June 2009 (n = 9 to 14). Station designations are based on a river kilometer scale provided by the District. Salinity values for the sampling sites for June 30, 2009 are shown plotted in **Figure 11**. The most curious feature of this graphic is the high levels of bottom salinity at stations 3.5 to 6.7 kilometers, the most upstream locations. The Withlacoochee River has a deeply incised channel which generally becomes somewhat shallower farther downstream. The deeper section allows for significant salinity stratification for a significant distance upstream. The results in **Figure 11** were also affected a very high tide on the sampling day due to a low pressure weather system and associated winds in the Gulf of Mexico, as previously exhibited by **Figure 4**. For visual comparison to the salinity data from June 2009, the average top meter and bottom salinity data from the District sampling conducted between October 2008 and June 2009 are plotted in **Figure 12.**

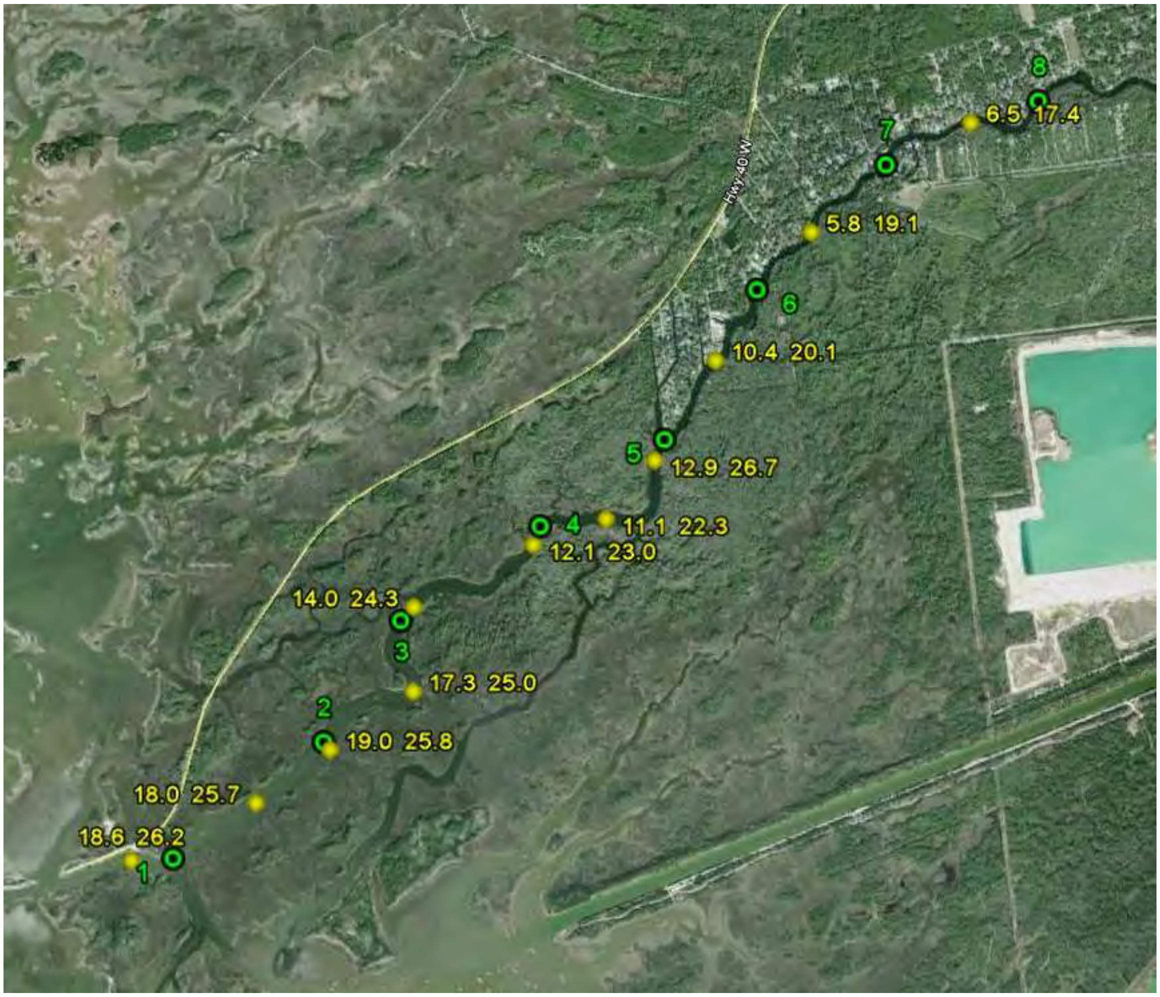


Figure 10. Average and maximum salinity values for near-bottom waters in the Withlacoochee River recorded by the District between October 2008 and June 2009.

The first barnacles that were found on hard substrates occurred at location WR-6.5. At this site sparse barnacles were observed growing in a zone 0.7 to 1.3 meters above the bottom. The total depth at the location for a very high tide was 2.7 meters. This trend held for stations WR-6.0, WR-5.0, WR-3.1. Sites downstream of station WR-3.1 had robust intertidal oyster / barnacle communities. It was not possible to sample barnacles growing on pilings at WR-1.2 or WR-2.3 due to the heavy dominance of oysters and other fouling organisms. In-situ barnacles could not be measured at WR-4.1 due to a lack of available substrates.

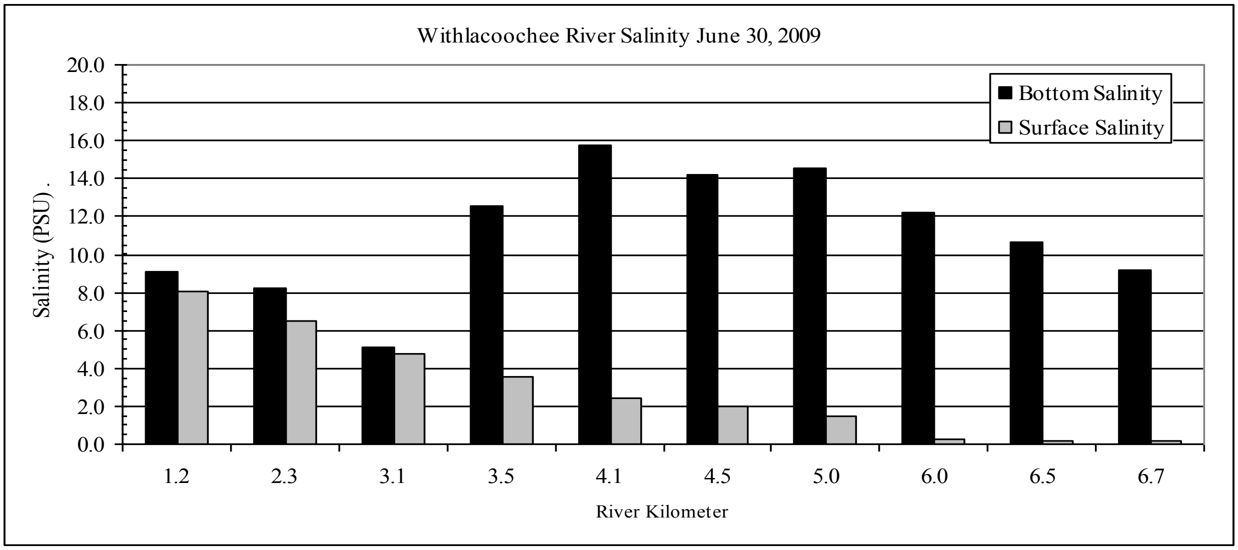


Figure 11. Salinity values for surface (0.5m) and near bottom for the Withlacoochee River, June 30, 2009.

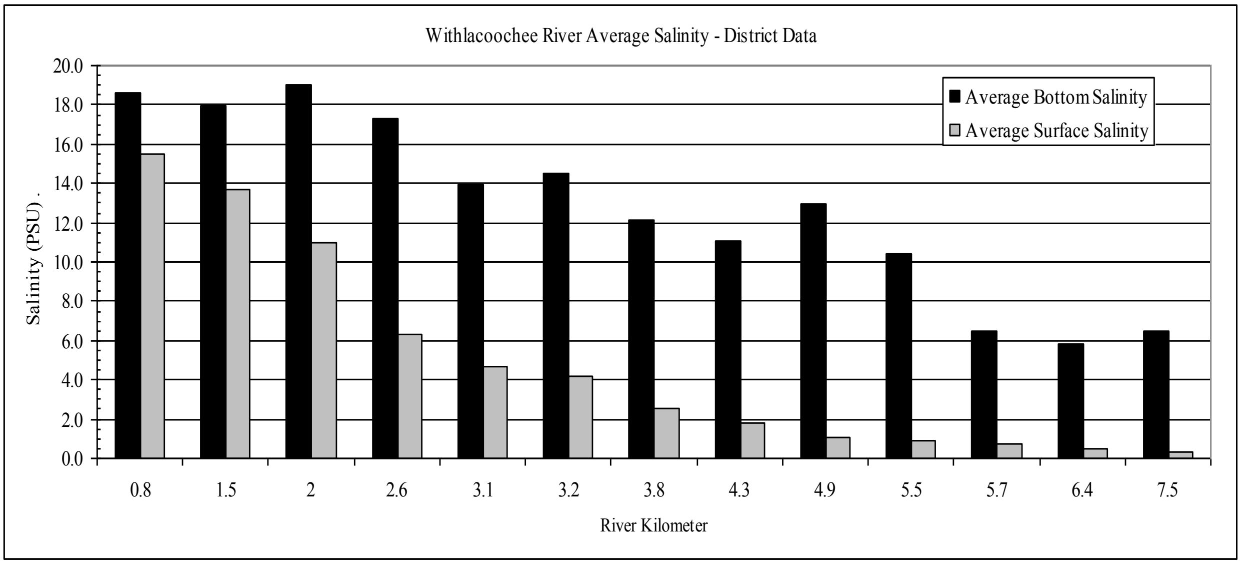


Figure 12. Average surface and near bottom salinity values for the lower Withlacoochee River recorded by the District.

III.4 Survey of Barnacles on Existing Hard Substrates

Basal diameters (BD) of the barnacles measured on hard substrates (pilings) in the rivers during the June 30 – July field trip are summarized in **Table 2**. Graphic representations of the data of Table 2 are shown in **Figures 13, 14 and 15,** ranked by the bottom salinity at each station on the sampling day. The largest barnacles on average were recovered from Kings Bay (16.81mm BD overall average) followed by the Withlacoochee (11.51 mm BD) and Homosassa Rivers (10.72 mm BD).

Table 2. Field measured barnacle basal diameters.

Field measured barnacle diameter										
Location (RK)	**Avg. Basal Diameter (mm)**	**St.Dev**		**Location**	**Avg. Basal Diameter (mm)**	**St.Dev**		**Location**	**Avg. Basal Diameter (mm)**	**St.Dev**
HR-9.35	11.76	4.02		WR-1.2	OC	OC		KB-1	12.88	4.35
HR-10.0	10.40	4.68		WR-2.3	OC	OC		KB-2	19.82	3.79
HR-10.55	12.04	3.63		WR-3.1	9.28	2.75		KB-3	26.32	4.37
HR-10.8	12.00	4.17		WR-4.1	np	np		KB-4	18.48	3.98
HR-11.2	13.56	6.96		WR-5.0	10.46	5.09		KB-5	13.32	4.39
HR-11.9	8.36	1.90		WR-6.0	12.83	4.12		KB-6	17.10	3.84
HR-12.3	4.56	1.58		WR-6.5	13.48	2.94		KB-7	np	np
HR-12.7	np	np		WR-6.7	np	np		KB-8	17.14	4.75
HR-12.6	np	np						KB-9	20.48	3.52
Halls 0.4	13.07	4.10						KB-10	6.36	2.10
								KB-11	16.26	3.26
								KB-12	18.48	3.94
								KB-13	14.02	2.72
								KB-14	20.80	4.37
								KB-15	13.84	2.28
All Mean:	10.72			All Mean	11.51			All Mean	16.81	
Notes: OC = oyster community, np = not present or no suitable substrate										

Table 3 presents the data for the counts of live and dead barnacles of the species *Balanus subalbidus* and *B. amphitrite* collected from the field scrapes of pilings. There is some undetermined error in these table values, since removing barnacles from an exact measured area underwater is difficult. Although *B. amphitrite* was observed in the Lower Withlacoochee during the March 18th reconnaissance trip, this species was only observed in the field scrape samples collected from the Homosassa River.

Overall, the greatest number of barnacles for a 100 cm sq area was recovered from HR-12.3 (303 barnacles / 100 cm^2). Areas where barnacles were not present (np) at two sites on the Homosassa, HR-12.7 and HR-12.6, two sites on the Withlacoochee WR-4.1 and WR-6.7 and one site in Kings Bay, KB-7. Graphic representation of barnacle counts for each station arranged from greatest to lowest salinity on the sampling days for the Homosassa River and Kings Bay are shown in **Figures 16** and **17**. Locations where very low numbers of barnacles were found are listed as <1. **Appendix Table 1** provides a list of other fauna that were associated with the barnacle scrape samples. Barnacle colonies serve as a structural basis for many other estuarine organisms.

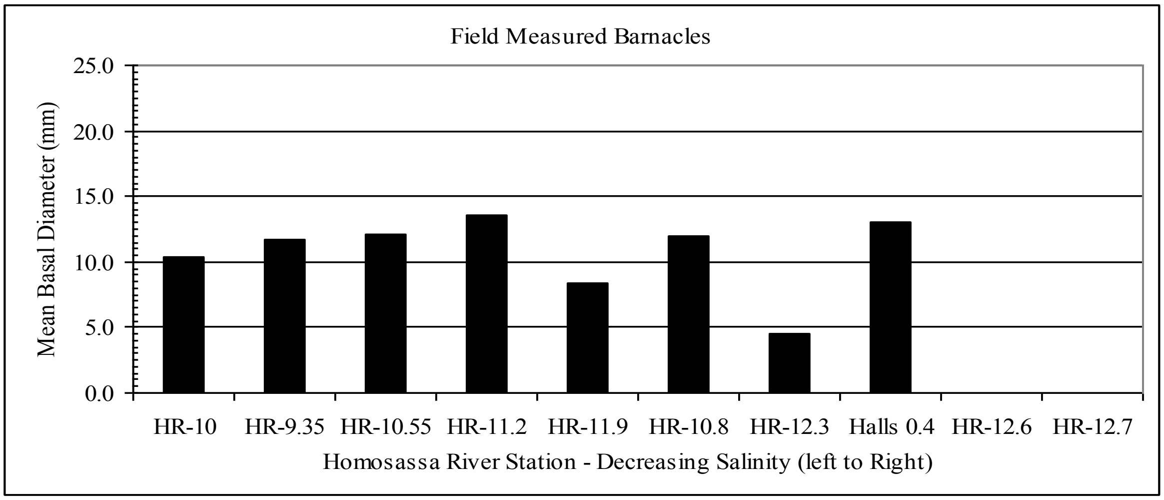


Figure 13. Mean basal diameter of barnacles in the Homosassa River.

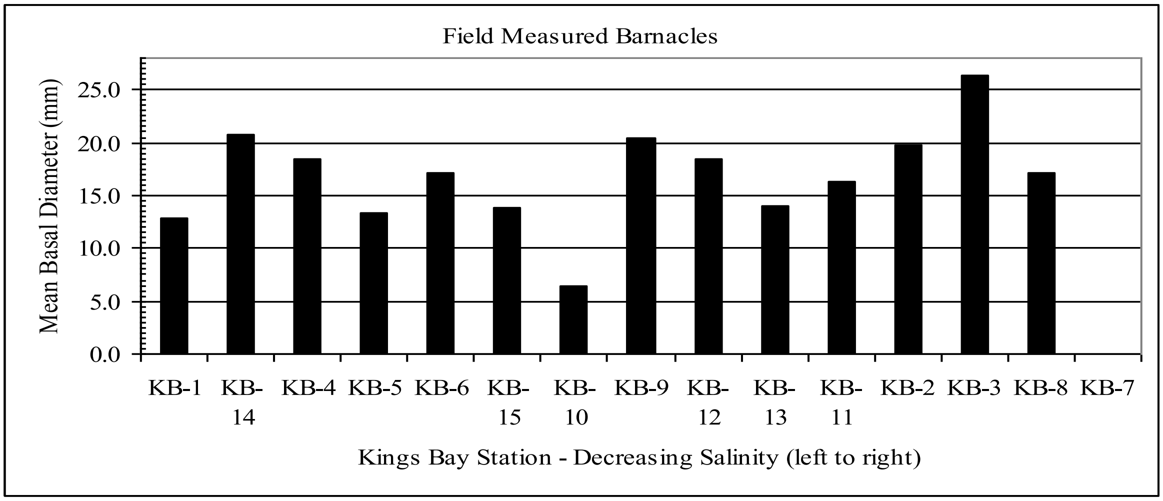


Figure 14. Mean basal diameter of barnacles in Kings Bay, Crystal River.

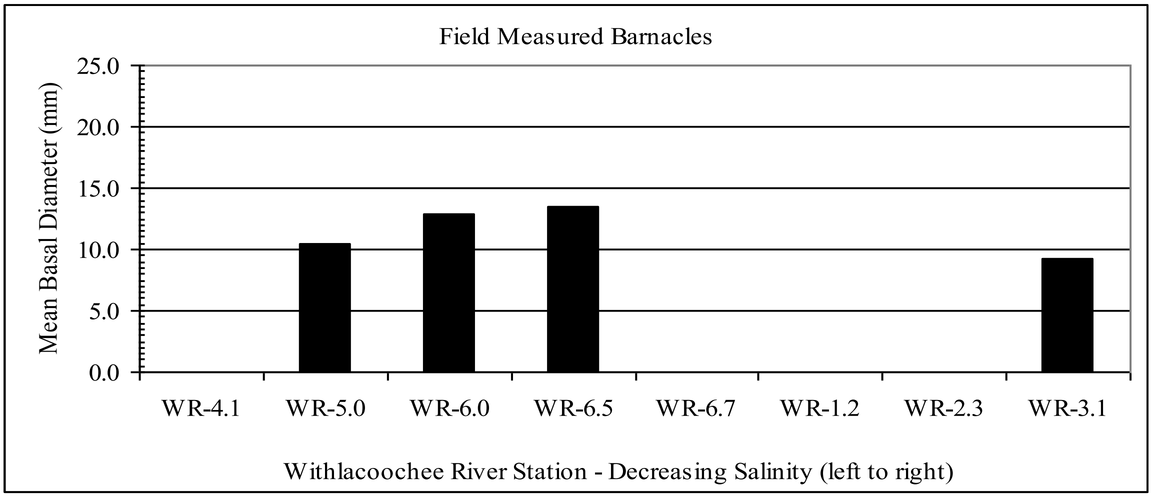


Figure 15. Mean basal diameter of barnacles in the Withlacoochee River.

Table 3. Barnacle counts for field scrape samples.

	***Balanus subalbidus* (count/100cm2)**				***Balanus amphitrite* (count/100cm2)**		
Station	**Live**	**Dead**	**Total**	**Live/Dead**	**Live**	**Dead**	**Total**
HR-9.35	162	13	175	12.5	0	0	0
HR-10	164	7	171	23.4	0	0	0
HR-10.55	107	17	124	6.3	0	0	0
HR-10.8	128	6	134	21.3	0	0	1
HR-11.2	144	22	168	6.5	0	0	0
HR-11.9	100	3	103	33.3	0	0	1
HR-12.3	303	9	312	33.7	1	0	1
HR-12.6	np	np	np	--	np	np	np
HR-12.7	np	np	np	--	np	np	np
Halls-0.4	143	2	145	71.5	0	0	1
KB-1	93	8	101	11.6	0	0	0
KB-2	47	0	47	--	0	0	0
KB-3	51	0	51	--	0	0	0
KB-4	114	20	134	5.7	0	0	0
KB-5	159	5	164	31.8	0	0	0
KB-6	145	11	156	13.2	0	0	0
KB-7	np	np	np	0.0	np	np	np
KB-8	78	15	93	5.2	0	0	0
KB-9	207	0	207	--	0	0	0
KB-10	26	0	26	--	0	0	0
KB-11	84	1	85	84.0	0	0	0
KB-12	93	6	99	15.5	0	0	0
KB-13	95	4	99	23.8	0	0	0
KB-14	47	2	49	23.5	0	0	0
KB-15	96	7	103	13.7	0	0	0
WR-3.1	239	12	251	19.9	0	0	0
WR-5.0	29	1	30	29.0	0	0	0
WR-6.0	<1	0	<1	0	0	0	0
WR-6.5	<1	0	<1	0	0	0	0
Total:	2,854	171	3,027	--	1	0	4

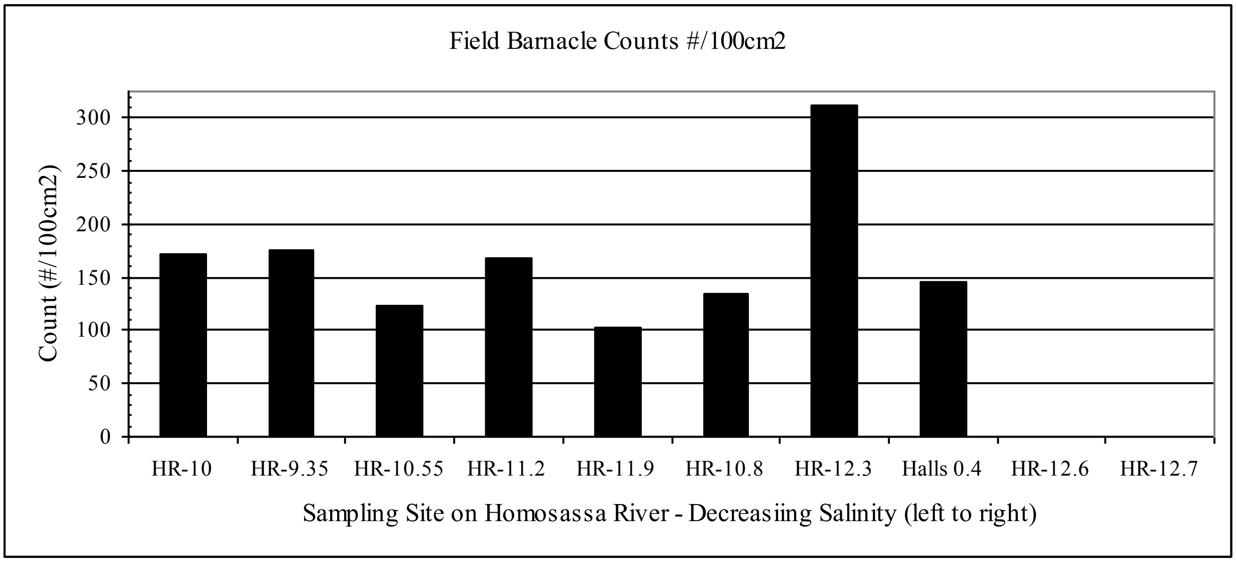


Figure 16. Total barnacle counts for the Homosassa River stations.

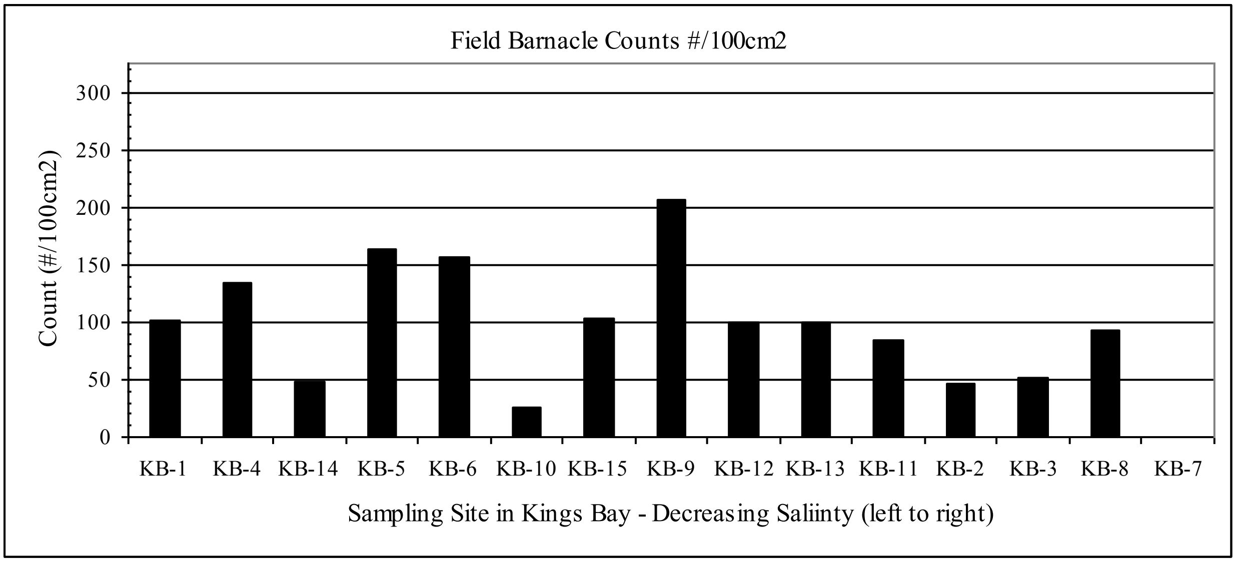


Figure 17. Total barnacle counts for the Kings Bay stations.

After measurement of barnacles, the field scrape samples were dried and combusted at ~525°C to determine the relative proportion of organic material versus organic shell material. **Table 4** presents the results of that analysis with the stations arranged in order of highest to lowest bottom salinity at time of collection. **Figures 18- 21** graphically illustrate the data of Table 5.

Table 4. Biomass values for 100 cm^2 scrape samples.

Station	**Bottom Salinity (PSU)**	**Surface Salinity (PSU)**	**Total Dry Weight (g/100cm2)**	**Volatile Solids (% loss on combustion)**	**Volatile solids (g/100cm2)**	**Inorganic (shell g/100cm2)**
HR-10	14.0	8.2	72.25	4.10	2.96	69.29
HR-9.35	13.4	10.7	17.01	4.37	0.74	16.26
HR-10.55	11.7	5.9	64.59	4.71	3.04	61.54
HR-11.2	9.7	2.4	58.89	6.37	3.75	55.14
HR-11.9	8.8	1.8	30.15	5.55	1.67	28.48
HR-10.8	7.9	5.4	27.88	6.82	1.90	25.98
HR-12.3	6.8	1.2	17.48	12.33	2.15	15.33
Halls-0.4	6.4	5.9	47.75	5.24	2.50	45.25
HR-12.6	2.4	1.0	np	np	np	np
HR-12.7	0.7	0.6	np	np	np	np
KB-1	4.8	6.1	82.10	3.36	2.76	79.34
KB-10	2.9	2.9	2.93	7.61	0.22	2.71
KB-9	2.7	2.8	123.32	4.80	5.92	117.40
KB-4	2.6	3.7	123.15	7.27	8.95	114.20
KB-5	2.5	3.6	95.18	3.01	2.86	92.31
KB-14	2.4	3.7	41.19	5.96	2.46	38.73
KB-11	2.0	2.5	42.95	3.17	1.36	41.58
KB-12	1.8	2.7	42.95	4.27	1.83	41.12
KB-15	1.8	2.9	90.54	3.17	2.87	87.66
KB-13	1.6	2.6	26.02	3.83	1.00	25.02
KB-6	0.9	3.4	102.53	3.19	3.27	99.26
KB-3	0.6	1.7	62.33	20.21	6.27	56.06
KB-8	0.5	0.8	65.87	4.42	2.91	62.96
KB-2	0.5	2.2	24.83	4.20	1.04	23.78
KB-7	0.2	0.2	np	np	np	np
WR-4.1	15.7	2.5	np	np	np	np
WR-5.0	14.5	1.4	12.77	4.53	0.58	12.19
WR-3.5	12.5	3.6	np	np	np	np
WR-4.5	14.2	2.0	np	np	np	np
WR-6.0	12.2	0.2	np	np	np	np
WR-6.5	10.7	0.2	np	np	np	np
WR-6.7	9.2	0.2	np	np	np	np
WR-1.2	9.1	8.1	np	np	np	np
WR-2.3	8.2	6.5	np	np	np	np
WR-3.1	5.2	4.7	43.97	2.77	1.22	42.75

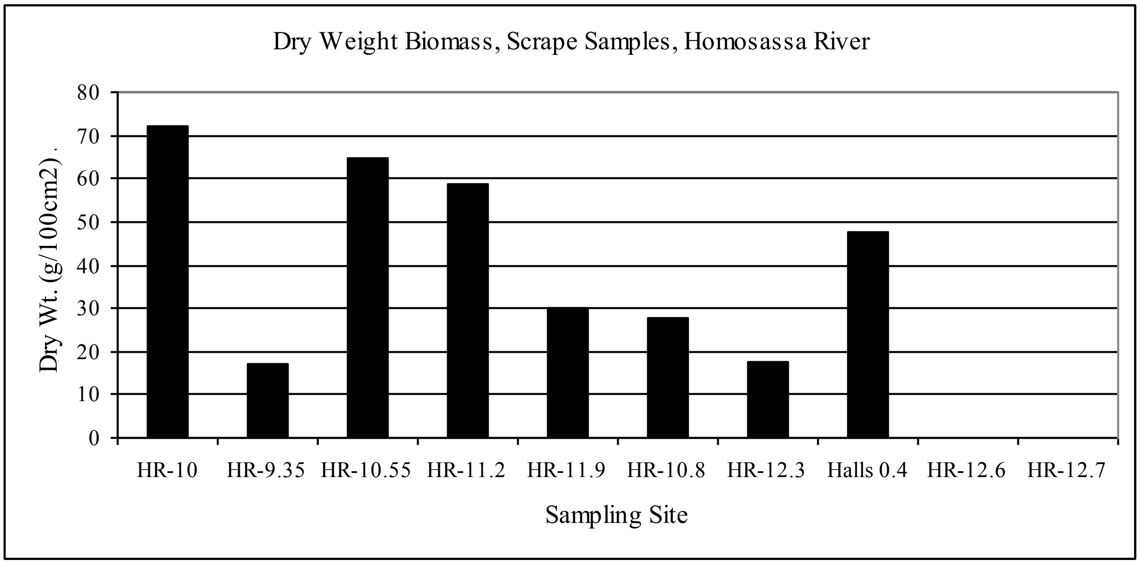


Figure 18. Dry weight biomass for barnacle community scrape samples arranged in order of highest to lowest observed field bottom salinity (L-R), Homosassa River.

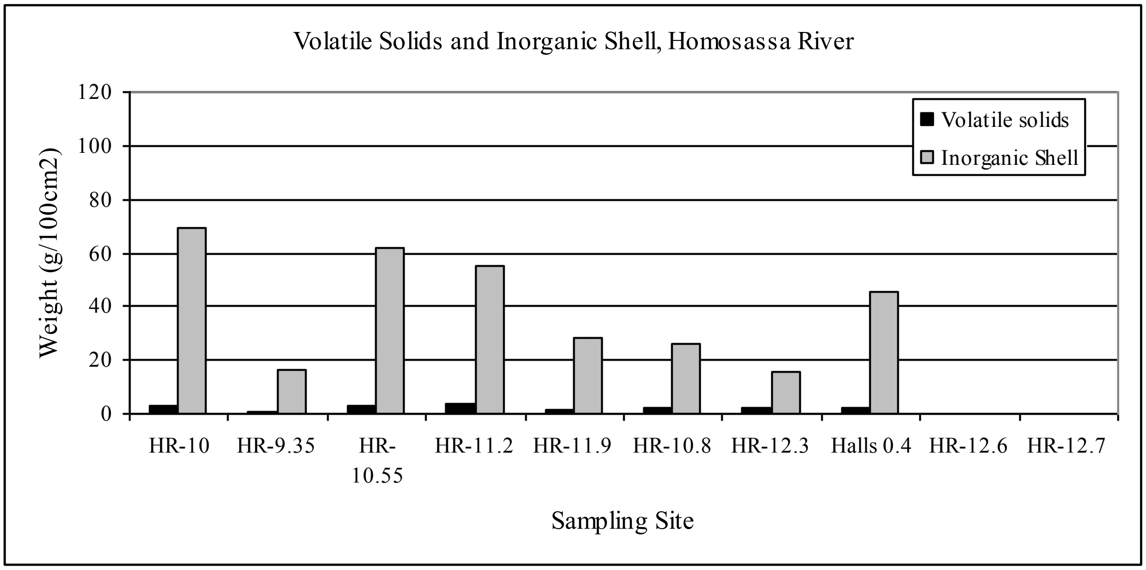


Figure 19. Volatile solids and inorganic shell for barnacle community scrape samples arranged in order of highest to lowest observed field bottom salinity (L-R), Homosassa River.

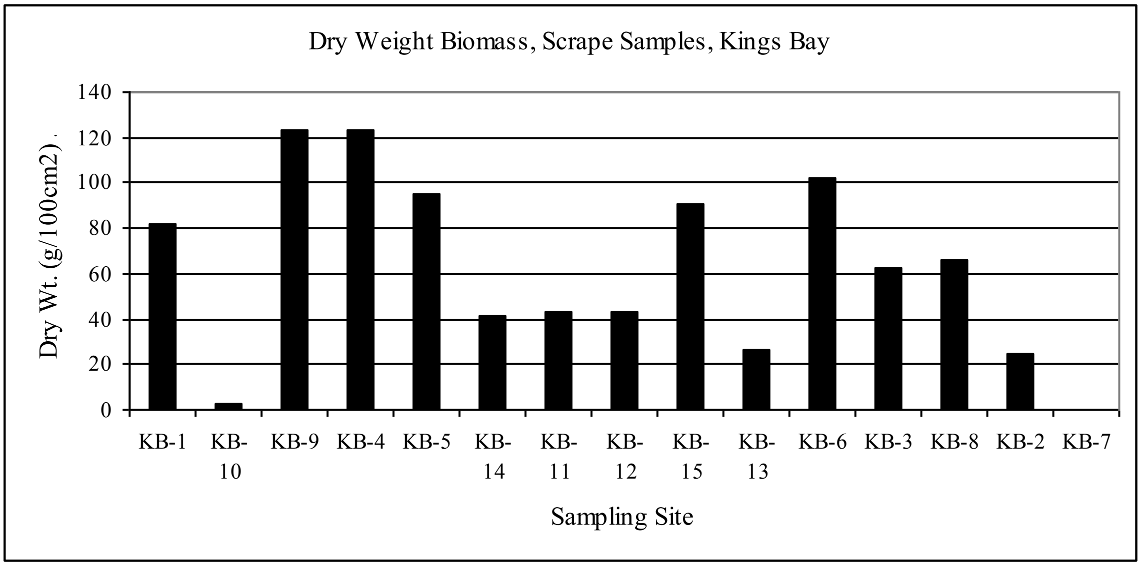


Figure 20. Dry weight biomass for barnacle community scrape samples, Kings Bay.

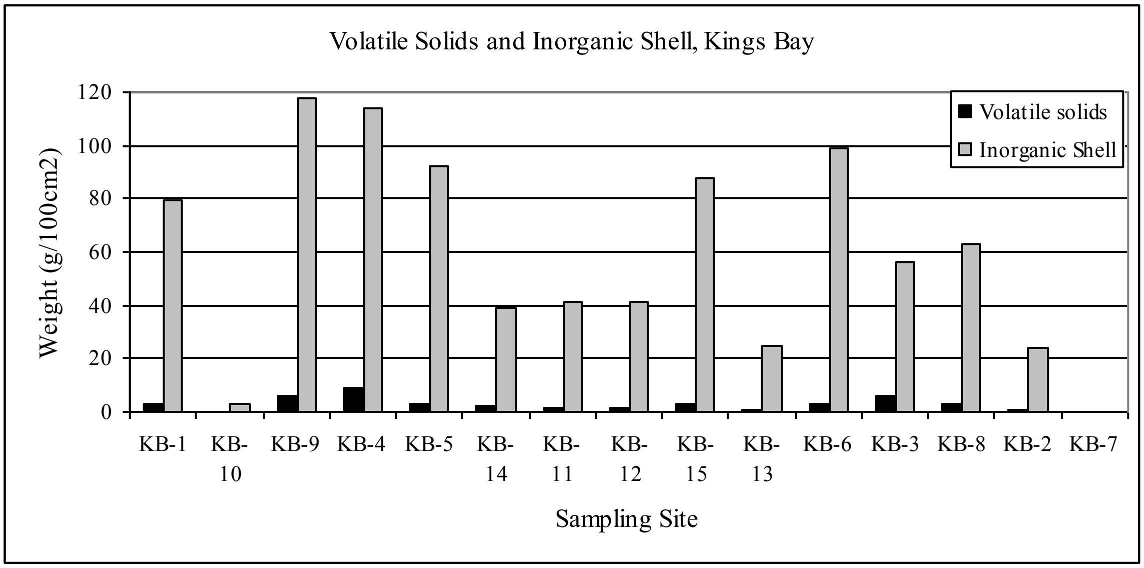


Figure 21. Volatile solids and inorganic shell for barnacle community scrape samples, Kings Bay.

III.5 Barnacle growth on Settlement Plates

During the field reconnaissance on March 18, 2009, artificial substrates were deployed at six locations among the three rivers. The substrates were subsequently retrieved on May 14th. **Table 5** summarizes the barnacle growth data for the resulting 57 day incubation period. Growth rates were estimated by dividing the maximum barnacle size by the total incubation period. The implied growth rates are subject to error since the exact time of settlement of the maximum sized barnacle could not be determined. The greatest growth rate was observed at Halls 0.9, which was located upstream of Halls 0.4. The slowest barnacle growth rates were observed at WR-6 and KB-1. **Figure 22** illustrates the size ranges of the barnacles that grew on the substrates over the same period. **Appendix Figures A1-A6** illustrates the graphs for the individual stations.

Table 5. Barnacle growth size ranges for the period March 18 - May 14, 2009.

Location	**Size (mm)** **Smallest**	 **Largest**	**Growth Rate (mm/day)**
HR-11.2	0.75	9.15	0.16
Halls 0.9	1.5	11.55	0.20
Halls 0.4	1.5	10.65	0.19
KB-1	0.45	4.5	0.08
KB-SW Buzzard Is.	0.3	6.3	0.11
WR-6.0 (WR-5)	0.9	4.35	0.08
Average	0.90	7.75	0.14
St. Dev	0.51	3.13	0.05
Coeff. Var.	0.57	0.40	0.40

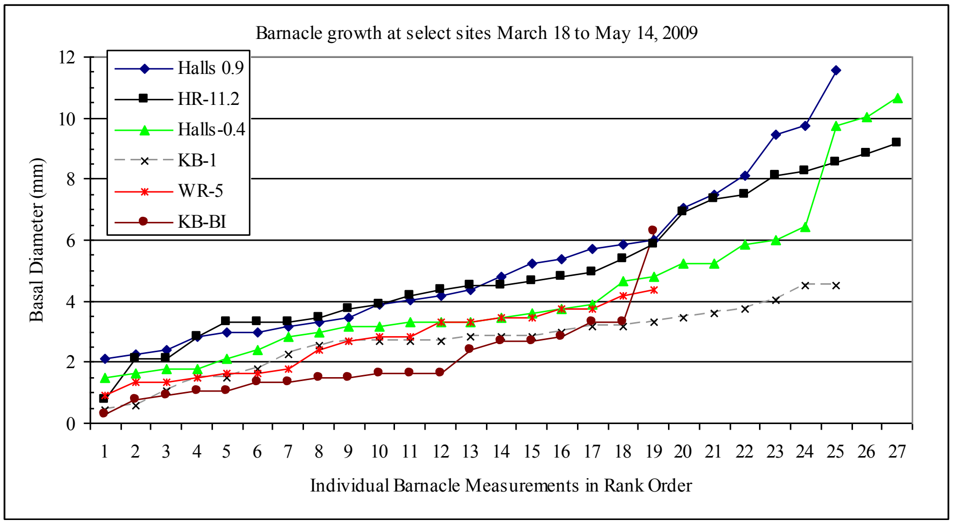


Figure 22. Barnacle basal diameters for 25 randomly picked barnacles for each artificial substrate plus the smallest and largest. Graph represents 6 sites with artificial substrate incubation period of 57 days, March 18 to May 14, 2009. Some sites had fewer than 25 barnacles.

A second set of artificial substrate settlement plates were deployed at thirty-five sites on May 14 and 15, 2009, including redeployment at four sites that were sampled by the first sampling period (sites Halls 0.9 and KB-SW Buzzard Island in Table 6 were deployed only once). The settlement plates were retrieved between June 29 -July 2, resulting in incubation periods of 46 to 48 days. For substrates that exhibited more than 25 barnacles, 23 randomly chosen barnacles were measured. In addition, the largest and smallest barnacles on the plate were measured for a total of 25 measures.

Results for laboratory measurements of basal diameters are shown in **Table 6,** together with the surface and bottom salinity measured on the date of retrieval and average salinity values for nearby stations recorded by the District. The station order is arranged from highest to lowest surface salinity at time of sampling, since barnacles typically are most abundant in the intertidal zone. Bottom salinity is also listed and at some sites there was considerable difference in surface and bottom salinity, possibly due to the very high tide on that day. This somewhat confounds the issue of barnacle distribution as related to salinity, particularly in shallow areas such as Kings Bay and portions of the Homosassa River.

There appeared to be a fairly clear lower surface salinity limit for settlement of barnacles at approximately 2.0 PSU. This relationship was most evident in Homosassa River, but not quite as clear in Kings Bay, where two artificial substrates exhibited significant number of barnacles at salinity values at or below 2.0 PSU (stations KB-11 and KB-6). However, a general pattern was found as there were no barnacles recorded at six or the eight sites which had salinity values of less than or equal to 2.0 PSU.

The settlement of barnacles is not only related to salinity. The relatively low numbers of barnacles found on the settling plate of KB-1 was likely due to very heavy colonization of the plate by tube building amphipods which clearly had an inhibitory effect on the colonization by barnacles (**Figure 23).** The artificial substrate located at KB-6 had a significant number of barnacles and bottom salinity was considerably greater than the surface salinity. The plate at this site had a coating of green filamentous algae, but barnacles were able to colonize the plate (**Figure 24)**.

An unexpected barnacle occurrence was at site KB-15, located at the deep spring vent in Kings Bay described as site 32 known as Hammett 16/King Spring/Grand Canyon Spring (VHB 2009) near the south-east side of Banana Island. This is the area that is typically marked off as a no entry zone for manatee protection during the winter months. We did not originally plan to sample this location as it was assumed that the spring flow would inhibit colonization of barnacles on the limestone. However, on July 2 we examined the vent which did not show any indication of significant water flow. Barnacles were found at this location extending down the limestone walls and into the cave. Barnacles were subsequently measured and a scrape sample was obtained. **Figure 25** illustrates barnacles growing on the walls inside the cave. Small calcareous polychaete tubes were also present. These tube dwelling polychaetes of Family *Serpulidae* have also been observed on the walls of offshore karst features and are believed to subsist on sulfur reducing bacteria associated with the sulfur cycling at the oxic / hypoxic interface.

Table 6. Barnacle growth on artificial substrates for periods from May 14 or May 15, 2009, to June 29 through July 2, 2009, with incubation periods ranging from 46 to 48 days.

Station ID	Number Barnacles	Avg. Basal Diameter (mm)	Salinity on Sampling Day		Average Salinity Values From District	
			Surf	Bottom	Top meter	Near Bottom
HR-9.35	>25	5.08	10.7	13.4	3.9	4.6
HR-10	>25	5.57	8.2	14.0		
HR-10.55	>25	4.27	5.9	11.7		
Halls-0.4	>25	6.85	5.9	6.4	2.9	4.4
HR-10.8	>25	5.05	5.4	7.9	2.8	3.1
HR-11.2	>25	5.32	2.4	9.7		
HR-11.9	0	--	1.8	8.8		
HR-12.3	0	--	1.2	6.8	1.6	2.4
HR-12.6	0	--	1.0	2.4		
HR-12.7	0	--	0.6	0.7	0.5	0.5
			Surf	**Bottom**	**Top meter**	**Near Bottom**
KB-1	11	4.79	4.8	6.1	4.0	5.1
KB-10	13	10.53	2.9	2.9	1.9	2.0
KB-9	23	7.46	2.7	2.8	2.1	2.2
KB-4	>25	7.00	2.6	3.7	2.1	2.9
KB-5	>25	6.81	2.5	3.6	2.1	2.9
KB-14	2	8.18	2.4	3.7	2.0	2.3
KB-11	8	8.57	2.0	2.5	1.7	2.3
KB-12	0	--	1.8	2.7	0.9	0.9
KB-15	NA	--	1.8	2.9	1.8	2.5
KB-13	0	--	1.6	2.6	1.1	1.2
KB-6	24	7.02	0.9	3.4	1.4	1.7
KB-3	0	--	0.7	1.7	0.6	0.9
KB-8	0	--	0.5	0.8	----	----
KB-2	0	--	0.5	2.2	0.7	0.9
KB-7	0	--	0.2	0.2	0.6	0.7
			Surf.	**Bottom**	**Top meter**	**Near Bottom**
WR-1.2	>25	5.43	8.1	9.1	13.7	18.0
WR-2.3	>25	3.44	6.5	8.2	11.0	19.0
WR-3.1	18	3.77	4.7	5.2	4.7	14.0
WR-4.1	0	--	2.5	15.7	2.5	12.1
WR-3.5	1	3.75	2.2	12.5	4.2	14.5
WR-5.0	0	--	1.4	14.5	1.0	12.9
WR-4.5	0	--	0.9	14.2	1.8	11.1
WR-6.0	0	--	0.2	12.2	0.8	6.5
WR-6.5	0	--	0.2	10.7	0.5	5.8
WR-6.7	0	--	0.2	9.2	------	-----

Figure 23. Artificial substrate from Site KB-1 illustrating thick amphipod coverage.

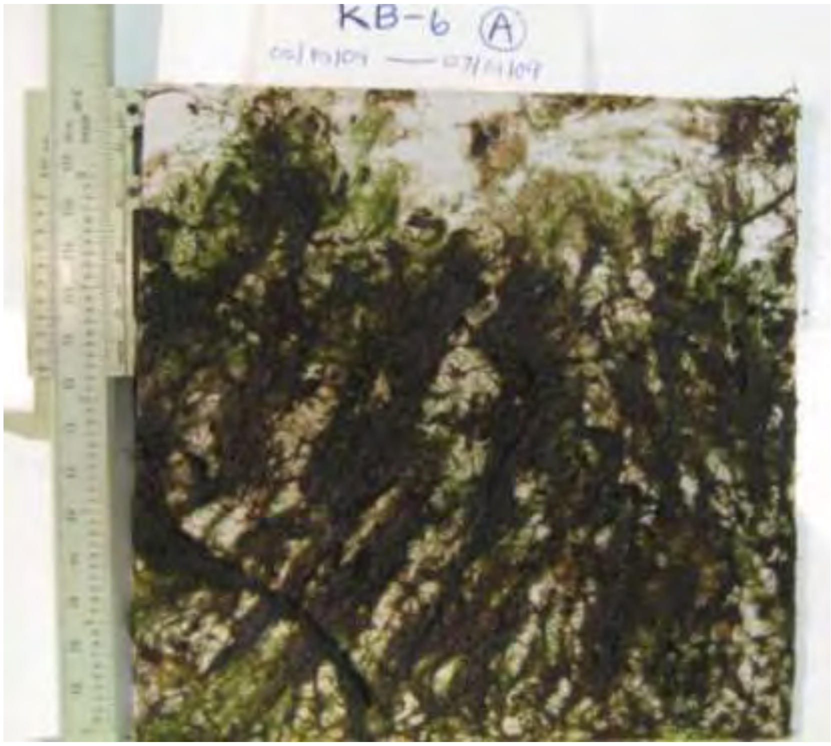


Figure 24. Artificial substrate from Site KB-6 illustrating algae and barnacles.

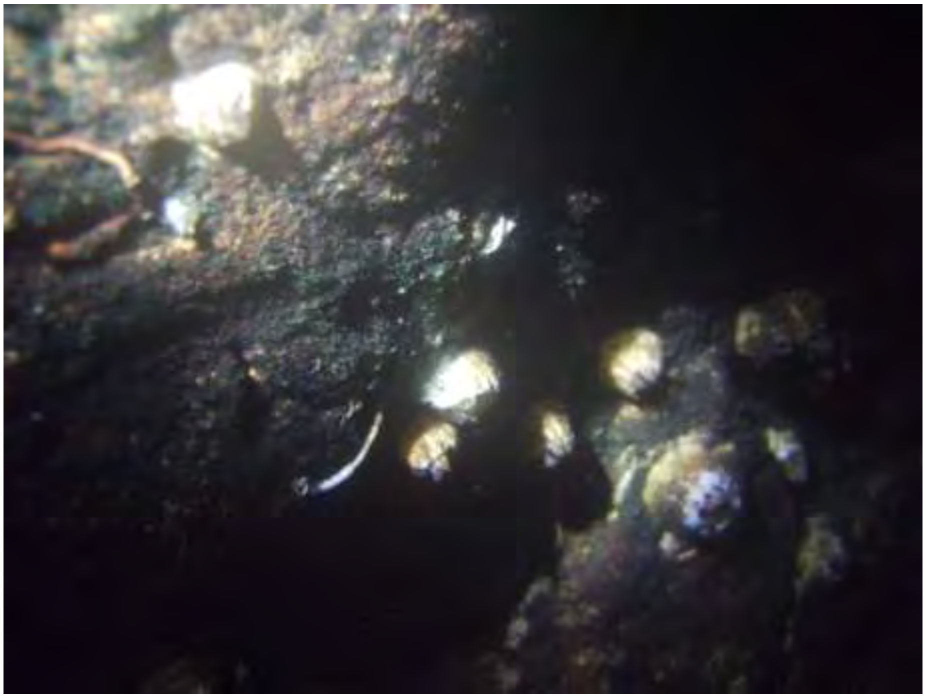


Figure 25. Barnacles growing in the cave of the Hammett 16 spring vent, KB-15. Note the small tube like structures which are the calcareous tubes of polychaete worms.

Biomass on Artificial Substrates

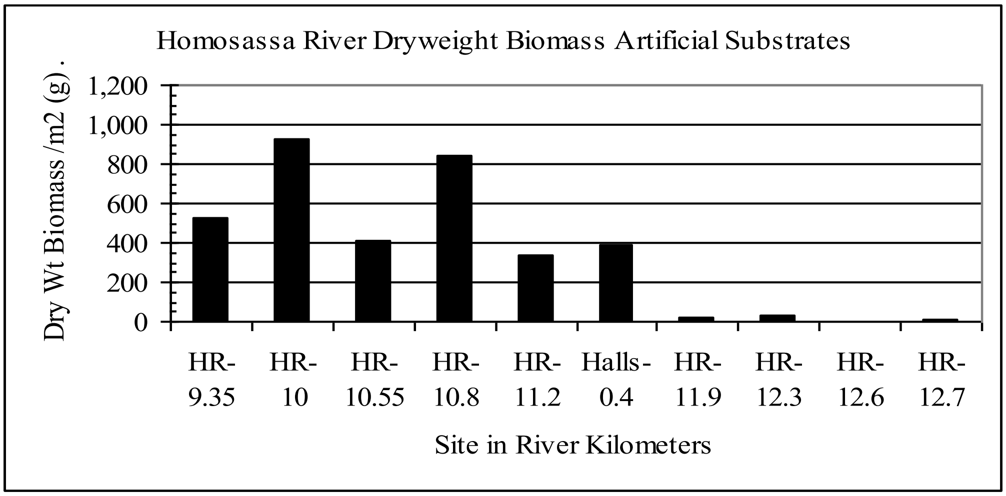
Biomass values for the settlement plates are shown in **Table 7** with the station data arranged in order of decreasing bottom salinity for each river. Graphic representations of dry weight (grams/m^2) and percentage volatile solids are shown as **Figures 26 - 31**. Overall, the Homosassa River exhibited the greatest dry weight biomass and the most discernable trend as related to salinity. The five of most downstream sites on the Homosassa River and the Halls river site exhibited dry weight biomass greater than 340 grams/m^2. However, all sites located upstream of kilometer 11.9 (station HR-11.9) had biomass values less than 30 grams/m2.

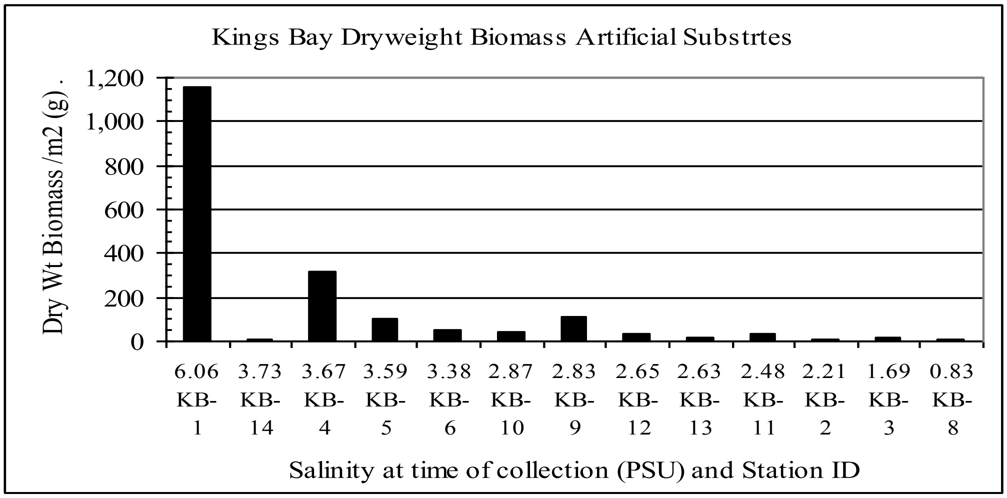
Site K-1 in Crystal River downstream of Kings Bay had a dry weight biomass of 1,160 grams/ m^2, but the majority of sites (10 of 15) in Kings Bay had dry weight biomass values of less than 100 grams/ m^2. Values over 100 grams/m^2 were observed at sites K4, K5, and K9, all of which are near the western side of Kings Bay, which is typically more brackish than the eastern side. The Withlacoochee River also exhibited one site with a very high biomass (WR-1.2) with a dry weight value of 815 grams/ m^{2,} , but all other sites had biomass values of less than 110 grams/ m^2. There was no apparent relationship between dry weight biomass and volatile solids as shown in **Figure 32**. The lack of any relationship between these parameters is the result of the differing biological communities found on the substrates from each area.

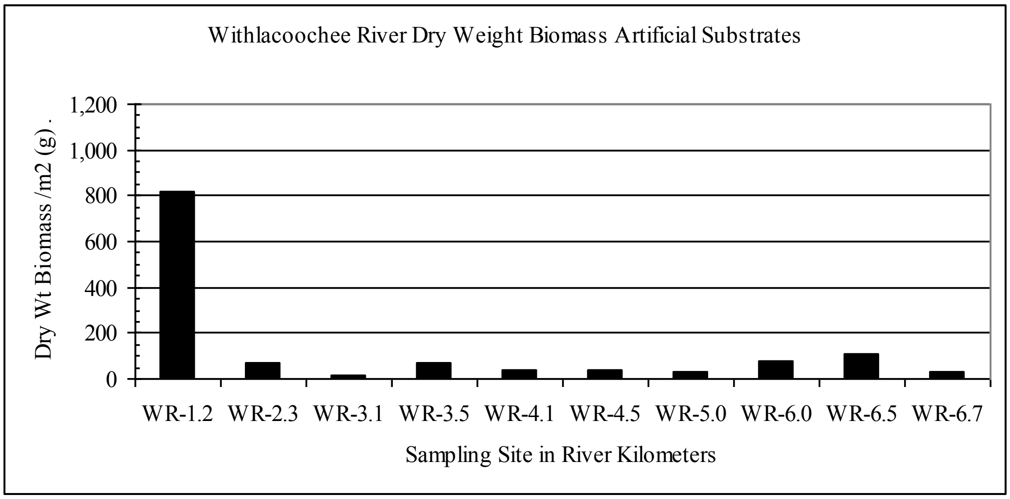
Ash weight primarily represents the quantity of barnacle and mollusk shell present in each sample. **Figures 33**, **34** and **35** are plots of the grams of shell produced per square meter of substrate for each river. Of the 10 sites sampled within the Homosassa River six showed shell of greater than or equal to 299 grams per square meter. In contrast most of the stations within Kings Bay and the Withlacoochee River had an ash shell component far below 299 grams per square meter with the notable exceptions of stations KB-1 and WR-1.2.

Table 7. Biomass measures for artificial substrates placed in each river.

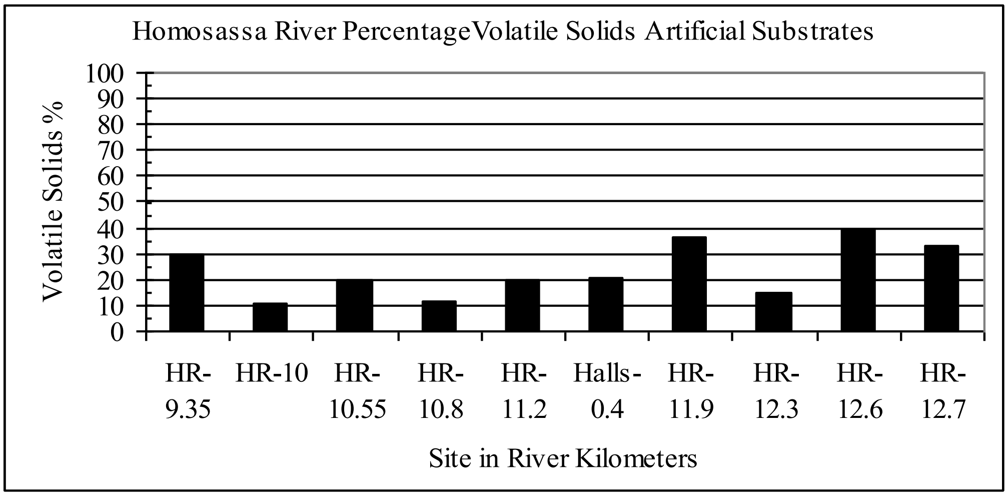
River and Station	Surface Salinity (PSU)	Bottom Salinity (PSU)	Dry Wt. Biomass g/m2	Volatile Solids %	Volatile Solids g/per m2	Ash % Barnacle shell	Ash (Barnacle shell) g/m2
HR-9.35	10.7	13.4	522	29.5	140	70.5	382
HR-10	8.2	14.0	923	10.7	97	89.3	826
HR-10.55	5.9	11.7	406	20.2	73	79.8	333
HR-10.8	5.4	7.9	845	11.4	111	88.6	734
HR-11.2	2.4	9.7	341	19.9	43	80.1	299
Halls-0.4	5.9	6.4	392	20.9	52	79.1	340
HR-11.9	1.8	8.8	24	36.3	11	63.7	13
HR-12.3	1.2	6.8	29	14.8	5	85.2	24
HR-12.6	1.0	0.7	4	39.6	1	60.4	3
HR-12.7	0.6	2.4	14	33.4	4	66.6	9
KB-1	4.8	6.1	1,160	58.3	446	91.7	713
KB-10	2.9	2.9	43	28.8	5	71.2	38
KB-9	2.7	2.8	113	24.9	19	75.1	94
KB-4	2.6	3.7	321	12.3	41	87.7	281
KB-5	2.5	3.6	100	28.2	20	71.8	79
KB-14	2.4	3.7	11	34.2	4	65.8	7
KB-11	2.0	2.5	33	31.6	11	68.4	22
KB-12	1.8	2.7	36	30.5	11	69.5	25
KB-13	1.6	2.6	19	44.9	6	55.1	13
KB-6	0.9	3.4	54	39.8	20	60.2	34
KB-3	0.6	1.7	15	30.6	4	69.4	12
KB-8	0.5	0.8	10	65.4	7	34.6	2
KB-2	0.5	2.2	8	28.7	2	71.3	5
KB-7	0.2	0.2	0	0.0	0	0.0	0
WR-4.1	2.5	15.7	41	40.8	17	59.2	24
WR-5.0	1.4	14.5	33	24.5	8	75.5	24
WR-4.5	2.0	14.2	37	67.8	26	32.2	11
WR-3.5	3.6	12.5	70	34.6	24	65.4	45
WR-6.0	0.2	12.2	76	4.0	6	46.0	70
WR-6.5	0.2	10.7	109	48.3	10	51.7	99
WR-6.7	0.2	9.2	28	28.5	10	71.5	19
WR-1.2	8.1	9.1	815	6.7	58	93.3	757
WR-2.3	6.5	8.2	73	25.6	19	74.4	54
WR-3.1	4.7	5.2	12	15.0	2	85.0	10

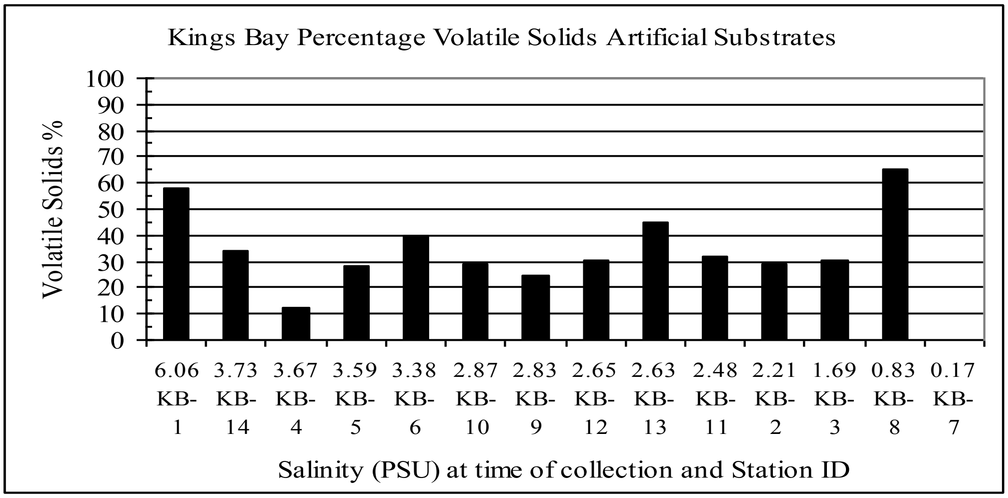


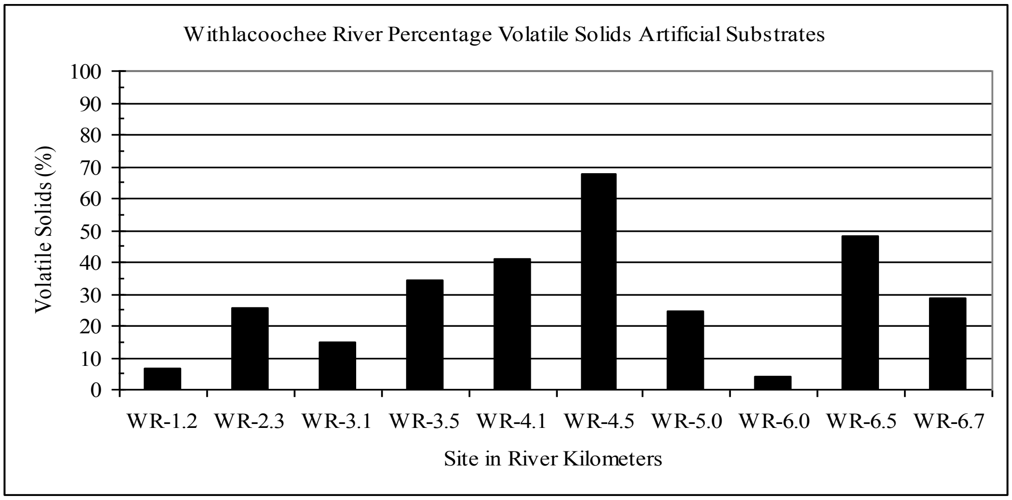




Figures 26, 27 and 28. Dry weight biomass for each river system artificial substrate samples.







Figures 29, 30 and 31.Percentage volatile solids for the three rivers, artificial substrate samples.

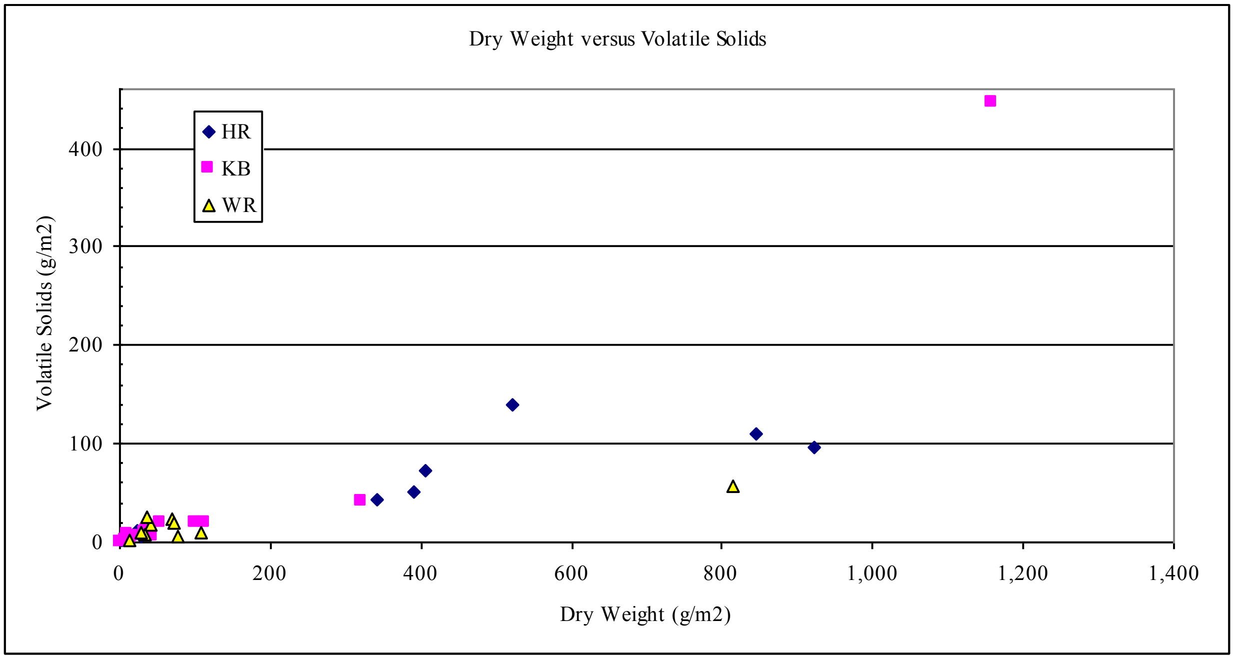
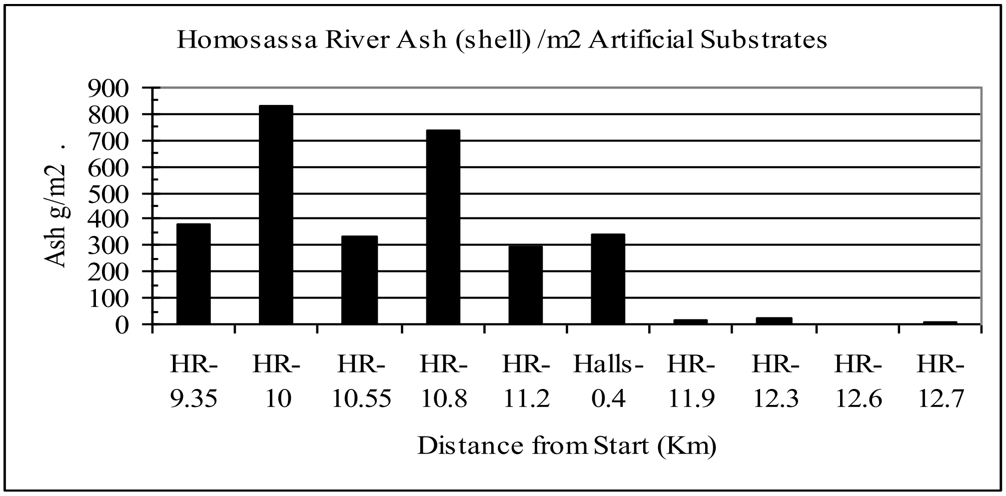
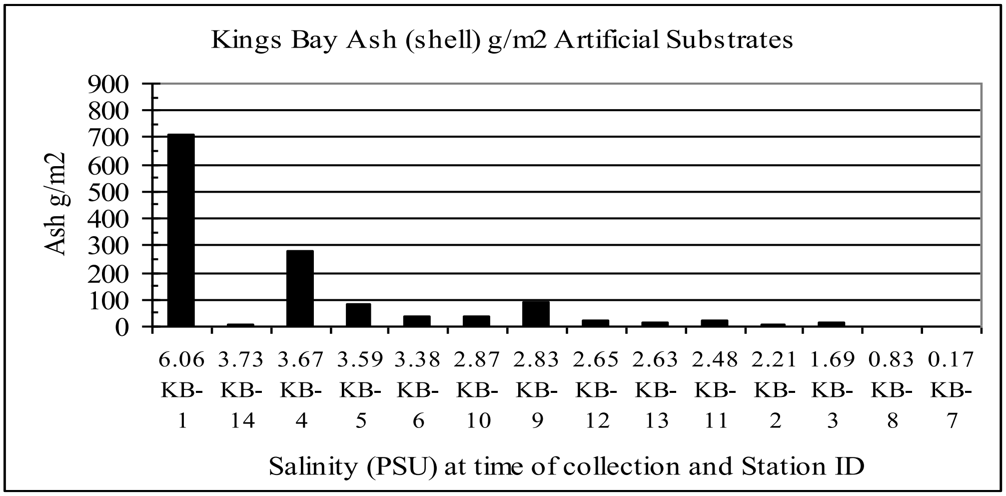
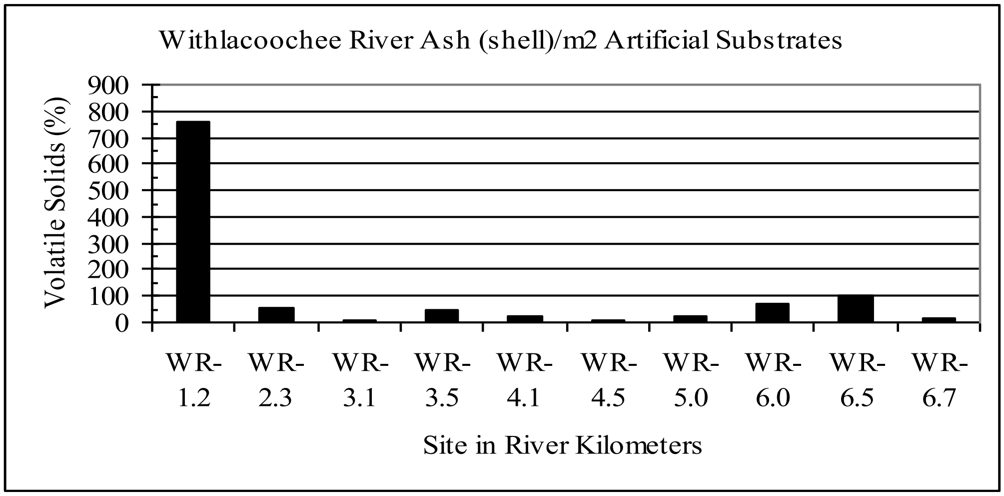


Figure 32. Plot of dry weight (grams/m^2) versus volatile solids (grams/m^2) for artificial substrate data from all three rivers.







Figures 33, 34 and 35. Ash (shell) content of artificial substrate samples for the three rivers.

IV. SUMMARY AND DISCUSSION

From March to July 2009 a series of visits were made the tidal portions of the Homosassa, Crystal and Withlacoochee Rivers on the Florida Gulf coast. The objective was to investigate and map the distribution of barnacles in these three systems, focusing on the upstream tidal freshwater and low salinity areas of the rivers. The barnacle populations in higher salinity downstream areas were not sampled. In all likelihood, barnacle populations in the farther downstream areas are more widespread and dense.

Site observations were supplemented with quantitative data describing the relative density and biomass of the barnacle communities in the three river systems. There were some patterns observed in each of the three rivers. The data from the deployment of settlement plates suggests that salinity lower than ~2.0 PSU may have an inhibitory effect on barnacle settlement. However, barnacles were present at a few sites with salinity values lower than 2.0 PSU, although not in great abundance. The implication is that once settled and growing, barnacles may be able to tolerate very low levels of salinity. Total time duration to exposure to low salinity may also be an important factor for barnacle survival. During the final site visits on June 29 through July 2, a very high tide illustrated that there is significant salt water incursion along the bottom that would otherwise under more normal tides would be much more oligohaline.

In the Homosassa River the barnacle community extended upstream to a point bordered by the main spring run into the river. The fresh water flowing from the shallow spring run is adequate to keep barnacles from penetrating further upstream, but brackish water conditions were observed in the deeper parts of the river. In the upper reaches of the river the barnacle communities do not occur in the intertidal zone; rather, they are restricted to the near bottom zone which could be characterized as a salinity tide.

In the Withlacoochee River the upstream confinement of barnacles to a near-bottom higher salinity zone was more pronounced. In the Withlacoochee the barnacles were located so deep in the upriver areas that they were not observed during the reconnaissance survey when intertidal and subtidal areas were inspected. As for the Homosassa River, barnacles in the upper reaches of the Withlacoochee survey area seem to be limited by the vertical extent of the bottom salinity tide.

In Kings Bay the distribution of barnacles seems to be more complex, but they are generally found throughout the entire bay and were found at every sampling site with the exception of KB-7 where freshwater spring flow was still significant. As noted earlier, *B. subalbidus* is known to be a self fertilizing hermaphrodite. This capability enhances the ability of this barnacle to colonize new areas where the presence of adjacent individuals is not necessary. Perhaps the most surprising area where barnacles were found was the large spring vent known as Hammett 16, where barnacles were discovered inside the cave of this once-flowing vent. At the time of this inspection, the water clarity of the area was very poor with a strong green color due to phytoplankton and an abundance of filamentous green algae which covered most of the bottom in this area. High primary production may be a factor in the maintenance of the robust barnacle population. Typically spring water is depauperate in organic particulates that could serve as barnacle food. Visibility in the area over Hammett 16 was less than 6 feet at the time of the survey compared to visibility of greater than 30 feet (surface to bottom) when the spring was actively flowing (author's personal observation). The large quantities of filamentous algae growing in the southeastern portions of the bay are a strong indication of eutrophication. There was also a paucity of fish and crabs that in years past were abundant at this site (Culter personal observation). There is the possibility that a reduction in euryhaline barnacle grazing species such as Sheepshead (fish) and crabs could be contributing to an overall increase in barnacle populations.

The longevity of barnacles in the three systems that were surveyed is unknown. The settling plate data showed that barnacles were growing up to 12.6 mm basal diameter within 48 days and are likely reproductive within that period. A study of intertidal populations of *B. amphitrite* in Australia estimated a mean longevity to be 22 months and a maximum age of 5-6 years (Calcagno et al 1998). Thus it is quite possible that barnacles that settle as a result of optimal salinity conditions may persist for a number of years in the absence of any new recruitment episodes.

The presence of man-made hard substrates within Kings Bay may also play a role in the maintenance of barnacle populations. All of the substrates sampled for this project were man-made. Although most of the pilings for sings and navigation markers were wood, they are fixed in place and are pressure treated thus not able to rot in a natural process. Natural tree deadfall in Kings Bay is very limited. In the Withlacoochee River natural wood was examined for barnacles but no suitably colonized materials could be located. Natural wood in these systems does not seem to provide a suitable substrate for barnacles perhaps because the normal rotting process makes natural wood too soft and prone to sloughing off surface layers. Oddly most of the sea walls that were inspected did not exhibit robust barnacle populations, but this may have been an observational oversight as pilings and floating docks were targeted in the surveys after having been determined that these were optimal barnacle settling sites.

Having determined that the barnacle colonization in the Homosassa River and Kings Bay are prevalent in all but the most oligohaline sections, what is the future prognosis? The short term condition of these areas as to whether Crystal River and Homosassa / Halls Rivers will continue to biologically function as rivers with both tidal freshwater and estuarine zones depends on spring flows and surface freshwater inflows. If freshwater flows decrease, the Homosassa and Crystal Rivers will become more estuarine in nature and could ultimately reduce the historic freshwater areas to small refugia around the individual spring vents that continue to flow. The fact that barnacles and associated estuarine fauna were nearly ubiquitous in the main channel of the Homosassa River and the open basin of Kings Bay, illustrates the freshwater flows during and preceding the field work of this project were not sufficient to maintain predominantly freshwater faunal characteristics in many upstream areas of those rivers

For the Withlacoochee River, the estuarine zone will migrate upriver somewhat, depending on river flows although the process would presumably occur at a much slower rate since the size of the drainage basin is much larger than the Crystal and Homosassa Rivers. The other invertebrates associated with the barnacle communities from the artificial substrates illustrate a "typical" estuarine fauna, complete with polychaetes and a robust microcrustacean fauna, particularly amphipods and isopods.

The long term biological condition of these areas will be tied to sea-level change, for which spring flow would have to increase to maintain the status quo. Increases in sea-level are consistent with robust data that illustrate average global increases in temperature. Global average sea-level rose at an average rate of 1.8 mm per year over 1961 to 2003 and at an average rate of about 3.1 mm per year from 1993 to 2003. Whether this faster rate for 1993 to 2003 reflects decadal variation or an increase in the longer term trend is unclear. Since 1993 thermal expansion of the oceans has contributed about 57% of the sum of the estimated individual contributions to the sea-level rise, with decreases in glaciers and ice caps contributing about 28% and losses from the polar ice sheets contributing the remainder (IPCC 2007).

A recently published analysis suggests that a sea level rise of 75 to 190 cm for the period 1990–2100 is probable (Vermeera and Rahmstorf 2009). The authors point out that observed sea-level rise exceeded that predicted by models (best estimates) by ≈50% for the periods 1990–2006 and 1961–2003. The increase modeled by Vermeera and Rahmstorf is considerably greater than the 1993-2003 average annual rates (3.1 mm/year) which if applied linearly to the next 90 years would result in an approximate 28 cm sea-level rise.

A recent graphic constructed by NOAA of the monthly mean sea level for the Cedar Key area without the regular seasonal fluctuations due to coastal ocean temperatures, salinities, winds, atmospheric pressures, and ocean currents is shown as **Figure 37**. The long-term linear trend is also shown, including its 95% confidence interval. The plotted values are relative to the most recent Mean Sea Level datum established by CO-OPS. The current rate of seal level increase is and 1.80 mm/year for Cedar Key and 2.36 mm/year for St. Petersburg. These observed rates for historical data are less than the projected rate of annual increase suggested by Vermeera and Rahmstorf.

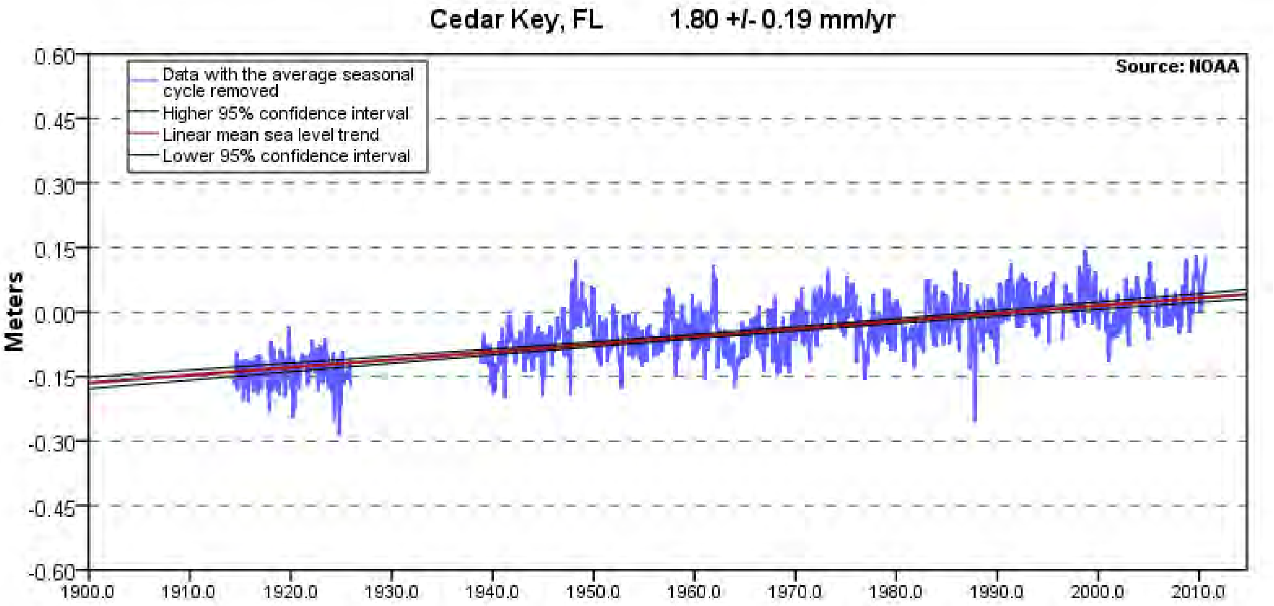


Figure 36. Current rate of sea level rise as constructed by NOAA based on of the monthly mean sea level for the Cedar Key water level tide monitoring station.

Regardless of the model that one chooses to use for planning, it seems certain that sea-level will continue to rise and the time frame where significant coastal alterations of natural systems will manifest is now within a human lifetime. Even small increases in sea-level will increase the frequency of salt wedges pushing into former freshwater and oligohaline areas of tidal river systems. The use of biological remains as indicators of Biological Mean Sea Level Indicators (BMSIs -Laborel et al., 1994) dates back to the 1950's (Donner 1959). The accuracy of such determinations by BMSIs has generally been between 5 and 20 centimeters, suitable for geologic determinations of sea level rise and fall. Comparatively the documented incursion of barnacles into the shallow tidal runs of coastal springs may be a first indicator of persistent biological changes that will accompany sea level rise.

Unless freshwater spring discharges increase to keep pace with sea-level rise, the Homosassa and Crystal Rivers will be altered to an estuarine condition with only small pockets of freshwater communities around spring vents of significant flow. In fact, such an alteration is now in progress as a probable result of long term reduced rainfall and reduced spring flows. During this survey the only section of Kings Bay that was notably absent of barnacles was the spring run upstream of KB-7. Even at KB-7 there were a few barnacles on a nearby PVC pipe and a floating dock. The barnacle based fouling community is evidence that estuarine fauna are presently invading these areas. The presence of barnacles and calcareous tube dwelling polychaetes within a cave of a once flowing spring are dramatic evidence of a shift in the biological community.

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Vermeer, M., Rahmstorf, S. Global sea level linked to global temperature**.** *Proceedings of the National Academy of Sciences*, 2009; DOI: 10.1073/pnas.0907765106

ON-LINE RESOURCES

Crystal River
http://www.protectingourwater.org/watersheds/map/springs_coast/
http://en.wikipedia.org/wiki/Crystal_River_(Florida)
http://www.floridacaves.com/crystalriver.htm

Homosassa River
http://www.protectingourwater.org/watersheds/map/springs_coast/

Withlacoochee River
http://www.protectingourwater.org/watersheds/map/withlacoochee/
http://en.wikipedia.org/wiki/Withlacoochee_River_(Florida)
http://www.amyhremleyfoundation.org/php/education/features/CoastalRivers/Withlacoochee.php

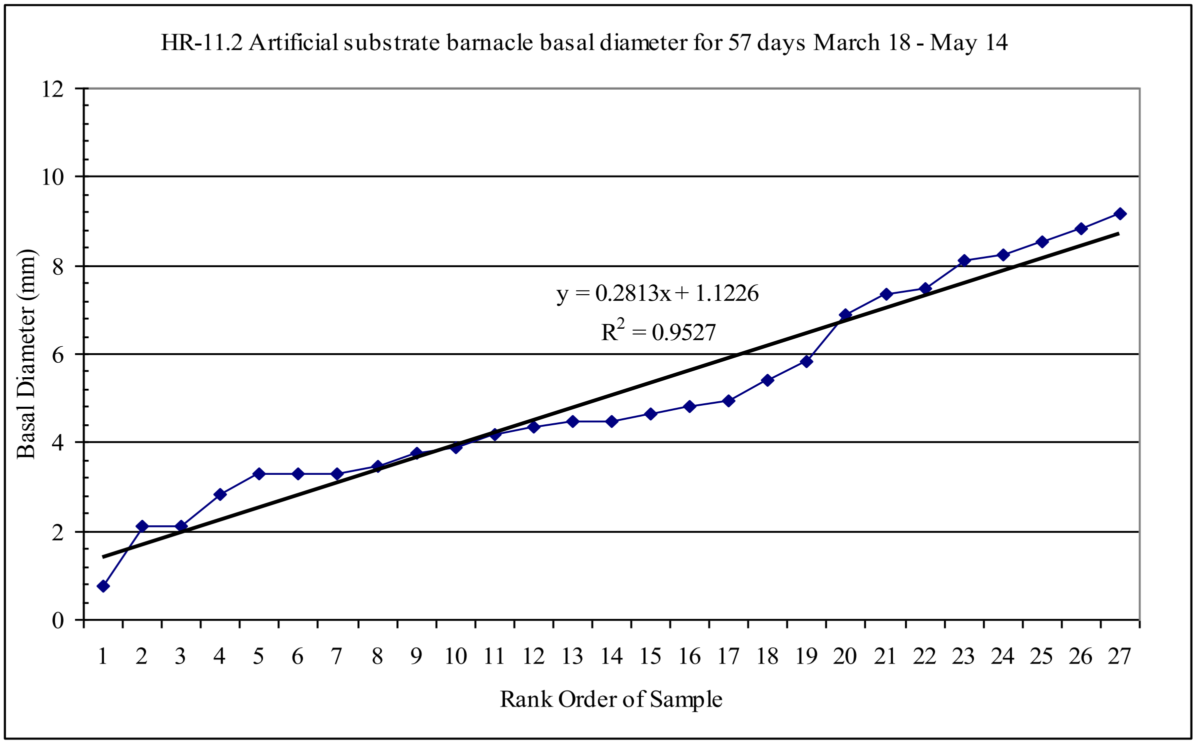
Barnacles
http://darwin-online.org.uk/
http://en.wikipedia.org/wiki/Barnacle

Sea Level Trends
http://tidesandcurrents.noaa.gov/sltrends/sltrends_station.shtml?stnid=8727520

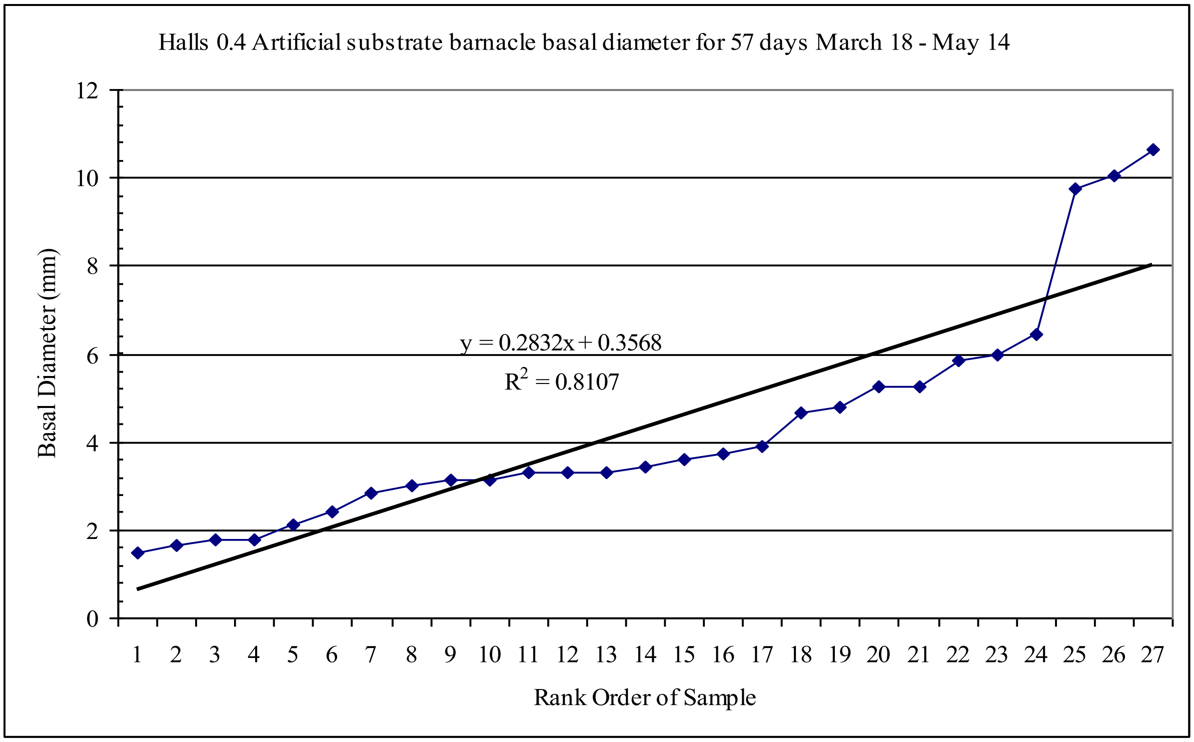
APPENDICES

Appendix Table 1. Barnacles and associated fauna collected in field scrape samples from pilings.

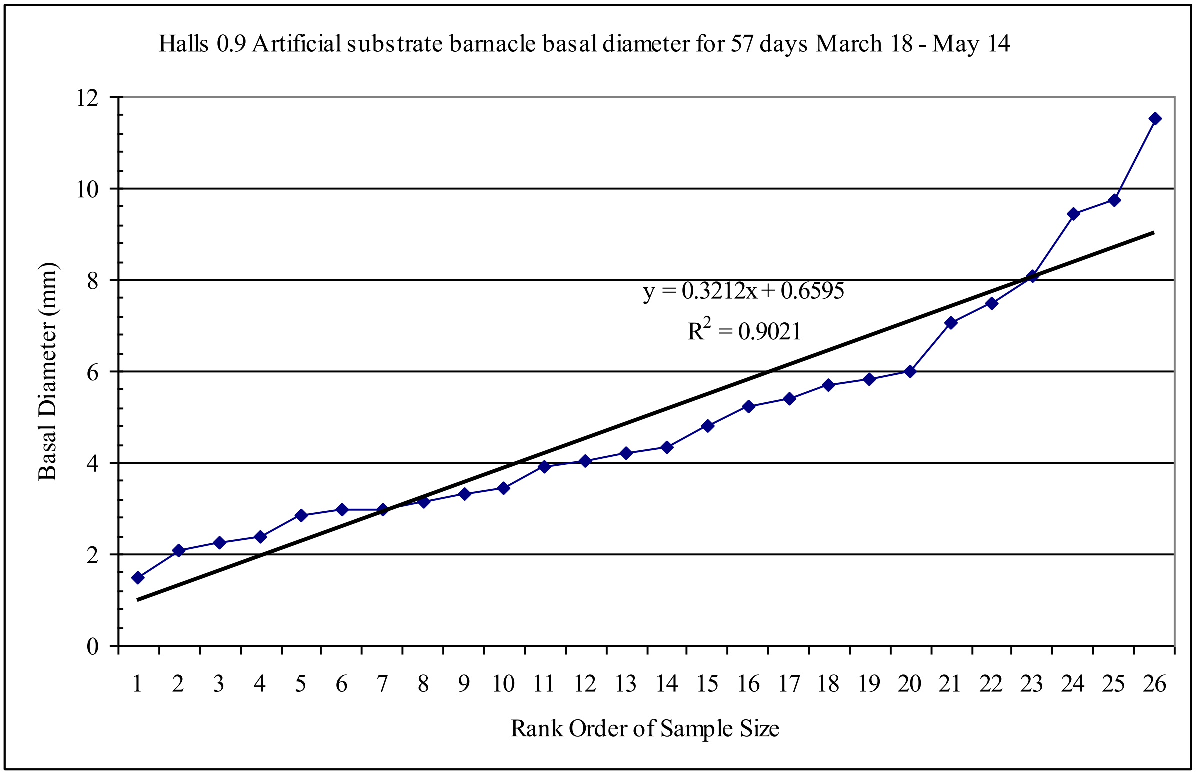
	Balanus subalbidus (count/100cm2)			**Balanus amphitrite (count/100cm2)**			**Mussels (count/100cm2)**			**Other Invertebrates**								
Station	**Live**	**Dead**	**Total**	**Live**	**Dead**	**Total**	**Live**	**Dead**	**Total**	**Amphipods**	**Isopods**	**Decapods**	**Chironomidae**	**Polychaetes**	**Tanaidacea**	**Insect Larvae**	**Snails**	**Fish**
HR-9.35	162	13	175	0	0	0	163	3	166	>100	20	2	15	20	>100	0	0	0
HR-10	164	7	171	0	0	0	132	8	140	400	48	4	0	8	124	0	0	0
HR-10.55	107	17	124	0	0	0	135	10	145	37	94	3	6	15	>100	0	0	2
HR-10.8	128	6	134	0	0	1	116	2	118	>100	3	2	0	12	77	0	0	0
HR-11.2	144	22	168	0	0	0	660	108	768	252	80	8	4	4	236	0	4	0
HR-11.9	100	3	103	0	0	1	>250	3	>250	65	1	0	11	5	47	0	0	0
HR-12.3	303	9	312	1	0	1	>225	3	0.228	7	6	4	7	11	>100	0	0	0
HR-12.7	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
HR-12.6	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Hall-0.4	143	2	145	0	0	1	19	1	20	>100	5	1	1	0	0	0	0	0
KB-1	93	8	101	0	0	0	20	4	24	7560	176	4	0	0	40	0	0	0
KB-2	47	0	47	0	0	0	16	0	16	18	12	0	27	4	0	14	20	0
KB-3	51	0	51	0	0	0	13	0	13	142	23	0	26	0	74	26	0	0
KB-4	114	20	134	0	0	0	4	0	4	800	4	4	4	0	0	0	0	0
KB-5	159	5	164	0	0	0	4	0	4	1360	40	4	0	0	196	0	0	0
KB-6	145	11	156	0	0	0	12	0	12	376	28	0	12	0	172	0	0	4
KB-7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
KB-8	78	15	93	0	0	0	56	0	56	384	52	8	0	0	84	0	0	4
KB-9	207	0	207	0	0	0	16	0	16	568	40	0	44	0	0	0	0	0
KB-10	26	0	26	0	0	0	0	0	0	8	0	0	0	0	4	0	1	0
KB-11	84	1	85	0	0	0	4	0	4	90	2	4	26	0	38	6	0	0
KB-12	93	6	99	0	0	0	28	0	28	196	8	8	12	0	48	4	4	0
KB-13	95	4	99	0	0	0	1	0	1	43	0	2	1	1	0	1	0	0
KB-14	47	2	49	0	0	0	30	0	30	502	4	0	4	0	46	0	1	0
KB-15	96	7	103	0	0	0	100	4	104	8	8	0	0	8	0	0	0	0
WR-3.1	239	12	251	0	0	0	0	1	1	97	0	1	68	2	0	0	1	0
WR-5.0	29	1	30	0	0	0	8	2	10	38	3	0	5	0	0	0	2	0
WR-6.0	<1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
WR-6.5	<1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total:	2,854	171	3,027	1	0	4	1,537	149	1,680	12,951	657	59	273	90	1,186	51	33	10



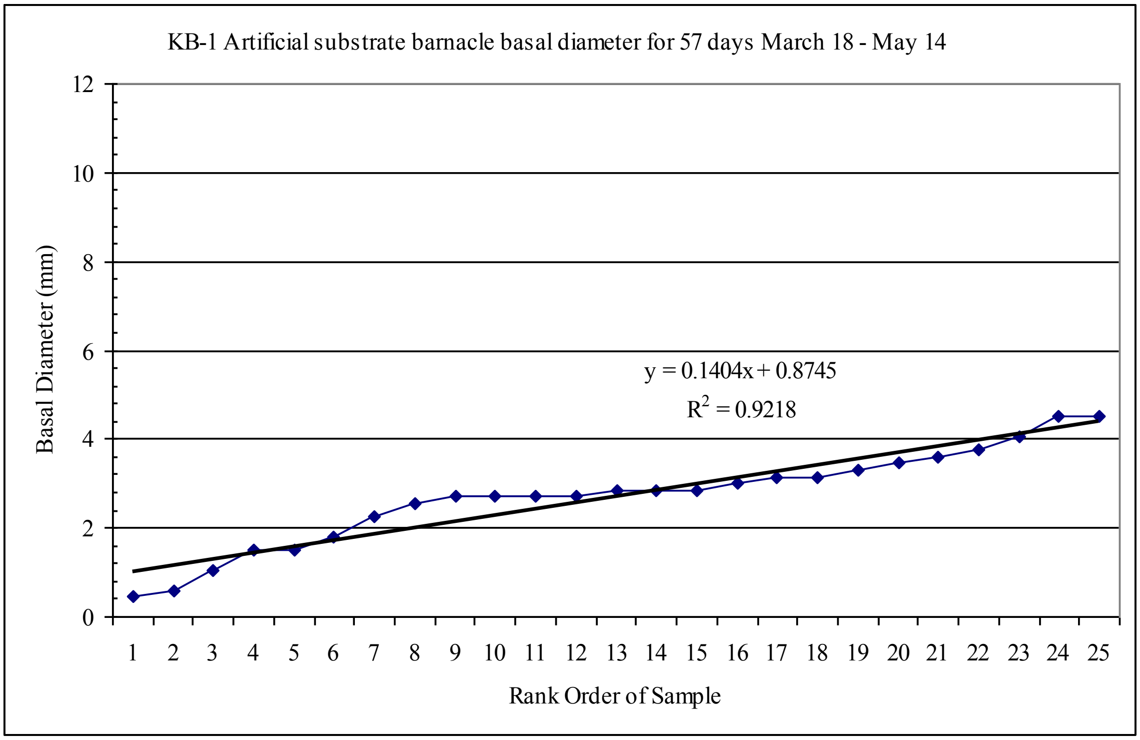
Appendix Figure A.1. Barnacle sizes for Homosassa River 11.2, for March – May 2009.



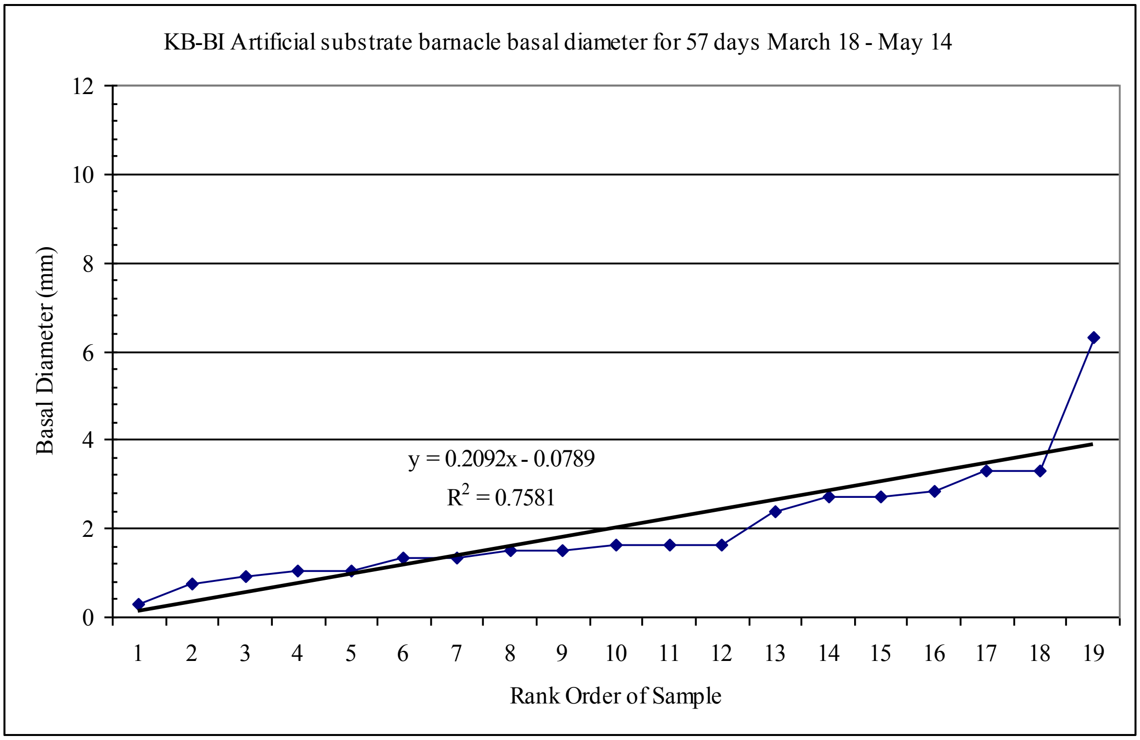
Appendix Figure A.2. Barnacle sizes for Halls River 0.4, for March – May 2009.



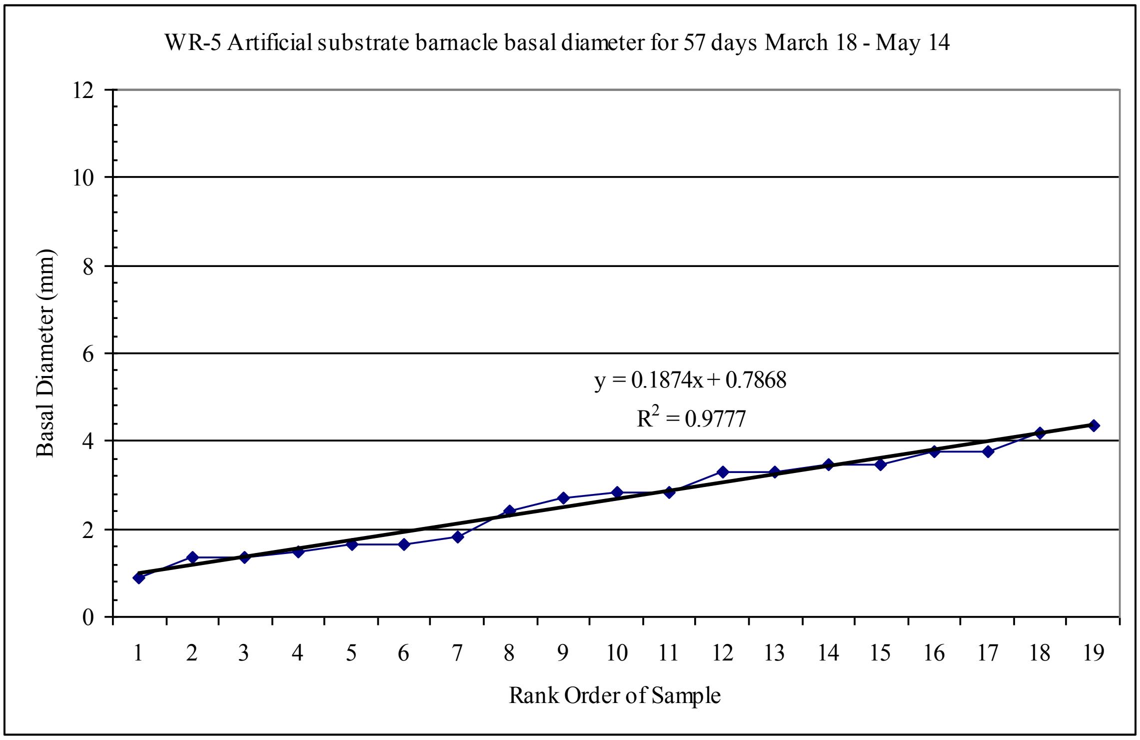
Appendix Figure A.3. Barnacle sizes for Halls River 0.9, for March – May 2009.



Appendix Figure A.4. Barnacle sizes for Crystal River (Kings Bay) at marker 27, for March – May 2009.

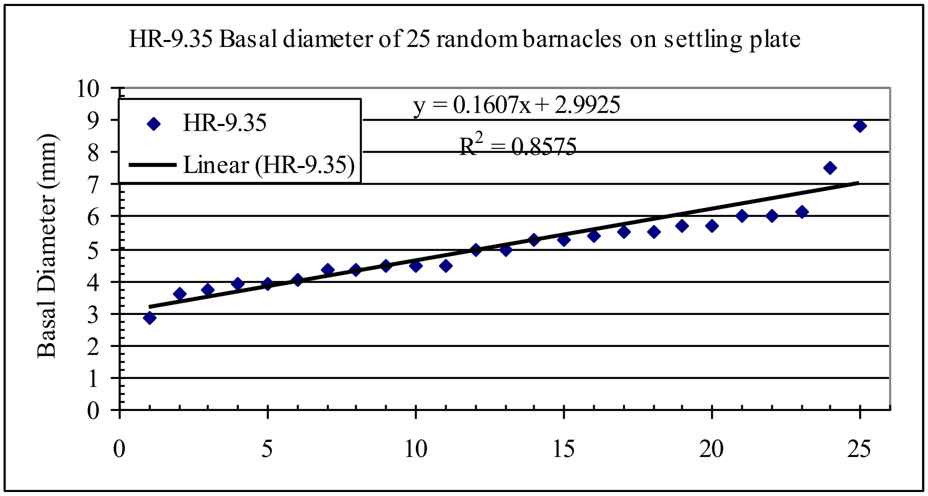


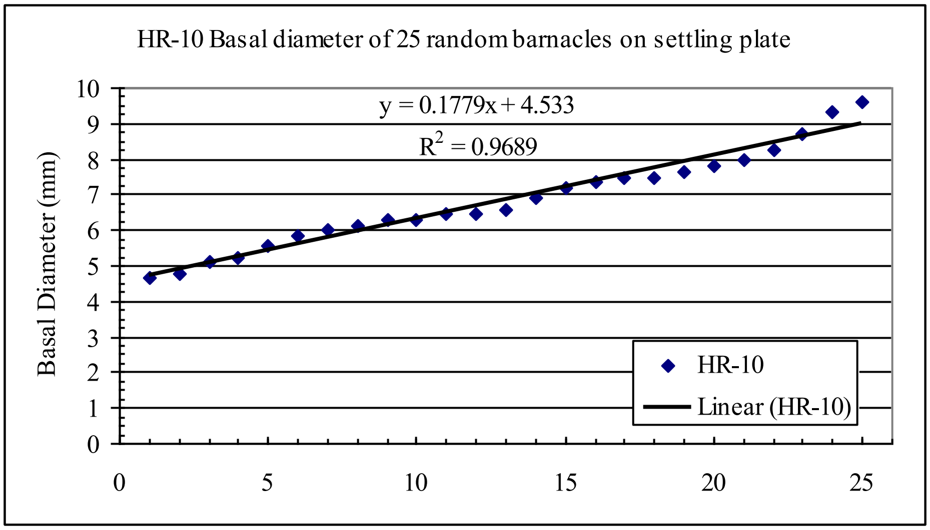
Appendix Figure A.5. Barnacle sizes for Buzzard Island in Kings Bay, Crystal River for March – May 2009.

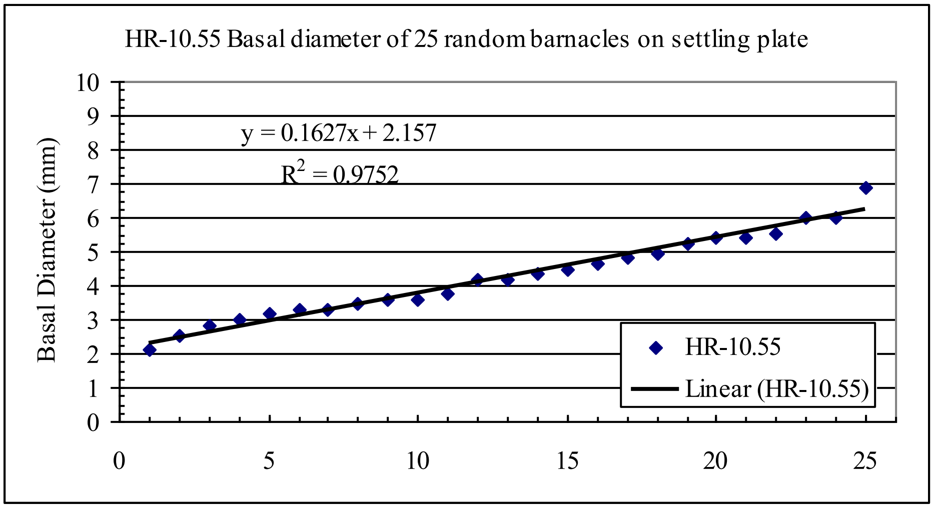


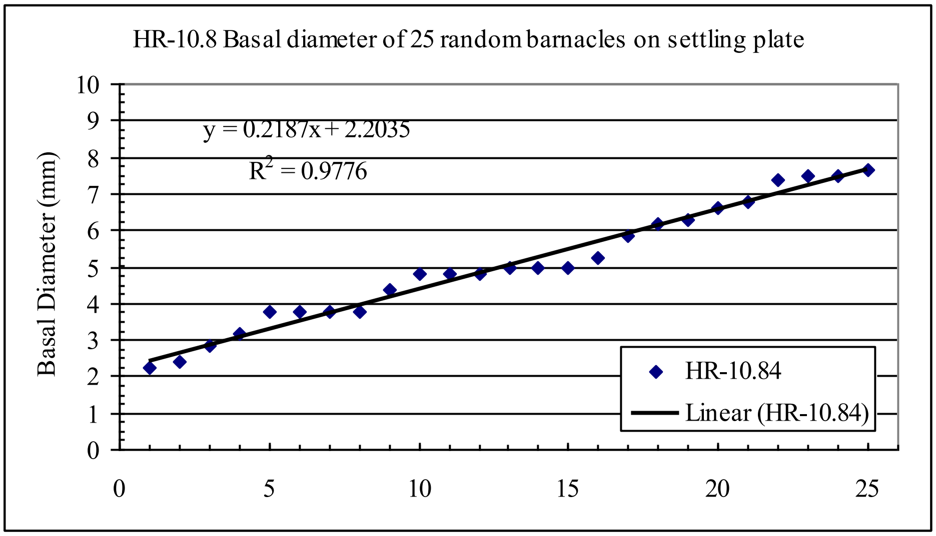
Appendix Figure A.6. Barnacle sizes for Withlacoochee River for March – May 2009.

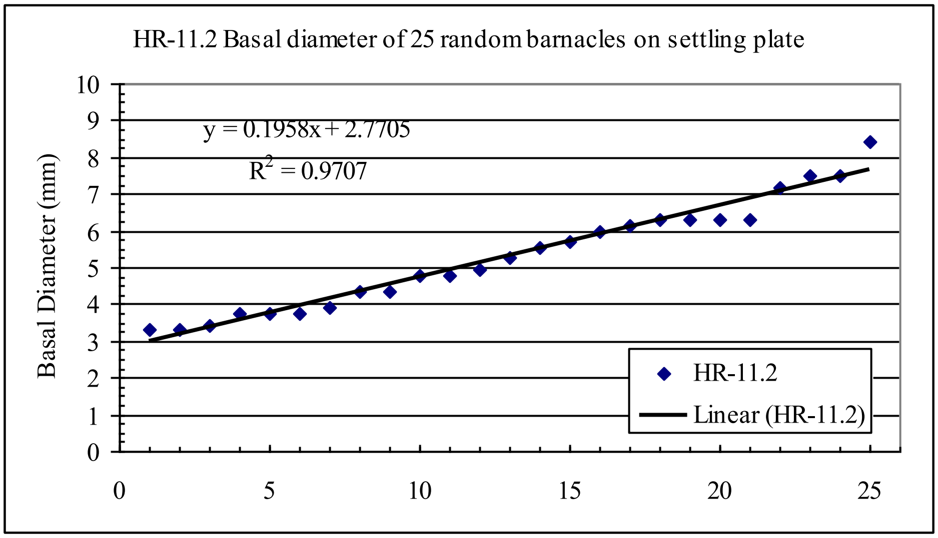
Appendix Figures A.7-A.12. Plots of barnacle sizes on artificial substrates Homosassa River.

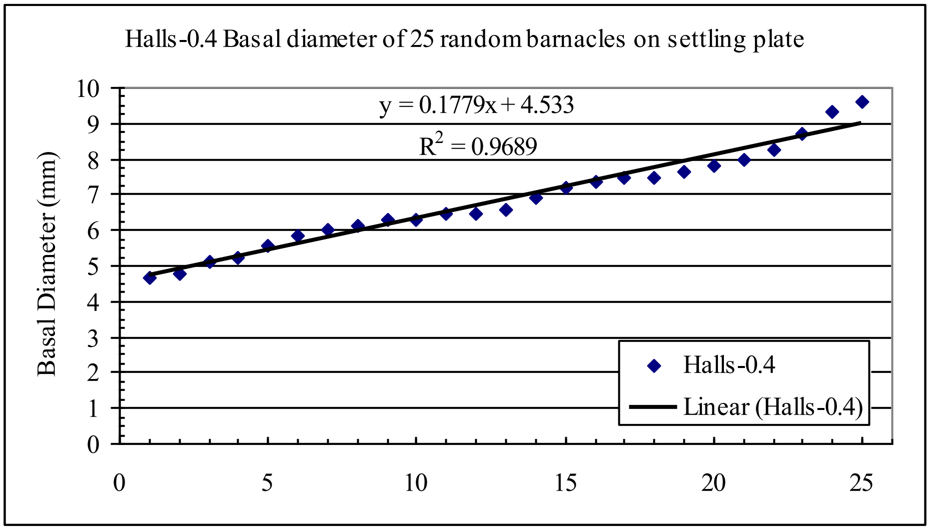




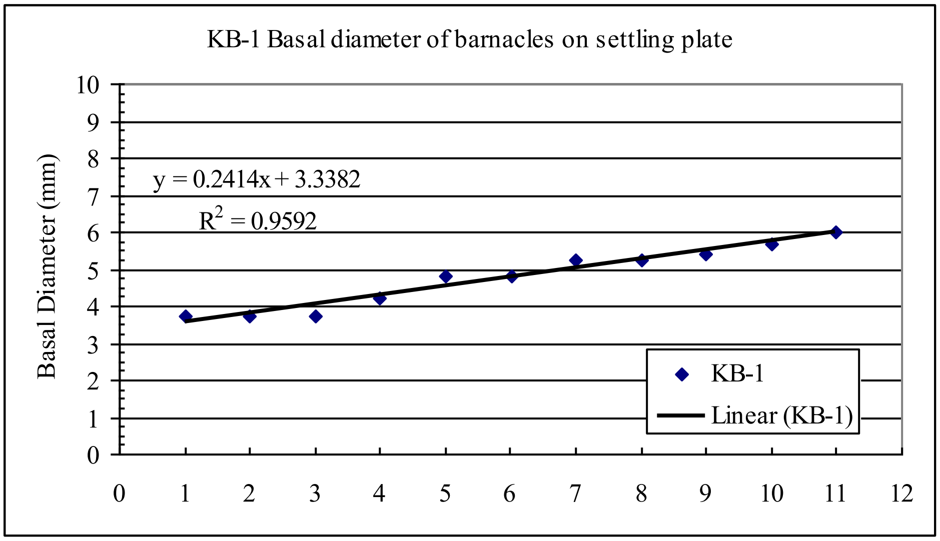


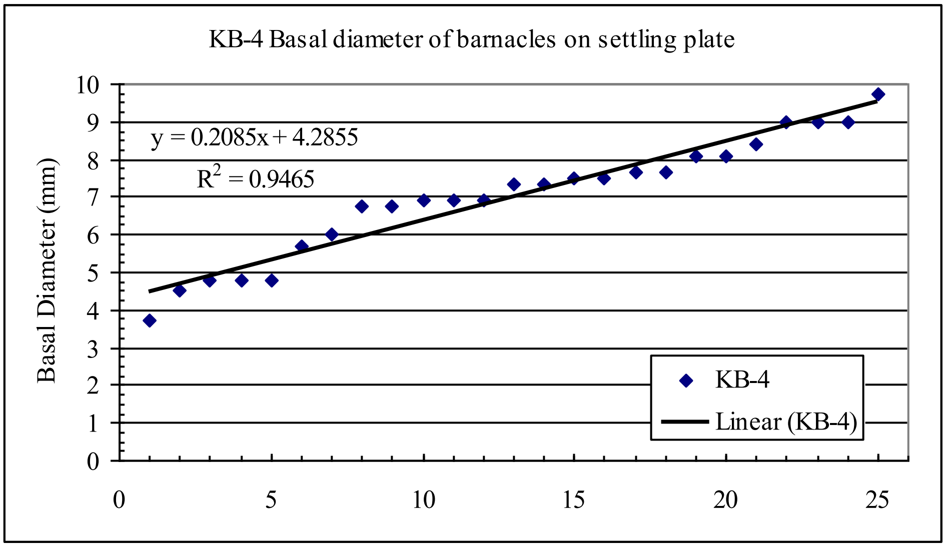

HR-10.8 Basal diameter of 25 random barnacles on settling plate

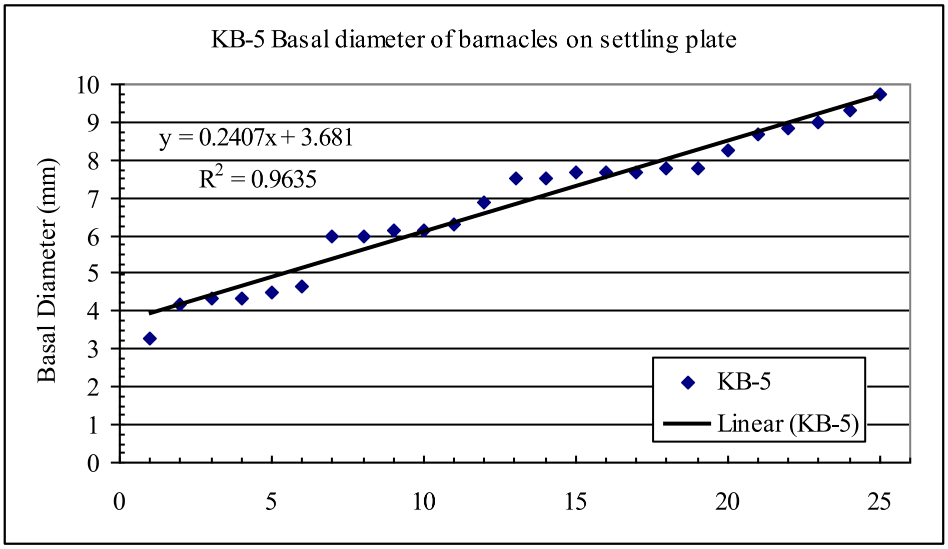

HR-11.2 Basal diameter of 25 random barnacles on settling plate

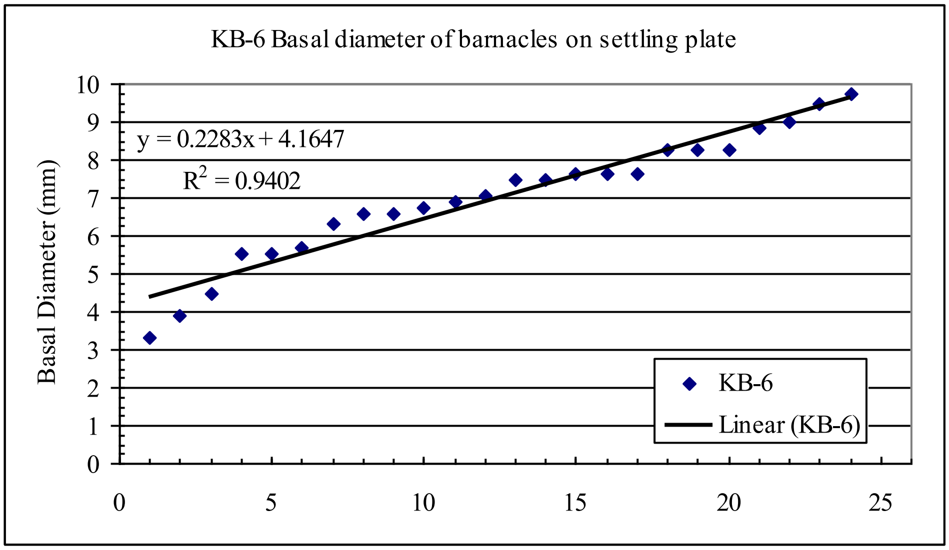

Halls-0.4 Basal diameter of 25 random barnacles on settling plate

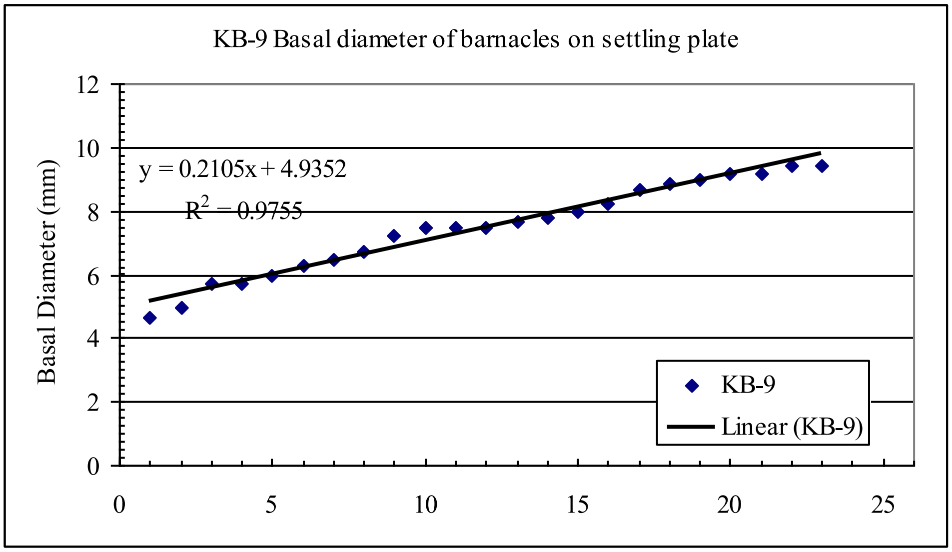
Appendix Figures A.13-A.20. Plots of barnacle sizes on artificial substrates, Kings Bay.

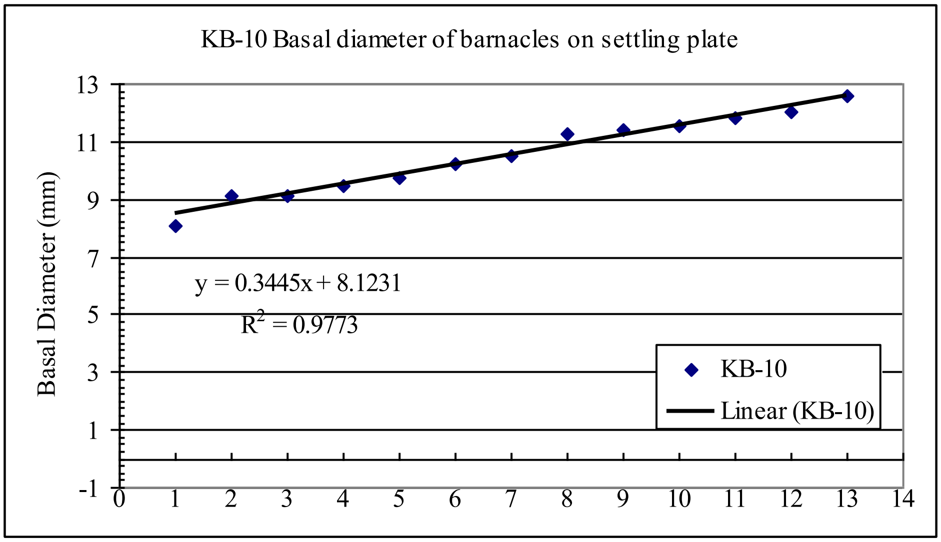


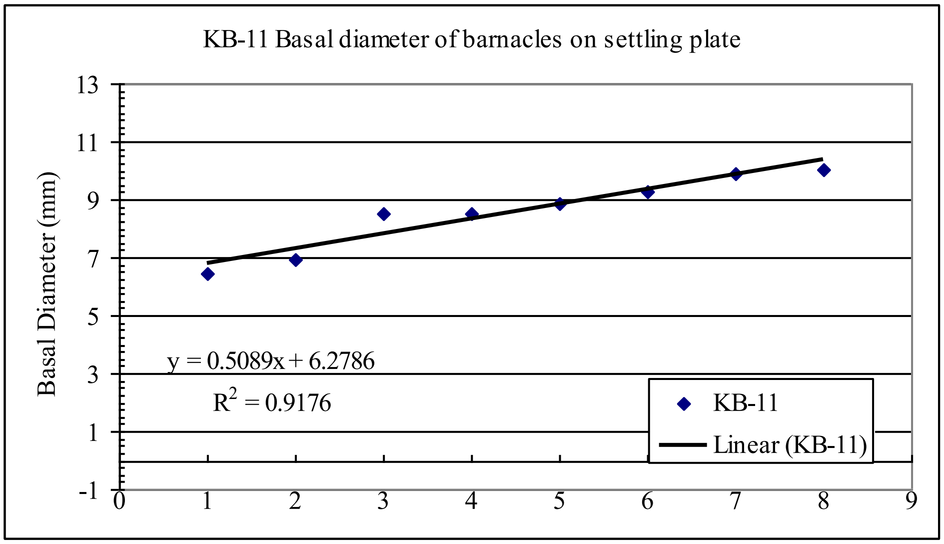


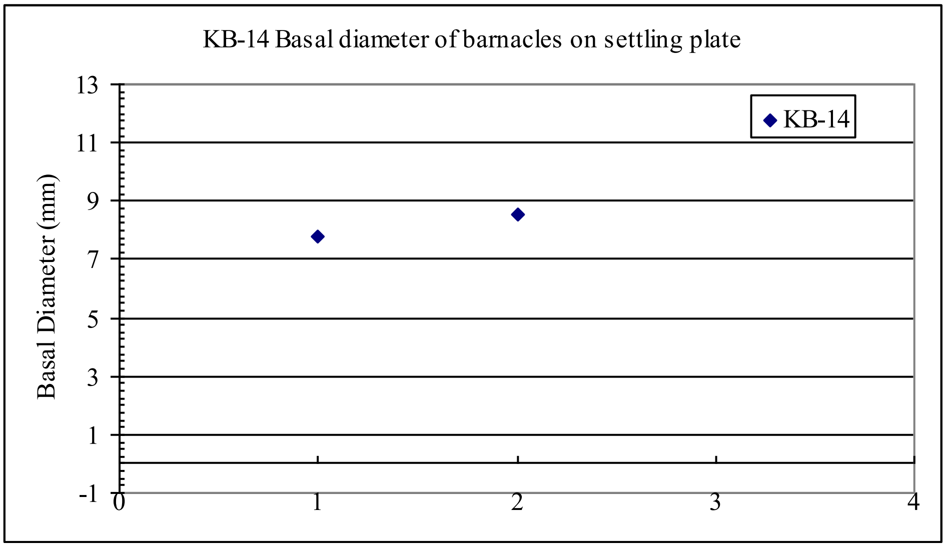



KB-6 Basal diameter of barnacles on settling plate
Basal Diameter (mm)
0
1
2
3
4
5
6
7
8
9
10
0
5
10
15
20
25
y = 0.2283x + 4.1647
R² = 0.9402
KB-6
Linear (KB-6)

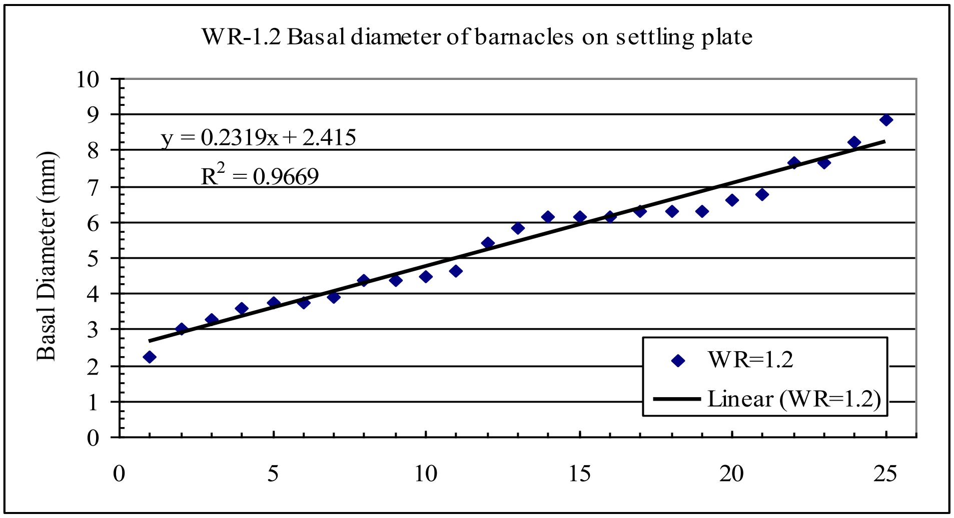

KB-9 Basal diameter of barnacles on settling plate
Basal Diameter (mm)
0
2
4
6
8
10
12
0
5
10
15
20
25
y = 0.2105x + 4.9352
R² = 0.9755
KB-9
Linear (KB-9)

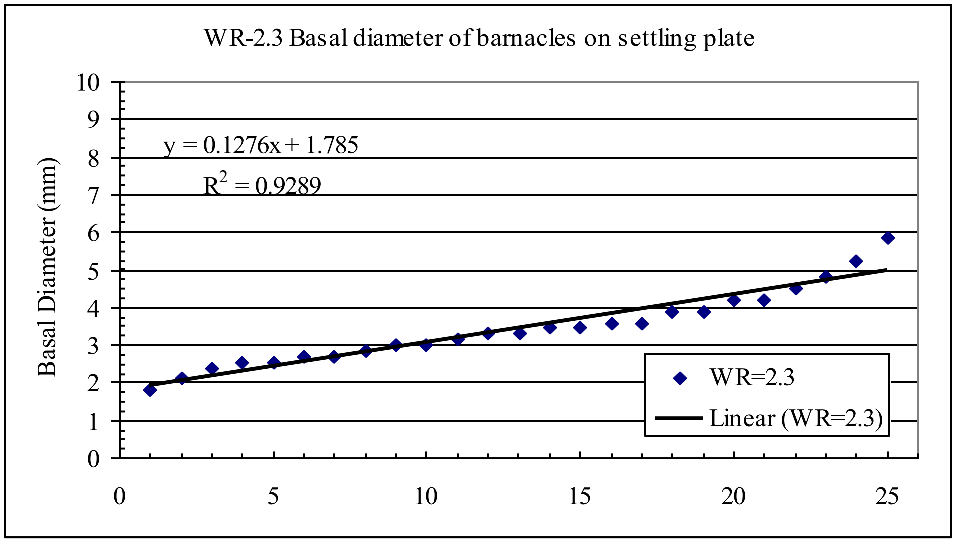

KB-10 Basal diameter of barnacles on settling plate
Basal Diameter (mm)
-1
1
3
5
7
9
11
13
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
y = 0.3445x + 8.1231
R² = 0.9773
KB-10
Linear (KB-10)

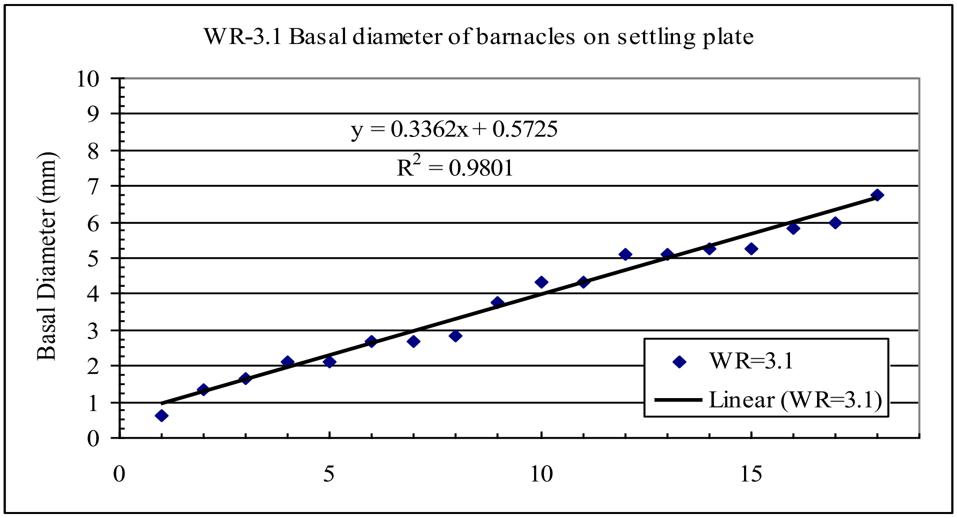

KB-11 Basal diameter of barnacles on settling plate


KB-14 Basal diameter of barnacles on settling plate

Appendix Figures A.21-A.23. Plots of barnacle sizes on artificial substrates, Withlacoochee River.







APPENDIX

Evans, D.L., Strom, D.G., and Mosura-Bliss, E.L. 2010. Spatial distribution of benthic macroinvertebrates in the Crystal River/Kings Bay system with emphasis on relationships with salinity, Purchase Order #09POSOW1364. Water & Air Research, Inc., Gainesville, Florida. Prepared for the Southwest Florida Water Management District, Brooksville, Florida.

Note: *This 2010 report includes previously reported discharge records for the U.S. Geological Survey (USGS) Crystal River at Bagley Cove, FL gage site that were revised by the USGS in November 2011, and also includes analyses based on the previously reported records.*

Spatial Distribution of Benthic Macroinvertebrates in the Crystal River / Kings Bay System with Emphasis on Relationships with Salinity

Purchase Order # 09POSOW1364

Prepared for

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Prepared by

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09-7180-01

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Sediment volatile solids were analyzed by Advanced Environmental Laboratories in Gainesville, Florida. Sediment grain size analysis was performed by MACTEC in Jacksonville, Florida.

Water & Air participants included:

David L. Evans	Project Manager, Principal Investigator
Douglas G. Strom	Invertebrate Taxonomist, Data Management & Analysis
Laura Line	Invertebrate Taxonomist
E. Lynn Mosura-Bliss	Project Ecologist
Barry Vance	Field Team Leader
Nicole Frederick	Field Sample Collection
CAD/GIS Staff	Mapping and Figures
Document Production Staff	Report Preparation

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Appendices

1.0 Introduction

The Southwest Florida Water Management District (District) is responsible for protection and management of water resources in southwest Florida. Establishment of minimum flows and levels (MFLs) for freshwater streams and estuarine waters is one of the District's charges. To that end, the project objectives are to quantify the relationship of physical characteristics, particularly salinity, and the spatial distribution of benthic macroinvertebrates in Crystal River/Kings Bay system.

1.1 Minimum Flows and Levels

Florida Statute 372.042 defines MFLs as "the limit at which further withdrawals would be significantly harmful to the water resources or the ecology of the area." MFLs are not static and vary seasonally and spatially. The MFL process establishes relationships between key ecological components, such as salinity, and flow to the structure of biological communities, such as benthic macroinvertebrates.

1.2 Benthic Macroinvertebrates

Benthic macroinvertebrates are small, typically sedentary, bottom-dwelling organisms that live on or in sediments of waterbodies or wetlands. Examples include shrimp, snails, worms, aquatic insects, and clams, among others. Benthic macroinvertebrates are ecologically important organisms in food webs, and are integral in establishing trophic structure of an aquatic ecosystem. They also mix the sediments allowing exchange of oxygen, nutrients, and pollutants between the water column and the bottom. Because of their inability to escape exposure to changing conditions (relative to more motile aquatic fauna), benthic macroinvertebrates are often used to assess the condition of an aquatic system, since they integrate numerous environmental factors over time spans exceeding those of typical water quality monitoring programs.

1.3 Relationship Between Flow and Benthos

Flow regimes are an important characteristic of a river influencing a wide array of biological communities, including benthic macroinvertebrates. Flow is a measure of both volume and velocity, and is typically measured in cubic feet per second (cfs) of water. Additionally, flows affect salinity, dissolved oxygen, sediments, and nutrients.

Salinity of tidal rivers shift, based on flow conditions and tidal state. Salinity affects the biological communities of the rivers, including the benthic community. A species distribution and abundance, as well as the community structure, are affected by salinity. Under low flow conditions, estuarine species habitat will increase upstream. Under high flow conditions, some freshwater species may occupy sediment areas farther downstream.

Changes in freshwater inflow can affect the benthic community structure, alter the availability of sediment types, and change water chemistry. The dynamic shifts that occur between freshwater and estuarine benthic species in a tidal river are driven by the osmotic tolerances of the individual species. In general, estuarine species are better adapted to these changes than are freshwater species. Also, sediment type significantly affects the type of benthic community present. An altered salinity regime along a reach of river can exclude those benthic organisms that normally inhabit a given sediment type. River inflows alter residence times and stratification, ultimately influencing availability of dissolved oxygen along the river course. Water quality constituents, such as nutrients and metals, may become more concentrated at lower flows. Increased residence times under low flow conditions allow phytoplankton to take up more nutrients, whereas under high flow conditions, downstream nutrient loading is increased. Sediment loading increases during periods of higher flow and can bury and suffocate benthic communities.

The type of substrate available in a stream for colonization by benthic organisms is determined by native soil material and geology, current velocity, and organic inputs. Substrate composition is also affected by grain size and the interstitial space between the grains. In general, increased substrate stability and presence of organic detritus as a food resource lead to an increase in invertebrate abundance and diversity.

1.4 Quantitative Response of Benthos to Changes in Freshwater Inflow

Benthic macroinvertebrates integrate responses to direct and indirect changes in freshwater inflows in tidal rivers. Although a high degree of natural variation exists, predictable responses can be discerned in species distribution, abundance, and composition. Species distributions are controlled by the degree to which the invertebrate fauna can physiologically adapt to changing water chemistry, particularly salinity. Species abundances are affected by altered flow due to: increased stress placed on individual species at the extremes of optimal salinity ranges, differential effects on early life stages of the organism, and effects on the availability of prey organisms. Community structure depends upon the integration of species presence and abundance on the entire benthic community. Measurements of the benthic community response to altered freshwater flows include species richness, abundance, and diversity.

1.5 Study Area and Previous Investigations

The Crystal River/Kings Bay watershed occurs in the Gulf Coastal Lowlands (Vernon 1951) of Citrus County (Figure 1-1). Crystal River and Kings Bay area is classified as a shelf embayment development by the dissolution of limestone bedrock (Hine and Belnap 1986). It occurs in the Chassahowitzka Coastal strip of the Big Bend Karst division of the Ocala Uplift District (Brooks 1981). Ocala formation limestone forms the basin of Kings Bay itself. The river starts in Kings Bay, where a complex of more than 30 springs (Rosenau et al., 1977) and canal cuts into the limestone bedrock discharge, contributing to the flow of Crystal River. Twenty-eight springs and their discharges were compiled by Hammett et al. (1996). More recently Vanasse, Hangen and Brustlin (2009 and 2010) documented locations of 41 spring complexes, some with multiple vents that yielded 70 total springs in Kings Bay and Crystal River. The combined flow creates a first magnitude spring flow, the fourth largest in the state (Rosenau et al. 1977).

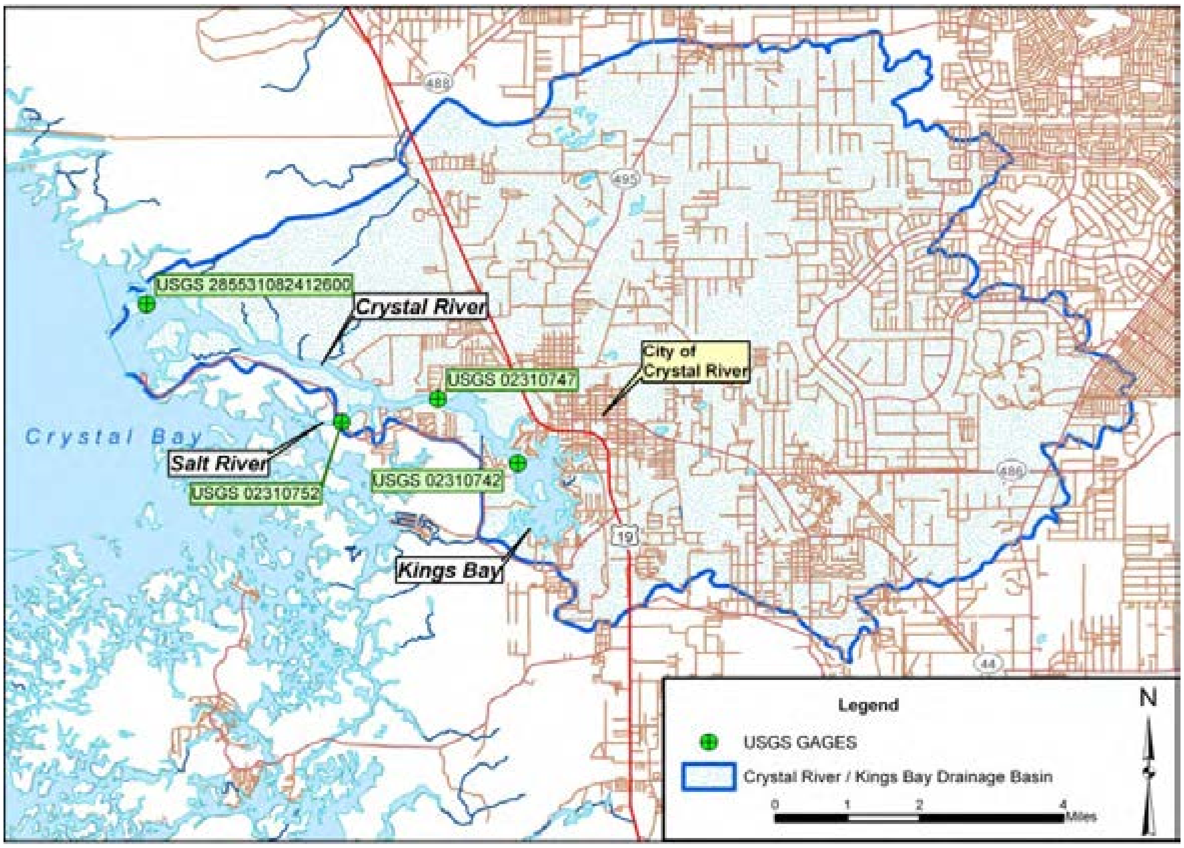

Figure 1-1. The Crystal River/Kings Bay Drainage Basin, Citrus County, Florida.

Crystal River flows approximately 11 kilometers to the Gulf of Mexico and encompasses a watershed of 54 sq. km. The river channel is from 400 to 2,000 feet wide and 3 to 10 feet deep in Kings Bay. At the river mouth, the channel is 1500 feet wide and 6 to 20 feet deep (Yobbi and Knochenmus, 1989). Hammett et al. (1996) depicts bathymentric contours of Kings Bay and part of Crystal River, while the more recent work by Wang (2008) provides detailed bathemetry of Kings Bay, Crystal River and the estuary. Water in the river is derived from groundwater artesian flow from Floridan aquifer. Lands adjacent to the river are urbanized around Kings Bay, and urbanization decreases downriver to become natural streamside shorelines. No streams contribute to the flow of Crystal River due to the karst geology of the area. However, numerous shallow streams occur along the coastal marsh, alternately draining and flooding the marshes during tidal fluctuations.

USGS water data are available for four stations in the Crystal River area: Crystal River mouth of Kings Bay (USGS 02310742), Crystal River at Bagley Cove (USGS 0210747), Crystal River at mouth near Shell Island (USGS 285531082412600), and Salt River near Crystal River (USGS 02310752)(USGS 2009). The periods of record presented for these sites span approximately three years, except for Bagley Cove which covers approximately six years.

Older USGS data show an average daily flow of 975 cfs for Crystal River from 1965 through 1977; however, these records are considered poor due to confounding influences of tides, winds, and aquatic vegetation (Clewell et al. 2002). Tidally corrected flow data have been available for the Bagley Cove station since 2002.

The entire river is tidally influenced. The headsprings in Kings Bay are topographically low and tidally affected, occurring near the saltwater-freshwater interface of the upper Floridan

Aquifer. This can result in brackish water discharge from the springs. The Kings Bay Springs that discharge mainly freshwater are clustered on the eastern side, while springs discharging brackish water are clustered in the central or western portions of the bay (Champion and Starks 2001).

The area experiences mixed diurnal tides, potentially producing a higher high, a lower high, a higher low, and a lower low tide daily. The tidal range at the mouth of Crystal River is 0.8 m but tidal height is influenced by wind direction and velocity (Yobbi and Knochenmus 1989). Tidal fluctuation in Kings Bay is about 0.3 m under normal conditions (Rosenau et al. 1977). Negative discharges from springs in Crystal River can occur due to tidal influence. Seasonal effects of rainfall and tides are manifested in river discharge. When rainfall and tides are highest in the summer and fall, river discharge is lowest. During winter and spring, when tidal influences and rainfall are lowest, river discharge is highest (Yobbi and Knochenmus 1989). This anomalous seasonal pattern was not prevalent in other coastal spring rivers of the area (Yobbi 1992).

The distribution of salinity in the river can vary longitudinally, vertically, and seasonally. At the river mouth, Crystal River is a well mixed estuary with some vertical distribution. Vertical differences in salinity increase as high-tide stage decreases. Salinity decreases as you move upstream but is quite variable: at 2 miles outside the mouth of the river the vertically averaged salinity range was 21 to 29 parts per thousand (ppt), at river mile 1.0 the range was 5 to 19 ppt, at river mile 2.92 the range was 1 to 18 ppt, and at river mile 6.16 the range was 1 to 3 ppt (Yobbi and Knochenmus 1989). Salinity of 2 ppt has been recorded in Kings Bay on numerous occasions. This typically occurs during low flow and high tidal conditions. The mineral content of the discharge water at the headsprings is variable, but typically high due to a mixture of both calcium bicarbonate and sodium chloride (Yobbi and Knochenmus, 1989).

Submerged aquatic vegetation (SAV) is plentiful in Kings Bay but diminishes downstream toward the Gulf of Mexico. Crystal River outside of Kings Bay is sufficiently deep so that low light near the bottom may prevent plant colonization. However, salinity of the waters likely controls macrophyte composition, abundance, and distribution. There was a strong negative correlation between vegetative biomass and salinity. SAV was only common in the first 2 km downstream of Kings Bay (Frazer et al. 2001; Notestein et al. 2005 and 2006). Common SAV in Kings Bay include eelgrass (*Vallisneria americana*), Eurasian watermilfoil (*Myriophyllum spicatum*), southern naiad (*Najas guadalupensis*), Hydrilla (*Hydrilla verticillata*), coontail (*Ceratophyllum demersum*), musk grass (*Chara* sp.), and the *Lyngbya* sp. (Frazer and Hale 2001). In a three year study by Frazer et al. (2001) of the river vegetation from springs to the coastal marsh, a few other submerged species, such as Sago pondweed (*Potamogeton pectinatus*), small pondweed (*P. pusillus*), and widgeongrass (*Ruppia maritima*), were also prevalent, in addition to those species common to Kings Bay. Since 1960, Hydrilla has increased in Kings Bay, displacing much of the native vegetation. After 1985, the filamentous blue-green alga, *Lyngbya* sp., became prevalent (Hammett et al. 1996).

Shallow sediments occur within the river and Kings Bay where limestone is not exposed. A thin layer of fine to very fine quartz sand occurs ranging from 0 to 4.7 feet deep. The organic and carbonate contribution to the sediment is low, averaging 7.7% and 8.4%, respectively, in 1992 (Belanger et al. 1993); however, more recently, between 1992 and 2005, the organic component has increased to an average of 13.8% due primarily to *Lyngbya* but also Hydrilla and *Myriophyllum* contributions (Belanger et al. 2005). The largest increases in the organic component were found in the central bay area.

In a comprehensive study of coastal rivers in Hernando, Citrus, and Levy counties, Mote Marine (1986b) sampled benthic macroinvertebrates at four stations along Crystal River and into the Gulf of Mexico (River Miles 7.03, 2.95, 0.0, -3.48) in 6 sampling events over two years. Chironomids and oligochaetes dominated the most upstream station, amphipods and tanaids dominated the middle stations, and polychaetes dominated the outmost station. Mote Marine (1986a, 1986c, 1986d, 1986e) also sampled oyster reefs and associated oyster fauna, water quality, fish, and sediments of five river and spring systems on the Springs Coast and Big Bend, including Crystal River.

Other previous studies and reports on the Crystal River/Kings Bay system include river water quality assessment and management (SWFWMD 2001; SWFWMD 2000; Frazer et al. 2001 and 2006; Champion and Starks, 2001; Cowell and Dawes 2008; Romie 1990; Hammett et al. 1996, Hauxwell et al. 2003; Frazer et al. 2002; Hoyer et al. 1997a and 1997b; Jones and Upchurch 1994), emergent vegetation and land cover (Florida Department of Environmental Protection, 1997; Clewell et al. 2002), and syntheses of the area (Cherry et al. 1970; Wolfe 1990; Estevez et al. 1991; Knochenmus and Yobbi 2001; McPherson and Hammett 1991).

2.0 Methods

2.1 Field Methods

Water & Air staff conducted benthic infauna sampling, sediment sampling, and water column physical-chemical measurements on July 21-23, 2009. These parameters were collected at ten (10) Kings Bay stations, five (5) Crystal River stations, and four (4) Gulf of Mexico stations. A single dipnet sample was collected in the Crystal River between Kings Bay and the Salt River confluence. Dipnet samples were also collected at six Kings Bay sites.

Oyster beds and resources were mapped at low tide from the river mouth to their upstream extent on July 23, 2009. Locations of emergent oyster beds were recorded using Global Positioning System (GPS) technology. Data collected included presence of live oysters, approximate river kilometer, and tidal stage. In addition, the location and presence of encrusting oyster clumps was noted on both man-made and natural substrates along the river course.

Sampling transects for benthic infauna were established at the following locations: RK 0.0, 2.5, 5.5, 7.5, and 9.4 (Figure 2-1). Three sample grabs were collected across the river channel at each transect location. Sampling points for benthic infauna were established at the following locations: Kings Bay (KB) – 1 thru 10 (Figure 2-2) and the Gulf of Mexico at Crystal Bay (Gulf) – 1 thru 4 (Figure 2-1). Benthic infauna samples were collected at all of these sites using a stainless steel petite Ponar dredge with sample surface area of 0.0232 square meters. A sampling point for benthic infauna was also established in the Crystal River between Kings Bay and the Salt River confluence (KB/SR-1, Figure 2-1). The samples at this site and at six Kings Bay sites (KB-3, KB-4, KB-6, KB-7, KB-9, KB-10) were collected via four (4) sweeps using a U.S. standard #30 (590-µm) mesh dipnet.

Figure 2-1. Crystal Bay (Gulf) and Kings Bay/Salt River (KB/SR-1) Sampling Locations, and Crystal River Main Channel (RK) Transect Locations, Crystal River, Citrus County, Florida.

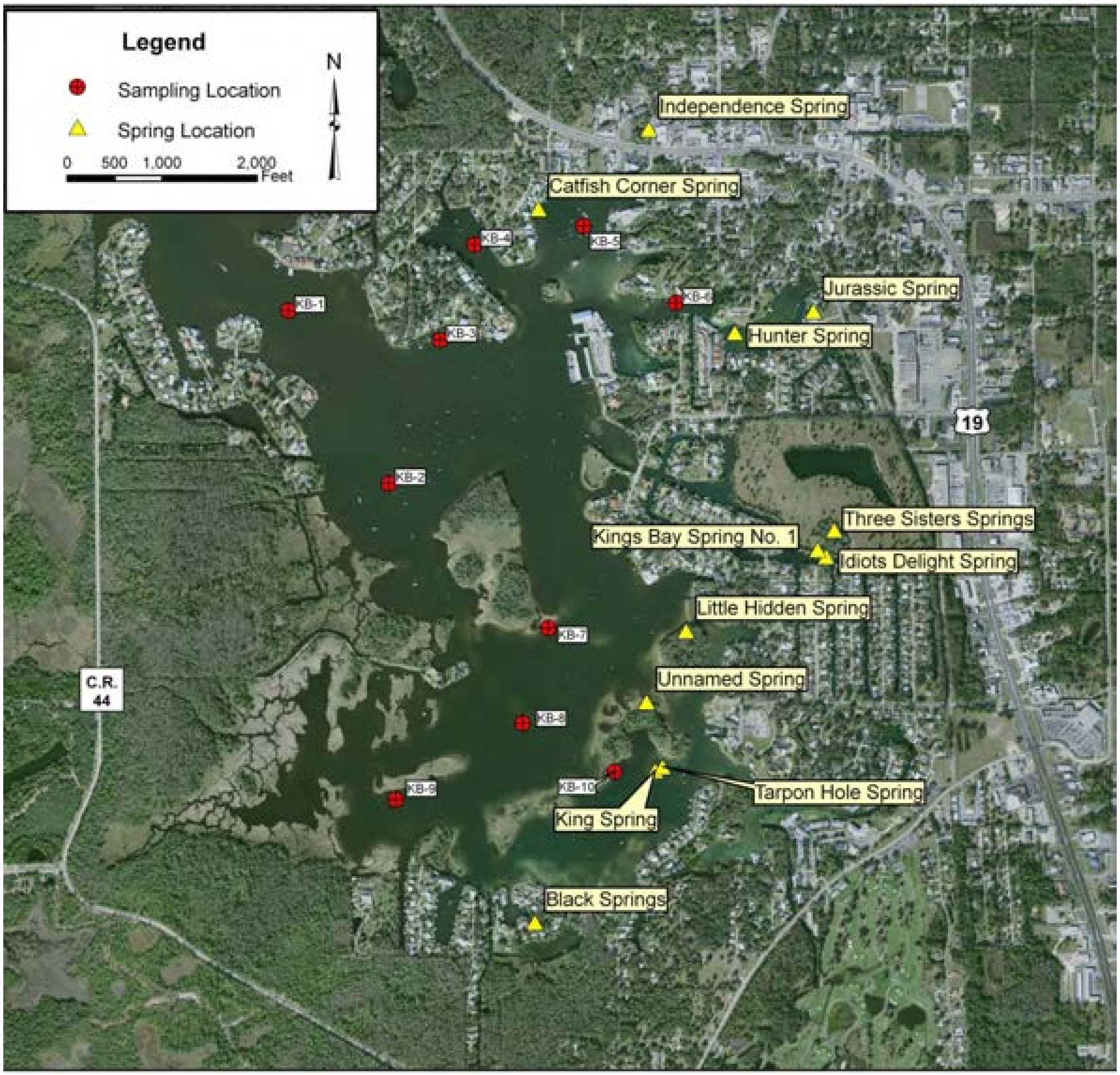

Figure 2-2. Kings Bay Sampling Locations and Spring Locations, Crystal River, Citrus County, Florida.

Each benthic sample was placed in a plastic bag with magnesium sulfate solution added to relax the organisms. Bags were placed on ice until further processing, and preservation was completed within 12 hours of sample collection. Samples were screened using a 500-µm mesh screen to remove fine sediments. Sieved samples were placed in plastic wide-mouth containers of appropriate size and fixed in 10% buffered formalin with Rose Bengal stain added to the solution to facilitate sorting efficiency in the laboratory. Water temperature, dissolved oxygen, salinity/conductivity, and pH were measured at the water surface, just above the bottom and at one-meter intervals between surface and bottom. Additional sediment samples were collected for grain size analysis (gravimetric method) and organic fraction (loss on ignition) analyses.

2.2 Laboratory Methods

Benthic infauna samples were processed and analyzed in Water & Air's biological laboratory using methods and quality assurance checks consistent with Water & Air's Quality Manual. Macroinvertebrates were identified and enumerated to the Lowest Practical Identification

Level, usually to species or genus level. Analysis of sediment grain size distribution was performed by MACTEC, Jacksonville, Florida, using methods ASTM D 422 and ASTM D 1140. Analysis of organic content of sediments as percent volatile solids by wet weight was performed by Advanced Environmental Laboratories, Gainesville, Florida.

2.3 Data Analysis

The biological, chemical, and physical data were entered into a database and reviewed for accuracy. The data were statistically analyzed using a variety of univariate, regression, and multivariate techniques available through Primer and MINITAB statistical software programs as described below. Particular emphasis was given to analysis of relationships between univariate biological metrics and chemical parameters that are known to influence macroinvertebrate spatial distribution and are known to be affected by water flow (e.g., salinity).

2.3.1 Historical and Primary Data

Historical salinity data provided by Sid Flannery, SWFWMD were reviewed. Data included in the review were measured at longitudinal river locations in close proximity to the benthic infauna sampling location chosen for the current study. SWFWMD salinity measurement locations and isohaline contours in Crystal River and Kings Bay are depicted in Figures 2-3 and 2-4, respectively. Locations of major springs in Kings Bay are also shown for reference in Figure 2-4. Trend analysis of historical flow data acquired from USGS site 02310747 at Bagley Cove was performed using fitted time series values in a linear trend model. Gage data from this site and three others were reviewed to assess tidal wave penetration into the Crystal River system. SWFWMD longitudinal mean salinity values were compared with current data.

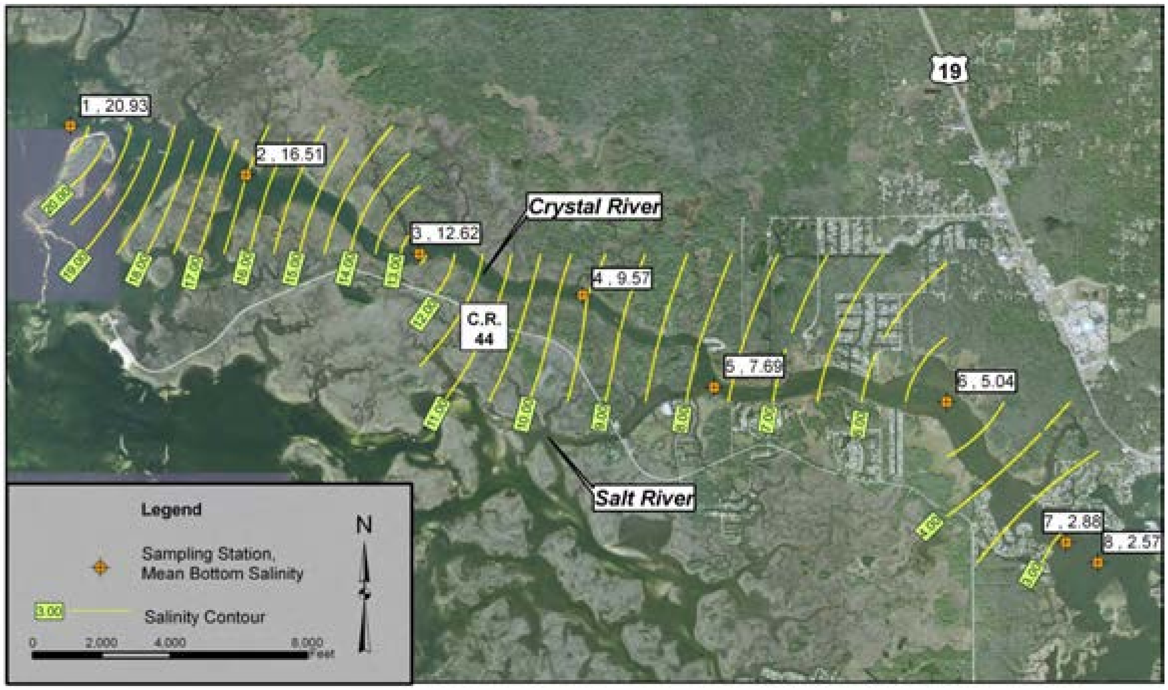

Figure 2-3. Surfer Plot of Mean Bottom Salinity in the Crystal River at the SWFWMD River Monitoring Stations. Data provided by SWFWMD.

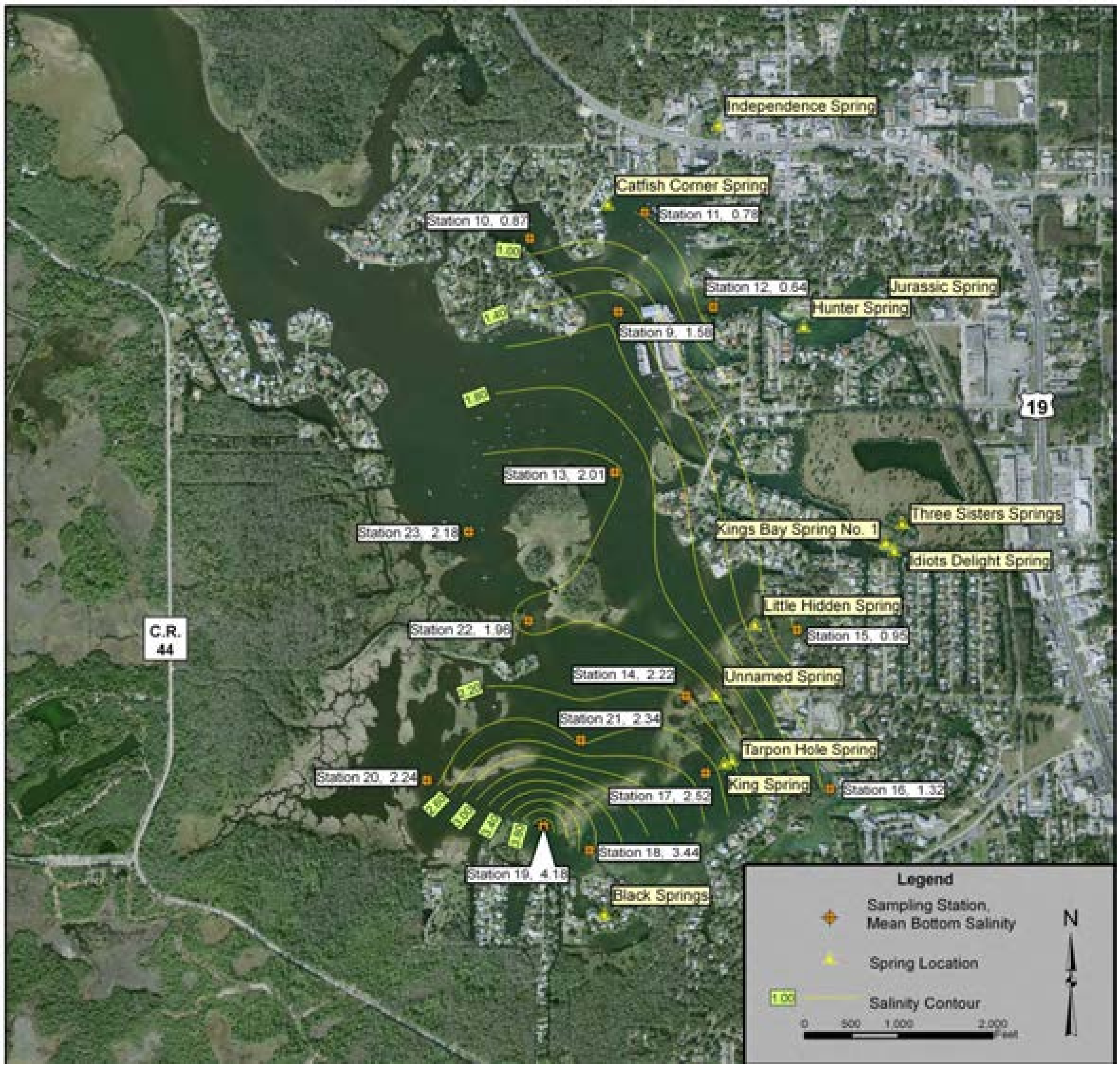

Figure 2-4. Kings Bay Area Major Springs and Surfer Plot of Mean Bottom Salinity at SWFWMD King's Bay Monitoring Stations. Data provided by SWFWMD.

Other studies relating benthic macroinvertebrate communities to salinity conditions in southwest Florida rivers in the context of minimum flows and levels assessments have utilized salinity and/or flow data for antecedent periods (often 30 days) prior to sampling as a factor explaining distribution and occurrence of benthic fauna (Grabe and Janicki 2008; Janicki 2007; Mote Marine Laboratory 2003). Available data included continuous discharge data from USGS site 02310747 for 45 days prior to the sampling period for this study. However, antecedent water quality data were not available for the study area.

The primary data collected and analyzed from the Crystal River included river location (as RK from the river mouth), water quality data from sample locations (conductivity/salinity, temperature, dissolved oxygen and pH), sediment grain size, benthic macroinvertebrate data, and oyster resource location. The benthic macroinvertebrate data were used to calculate community metrics of species richness, diversity, and total abundance.

2.3.2 Univariate Analyses

Conventional statistical analyses were performed using MINITAB® version 15.1.1.0 (Minitab 2000). Results were considered significant if $P<0.05$. All analyses were performed on raw, untransformed data unless otherwise noted. Trend and regression analyses were performed using a linear model. Regression analyses were performed on the same data as the trend analyses in order to determine if the trends observed were significant. These data were regressed versus a column of sequential numbers representing sampling dates in order (as advised by MINITAB® help section staff), resulting in a regression equation that was the same as that produced by the trend analysis. Significance levels for Spearman's rank correlation coefficients were determined using Table A-11 (or Table 7.11.2 if the number of observations was ten or less) from Snedecor and Cochran (1967).

Where possible, both the mean (using analysis of variance or ANOVA) and the median (using the Mann-Whitney test) were compared between groups. The mean (e.g., the average) is "easy to calculate and employs all available information…but it may be affected adversely by extreme values" (Walpole and Myers 1978). The median (the mean of the two central values) "gives a truer average" when extreme values are present, but is more variable than the mean (Walpole and Myers 1978). In addition, the nonparametric Mann-Whitney test (for medians) is not restrained by the requirements for normality and homogeneity of variances that are needed to optimize the effectiveness of the ANOVA process (used to test for differences in means). Thus, presenting and testing both the mean and median gives the observer a better feel for the population represented by the sample, and allows effective testing for significant differences for more groups (not just those that conform to normality and homogeneity of variances requirements).

The fifty dominant macroinvertebrate taxa for this study were determined using a procedure developed by Janicki (2007) and Grabe and Janicki (2008).

The Dominance Index (DI) was calculated for all taxa as the geometric mean of the frequency of occurrence (P_o) and the relative abundance (P_a) where:

P_o = (Number of Samples with Taxon/Total Number of Samples Collected) X100

P_a = (Total Number of Taxon Individuals in all Samples/Total Number of Individuals of all Species in all Samples) X100

The geometric mean of these terms equals the square root of their product:

$DI = (P_o * P_a)^{-0.5}$

P_o was calculated from the unpooled petite Ponar data (replicates separate). P_a was calculated from the pooled data (replicates combined).

The center of abundance (given as river kilometer) for the 50 most dominant taxa was determined using a weighted averaging method. The number of individuals for the taxon for each site where a taxon occurred was multiplied by the river kilometer location of the site. This was repeated for each site where the taxon was identified, and then the sum of these products was divided by the sum of all the individuals for that species. Salinity data were also treated in this manner to give mean salinity at capture, and these data are presented in a table that also gives mean salinity and densities (number of individuals per square meter) for the 50 most dominant taxa.

Other univariate metrics calculated included number of taxa (species richness) and abundance (raw counts of individuals). Three diversity indices were calculated including Shannon-Wiener H', Margalef's d, and Simpson's d (1-λ). Pielou's evenness was also calculated. The diversity indices use various mathematical formulations of the number of taxa and number of individuals to calculate a value representing the diversity of a given sample. Higher values indicate a sample with higher diversity. The Shannon-Wiener index incorporates a measure of the evenness of distribution of individuals that can be represented by the value for Pielou's evenness for a given sample. Further details about these measures can be found in Washington (1984). Three Shannon-Wiener index permutations are given in the metrics tables (base e, 2, and 10) for comparison purposes. The base 2 value was used in data analyses.

Forward stepwise multiple linear regression (with P=0.05) was performed to identify relationships between taxa richness, Shannon-Wiener diversity (base 2), and abundance and the physicochemical variables measured at the time of collection of macroinvertebrate samples. This analysis was intended to generate equations significantly relating these community metrics to the abiotic variables (Grabe and Janicki 2008).

Fully nested ANOVA was used to identify significant differences among macroinvertebrate metrics for each discrete sampling area and river kilometer group (for Crystal River transect sites only). Where significant differences were found, one-way ANOVA was used with the Tukey method to determine which site metrics were significantly different. Fully nested ANOVA could not be used to find significant differences for the means of river kilometer groups for the physicochemical data, because the number of records between sites was uneven. One-way ANOVA was used instead to determine if there were any significant differences among the means for those data. Conductivity was excluded from this analysis, since it is correlated to the salinity data, and dissolved oxygen percent saturation was excluded from this analysis, since it is correlated to the dissolved oxygen milligrams per liter (mg/L) data.

All univariate outputs from the statistical software are given in Appendix A.

2.3.3 Multivariate Analyses

Multivariate ordinations and procedures were performed using Primer version 6.1.8 (Clarke and Gorley 2001 and 2006; Clarke and Warwick 2001). Bray-Curtis similarity matrices were used to construct cluster diagrams and non-metric multidimensional scaling (MDS) ordination plots for the unpooled and pooled macroinvertebrate data.

A Principal Components Analysis (PCA) ordination for the mean values of the physicochemical data (excluding the non-independent variables conductivity and dissolved oxygen percent saturation) was performed as an independent method to determine site groups. PCA was performed on the normalized environmental data.

A Bray-Curtis similarity matrix derived from the unpooled macroinvertebrate data was used for the ANOSIM procedure to test for significant differences among replicates for each river kilometer group and among salinity groups determined using PCA. Fourth root transformed unpooled macroinvertebrate density (individuals per square meter) data were used for these tests. Nine thousand nine hundred ninety nine (9999) permutations were performed.

Where significant differences were found by the ANOSIM procedure, the SIMPER method was used to identify taxa contributing most to the differences between the groups.

Organism abundance, dominance index values, and SIMPER output of average contribution to dissimilarity were used to identify 15 dominant taxa having the greatest contribution toward differences in benthic invertebrate community structure along the salinity gradient. This selection method is further described in Section 3.3.5.

The Primer BEST procedure was run to determine which variables best explained the multivariate relationship between the biotic and abiotic matrices.

Primer Statistical Outputs are given in Appendix B, except for the SIMPER results, which are presented in Appendix C.

3.0 Results

3.1 Abiotic Physical–Chemical Factors

Trends in historical flow and salinity are discussed in this section. Primary physicochemical water and sediment data are described, and some interrelationships between these factors are discussed.

3.1.1 Historical Trends in Flow and Salinity

Trend analysis of historical flow data at USGS flow station 02310747 at Bagley Cove (approximately RK 8.6) from 2003 to 2009 shows a gradual but significant decrease in flow over time (p=0.002, Figure 3.1.1-1). This figure also depicts seasonal variation in flow.

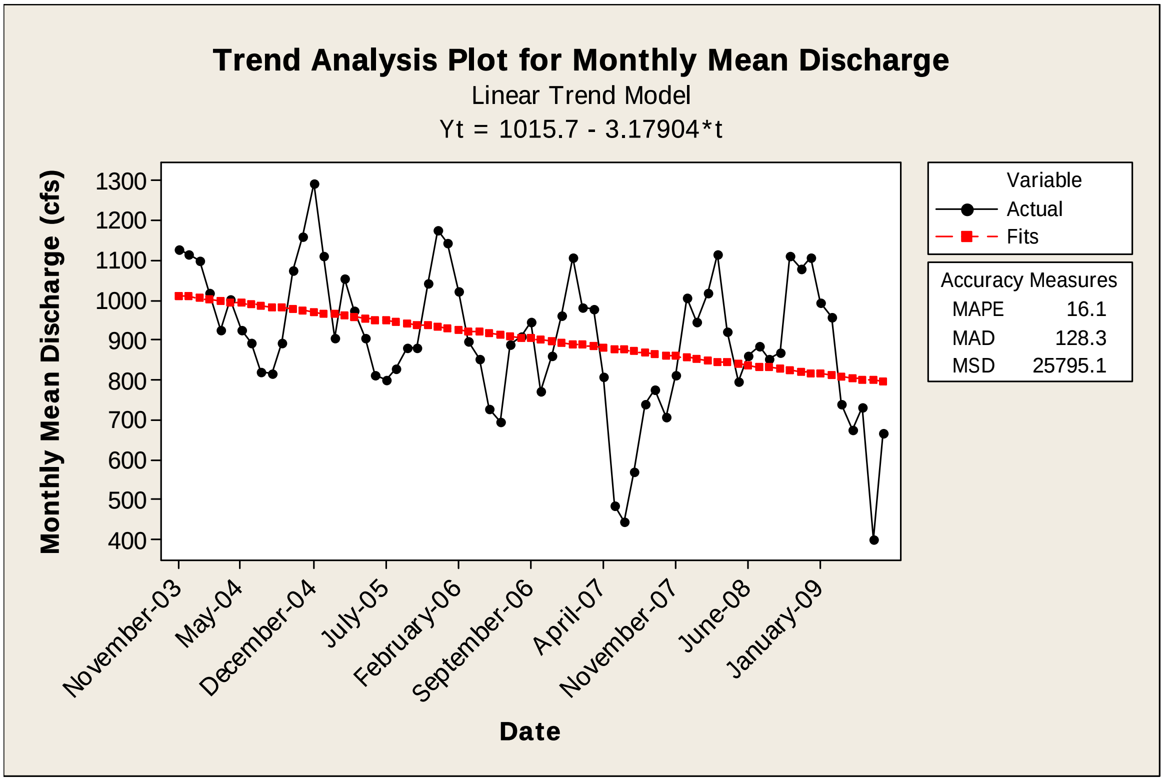

Figure 3.1.1-1. Crystal River Mean Monthly Discharge (Daily Mean Residual Discharge in Cubic Feet per Second; cfs) Data from the USGS Station 02310747 at Bagley Cove (Approximately River Kilometer 8.6).

Gage height daily minima and maxima for the 30-day period prior to the July 2009 sampling event illustrate tidal influence from the river mouth upstream to the mouth of Kings Bay (Appendix D, Figures D-1 through D-4). To help illustrate temporal changes in salinity, April 2008 – July 2009 SWFWMD data are plotted with the Water & Air July 2009 data, showing temporal variation in salinity (Figure 3.1.1-2). In April 2008 through July 2009, SWFWMD mean water column salinity concentrations at or near the current sampling locations were generally higher than during the single event measured by Water & Air in July 2009. SWFWMD mean and bottom salinity data are given in Appendix D, Table D-1; descriptive statistics are given in Appendix E, Table E-1.

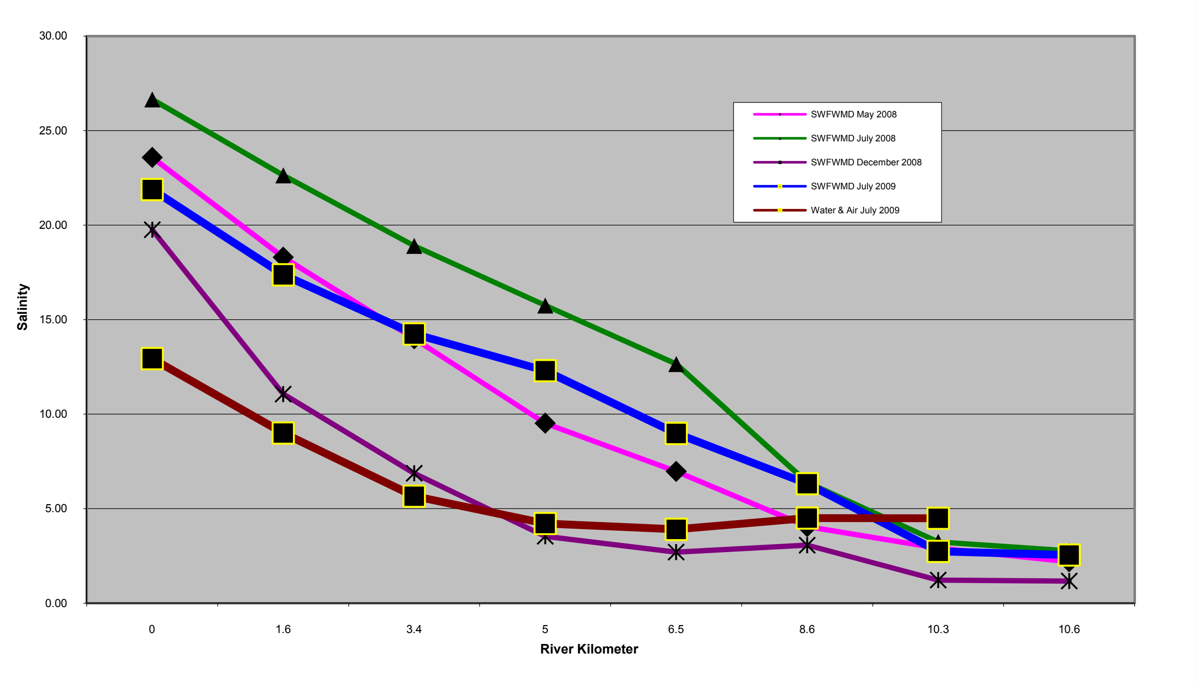

Figure 3.1.1-2. Mean water Column Profile Salinity Concentrations in the Crystal River Channel April 2008 - July 2009.

July 2009 data were also low in comparison to historical data (1984-1986) reported by Mote Marine (1986; Figure 3.1.1-3).

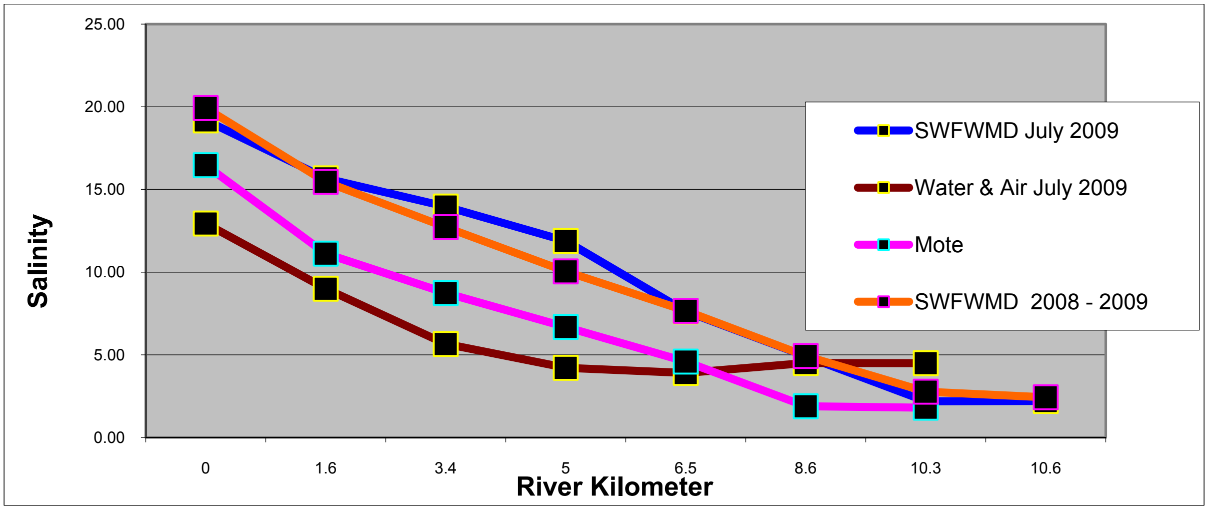

Figure 3.1.1-3. Mean Water Column Profile Salinity Concentrations in the Crystal River Channel April 2008 - July 2009 (SWFWMD and Water & Air) and 1984- 1986 (Mote Marine 1986).

3.1.2 Sediments

Based on PCA analysis of grain size data collected from five Tampa Bay rivers, including the Manatee and Braden Rivers, Janicki (2007) classified sediments of 18% or less silt and clay are classified as sand, and those with > 18% silt and clay are classified as mud. This convention is followed herein. Percent silt + clay in Crystal River sand sediments ranged from 20.2% at RK 7.5 to 98.8% at KB-2, all classified as mud. Finer sediments tended to be more prevalent in Kings Bay than in the river channel and the Gulf. Organic content of sediments ranged from 1.0% to 27.5% dry weight (Table 3.1.2-1). Descriptive summary statistics for sediment grain size are given in Appendix E, Table E-2

			Grain Size									
			Gravel	Gravel	Sand	Sand	Sand	Fines	Fines	SUM		
Sample Date	Sample No.	%>3"	% Coarse Gravel	% Fine	% Coarse Sand	% Medium	% Fine	% Silt	% Clay	*% Silt+Clay	*Classification	Percent Organics
7/22/2009	Gulf-1	0.0	0.0	0.0	0.1	0.5	60.9	26.1	12.4	38.5	Mud	3.70
7/22/2009	Gulf-2	0.0	0.0	0.4	1.0	3.8	61.3	23.3	10.2	33.5	Mud	3.20
7/22/2009	Gulf-3	0.0	0.0	0.0	0.2	1.0	65.1	22.5	11.2	33.7	Mud	3.30
7/22/2009	Gulf-4	0.0	0.0	0.0	0.5	1.5	54.1	31.3	12.6	43.9	Mud	4.30
07/22/09	RK 0	0.0	0.0	0.0	0.9	2.7	62.8	18.5	11.1	29.6	Mud	3.50
07/22/09	RK 2.5	0.0	0.0	0.0	1.4	1.0	64.6	25.3	7.0	32.3	Mud	2.50
07/23/09	RK 5	0.0	0.0	0.0	0.4	0.5	74.4	17.5	7.2	24.7	Mud	1.90
07/21/09	RK 7.5	0.0	0.0	0.0	0.3	0.7	78.8	13.9	6.3	20.2	Mud	1.90
07/22/09	RK 9.4	0.0	0.0	0.0	0.1	1.0	68.6	23.5	6.8	30.3	Mud	2.70
07/21/09	KB 1	0.0	0.0	0.0	0.2	1.2	68.4	23.7	6.5	30.2	Mud	2.00
07/22/09	KB 2	0.0	0.0	0.0	0.1	0.2	0.9	66.0	32.8	98.8	Mud	27.50
07/23/09	KB 3	0.0	0.0	0.0	0.1	1.1	64.2	30.6	4.0	34.6	Mud	1.50
07/23/09	KB 3-Dup	0.0	0.0	0.0	0.0	30.1	35.9	28.7	5.3	34	Mud	1.60
07/23/09	KB 4	0.0	0.0	0.1	0.0	1.5	73.8	19.4	5.2	24.6	Mud	1.00
07/23/09	KB 5	0.0	0.0	0.0	0.2	0.6	32.3	56.2	10.7	66.9	Mud	8.50
07/23/09	KB 6	0.0	0.0	0.0	0.6	2.9	50.9	40.2	5.4	45.6	Mud	2.40
07/23/09	KB 7	0.0	0.0	0.0	0.0	1.2	76.6	17.7	4.5	22.2	Mud	1.20
07/23/09	KB 8	0.0	0.0	0.0	0.0	1.0	41.7	47.7	9.6	57.3	Mud	4.70
07/23/09	KB 9	0.0	0.0	0.0	2.4	0.7	14.0	75.1	7.8	82.9	Mud	6.70
07/23/09	KB 10	0.0	0.0	0.0	0.0	1.5	71.9	20.2	6.4	26.6	Mud	2.00

Table 3.1.2-1. Crystal River Benthic Infauna Survey Sediment Grain Size and Percent Volatile Organic Material

3.1.3 Water

Salinity and dissolved oxygen at the water surface and bottom in July 2009 were similar at most sites, suggesting that waters were relatively well mixed (Appendix F, Table F-1, and Figures F-1 through F-6). Some stratification in salinity concentration was apparent at RK 0 and some of the relatively deep (2.8 to 3.3 meters) Kings Bay sites (KB-1, KB-2, and KB-8). Mean water column salinity ranged from 16 to 19 ppt in Gulf, from 4 to 13 ppt in the river channel, and from 0.3 to 4 in Kings Bay (Table 3.1.3-1, Appendix F, Figures F-7 through F-9). Descriptive summary statistics for water column physical and chemical data are given in (Appendix E, Table E3).

Station	Temperature (C)	pH	Specific Conductance (µmho/cm)	Salinity (ppt)	Dissolved Oxygen (% Sat.)	Dissolved Oxygen (mg/L)	Total Water Depth (m)	Tidal Stage
RK 0.0	29.37	7.83	21574.67	12.94	71.80	5.07	2.40	Outgoing (low)
RK 2.5	28.73	7.68	10028.75	5.66	64.45	4.81	3.40	Outgoing
RK 5.0	28.79	7.83	7556.80	4.21	80.50	6.05	3.90	Outgoing
RK 7.5	28.24	7.56	7021.50	3.91	71.53	5.43	3.10	Incoming
RK 9.4	29.36	7.80	8028.25	4.50	77.38	5.73	4.20	Incoming
Gulf-1	29.82	7.92	26756.33	16.78	78.27	5.37	2.00	Incoming
Gulf-2	29.87	8.01	26471.67	16.15	86.87	5.94	1.80	Incoming
Gulf-3	30.37	8.08	29773.00	18.40	99.47	6.67	2.20	Incoming
Gulf-4	30.34	8.09	30684.00	19.03	99.33	6.65	2.40	Incoming
KB-1	26.64	8.04	4030.50	2.16	75.68	6.59	3.30	Incoming
KB-2	29.35	7.95	6965.50	3.90	83.15	6.21	3.20	Outgoing
KB-3	27.89	8.53	2977.00	1.61	117.50	9.14	0.85	Incoming (low)
KB-4	28.08	8.59	2270.50	1.22	129.43	10.03	0.80	Incoming
KB-5	27.06	8.89	1640.33	0.87	132.43	10.47	1.90	Incoming
KB-6	27.00	9.15	596.35	0.31	155.35	12.31	1.20	Incoming
KB-7	29.52	8.30	4302.50	2.35	109.70	8.26	1.00	Incoming
KB-8	27.77	8.28	4548.00	2.49	109.00	8.42	2.80	Incoming
KB-9	28.41	8.39	4197.00	2.30	113.35	8.65	1.50	Incoming
KB-10	28.06	8.38	3709.50	2.02	106.45	8.20	1.50	Incoming (high)
KB-SR	29.23	7.52	10553.00	6.00	66.55	4.90	1.30	Incoming

Table 3.1.3-1. Crystal River Mean Values for Water Column Physicochemical Data Profiles from July 2009.

Janicki (2007) divided river segments into the following salinity zones based on PCA analysis of benthic community structure occurring along a wide range of salinities within multiple river systems along Florida's west coast: Oligohaline (0-7 ppt), Mesohaline (7-18 ppt), Polyhaline (18-29 ppt), and Euhaline (>29 ppt). Using this classification framework, historical data reported by Mote Marine (1986; Figure 3.1.1-3) shows the oligohaline zone starting near RK 5 and the mesohaline zone extending from RK 0 to RK 4. Salinities in the area of Gulf-1 through Gulf-4 may typically be in the polyhaline range.

Salinity as measured by Water &Air in July 2009 was considerably lower than most values encountered by SWFWMD in April 2008 - July 2009 and the more extensive historical data collected by Mote Marine and SWFWMD during the 1980's. The historical data indicate the oligohaline zone starting well above RK 2.5. This point emphasizes the limitation of inferences that can be made based on salinities measured during the single July 2009 sampling event.

Mean water column dissolved oxygen ranged from 4.81 to 6.67 mg/L (64 to 99 percent saturation) in the Gulf and river channel and from 6.21 to 12.31 mg/L (75 to 155 percent saturation) in Kings Bay. At the Gulf and river channel sites, mean water column pH ranged from 7.56 to 8.09. In Kings Bay, pH was higher, ranging from 7.95 to 9.15.

One-way ANOVA was employed to determine significant differences among sampling site groups (Kings Bay sites versus Crystal River channel/transect sites versus Gulf sites) for mean site physicochemical data. No significant differences among site groups were found for the site depth data. Mean temperature for Gulf sites was significantly greater than means for Crystal River channel and Kings Bay sites, and Crystal River channel mean temperature was significantly higher than Kings Bay mean temperature (P=0.0001). Kings Bay mean pH was significantly greater than Gulf and Crystal River sites' mean pH, and Gulf mean pH was significantly greater than Crystal River sites' mean pH (P=0.0001; Appendix A).

Mean salinity for Gulf sites was significantly higher than that for Crystal River and Kings Bay sites, and Crystal River mean salinity was significantly higher than mean salinity for Kings Bay (P=0.0001). Kings Bay mean dissolved oxygen was significantly higher than dissolved oxygen for Gulf and Crystal River sites (P=0.0001). Hammett et al. (1996) reported near freshwater conditions in the northeastern portion of Kings Bays with the northwestern and southeastern portions of the bay tending towards oligohaline conditions. Mean dissolved oxygen was not significantly different between Gulf and Crystal River sites (Appendix A).

3.2 Oyster Distribution

Oyster bars were defined as intertidal mounds of living oysters and dead shell. Fourteen (14) oyster bars were observed in the river channel within 2.4 km of the river mouth (Figure 3.2-1). Oyster bar #1 was located at RK 0.05 closest to the mouth of the river, and oyster bar #14 was located farthest upstream at RK 2.4 (Table 3.2-1). Oyster bars #7 through #13 were all associated with rock outcroppings. (Figure 3.2-2)

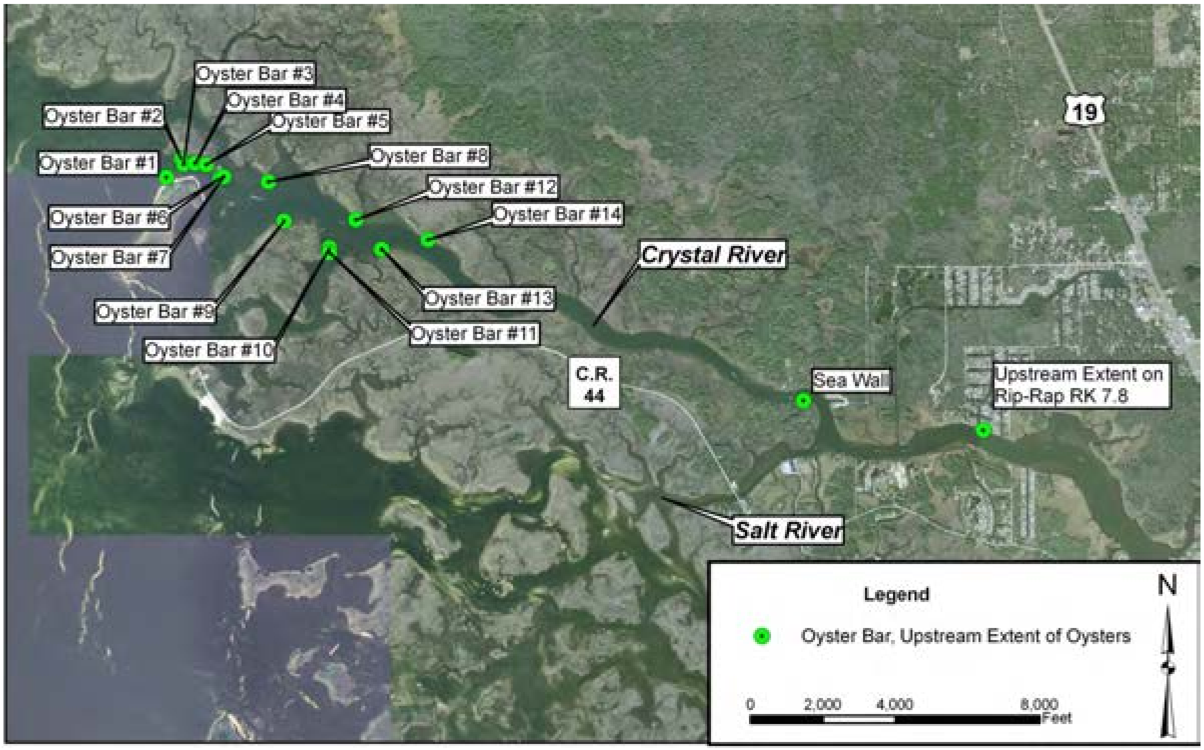

Figure 3.2-1. Oyster Bar Locations and Upstream Oyster Extent

ID	Waypoint ID	Date	Time	Latitude	Longitude	River Kilometer	*Tidal Stage (Feet Above Mean Lower Low Water)	Oyster Bar Submerged / Exposed
1	22	7/23/2009	8:43	28.92563	-82.69510	0.05	0.84	Submerged
2	25	7/23/2009	8:54	28.92700	-82.69382	0.15	0.78	Exposed
3	26	7/23/2009	8:56	28.92665	-82.69362	1.50	0.77	Exposed
4	27	7/23/2009	9:01	28.92672	-82.69263	0.25	0.74	Exposed
5	28	7/23/2009	9:08	28.92661	-82.69168	0.30	0.72	Exposed
6	30	7/23/2009	9:13	28.92559	-82.69049	0.50	0.69	Exposed
7	31	7/23/2009	9:16	28.92570	-82.69017	0.50	0.68	Submerged
8	35	7/23/2009	9:59	28.92535	-82.68630	0.90	0.54	Exposed
9	36	7/23/2009	10:04	28.92235	-82.68493	1.10	0.53	Exposed
10	37	7/23/2009	10:13	28.92035	-82.68097	1.60	0.52	Exposed
11	38	7/23/2009	10:14	28.91997	-82.68095	1.65	0.52	Exposed
12	40	7/23/2009	10:21	28.92250	-82.67869	1.70	0.51	Exposed
13	42	7/23/2009	10:32	28.92025	-82.67646	2.00	0.51	Exposed
14	43	7/23/2009	10:40	28.92101	-82.67245	2.40	0.52	Exposed

* Source of tidal stage data:

http://tbone.biol.sc.edu/tide/tideshow.cgi?site=Shell+Island%2C+north+end%2C+Crystal+River%2C+Florida&units=f

Table 3.2-1. Locations of Oyster Beds Observed in the Lower Crystal River.

Figure 3.2-2. Oyster Bar Near the Mouth of Crystal River.

Oysters were seen sporadically growing on various substrates, including metal and wood channel markers (Figure 3.2-3), natural rock outcroppings (Figure 3.2-4), mud, concrete seawalls (Figure 3.2-5) and rip-rap (Figure 3.2-6). Live oysters were also collected using the petite Ponar dredge while sampling for sediments and macroinvertebrates in approximately 12 feet of water, mid-channel at site RK 2.5.

Figure 3.2-3. Oyster Colonization of Artificial Substrates.

Figure 3.2-4. Oyster Colonization of Natural Rock Outcroppings.

Figure 3.2-5. Oyster Colonization of Mud and Concrete Seawalls.

Figure 3.2-6. Oyster Colonization of Rip-rap.

Based on live oyster sightings on various substrates, the upstream extent of oyster is approximately RK 7.8. Thick clumps of oysters were observed growing on a concrete seawall at RK 6.0. However, no live oysters were observed on a concrete seawall at RK 8.2. Live oysters were growing on exposed rip-rap at RK 7.8. Only dead oyster shells were found on rip-rap at RK 8.0 on the opposite side of the river.

3.3 Macroinvertebrate Community Analyses

Characteristic benthic macroinvertebrate taxa and benthic community metrics of the Crystal Bay (Gulf sites), Crystal River, and Kings Bay are discussed in relation to longitudinal distribution within the Crystal River, the salinity gradient, and other physicochemical parameters.

3.3.1 Dominant Crystal River Macroinvertebrate Taxa

Characteristic macroinvertebrates of the river were tabulated based on their dominance index score. The 50 macroinvertebrate taxa from petite Ponar samples with the highest dominance scores are listed in a table also giving values for mean density, mean salinity at capture, and the abundance-weighted salinity (Table 3.3.1-1). Mean salinity at capture is an average of the bottom salinity concentrations at locations where a given taxon was collected, without regard to organism abundance. Abundance-weighted salinity uses organism abundance to calculate the salinity at which peak abundance occurred (also called optimal salinity). These 50 taxa made up 89.3% of the total number of organisms collected during this study.

Taxa	Mean Density (m2)	Dominance Index	Mean Salinity of Capture (ppt)	Abundance-weighted Salinity (ppt)
Apocorophium louisianum	7892.31	34.21	6.47	4.58
Cyrenoida floridana	5356.76	26.98	2.94	4.54
Cerapus benthophilus	5597.41	24.95	3.64	4.43
Hobsonia florida	1116.21	13.89	3.51	3.90
Littoridinops sp.	1189.03	11.50	2.69	2.57
Laeonereis culveri	520.21	10.14	5.32	4.32
Ampelisca abdita	697.10	8.30	7.16	5.15
Halmyrapseudes cf. bahamensis Heard	413.14	6.39	7.94	5.28
Pyrgophorus platyrachis	491.97	5.51	3.12	2.85
Streblospio sp.	161.97	5.48	5.97	4.99
Limnodrilus hoffmeisteri	382.03	4.86	2.06	2.46
Dero digitata complex Milligan	426.59	4.59	1.62	1.12
Cyathura polita	120.41	4.56	5.52	3.96
Tubificoid Naididae imm. w/o hair setae (LPIL)	254.17	4.34	2.69	2.09
Gammarus sp. B LeCroy	154.55	4.15	2.60	2.30
Tubificoid Naididae (LPIL)	178.41	3.93	10.24	5.46
Pristina leidyi	288.31	3.77	1.62	2.21
Grandidierella bonnieroides	151.59	3.62	3.00	2.78
Rhithropanopeus harrisii	69.79	3.22	6.02	4.62
Tubificoides sp.	245.28	3.01	4.26	4.50
Aricidea taylori	166.45	2.87	16.41	17.22
Edotia triloba	115.90	2.39	4.39	4.64
Nemertea (LPIL)	40.07	2.34	9.32	12.25
Polypedilum scalaenum group Epler	49.03	1.91	3.67	3.82
Aoridae (LPIL)	40.10	1.86	9.32	13.15
Cyclaspis varians	46.07	1.85	9.12	6.10
Monticellina sp.	63.90	1.78	16.41	16.96
Taphromysis bowmani	44.55	1.66	6.73	5.84
Actiniaria (LPIL)	35.62	1.63	10.67	7.45
Ampelisca sp. C LeCroy	41.62	1.60	12.82	12.13
Xenanthura brevitelson	41.62	1.60	9.28	5.03
Chironomus sp.	47.55	1.53	2.06	1.47
Dicrotendipes sp.	43.10	1.46	2.06	2.45
Heteromastus filiformis	28.24	1.45	12.82	10.51
Psammoryctides convolutus	53.52	1.41	1.83	1.16
Mooreonuphis nebulosa	40.14	1.41	16.41	17.28
Mytilopsis leucophaeata	49.03	1.35	2.52	2.52
Melita nitida complex LeCroy	31.24	1.24	12.82	12.35
Mediomastus ambiseta	23.76	1.21	16.41	17.59
Magelona riojai	28.24	1.18	16.41	17.15
Aricidea philbinae	22.28	1.17	12.82	15.29
Glycinde solitaria	26.76	1.15	17.98	17.98
Americorophium ellisi	26.76	1.15	3.68	4.25
Gammarus cf. tigrinus LeCroy	107.00	1.15	4.59	4.59
Scoletoma verrilli	25.28	1.12	16.41	17.43
Crassostrea virginica	50.52	1.12	10.24	5.91
Coelotanypus concinnus group Epler	28.24	1.02	3.35	4.30
Sayella sp.	20.79	1.01	4.94	4.43
Fabricinuda trilobata	17.83	0.94	16.41	15.88
Procladius (Holotanypus) sp.	17.83	0.94	2.06	1.66

Table 3.3.1-1. Fifty Dominant Benthic Taxa, Mean Abundance, and Mean Salinity at Capture for All Petite Ponar Stations Sampled in the Crystal River Project, July 2009.

The amphipods *Apocorophium louisianum* and *Cerapus benthophilus*, and the bivalve mollusc, *Cyrenoida floridana*, were ranked highest in dominance with index scores of 34.21, 26.98, and 24.95, respectively. These three species made up 67.5% of the total number of organisms collected by petite Ponar dredge during this study.

3.3.2 Longitudinal Patterns in Macroinvertebrate Community Metrics

For the following two sections, macroinvertebrate data collected using a petite Ponar dredge were used. Dipnet data are discussed in Section 3.5 of this report. The term unpooled data refers to data generated from single discrete grabs of the dredge. The term pooled data refers to data which have been composited from three or more grabs. For the Crystal River channel sites, transects of three samples were collected across the channel, so for each river kilometer location, data for these three grabs were composited for the pooled data set. The four Gulf station grabs were composited together. Samples from Kings Bay, stations were composited as follows: KB 1-3; KB 4-6; and KB 7-10. The unpooled data are useful for statistical tests that show more robust results, because there are a higher number of observations. The pooled data tend to dampen random variability evident in the unpooled replicates, and, thus, are more representative of the fauna of the general area of sampling.

The macroinvertebrate metrics number of taxa, density, and the Shannon-Wiener diversity index (base 2) were used to explore the longitudinal distribution of macroinvertebrate community characteristics (Tables 3.3.2-1 and 3.3.2-2). Despite the complex and unique hydrology of the Crystal River system, which has two major outlets to the Gulf of Mexico (Crystal and Salt Rivers) and the lack of extensive freshwater headwaters (having instead the freshwater and oligohaline zones of Kings Bay at its head), the pattern of macroinvertebrate longitudinal distribution resembles that of the typical Gulf coast river. Number of taxa and diversity indices decrease along the upstream salinity gradient of the Crystal River channel (e.g., Figures 3.3.2-1 and 3.3.2-2), then increase in Kings Bay, giving the typical bowl-shaped pattern for these metrics over the greater system. Number of taxa and the diversity index decreased to a nadir (the artenminimum) at station RK 9.4 (Figures 3.3.2-3 and 3.3.2-4).

Site/Metrics	Number of Taxa	Number of Individuals	Margalef's d	Pielou's Evenness	Shannon Diversity			Simpson's d (1-λ)
	S	N	d	J'	H'(loge)	H'(log2)	H'(log10)	1-Lambda
Gulf-1	34	177	6.375	0.837	2.953	4.260	1.283	0.900
Gulf-2	28	71	6.334	0.913	3.044	4.391	1.322	0.937
Gulf-3	34	124	6.846	0.795	2.802	4.043	1.217	0.889
Gulf-4	18	33	4.862	0.916	2.649	3.821	1.150	0.913
RK 0-A	32	123	6.442	0.859	2.978	4.296	1.293	0.918
RK 0-B	12	24	3.461	0.852	2.117	3.054	0.919	0.830
RK 0-C	20	54	4.763	0.858	2.570	3.708	1.116	0.893
RK 2.5-A	25	382	4.037	0.503	1.619	2.335	0.703	0.679
RK 2.5-B	20	113	4.019	0.745	2.231	3.219	0.969	0.835
RK 2.5-C	17	294	2.815	0.594	1.683	2.428	0.731	0.658
RK 5-A	17	110	3.404	0.771	2.184	3.151	0.949	0.802
RK 5-B	16	325	2.593	0.643	1.782	2.570	0.774	0.755
RK 5-C	22	182	4.035	0.760	2.350	3.390	1.021	0.847
RK 7.5-A	15	63	3.379	0.758	2.053	2.961	0.891	0.805
RK 7.5-B	6	27	1.517	0.688	1.233	1.778	0.535	0.598
RK 7.5-C	19	129	3.704	0.699	2.057	2.968	0.893	0.763
RK 9.4-A	9	104	1.723	0.679	1.493	2.153	0.648	0.680
RK 9.4-B	10	13068	0.950	0.579	1.334	1.925	0.579	0.693
RK 9.4-C	11	168	1.952	0.924	2.215	3.196	0.962	0.871
KB-1	13	155	2.379	0.694	1.781	2.570	0.774	0.765
KB-2	14	377	2.191	0.349	0.920	1.328	0.400	0.367
KB-3	20	501	3.056	0.617	1.847	2.665	0.802	0.748
KB-4	13	324	2.076	0.541	1.387	2.001	0.602	0.542
KB-5	9	108	1.709	0.682	1.499	2.162	0.651	0.626
KB-6	10	156	1.782	0.652	1.501	2.166	0.652	0.625
KB-7	15	360	2.378	0.858	2.324	3.353	1.009	0.879
KB-8	11	28	3.001	0.832	1.995	2.879	0.867	0.814
KB-9	8	125	1.450	0.599	1.245	1.797	0.541	0.664
KB-10	17	1074	2.293	0.505	1.432	2.065	0.622	0.584

Table 3.3.2-1. Unpooled Metrics for all Petite Ponar Samples.

Table 3.3.2-2. Pooled Metrics for all Petite Ponar Samples.

Site/Metrics	Number of Taxa	Number of Individuals	Margalef's d	Pielou's Evenness	Shannon Diversity			Simpson's d (1-λ)
	S	N	d	J'	H'(loge)	H'(log2)	H'(log10)	1-Lambda
Gulf	71	405	11.66	0.81	3.47	5.01	1.51	0.94
RK 0	52	201	9.62	0.87	3.44	4.96	1.49	0.96
RK 2.5	43	789	6.30	0.58	2.19	3.16	0.95	0.78
RK 5	33	617	4.98	0.68	2.36	3.41	1.03	0.84
RK 7.5	28	219	5.01	0.76	2.53	3.66	1.10	0.88
RK 9.4	22	13340	2.21	0.46	1.43	2.07	0.62	0.70
KB-1-3	28	1033	3.89	0.65	2.16	3.12	0.94	0.83
KB-4-6	22	588	3.29	0.70	2.15	3.10	0.93	0.80

Table 3.3.2-2. Pooled Metrics for all Petite Ponar Samples.

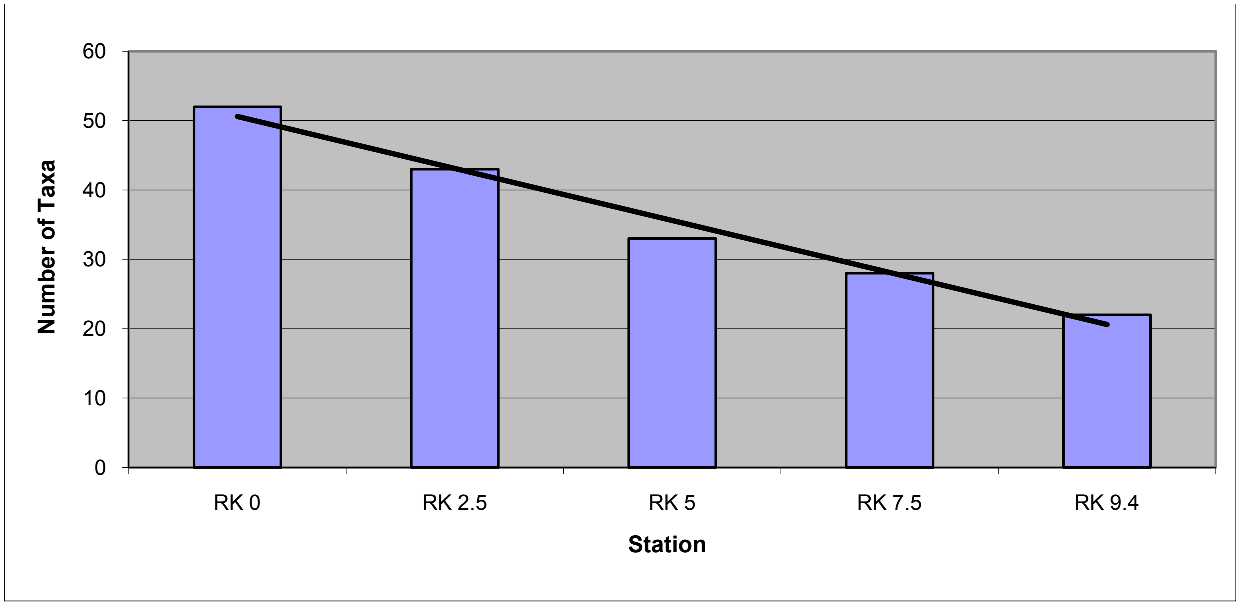

Figure 3.3.2-1. Number of Taxa for Pooled Crystal River Transect Petite Ponar Stations.

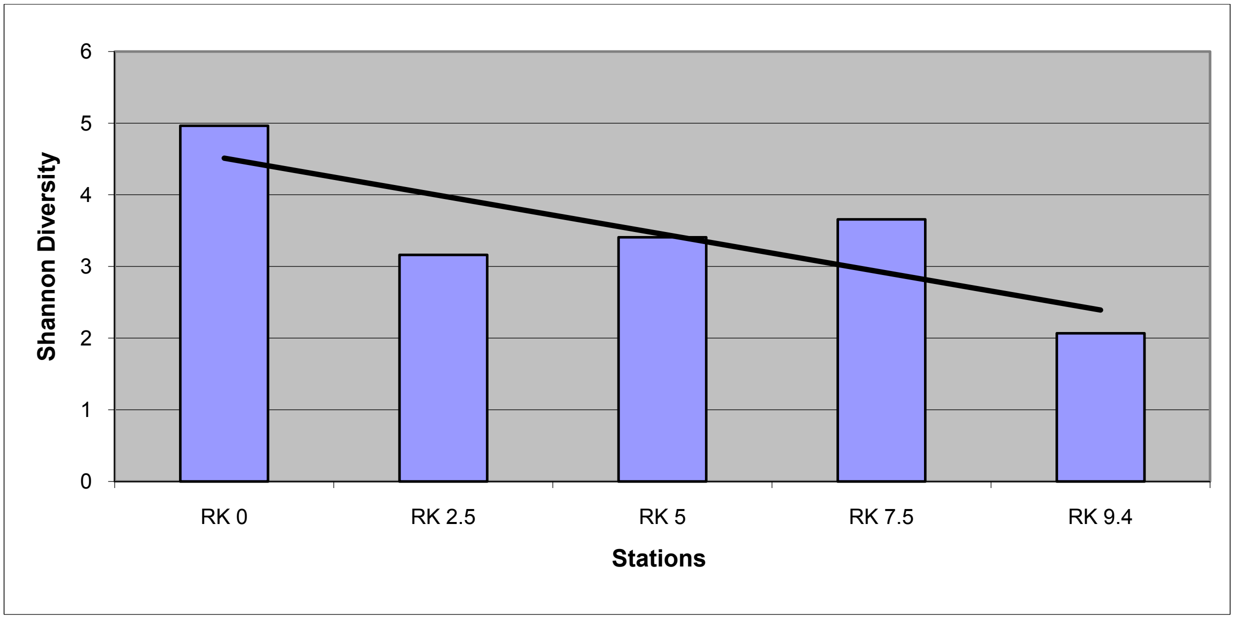

Figure 3.3.2-2. Shannon-Wiener Diversity (Base 2) for Pooled Crystal River Transect Petite Ponar Stations.

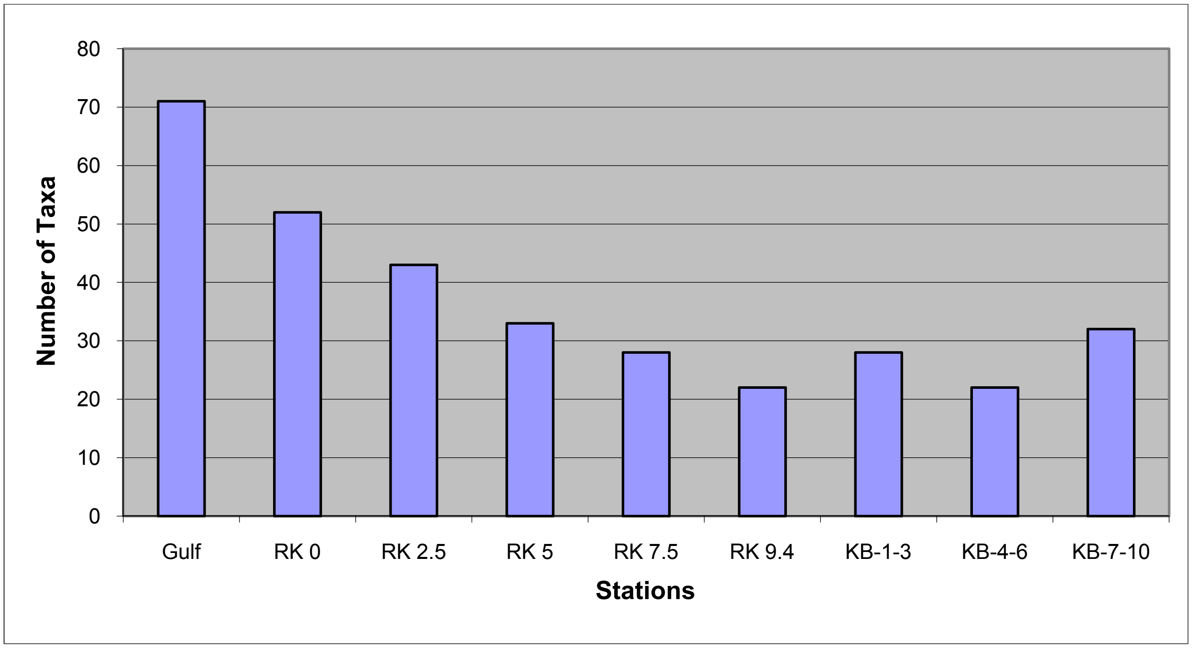

Figure 3.3.2-3. Number of Taxa for All Pooled Crystal River Project Petite Ponar Samples.

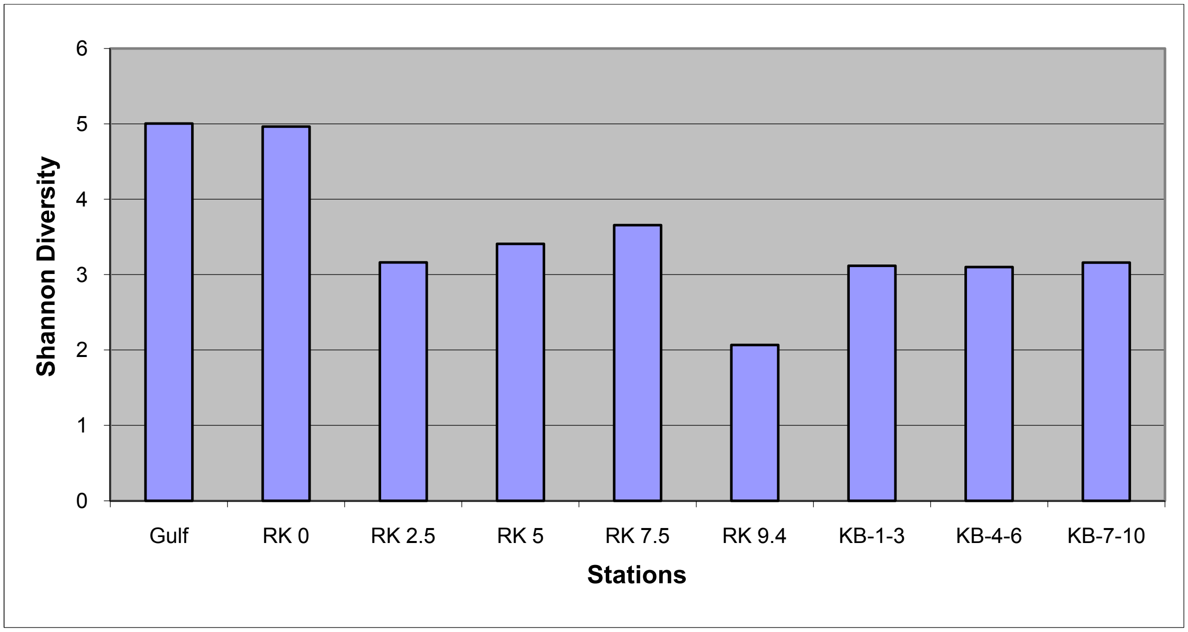

Figure 3.3.2-4. Shannon-Wiener Diversity for All Pooled Crystal River Project Petite Ponar Samples.

There is a well-known relationship between estuarine salinity and numbers of species. Taxa richness is highest in full strength seawater. Marine species decline in richness as salinity decreases, with some tolerant estuarine opportunistic species appearing. Between 5 and 10 ppt, taxa richness reaches a nadir, with most species captured being estuarine specialists with some freshwater taxa also present. Below 5 ppt, taxa richness increases as freshwater taxa begin to predominate (Remane 1934; Remane and Schlieper 1971; Attrill 2002).

Macroinvertebrate density did not show any regular longitudinal relationship (Figure 3.3.2-5). Density was highest at station RK 9.4 (191,667 individuals per square meter for three pooled replicates) and lowest at RK 0 (2,888 individuals per square meter for three pooled replicates). High organism density at RK 9.4 was primarily driven by *Apocorophium louisianum* (75, 517 per square meter; 39.4% of total density), *Cerapus benthophilus* (51,753 per square meter; 27.0% of total density) and *Cyrenoida floridana* (49,253 per square meter; 25.7% of total density). These extremely high densities occurred in a single Ponar grab sample. Results at Transect RK 9.4 exemplify the contagious spatial distribution of the benthic infauna and emphasize the importance of collecting a sufficient number of replicates to capture the variability in spatial distribution and achieve a representative sample. Descriptive summary statistics for unpooled and pooled macroinvertebrate Ponar metrics are given in Appendix E; Tables E-4 and E-5, respectively.

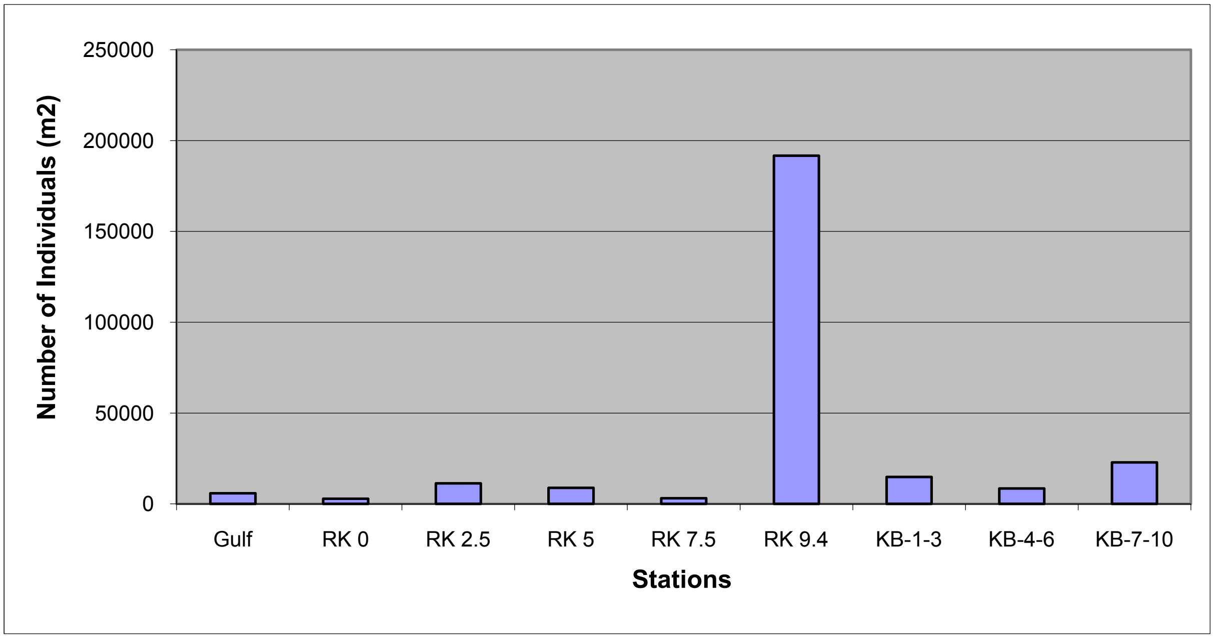

Figure 3.3.2-5. Number of Individuals per Square Meter for All Pooled Crystal River Project Petite Ponar Samples.

3.3.3 Association of Macroinvertebrate Metrics with Physiochemical Parameters

Forward stepwise linear regression was used to seek relationships between univariate metrics and the physicochemical variables measured at the time of sampling. Number of taxa, Shannon-Wiener diversity, and density were the metrics selected for this exercise. Significant relationships (whereby the variables included in the model met the condition of $P< 0.05$) were found between number of taxa and salinity, and between Shannon-Wiener diversity and salinity and percent silt plus clay. These relationships are based on a single sampling event and should be viewed with caution. Significant relationships were not found between density and any physicochemical variables using this procedure (Table 3.3.3-1).

Models	Adjusted Multiple R2
Number of Taxa (P=0.0001)	
Number of Taxa = 11.2 + 0.924 Salinity	0.45
Shannon Diversity - log base 2 version - Salinity (P=0.0001); % Silt+Clay (P=0.018)	
Shannon Diversity (log2) = 2.63 + 0.108 Salinity - 0.0129 % Silt+Clay	0.64
Number of Individuals per Square Meter	
No Significant Regression Relationship was found	NA

Table 3.3.3-1. Results of Forward Stepwise Regression Analyses Examining Relationships between Numbers of Taxa, Shannon-Wiener Diversity, and Density with the Abiotic Variables for Crystal River Project Data. Variables Selected were Required to Have P< 0.5 to Be Included.

The Spearman's rank correlation method was used to reveal correlations among and between physicochemical parameters and select macroinvertebrate metrics (Tables 3.3.3-2 – 3.3.3-4). Percent silt plus clay was significantly correlated with pH. Total site depth was significantly inversely correlated with pH, dissolved oxygen percent saturation, and dissolved oxygen (mg/L). Water column pH was also significantly inversely correlated with salinity and conductivity. Dissolved oxygen percent saturation was significantly correlated to dissolved oxygen (mg/L), conductivity (specific conductance), salinity, and pH. Dissolved oxygen (mg/L) was significantly correlated with pH and inversely with number of taxa, salinity, and conductivity. pH was significantly correlated with dissolved oxygen percent saturation. pH was inversely correlated with river kilometer. Conductivity was significantly correlated with temperature and highly correlated with salinity. Salinity was also significantly correlated with temperature, number of taxa, Pielou's evenness, and Shannon-Wiener diversity. Temperature was also significantly inversely correlated with dissolved oxygen (mg/L), number of taxa, Pielou's evenness, and Shannon-Wiener diversity (log 2).

Variable	Temperature	pH	Specific Conductance	Salinity	Dissolved Oxygen (% Saturation)	Dissolved Oxygen (mg/L)
pH	-0.429					
Specific Conductance	**0.859**	**-0.683**				
Salinity	**0.859**	**-0.683**	**1.000**			
Dissolved Oxygen (% Saturation)	-0.329	**0.956**	**-0.636**	**-0.636**		
Dissolved Oxygen (mg/L)	**-0.496**	**0.955**	**-0.738**	**-0.738**	**0.962**	
Total Depth	0.123	**-0.642**	0.411	0.411	**-0.646**	**-0.556**
Significance levels: N = 19; degrees of freedom = 17; for P=0.05, ρ = 0.456; for P=0.01, ρ = 0.575 (Snedecor and Cochran 1967; Table A-11). Significant correlations are given in bold font.						

Table 3.3.3-2. Spearman's Rank Correlation Coefficients (ρ) Among Mean Profile Physicochemical Variables for Data Collected by Water and Air Research in July 2009.

Variable	Number of Taxa	Number of Individuals	Margalefs d	Pielous Evenness	Shannon Diversity (loge)	Shannon Diversity (log2)	Shannon Diversity (log10)
Number of Individuals	0.151						
Margalefs d	**0.908**	-0.223					
Pielous Evenness	0.295	**-0.589**	**0.533**				
Shannon Diversity (loge)	**0.729**	-0.308	**0.844**	**0.850**			
Shannon Diversity (log2)	**0.729**	-0.308	**0.844**	**0.850**	**1.000**		
Shannon Diversity (log10	**0.729**	-0.308	**0.844**	**0.850**	**1.000**	**1.000**	
Simpsons d (1-λ)	**0.586**	**-0.374**	**0.742**	**0.896**	**0.950**	**0.950**	**0.950**

Significance levels: N = 29; degrees of freedom = 27; for P=0.05, ρ = 0.367; for P=0.01, ρ = 0.470 (Snedecor and Cochran 1967; Table A-11). Significant correlations are given in bold font.

Table 3.3.3-3. Spearman's Rank Correlation Coefficients (ρ) among All Crystal River Project Unpooled Ponar Metrics.

Variable	Temperature	pH	Salinity	Dissolved Oxygen (mg/L)	Total Depth	Percent Silt+Clay	Number of Taxa	Number of Individuals	Pielou's Evenness
pH	-0.180								
Salinity	**0.832**	**-0.447**							
Dissolved Oxygen (mg/L)	**-0.376**	**0.840**	**-0.682**						
Total Depth	0.117	**-0.767**	0.319	**-0.540**					
Percent Silt+Clay	-0.001	**0.455**	0.039	0.283	-0.169				
Number of Taxa	**0.446**	-0.115	**0.567**	**-0.355**	-0.090	-0.047			
Number of Individuals	-0.138	0.133	-0.310	0.180	-0.004	0.028	0.151		
Pielou's Evenness	**0.559**	-0.045	**0.525**	-0.184	-0.036	-0.102	0.295	**-0.589**	
Shannon Diversity (log2)	**0.613**	-0.064	**0.650**	-0.286	-0.068	-0.075	**0.729**	-0.308	**0.850**

Significance levels: N = 29; degrees of freedom = 27; for P=0.05, ρ = 0.367; for P=0.01, ρ = 0.470 (Snedecor and Cochran 1967; Table A-11). Significant correlations are given in bold font.

Table 3.3.3-4. Spearman's Rank Correlation Coefficients (ρ) Among Select Crystal River Project Unpooled Ponar Metrics and Physicochemical Variables.

Number of individuals was significantly correlated with Pielou’s evenness and Simpson’s d index. Pielou’s evenness was also significantly correlated with all versions of Shannon-Wiener diversity (log 2, e, and 10), Margalef’s d index, and Simpson’s d index. Shannon-Wiener diversity (log 2) was highly correlated with log e and log 10 versions of this index, which were all highly correlated with Simpson’s d index. Number of taxa was significantly correlated with all versions of Shannon-Wiener diversity (log 2, e, and 10), Simpson’s d index, and Margalef’s d index. Margalef’s d index was significantly correlated with all versions of Shannon-Wiener diversity (log 2, e, and 10) and Simpson’s d index.

The high degree of correlation between conductivity and salinity and the correlation between dissolved oxygen percent saturation and dissolved oxygen (mg/L) can be explained by the fact that the instrument recording these parameters used the same data to calculate their values. In other words, conductivity data are used to calculate salinity, and dissolved oxygen data are used in the calculation of dissolved oxygen percent saturation. This justifies the exclusion of conductivity and dissolved oxygen percent saturation from many of the analyses performed due to the redundancy of these variables with salinity and dissolved oxygen (mg/L), respectively.

For macroinvertebrate metrics, in some cases number of individuals was used in analyses, and in others number of individuals per square meter (density) was used, based on the precedent set by previous research. These metrics are forms of each other (individuals per square meter is calculated from number of individuals by multiplication by a factor), so these two metrics were not used together due to their redundancy. Of the diversity indices, only Shannon-Wiener diversity (base 2) was used in subsequent analyses, since it was significantly correlated to all the other diversity indices. Although this diversity index was significantly correlated to number of taxa and Pielou’s Evenness, these metrics were retained, as they represent unique aspects that contribute to the index, and their statistical behavior may vary from it.

The correlations of salinity with temperature and pH with dissolved oxygen (mg/L) can be explained by the unusual physiography of the Crystal River system and the buffering capacity of seawater. Abundant freshwater issuing from the many springs in the Kings Bay area was cooler than surrounding ambient waters in July when sampling was conducted (Rosenau et al. 1977 give temperatures of 22.9^{o}C and 23.0^{o}C for Tarpon Hole and Hunter springs, respectively) which generally results in cooler water temperatures for Kings Bay. As water discharges from Kings Bay, it is warmed by sunlight and by dilution with warmer seawater originating from the Gulf of Mexico and driven upriver by tidal forces. Thus, temperatures are warmer in the Crystal River channel than in Kings Bay, and Gulf waters are warmer than those of the Crystal River channel. Since salinity is also higher in the Gulf and decreases upriver, in this system it is significantly correlated with temperature.

Dissolved oxygen is higher in Kings Bay, likely due to dissolved oxygen production by extensive aquatic plant communities and associated periphyton in this water body. Where plant production is high in aquatic systems, especially when there is a substantial algal component to the plant community, pH may be elevated due to consumption of acidic carbonic acid in the photosynthesis process (Meyer and Barclay 1990). The higher pH measured for Kings Bay was likely due to this phenomenon. As water flows from Kings Bay, it loses oxygen due to physical and biological processes in the water as it flows through the Crystal River channel to the Gulf of Mexico. This dissolved oxygen is not replenished to the levels found in Kings Bay due to less luxuriant vegetative communities and turbidity-induced shading in the Crystal River channel and the Gulf of Mexico. Thus, there is a gradient of decreasing oxygen from Kings Bay through the Crystal River to the Gulf. Full strength seawater has a large capacity for buffering due to its calcium-magnesium hardness content (Mitchell and Rakestraw 1933). Thus, as water travels towards the Gulf of Mexico where salinity is higher, the pH of the inflowing freshwater is neutralized. It is suggested that significant correlation of pH with dissolved oxygen is due to these parallel processes affecting pH and dissolved oxygen levels along the gradient of increasing salinity.

One-way ANOVA showed that mean number of taxa was significantly higher for Gulf sites than for Crystal River and Kings Bay sites. Mean number of taxa was not significantly different between Crystal River and Kings Bay sites (ρ=0.001). Mean number of individuals was not significantly different among any of the site groups. Mean Pielou’s evenness for Gulf sites was significantly higher than this index for Kings Bay (ρ=0.014), but Gulf and Crystal River and Kings Bay and Crystal River Pielou’s evenness means were not significantly different from each other. Mean base 2 Shannon-Wiener diversity index (SWDI) for Gulf sites was significantly higher than that for stations in Crystal River and Kings Bay (ρ=0.001), but Kings Bay and Crystal River SWDI means were not significantly different from each other (Appendix A).

3.3.4 Multivariate Community Analyses

Relationships among the macroinvertebrate communities for unpooled (replicates separate) and pooled (replicates combined) data were explored using cluster diagrams and MDS. Both of these methods employ Bray-Curtis similarity matrices (Appendix G). The Primer ANOSIM procedure was used to determine if priori groups were significantly different from each other. To determine the taxa most responsible for dissimilarity among the groups, the Primer SIMPER procedure was applied. The Primer BEST procedure was used to determine which abiotic variables best matched or explained the multivariate distribution of the macroinvertebrate communities.

The cluster diagram with the replicates separate (unpooled) shows that most of the replicates for a given site transect were very similar to each other, and, thus, clustered together, though there was some inter-digitation of replicates for Crystal River channel transect sites with adjacent station replicates (Figure 3.3.4-1). The Gulf and Kings Bay samples also tended to cluster with each other, and there also was a tendency for Kings Bay samples that were pooled according to the scheme outlined above to cluster together. The generally close relationship among these replicates supports the idea that samples taken at the same position in the river system will share similar macroinvertebrate communities, and justifies pooling the replicates. The MDS ordination diagram (drawn from the same Bray-Curtis similarity matrix used to create the cluster diagram) shows that the replicates group together, and also shows a trend from the downstream Gulf group (on the left side of the ordination) to the upstream Kings Bay group (on the right side of the ordination) along the salinity gradient (Figure 3.3.4-2). These diagrams support the distinctiveness of the discrete sampling areas, while showing some similarity or linkage between the areas for sites that bridge them (e.g., the Crystal River channel site RK 0 shows similarity to the Gulf sites, and Crystal River channel site RK 9.4 exhibits similarity to the Kings Bay sites).

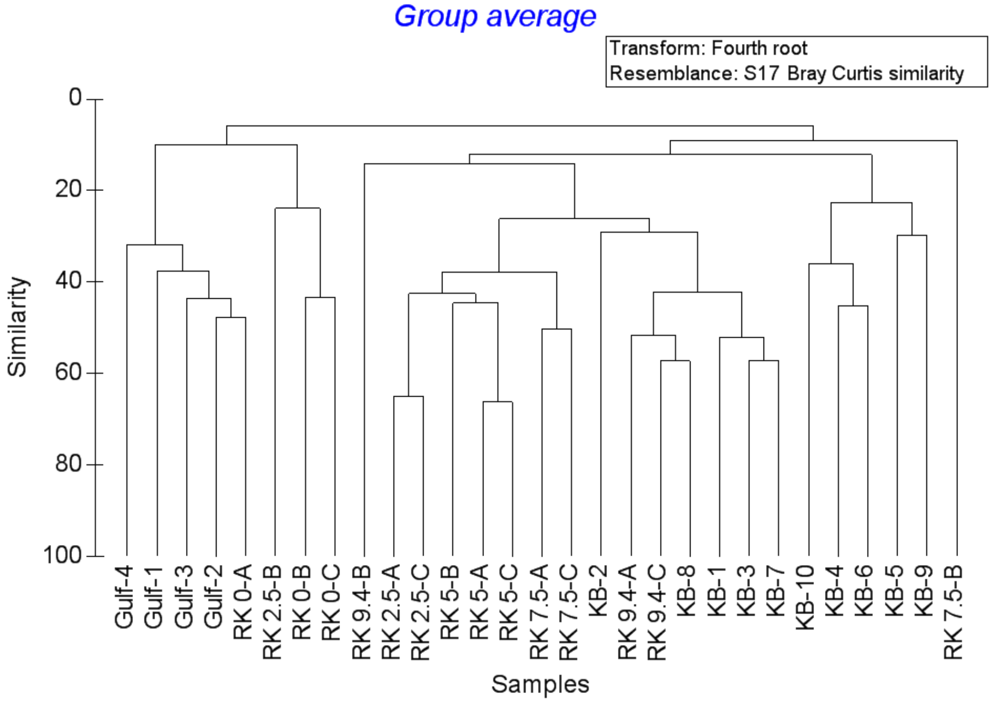

Figure 3.3.4-1. Agglomerative Hierarchical Cluster Diagram for All Unpooled Crystal River Macroinvertebrate Petite Ponar Data.
Data were fourth root transformed prior to being standardized and converted to a Bray-Curtis similarity matrix. The cluster diagram was constructed using the group averaging method

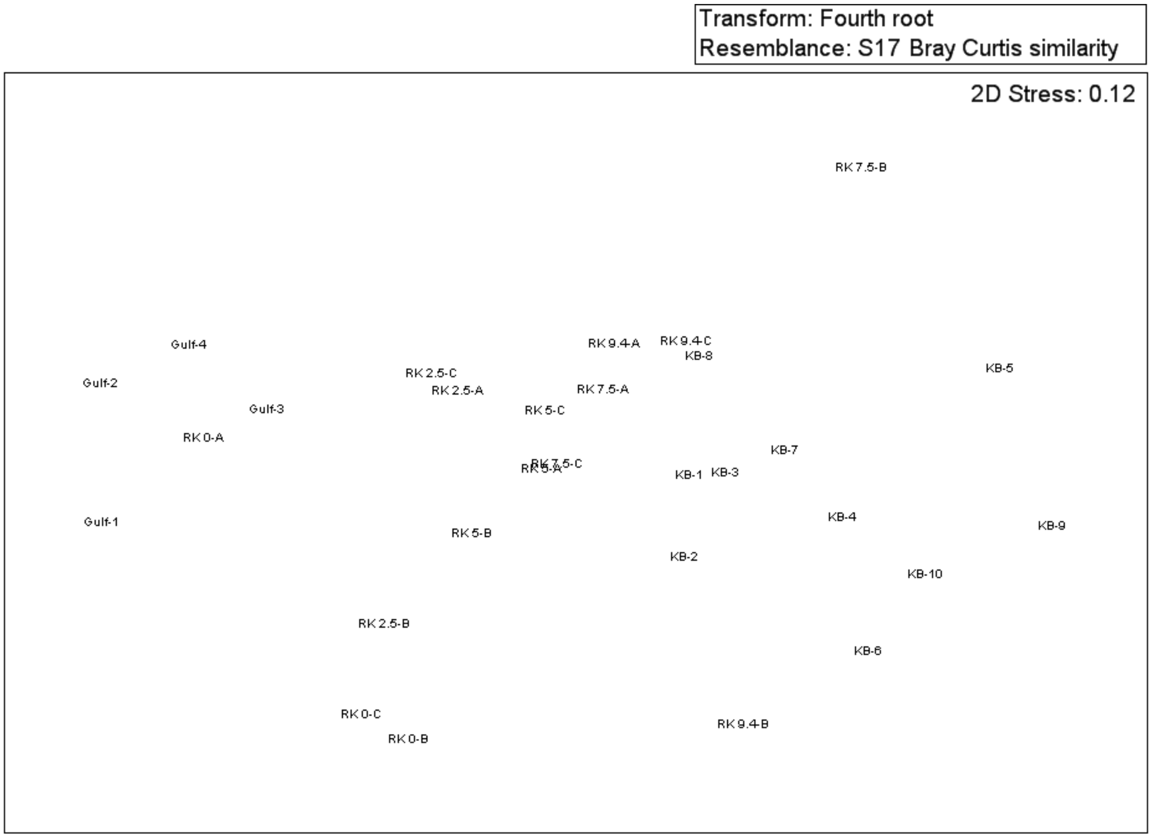

Figure 3.3.4-2. Non-Metric Multidimensional Scaling Ordination for All Unpooled Crystal River Project Macroinvertebrate Petite Ponar Data.
Data were fourth root transformed and converted to a Bray-Curtis similarity matrix. The Primer 6 Kruskal fit option 1 was selected, and 100 restarts were performed. The stress level of 0.12 "still gives a potentially useful 2-dimensional picture…" (Clarke and Warwick 2001).

The cluster diagram with the replicates combined (pooled) shows three main groups – the Gulf sites and RK 0 in one group that was most dissimilar to the other two groups together. The second main cluster included a group of RK 2.5, RK 5, and RK 7.5, and another group, including RK 9.4, linked to the three Kings Bay pooled stations (Figure 3.3.4-3). The MDS diagram for the pooled data shows a left to right relationship similar to that of the unpooled data along the salinity gradient. The sampling site groups are better depicted on this diagram compared to the unpooled figures, which further supports the distinctiveness of the discrete sampling areas (Figure 3.3.4-4). The stress value of 0.03 associated with this ordination suggests that it "gives an excellent representation with no prospect of misinterpretation" (Clarke and Warwick 2001).

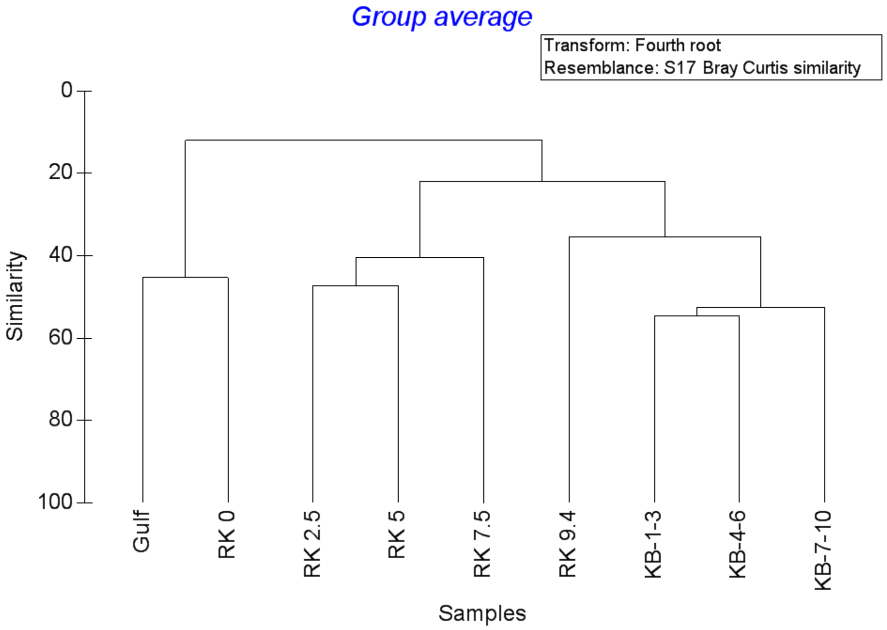

Figure 3.3.4-3. Agglomerative Hierarchical Cluster Diagram for All Pooled Crystal River Macroinvertebrate Petite Ponar Data. Data were fourth root transformed prior to being standardized and converted to a Bray-Curtis similarity matrix. The cluster diagram was constructed using the group averaging method.

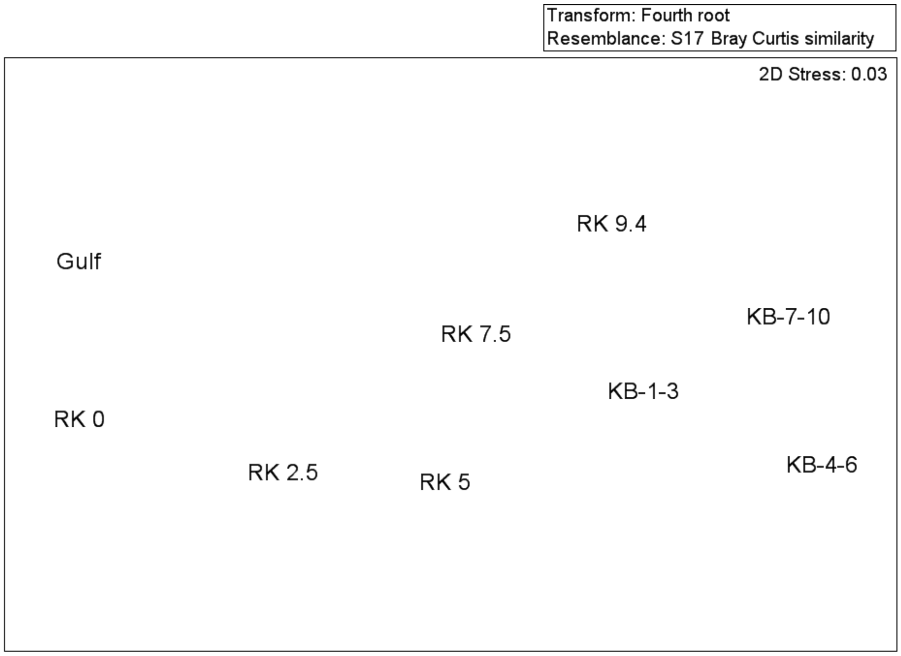

Figure 3.3.4-4. Non-Metric Multidimensional Scaling Ordination for All pooled Crystal River Macroinvertebrate Petite Ponar Data. Data were fourth root transformed and converted to a Bray-Curtis similarity matrix. The Primer 6 Kruskal fit option 1 was selected, and 100 restarts were performed. The stress level of 0.03 "gives an excellent representation with no prospect of misinterpretation" (Clarke and Warwick 2001).

A PCA ordination for the mean values of select physicochemical data (excluding the non-independent correlated variables conductivity and dissolved oxygen percent saturation and including percent silt plus clay) was performed as an independent method to validate site groups. The PCA ordination diagram shows the sites in relation to gradients for the included parameters (Figure 3.3.4-5). The discrete sampling areas (depicted on the figure as “Sub Areas”) are clearly separated on this diagram, with some indication of bridging between them (e.g., site RK 0 is shown closer to the Gulf group than the rest of the Crystal River transect sites). The pointers representing the physicochemical parameters indicate that salinity, temperature, and total depth increase to the right side of the diagram and decrease to the left. Dissolved oxygen and pH (and to a lesser extent percent silt plus clay) are shown to increase towards the left side of the diagram and decrease towards the right. This PCA diagram resembles the MDS ordination derived from macroinvertebrate community data (Figure 3.3.4-2) but inverted horizontally. This indicates that the macroinvertebrate community distribution reflected water quality characteristics as measured at the time of sampling.

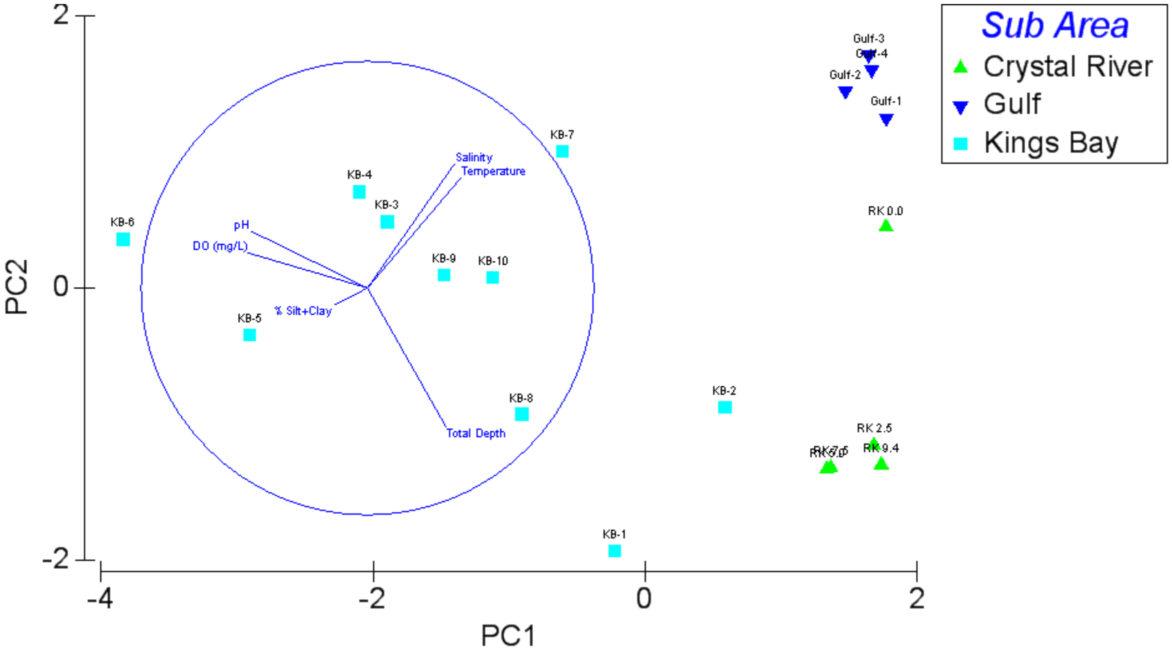

Figure 3.3.4-5. Principal Components Analysis Ordination for the Mean Values of the Physicochemical Data Including Percent Silt and Clay and Excluding Conductivity and Dissolved Oxygen Percent Saturation for All Crystal River Project Sites. Sub Areas are given as different symbols to highlight their separation on the ordination. PCA was performed on the normalized environmental data.

Mann-Whitney tests were performed for physicochemical parameters to test for differences among sub areas. When Gulf site data were compared to Crystal River channel transect data, it was found that temperature, conductance, pH, salinity, percent silt and clay, and dissolved oxygen percent saturation were significantly different between these two sub areas. With the exception of total site depth, medians for all of these parameters were higher for the Gulf sub area. For the Crystal River channel/Kings Bay comparison, median pH and dissolved oxygen (mg/L) were higher for Kings Bay, while total site depth and salinity were higher for the Crystal River channel sub area. Kings Bay sub area median pH and dissolved oxygen (mg/L) were significantly higher than medians for Gulf sites, while median conductance was higher for the Gulf sub area (Appendix A).The Primer ANOSIM procedure was performed on the three areas discussed above using sub area as the factor.

The test was performed on a Bray-Curtis similarity matrix constructed from standardized, fourth root transformed unpooled abundance data. All of the adjacent groups had R-values below the global R-statistic of 0.52 (significance level of P<0.001), except for the Gulf – Kings Bay pair. The significance level for the Gulf – Crystal River pair was P<0.003; the significance level for the Gulf – Kings Bay pair was P<0.002; and the significance level for the Gulf – Kings Bay pair was P<0.001.

The Primer BEST procedure was run with the Bray-Curtis similarity matrix of the pooled data (data square root transformed) and select abiotic parameters (temperature, pH, salinity, dissolved oxygen (mg/L), total site depth, and percent silt and clay) square root transformed and normalized (Table 3.3.4-1). The procedure found that the variable best explaining the multivariate relationship between the biotic and abiotic matrices was salinity (ρ=0.605; P≤0.001). The best solution, including two variables, involved dissolved oxygen (mg/L) and salinity (ρ=0.598; P≤0.001). The best solution including three variables involved pH, dissolved oxygen (mg/L), and salinity (ρ=0.539; P≤0.001). The best solution including four variables involved pH, dissolved oxygen (mg/L), total depth, and salinity (ρ=0.539; P≤0.001). Neither temperature nor percent silt plus clay factored in any of the top ten best explanatory variable combinations. Salinity alone explained more of the variation in the benthic community composition than any of the other variable combinations generated by this procedure, and salinity was a factor in all of the best multi-variable solutions (Appendix B). This result emphasizes the importance of salinity in shaping the benthic macroinvertebrate assemblages in the Crystal River system. This result implies that salinity in the Crystal River system was most important in determining the composition of the macroinvertebrate community during low flow conditions.

Number of Variables	ρ	Salinity	DO (mg/L)	pH	Total Depth	Temperature*	% Silt+Clay*
1	0.605	■					
2	0.598	■	■				
3	0.539	■	■	■			
4	0.499	■	■	■	■		

*Temperature and percent silt and clay were included, but did not figure in any of the BEST procedure results. P≤0.001.

Table 3.3.4-1. Association (Primer Version 6 BEST Procedure Spearman's Rank Correlation, ρ) between Unpooled Petite Ponar Benthic Community Structure for all Crystal River Project Sites Sampled in July 2009 with Selected Abiotic Variables.

3.3.5 Characterization of Sub Areas

Analyses and ordinations given in the section above, plus significant differences revealed for physicochemical data in section 3.3.1 and for select macroinvertebrate metrics in section 3.3.4, present numerous criteria in which the discrete sampling areas differ significantly. These results justify separate discussion of sub area characteristics for the Gulf, Crystal River, and Kings Bay. Descriptive statistics for mean profile physicochemical data by sub area are given in Table E-3. Descriptive statistics for unpooled macroinvertebrate metrics by sub area are given in Table E-6. These data were used to characterize each area and to compare them to the other sub areas. The discussion regarding macroinvertebrate communities below refers to unpooled petite Ponar dredge samples unless otherwise specified.

3.3.5.1 Gulf Sub Area

The Gulf sub area was characterized by higher temperature and salinity and intermediate pH, dissolved oxygen, and percent silt plus clay relative to the other sub areas. No significant correlations were found among select physicochemical variables for the Gulf sites due to small sample size, but dissolved oxygen (mg/L; DO) exhibited a high degree of correlation with temperature, and salinity showed a high degree of correlation with total site depth (ρ= 1.000; Table 3.3.5.1-1).

Variable	Temperature	pH	Salinity	Dissolved Oxygen (mg/L)	Total Depth
pH	0.800				
Salinity	0.600	0.800			
Dissolved Oxygen (mg/L)	1.000	0.800	0.600		
Total Depth	0.600	0.800	1.000	0.600	
Percent silt plus clay	0.000	0.400	0.800	0.000	0.800
Significance levels: Sample Size = 4; for P=0.05, ρ = "none"; for P=0.01, ρ = "none" (Snedecor and Cochran 1967; Table 7.11.2). Significant correlations are given in bold font. Significance criteria could not be applied to these correlations due to small					

Table 3.3.5.1-1. Spearman's Rank Correlation Coefficients (ρ) among Select Mean Profile Physicochemical Variables for Gulf Site Data Collected by Water & Air Research in July 2009.

Figure 3.3.5.1-1 depicts Gulf sites on a PCA ordination for select physicochemical variables. From this diagram it can be seen that the abiotic environments of Gulf-1 and Gulf-2 were similar to each other, and Gulf-3 and Gulf-4 were closest to each other. The pattern of similarity can also be seen with an examination of Table 3.1.3-2. Temperature and pH exhibited little variation among the Gulf group. Salinity, dissolved oxygen, and total site depth were highest for the Gulf-3 and Gulf-4 sites. Percent silt plus clay was highest for Gulf-4 and lowest for Gulf-2 (Table 3.1.2-1).

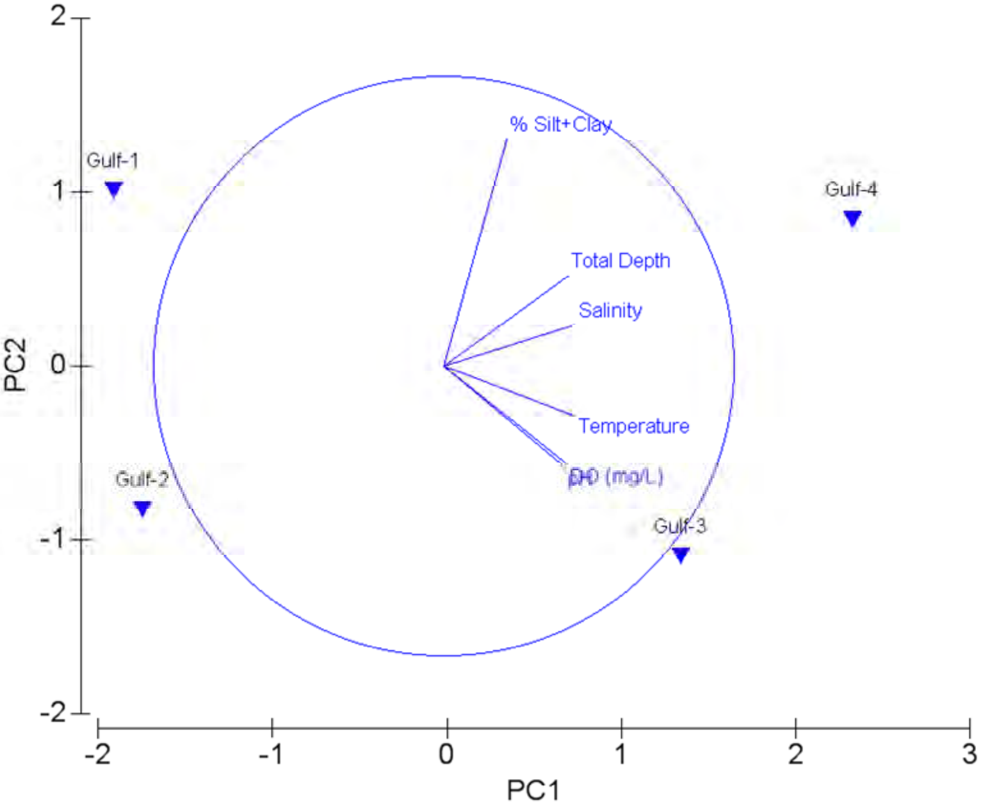

Figure 3.3.5.1-1. Principal Components Analysis Ordination for the Mean Values of Physicochemical Data Including Percent Silt and Clay and Excluding Conductivity and Dissolved Oxygen Percent Saturation for Gulf Sites. PCA was performed on the normalized environmental data.

The Gulf sub area had higher mean number of taxa, Shannon diversity (SWDI), and Pielou's evenness, and lower numbers of individuals than the other sub area groups. Gulf-1 had the highest number of taxa (tied with Gulf-3), number of individuals, and lowest Pielou's evenness. Gulf-2 had the highest SWDI. Gulf 4 had the highest Pielou's evenness, and the lowest number of taxa, number of individuals, and SWDI of the Gulf sites (Table 3.3.2-1).

Figure 3.3.5.1-2 gives a cluster diagram for the Gulf sites based on the Ponar macroinvertebrate data. Gulf-1 is shown as least similar to all the other Gulf sites. Gulf-4 is depicted in a cluster with Gulf-2 and Gulf-3. The latter two sites are shown to be most similar of the Gulf sites, based on similarity of the macroinvertebrate communities. All sites were less than 50 percent similar to each other, indicating a high degree of variability among these samples. Figure 3.3.5.1-3 presents a nonmetric MDS ordination based on the same similarity data as those used to generate the cluster diagram, and depicting the same relationships in another form. This ordination was unusual in having zero stress, which is very rare, and indicates that the two-dimensional image given in the ordination was a perfect representation of the similarity relationships among these sites (Clarke and Warwick 2001).

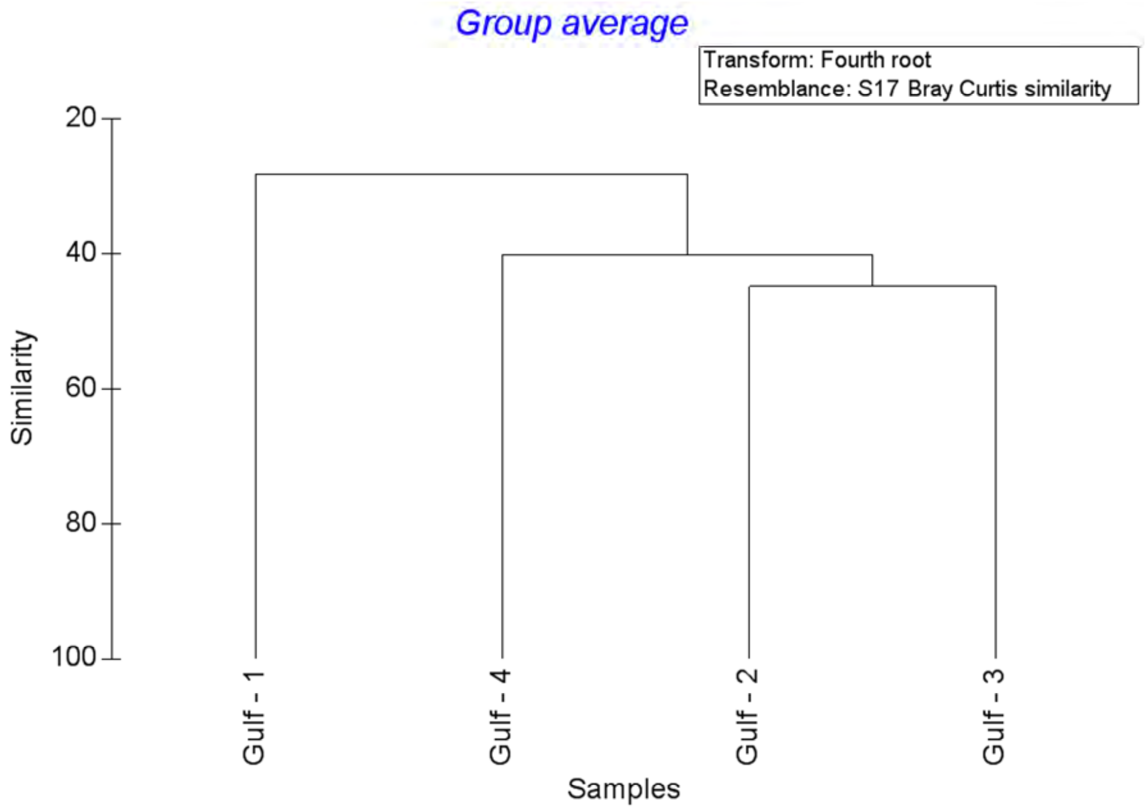

Figure 3.3.5.1-2. Agglomerative Hierarchical Cluster Diagram for Gulf Stations Macroinvertebrate Petite Ponar Data. Data were fourth root transformed prior to being standardized and converted to a Bray-Curtis similarity matrix. The cluster diagram was constructed using the group averaging method.

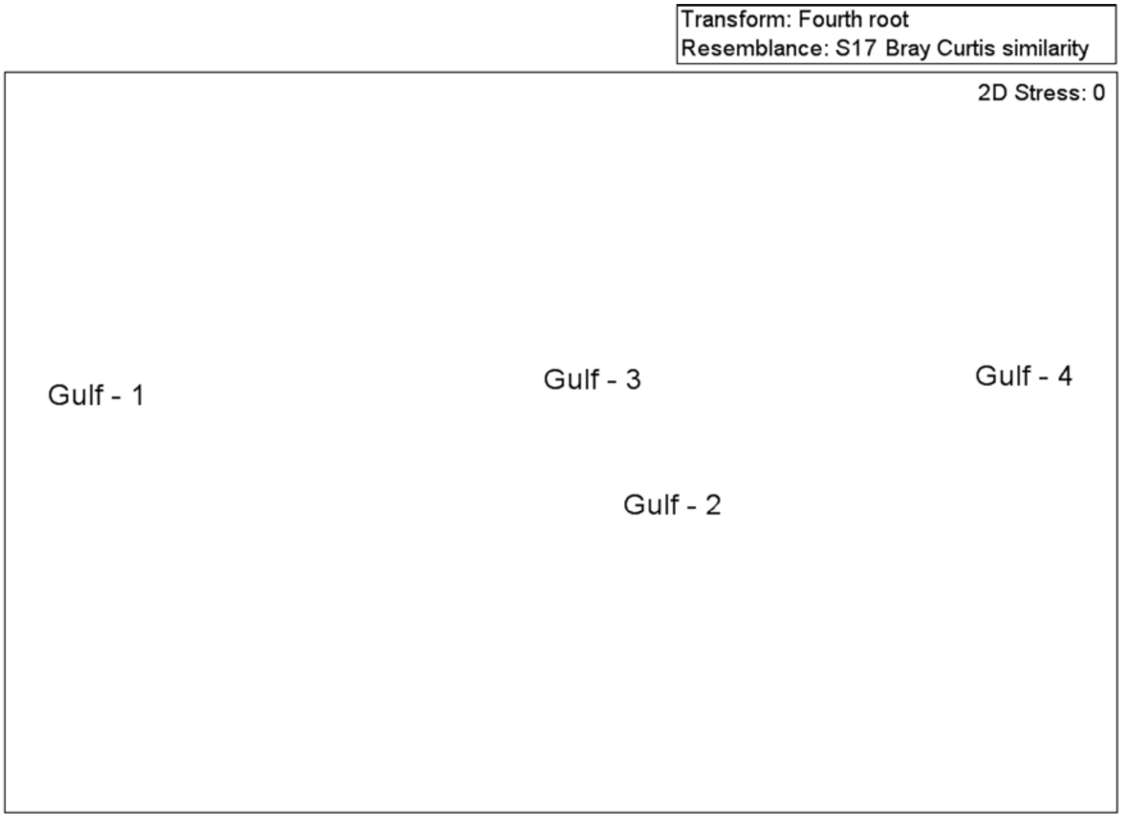

Figure 3.3.5.1-3. Non-Metric Multidimensional Scaling Ordination for Gulf Stations Macroinvertebrate Petite Ponar Data.
Data were fourth root transformed and converted to a Bray-Curtis similarity matrix. The Primer 6 Kruskal fit option 1 was selected, and 100 restarts were performed. The stress level of 0.0 "gives an excellent representation with no prospect of misinterpretation…a perfect representation would probably be one with stress <0.01" (Clarke and Warwick 2001).

Table 3.3.5.1-2 lists the top 50 most dominant macroinvertebrate taxa for the Gulf sub area ranked by the dominance index. Looking at the top 15 most dominant taxa, it can be seen that polychaete annelids dominated the fauna of this site group. Eleven of these taxa were polychaetes, two were gastropod molluscs, one was an amphipod crustacean, and one was a Nemertean. These taxa are primarily known from marine waters.

Taxa	Mean Density (m2)	Dominance Index	Mean Salinity of Capture (ppt)	Abundance-weighted Salinity (ppt)
Aricidea taylori	915.75	39.67	17.62	18.09
Glycinde solitaria	194.00	21.08	18.16	18.38
Mooreonuphis nebulosa	226.25	19.72	18.24	17.57
Monticellina sp.	312.50	18.92	18.24	18.36
Mediomastus ambiseta	150.75	18.59	18.16	17.97
Nemertea (LPIL)	118.50	16.48	18.16	17.50
Scoletoma verrilli	151.00	16.10	17.62	17.64
Magelona riojai	150.75	16.10	17.62	18.04
Ampelisca sp. C LeCroy	118.50	14.27	18.24	18.61
Haminoea succinea	118.50	14.27	18.24	18.33
Fabricinuda trilobata	107.75	13.61	18.24	17.80
Acteocina canaliculata	86.00	12.17	18.24	18.90
Aricidea philbinae	86.00	12.17	17.62	17.70
Heteromastus filiformis	64.50	10.54	18.24	17.67
Leitoscoloplos fragilis	86.25	9.94	18.87	18.16
Aricidea catherinae	75.25	9.30	18.24	18.20
Ogyrides alphaerostris	64.75	8.61	18.24	18.03
Sabellinae (LPIL)	64.50	8.61	17.15	17.41
Scoloplos rubra	43.00	8.61	18.03	17.62
Aoridae (LPIL)	53.75	7.86	17.15	17.62
Crepidula fornicata	53.75	7.86	17.15	17.62
Axiothella sp.	97.00	7.45	16.37	16.37
Paraprionospio sp.	43.00	7.03	18.24	18.09
Bittium varium	75.50	6.57	17.93	17.93
Nasageneia bacescui	75.50	6.57	17.93	17.93
Prionospio heterobranchia	32.25	6.09	17.46	17.10
Polydora cornuta	54.00	5.56	17.93	17.93
Tubificoid Naididae (LPIL)	54.00	5.56	17.93	17.93
Astyris lunata	43.00	4.97	17.93	17.93
Paradialychone sp.	43.00	4.97	17.93	17.93
Lysilla sp.	21.50	4.97	18.24	18.24
Maldanidae (LPIL)	21.50	4.97	19.18	19.18
Syllis sp.	21.50	4.97	18.09	18.09
Angulus versicolor	32.25	4.30	18.55	18.55
Taphromysis bowmani	32.25	4.30	19.80	19.80
Acteocina candei	21.50	3.51	17.93	17.93
Amakusanthura signata	21.50	3.51	17.93	17.93
Cyclaspis varians	21.50	3.51	17.93	17.93
Eteone heteropoda	21.50	3.51	16.37	16.37
Eupolymnia sp.	21.50	3.51	16.37	16.37
Janua sp.	21.50	3.51	17.93	17.93
Melinna sp.	21.50	3.51	18.55	18.55
Streblospio sp.	21.50	3.51	18.55	18.55
Actiniaria (LPIL)	10.75	2.48	19.80	19.80
Amygdalum papyrium	10.75	2.48	16.37	16.37
Apocorophium louisianum	10.75	2.48	18.55	18.55
Boccardiella sp.	10.75	2.48	18.55	18.55
Boonea impressa	10.75	2.48	17.93	17.93
Caridea (LPIL)	10.75	2.48	16.37	16.37
Caryocorbula contracta	10.75	2.48	16.37	16.37

Species were sorted by dominance index, then density; from Actiniaria (LPIL) and below, all values for these measures were identical, thus listing from this point and below was done alphabetically to complete the list of fifty taxa.

Table 3.3.5.1-2. Fifty Dominant Benthic Taxa, Mean Abundance, Mean Center of Abundance as River Kilometer (RK), and Mean Salinity of Capture for Gulf Sites, July 2009.

3.3.5.2 Crystal River Sub Area

The Crystal River sub area refers to the transect station sites in the channel of the Crystal River proper. The Crystal River sub area was characterized by higher total depth, intermediate temperature and salinity, and lower pH, dissolved oxygen, and percent silt plus clay relative to the other sub areas. No significant correlations were found among select physicochemical variables for the Crystal River sites due to small sample size; however, dissolved oxygen exhibited a high degree of correlation with temperature (ρ= 0.900; Table 3.3.5.2-1).

Variable	Temperature	pH	Salinity	Dissolved Oxygen (mg/L)	Total Depth
pH	0.900				
Salinity	0.700	0.600			
Dissolved Oxygen (mg/L)	0.100	0.200	-0.600		
Total Depth	0.000	-0.100	-0.300	0.600	
Percent silt plus clay	0.300	0.100	0.700	-0.500	0.300

Significance levels: Sample Size = 5; for P=0.05, ρ = 1.000; for P=0.01, ρ = "none" (Snedecor and Cochran 1967; Table 7.11.2). Significant correlations are given in bold font. Significance criteria at the 0.01 level could not be applied to these correlat

Table 3.3.5.2-1. Spearman's Rank Correlation Coefficients (ρ) among Select Mean Profile Physicochemical Variables for Crystal River. Transect Site Data Collected by Water & Air Research in July 2009.

Figure 3.3.5.2-1 shows a PCA ordination for select physicochemical variables. The spread of the Crystal River transect sites on the PCA diagram indicates that these sites generally varied from each other with few clear groupings of sites, though RK 5 and RK 9.4 were closest to each other, and with the exception of temperature, these sites were most similar among the five sites in this group (Table 3.1.3-2). Temperature was highest for RK 9.4 and lowest for RK 7.5. pH was highest for RK 5 and lowest for RK 7.5. Salinity was highest for RK 0 and lowest for RK 7.5. Salinity generally decreased up the river corridor, except that salinity was higher for RK 9.4 than for RK 7.5. Dissolved oxygen was highest for RK 5 and lowest for RK 2.5. Total site depth was highest for RK 9.4 and lowest for RK 0. RK 9.4 was over a meter deeper than RK 7.5; this may explain the higher salinity for RK 9.4 (Table 3.1.2-2). Percent silt plus clay was highest for RK 9.4 and lowest for RK 7.5 (Table 3.1.2-1).

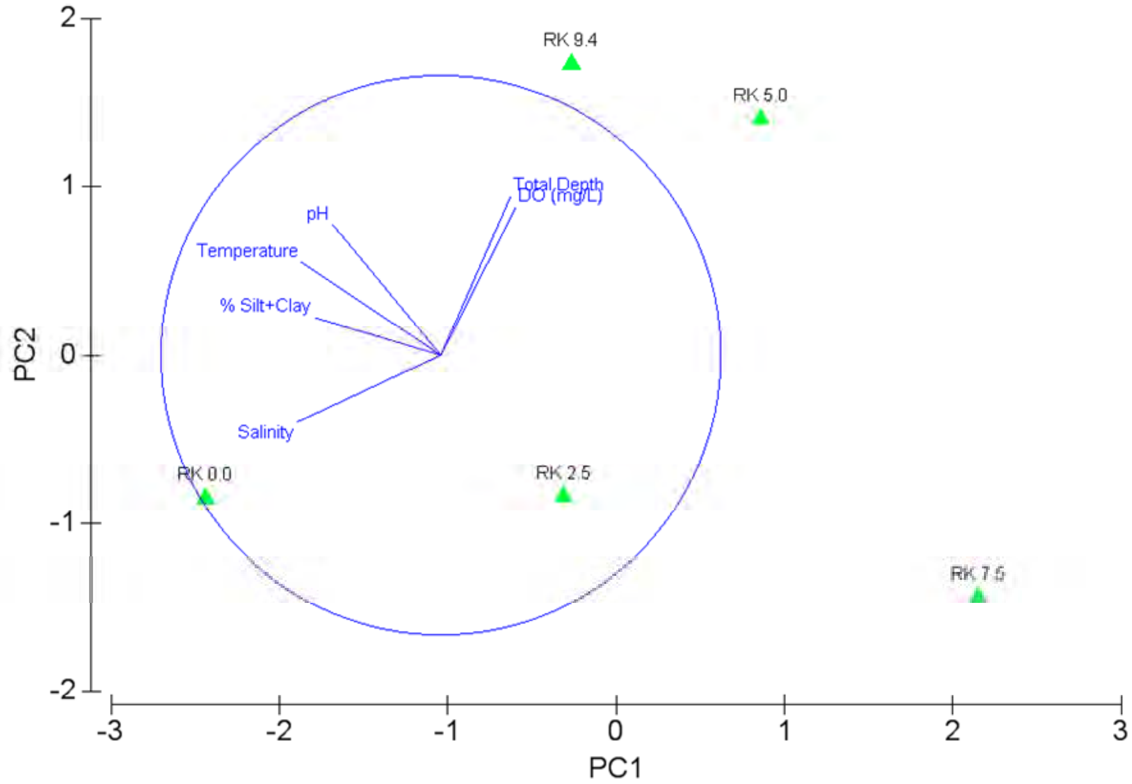

Figure 3.3.5.2-1. Principal Components Analysis Ordination for the Mean Values of Physicochemical Data Including Percent Silt and Clay and Excluding Conductivity and Dissolved Oxygen Percent Saturation for Crystal River Transect Sites.
PCA was performed on the normalized environmental data.

The Crystal River sub area had higher mean numbers of individuals than the other sub area groups. Values for number of taxa, SWDI, and Pielou's evenness were intermediate between the means for the other two site groups. Due to the study design, petite Ponar data for the Crystal River transect sites can be pooled for analysis within the site group. The following discussion refers to pooled data metrics. RK 0 had the highest number of taxa, SWDI, Pielou's evenness, and the lowest number of individuals. RK 9.4 had the highest number of individuals, by far, and the lowest number of taxa, SWDI, and Pielou's evenness (Table 3.3.2-2).

As mentioned above, the petite Ponar dredge data for the Crystal River sub area could be pooled due to the study design. Thus, the multivariate cluster and ordinations were performed on both the pooled and unpooled data. Figure 3.3.5.2-2 depicts an unpooled cluster diagram for the Crystal River site group. This diagram and the MDS diagram (Figure 3.3.5.2-3) illustrate the relatively high degree of similarity among the transect replicates, whereby they group together, or group with adjacent site replicates. Similarity for some of the samples is over 60 percent. This justified pooling the replicate samples. The stress level of 0.1 for the unpooled Crystal River MDS "corresponds to a good ordination with no real prospect of a misleading interpretation" (Clarke and Warwick 2001). Pooled data are useful, because they are less variable than unpooled data. The pooled cluster diagram shows that site RK 0 was least similar to all the other sites combined (Figure 3.3.5.2-4). As mentioned earlier in this report, RK 0 shows similarity to the Gulf sites, likely due to its position at the mouth of the Crystal River channel to the Gulf (Figure 3.3.4-2). The gap between RK 0 and

RK 2.5 represented a salinity transition (from a mean profile value of 12.94 ppt for RK 0 to a mean value of 5.66 ppt for RK 2.5) that corresponds to the transition from the mesohaline zone to the oligohaline zone (Janicki 2007). The other sites exhibit serial similarity to each other in order of their position in the channel, with the middle sites RK 2.5 and RK 5 being most similar to each with about 50 percent similarity. Figure 3.3.5.2-5 presents the MDS ordination corresponding to the pooled cluster diagram. This diagram shows the Crystal River channel sites in an arc in order of the sites. As per the Gulf sites, this ordination was unusual in having zero stress, which is very rare, and indicates that the two-dimensional image given in the ordination was a perfect representation of the similarity relationships among these sites (Clarke and Warwick 2001).

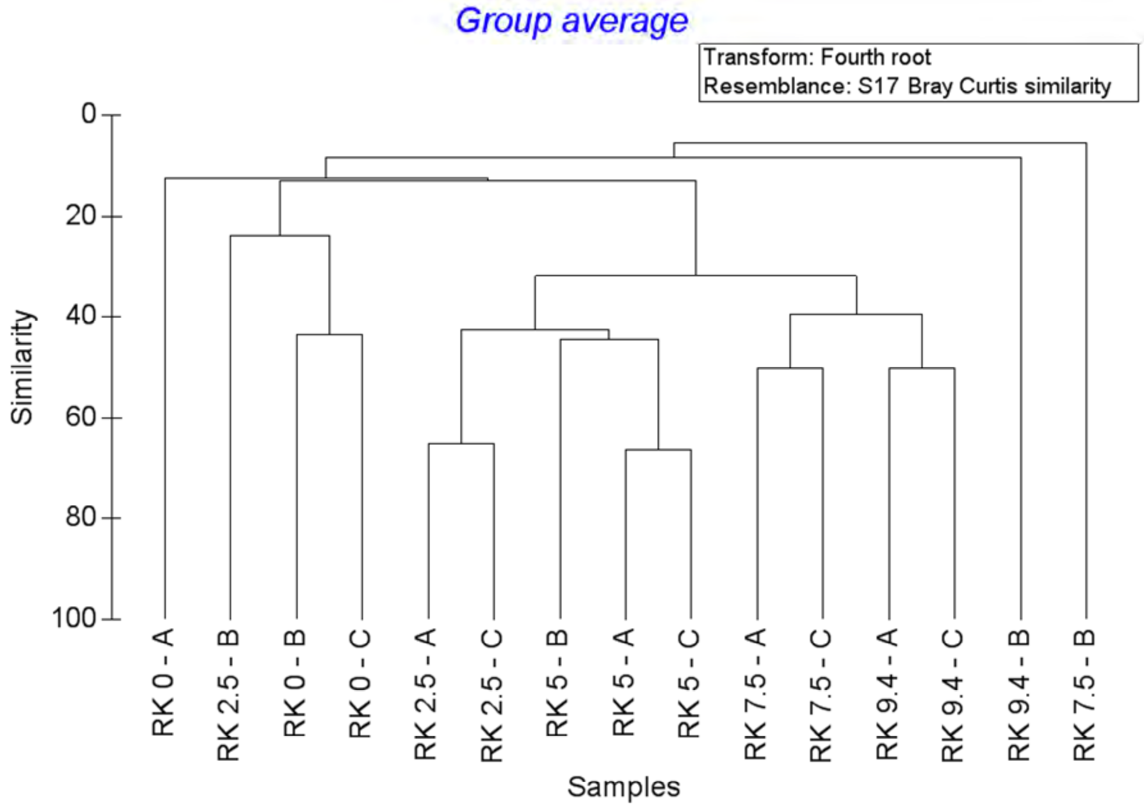

Figure 3.3.5.2-2. Agglomerative Hierarchical Cluster Diagram for Crystal River Transect Sites Unpooled Macroinvertebrate Petite Ponar Data.
Data were fourth root transformed prior to being standardized and converted to a Bray-Curtis similarity matrix. The cluster diagram was constructed using the group averaging method.

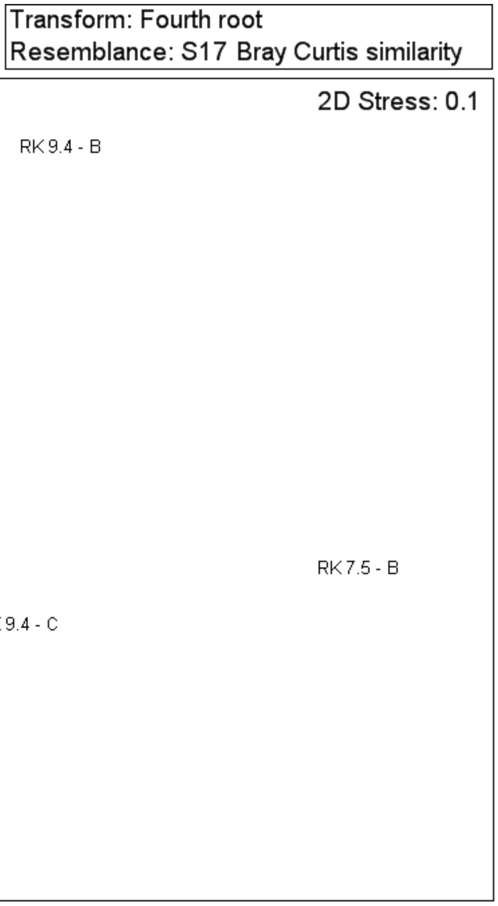

Figure 3.3.5.2-3. Non-metric Multidimensional Scaling Ordination for Crystal River Transect Sites Macroinvertebrate Petite Ponar Data. Data were fourth root transformed and converted to a Bray-Curtis similarity matrix. The Primer 6 Kruskal fit option 1 was selected, and 100 restarts were performed. The stress level of 0.1 “corresponds to a good ordination with no real prospect of a misleading interpretation” (Clarke and Warwick 2001).

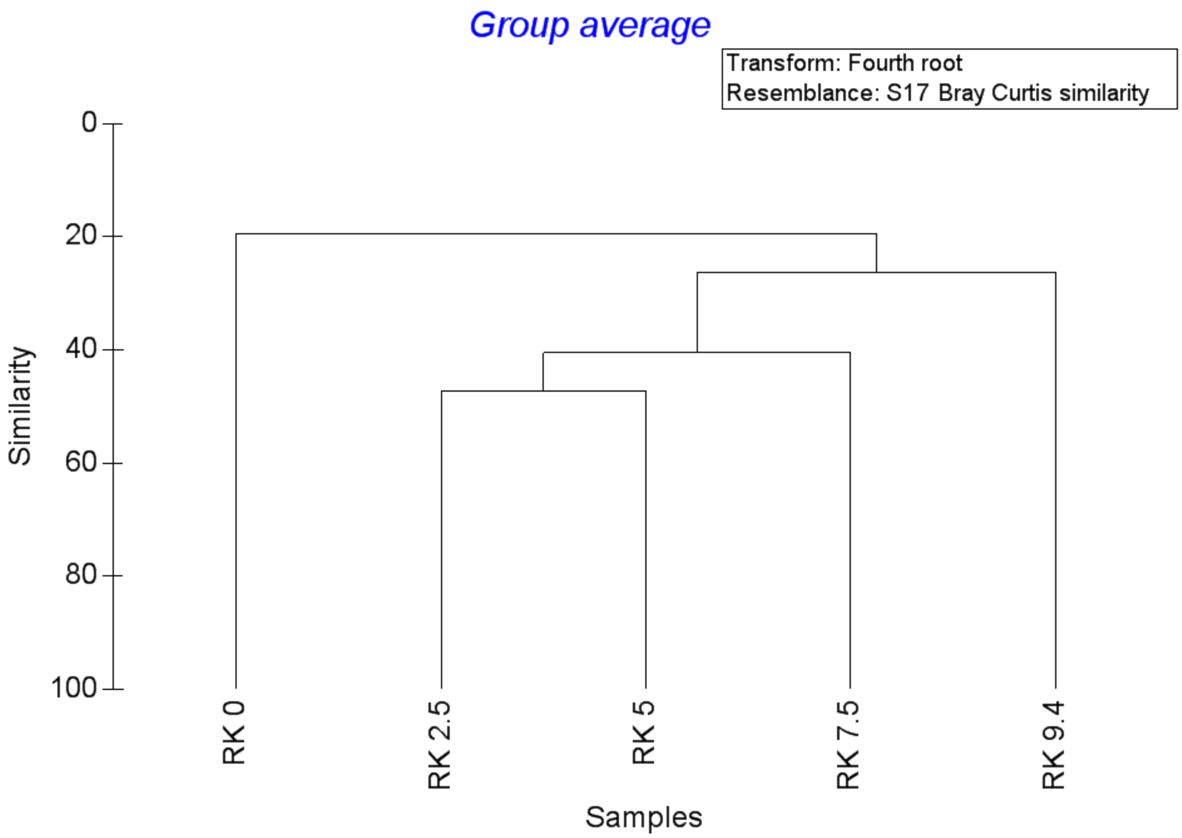

Figure 3.3.5.2-4. Agglomerative Hierarchical Cluster Diagram for Crystal River Transect Sites Pooled Macroinvertebrate Petite Ponar Data. Data were fourth root transformed prior to being standardized and converted to a Bray-Curtis similarity matrix. The cluster diagram was constructed using the group averaging method.

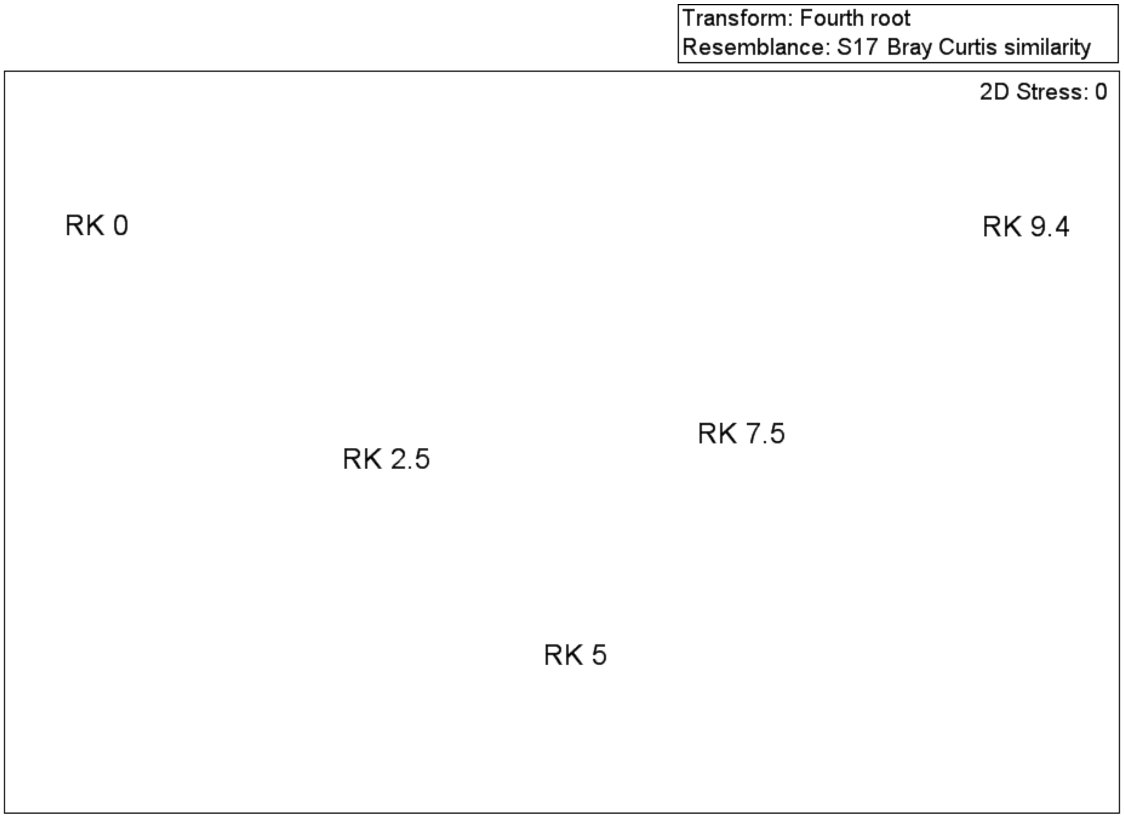

Figure 3.3.5.2-5. Non-metric Multidimensional Scaling Ordination for Crystal River Transect Sites Pooled Macroinvertebrate Petite Ponar Data. Data were fourth root transformed and converted to a Bray-Curtis similarity matrix. The Primer 6 Kruskal fit option 1 was selected, and 100 restarts were performed. The stress level of 0.0 “gives an excellent representation with no prospect of misinterpretation…a perfect representation would probably be one with stress <0.01” (Clarke and Warwick 2001).

Table 3.3.5.2-2 lists the top 50 most dominant macroinvertebrate taxa for the Crystal River sub area ranked by the dominance index. The top fifteen dominant organisms represent a wider array of higher taxonomic groups compared to the Gulf sub area. Four of the fifteen taxa were amphipod crustaceans, three were polychaetes, two were tubificoid annelids, two were tanaid crustaceans, and bivalve molluscs, gastropod molluscs, isopod crustaceans, and sea anemones were represented by one taxon each. Most of these taxa are estuarine specialists, with only a few marine/estuarine or marine taxa represented among the fifteen most dominant species for the Crystal River site group.

Taxa	Mean Density	Dominance Index	Center of Abundance	Mean Salinity of Capture	Abundance-weighted Salinity
Apocorophium louisianum	12617.17	40.25	9.39	6.89	4.59
Cerapus benthophilus	9317.50	38.50	6.77	4.25	4.58
Cyrenoida floridana	8268.67	21.34	9.59	4.26	4.59
Gammarus cf. tigrinus LeCroy	172.33	5.34	9.40	4.59	4.59
Tubificoides sp.	395.17	4.66	9.16	4.26	4.50
Ampelisca abdita	1518.17	4.54	1.66	7.16	5.15
Hobsonia florida	1130.00	4.51	10.94	4.60	4.58
Halmyrapseudes cf. bahamensis Heard	682.50	3.49	3.64	4.60	5.24
Edotia triloba	184.33	3.19	9.47	5.12	4.66
Tubificoid Naididae (LPIL)	488.67	3.18	1.17	7.66	4.92
Laeonereis culveri	375.83	2.53	10.72	4.60	4.51
Crepidula plana	31.00	2.27	4.42	10.24	14.12
Actiniaria (LPIL)	64.50	2.25	1.63	8.23	6.99
Cyclaspis varians	95.67	2.22	2.05	8.23	5.36
Streblospio sp.	347.33	2.10	2.16	4.60	4.85
Polymesoda caroliniana	86.17	1.78	15.65	4.59	4.59
Leitoscoloplos foliosus	16.83	1.66	2.50	5.64	5.64
Xenanthura brevitelson	105.33	1.54	0.14	4.94	4.75
Nemertea (LPIL)	40.50	1.45	7.19	7.16	8.32
Cyathura polita	146.00	1.44	4.46	6.64	4.87
Neanthes succinea	33.50	1.41	7.78	9.53	8.94
Aoridae (LPIL)	59.83	1.39	1.70	7.16	12.05
Rhithropanopeus harrisii	138.83	1.29	7.26	6.64	4.84
Mooreonuphis nebulosa	14.33	1.26	1.67	14.83	14.83
Amphilochidae (LPIL)	86.17	1.26	9.40	4.59	4.59
Littoridinops sp.	86.17	1.26	9.40	4.59	4.59
Erichsonella attenuata	12.00	1.24	3.76	9.71	10.73
Crassostrea virginica	81.33	1.22	2.43	10.24	5.91
Americorophium ellisi	38.33	1.19	9.04	4.26	4.46
Sayella sp.	62.17	1.11	0.36	4.94	4.43
Aricidea taylori	64.67	1.09	2.22	14.83	14.83
Grandidierella bonnieroides	105.50	1.07	2.89	4.41	4.34
Taphromysis bowmani	64.50	1.07	12.43	4.25	4.55
Chthamalus fragilis	62.33	1.07	2.69	5.64	5.64
Nemertea sp. D (Strom)	14.33	1.03	0.00	4.23	4.23
Leptochelia sp.	28.83	1.03	2.29	10.24	11.00
Polypedilum scalaenum group Epler	62.17	1.01	7.63	4.60	4.50
Orbiniidae (LPIL)	19.17	0.94	3.00	9.53	8.47
Melita nitida complex LeCroy	47.83	0.94	1.50	10.24	12.07
Ampelisca sp. C LeCroy	40.67	0.86	1.76	10.24	8.34
Tubificoid Naididae imm. w/o hair setae (LPIL)	19.17	0.84	9.40	4.59	4.59
Coelotanypus concinnus group Epler	38.33	0.84	9.40	4.59	4.59
Monticellina sp.	33.50	0.78	0.00	14.83	14.83
Heteromastus filiformis	31.17	0.76	2.12	10.24	7.05
Scoletoma verrilli	7.17	0.73	0.00	14.83	14.83
Turbellaria (LPIL)	16.67	0.73	0.63	4.94	4.58
Dipolydora socialis	4.83	0.73	10.00	5.64	5.64
Tagelus plebeius	4.83	0.73	7.50	3.92	3.92
Americamysis almyra	35.83	0.70	3.86	4.60	4.35
Veneridae (LPIL)	12.00	0.66	6.50	5.64	5.64

Table 3.3.5.2-2. 50 Dominant Benthic Taxa, Mean Abundance, Mean Center of Abundance (as river kilometer; RK), and Mean Salinity of Capture for Crystal River Transect Stations, July 2009.

3.3.5.3 Kings Bay Sub Area

Kings Bay was characterized by higher pH, dissolved oxygen, and percent silt plus clay, and lower temperature, salinity, and total depth relative to the other sub areas. As mentioned previously, higher pH and dissolved oxygen are likely related to the photosynthesis processes of lush aquatic macrophyte and periphyton communities found in the bay. Lower temperature and salinity is likely caused by discharge from the many springs in and around Kings Bay. pH was significantly correlated with dissolved oxygen, and was found to have significant negative correlations with salinity and total depth. Dissolved oxygen had a significant negative correlation with salinity (all of these correlations were with $P \leq 0.01$; Table 3.3.5.3-1). The pH/dissolved oxygen correlation was likely caused by reduction of carbonic acid concentrations, due to the photosynthesis process. The negative correlations of pH and dissolved oxygen with salinity may have been caused by dilution, or by interference with freshwater photosynthesis processes. The negative correlation of pH with total depth may be related to less photosynthetic production (due to shading) in deeper waters.

Variable	Temperature	pH	Salinity	Dissolved Oxygen (mg/L)	Total Depth
pH	-0.285				
Salinity	0.539	**-0.903**			
Dissolved Oxygen (mg/L)	-0.333	**0.952**	**-0.806**		
Total Depth	-0.322	**-0.632**	0.468	-0.571	
Percent silt plus clay	-0.067	-0.091	0.224	0.006	0.541
Significance levels: N = 10; degrees of freedom = 8; for P=0.05, ρ = 0.632; for P=0.01, ρ = 0.765 (Snedecor and Cochran 1967; Table A-11). Significant correlations are given in bold font.					

Table 3.3.5.3-1. Spearman's Rank Correlation Coefficients (ρ) Among Select Mean Profile Physicochemical Variables for Kings Bay Site Data Collected by Water and Air Research. in July 2009.

Figure 3.3.5.3-1 shows a PCA ordination for select physicochemical variables. No clear groupings were seen, but a few trends are evident. Six sites are arrayed along an arc roughly paralleling the vectors for total site depth and percent silt plus clay. KB-4 is at the base of the arc near the center of the vector tree. KB-4 had the lowest total site depth and the second lowest percent silt plus clay value. KB-1, which was shown at the end of the arc, had the highest total site depth. Beyond and slightly below KB-1 was KB-2, which had the highest percent silt plus clay value. KB-5 and KB-6 were parallel to KB-1 to the left of the diagram. KB-1, KB-6, and KB-5 had the three lowest temperatures of the Kings Bay sites. KB-7 was the lowest site icon on the diagram; it had the highest temperature. The relative positions of these sites were reflected by the direction of the temperature vector. The orientation of the icons from left to right was determined by pH and dissolved oxygen (with vectors pointing to the left side of the diagram) and salinity (whose vector pointed to the right side and slightly down). The highest pH was recorded for KB-6, and the lowest pH was recorded for KB-2. Highest salinity was recorded for KB-2, and the lowest pH was recorded for KB-6. Proximity to springs was likely the most influential factor affecting Kings Bay site salinity (Figure 2-4). Highest dissolved oxygen was recorded for KB-6, and the lowest dissolved oxygen was recorded for KB-2. The high values for dissolved oxygen and pH for KB-6 (mean profile dissolved oxygen of 12.31 mg/L, and 155.35 %saturation; mean pH of 9.15) supports the theory that algal blooms or other overactive plant photosynthesis processes were active at the time of sampling (Meyer and Barclay 1990; Table 3.1.3-1). Percent silt plus clay was highest for KB-2 and lowest for KB-7 (Table 3.1.2-1).

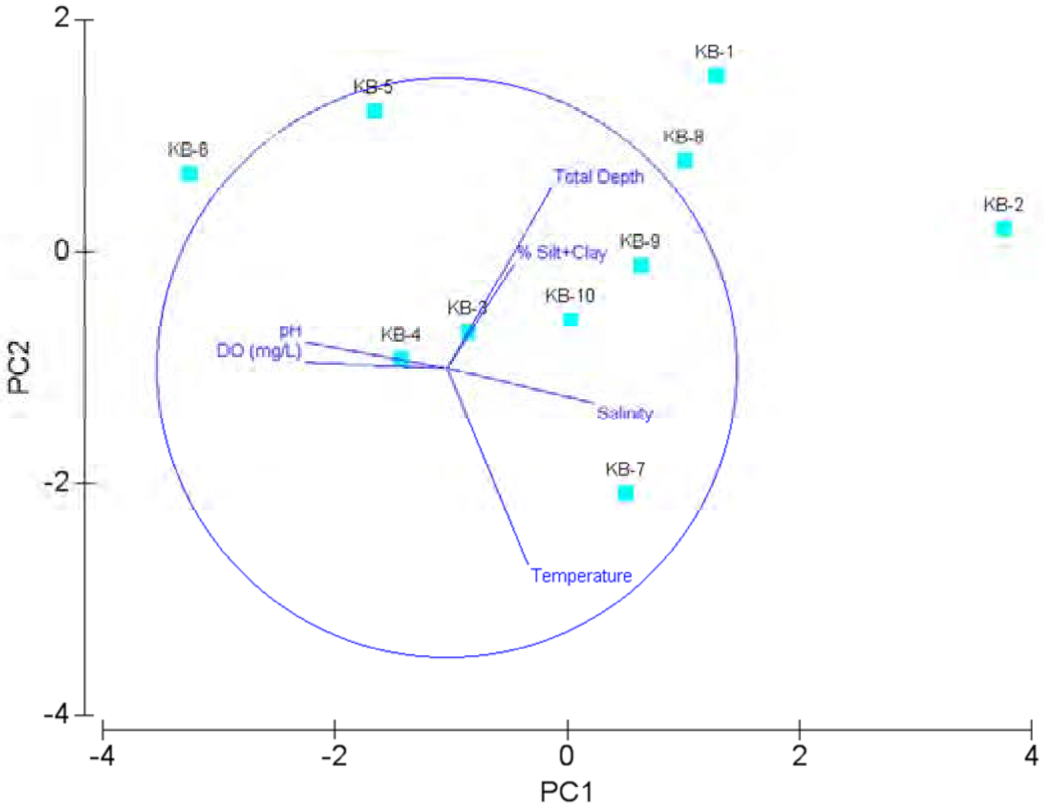

Figure 3.3.5.3-1. Principal Components Analysis Ordination for the Mean Values of Physicochemical Data Including Percent Silt and Clay and Excluding Conductivity and Dissolved Oxygen Percent Saturation for Kings Bay Sites. PCA was performed on the normalized environmental data.

Petite Ponar Results

The Kings Bay sub area had lower mean number of taxa, SWDI, and Pielou's evenness, and intermediate numbers of individuals relative to the other sub area groups. Number of taxa was highest for KB-3 and lowest for KB-9. Number of individuals was highest for KB-10 and lowest for KB-8. Pielou's evenness was highest for KB-7 and lowest for KB-2. SWDI was highest for KB-7, and lowest for KB-2 (Table 3.3.2-1).

Figure 3.3.5.3-2 depicts a cluster diagram for the Kings Bay site group petite Ponar data. Sites KB-5 and KB-9 are in a group that is most dissimilar to all the other sites combined. These other sites are in two groups – a group composed of KB-4, KB-6, and KB-10, and a group with KB-1, KB-2, KB-3, KB-7, and KB-8. Of all the Kings Bay Ponar sites, KB-3 and KB-7 were most similar, with about 60 percent similarity. The MDS reflects these relationships, with KB-5 and KB-9 somewhat isolated on the left side of the diagram, KB-4, KB-6, and KB-10 in the upper right corner, and KB-1, KB-2, KB-3, KB-7, and KB-8 in the lower right corner (Figure 3.3.5.3-3).

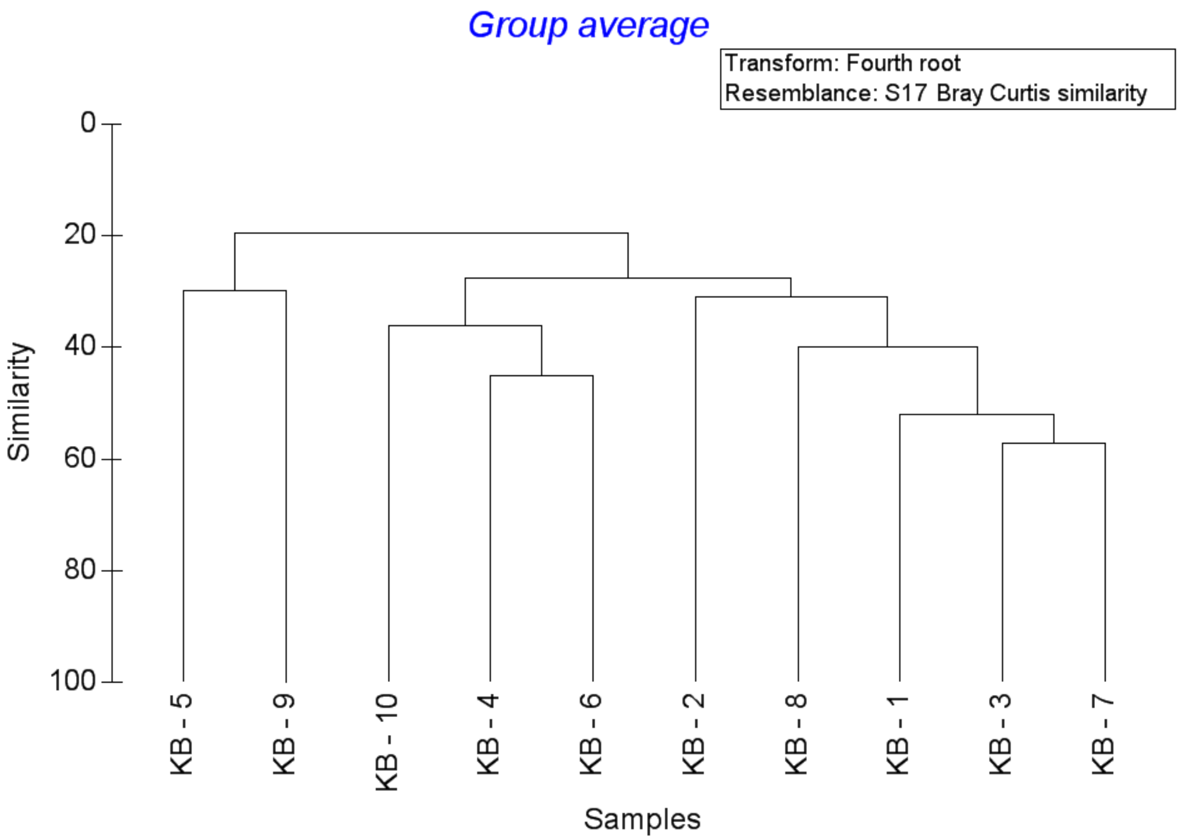

Figure 3.3.5.3-2. Agglomerative Hierarchical Cluster Diagram for Kings Bay Stations Macroinvertebrate Petite Ponar Data. Data were fourth root transformed prior to being standardized and converted to a Bray-Curtis similarity matrix. The cluster diagram was constructed using the group averaging method.

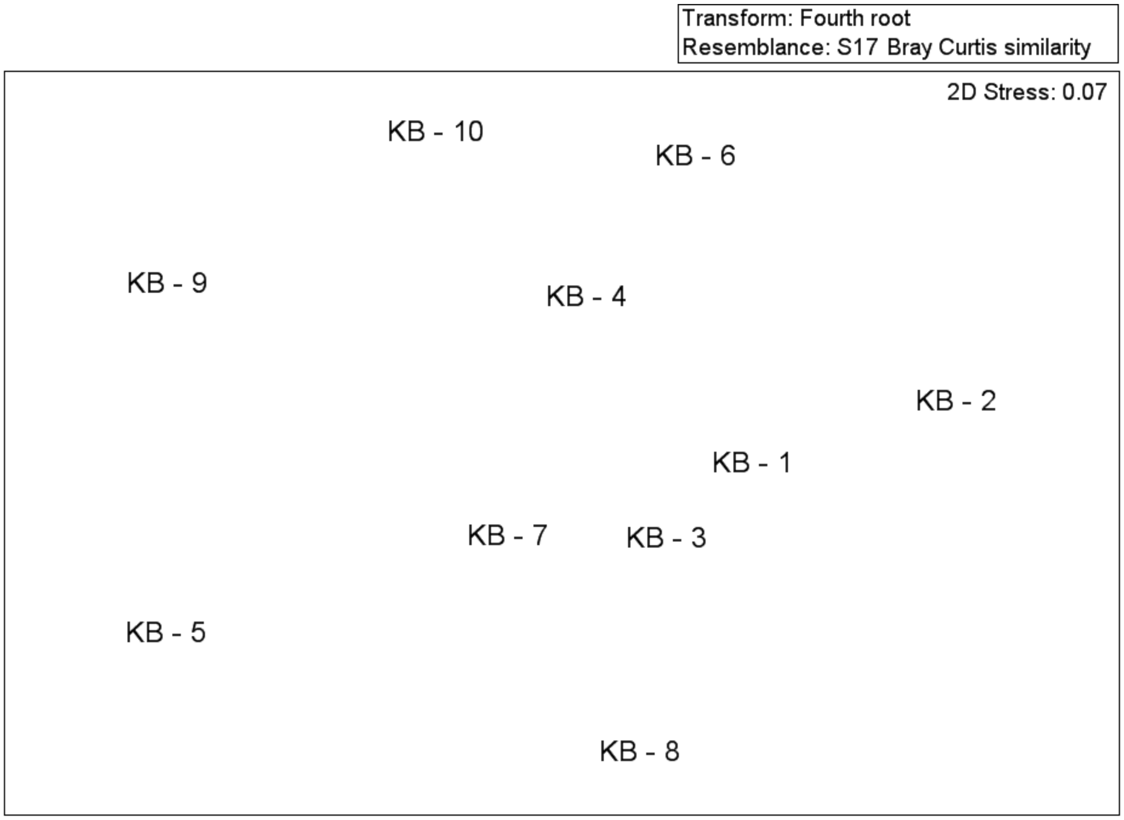

Figure 3.3.5.3-3. Non-Metric Multidimensional Scaling Ordination for All Kings Bay Macroinvertebrate Petite Ponar Data. Data were fourth root transformed and converted to a Bray-Curtis similarity matrix. The Primer 6 Kruskal fit option 1 was selected, and 100 restarts were performed. The stress level of 0.07 "gives an excellent representation with no prospect of misinterpretation" (Clarke and Warwick 2001).

Table 3.3.5.3-2 lists the top 46 most dominant macroinvertebrate taxa for the Kings Bay sub area ranked by the dominance index. As was found for the Crystal River transect sub area, the Kings Bay top fifteen dominant organisms represent a wider array of higher taxonomic groups compared to the Gulf sub area. Three of the fifteen taxa were amphipod crustaceans, two were polychaetes, two were tubificoid annelids, two were naidinae annelids, two were gastropod molluscs, two were chironomid midge fly larvae, and isopod crustaceans, tanaid crustaceans, and bivalve molluscs were represented by one taxon each. Most of these taxa are estuarine specialists, with a few freshwater taxa present. No marine estuarine or marine taxa were represented among the fifteen most dominant species for the Kings Bay site group Ponar samples.

Twenty-six of the 46 most dominant taxa in petite Ponar samples were freshwater taxa. Some of the more dominant freshwater taxa collected by petite Ponar included: *Littoridinops* sp., *Limnodrilus hoffmeisteri*, *Dero digitata* complex, *Pyrgophorus platyrachis*, *Pristina leidyi*, *Chironomus* sp., *Dicrotendipes* sp., and *Procladius* (*Holotanypus*) sp. (Table 3.3.5.3-2). Highest percent occurrence of freshwater organisms occurred at KB 2 (85%), KB 4 (89%), KB 5 (89%), KB 6 (87%), KB 9 (98%), and KB 10 (96%). Percent occurrence of freshwater taxa ranged from 17% to 36% at the remainder of the Kings Bay sites.

Taxa	Mean Density (m2)	Dominance Index	Mean Salinity of Capture (ppt)	Abundance-weighted Salinity (ppt)
Littoridinops sp.	3293.00	43.65	2.07	2.00
Hobsonia florida	1241.40	21.19	2.15	1.83
Limnodrilus hoffmeisteri	1107.90	20.01	2.03	1.57
Laeonereis culveri	875.00	19.49	2.13	2.25
Dero digitata complex Milligan	1237.10	18.92	1.57	1.17
Pyrgophorus platyrachis	1400.80	17.43	2.74	4.28
Cyrenoida floridana	650.90	16.81	2.16	2.09
Gammarus sp. B LeCroy	443.90	16.03	1.93	2.03
Tubificoid Naididae imm. w/o hair setae (LPIL)	702.60	15.94	2.16	1.65
Pristina leidyi	836.10	15.55	1.95	2.06
Grandidierella bonnieroides	327.50	10.88	1.75	2.05
Apocorophium louisianum	189.50	8.28	2.27	2.27
Cyathura polita	146.60	7.28	2.88	2.46
Chironomus sp.	137.90	6.32	1.91	1.33
Dicrotendipes sp.	125.00	6.01	1.21	1.52
Psammoryctides convolutus	155.20	5.80	0.94	0.70
Mytilopsis leucophaeata	142.20	5.56	2.23	2.11
Cerapus benthophilus	81.80	4.22	3.18	3.93
Procladius (Holotanypus) sp.	51.70	3.87	2.06	1.63
Opistocystidae (LPIL)	69.00	3.16	0.68	0.68
Leptochelia rapax	60.40	2.95	2.19	2.21
Streblospio sp.	30.10	2.95	3.02	3.65
Rhithropanopeus harrisii	38.70	2.90	2.90	2.37
Piona sp.	43.10	2.50	1.55	1.64
Polypedilum scalaenum group Epler	43.10	2.50	1.27	1.44
Chaetogaster diaphanus	77.60	2.37	2.02	2.02
Uromunna reynoldsi	30.20	2.09	2.11	1.82
Tubificoid Naididae imm. w/ hair setae (LPIL)	25.80	1.93	1.80	1.56
Monopylephorus rubroniveus	17.20	1.58	1.27	1.06
Edwardsiidae (LPIL)	25.90	1.37	4.49	4.49
Labrundinia sp.	25.90	1.37	2.02	2.02
Nanocladius alternantherae	25.90	1.37	2.02	2.02
Oxyethira sp.	25.90	1.37	2.02	2.02
Parachironomus directus	25.90	1.37	2.02	2.02
Coelotanypus concinnus group Epler	12.90	1.37	3.93	4.11
Aulodrilus pigueti	17.20	1.12	1.08	1.08
Cryptochironomus sp.	17.20	1.12	2.35	2.35
Parachironomus sp.	17.20	1.12	2.35	2.35
Physidae (LPIL)	17.20	1.12	0.28	0.28
Americorophium ellisi	8.60	0.79	3.36	3.36
Baetidae (LPIL)	4.30	0.56	2.33	2.33
Cyclaspis varians	4.30	0.56	4.49	4.49
Edotia triloba	4.30	0.56	4.49	4.49
Hydra sp.	4.30	0.56	2.33	2.33
Limnesia sp.	4.30	0.56	1.70	1.70
Taphromysis bowmani	4.30	0.56	2.52	2.52

*Because there were only 46 taxa found in Kings Bay petit Ponar samples, all taxa are listed in this table, sorted by the dominance index, then by density.

Table 3.3.5.3-2. Forty-six Dominant Benthic Taxa*, Mean Abundance, and Mean Salinity of Capture for Kings Bay Sites, July 2009.

Dipnet Results

Cluster analysis and MDS plots created using Bray-Curtis similarity matrices showed a strong separation between the benthic macroinvertebrate assemblages at the Kings Bay/Salt River (KB/SR) dipnet site and the Kings Bay sites (Figures 3.3.5.3-4 and 3.3.5.3-5, respectively). KB/SR was less than ten percent similar to all the other dipnet sampling sites (Figure 3.3.5.3-4). Likely reasons for this difference are discussed below. Otherwise, the dipnet multivariate diagrams reflected the same pattern seen for Kings Bay petite Ponar samples, with KB-9 being most dissimilar to a group composed of KB-3, KB-4, KB-6, KB-7, and KB-10, and with KB-3 and KB-7 being most similar to each other, with over 40 percent similarity.

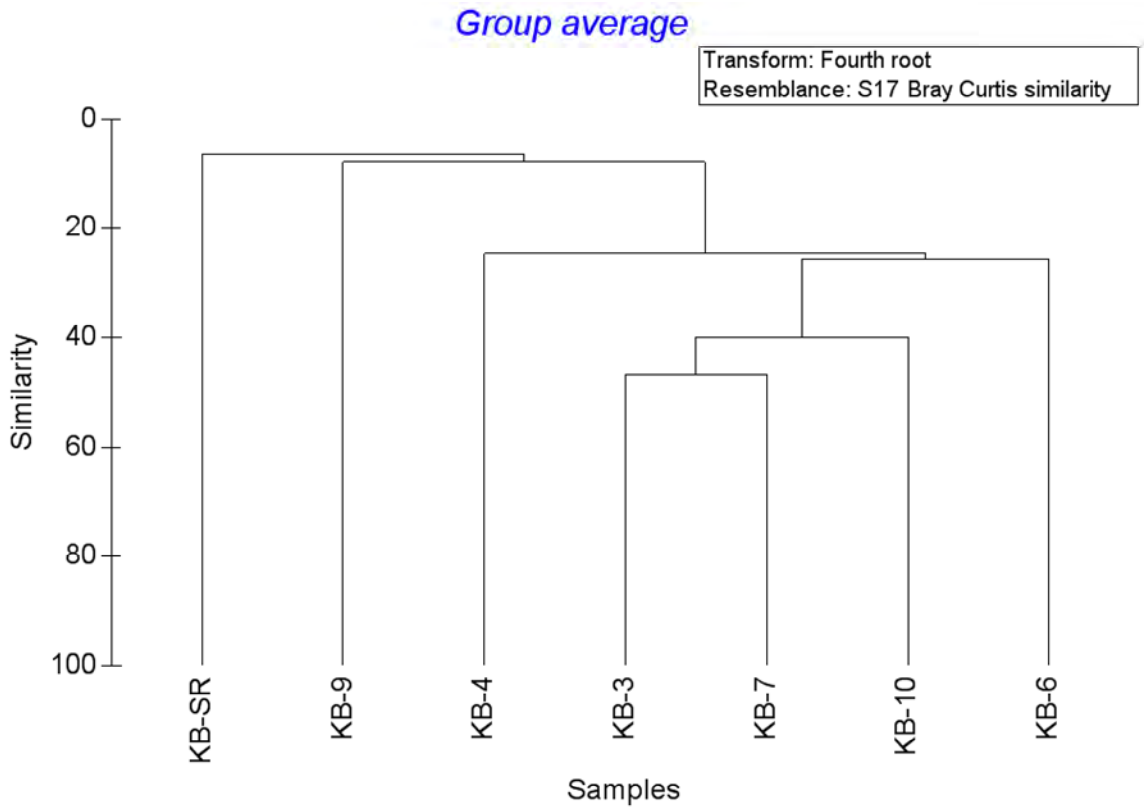

Figure 3.3.5.3-4. Agglomerative Hierarchical Cluster Diagram for All Crystal River Project Macroinvertebrate Dipnet Data.
Data were fourth root transformed prior to being standardized and converted to a Bray-Curtis similarity matrix. The cluster diagram was constructed using the group averaging method.

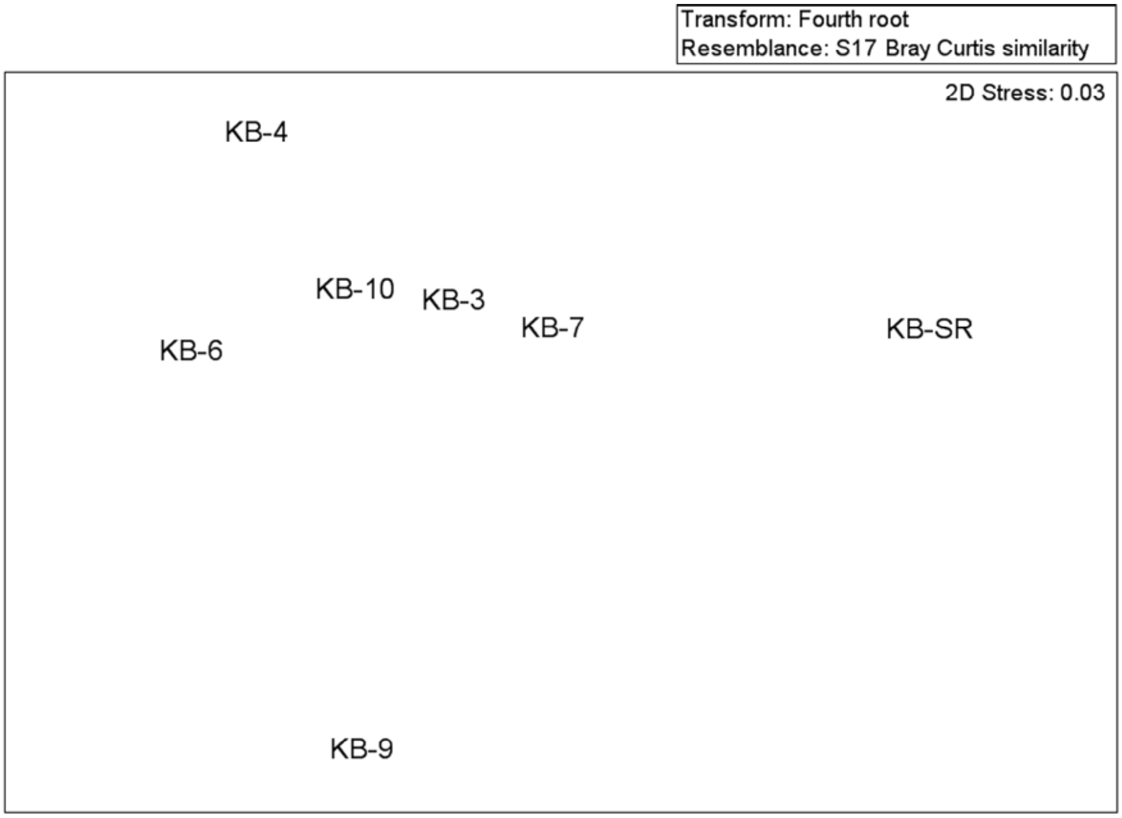

Figure 3.3.5.3-5. Non-Metric Multidimensional Scaling Ordination for All Crystal River Project Macroinvertebrate Dipnet Data.
Data were fourth root transformed and converted to a Bray-Curtis similarity matrix. The Primer 6 Kruskal fit option 1 was selected, and 100 restarts were performed. The stress level of 0.03 "gives an excellent representation with no prospect of misinterpretation" (Clarke and Warwick 2001).

Submerged vegetation was absent at the KB/SR dipnet site, and the benthic assemblage was dominated by polychaetes and crustaceans including *Rhithropanopeus harrisii* (30.71%), *Hobsonia florida* (15.75%), *Laeonereis culveri* (14.96%), *Americorophium ellisi* (9.45%), *Bowmaniella dissimilis* (9.45%), and *Cyathura polita* (5.51%). These taxa tend to tolerate or prefer mesohaline conditions.

Submerged vegetation at Kings Bay dipnet collection sites consisted primarily of *Chara* sp. Three taxa, representing naidinae oligochaetes, amphipods and gastropods, were dominant at three or more Kings Bay sites: *Pristina leidyi* (18.88–35.92% occurrence where dominant), *Gammarus* sp. *B* LeCroy (13.02-21.51% occurrence where dominant) and *Littoridinops* sp. (8.05-58.16% occurrence where dominant). Locally dominant taxa, representing chironomids and isopods, included *Labrundinia neopilosella* (45.45% at KB-9), *Dicrotendipes modestus* (27.27% at KB-9), *Parachironomus carinatus* (18.18% at KB-9), and *Uromunna reynoldsi* (21.51% at KB-3). *Dero* sp. (21.32%) and *Dero nivea* (16.18%) were locally dominant at KB-4. The above-mentioned naidinae worms, gastropods, chironomids, and crustaceans were among the taxa with highest dominance index values (Table 3.3.5.3-3).

Taxa	Dominance Index	Mean Salinity of Capture (ppt)	Abundance-weighted Salinity (ppt)
Pristina leidyi	43.71	1.50	1.15
Littoridinops sp.	27.17	1.29	1.28
Dero nivea	24.71	1.86	1.22
Dero sp.	23.12	1.42	1.22
Chaetogaster diaphanus	15.96	1.18	1.22
Dicrotendipes sp.	10.34	1.90	1.32
Dero digitata complex Milligan	9.60	1.22	1.22
Labrundinia neopilosella	9.20	1.64	1.24
Cyrenoida floridana	6.35	1.73	1.37
Dero pectinata	6.07	1.22	1.22
Apocorophium louisianum	5.14	1.80	1.74
Gammarus sp. B LeCroy	4.92	1.99	1.87
Gammarus sp. B/mucronatus group LeCroy	4.32	0.31	0.31
Uromunna reynoldsi	4.20	1.42	1.53
Gammarus mucronatus group LeCroy	3.72	1.22	1.22
Limnesia sp.	3.50	1.37	1.13
Nanocladius alternantherae	3.19	1.57	1.50
Mytilopsis leucophaeata	3.13	1.86	1.52
Nais communis complex Milligan	3.12	0.31	0.31
Tarebia sp.	3.09	1.17	0.37
Hyalella azteca complex LeCroy	2.77	0.77	0.86
Glyptotendipes sp.	2.63	1.22	1.22
Dicrotendipes modestus	2.60	1.31	0.35
Turbellaria (LPIL)	2.57	1.42	0.41
Littoridinops monroensis	2.37	2.35	2.35
Grandidierella bonnieroides	2.33	3.32	2.22
Rhithropanopeus harrisii	2.12	3.32	4.07
Parachironomus sp.	1.79	1.31	0.74
Callibaetis floridanus	1.75	2.19	2.24
Hobsonia florida	1.60	3.32	4.06
Tanytarsus sp.	1.52	1.22	1.22
Tanytarsus sp. C Epler	1.52	1.22	1.22
Caenis diminuta	1.52	1.22	1.22
Hydrobiidae (LPIL)	1.43	1.61	1.61
Limnodrilus hoffmeisteri	1.34	0.31	0.31
Nais pardalis	1.24	0.31	0.31
Physidae (LPIL)	1.24	0.31	0.31
Pyrgophorus platyrachis	1.09	1.17	1.29
Laeonereis culveri	1.01	4.18	5.24
Pseudochironomus sp.	1.01	0.31	0.31
Taphromysis bowmani	1.00	2.35	2.35
Cyathura polita	0.90	3.16	2.41
Tubificoid Naididae imm. w/o hair setae (LPIL)	0.80	3.46	2.45
Plumatella repens	0.74	1.33	0.47
Tubificoid Naididae imm. w/ hair setae (LPIL)	0.72	0.31	0.31
Leptochelia sp.	0.72	2.35	2.35
Bezzia-Palpomyia complex Brigham	0.72	0.31	0.31
Parachironomus directus	0.70	2.35	2.35
Endochironomus nigricans	0.62	2.19	2.06
Helobdella stagnalis	0.51	0.31	0.31

Table 3.3.5.3-3. Fifty Dominant Benthic Taxa and Mean Salinity of Capture for All Dipnet Sample Stations Sampled in Kings Bay and Crystal River, July 2009.

Thirty-six of the 50 most dominant taxa in dipnet samples were freshwater taxa. Important freshwater taxa in dipnet samples included a large variety of naidinae worms, *Littoridinops* sp. (Table 3.3.5.3-3). Highest percent occurrence of freshwater organisms occurred at KB-4 (98%), KB-6 (80%), KB-9 (100%), and KB-10 (97%). Percent occurrence of freshwater taxa was lower at KB-3 (41%) and KB-7 (48%).

Differences between dominant taxa at KB/SR and the Kings Bay sites appear to be largely driven by salinity and osmotic tolerances of the organisms, although the absence of submerged vegetation at the Salt River site may have also been a factor affecting observed differences in fauna. Taxa collected at KB/SR tended to tolerate mesohaline conditions and many of the chironomid, oligochaete, and gastropod taxa dominating the Kings Bay sites tolerate oligohaline to freshwater conditions.

Although dipnet and petite Ponar samples cannot be compared quantitatively with validity, it is interesting to note that within Kings Bay many of the above-mentioned dominant macroinvertebrate taxa associated with vegetation represented in the dipnet samples were not among the most dominant taxa in Kings Bay petite Ponar samples collected in areas where vegetation was absent (e.g., *Hobsonia florida*, *Limnodrilus hoffmeisteri*, *Laeonereis culveri*, *Dero digitata* complex, *Pyrgophorus platyrachis*, and *Cyrenoida floridana*).

Select metrics for dipnet samples are presented in Table 3.3.5.3-4. Although use of the Florida Index is not considered to be a reliable indicator of pollution in estuarine systems, due in part to the confounding influence of varying salinity (Beck 1955), index values are provided to demonstrate the presence of some Florida Index taxa used in the index calculation, including *Gammarus* spp., *Palaemonetes paludosus*, *Endochironomus nigricans*, *Labrundinia neopilosella*, and *Procladius* spp. Values were low, ranging from 1 at KB/SR to 6 at KB-7. These values are within the range characteristic of many Florida springs (Walsh et al. 2009).

Station	**KB-3**	**KB-4**	**KB-6**	**KB-7**	**KB-9**	**KB-10**	**KB-SR**
Florida Index	3	3	4	6	2	4	1
% Dominance Raw Metric	22.58%	27.21%	35.92%	27.94%	45.45%	58.16%	30.71%
% Very Tolerant Taxa Raw Metric	0.54%	48.35%	17.96%	1.06%	27.27%	3.95%	0.79%
Number of Taxa	20	19	28	35	4	16	13
Number of Individuals	1116	58752	4476	945	11	1568	127

Table 3.3.5.3-4. Metrics for all Dipnet Samples

The percent Dominance metric value is the percent occurrence of the most dominant taxon at a given sampling location. The snail, *Littoridinops* sp., was the most dominant taxon at KB-3 (22.58%), KB-7 (27.94%), and KB-10 (58.16%). The naidinae oligochaete, *Pristina leidyi*, was most dominant at KB-4 (27.21%) and KB-6 (35.92%). The chironomid, *Labrundinia pilosella*, was dominant at KB-9 (45.45%). The salt-tolerant crab, *Rhithropanopeus harrisii*, was dominant at KB/SR (30.71%).

The percent Very Tolerant Taxa metric is the percent occurrence of taxa listed by FDEP as being very tolerant of human disturbance; FDEP SOP LT-7200. Highest values were observed at KB-4 (48.35%), KB-9 (27.27%), and KB-6 (17.96%), where tolerant taxa consisted primarily of annelids (*Dero* spp., *Nais* spp., *Limnodrilus hoffmeisteri*) and the chironomid, *Dicrotendipes modestus*. Values at other sampling locations were quite low.

Sensitive Taxa listed by FDEP (FDEP SOP LT-7100) did not occur in any dipnet samples. The number of taxa in Kings Bay dipnet samples ranged from 4 at KB-9 to 35 at KB-7. The number of individuals ranged from 11 at KB-9 to 58,742 at KB-4, where naidinae annelid worm “blooms” occurred.

3.3.6 River Longitudinal Distribution of Fourteen Important Taxa and Relationships with Salinity Concentration

A rank analysis was performed to determine which of the dominant taxa had the greatest contribution to differences in benthic macroinvertebrate community structure along the river longitudinal and salinity gradients. All taxa collected in the Gulf, Crystal River, and Kings Bay were ranked by descending dominance index value, abundance (Table 3.3.1-1), and average contribution to dissimilarity based on SIMPER results in Appendix C (Tables C-1, C-2, and C-3). Based on these three rankings, an average ranking was calculated for each taxon. Average rankings were used to identify the following fourteen important taxa (given in order of descending rank:

Amphipoda	Ampelisca abdita
Amphipoda	Apocorophium louisianum
Polychaeta	Aricidea taylori
Amphipoda	Cerapus benthophilus
Bivalvia	Cyrenoida floridana
Oligochaeta	*Dero digitata* complex Milligan
Amphipoda	*Gammarus* sp. B LeCroy
Tanaidacea	Halmyrapseudes cf. bahamensis Heard
Polychaeta	Hobsonia florida
Polychaeta	Laeonereis culveri
Oligochaeta	Limnodrilus hoffmeisteri
Gastropoda	*Littoridinops* sp.
Gastropoda	Pyrgophorus platyrachis
Polychaeta	*Streblospio* sp.

Total density (number per square meter) of the fourteen select taxa, as well as other dominant taxa constituting a greater than 5 percent occurrence by pooled stations, is presented in Table 3.3.6-1. Range in salinity of occurrence, optimal (abundance-weighted) salinity, and center of abundance of each important taxon are presented in Table 3.3.6-2. Figures 3.3.6-1 and 3.3.6-2 depict salinity ranges and abundance-weighted salinity (referenced below as "optimal" salinity) for each of the fourteen taxa. Additional figures showing total density of these taxa by river kilometer and salinity concentrations are given in Appendix H.

Important taxa collected solely or primarily in Kings Bay may be important indicators within the MFL framework; these taxa consist of *Dero digitata* complex, *Gammarus* sp. B LeCroy, *Limnodrilus hoffmeisteri*, and *Pyrgophorus platyrachis*. The true distribution of *Limnodrilus hoffmeisteri* may be underestimated because immature specimens of this species may have been collected along the Crystal transects but cannot be identified as this species with certainty. *Littoridinops* sp. were far more abundant in Kings Bay than Crystal River, particularly at KB-2 where a density of 12,845 per square meter was recorded. The polychaetes, *Hobsonia florida*, *Laeoneris culveri* and *Streblospio* sp., were more abundant in Crystal River and were generally absent from the fresher portions of Kings Bay (KB-4, KB-6, KB-9 and KB-10).

Taxa	**Gulf**	**RK 0**	**RK 2.5**	**RK 5**	**RK 7.5**	**RK 9.4**	**KB-1-3**	**KB-4-6**	**KB-7-10**	**Total**
Apocorophium louisianum	11	29	0	57	43	**75517**	115	57	345	76174
Cerapus benthophilus	0	0	0	2069	14	**51753**	244	0	22	54102
Cyrenoida floridana	0	0	0	0	359	**49253**	1523	417	172	51724
Hobsonia florida	0	0	43	129	57	**6422**	3520	86	399	10656
Littoridinops sp.	0	0	0	0	0	517	388	316	**7705**	8926
Ampelisca abdita	0	14	**4296**	2371	57	0	0	0	0	6738
Laeonereis culveri	11	0	187	158	445	1307	**1580**	43	970	4701
Pyrgophorus platyrachis	0	0	0	0	86	0	**4325**	0	259	4670
Halmyrapseudes cf. bahamensis Heard	11	0	**3032**	115	833	0	0	0	0	3991
Dero digitata complex Milligan	0	0	0	0	0	0	0	**3218**	679	3897
Limnodrilus hoffmeisteri	0	0	0	0	0	0	776	**1537**	1034	3347
Tubificoides sp.	0	0	0	0	302	**2069**	0	0	0	2371
Tubificoid Naididae imm. w/o hair setae (LPIL)	0	0	0	0	0	115	891	**920**	399	2325
Pristina leidyi	0	0	0	0	0	0	0	57	**2047**	2104
Tubificoid Naididae (LPIL)	54	115	0	**1279**	259	0	0	0	0	1707
Streblospio sp.	22	0	603	**647**	43	144	86	0	11	1556
Aricidea taylori	**916**	388	0	0	0	0	0	0	0	1304
Monticellina sp.	**313**	201	0	0	0	0	0	0	0	514
Aoridae (LPIL)	54	**230**	29	43	14	0	0	0	0	370
Mooreonuphis nebulosa	**226**	86	0	0	0	0	0	0	0	312
Melita nitida complex LeCroy	11	**201**	86	0	0	0	0	0	0	298
Crepidula plana	11	**172**	14	0	0	0	0	0	0	197

Table 3.3.6-1. Taxa Contributing Greater than 5 Percent of Density in at Least One Pooled Ponar Sample. Highest Density (Number per Square Meter) are Indicated with Bold Font.

	Salinity (ppt)			**Center of Abundance**
	Max	**Min**	**Optimal**	**(RK)**
Ampelisca abdita	12.94	3.91	5.15	1.66
Apocorophium louisianum	18.4	0.31	4.58	**9.39**
Aricidea taylori	18.4	12.94	17.22	2.22
Cerapus benthophilus	4.5	1.61	4.43	6.77
Cyrenoida floridana	4.5	0.87	4.54	**9.59**
Dero digitata complex Milligan	2.3	0.87	1.12	**Kings Bay Only**
Gammarus sp. B LeCroy	4.21	0.31	2.3	**Kings Bay Only**
Halmyrapseudes cf. bahamensis Heard	19.03	3.91	5.28	3.64
Hobsonia florida	5.66	1.22	3.9	**10.94**
Laeonereis culveri	18.4	1.22	4.32	**10.72**
Limnodrilus hoffmeisteri	3.9	0.31	2.46	**Kings Bay Only**
Littoridinops sp.	4.5	0.31	2.57	**9.4**
Pyrgophorus platyrachis	3.91	1.61	2.85	**Primarily Kings Bay**
Streblospio sp.	18.4	1.61	4.99	2.16
Bold indicates prevalence in Kings Bay, collected at 5 or more sites of 10				

Table 3.3.6-2. Salinity Ranges, Optima and Centers of Abundance for Fourteen Important Taxa, Crystal River and Kings Bay, July 2009.

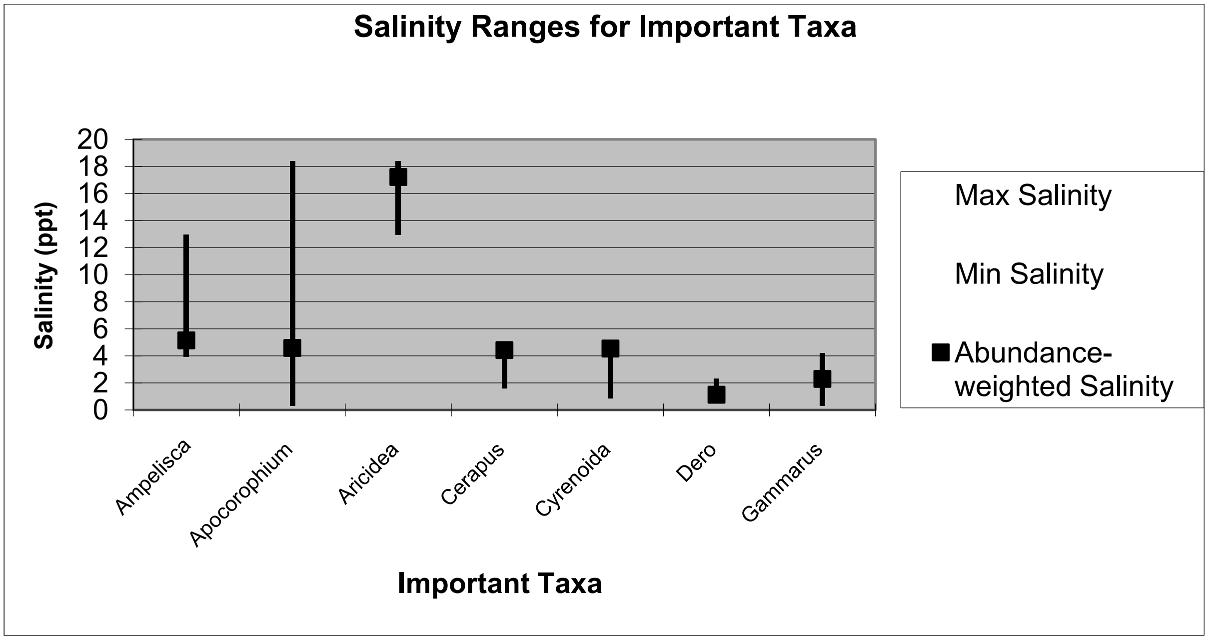

Figure 3.3.6-1. Optimal (Abundance-weighted) Salinity and Salinity Ranges for 7 of 14 Important Taxa.

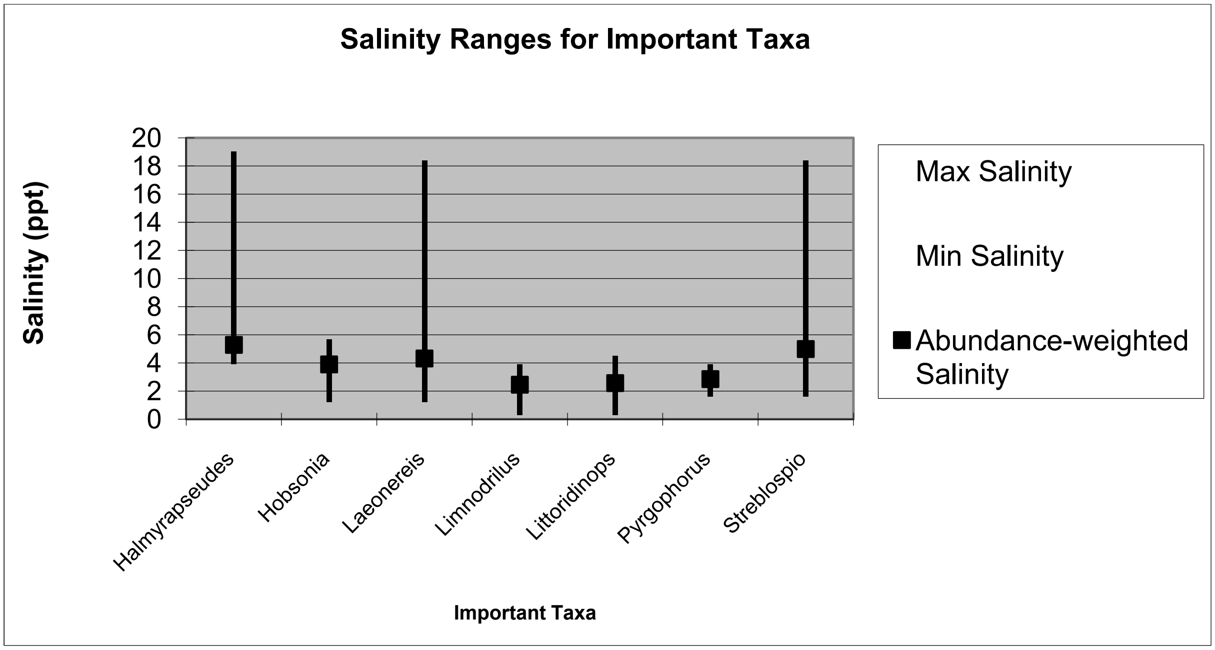

Figure 3.3.6-2. Optimal (Abundance-weighted) Salinity and Salinity Ranges for 7 of 14 Important Taxa.

Aricidea taylori occurred in the mesohaline portions of the study area with an optimal salinity of 17.22 ppt. All other important taxa occurred primarily in oligohaline reaches of the system with optimal salinities ranging from 1.12 to 5.28 ppt. *Dero digitata* complex, *Gammarus* sp. B LeCroy, *Limnodrilus hoffmeisteri*, and *Pyrgophorus platyrachis* occurred exclusively, or almost exclusively, in Kings Bay. Centers of abundance for *Hobsonia florida*, *Laeonereis culveri*, *Apocorophium louisianum*, *Cyrenoida floridana*, and *Littoridinops* sp. ranged from RK 9.39 to RK 10.94 or the uppermost reaches of Crystal River to lower Kings Bay. Optimal salinities for these taxa ranged from 2.57 to 4.58 ppt. The amphipod, *Cerapus benthophilus*, had a center of abundance at RK 6.77 and an optimal salinity of 4.43 ppt. Centers of abundance for *Ampelisca abdita*, *Streblospio* sp., and *Halmyrapseudes* cf. *bahamensis* Heard were in the lower reaches of the Crystal River, ranging from RK 1.66 to RK 3.64. These taxa had optimal salinities ranging from 4.99 to 5.28 ppt.

Given the ANOSIM results described in Section 3.3.4, it is appropriate to explore in more detail a comparison of taxa contributing to the observed differences in benthic community structure within the Gulf, Crystal River, and Kings Bay sub areas. Mean densities of dominant taxa (> 5 percent at any one pooled station) are summarized by pooled station in Table 3.3.6-1.

The polychaetes, *Aricidea taylori, Mooreonuphis nebulosa, and Monticellina* sp., were notably more abundant in the Gulf. The amphipods, *Ampelisca abdita,* the tanaid, *Halmyrapseudes* cf. *bahamensis* Heard, and the polychaete, *Streblospio* sp., were more abundant in Crystal River at RK 2.5 and RK 5. *Apocorophium louisianum, Cerapus benthophilus, Cyrenoida floridana*, and *Hobsonia florida* were strongly dominant at RK 9.4. *Laeonereis culveri, Dero digitata* complex Milligan, *Limnodrilus hoffmeisteri, Pristina leidyi, Littoridinops* sp., *Pyrgophorus platyrachis* dominated macroinfauna in Kings Bay. Many of these taxa that were relatively high in abundance were among the greatest contributors toward dissimilarity between benthic communities in these sub areas (Appendix C; Tables C-1, C-2 and C-3)**.**

Gulf vs. Crystal River

SIMPER results showed that several of the above-mentioned polychaete taxa and *Ampelisca abdita* were relatively high in abundance in the Gulf and/or Crystal River, and contributed the most toward dissimilarity between benthic communities in these sub areas (Table C-1). The average dissimilarity between benthic assemblages of these sub areas was 90.17% (Appendix C).

Gulf vs. Kings Bay

Important Kings Bay taxa included *Littoridinops* sp. and *Gammarus* sp. B LeCroy. Gulf polychaetes *Glycinde solitaria*, *Aricidea taylori*, and *Mediomastus ambiseta,* were relatively abundant, and were important contributors to the dissimilarity between these two sub areas (Table C-2). Benthic assemblages in these two sub areas exhibited a very high average dissimilarity of 98.65% (Appendix C).

Crystal River vs. Kings Bay

Freshwater snails (*Littoridinops* sp., Pyrgophorus platyrachis), oligochaete worms (*Limnodrilus* hoffmeisteri, Tubificoid naidids, *Dero digitata* complex, *Pristina leidyi*, *Psammoryctides convolutus*), and chironomid larvae (*Chironomus* sp., *Dicrotendipes* sp., *Procladius* (*Holotanypus*) sp.) were more abundant in Kings Bay. Salt-tolerant forms like *Ampelisca abdita*, *Cerapus benthophilus*, *Halmyrapseudes* cf. *bahamensis* Heard, and *Streblospio* sp. tended to be more prevalent within Crystal River.

Littoridinops sp., *Gammarus* sp. B LeCroy, *Hobsonia florida*, *Cyrenoida floridana,* and *Laeonereis culveri* contributed the most toward dissimilarity between the benthic assemblages of Crystal River and Kings Bay (Table C-3). The average dissimilarity between Crystal River and Kings Bay benthic assemblages was 86.82% (Appendix C).

4.0 Conclusions

In order to establish minimum flow for tidal rivers, it is necessary to establish quantitative relationships between flow or factors influenced by flow (salinity) and important biological communities, including benthic infauna. One objective of this work was to document quantitative relationships that explain the spatial distribution of the benthic invertebrate assemblages.

Mean water column salinity ranged from 16 to 19 ppt in the Gulf (Crystal Bay), from 4 to 13 ppt in the river channel, and from 0.3 to 4 in Kings Bay. During low flow conditions, there is a zone of rapid change in salinity along the longitudinal river axis between RK 0 (12.94 ppt) and RK 2.5 (5.66 ppt) that roughly represents the transition between the mesohaline zone (salinity of 8 to 18 ppt) and the oligohaline zone (salinity of 0 to 7 ppt). This may be an important zone of transition that has a strong influence on benthic community structure during low flow conditions.

Live oysters were observed from the river mouth upstream to RK 7.8 where mean water column salinity was approximately 4 ppt at the time of sample collection.

The amphipods *Apocorophium louisianum* and *Cerapus benthophilus*, and the bivalve mollusc, *Cyrenoida floridana*, were ranked highest in dominance with index scores of 34.21, 26.98, and 24.95, respectively. These three species made up 67.5% of the total number of organisms collected by petite Ponar dredge during this study.

Number of taxa and Shannon-Wiener diversity declined longitudinally from the river mouth upstream to a low at RK 9.4 and then increased in Kings Bay.

Forward stepwise regression revealed significant relationships between number of taxa and salinity, and between SWDI and salinity and sediments percent silt plus clay. Rank correlation analysis indicated a significant decline in number of taxa with decreasing salinity. Number of taxa declined from 52 taxa at RK 0 (12.94 ppt) to 22 taxa observed at RK 9.4 (4.5 ppt). The decline in number of benthic species with decreasing salinity is a commonly observed spatial pattern in estuaries that may, in part, be attributed to relatively wide fluctuations in environmental conditions along the river longitudinal axis. Total macroinvertebrate density (number per square meter) did not show any regular longitudinal relationship.

The significant correlation between salinity and temperature is thought to be largely driven by the tidal influence gradient from the river mouth in combination with the introduction of relatively cool, fresh spring water in Kings Bay. Inverse correlation of pH with salinity may be caused by relatively high pH in Kings Bay as a result of algal activity in combination with a decline in pH driven by increased buffering capacity of sea water nearer the mouth of Crystal River.

One-way ANOVA revealed a significantly higher number of taxa and higher SWDI in the Gulf than in Crystal River and Kings Bay. Number of taxa and SWDI were not significantly different between Crystal River and Kings Bay. Organism densities were not significantly different between these three sub areas.

The cluster and MDS benthic assemblage diagrams illustrated three distinct groups – (1) a group consisting of the Gulf sites and the mouth of the Crystal River (RK 0) was most dissimilar to the other two groups; (2) a group consisting of Crystal River sites RK 2.5, RK 5, and RK 7.5; and (3) another group consisting of the upper most Crystal River transect, RK 9.4, and the Kings Bay stations. PCA ordination showed similar site groupings along gradients of salinity, temperature, depth, pH, and dissolved oxygen, suggesting that one or more of these parameters, perhaps most importantly salinity, may have influenced benthic macroinvertebrate spatial distribution. The BEST procedure exploring relationships between Bray-Curtis similarity and physicochemical factors demonstrated that the variable best explaining the multivariate relationship between the biotic and abiotic matrices was salinity.

The multivariate results demonstrate that the benthic community structure varied longitudinally along the Crystal River axis, with RK 0 being distinct from RK 9.4. ANOSIM results demonstrated a significant difference between benthic infauna assemblages in the Gulf and assemblages in both Crystal River and Kings Bay. The Crystal River assemblage also significantly differed from the Kings Bay assemblage. Based on the BEST procedure, PCA, rank correlation, and one-way ANOVA results, these differences were most strongly driven by the response of benthic community structure to the salinity gradient.

The petite Ponar and dipnet multivariate diagrams based on Bray-Curtis similarity reflected similar patterns within Kings Bay, with KB-9 being most dissimilar to a group composed of KB-3, KB-4, KB-6, KB-7, and KB-10, with KB-3 and KB-7 being most similar to each other. Although dipnet and petite Ponar samples cannot be compared quantitatively with validity, it is interesting to note that within Kings Bay many of the dominant macroinvertebrate taxa associated with vegetation represented in the dipnet samples were not among the most dominant taxa in Kings Bay petite Ponar samples collected in areas where vegetation was absent (e.g., *Hobsonia florida*, *Limnodrilus hoffmeisteri*, *Laeonereis culveri*, *Dero digitata* complex, *Pyrgophorus platyrachis*, *Cyrenoida floridana*). Although similar patterns in benthic community structure may be revealed by using either method of collection, differences in species dominance and benthic community structure can be attributed to variation in habitat structure (vegetated vs. non-vegetated).

The following fourteen dominant taxa were identified as having the greatest influence on dissimilarity in benthic community structure along the river's longitudinal axis and in the three sub areas (Gulf, Crystal River, and Kings Bay):

Amphipoda	Ampelisca abdita
Amphipoda	Apocorophium louisianum
Polychaeta	Aricidea taylori
Amphipoda	Cerapus benthophilus
Amphipoda	Cyrenoida floridana
Oligochaeta	*Dero digitata complex* Milligan
Amphipoda	*Gammarus* sp. *B* LeCroy
Tanaidacea	Halmyrapseudes cf. bahamensis Heard
Polychaeta	Hobsonia florida
Polychaeta	Laeonereis culveri
Oligochaeta	Limnodrilus hoffmeisteri
Gastropoda	*Littoridinops* sp.
Gastropoda	Pyrgophorus platyrachis
Polychaeta	*Streblospio* sp.

Aricidea taylori, which may be an important indicator organism, occurred in the mesohaline portions of the study area with an optimal salinity of 17.22 ppt. Potential biological indicators in the lower reaches of Crystal River included *Ampelisca abdita*, *Streblospio* sp., and *Halmyrapseudes* cf. *bahamensis* Heard, with centers of abundance ranging from RK 1.66 to RK 3.64 and optimal salinities ranging from 4.99 to 5.28 ppt. All other important taxa listed above, with optimal salinities ranging from 1.12 to 5.28 ppt, are likely to be useful biological indicators in Kings Bay and the uppermost portion of the Crystal River. *Dero digitata* complex, *Gammarus* sp. B LeCroy, *Limnodrilus hoffmeisteri*, and *Pyrgophorus platyrachis* occurred exclusively, or almost exclusively, in Kings Bay and *Hobsonia florida*, *Laeonereis culveri*, *Apocorophium louisianum*, *Cyrenoida floridana*, and *Littoridinops* sp. had centers of abundance in the uppermost reaches of Crystal River.

Sustained decline in river flow and resultant elevated salinity concentrations might lead to an increase in number of taxa, an increase in number of salt-tolerant taxa, and perhaps a decrease in chironomids, freshwater oligochaetes, *Gammarus* sp. B LeCroy, freshwater gastropods (e.g., *Pyrgophorus platyrachis*, *Littoridinops* sp.), and other taxa characteristic of the oligohaline and freshwater zones of the Crystal River system.

The polychaetes, Hobsonia florida, Laeoneris culveri and Streblospio sp., which were generally absent from the fresher portions of Kings Bay (KB-4, KB-6, KB-9 and KB-10) during the current study may become more prevalent in those portions of the bay. The potential for salinity-driven shifts in benthic fauna may be most prevalent in the northeastern portion of the bay where freshwater or near freshwater conditions have existed historically (Hammett et al. 1996) and susceptibility to tidal influx via the Crystal River is greatest.

5.0 References

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Appendix A

Raw Statistical Outputs

MINITAB Outputs

Salinity Data – Crystal River

Results for: Crystal River Bottom & Mean Profile Salinity.MTW

Descriptive Statistics: All Bottom Salinity, All Mean Profile Salinity

```
Variable                   N   Mean  StDev  Minimum     Q1  Median      Q3
All Bottom Salinity       79  9.813  7.104    1.170  3.600   7.480  15.160
All Mean Profile Salinity  79  9.813  7.104    1.170  3.600   7.480  15.160

Variable                  Maximum
All Bottom Salinity        26.650
All Mean Profile Salinity   26.650
```

Descriptive Statistics: 1_Bottom Sal, 1_Mean Profi, 2_Bottom Sal, ...

```
Variable                  N   Mean  StDev  Minimum     Q1  Median     Q3
1_Bottom Salinity        10  20.93   5.46     6.46  20.51   21.67  23.79
1_Mean Profile Salinity  10  20.93   5.46     6.46  20.51   21.67  23.79
2_Bottom Salinity        10  16.51   4.40     8.64  13.90   17.01  19.38
2_Mean Profile Salinity  10  16.51   4.40     8.64  13.90   17.01  19.38
3_Bottom Salinity        10  12.62   4.67     3.60  10.42   13.13  15.68
3_Mean Profile Salinity  10  12.62   4.67     3.60  10.42   13.13  15.68
4_Bottom Salinity        10   9.57   4.18     3.54   6.09    9.30  13.02
4_Mean Profile Salinity  10   9.57   4.18     3.54   6.09    9.30  13.02
5_Bottom Salinity        10  7.691  2.902    2.700  5.460   7.545  9.795
5_Mean Profile Salinity  10  7.691  2.902    2.700  5.460   7.545  9.795
6_Bottom Salinity        10  5.035  1.921    1.290  3.805   5.000  6.493
6_Mean Profile Salinity  10  5.035  1.921    1.290  3.805   5.000  6.493
7_Bottom Salinity         9  2.884  1.775    1.190  1.310   2.740  3.700
7_Mean Profile Salinity   9  2.884  1.775    1.190  1.310   2.740  3.700
8_Bottom Salinity        10  2.574  1.273    1.170  1.395   2.370  3.413
8_Mean Profile Salinity  10  2.574  1.273    1.170  1.395   2.370  3.413

Variable                 Maximum
1_Bottom Salinity          26.65
1_Mean Profile Salinity    26.65
2_Bottom Salinity          22.63
2_Mean Profile Salinity    22.63
3_Bottom Salinity          18.90
3_Mean Profile Salinity    18.90
4_Bottom Salinity          15.75
4_Mean Profile Salinity    15.75
5_Bottom Salinity         12.650
5_Mean Profile Salinity   12.650
6_Bottom Salinity          7.770
6_Mean Profile Salinity    7.770
7_Bottom Salinity          6.790
7_Mean Profile Salinity    6.790
8_Bottom Salinity          5.230
8_Mean Profile Salinity    5.230
```

Mann-Whitney Test and CI: Crystal River - All Bottom Salinity versus All Mean Profile Salinity

```
                            N  Median
All Bottom Salinity        79   7.480
All Mean Profile Salinity  79   7.480


Point estimate for ETA1-ETA2 is -0.000
95.0 Percent CI for ETA1-ETA2 is (-1.869,1.869)
W = 6280.5
Test of ETA1 = ETA2 vs. ETA1 not = ETA2 is significant at 1.0000
The test is significant at 1.0000 (adjusted for ties)
```

Results for: Crystal River Bottom & Mean Profile Salinity.MTW

Correlations: All Bottom Salinity_Ranks, All Mean Profile Salinity_Ranks

```
Pearson correlation of All Bottom Salinity_Ranks and All Mean Profile
     Salinity_Ranks = 1.000
```

For $\rho=1.000$, $P<0.01$ (Snedecor and Cochran 1972)

Salinity Data – Kings Bay

Results for: Kings Bay Bottom & Mean Profile Salinity.MTW

Descriptive Statistics: All Bottom S, All Mean Pro, 9_Bottom Sal, ...

```
Variable                    N    Mean   StDev  Minimum      Q1  Median      Q3
All Bottom Salinity       143  1.9176  1.1616   0.1500  1.0500  1.7100  2.5200
All Mean Profile Salinity  143  1.9179  1.1628   0.1500  1.0500  1.7100  2.5300
9_Bottom Salinity          10   1.584   0.723    0.840   1.150   1.435   1.745
9_ Mean Profile Salinity   10   1.584   0.723    0.840   1.150   1.435   1.745
10_ Bottom Salinity        10   0.872   0.590    0.400   0.433   0.785   0.953
10_ Mean Profile Salinity   10   0.872   0.590    0.400   0.433   0.785   0.953
11_ Bottom Salinity        10   0.776   0.656    0.230   0.250   0.570   1.085
11_ Mean Profile Salinity   10   0.776   0.656    0.230   0.250   0.570   1.085
12_ Bottom Salinity        10   0.642   0.521    0.150   0.225   0.545   0.880
12_ Mean Profile Salinity   10   0.642   0.521    0.150   0.225   0.545   0.880
13_ Bottom Salinity        10   2.043   0.787    1.130   1.442   1.890   2.507
13_ Mean Profile Salinity   10   2.043   0.787    1.130   1.442   1.890   2.507
14_ Bottom Salinity         9   2.222   0.782    1.400   1.630   1.810   2.940
14_ Mean Profile Salinity    9   2.222   0.782    1.400   1.630   1.810   2.940
15_ Bottom Salinity        10  0.9540  0.3095   0.4800  0.7300  0.9700  1.1075
15_ Mean Profile Salinity   10  0.9540  0.3095   0.4800  0.7300  0.9700  1.1075
16_ Bottom Salinity        10   1.324   0.466    0.620   0.935   1.395   1.710
16_ Mean Profile Salinity   10   1.331   0.469    0.620   0.935   1.430   1.710
17_ Bottom Salinity        10   2.522   0.609    1.680   2.063   2.425   3.105
17_ Mean Profile Salinity   10   2.482   0.640    1.680   1.849   2.425   3.105
18_ Bottom Salinity         9   3.443   1.156    1.540   2.320   3.580   4.505
18_ Mean Profile Salinity    9   3.443   1.156    1.540   2.320   3.580   4.505
19_ Bottom Salinity         9   4.182   0.850    2.900   3.225   4.590   4.825
19_ Mean Profile Salinity    9   4.182   0.850    2.900   3.225   4.590   4.825
20_ Bottom Salinity         9   2.236   0.387    1.710   1.820   2.390   2.565
20_ Mean Profile Salinity    9   2.277   0.435    1.710   1.820   2.390   2.670
21_ Bottom Salinity         9   2.336   0.589    1.540   1.805   2.390   2.815
21_ Mean Profile Salinity    9   2.336   0.589    1.540   1.805   2.390   2.815
22_ Bottom Salinity         9   1.962   0.522    1.090   1.580   1.970   2.370
23_ Bottom Salinity         9   2.180   1.072    1.150   1.330   1.930   2.940
23_ Mean Profile Salinity    9   2.180   1.072    1.150   1.330   1.930   2.940

Variable                  Maximum
All Bottom Salinity        5.2400
All Mean Profile Salinity   5.2400
9_Bottom Salinity           3.460
9_ Mean Profile Salinity    3.460
10_ Bottom Salinity         2.440
10_ Mean Profile Salinity    2.440
11_ Bottom Salinity         2.300
11_ Mean Profile Salinity    2.300
12_ Bottom Salinity         1.830
12_ Mean Profile Salinity    1.830
13_ Bottom Salinity         3.730
13_ Mean Profile Salinity    3.730
14_ Bottom Salinity         3.510
14_ Mean Profile Salinity    3.510
15_ Bottom Salinity        1.5400
15_ Mean Profile Salinity   1.5400
16_ Bottom Salinity         2.000
16_ Mean Profile Salinity    2.000
17_ Bottom Salinity         3.550
17_ Mean Profile Salinity    3.550
18_ Bottom Salinity         4.840
18_ Mean Profile Salinity    4.840
```

```
Variable (continued)        Maximum
19_ Bottom Salinity         5.240
19_ Mean Profile Salinity     5.240
20_ Bottom Salinity         2.710
20_ Mean Profile Salinity     2.865
21_ Bottom Salinity         3.300
21_ Mean Profile Salinity     3.300
22_ Bottom Salinity         2.760
23_ Bottom Salinity         4.230
23_ Mean Profile Salinity     4.230
```

Descriptive Statistics: 22_ Mean Profile Salinity

```
Variable                   N   Mean  StDev  Minimum     Q1  Median     Q3
22_ Mean Profile Salinity  9  1.962  0.522    1.090  1.580   1.970  2.370

Variable                  Maximum
22_ Mean Profile Salinity    2.760
```

Results for: Kings Bay Bottom & Mean Profile Salinity.MTW

Mann-Whitney Test and CI: All Bottom Salinity, All Mean Profile Salinity

```
                             N  Median
All Bottom Salinity        143  1.7100
All Mean Profile Salinity  143  1.7100


Point estimate for ETA1-ETA2 is 0.0000
95.0 Percent CI for ETA1-ETA2 is (-0.2400,0.2402)
W = 20517.5
Test of ETA1 = ETA2 vs ETA1 not = ETA2 is significant at 0.9971
The test is significant at 0.9971 (adjusted for ties)
```

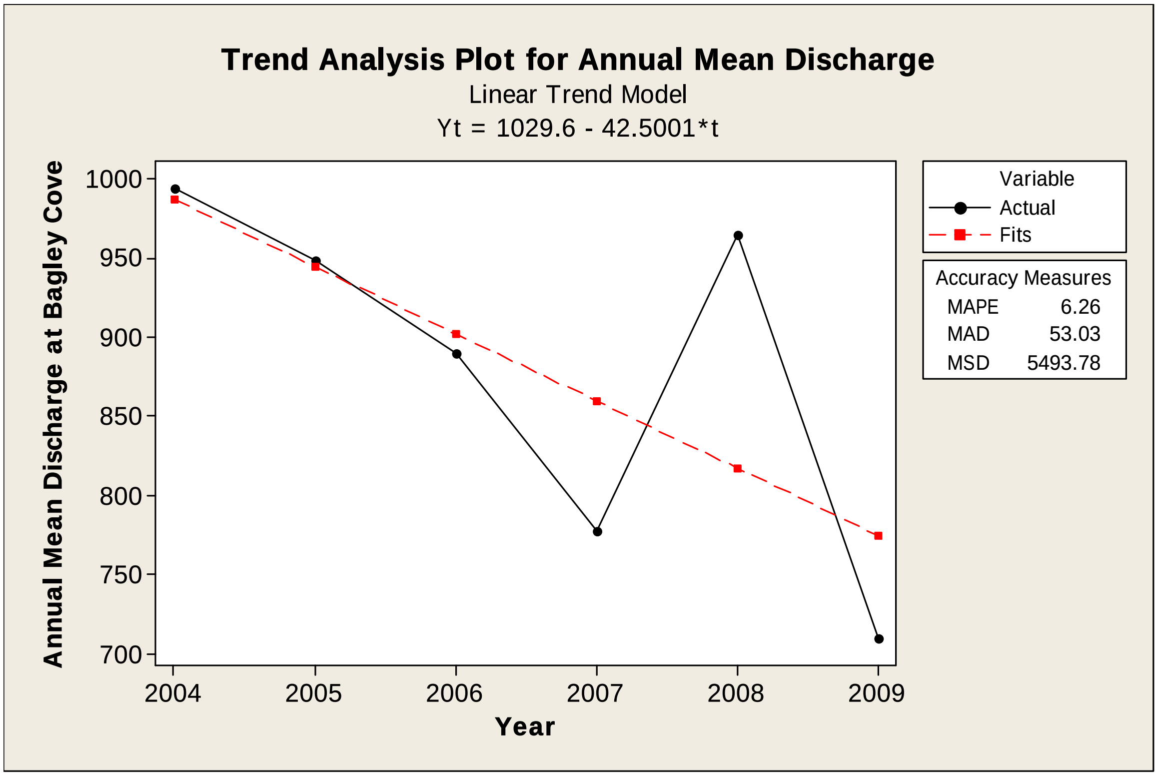
Correlations: All Bottom Salinity_Ranks, All Mean Profile Salinity_Ranks

```
Pearson correlation of All Bottom Salinity_Ranks and All Mean Profile
     Salinity_Ranks = 0.999
```

For $\rho=0.999$, $P<0.01$ (Snedecor and Cochran 1972)

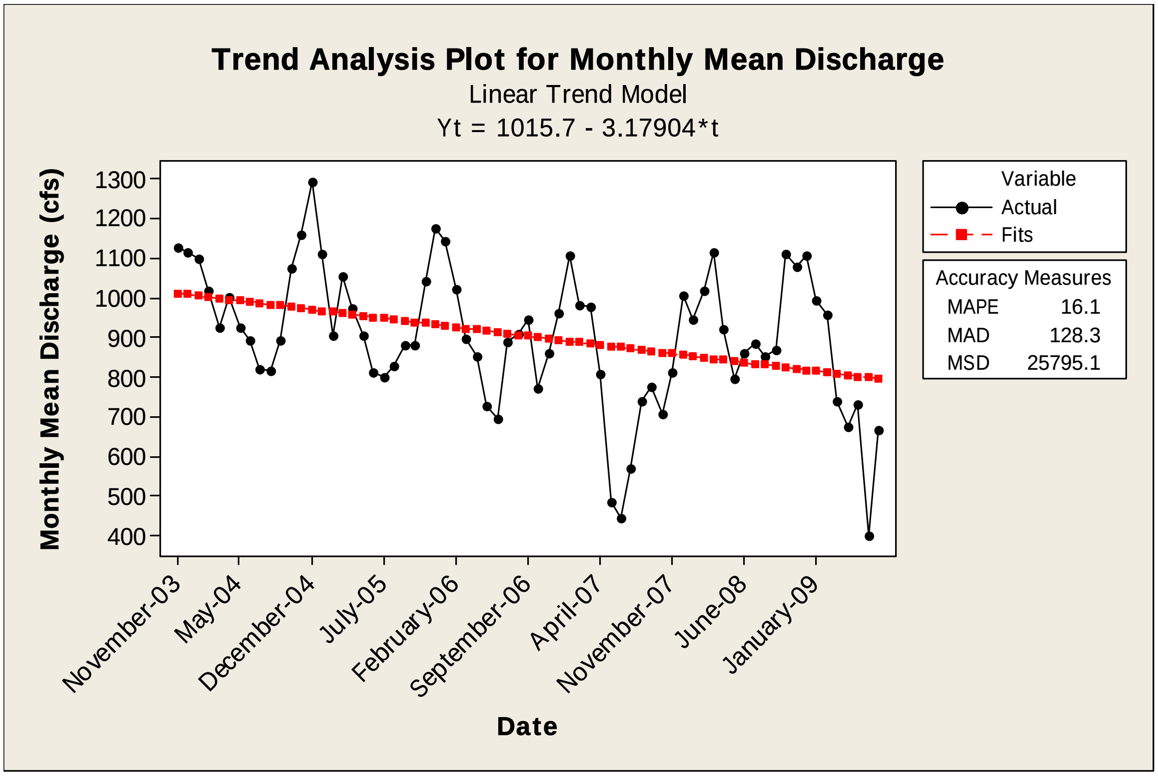
Flow – Discharge Data

Trend and Regression Analysis



Regression Analysis: Annual Mean Discharge_1 versus Date_2

```
The regression equation is
Annual Mean Discharge_1 = 1030 - 42.5 Date_2


Predictor      Coef  SE Coef      T      P
Constant    1029.60    84.51  12.18  0.000
Date_2       -42.50    21.70  -1.96  0.122


S = 90.7782   R-Sq = 49.0%   R-Sq(adj) = 36.2%


Analysis of Variance

Source          DF      SS     MS     F      P
Regression       1   31609  31609  3.84  0.122
Residual Error   4   32963   8241
Total            5   64572
```



Trend Analysis Plot for Monthly Mean Discharge

Regression Analysis: Monthly Mean Discharge versus Date Sequence

```
The regression equation is
Monthly Mean Discharge = 1016 - 3.18 Date Sequence


Predictor          Coef  SE Coef      T      P
Constant        1015.73    39.67  25.60  0.000
Date Sequence   -3.1790   0.9852  -3.23  0.002


S = 162.988   R-Sq = 13.5%   R-Sq(adj) = 12.2%


Analysis of Variance

Source          DF       SS      MS      F      P
Regression       1   276609  276609  10.41  0.002
Residual Error  67  1779860   26565
Total           68  2056470


Unusual Observations

                  Monthly
         Date        Mean
Obs  Sequence   Discharge    Fit  SE Fit  Residual  St Resid
 14      14.0      1292.5  971.2    28.5     321.3     2.00R
 43      43.0       486.5  879.0    21.1    -392.5    -2.43R
```

```
 44      44.0      445.7  875.9    21.5    -430.2     -2.66R
 68      68.0      402.4  799.6    38.0    -397.2     -2.51R

R denotes an observation with a large standardized residual.
```

Results for: Mean PChem data July 2009.MTW

Descriptive Statistics: Temperature, pH, Conductance, Salinity, ...

```
Variable            N    Mean   StDev  Minimum      Q1  Median      Q3  Maximum
Temperature        20  28.694   1.096   26.637  27.931  28.761  29.480   30.367
pH                 20  8.1399  0.4261   7.5200  7.8285  8.0613  8.3838   9.1450
Conductance        20   10684   10162      596    3790    6994   18819    30684
Salinity           20    6.34    6.38     0.31    2.05    3.90   11.20    19.03
DO (% Saturation)  20   96.41   24.95    64.45   76.10   93.10  112.44   155.35
DO (mg/L)          20   7.243   2.093    4.810   5.506   6.618   8.593   12.305
Total Depth        20   2.238   1.028    0.800   1.350   2.100   3.175    4.200
```

Descriptive Statistics: Temperature_, pH_CR, Conductance_, Salinity_CR, ...

```
Variable                  N    Mean   StDev  Minimum      Q1  Median      Q3
Temperature_CR            5  28.898   0.479   28.235  28.481  28.794  29.367
pH_CR                     5  7.7391  0.1187   7.5600  7.6175  7.8025  7.8290
Conductance_CR            5   10842    6107     7022    7289    8028   15802
Salinity_CR               5    6.24    3.80     3.91    4.06    4.50    9.30
DO (% Saturation)_CR      5   73.13    6.16    64.45   67.99   71.80   78.94
DO (mg/L)_CR              5   5.418   0.499    4.810   4.938   5.430   5.892
Total Depth_CR            5   3.400   0.704    2.400   2.750   3.400   4.050
pH_Gulf                   4  8.0242  0.0764   7.9233  7.9442  8.0433  8.0850
Conductance_Gulf          4   28421    2123    26472   26543   28265   30456
Salinity_Gulf             4  17.590   1.351   16.150  16.307  17.588  18.875
DO (% Saturation)_Gulf    4   90.98   10.33    78.27   80.42   93.10   99.43
DO (mg/L)_Gulf            4   6.155   0.625    5.367   5.510   6.293   6.662
Total Depth_Gulf          4   2.100   0.258    1.800   1.850   2.100   2.350
Temperature_Kings Bay    10  27.976   0.948   26.637  27.044  27.973  28.644
pH_Kings Bay             10   8.449   0.362    7.950   8.223   8.383   8.664
Conductance_Kings Bay    10    3524    1771      596    2113    3870    4364
Salinity_Kings Bay       10   1.921   0.995    0.310   1.131   2.085   2.385
DO (% Saturation)_Kings  10  113.20   23.13    75.67  100.63  111.53  130.18
DO (mg/L)_Kings Bay      10   8.825   1.799    6.205   7.794   8.536  10.139
Total Depth_Kings Bay    10   1.805   0.960    0.800   0.963   1.500   2.900

Variable                 Maximum
Temperature_CR            29.373
pH_CR                     7.8300
Conductance_CR             21575
Salinity_CR                12.94
DO (% Saturation)_CR       80.50
DO (mg/L)_CR               6.052
Total Depth_CR             4.200
pH_Gulf                   8.0867
Conductance_Gulf           30684
Salinity_Gulf             19.033
DO (% Saturation)_Gulf     99.47
DO (mg/L)_Gulf             6.667
Total Depth_Gulf           2.400
Temperature_Kings Bay     29.515
pH_Kings Bay               9.145
Conductance_Kings Bay       6966
Salinity_Kings Bay         3.898
DO (% Saturation)_Kings   155.35
DO (mg/L)_Kings Bay       12.305
Total Depth_Kings Bay      3.300
```

Mann-Whitney Tests for Sub-Area Physicochemical Medians

Mann-Whitney Test and CI: Temperature_CR, Temperature_Gulf

```
                  N  Median
Temperature_CR    5  28.794
Temperature_Gulf  4  30.108


Point estimate for ETA1-ETA2 is -1.086
96.3 Percent CI for ETA1-ETA2 is (-2.108,-0.460)
W = 15.0
Test of ETA1 = ETA2 vs ETA1 not = ETA2 is significant at 0.0200
```

Mann-Whitney Test and CI: pH_CR, pH_Gulf

```
         N  Median
pH_CR    5  7.8025
pH_Gulf  4  8.0433


Point estimate for ETA1-ETA2 is -0.2577
96.3 Percent CI for ETA1-ETA2 is (-0.5200,-0.0954)
W = 15.0
Test of ETA1 = ETA2 vs ETA1 not = ETA2 is significant at 0.0200
```

Mann-Whitney Test and CI: Conductance_CR, Conductance_Gulf

```
                  N  Median
Conductance_CR    5    8028
Conductance_Gulf  4   28265


Point estimate for ETA1-ETA2 is -19325
96.3 Percent CI for ETA1-ETA2 is (-23127,-5182)
W = 15.0
Test of ETA1 = ETA2 vs ETA1 not = ETA2 is significant at 0.0200
```

Mann-Whitney Test and CI: Salinity_CR, Salinity_Gulf

```
               N  Median
Salinity_CR    5   4.495
Salinity_Gulf  4  17.588


Point estimate for ETA1-ETA2 is -12.422
96.3 Percent CI for ETA1-ETA2 is (-14.817,-3.841)
W = 15.0
Test of ETA1 = ETA2 vs ETA1 not = ETA2 is significant at 0.0200
```

Mann-Whitney Test and CI: DO (% Saturation)_CR, DO (% Saturation)_Gulf

```
                        N  Median
DO (% Saturation)_CR    5   71.80
DO (% Saturation)_Gulf  4   93.10
```

```
Point estimate for ETA1-ETA2 is -18.90
96.3 Percent CI for ETA1-ETA2 is (-34.88,-0.89)
W = 16.0
Test of ETA1 = ETA2 vs ETA1 not = ETA2 is significant at 0.0373
```

Mann-Whitney Test and CI: DO (mg/L)_CR, DO (mg/L)_Gulf

```
                N  Median
DO (mg/L)_CR    5   5.430
DO (mg/L)_Gulf  4   6.293


Point estimate for ETA1-ETA2 is -0.744
96.3 Percent CI for ETA1-ETA2 is (-1.837,0.366)
W = 19.0
Test of ETA1 = ETA2 vs ETA1 not = ETA2 is significant at 0.1779
```

Mann-Whitney Test and CI: Total Depth_CR, Total Depth_Gulf

```
                  N  Median
Total Depth_CR    5   3.400
Total Depth_Gulf  4   2.100


Point estimate for ETA1-ETA2 is 1.350
96.3 Percent CI for ETA1-ETA2 is (0.200,2.200)
W = 34.5
Test of ETA1 = ETA2 vs ETA1 not = ETA2 is significant at 0.0275
The test is significant at 0.0268 (adjusted for ties)
```

Mann-Whitney Test and CI: Temperature_CR, Temperature_Kings Bay

```
                        N  Median
Temperature_CR          5  28.794
Temperature_Kings Bay  10  27.973


Point estimate for ETA1-ETA2 is 0.960
95.7 Percent CI for ETA1-ETA2 is (-0.141,1.799)
W = 56.0
Test of ETA1 = ETA2 vs ETA1 not = ETA2 is significant at 0.0576
```

Mann-Whitney Test and CI: pH_CR, pH_Kings Bay

```
               N  Median
pH_CR          5  7.8025
pH_Kings Bay  10  8.3825


Point estimate for ETA1-ETA2 is -0.6960
95.7 Percent CI for ETA1-ETA2 is (-1.0654,-0.3899)
W = 15.0
Test of ETA1 = ETA2 vs ETA1 not = ETA2 is significant at 0.0027
```

Mann-Whitney Test and CI: Conductance_CR, Conductance_Gulf

```
                   N  Median
Conductance_CR     5    8028
Conductance_Gulf   4   28265


Point estimate for ETA1-ETA2 is -19325
96.3 Percent CI for ETA1-ETA2 is (-23127,-5182)
W = 15.0
Test of ETA1 = ETA2 vs ETA1 not = ETA2 is significant at 0.0200
```

Mann-Whitney Test and CI: Salinity_CR, Salinity_Kings Bay

```
                      N  Median
Salinity_CR           5   4.495
Salinity_Kings Bay   10   2.085


Point estimate for ETA1-ETA2 is 3.101
95.7 Percent CI for ETA1-ETA2 is (1.764,10.445)
W = 65.0
Test of ETA1 = ETA2 vs ETA1 not = ETA2 is significant at 0.0027
```

Mann-Whitney Test and CI: DO (% Saturation)_CR, DO (% Saturation)_Kings Bay

```
                               N  Median
DO (% Saturation)_CR           5   71.80
DO (% Saturation)_Kings Bay   10  111.53


Point estimate for ETA1-ETA2 is -39.15
95.7 Percent CI for ETA1-ETA2 is (-60.64,-11.63)
W = 17.0
Test of ETA1 = ETA2 vs ETA1 not = ETA2 is significant at 0.0059
```

Mann-Whitney Test and CI: DO (mg/L)_CR, DO (mg/L)_Kings Bay

```
                       N  Median
DO (mg/L)_CR           5   5.430
DO (mg/L)_Kings Bay   10   8.536


Point estimate for ETA1-ETA2 is -3.288
95.7 Percent CI for ETA1-ETA2 is (-5.037,-1.523)
W = 15.0
Test of ETA1 = ETA2 vs ETA1 not = ETA2 is significant at 0.0027
```

Mann-Whitney Test and CI: Total Depth_CR, Total Depth_Kings Bay

```
                         N  Median
Total Depth_CR           5   3.400
Total Depth_Kings Bay   10   1.500


Point estimate for ETA1-ETA2 is 1.600
95.7 Percent CI for ETA1-ETA2 is (0.500,2.700)
W = 60.0
```

```
Test of ETA1 = ETA2 vs ETA1 not = ETA2 is significant at 0.0169
The test is significant at 0.0168 (adjusted for ties)
```

Mann-Whitney Test and CI: Temperature_Gulf, Temperature_Kings Bay

```
                        N  Median
Temperature_Gulf        4  30.108
Temperature_Kings Bay  10  27.973


Point estimate for ETA1-ETA2 is 2.182
96.0 Percent CI for ETA1-ETA2 is (0.852,3.283)
W = 50.0
Test of ETA1 = ETA2 vs ETA1 not = ETA2 is significant at 0.0058
```

Mann-Whitney Test and CI: pH_Gulf, pH_Kings Bay

```
               N  Median
pH_Gulf        4  8.0433
pH_Kings Bay  10  8.3825


Point estimate for ETA1-ETA2 is -0.3725
96.0 Percent CI for ETA1-ETA2 is (-0.8868,-0.0265)
W = 15.0
Test of ETA1 = ETA2 vs ETA1 not = ETA2 is significant at 0.0403
```

Mann-Whitney Test and CI: Conductance_Gulf, Conductance_Kings Bay

```
                        N  Median
Conductance_Gulf        4   28265
Conductance_Kings Bay  10    3870


Point estimate for ETA1-ETA2 is 25171
96.0 Percent CI for ETA1-ETA2 is (22275,27707)
W = 50.0
Test of ETA1 = ETA2 vs ETA1 not = ETA2 is significant at 0.0058
```

Mann-Whitney Test and CI: Salinity_Gulf, Salinity_Kings Bay

```
                     N  Median
Salinity_Gulf        4  17.588
Salinity_Kings Bay  10   2.085


Point estimate for ETA1-ETA2 is 15.872
96.0 Percent CI for ETA1-ETA2 is (13.995,17.429)
W = 50.0
Test of ETA1 = ETA2 vs ETA1 not = ETA2 is significant at 0.0058
```

Mann-Whitney Test and CI: DO (% Saturation)_Gulf, DO (% Saturation)_Kings Bay

```
                              N  Median
DO (% Saturation)_Gulf        4   93.10
DO (% Saturation)_Kings Bay  10  111.53
```

```
Point estimate for ETA1-ETA2 is -22.48
96.0 Percent CI for ETA1-ETA2 is (-51.15,3.72)
W = 17.0
Test of ETA1 = ETA2 vs ETA1 not = ETA2 is significant at 0.0771
```

Mann-Whitney Test and CI: DO (mg/L)_Gulf, DO (mg/L)_Kings Bay

```
                      N  Median
DO (mg/L)_Gulf        4   6.293
DO (mg/L)_Kings Bay  10   8.536


Point estimate for ETA1-ETA2 is -2.485
96.0 Percent CI for ETA1-ETA2 is (-4.663,-0.650)
W = 14.0
Test of ETA1 = ETA2 vs ETA1 not = ETA2 is significant at 0.0284
```

Mann-Whitney Test and CI: Total Depth_Gulf, Total Depth_Kings Bay

```
                        N  Median
Total Depth_Gulf        4   2.100
Total Depth_Kings Bay  10   1.500


Point estimate for ETA1-ETA2 is 0.550
96.0 Percent CI for ETA1-ETA2 is (-1.000,1.200)
W = 37.0
Test of ETA1 = ETA2 vs ETA1 not = ETA2 is significant at 0.3580
The test is significant at 0.3574 (adjusted for ties)
```

Results for: Sediment Data.MTW

Mann-Whitney Test and CI: % Silt+Clay_Gulf, % Silt+Clay_KB

```
                   N  Median
% Silt+Clay_Gulf   4   36.10
% Silt+Clay_KB    11   34.60


Point estimate for ETA1-ETA2 is -0.70
95.7 Percent CI for ETA1-ETA2 is (-44.40,11.90)
W = 30.0
Test of ETA1 = ETA2 vs ETA1 not = ETA2 is significant at 0.8447
```

Mann-Whitney Test and CI: Percent Organics_Gulf, Percent Organics_KB

```
                        N  Median
Percent Organics_Gulf   4   3.500
Percent Organics_KB    11   2.000


Point estimate for ETA1-ETA2 is 1.300
95.7 Percent CI for ETA1-ETA2 is (-4.802,2.300)
W = 38.0
Test of ETA1 = ETA2 vs ETA1 not = ETA2 is significant at 0.4727
The test is significant at 0.4723 (adjusted for ties)
```

Mann-Whitney Test and CI: % Silt+Clay_Gulf, % Silt+Clay_CR

```
                  N  Median
% Silt+Clay_Gulf  4   36.10
% Silt+Clay_CR    5   29.60


Point estimate for ETA1-ETA2 is 8.95
96.3 Percent CI for ETA1-ETA2 is (1.40,19.20)
W = 30.0
Test of ETA1 = ETA2 vs ETA1 not = ETA2 is significant at 0.0200
```

Mann-Whitney Test and CI: % Silt+Clay_CR, % Silt+Clay_KB

```
                 N  Median
% Silt+Clay_CR   5   29.60
% Silt+Clay_KB  11   34.60


Point estimate for ETA1-ETA2 is -10.00
95.9 Percent CI for ETA1-ETA2 is (-50.60,2.49)
W = 28.0
Test of ETA1 = ETA2 vs ETA1 not = ETA2 is significant at 0.1127
```

Mann-Whitney Test and CI: Percent Organics_Gulf, Percent Organics_CR

```
                       N  Median
Percent Organics_Gulf  4   3.500
Percent Organics_CR    5   2.500


Point estimate for ETA1-ETA2 is 1.250
96.3 Percent CI for ETA1-ETA2 is (-0.200,2.400)
W = 28.0
Test of ETA1 = ETA2 vs ETA1 not = ETA2 is significant at 0.0662
The test is significant at 0.0651 (adjusted for ties)
```

Mann-Whitney Test and CI: Percent Organics_CR, Percent Organics_KB

```
                      N  Median
Percent Organics_CR   5   2.500
Percent Organics_KB  11   2.000


Point estimate for ETA1-ETA2 is 0.300
95.9 Percent CI for ETA1-ETA2 is (-4.998,1.298)
W = 44.0
Test of ETA1 = ETA2 vs ETA1 not = ETA2 is significant at 0.9098
The test is significant at 0.9097 (adjusted for ties)
```

Spearman’s Rank Correlation for Physicochemical Data

Correlations: Temperature_, pH_Ranks, Conductance_, Salinity_Ran, ...

```
                  Temperature_Rank          pH_Ranks  Conductance_Rank
pH_Ranks                    -0.429
Conductance_Rank             0.859            -0.683
Salinity_Ranks               0.859            -0.683             1.000
DO (% Saturation            -0.329             0.956            -0.636
DO (mg/L)_Ranks             -0.496             0.955            -0.738
Total Depth_Rank             0.123            -0.642             0.411

                    Salinity_Ranks  DO (% Saturation   DO (mg/L)_Ranks
DO (% Saturation            -0.636
DO (mg/L)_Ranks             -0.738             0.962
Total Depth_Rank             0.411            -0.646            -0.556

Cell Contents: Pearson correlation
```

Results for: Unpooled Ponar Metrics.MTW

Descriptive Statistics: Number of Ta, Number of In, Margalefs d, ...

```
Variable                    N    Mean   StDev  Minimum      Q1  Median      Q3
Number of Taxa             29   17.07    7.61     6.00   11.00   16.00   20.00
Number of Individuals      29     648    2398       24      88     129     325
Margalefs d                29   3.294   1.638    0.950   2.014   3.001   4.036
Pielous Evenness           29  0.7139  0.1426   0.3487  0.6078  0.6987  0.8446
Shannon Diversity (loge)   29   1.975   0.576    0.920   1.496   1.995   2.337
Shannon Diversity (log2)   29   2.849   0.831    1.328   2.158   2.879   3.372
Shannon Diversity (log10   29  0.8578  0.2502   0.3996  0.6496  0.8666  1.0150
Simpsons d (1-λ)           29  0.7544  0.1358   0.3666  0.6613  0.7647  0.8746

Variable                  Maximum
Number of Taxa              34.00
Number of Individuals       13068
Margalefs d                 6.846
Pielous Evenness           0.9239
Shannon Diversity (loge)    3.044
Shannon Diversity (log2)    4.391
Shannon Diversity (log10   1.3218
Simpsons d (1-λ)           0.9367
```

Results for: Pooled Ponar Metrics.MTW

Descriptive Statistics: Number of Ta, Number of In, Margalefs d, ...

```
Variable                  N    Mean   StDev  Minimum      Q1  Median      Q3
Number of Taxa            6   35.17   10.76    22.00   26.50   33.00   45.25
Number of Individuals     6    2631    5252      201     215     617    3927
Margalefs d               6   5.516   2.416    2.211   4.288   4.995   7.126
Pielous Evenness          6  0.6715  0.1406   0.4636  0.5530  0.6756  0.7882
Shannon Diversity (loge)  6   2.387   0.645    1.433   2.002   2.362   2.761
Shannon Diversity (log2)  6   3.444   0.931    2.067   2.889   3.408   3.984
Shannon Diversity (log10  6   1.037   0.280    0.622   0.870   1.026   1.199
Simpsons d (1-λ)          6  0.8342  0.0860   0.7045  0.7594  0.8442  0.8980

Variable                  Maximum
Number of Taxa              52.00
Number of Individuals       13340
Margalefs d                 9.617
Pielous Evenness           0.8708
Shannon Diversity (loge)    3.441
Shannon Diversity (log2)    4.964
Shannon Diversity (log10    1.494
Simpsons d (1-λ)           0.9558
```

Results for: Unpooled Ponar Metrics.MTW

Spearman’s Rank Correlations

```
                  Number of Taxa_R  Number of Indivi  Margalefs d_Rank
Number of Indivi             0.151
Margalefs d_Rank             0.908            -0.223
Pielous Evenness             0.295            -0.589             0.533
Shannon Diversit             0.729            -0.308             0.844
Shannon Diversit             0.729            -0.308             0.844
Shannon Diversit             0.729            -0.308             0.844
Simpsons d (1-λ)             0.586            -0.374             0.742

                  Pielous Evenness  Shannon Diversit  Shannon Diversit
Shannon Diversit             0.850
Shannon Diversit             0.850             1.000
Shannon Diversit             0.850             1.000             1.000
Simpsons d (1-λ)             0.896             0.950             0.950

                  Shannon Diversit
Simpsons d (1-λ)             0.950
```

Mann-Whitney Test for Significant Differences of Medians

Mann-Whitney Test and CI: Number of Taxa_Gulf, Number of Taxa_Crystal River

```
                             N  Median
Number of Taxa_Gulf           4   31.00
Number of Taxa_Crystal River  15   17.00


Point estimate for ETA1-ETA2 is 12.50
96.0 Percent CI for ETA1-ETA2 is (2.00,22.00)
W = 63.0
Test of ETA1 = ETA2 vs ETA1 not = ETA2 is significant at 0.0244
The test is significant at 0.0243 (adjusted for ties)
```

Mann-Whitney Test and CI: Number of Indivi, Number of Indivi

```
                                N  Median
Number of Individuals_Gulf       4    97.5
Number of Individuals_Crystal R  15   123.0


Point estimate for ETA1-ETA2 is -40.5
96.0 Percent CI for ETA1-ETA2 is (-253.8,63.8)
W = 34.0
Test of ETA1 = ETA2 vs ETA1 not = ETA2 is significant at 0.5823
```

Mann-Whitney Test and CI: Pielous Evenness_Gulf, Pielous Evenness_Crystal River

```
                                N  Median
Pielous Evenness_Gulf            4  0.8754
Pielous Evenness_Crystal River  15  0.7447


Point estimate for ETA1-ETA2 is 0.1474
```

```
96.0 Percent CI for ETA1-ETA2 is (-0.0075,0.2707)
W = 60.0
Test of ETA1 = ETA2 vs ETA1 not = ETA2 is significant at 0.0512
```

Mann-Whitney Test and CI: Shannon Diversit, Shannon Diversit

```
                                  N  Median
Shannon Diversity (log2)_Gulf     4  4.1516
Shannon Diversity (log2)_Crysta  15  2.9681


Point estimate for ETA1-ETA2 is 1.2234
96.0 Percent CI for ETA1-ETA2 is (0.6251,2.0425)
W = 67.0
Test of ETA1 = ETA2 vs ETA1 not = ETA2 is significant at 0.0080
```

Mann-Whitney Test and CI: Number of Taxa_Gulf, Number of Taxa_Kings Bay

```
                           N  Median
Number of Taxa_Gulf        4   31.00
Number of Taxa_Kings Bay  10   13.00


Point estimate for ETA1-ETA2 is 17.00
96.0 Percent CI for ETA1-ETA2 is (5.00,24.00)
W = 49.0
Test of ETA1 = ETA2 vs ETA1 not = ETA2 is significant at 0.0089
The test is significant at 0.0087 (adjusted for ties)
```

Mann-Whitney Test and CI: Number of Indivi, Number of Indivi

```
                                  N  Median
Number of Individuals_Gulf        4    97.5
Number of Individuals_Kings Bay  10   240.0


Point estimate for ETA1-ETA2 is -135.0
96.0 Percent CI for ETA1-ETA2 is (-430.0,22.0)
W = 19.0
Test of ETA1 = ETA2 vs ETA1 not = ETA2 is significant at 0.1376
```

Mann-Whitney Test and CI: Pielous Evenness_Gulf, Pielous Evenness_Kings Bay

```
                             N  Median
Pielous Evenness_Gulf        4  0.8754
Pielous Evenness_Kings Bay  10  0.6344


Point estimate for ETA1-ETA2 is 0.2328
96.0 Percent CI for ETA1-ETA2 is (0.0582,0.4082)
W = 47.0
Test of ETA1 = ETA2 vs ETA1 not = ETA2 is significant at 0.0196
```

Mann-Whitney Test and CI: Shannon Diversit, Shannon Diversit

```
                                 N  Median
```

```
Shannon Diversity (log2)_Gulf    4  4.1516
Shannon Diversity (log2)_Kings  10  2.1642


Point estimate for ETA1-ETA2 is 1.8490
96.0 Percent CI for ETA1-ETA2 is (1.1562,2.4639)
W = 50.0
Test of ETA1 = ETA2 vs ETA1 not = ETA2 is significant at 0.0058
```

Mann-Whitney Test and CI: Number of Taxa_Crystal River, Number of Taxa_Kings Ba

```
                               N  Median
Number of Taxa_Crystal River  15  17.000
Number of Taxa_Kings Bay      10  13.000


Point estimate for ETA1-ETA2 is 3.000
95.1 Percent CI for ETA1-ETA2 is (-1.002,7.999)
W = 222.0
Test of ETA1 = ETA2 vs ETA1 not = ETA2 is significant at 0.1416
The test is significant at 0.1406 (adjusted for ties)
```

Mann-Whitney Test and CI: Number of Indivi, Number of Indivi

```
                                  N  Median
Number of Individuals_Crystal R  15   123.0
Number of Individuals_Kings Bay  10   240.0


Point estimate for ETA1-ETA2 is -68.5
95.1 Percent CI for ETA1-ETA2 is (-260.9,25.9)
W = 171.0
Test of ETA1 = ETA2 vs ETA1 not = ETA2 is significant at 0.1924
```

Mann-Whitney Test and CI: Pielous Evenness, Pielous Evenness

```
                                 N  Median
Pielous Evenness_Crystal River  15  0.7447
Pielous Evenness_Kings Bay      10  0.6344


Point estimate for ETA1-ETA2 is 0.0888
95.1 Percent CI for ETA1-ETA2 is (-0.0150,0.2170)
W = 223.0
Test of ETA1 = ETA2 vs ETA1 not = ETA2 is significant at 0.1272
```

Mann-Whitney Test and CI: Shannon Diversit, Shannon Diversit

```
                                  N  Median
Shannon Diversity (log2)_Crysta  15  2.9681
Shannon Diversity (log2)_Kings   10  2.1642


Point estimate for ETA1-ETA2 is 0.5461
95.1 Percent CI for ETA1-ETA2 is (-0.0092,1.1309)
W = 230.0
Test of ETA1 = ETA2 vs ETA1 not = ETA2 is significant at 0.0557
```

Results for: Mean PChem data July 2009.MTW

Correlations: Salinity_CR Transect Only_Ranks, River Kilometer Ranks

```
Pearson correlation of Salinity_CR Transect Only_Ranks and River Kilometer
     Ranks = -0.700
```

Results for: Trimmed PCHEM vs Select Unpooled Metrics.MTW

Correlations: Temperature_, pH__Rank, Salinity__Ra, DO (mg/L)__R, ...

```
                  Temperature_Rank         pH__Rank    Salinity__Rank
pH__Rank                    -0.180
Salinity__Rank               0.832           -0.447
DO (mg/L)__Rank             -0.376            0.840            -0.682
Total Depth__Ran             0.117           -0.767             0.319
% Silt+Clay__Ran            -0.001            0.455             0.039
Number of Taxa__             0.446           -0.115             0.567
Number of Indivi            -0.138            0.133            -0.310
Pielous Evenness             0.559           -0.045             0.525
Shannon Diversit             0.613           -0.064             0.650

                   DO (mg/L)__Rank  Total Depth__Ran  % Silt+Clay__Ran
Total Depth__Ran            -0.540
% Silt+Clay__Ran             0.283           -0.169
Number of Taxa__            -0.355           -0.090            -0.047
Number of Indivi             0.180           -0.004             0.028
Pielous Evenness            -0.184           -0.036            -0.102
Shannon Diversit            -0.286           -0.068            -0.075

                  Number of Taxa__  Number of Indivi  Pielous Evenness
Number of Indivi             0.151
Pielous Evenness             0.295           -0.589
Shannon Diversit             0.729           -0.308             0.850
```

Forward Stepwise Regression: Number of Taxa versus Temperature, pH, ...

```
  Alpha-to-Enter: 0.15  Alpha-to-Remove: 0.15


Response is Number of Taxa on 6 predictors, with N = 29


Step             1
Constant     11.23

Salinity      0.92
T-Value       4.89
P-Value     0.0001

S             5.64
R-Sq         46.92
R-Sq(adj)    44.95
Mallows Cp     0.8
```

Results for: Trimmed PCHEM vs Select Unpooled Metrics.MTW

Regression Analysis: Number of Taxa versus Salinity

```
The regression equation is
Number of Taxa = 11.2 + 0.924 Salinity


Predictor    Coef  SE Coef     T      P
Constant   11.229    1.590  7.06  0.000
Salinity   0.9244   0.1892  4.89  0.000


S = 5.64319   R-Sq = 46.9%   R-Sq(adj) = 45.0%


Analysis of Variance

Source          DF       SS      MS      F       P
Regression       1   760.03  760.03  23.87  0.0001
Residual Error  27   859.83   31.85
Total           28  1619.86


Unusual Observations

                Number
Obs  Salinity  of Taxa    Fit  SE Fit  Residual  St Resid
  4      19.0    18.00  28.82    2.62    -10.82     -2.17RX
  6      12.9    12.00  23.19    1.63    -11.19     -2.07R

R denotes an observation with a large standardized residual.
X denotes an observation whose X value gives it large leverage.
```

Stepwise Regression: Shannon Diversit versus Temperature, pH, ...

```
  Alpha-to-Enter: 0.15  Alpha-to-Remove: 0.15


Response is Shannon Diversity (log2) on 6 predictors, with N = 29


Step            1        2
Constant     2.138    2.645

Salinity     0.113    0.108
T-Value       6.15     6.42
P-Value      0.000    0.0001

% Silt+Clay         -0.0131
T-Value               -2.52
P-Value               0.018

S            0.546    0.499
R-Sq         58.38    66.53
R-Sq(adj)    56.84    63.96
Mallows Cp     3.6      0.0
```

Results for: Trimmed PCHEM vs Select Unpooled Metrics.MTW

Regression Analysis: Shannon Diversity versus Salinity + % Silt+Clay

```
The regression equation is
Shannon Diversity (log2) = 2.63 + 0.108 Salinity - 0.0129 % Silt+Clay


Predictor         Coef   SE Coef      T      P
Constant        2.6328    0.2415  10.90  0.0001
Salinity       0.10843   0.01681   6.45  0.0001
% Silt+Clay  -0.012928  0.005128  -2.52  0.018


S = 0.498826   R-Sq = 66.6%   R-Sq(adj) = 64.0%


Analysis of Variance

Source          DF       SS      MS      F      P
Regression       2  12.8756  6.4378  25.87  0.0001
Residual Error  26   6.4695  0.2488
Total           28  19.3451


Source       DF   Seq SS
Salinity      1  11.2939
% Silt+Clay   1   1.5817
```

Stepwise Regression: Number of Indivi versus Temperature, pH, ...

```
  Alpha-to-Enter: 0.15  Alpha-to-Remove: 0.15


Response is Number of Individuals per M2 on 6 predictors, with N = 29


No variables entered or removed
```

[No variables were significantly related to Number of Individuals among the physicochemical variables tested]

Results for: Trimmed PCHEM vs Select Unpooled Metrics.MTW

Nested ANOVA: Number of Ta, Number of In, Pielous Even, Shannon Dive, Number of

Nested ANOVA: Number of Taxa_1 versus RK Transect Groups

```
Analysis of Variance for Number of Taxa_1

Source              DF        SS       MS      F      P
RK Transect Groups   4  288.2667  72.0667  2.079  0.159
Error               10  346.6667  34.6667
Total               14  634.9333


Variance Components

                                % of
Source              Var Comp.  Total  StDev
RK Transect Groups     12.467  26.45  3.531
Error                  34.667  73.55  5.888
Total                  47.133         6.865


Expected Mean Squares

1  RK Transect Groups    1.00(2) +  3.00(1)
2  Error                 1.00(2)
```

Nested ANOVA: Number of Individuals_1 versus RK Transect Groups

```
Analysis of Variance for Number of Individuals_1

Source              DF           SS           MS      F      P
RK Transect Groups   4  4.43486E+07  1.10871E+07  0.994  0.454
Error               10  1.11565E+08  1.11565E+07
Total               14  1.55914E+08


Variance Components

Source                Var Comp.   % of Total     StDev
RK Transect Groups   -23127.578*        0.00     0.000
Error               1.11565E+07       100.00  3340.138
Total               1.11565E+07               3340.138

* Value is negative, and is estimated by zero.


Expected Mean Squares

1  RK Transect Groups    1.00(2) +  3.00(1)
2  Error                 1.00(2)
```

Nested ANOVA: Pielous Evenness_1 versus RK Transect Groups

```
Analysis of Variance for Pielous Evenness_1

Source              DF      SS      MS      F      P
```

```
RK Transect Groups   4  0.0890  0.0223  2.105  0.155
Error               10  0.1057  0.0106
Total               14  0.1947


Variance Components

                                % of
Source              Var Comp.  Total  StDev
RK Transect Groups      0.004  26.92  0.062
Error                   0.011  73.08  0.103
Total                   0.014         0.120


Expected Mean Squares

1  RK Transect Groups    1.00(2) +  3.00(1)
2  Error                 1.00(2)
```

Nested ANOVA: Shannon Diversity (log2)_1 versus RK Transect Groups

```
Analysis of Variance for Shannon Diversity (log2)_1

Source              DF      SS      MS      F      P
RK Transect Groups   4  3.0784  0.7696  2.226  0.139
Error               10  3.4567  0.3457
Total               14  6.5351


Variance Components

                                % of
Source              Var Comp.  Total  StDev
RK Transect Groups      0.141  29.02  0.376
Error                   0.346  70.98  0.588
Total                   0.487         0.698


Expected Mean Squares

1  RK Transect Groups    1.00(2) +  3.00(1)
2  Error                 1.00(2)
```

Nested ANOVA: Number of Individuals per M2_1 versus RK Transect Groups

```
Analysis of Variance for Number of Individuals per M2_1

Source              DF           SS           MS      F      P
RK Transect Groups   4  8.23972E+10  2.05993E+10  0.994  0.454
Error               10  2.07278E+11  2.07278E+10
Total               14  2.89675E+11


Variance Components

Source                 Var Comp.   % of Total       StDev
RK Transect Groups  -4.28178E+07*        0.00       0.000
Error                2.07278E+10       100.00  143971.370
Total                2.07278E+10               143971.370
```

```
* Value is negative, and is estimated by zero.


Expected Mean Squares

1  RK Transect Groups    1.00(2) +  3.00(1)
2  Error                 1.00(2)
```

Nested ANOVA: Temperature_, pH_1, Salinity_1, DO (mg/L)_1, Total Depth_, % Silt

Nested ANOVA: Temperature_1 versus RK Transect Groups

```
Analysis of Variance for Temperature_1

Source              DF       SS       MS   F   P
RK Transect Groups   4   2.7565   0.6891  **  **
Error               10  -0.0000  -0.0000
Total               14   2.7565

** Denominator of F-test is zero.


Variance Components

Source              Var Comp.   % of Total  StDev
RK Transect Groups      0.230       100.00  0.479
Error                  -0.000*        0.00  0.000
Total                   0.230               0.479

* Value is negative, and is estimated by zero.


Expected Mean Squares

1  RK Transect Groups    1.00(2) +  3.00(1)
2  Error                 1.00(2)
```

Nested ANOVA: pH_1 versus RK Transect Groups

```
Analysis of Variance for pH_1

Source              DF       SS       MS   F   P
RK Transect Groups   4   0.1691   0.0423  **  **
Error               10  -0.0000  -0.0000
Total               14   0.1691

** Denominator of F-test is zero.


Variance Components

Source              Var Comp.   % of Total  StDev
RK Transect Groups      0.014       100.00  0.119
Error                  -0.000*        0.00  0.000
Total                   0.014               0.119

* Value is negative, and is estimated by zero.


Expected Mean Squares
```

```
1  RK Transect Groups    1.00(2) +  3.00(1)
2  Error                 1.00(2)
```

Nested ANOVA: Salinity_1 versus RK Transect Groups

```
Analysis of Variance for Salinity_1

Source              DF        SS       MS   F   P
RK Transect Groups   4  173.3509  43.3377  **  **
Error               10    0.0000   0.0000
Total               14  173.3509

** Denominator of F-test is zero.


Variance Components

Source              Var Comp.  % of Total  StDev
RK Transect Groups     14.446      100.00  3.801
Error                   0.000        0.00  0.000
Total                  14.446              3.801


Expected Mean Squares

1  RK Transect Groups    1.00(2) +  3.00(1)
2  Error                 1.00(2)
```

Nested ANOVA: DO (mg/L)_1 versus RK Transect Groups

```
Analysis of Variance for DO (mg/L)_1

Source              DF       SS       MS   F   P
RK Transect Groups   4   2.9823   0.7456  **  **
Error               10  -0.0000  -0.0000
Total               14   2.9823

** Denominator of F-test is zero.


Variance Components

Source              Var Comp.   % of Total  StDev
RK Transect Groups      0.249       100.00  0.499
Error                  -0.000*        0.00  0.000
Total                   0.249               0.499

* Value is negative, and is estimated by zero.


Expected Mean Squares

1  RK Transect Groups    1.00(2) +  3.00(1)
2  Error                 1.00(2)
```

Nested ANOVA: Total Depth_1 versus RK Transect Groups

```
Analysis of Variance for Total Depth_1
```

```
Source              DF       SS       MS   F   P
RK Transect Groups   4   5.9400   1.4850  **  **
Error               10  -0.0000  -0.0000
Total               14   5.9400

** Denominator of F-test is zero.


Variance Components

Source              Var Comp.   % of Total  StDev
RK Transect Groups      0.495       100.00  0.704
Error                  -0.000*        0.00  0.000
Total                   0.495               0.704

* Value is negative, and is estimated by zero.


Expected Mean Squares

1  RK Transect Groups    1.00(2) +  3.00(1)
2  Error                 1.00(2)
```

Nested ANOVA: % Silt+Clay_1 versus RK Transect Groups

```
Analysis of Variance for % Silt+Clay_1

Source              DF        SS       MS       F      P
RK Transect Groups   4  278.4840  69.6210  87.026  0.000
Error               10    8.0000   0.8000
Total               14  286.4840


Variance Components

                               % of
Source              Var Comp.  Total  StDev
RK Transect Groups     22.940  96.63  4.790
Error                   0.800   3.37  0.894
Total                  23.740         4.872


Expected Mean Squares

1  RK Transect Groups    1.00(2) +  3.00(1)
2  Error                 1.00(2)
```

One-way ANOVA: Number of Taxa_1 versus RK Transect Groups

```
Source              DF     SS    MS     F      P
RK Transect Groups   4  288.3  72.1  2.08  0.159
Error               10  346.7  34.7
Total               14  634.9

S = 5.888   R-Sq = 45.40%   R-Sq(adj) = 23.56%


                           Individual 95% CIs For Mean Based on
                           Pooled StDev
Level   N    Mean   StDev  -------+---------+---------+---------+--
RK 0    3  21.333  10.066                   (---------*----------)
RK 2.5  3  20.667   4.041                  (----------*---------)
RK 5    3  18.333   3.215              (----------*----------)
RK 7.5  3  13.333   6.658       (----------*----------)
RK 9.4  3  10.000   1.000  (----------*----------)
                           -------+---------+---------+---------+--
                                7.0      14.0      21.0      28.0

Pooled StDev = 5.888


Hsu's MCB (Multiple Comparisons with the Best)

Family error rate = 0.1
Critical value = 2.02

Intervals for level mean minus largest of other level means

Level     Lower   Center   Upper  ------+---------+---------+---------+---
RK 0     -9.065    0.667  10.398                 (-----------*-----------)
RK 2.5  -10.398   -0.667   9.065               (-----------*-----------)
RK 5    -12.731   -3.000   6.731            (-----------*-----------)
RK 7.5  -17.731   -8.000   1.731      (-----------*-----------)
RK 9.4  -21.065  -11.333   0.000  (-----------*-------------)
                                  ------+---------+---------+---------+---
                                    -16.0      -8.0       0.0       8.0


Tukey 90% Simultaneous Confidence Intervals
All Pairwise Comparisons among Levels of RK Transect Groups

Individual confidence level = 98.25%


RK Transect Groups = RK 0 subtracted from:

RK Transect
Groups         Lower   Center   Upper  -------+---------+---------+---------+--
RK 2.5        -14.332   -0.667  12.999         (---------*--------)
RK 5          -16.665   -3.000  10.665        (--------*--------)
RK 7.5        -21.665   -8.000   5.665     (--------*--------)
RK 9.4        -24.999  -11.333   2.332  (--------*---------)
                                       -------+---------+---------+---------+--
                                            -15         0        15        30


RK Transect Groups = RK 2.5 subtracted from:

RK Transect
Groups         Lower   Center   Upper  -------+---------+---------+---------+--
```

```
RK 5         -15.999   -2.333  11.332        (--------*---------)
RK 7.5       -20.999   -7.333   6.332     (--------*--------)
RK 9.4       -24.332  -10.667   2.999   (--------*--------)
                                       -------+---------+---------+---------+--
                                            -15         0        15        30


RK Transect Groups = RK 5 subtracted from:

RK Transect
Groups         Lower  Center  Upper  -------+---------+---------+---------+--
RK 7.5       -18.665  -5.000  8.665       (--------*--------)
RK 9.4       -21.999  -8.333  5.332    (--------*---------)
                                     -------+---------+---------+---------+--
                                          -15         0        15        30


RK Transect Groups = RK 7.5 subtracted from:

RK Transect
Groups         Lower  Center   Upper  -------+---------+---------+---------+--
RK 9.4       -16.999  -3.333  10.332        (--------*--------)
                                      -------+---------+---------+---------+--
                                           -15         0        15        30
```

One-way ANOVA: Number of Individuals_1 versus RK Transect Groups

```
Source              DF         SS        MS     F      P
RK Transect Groups   4   44348554  11087138  0.99  0.454
Error               10  111565211  11156521
Total               14  155913765

S = 3340   R-Sq = 28.44%   R-Sq(adj) = 0.00%


                        Individual 95% CIs For Mean Based on Pooled StDev
Level   N  Mean  StDev    --+---------+---------+---------+-------
RK 0    3    67     51    (-----------*-----------)
RK 2.5  3   263    137    (------------*-----------)
RK 5    3   206    109    (------------*-----------)
RK 7.5  3    73     52    (-----------*-----------)
RK 9.4  3  4447   7466                (------------*-----------)
                          --+---------+---------+---------+-------
                        -3500         0      3500      7000

Pooled StDev = 3340


Hsu's MCB (Multiple Comparisons with the Best)

Family error rate = 0.1
Critical value = 2.02

Intervals for level mean minus largest of other level means

Level   Lower  Center  Upper       +---------+---------+---------+---------
RK 0    -9900   -4380   1141       (----------*----------)
RK 2.5  -9704   -4184   1337        (----------*----------)
RK 5    -9762   -4241   1280       (-----------*----------)
RK 7.5  -9894   -4374   1147       (----------*----------)
RK 9.4  -1337    4184   9704                        (----------*----------)
                                   +---------+---------+---------+---------
```

```
                              -10000     -5000         0      5000
```

```
Tukey 90% Simultaneous Confidence Intervals
All Pairwise Comparisons among Levels of RK Transect Groups

Individual confidence level = 98.25%


RK Transect Groups = RK 0 subtracted from:

RK Transect
Groups       Lower  Center  Upper  -------+---------+---------+---------+--
RK 2.5       -7556     196   7948        (----------*----------)
RK 5         -7614     139   7891        (----------*----------)
RK 7.5       -7746       6   7758        (----------*----------)
RK 9.4       -3373    4380  12132              (----------*----------)
                                   -------+---------+---------+---------+--
                                      -7000         0      7000     14000


RK Transect Groups = RK 2.5 subtracted from:

RK Transect
Groups       Lower  Center  Upper  -------+---------+---------+---------+--
RK 5         -7810     -57   7695        (----------*----------)
RK 7.5       -7942    -190   7562        (----------*----------)
RK 9.4       -3569    4184  11936              (----------*----------)
                                   -------+---------+---------+---------+--
                                      -7000         0      7000     14000


RK Transect Groups = RK 5 subtracted from:

RK Transect
Groups       Lower  Center  Upper  -------+---------+---------+---------+--
RK 7.5       -7885    -133   7620        (----------*----------)
RK 9.4       -3511    4241  11993              (----------*----------)
                                   -------+---------+---------+---------+--
                                      -7000         0      7000     14000


RK Transect Groups = RK 7.5 subtracted from:

RK Transect
Groups       Lower  Center  Upper  -------+---------+---------+---------+--
RK 9.4       -3379    4374  12126              (----------*----------)
                                   -------+---------+---------+---------+--
                                      -7000         0      7000     14000
```

One-way ANOVA: Pielous Evenness_1 versus RK Transect Groups

```
Source              DF      SS      MS     F      P
RK Transect Groups   4  0.0890  0.0223  2.11  0.155
Error               10  0.1057  0.0106
Total               14  0.1947

S = 0.1028   R-Sq = 45.71%   R-Sq(adj) = 24.00%


                           Individual 95% CIs For Mean Based on
                           Pooled StDev
```

```
Level   N    Mean   StDev  --------+---------+---------+---------+-
RK 0    3  0.8563  0.0040                  (--------*--------)
RK 2.5  3  0.6139  0.1221  (--------*--------)
RK 5    3  0.7246  0.0712         (--------*--------)
RK 7.5  3  0.7149  0.0377         (--------*-------)
RK 9.4  3  0.7275  0.1773          (--------*-------)
                           --------+---------+---------+---------+-
                                 0.60      0.75      0.90      1.05

Pooled StDev = 0.1028


Hsu's MCB (Multiple Comparisons with the Best)

Family error rate = 0.1
Critical value = 2.02

Intervals for level mean minus largest of other level means

Level     Lower   Center   Upper    -+---------+---------+---------+--------
RK 0    -0.0411   0.1288  0.2987                       (-------*--------)
RK 2.5  -0.4123  -0.2424  0.0000    (--------*-----------)
RK 5    -0.3016  -0.1317  0.0382          (-------*--------)
RK 7.5  -0.3114  -0.1414  0.0285         (--------*-------)
RK 9.4  -0.2987  -0.1288  0.0411          (--------*-------)
                                    -+---------+---------+---------+--------
                                  -0.40     -0.20     -0.00      0.20


Tukey 90% Simultaneous Confidence Intervals
All Pairwise Comparisons among Levels of RK Transect Groups

Individual confidence level = 98.25%


RK Transect Groups = RK 0 subtracted from:

RK Transect
Groups         Lower   Center    Upper
RK 2.5       -0.4810  -0.2424  -0.0038
RK 5         -0.3703  -0.1317   0.1069
RK 7.5       -0.3800  -0.1414   0.0972
RK 9.4       -0.3674  -0.1288   0.1098

RK Transect
Groups       ---------+---------+---------+---------+
RK 2.5       (--------*---------)
RK 5             (---------*--------)
RK 7.5           (--------*---------)
RK 9.4           (---------*--------)
             ---------+---------+---------+---------+
                   -0.25      0.00      0.25      0.50


RK Transect Groups = RK 2.5 subtracted from:

RK Transect
Groups         Lower  Center   Upper  ---------+---------+---------+---------+
RK 5         -0.1279  0.1107  0.3493                (--------*---------)
RK 7.5       -0.1376  0.1010  0.3396               (---------*---------)
RK 9.4       -0.1250  0.1136  0.3522                (---------*--------)
                                      ---------+---------+---------+---------+
                                            -0.25      0.00      0.25      0.50
```

```
RK Transect Groups = RK 5 subtracted from:

RK Transect
Groups         Lower   Center   Upper
RK 7.5       -0.2483  -0.0097  0.2289
RK 9.4       -0.2357   0.0029  0.2415

RK Transect
Groups       ---------+---------+---------+---------+
RK 7.5                (---------*--------)
RK 9.4                 (--------*---------)
             ---------+---------+---------+---------+
                   -0.25      0.00      0.25      0.50


RK Transect Groups = RK 7.5 subtracted from:

RK Transect
Groups         Lower  Center   Upper  ---------+---------+---------+---------+
RK 9.4       -0.2260  0.0126  0.2512            (---------*--------)
                                      ---------+---------+---------+---------+
                                            -0.25      0.00      0.25      0.50
```

One-way ANOVA: Shannon Diversity (log2)_1 versus RK Transect Groups

```
Source              DF     SS     MS     F      P
RK Transect Groups   4  3.078  0.770  2.23  0.139
Error               10  3.457  0.346
Total               14  6.535

S = 0.5879   R-Sq = 47.11%   R-Sq(adj) = 25.95%


                           Individual 95% CIs For Mean Based on
                           Pooled StDev
Level   N    Mean   StDev  ------+---------+---------+---------+---
RK 0    3  3.6859  0.6216                    (----------*---------)
RK 2.5  3  2.6608  0.4854     (----------*----------)
RK 5    3  3.0374  0.4217           (---------*----------)
RK 7.5  3  2.5692  0.6849    (----------*----------)
RK 9.4  3  2.4247  0.6778  (----------*---------)
                           ------+---------+---------+---------+---
                               2.10      2.80      3.50      4.20

Pooled StDev = 0.5879


Hsu's MCB (Multiple Comparisons with the Best)

Family error rate = 0.1
Critical value = 2.02

Intervals for level mean minus largest of other level means

Level     Lower   Center   Upper   --+---------+---------+---------+-------
RK 0    -0.3232   0.6486  1.6203                       (--------*---------)
RK 2.5  -1.9969  -1.0252  0.0000     (---------*----------)
RK 5    -1.6203  -0.6486  0.3232         (---------*--------)
RK 7.5  -2.0884  -1.1167  0.0000    (---------*----------)
RK 9.4  -2.2330  -1.2612  0.0000   (--------*------------)
```

```
                                   --+---------+---------+---------+-------
                                  -2.0      -1.0       0.0       1.0


Tukey 90% Simultaneous Confidence Intervals
All Pairwise Comparisons among Levels of RK Transect Groups

Individual confidence level = 98.25%


RK Transect Groups = RK 0 subtracted from:

RK Transect
Groups         Lower   Center   Upper
RK 2.5       -2.3897  -1.0252  0.3394
RK 5         -2.0131  -0.6486  0.7160
RK 7.5       -2.4813  -1.1167  0.2479
RK 9.4       -2.6258  -1.2612  0.1033

RK Transect
Groups        --+---------+---------+---------+-------
RK 2.5          (----------*-----------)
RK 5               (-----------*----------)
RK 7.5         (-----------*----------)
RK 9.4        (----------*-----------)
              --+---------+---------+---------+-------
             -2.4      -1.2       0.0       1.2


RK Transect Groups = RK 2.5 subtracted from:

RK Transect
Groups         Lower   Center   Upper
RK 5         -0.9880   0.3766  1.7412
RK 7.5       -1.4561  -0.0915  1.2730
RK 9.4       -1.6006  -0.2361  1.1285

RK Transect
Groups        --+---------+---------+---------+-------
RK 5                        (----------*-----------)
RK 7.5                  (----------*-----------)
RK 9.4                 (----------*----------)
              --+---------+---------+---------+-------
             -2.4      -1.2       0.0       1.2


RK Transect Groups = RK 5 subtracted from:

RK Transect
Groups         Lower   Center   Upper
RK 7.5       -1.8327  -0.4681  0.8964
RK 9.4       -1.9772  -0.6127  0.7519

RK Transect
Groups        --+---------+---------+---------+-------
RK 7.5               (----------*----------)
RK 9.4              (----------*----------)
              --+---------+---------+---------+-------
             -2.4      -1.2       0.0       1.2


RK Transect Groups = RK 7.5 subtracted from:
```

```
RK Transect
Groups         Lower   Center   Upper
RK 9.4       -1.5091  -0.1446  1.2200

RK Transect
Groups        --+---------+---------+---------+-------
RK 9.4                 (-----------*----------)
              --+---------+---------+---------+-------
             -2.4      -1.2       0.0       1.2
```

One-way ANOVA: Number of Individuals per M2_1 versus RK Transect Groups

```
Source              DF           SS           MS     F      P
RK Transect Groups   4  82397207766  20599301942  0.99  0.454
Error               10  2.07278E+11  20727755247
Total               14  2.89675E+11

S = 143971   R-Sq = 28.44%   R-Sq(adj) = 0.00%


                           Individual 95% CIs For Mean Based on Pooled StDev
Level   N    Mean   StDev     --+---------+---------+---------+-------
RK 0    3    2886    2188      (-----------*------------)
RK 2.5  3   11335    5911      (------------*-----------)
RK 5    3    8864    4717      (------------*-----------)
RK 7.5  3    3145    2229      (-----------*------------)
RK 9.4  3  191667  321826                  (------------*-----------)
                              --+---------+---------+---------+-------
                           -150000         0    150000    300000

Pooled StDev = 143971


Hsu's MCB (Multiple Comparisons with the Best)

Family error rate = 0.1
Critical value = 2.02

Intervals for level mean minus largest of other level means

Level     Lower   Center   Upper  -------+---------+---------+---------+--
RK 0    -426738  -188781   49176  (--------*---------)
RK 2.5  -418289  -180332   57625  (---------*--------)
RK 5    -420760  -182803   55154  (---------*--------)
RK 7.5  -426479  -188522   49435  (--------*---------)
RK 9.4   -57625   180332  418289               (--------*---------)
                                  -------+---------+---------+---------+--
                                   -250000         0    250000    500000


Tukey 90% Simultaneous Confidence Intervals
All Pairwise Comparisons among Levels of RK Transect Groups

Individual confidence level = 98.25%


RK Transect Groups = RK 0 subtracted from:

RK Transect
Groups         Lower  Center   Upper  -------+---------+---------+---------+--
RK 2.5       -325701    8449  342599        (----------*----------)
RK 5         -328172    5978  340128        (----------*----------)
```

```
RK 7.5       -333890     260  334410        (----------*----------)
RK 9.4       -145369  188781  522931              (----------*----------)
                                      -------+---------+---------+---------+--
                                       -300000         0    300000    600000


RK Transect Groups = RK 2.5 subtracted from:

RK Transect
Groups         Lower  Center   Upper  -------+---------+---------+---------+--
RK 5         -336621   -2471  331679        (----------*----------)
RK 7.5       -342339   -8189  325961        (----------*----------)
RK 9.4       -153818  180332  514482              (----------*----------)
                                      -------+---------+---------+---------+--
                                       -300000         0    300000    600000


RK Transect Groups = RK 5 subtracted from:

RK Transect
Groups         Lower  Center   Upper  -------+---------+---------+---------+--
RK 7.5       -339868   -5718  328432        (----------*----------)
RK 9.4       -151347  182803  516953              (----------*----------)
                                      -------+---------+---------+---------+--
                                       -300000         0    300000    600000


RK Transect Groups = RK 7.5 subtracted from:

RK Transect
Groups         Lower  Center   Upper  -------+---------+---------+---------+--
RK 9.4       -145628  188522  522672              (----------*----------)
                                      -------+---------+---------+---------+--
                                       -300000         0    300000    600000
```

Nested ANOVA: Temperature, pH, Salinity, DO (mg/L), Total Depth, % Silt+Clay, N

Nested ANOVA: Temperature versus Sub Area

```
Analysis of Variance for Temperature

Source    DF       SS      MS
Sub Area   2  13.6177  6.8089
Error     26  11.1081  0.4272
Total     28  24.7258


Variance Components

                      % of
Source    Var Comp.  Total  StDev
Sub Area      0.740  63.41  0.860
Error         0.427  36.59  0.654
Total         1.168         1.081


Expected Mean Squares

1  Sub Area    1.00(2) +  8.62(1)
2  Error       1.00(2)
```

Nested ANOVA: pH versus Sub Area

```
Analysis of Variance for pH

Source    DF      SS      MS
Sub Area   2  3.0202  1.5101
Error     26  1.3680  0.0526
Total     28  4.3882


Variance Components

                      % of
Source    Var Comp.  Total  StDev
Sub Area      0.169  76.27  0.411
Error         0.053  23.73  0.229
Total         0.222         0.471


Expected Mean Squares

1  Sub Area    1.00(2) +  8.62(1)
2  Error       1.00(2)
```

Nested ANOVA: Salinity versus Sub Area

```
Analysis of Variance for Salinity

Source    DF        SS        MS
Sub Area   2  701.6690  350.8345
Error     26  187.7309    7.2204
Total     28  889.3999
```

```
Variance Components

                       % of
Source    Var Comp.  Total  StDev
Sub Area     39.859  84.66  6.313
Error         7.220  15.34  2.687
Total        47.080         6.861


Expected Mean Squares

1  Sub Area    1.00(2) +  8.62(1)
2  Error       1.00(2)
```

Nested ANOVA: DO (mg/L) versus Sub Area

```
Analysis of Variance for DO (mg/L)

Source    DF        SS       MS
Sub Area   2   71.0051  35.5026
Error     26   33.2812   1.2800
Total     28  104.2864


Variance Components

                       % of
Source    Var Comp.  Total  StDev
Sub Area      3.970  75.62  1.992
Error         1.280  24.38  1.131
Total         5.250         2.291


Expected Mean Squares

1  Sub Area    1.00(2) +  8.62(1)
2  Error       1.00(2)
```

Nested ANOVA: Total Depth versus Sub Area

```
Analysis of Variance for Total Depth

Source    DF       SS      MS
Sub Area   2  16.7753  8.3877
Error     26  14.4422  0.5555
Total     28  31.2176


Variance Components

                       % of
Source    Var Comp.  Total  StDev
Sub Area      0.909  62.06  0.953
Error         0.555  37.94  0.745
Total         1.464         1.210


Expected Mean Squares
```

```
1  Sub Area    1.00(2) +  8.62(1)
2  Error       1.00(2)
```

Nested ANOVA: % Silt+Clay versus Sub Area

```
Analysis of Variance for % Silt+Clay

Source    DF         SS         MS
Sub Area   2  2792.7929  1396.3965
Error     26  6767.7850   260.2994
Total     28  9560.5779


Variance Components

                      % of
Source    Var Comp.  Total   StDev
Sub Area    131.787  33.61  11.480
Error       260.299  66.39  16.134
Total       392.087         19.801


Expected Mean Squares

1  Sub Area    1.00(2) +  8.62(1)
2  Error       1.00(2)
```

Nested ANOVA: Number of Taxa versus Sub Area

```
Analysis of Variance for Number of Taxa

Source    DF         SS        MS
Sub Area   2   689.9287  344.9644
Error     26   929.9333   35.7667
Total     28  1619.8621


Variance Components

                      % of
Source    Var Comp.  Total  StDev
Sub Area     35.867  50.07  5.989
Error        35.767  49.93  5.981
Total        71.634         8.464


Expected Mean Squares

1  Sub Area    1.00(2) +  8.62(1)
2  Error       1.00(2)
```

Nested ANOVA: Number of Individuals versus Sub Area

```
Analysis of Variance for Number of Individuals

Source    DF           SS           MS
Sub Area   2  4.24360E+06  2.12180E+06
Error     26  1.56754E+08  6.02900E+06
Total     28  1.60998E+08
```

```
Variance Components

Source      Var Comp.   % of Total     StDev
Sub Area  -453235.810*        0.00     0.000
Error     6029003.203       100.00  2455.403
Total     6029003.203               2455.403

* Value is negative, and is estimated by zero.


Expected Mean Squares

1  Sub Area    1.00(2) +  8.62(1)
2  Error       1.00(2)
```

Nested ANOVA: Pielous Evenness versus Sub Area

```
Analysis of Variance for Pielous Evenness

Source    DF      SS      MS
Sub Area   2  0.1602  0.0801
Error     26  0.4094  0.0157
Total     28  0.5696


Variance Components

                      % of
Source    Var Comp.  Total  StDev
Sub Area      0.007  32.16  0.086
Error         0.016  67.84  0.125
Total         0.023         0.152


Expected Mean Squares

1  Sub Area    1.00(2) +  8.62(1)
2  Error       1.00(2)
```

Nested ANOVA: Shannon Diversity (log2) versus Sub Area

```
Analysis of Variance for Shannon Diversity (log2)

Source    DF       SS      MS
Sub Area   2   9.5924  4.7962
Error     26   9.7527  0.3751
Total     28  19.3451


Variance Components

                      % of
Source    Var Comp.  Total  StDev
Sub Area      0.513  57.76  0.716
Error         0.375  42.24  0.612
Total         0.888         0.942
```

```
Expected Mean Squares

1  Sub Area    1.00(2) +  8.62(1)
2  Error       1.00(2)
```

Nested ANOVA: Number of Individuals per M2 versus Sub Area

```
Analysis of Variance for Number of Individuals per M2

Source    DF           SS           MS
Sub Area   2  7.88440E+09  3.94220E+09
Error     26  2.91236E+11  1.12014E+10
Total     28  2.99121E+11


Variance Components

Source       Var Comp.   % of Total       StDev
Sub Area  -8.42066E+08*        0.00       0.000
Error      1.12014E+10       100.00  105836.629
Total      1.12014E+10               105836.629

* Value is negative, and is estimated by zero.


Expected Mean Squares

1  Sub Area    1.00(2) +  8.62(1)
2  Error       1.00(2)
```

One-way ANOVA: Temperature versus Sub Area

```
Source    DF      SS     MS      F       P
Sub Area   2  13.618  6.809  15.94  0.0001
Error     26  11.108  0.427
Total     28  24.726

S = 0.6536   R-Sq = 55.07%   R-Sq(adj) = 51.62%


                                  Individual 95% CIs For Mean Based on
                                  Pooled StDev
Level           N    Mean  StDev  ----+---------+---------+---------+-----
Crystal River  15  28.898  0.444            (--*--)
Gulf            4  30.101  0.294                    (------*------)
Kings Bay      10  27.976  0.948  (---*---)
                                  ----+---------+---------+---------+-----
                                   28.0      29.0      30.0      31.0

Pooled StDev = 0.654


Hsu's MCB (Multiple Comparisons with the Best)

Family error rate = 0.1
Critical value = 1.66

Intervals for level mean minus largest of other level means

Level            Lower   Center   Upper
Crystal River  -1.8138  -1.2029  0.0000
Gulf            0.0000   1.2029  1.8138
Kings Bay      -2.7672  -2.1248  0.0000

Level          ---+---------+---------+---------+------
Crystal River          (----*---------)
Gulf                                  (---------*----)
Kings Bay      (----*-----------------)
               ---+---------+---------+---------+------
               -2.4      -1.2       0.0       1.2


Tukey 90% Simultaneous Confidence Intervals
All Pairwise Comparisons among Levels of Sub Area

Individual confidence level = 95.89%


Sub Area = Crystal River subtracted from:

Sub Area     Lower   Center    Upper
Gulf        0.4122   1.2029   1.9935
Kings Bay  -1.4956  -0.9220  -0.3484

Sub Area      +---------+---------+---------+---------
Gulf                                 (----*----)
Kings Bay               (---*---)
              +---------+---------+---------+---------
           -3.0      -1.5       0.0       1.5


Sub Area = Gulf subtracted from:
```

```
Sub Area      Lower   Center    Upper
Kings Bay  -2.9561  -2.1248  -1.2936

Sub Area       +---------+---------+---------+---------
Kings Bay      (-----*----)
               +---------+---------+---------+---------
            -3.0      -1.5       0.0       1.5
```

One-way ANOVA: pH versus Sub Area

```
Source    DF      SS      MS      F       P
Sub Area   2  3.0202  1.5101  28.70  0.0001
Error     26  1.3680  0.0526
Total     28  4.3882

S = 0.2294   R-Sq = 68.83%   R-Sq(adj) = 66.43%


                                  Individual 95% CIs For Mean Based on
                                  Pooled StDev
Level           N    Mean   StDev  -----+---------+---------+---------+----
Crystal River  15  7.7391  0.1099  (----*---)
Gulf            4  8.0242  0.0764         (--------*--------)
Kings Bay      10  8.4486  0.3623                            (-----*-----)
                                  -----+---------+---------+---------+----
                                     7.75      8.00      8.25      8.50

Pooled StDev = 0.2294


Hsu's MCB (Multiple Comparisons with the Best)

Family error rate = 0.1
Critical value = 1.66

Intervals for level mean minus largest of other level means

Level            Lower   Center   Upper
Crystal River  -0.8650  -0.7095  0.0000
Gulf           -0.6498  -0.4244  0.0000
Kings Bay       0.0000   0.4244  0.6498

Level           --+---------+---------+---------+-------
Crystal River   (---*------------------)
Gulf                  (----*----------)
Kings Bay                             (----------*----)
                --+---------+---------+---------+-------
               -0.80     -0.40     -0.00      0.40


Tukey 90% Simultaneous Confidence Intervals
All Pairwise Comparisons among Levels of Sub Area

Individual confidence level = 95.89%


Sub Area = Crystal River subtracted from:

Sub Area    Lower  Center   Upper  ----+---------+---------+---------+-----
Gulf       0.0076  0.2851  0.5625              (-----*----)
Kings Bay  0.5082  0.7095  0.9108                        (---*---)
                                   ----+---------+---------+---------+-----
```

```
                                    -0.50      0.00      0.50      1.00


Sub Area = Gulf subtracted from:

Sub Area    Lower  Center   Upper  ----+---------+---------+---------+-----
Kings Bay  0.1327  0.4244  0.7161                   (----*-----)
                                   ----+---------+---------+---------+-----
                                    -0.50      0.00      0.50      1.00
```

One-way ANOVA: Salinity versus Sub Area

```
Source    DF      SS      MS      F       P
Sub Area   2  701.67  350.83  48.59  0.0001
Error     26  187.73    7.22
Total     28  889.40

S = 2.687   R-Sq = 78.89%   R-Sq(adj) = 77.27%



Level           N    Mean  StDev
Crystal River  15   6.242  3.519
Gulf            4  17.590  1.351
Kings Bay      10   1.921  0.995

               Individual 95% CIs For Mean Based on Pooled StDev
Level            +---------+---------+---------+---------
Crystal River            (-*--)
Gulf                                      (---*----)
Kings Bay        (--*--)
                 +---------+---------+---------+---------
               0.0       6.0      12.0      18.0

Pooled StDev = 2.687


Hsu's MCB (Multiple Comparisons with the Best)

Family error rate = 0.1
Critical value = 1.66

Intervals for level mean minus largest of other level means

Level            Lower   Center   Upper
Crystal River  -13.860  -11.348   0.000
Gulf             0.000   11.348  13.860
Kings Bay      -18.310  -15.669   0.000

Level          --------+---------+---------+---------+-
Crystal River      (--*----------)
Gulf                             (----------*--)
Kings Bay      (-*---------------)
               --------+---------+---------+---------+-
                     -10         0        10        20


Tukey 90% Simultaneous Confidence Intervals
All Pairwise Comparisons among Levels of Sub Area

Individual confidence level = 95.89%
```

```
Sub Area = Crystal River subtracted from:

Sub Area    Lower  Center   Upper  ---------+---------+---------+---------+
Gulf        8.097  11.348  14.598                            (--*---)
Kings Bay  -6.679  -4.321  -1.963             (--*-)
                                   ---------+---------+---------+---------+
                                          -10         0        10        20


Sub Area = Gulf subtracted from:

Sub Area     Lower   Center    Upper  ---------+---------+---------+---------+
Kings Bay  -19.086  -15.669  -12.252  (--*---)
                                      ---------+---------+---------+---------+
                                             -10         0        10        20
```

One-way ANOVA: DO (mg/L) versus Sub Area

```
Source    DF      SS     MS      F      P
Sub Area   2   71.01  35.50  27.74  0.0001
Error     26   33.28   1.28
Total     28  104.29

S = 1.131   R-Sq = 68.09%   R-Sq(adj) = 65.63%



Level           N   Mean  StDev
Crystal River  15  5.418  0.462
Gulf            4  6.155  0.625
Kings Bay      10  8.825  1.799

               Individual 95% CIs For Mean Based on Pooled StDev
Level            +---------+---------+---------+---------
Crystal River    (----*----)
Gulf               (--------*---------)
Kings Bay                                   (------*-----)
                 +---------+---------+---------+---------
               4.8       6.0       7.2       8.4

Pooled StDev = 1.131


Hsu's MCB (Multiple Comparisons with the Best)

Family error rate = 0.1
Critical value = 1.66

Intervals for level mean minus largest of other level means

Level           Lower  Center  Upper
Crystal River  -4.174  -3.407  0.000
Gulf           -3.782  -2.670  0.000
Kings Bay       0.000   2.670  3.782

Level            -+---------+---------+---------+--------
Crystal River    (---*-----------------)
Gulf               (-----*------------)
Kings Bay                             (------------*-----)
                 -+---------+---------+---------+--------
               -4.0      -2.0       0.0       2.0
```

```
Tukey 90% Simultaneous Confidence Intervals
All Pairwise Comparisons among Levels of Sub Area

Individual confidence level = 95.89%


Sub Area = Crystal River subtracted from:

Sub Area    Lower  Center  Upper  ------+---------+---------+---------+---
Gulf       -0.632   0.737  2.105              (-----*----)
Kings Bay   2.414   3.407  4.400                           (---*---)
                                  ------+---------+---------+---------+---
                                     -2.5       0.0       2.5       5.0


Sub Area = Gulf subtracted from:

Sub Area   Lower  Center  Upper  ------+---------+---------+---------+---
Kings Bay  1.232   2.670  4.109                       (-----*----)
                                 ------+---------+---------+---------+---
                                    -2.5       0.0       2.5       5.0
```

One-way ANOVA: Total Depth versus Sub Area

```
Source    DF      SS     MS      F      P
Sub Area   2  16.775  8.388  15.10  0.0001
Error     26  14.442  0.555
Total     28  31.218

S = 0.7453   R-Sq = 53.74%   R-Sq(adj) = 50.18%


                                   Individual 95% CIs For Mean Based on
                                   Pooled StDev
Level           N    Mean   StDev   -+---------+---------+---------+--------
Crystal River  15  3.4000  0.6514                               (-----*----)
Gulf            4  2.1000  0.2582   (----------*----------)
Kings Bay      10  1.8050  0.9605   (------*------)
                                    -+---------+---------+---------+--------
                                   1.40      2.10      2.80      3.50

Pooled StDev = 0.7453


Hsu's MCB (Multiple Comparisons with the Best)

Family error rate = 0.1
Critical value = 1.66

Intervals for level mean minus largest of other level means

Level            Lower   Center   Upper
Crystal River   0.0000   1.3000  1.9967
Gulf           -1.9967  -1.3000  0.0000
Kings Bay      -2.1004  -1.5950  0.0000

Level          --------+---------+---------+---------+-
Crystal River                    (----------*-----)
Gulf            (-----*----------)
Kings Bay      (----*------------)
```

```
               --------+---------+---------+---------+-
                    -1.2       0.0       1.2       2.4


Tukey 90% Simultaneous Confidence Intervals
All Pairwise Comparisons among Levels of Sub Area

Individual confidence level = 95.89%


Sub Area = Crystal River subtracted from:

Sub Area     Lower   Center    Upper   --+---------+---------+---------+-------
Gulf       -2.2016  -1.3000  -0.3984   (--------*--------)
Kings Bay  -2.2491  -1.5950  -0.9409   (-----*------)
                                       --+---------+---------+---------+-------
                                      -2.0      -1.0       0.0       1.0


Sub Area = Gulf subtracted from:

Sub Area     Lower   Center   Upper   --+---------+---------+---------+-------
Kings Bay  -1.2428  -0.2950  0.6528             (--------*---------)
                                      --+---------+---------+---------+-------
                                     -2.0      -1.0       0.0       1.0
```

One-way ANOVA: % Silt+Clay versus Sub Area

```
Source    DF    SS    MS     F      P
Sub Area   2  2793  1396  5.36  0.011
Error     26  6768   260
Total     28  9561

S = 16.13   R-Sq = 29.21%   R-Sq(adj) = 23.77%


                                 Individual 95% CIs For Mean Based on
                                 Pooled StDev
Level           N   Mean  StDev  ----+---------+---------+---------+-----
Crystal River  15  27.42   4.54  (------*------)
Gulf            4  37.40   4.91   (-------------*-------------)
Kings Bay      10  48.97  26.68                 (--------*--------)
                                 ----+---------+---------+---------+-----
                                    24        36        48        60

Pooled StDev = 16.13


Hsu's MCB (Multiple Comparisons with the Best)

Family error rate = 0.1
Critical value = 1.66

Intervals for level mean minus largest of other level means

Level            Lower  Center  Upper  --+---------+---------+---------+-------
Crystal River   -32.49  -21.55   0.00  (-------*-------------)
Gulf            -27.42  -11.57   4.28      (---------*----------)
Kings Bay        -4.28   11.57  27.42                     (----------*---------)
                                       --+---------+---------+---------+-------
                                       -30       -15         0        15
```

```
Tukey 90% Simultaneous Confidence Intervals
All Pairwise Comparisons among Levels of Sub Area

Individual confidence level = 95.89%


Sub Area = Crystal River subtracted from:

Sub Area   Lower  Center  Upper  ------+---------+---------+---------+---
Gulf       -9.54    9.98  29.50             (---------*---------)
Kings Bay   7.39   21.55  35.71                      (------*------)
                                 ------+---------+---------+---------+---
                                     -20         0        20        40


Sub Area = Gulf subtracted from:

Sub Area   Lower  Center  Upper  ------+---------+---------+---------+---
Kings Bay  -8.95   11.57  32.09              (---------*---------)
                                 ------+---------+---------+---------+---
                                     -20         0        20        40
```

One-way ANOVA: Number of Taxa versus Sub Area

```
Source    DF      SS     MS     F      P
Sub Area   2   689.9  345.0  9.64  0.001
Error     26   929.9   35.8
Total     28  1619.9

S = 5.981   R-Sq = 42.59%   R-Sq(adj) = 38.18%


                                  Individual 95% CIs For Mean Based on
                                  Pooled StDev
Level           N    Mean  StDev  -------+---------+---------+---------+--
Crystal River  15  16.733  6.734        (----*---)
Gulf            4  28.500  7.550                     (--------*-------)
Kings Bay      10  13.000  3.712  (-----*----)
                                  -------+---------+---------+---------+--
                                      14.0      21.0      28.0      35.0

Pooled StDev = 5.981


Hsu's MCB (Multiple Comparisons with the Best)

Family error rate = 0.1
Critical value = 1.66

Intervals for level mean minus largest of other level means

Level            Lower   Center   Upper
Crystal River  -17.357  -11.767   0.000
Gulf             0.000   11.767  17.357
Kings Bay      -21.377  -15.500   0.000

Level           -+---------+---------+---------+--------
Crystal River       (----*-----------)
Gulf                                 (-----------*----)
Kings Bay       (-----*--------------)
                -+---------+---------+---------+--------
```

```
               -20       -10         0        10


Tukey 90% Simultaneous Confidence Intervals
All Pairwise Comparisons among Levels of Sub Area

Individual confidence level = 95.89%


Sub Area = Crystal River subtracted from:

Sub Area    Lower  Center   Upper  ---------+---------+---------+---------+
Gulf        4.532  11.767  19.001                         (-----*-----)
Kings Bay  -8.982  -3.733   1.515             (---*---)
                                   ---------+---------+---------+---------+
                                          -12         0        12        24


Sub Area = Gulf subtracted from:

Sub Area     Lower   Center   Upper  ---------+---------+---------+---------+
Kings Bay  -23.106  -15.500  -7.894  (-----*-----)
                                     ---------+---------+---------+---------+
                                            -12         0        12        24
```

One-way ANOVA: Number of Individuals versus Sub Area

```
Source    DF         SS       MS     F      P
Sub Area   2    4243596  2121798  0.35  0.707
Error     26  156754083  6029003
Total     28  160997679

S = 2455   R-Sq = 2.64%   R-Sq(adj) = 0.00%


                                Individual 95% CIs For Mean Based on
                                Pooled StDev
Level           N  Mean  StDev  ------+---------+---------+---------+---
Crystal River  15  1011   3337              (--------*-------)
Gulf            4   101     63  (----------------*---------------)
Kings Bay      10   321    303         (----------*----------)
                                ------+---------+---------+---------+---
                                  -1500         0      1500      3000

Pooled StDev = 2455


Hsu's MCB (Multiple Comparisons with the Best)

Family error rate = 0.1
Critical value = 1.66

Intervals for level mean minus largest of other level means

Level          Lower  Center  Upper
Crystal River  -1385     690   2355
Gulf           -3205    -910   1385
Kings Bay      -2355    -690    975

Level             -+---------+---------+---------+--------
Crystal River                 (-------------*----------)
Gulf              (--------------*--------------)
```

```
Kings Bay              (----------*----------)
                  -+---------+---------+---------+--------
               -3000     -1500         0      1500


Tukey 90% Simultaneous Confidence Intervals
All Pairwise Comparisons among Levels of Sub Area

Individual confidence level = 95.89%


Sub Area = Crystal River subtracted from:

Sub Area   Lower  Center  Upper  ---------+---------+---------+---------+
Gulf       -3880    -910   2060  (-------------*--------------)
Kings Bay  -2845    -690   1465       (----------*---------)
                                 ---------+---------+---------+---------+
                                      -2000         0      2000      4000


Sub Area = Gulf subtracted from:

Sub Area   Lower  Center  Upper  ---------+---------+---------+---------+
Kings Bay  -2903     220   3342      (---------------*---------------)
                                 ---------+---------+---------+---------+
                                      -2000         0      2000      4000
```

One-way ANOVA: Pielous Evenness versus Sub Area

```
Source    DF      SS      MS     F      P
Sub Area   2  0.1602  0.0801  5.09  0.014
Error     26  0.4094  0.0157
Total     28  0.5696

S = 0.1255   R-Sq = 28.13%   R-Sq(adj) = 22.60%


                                   Individual 95% CIs For Mean Based on
                                   Pooled StDev
Level           N    Mean   StDev  ----+---------+---------+---------+-----
Crystal River  15  0.7274  0.1179           (-----*----)
Gulf            4  0.8655  0.0597                 (----------*----------)
Kings Bay      10  0.6329  0.1505  (------*------)
                                   ----+---------+---------+---------+-----
                                     0.60      0.72      0.84      0.96

Pooled StDev = 0.1255


Hsu's MCB (Multiple Comparisons with the Best)

Family error rate = 0.1
Critical value = 1.66

Intervals for level mean minus largest of other level means

Level            Lower   Center   Upper
Crystal River  -0.2553  -0.1380  0.0000
Gulf            0.0000   0.1380  0.2553
Kings Bay      -0.3558  -0.2325  0.0000

Level           --+---------+---------+---------+-------
```

```
Crystal River         (------*--------)
Gulf                                  (--------*------)
Kings Bay       (------*--------------)
                --+---------+---------+---------+-------
               -0.32     -0.16      0.00      0.16


Tukey 90% Simultaneous Confidence Intervals
All Pairwise Comparisons among Levels of Sub Area

Individual confidence level = 95.89%


Sub Area = Crystal River subtracted from:

Sub Area     Lower   Center   Upper
Gulf       -0.0138   0.1380  0.2898
Kings Bay  -0.2046  -0.0945  0.0156

Sub Area      +---------+---------+---------+---------
Gulf                             (-------*------)
Kings Bay               (----*-----)
              +---------+---------+---------+---------
           -0.40     -0.20      0.00      0.20


Sub Area = Gulf subtracted from:

Sub Area     Lower   Center    Upper
Kings Bay  -0.3921  -0.2325  -0.0730

Sub Area      +---------+---------+---------+---------
Kings Bay     (-------*-------)
              +---------+---------+---------+---------
           -0.40     -0.20      0.00      0.20
```

One-way ANOVA: Shannon Diversity (log2) versus Sub Area

```
Source    DF      SS     MS      F       P
Sub Area   2   9.592  4.796  12.79  0.0001
Error     26   9.753  0.375
Total     28  19.345

S = 0.6125   R-Sq = 49.59%   R-Sq(adj) = 45.71%


                                   Individual 95% CIs For Mean Based on
                                   Pooled StDev
Level           N    Mean   StDev  ------+---------+---------+---------+---
Crystal River  15  2.8756  0.6832          (---*---)
Gulf            4  4.1289  0.2504                      (-------*------)
Kings Bay      10  2.2986  0.5802  (----*----)
                                   ------+---------+---------+---------+---
                                       2.40      3.20      4.00      4.80

Pooled StDev = 0.6125


Hsu's MCB (Multiple Comparisons with the Best)

Family error rate = 0.1
Critical value = 1.66
```

```
Intervals for level mean minus largest of other level means

Level            Lower   Center   Upper
Crystal River  -1.8258  -1.2533  0.0000
Gulf            0.0000   1.2533  1.8258
Kings Bay      -2.4322  -1.8303  0.0000

Level             +---------+---------+---------+---------
Crystal River          (----*---------)
Gulf                                  (---------*----)
Kings Bay         (----*--------------)
                  +---------+---------+---------+---------
               -2.4      -1.2       0.0       1.2


Tukey 90% Simultaneous Confidence Intervals
All Pairwise Comparisons among Levels of Sub Area

Individual confidence level = 95.89%


Sub Area = Crystal River subtracted from:

Sub Area     Lower   Center    Upper  -------+---------+---------+---------+--
Gulf        0.5124   1.2533   1.9941                    (----*----)
Kings Bay  -1.1145  -0.5770  -0.0395            (--*---)
                                      -------+---------+---------+---------+--
                                          -1.5       0.0       1.5       3.0


Sub Area = Gulf subtracted from:

Sub Area     Lower   Center    Upper  -------+---------+---------+---------+--
Kings Bay  -2.6092  -1.8303  -1.0514  (----*----)
                                      -------+---------+---------+---------+--
                                          -1.5       0.0       1.5       3.0
```

Results for: Raw Profile PChem data July 2009.MTW

Nested ANOVA: Depth, Temperature, pH, Salinity, Dissolved Oxygen (mg/l)

Nested ANOVA: Depth versus Sub Area

```
Analysis of Variance for Depth

Source    DF       SS      MS
Sub Area   2   4.3321  2.1660
Error     56  55.4710  0.9906
Total     58  59.8031


Variance Components

                      % of
Source    Var Comp.  Total  StDev
Sub Area      0.063   5.96  0.251
Error         0.991  94.04  0.995
Total         1.053         1.026
```

```
Expected Mean Squares

1  Sub Area    1.00(2) + 18.71(1)
2  Error       1.00(2)
```

Nested ANOVA: Temperature versus Sub Area

```
Analysis of Variance for Temperature

Source    DF       SS       MS
Sub Area   2  39.5770  19.7885
Error     56  35.2381   0.6293
Total     58  74.8150


Variance Components

                      % of
Source    Var Comp.  Total  StDev
Sub Area      1.024  61.94  1.012
Error         0.629  38.06  0.793
Total         1.653         1.286


Expected Mean Squares

1  Sub Area    1.00(2) + 18.71(1)
2  Error       1.00(2)
```

Nested ANOVA: pH versus Sub Area

```
Analysis of Variance for pH

Source    DF      SS      MS
Sub Area   2  4.9505  2.4753
Error     56  3.9644  0.0708
Total     58  8.9149


Variance Components

                      % of
Source    Var Comp.  Total  StDev
Sub Area      0.128  64.48  0.358
Error         0.071  35.52  0.266
Total         0.199         0.446


Expected Mean Squares

1  Sub Area    1.00(2) + 18.71(1)
2  Error       1.00(2)
```

Nested ANOVA: Salinity versus Sub Area

```
Analysis of Variance for Salinity

Source    DF         SS         MS
Sub Area   2  2017.9264  1008.9632
```

```
Error     56   247.6075     4.4216
Total     58  2265.5339


Variance Components

                      % of
Source    Var Comp.  Total  StDev
Sub Area     53.685  92.39  7.327
Error         4.422   7.61  2.103
Total        58.106         7.623


Expected Mean Squares

1  Sub Area    1.00(2) + 18.71(1)
2  Error       1.00(2)
```

Nested ANOVA: Dissolved Oxygen (mg/l) versus Sub Area

```
Analysis of Variance for Dissolved Oxygen (mg/l)

Source    DF        SS       MS
Sub Area   2  121.4628  60.7314
Error     56  114.8920   2.0516
Total     58  236.3548


Variance Components

                      % of
Source    Var Comp.  Total  StDev
Sub Area      3.136  60.45  1.771
Error         2.052  39.55  1.432
Total         5.188         2.278


Expected Mean Squares

1  Sub Area    1.00(2) + 18.71(1)
2  Error       1.00(2)
```

One-way ANOVA: Depth versus Sub Area

```
Source    DF      SS     MS     F      P
Sub Area   2   4.332  2.166  2.19  0.122
Error     56  55.471  0.991
Total     58  59.803

S = 0.9953   R-Sq = 7.24%   R-Sq(adj) = 3.93%


                                   Individual 95% CIs For Mean Based on
                                   Pooled StDev
Level           N    Mean   StDev  ---------+---------+---------+---------+
Crystal River  20  1.5600  1.1713                  (----------*----------)
Gulf           12  1.0333  0.8105  (--------------*-------------)
Kings Bay      27  0.9704  0.9235      (--------*---------)
                                   ---------+---------+---------+---------+
                                          0.80      1.20      1.60      2.00

Pooled StDev = 0.9953


Hsu's MCB (Multiple Comparisons with the Best)

Family error rate = 0.1
Critical value = 1.62

Intervals for level mean minus largest of other level means

Level            Lower   Center   Upper
Crystal River  -0.0631   0.5267  1.0661
Gulf           -1.1164  -0.5267  0.0631
Kings Bay      -1.0661  -0.5896  0.0000

Level          ---------+---------+---------+---------+
Crystal River                     (---------*--------)
Gulf           (---------*---------)
Kings Bay       (-------*---------)
               ---------+---------+---------+---------+
                     -0.60      0.00      0.60      1.20


Tukey 90% Simultaneous Confidence Intervals
All Pairwise Comparisons among Levels of Sub Area

Individual confidence level = 95.91%


Sub Area = Crystal River subtracted from:

Sub Area     Lower   Center   Upper    -+---------+---------+---------+--------
Gulf       -1.2873  -0.5267  0.2340    (-----------*------------)
Kings Bay  -1.2042  -0.5896  0.0249     (---------*---------)
                                       -+---------+---------+---------+--------
                                     -1.20     -0.60      0.00      0.60


Sub Area = Gulf subtracted from:

Sub Area     Lower   Center   Upper    -+---------+---------+---------+--------
Kings Bay  -0.7857  -0.0630  0.6598            (-----------*-----------)
                                       -+---------+---------+---------+--------
                                     -1.20     -0.60      0.00      0.60
```

One-way ANOVA: Temperature versus Sub Area

```
Source    DF      SS      MS      F      P
Sub Area   2  39.577  19.788  31.45  0.000
Error     56  35.238   0.629
Total     58  74.815

S = 0.7933   R-Sq = 52.90%   R-Sq(adj) = 51.22%


                                  Individual 95% CIs For Mean Based on
                                  Pooled StDev
Level           N    Mean  StDev  -----+---------+---------+---------+----
Crystal River  20  28.869  0.427             (----*---)
Gulf           12  30.101  0.292                            (----*-----)
Kings Bay      27  27.943  1.089  (---*---)
                                  -----+---------+---------+---------+----
                                    28.00     28.80     29.60     30.40

Pooled StDev = 0.793


Hsu's MCB (Multiple Comparisons with the Best)

Family error rate = 0.1
Critical value = 1.62

Intervals for level mean minus largest of other level means

Level             Lower   Center   Upper
Crystal River  -1.7019  -1.2318  0.0000
Gulf            0.0000   1.2318  1.7019
Kings Bay      -2.6041  -2.1575  0.0000

Level           --+---------+---------+---------+-------
Crystal River           (---*---------)
Gulf                                  (---------*---)
Kings Bay       (---*-----------------)
                --+---------+---------+---------+-------
               -2.4      -1.2       0.0       1.2


Tukey 90% Simultaneous Confidence Intervals
All Pairwise Comparisons among Levels of Sub Area

Individual confidence level = 95.91%


Sub Area = Crystal River subtracted from:

Sub Area     Lower   Center    Upper  --------+---------+---------+---------+-
Gulf        0.6256   1.2318   1.8381                        (---*---)
Kings Bay  -1.4155  -0.9257  -0.4358           (--*--)
                                      --------+---------+---------+---------+-
                                           -1.5       0.0       1.5       3.0


Sub Area = Gulf subtracted from:

Sub Area     Lower   Center    Upper  --------+---------+---------+---------+-
Kings Bay  -2.7335  -2.1575  -1.5815  (---*--)
```

```
                                      --------+---------+---------+---------+-
                                           -1.5       0.0       1.5       3.0
```

One-way ANOVA: pH versus Sub Area

```
Source    DF      SS      MS      F      P
Sub Area   2  4.9505  2.4753  34.97  0.000
Error     56  3.9644  0.0708
Total     58  8.9149

S = 0.2661   R-Sq = 55.53%   R-Sq(adj) = 53.94%


                                   Individual 95% CIs For Mean Based on
                                   Pooled StDev
Level           N    Mean   StDev  -----+---------+---------+---------+----
Crystal River  20  7.7390  0.1129  (----*---)
Gulf           12  8.0242  0.0730            (-----*-----)
Kings Bay      27  8.3904  0.3754                             (---*---)
                                   -----+---------+---------+---------+----
                                      7.75      8.00      8.25      8.50

Pooled StDev = 0.2661


Hsu's MCB (Multiple Comparisons with the Best)

Family error rate = 0.1
Critical value = 1.62

Intervals for level mean minus largest of other level means

Level            Lower   Center   Upper
Crystal River  -0.7788  -0.6514  0.0000
Gulf           -0.5160  -0.3662  0.0000
Kings Bay       0.0000   0.3662  0.5160

Level           --+---------+---------+---------+-------
Crystal River   (--*------------------)
Gulf                   (----*---------)
Kings Bay                             (---------*----)
                --+---------+---------+---------+-------
               -0.70     -0.35      0.00      0.35


Tukey 90% Simultaneous Confidence Intervals
All Pairwise Comparisons among Levels of Sub Area

Individual confidence level = 95.91%


Sub Area = Crystal River subtracted from:

Sub Area    Lower  Center   Upper  ------+---------+---------+---------+---
Gulf       0.0818  0.2852  0.4885                    (-----*-----)
Kings Bay  0.4871  0.6514  0.8157                                (----*---)
                                   ------+---------+---------+---------+---
                                      -0.35      0.00      0.35      0.70


Sub Area = Gulf subtracted from:
```

```
Sub Area    Lower  Center   Upper  ------+---------+---------+---------+---
Kings Bay  0.1730  0.3662  0.5594                      (----*-----)
                                   ------+---------+---------+---------+---
                                      -0.35      0.00      0.35      0.70
```

One-way ANOVA: Salinity versus Sub Area

```
Source    DF       SS       MS       F      P
Sub Area   2  2017.93  1008.96  228.19  0.000
Error     56   247.61     4.42
Total     58  2265.53

S = 2.103   R-Sq = 89.07%   R-Sq(adj) = 88.68%


                                  Individual 95% CIs For Mean Based on
                                  Pooled StDev
Level           N    Mean  StDev  --------+---------+---------+---------+-
Crystal River  20   5.806  3.186          (-*)
Gulf           12  17.590  1.448                               (-*--)
Kings Bay      27   2.059  1.105  (-*-)
                                  --------+---------+---------+---------+-
                                        5.0      10.0      15.0      20.0

Pooled StDev = 2.103


Hsu's MCB (Multiple Comparisons with the Best)

Family error rate = 0.1
Critical value = 1.62

Intervals for level mean minus largest of other level means

Level             Lower   Center   Upper
Crystal River   -13.030  -11.784   0.000
Gulf              0.000   11.784  13.030
Kings Bay       -16.715  -15.531   0.000

Level             -+---------+---------+---------+--------
Crystal River          (*--------------)
Gulf                                   (--------------*)
Kings Bay         (-*------------------)
                  -+---------+---------+---------+--------
               -16.0      -8.0       0.0       8.0


Tukey 90% Simultaneous Confidence Intervals
All Pairwise Comparisons among Levels of Sub Area

Individual confidence level = 95.91%


Sub Area = Crystal River subtracted from:

Sub Area    Lower  Center   Upper  -------+---------+---------+---------+--
Gulf       10.177  11.784  13.391                              (-*)
Kings Bay  -5.045  -3.747  -2.448              (*-)
                                   -------+---------+---------+---------+--
                                        -10         0        10        20
```

```
Sub Area = Gulf subtracted from:

Sub Area     Lower   Center    Upper  -------+---------+---------+---------+--
Kings Bay  -17.058  -15.531  -14.004  (*-)
                                      -------+---------+---------+---------+--
                                           -10         0        10        20
```

One-way ANOVA: Dissolved Oxygen (mg/l) versus Sub Area

```
Source    DF      SS     MS      F      P
Sub Area   2  121.46  60.73  29.60  0.000
Error     56  114.89   2.05
Total     58  236.35

S = 1.432   R-Sq = 51.39%   R-Sq(adj) = 49.65%



Level           N   Mean  StDev
Crystal River  20  5.467  0.498
Gulf           12  6.155  0.580
Kings Bay      27  8.563  2.024

               Individual 95% CIs For Mean Based on Pooled StDev
Level            +---------+---------+---------+---------
Crystal River    (-----*----)
Gulf                 (------*------)
Kings Bay                                   (---*----)
                 +---------+---------+---------+---------
               4.8       6.0       7.2       8.4

Pooled StDev = 1.432


Hsu's MCB (Multiple Comparisons with the Best)

Family error rate = 0.1
Critical value = 1.62

Intervals for level mean minus largest of other level means

Level           Lower  Center  Upper  ---------+---------+---------+---------+
Crystal River  -3.781  -3.095  0.000  (---*--------------)
Gulf           -3.214  -2.408  0.000     (---*-----------)
Kings Bay       0.000   2.408  3.214                     (-----------*---)
                                      ---------+---------+---------+---------+
                                            -2.0       0.0       2.0       4.0


Tukey 90% Simultaneous Confidence Intervals
All Pairwise Comparisons among Levels of Sub Area

Individual confidence level = 95.91%


Sub Area = Crystal River subtracted from:

Sub Area    Lower  Center  Upper  -------+---------+---------+---------+--
Gulf       -0.407   0.688  1.782                 (----*-----)
Kings Bay   2.211   3.095  3.980                              (---*----)
                                  -------+---------+---------+---------+--
                                      -2.0       0.0       2.0       4.0
```

```
Sub Area = Gulf subtracted from:

Sub Area   Lower  Center  Upper  -------+---------+---------+---------+--
Kings Bay  1.368   2.408  3.448                           (----*----)
                                 -------+---------+---------+---------+--
                                     -2.0       0.0       2.0       4.0
```

Results for: Sediment Data.MTW

Descriptive Statistics: %>3 Inch, % Coarse Gra, % Fine Grave, % Coarse San, ...

```
Variable                 N      Mean     StDev   Minimum        Q1    Median
%>3 Inch                20  0.000000  0.000000  0.000000  0.000000  0.000000
% Coarse Gravel         20  0.000000  0.000000  0.000000  0.000000  0.000000
% Fine Gravel           20    0.0250    0.0910    0.0000    0.0000    0.0000
% Coarse Sand           20     0.425     0.604     0.000     0.025     0.200
% Medium Sand           20      2.74      6.50      0.20      0.70      1.05
% Fine Sand             20     56.06     21.13      0.90     44.00     63.50
% Silt                  20     31.37     17.06     13.90     19.60     24.50
% Clay                  20      9.15      6.18      4.00      5.63      7.10
% Silt+Clay             20     40.52     20.81     20.20     27.35     33.60
Percent Organics        20      4.31      5.77      1.00      1.90      2.60
%>3 Inch_Gulf            4  0.000000  0.000000  0.000000  0.000000  0.000000
% Coarse Gravel_Gulf     4  0.000000  0.000000  0.000000  0.000000  0.000000
% Fine Gravel_Gulf       4     0.100     0.200     0.000     0.000     0.000
% Coarse Sand_Gulf       4     0.450     0.404     0.100     0.125     0.350
% Medium Sand_Gulf       4     1.700     1.458     0.500     0.625     1.250
% Fine Sand_Gulf         4     60.35      4.58     54.10     55.80     61.10
% Silt_Gulf              4     25.80      3.98     22.50     22.70     24.70
% Clay_Gulf              4    11.600     1.120    10.200    10.450    11.800
% Silt+Clay_Gulf         4     37.40      4.91     33.50     33.55     36.10
Percent Organics_Gulf    4     3.625     0.499     3.200     3.225     3.500
%>3 Inch_CR              5  0.000000  0.000000  0.000000  0.000000  0.000000
% Coarse Gravel_CR       5  0.000000  0.000000  0.000000  0.000000  0.000000
% Fine Gravel_CR         5  0.000000  0.000000  0.000000  0.000000  0.000000
% Coarse Sand_CR         5     0.620     0.526     0.100     0.200     0.400
% Medium Sand_CR         5     1.180     0.876     0.500     0.600     1.000
% Fine Sand_CR           5     69.84      6.70     62.80     63.70     68.60
% Silt_CR                5     19.74      4.63     13.90     15.70     18.50
% Clay_CR                5     7.680     1.941     6.300     6.550     7.000
% Silt+Clay_CR           5     27.42      4.91     20.20     22.45     29.60
Percent Organics_CR      5     2.500     0.663     1.900     1.900     2.500
%>3 Inch_KB             11  0.000000  0.000000  0.000000  0.000000  0.000000
% Coarse Gravel_KB      11  0.000000  0.000000  0.000000  0.000000  0.000000
% Fine Gravel_KB        11   0.00909   0.03015   0.00000   0.00000   0.00000
% Coarse Sand_KB        11     0.327     0.710     0.000     0.000     0.100
% Medium Sand_KB        11      3.82      8.74      0.20      0.70      1.20
% Fine Sand_KB          11     48.24     25.59      0.90     32.30     50.90
% Silt_KB               11     38.68     20.02     17.70     20.20     30.60
% Clay_KB               11      8.93      8.19      4.00      5.20      6.40
% Silt+Clay_KB          11     47.61     25.71     22.20     26.60     34.60
Percent Organics_KB     11      5.37      7.74      1.00      1.50      2.00

Variable                      Q3   Maximum
%>3 Inch                0.000000  0.000000
% Coarse Gravel         0.000000  0.000000
% Fine Gravel             0.0000    0.4000
% Coarse Sand              0.575     2.400
% Medium Sand               1.50     30.10
% Fine Sand                71.08     78.80
% Silt                     37.98     75.10
% Clay                     11.00     32.80
% Silt+Clay                45.18     98.80
Percent Organics            4.15     27.50
%>3 Inch_Gulf           0.000000  0.000000
% Coarse Gravel_Gulf    0.000000  0.000000
% Fine Gravel_Gulf         0.300     0.400
% Coarse Sand_Gulf         0.875     1.000
% Medium Sand_Gulf         3.225     3.800
```

```
% Fine Sand_Gulf          64.15     65.10
% Silt_Gulf               30.00     31.30
% Clay_Gulf              12.550    12.600
% Silt+Clay_Gulf          42.55     43.90
Percent Organics_Gulf     4.150     4.300
%>3 Inch_CR            0.000000  0.000000
% Coarse Gravel_CR     0.000000  0.000000
% Fine Gravel_CR       0.000000  0.000000
% Coarse Sand_CR          1.150     1.400
% Medium Sand_CR          1.850     2.700
% Fine Sand_CR            76.60     78.80
% Silt_CR                 24.40     25.30
% Clay_CR                 9.150    11.100
% Silt+Clay_CR            31.30     32.30
Percent Organics_CR       3.100     3.500
%>3 Inch_KB            0.000000  0.000000
% Coarse Gravel_KB     0.000000  0.000000
% Fine Gravel_KB        0.00000   0.10000
% Coarse Sand_KB          0.200     2.400
% Medium Sand_KB           1.50     30.10
% Fine Sand_KB            71.90     76.60
% Silt_KB                 56.20     75.10
% Clay_KB                  9.60     32.80
% Silt+Clay_KB            66.90     98.80
Percent Organics_KB        6.70     27.50
```

Results for: Mean PChem data July 2009.MTW

Correlations: Temperature_, pH_CR__Ranks, Salinity_CR_, DO (mg/L)_CR, ...

```
                    Temperature_CR__      pH_CR__Ranks  Salinity_CR__Ran
pH_CR__Ranks                   0.900
Salinity_CR__Ran               0.700             0.600
DO (mg/L)_CR__Ra               0.100             0.200            -0.600
Total Depth_CR__               0.000            -0.100            -0.300
% Silt+Clay_CR_R               0.300             0.100             0.700

                    DO (mg/L)_CR__Ra  Total Depth_CR__
Total Depth_CR__               0.600
% Silt+Clay_CR_R              -0.500             0.300

Cell Contents: Pearson correlation
```

Correlations: Temperature_, pH_Gulf__Ran, Salinity_Gul, DO (mg/L)_Gu, ...

```
                    Temperature_Gulf    pH_Gulf__Ranks  Salinity_Gulf__R
pH_Gulf__Ranks                 0.800
Salinity_Gulf__R               0.600             0.800
DO (mg/L)_Gulf__               1.000             0.800             0.600
Total Depth_Gulf               0.600             0.800             1.000
% Silt+Clay_Gulf               0.000             0.400             0.800

                    DO (mg/L)_Gulf__  Total Depth_Gulf
Total Depth_Gulf               0.600
% Silt+Clay_Gulf               0.000             0.800

Cell Contents: Pearson correlation
```

Correlations: Temperature_, pH_Kings Bay, Salinity_Kin, DO (mg/L)_Ki, ...

```
                    Temperature_King  pH_Kings Bay__Ra  Salinity_Kings B
pH_Kings Bay__Ra              -0.285
Salinity_Kings B               0.539            -0.903
DO (mg/L)_Kings               -0.333             0.952            -0.806
Total Depth_King              -0.322            -0.632             0.468
% Silt+Clay_King              -0.067            -0.091             0.224

                    DO (mg/L)_Kings   Total Depth_King
Total Depth_King              -0.571
% Silt+Clay_King               0.006             0.541

Cell Contents: Pearson correlation
```

Results for: Unpooled Ponar Metrics.MTW

Descriptive Statistics: Number of Ta, Number of In, Pielous Even, ...

```
Variable                    N    Mean   StDev  Minimum      Q1  Median      Q3
Number of Taxa_Crystal R   15   16.73    6.73     6.00   11.00   17.00   20.00
Number of Individuals_Cr   15    1011    3337       24      63     123     294
Pielous Evenness_Crystal   15  0.7274  0.1179   0.5029  0.6426  0.7447  0.8518
Shannon Diversity (log2)   15   2.876   0.683    1.778   2.335   2.968   3.219
Number of Taxa_Gulf         4   28.50    7.55    18.00   20.50   31.00   34.00
Number of Individuals_Gu    4   101.3    62.8     33.0    42.5    97.5   163.8
Pielous Evenness_Gulf       4  0.8655  0.0597   0.7947  0.8053  0.8754  0.9156
Shannon Diversity (log2)    4   4.129   0.250    3.821   3.877   4.152   4.358
Number of Taxa_Kings Bay   10   13.00    3.71     8.00    9.75   13.00   15.50
Number of Individuals_Ki   10   320.8   303.4     28.0   120.8   240.0   408.0
Pielous Evenness_Kings B   10  0.6329  0.1505   0.3487  0.5320  0.6344  0.7289
Shannon Diversity (log2)   10   2.299   0.580    1.328   1.950   2.164   2.719

Variable                  Maximum
Number of Taxa_Crystal R    32.00
Number of Individuals_Cr    13068
Pielous Evenness_Crystal   0.9239
Shannon Diversity (log2)    4.296
Number of Taxa_Gulf         34.00
Number of Individuals_Gu    177.0
Pielous Evenness_Gulf      0.9164
Shannon Diversity (log2)    4.391
Number of Taxa_Kings Bay    20.00
Number of Individuals_Ki   1074.0
Pielous Evenness_Kings B   0.8582
Shannon Diversity (log2)    3.353
```

Results for: Mean PChem data July 2009.MTW

Descriptive Statistics: Temperature_, % Silt+Clay_, % Silt+Clay_, % Silt+Clay_

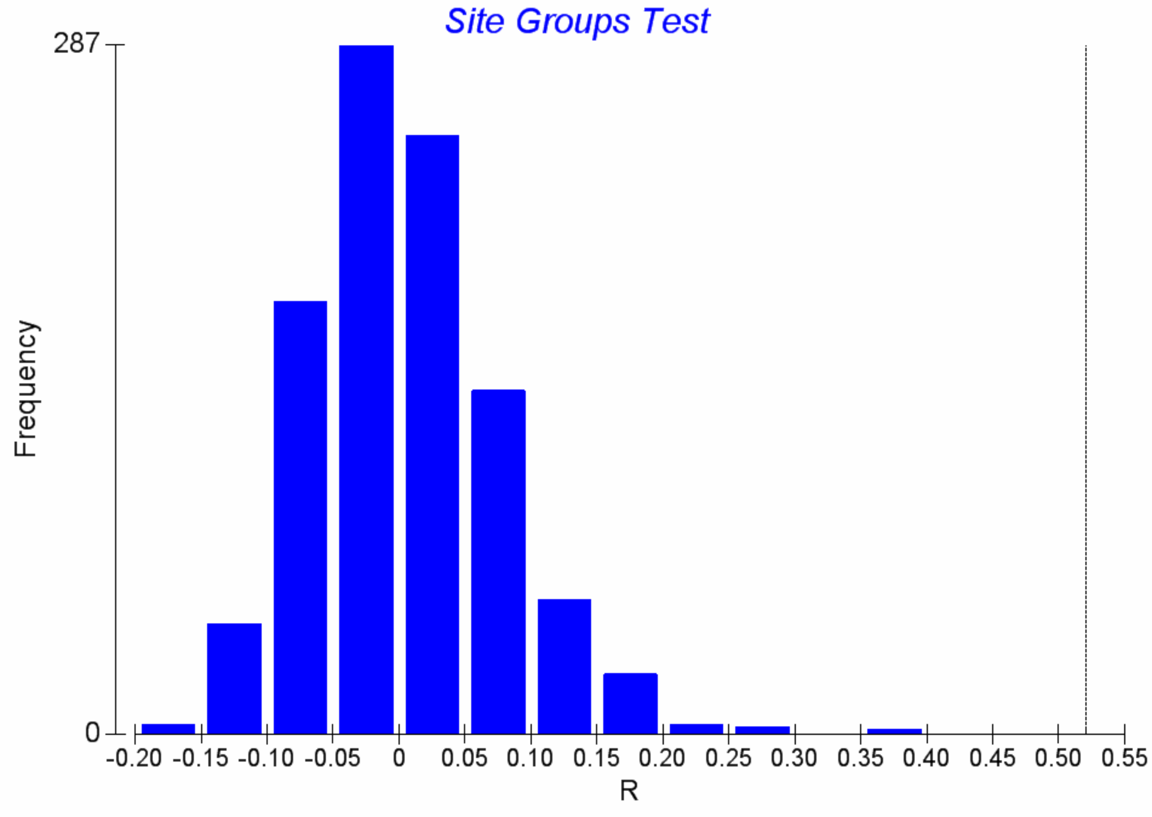
```
Variable                N    Mean  StDev  Minimum      Q1  Median      Q3
Temperature_Gulf        4  30.101  0.294   29.820  29.833  30.108  30.361
% Silt+Clay_Gulf        4   37.40   4.91    33.50   33.55   36.10   42.55
% Silt+Clay_Kings Bay  10   48.97  26.68    22.20   26.10   40.10   70.90
% Silt+Clay_CR_Ranks    5   3.000  1.581    1.000   1.500   3.000   4.500

Variable               Maximum
Temperature_Gulf        30.367
% Silt+Clay_Gulf         43.90
% Silt+Clay_Kings Bay    98.80
% Silt+Clay_CR_Ranks     5.000
```

Descriptive Statistics: % Silt+Clay_CR

```
Variable        N   Mean  StDev  Minimum     Q1  Median     Q3  Maximum
% Silt+Clay_CR  5  27.42   4.91    20.20  22.45   29.60  31.30    32.30
```

Appendix B

Primer Outputs



ANOSIM
Analysis of Similarities

One-Way Analysis

```
Resemblance worksheet
Name: All Unpooled Ponar Bray Curtis
Data type: Similarity
Selection: All

Factor Values
Factor: Site Groups
Gulf
Crystal River
Kings Bay

Factor Groups
Sample    Site Groups
Gulf-1    Gulf
Gulf-2    Gulf
Gulf-3    Gulf
Gulf-4    Gulf
RK 0-A    Crystal River
RK 0-B    Crystal River
RK 0-C    Crystal River
RK 2.5-A  Crystal River
RK 2.5-B  Crystal River
```

```
RK 2.5-C Crystal River
RK 5-A   Crystal River
RK 5-B   Crystal River
RK 5-C   Crystal River
RK 7.5-A Crystal River
RK 7.5-B Crystal River
RK 7.5-C Crystal River
RK 9.4-A Crystal River
RK 9.4-B Crystal River
RK 9.4-C Crystal River
KB-1     Kings Bay
KB-2     Kings Bay
KB-3     Kings Bay
KB-4     Kings Bay
KB-5     Kings Bay
KB-6     Kings Bay
KB-7     Kings Bay
KB-8     Kings Bay
KB-9     Kings Bay
KB-10    Kings Bay

Global Test
Sample statistic (Global R): 0.52
Significance level of sample statistic: 0.1% [=P<0.001; see Clarke and
Gorley 2006]
Number of permutations: 999 (Random sample from a large number)
Number of permuted statistics greater than or equal to Global R: 0

Pairwise Tests
                                  R Significance     Possible
Actual                    Number >=
Groups                    Statistic      Level %  Permutations
                          Permutations             Observed
Gulf, Crystal River           0.467          0.3     3876      999                   2
Gulf, Kings Bay               0.995          0.2     1001      999                   1
Crystal River, Kings Bay       0.39          0.1     3268760   999                   0

Outputs
Plot: Graph3
Worksheet: Resem1
```

Primer BEST Procedure Output for Trimmed Physicochemical Variables versus Unpooled Ponar Macroinvertebrate Data

Primer BEST Procedure Output

Biota and/or Environment matching

```
Data worksheet
Name: Normalized PCHEM
Data type: Environmental
Sample selection: All
Variable selection: All

Resemblance worksheet
Name: Resem1
Data type: Similarity
Selection: All

Parameters
Rank correlation method: Spearman
Method: BIOENV
Maximum number of variables: 5
Resemblance:
Analyse between: Samples
Resemblance measure: D1 Euclidean distance

Variables
  1 Temperature
  2 pH
  3 Salinity
  4 DO (mg/L)
  5 Total Depth

Number of variables: 1
No.Vars    Corr. Selections
      1    0.605 3
      1    0.270 2
      1    0.264 4
      1    0.257 1
      1    0.249 5

Number of variables: 2
No.Vars    Corr. Selections
      2    0.598 3,4
      2    0.589 2,3
      2    0.520 3,5
      2    0.477 1,3
      2    0.365 4,5
      2    0.329 2,5
      2    0.326 1,5
      2    0.308 1,4
      2    0.291 1,2
      2    0.270 2,4

Number of variables: 3
No.Vars    Corr. Selections
      3    0.539 2-4
      3    0.529 3-5
      3    0.509 1,3,4
      3    0.504 2,3,5
```

```
      3    0.503 1-3
      3    0.488 1,3,5
      3    0.366 1,4,5
      3    0.357 2,4,5
      3    0.342 1,2,5
      3    0.301 1,2,4
```

Number of variables: 4

```
No.Vars    Corr. Selections
      4    0.499 2-5
      4    0.496 1,3-5
      4    0.489 1-3,5
      4    0.484 1-4
      4    0.354 1,2,4,5
```

Number of variables: 5

```
No.Vars    Corr. Selections
      5    0.470 All
```

Best results

```
No.Vars    Corr. Selections
      1    0.605 3
      2    0.598 3,4
      2    0.589 2,3
      3    0.539 2-4
      3    0.529 3-5
      2    0.520 3,5
      3    0.509 1,3,4
      3    0.504 2,3,5
      3    0.503 1-3
      4    0.499 2-5
```

Primer BEST Run Including Percent Silt Plus Clay as a Variable

BEST

Biota and/or Environment matching

```
Data worksheet
Name: Data2
Data type: Environmental
Sample selection: All
Variable selection: All

Resemblance worksheet
Name: Resem1
Data type: Similarity
Selection: All

Parameters
Rank correlation method: Spearman
Method: BIOENV
Maximum number of variables: 6
Resemblance:
Analyse between: Samples
Resemblance measure: D1 Euclidean distance

Variables
  1 Temperature
  2 pH
  3 Salinity
  4 DO (mg/L)
  5 Total Depth
  6 % Silt+Clay

Best results
No.Vars    Corr. Selections
      1    0.605 3
      2    0.598 3,4
      2    0.589 2,3
      3    0.539 2-4
      3    0.529 3-5
      2    0.520 3,5
      3    0.509 1,3,4
      3    0.504 2,3,5
      3    0.503 1-3
      4    0.499 2-5
```

Note: These results were essentially the same as above.

BEST Procedure Run for Antecedent Flow and River Kilometer

BEST
Biota and/or Environment matching

```
Data worksheet
Name: Flow for RK Sites
Data type: Environmental
Sample selection: All
Variable selection: All

Resemblance worksheet
Name: Resem1
Data type: Similarity
Selection: All

Parameters
Rank correlation method: Spearman
Method: BIOENV
Maximum number of variables: 5
Resemblance:
Analyse between: Samples
Resemblance measure: D1 Euclidean distance

Variables
  1 River Kilometer
  2 14 day cumulative flow
  3 30 Day Cumulative Flow
  4 45 Day Cumulative Flow

Best results
No.Vars    Corr. Selections
      1    0.652 1
      2    0.652 1,2
      2    0.652 1,3
      2    0.652 1,4
      3    0.652 1-3
      3    0.652 1,2,4
      3    0.652 1,3,4
      4    0.652 All
```

Appendix C

Primer SIMPER Outputs

SIMPER
Similarity Percentages - species contributions

One-Way Analysis

Data worksheet
Name: Data1
Data type: Abundance
Sample selection: All
Variable selection: All

Parameters
Resemblance: S17 Bray Curtis similarity
Cut off for low contributions: 80.00%

Factor Groups

Sample	Site Groups
Gulf-1	Gulf
Gulf-2	Gulf
Gulf-3	Gulf
Gulf-4	Gulf
RK 0-A	Crystal River
RK 0-B	Crystal River
RK 0-C	Crystal River
RK 2.5-A	Crystal River
RK 2.5-B	Crystal River
RK 2.5-C	Crystal River
RK 5-A	Crystal River
RK 5-B	Crystal River
RK 5-C	Crystal River
RK 7.5-A	Crystal River
RK 7.5-B	Crystal River
RK 7.5-C	Crystal River
RK 9.4-A	Crystal River
RK 9.4-B	Crystal River
RK 9.4-C	Crystal River
KB-1	Kings Bay
KB-2	Kings Bay
KB-3	Kings Bay
KB-4	Kings Bay
KB-5	Kings Bay
KB-6	Kings Bay
KB-7	Kings Bay
KB-8	Kings Bay
KB-9	Kings Bay
KB-10	Kings Bay

Group Gulf
Average similarity: 35.05

Species	Av.Abund	Av.Sim	Sim/SD	Contrib%	Cum.%
Glycinde solitaria	1.43	3.82	5.53	10.89	10.89
Nemertea (LPIL)	1.25	3.18	9.26	9.07	19.97
Mediomastus ambiseta	1.3	3.18	10.84	9.06	29.03
Aricidea taylori	1.61	2.11	0.88	6.02	35.04
Haminoea succinea	1.02	2.05	0.87	5.84	40.88
Ampelisca sp. C Lecroy	1.02	2.03	0.89	5.79	46.67
Mooreonuphis nebulosa	1.14	1.95	0.89	5.56	52.23
Fabricinuda trilobata	0.98	1.79	0.91	5.1	57.33
Acteocina canaliculata	0.93	1.77	0.88	5.06	62.39
Heteromastus filiformis	0.88	1.69	0.91	4.81	67.2
Scoloplos rubra	0.8	1.54	0.89	4.38	71.58
Aricidea philbinae	0.95	1.47	0.91	4.19	75.77
Scoletoma verrilli	1.04	1.42	0.9	4.05	79.83
Magelona riojai	1.02	1.37	0.89	3.9	83.72

Group Crystal River
Average similarity: 20.40

Species	Av.Abund	Av.Sim	Sim/SD	Contrib%	Cum.%
Streblospio sp.	1.06	2.19	0.83	10.74	10.74
Laeonereis culveri	1.08	2.1	0.64	10.31	21.05
Cyathura polita	0.88	1.79	0.67	8.79	29.84
Rhithropanopeus harrisii	0.81	1.74	0.68	8.51	38.35
Ampelisca abdita	1.23	1.69	0.55	8.26	46.61
Hobsonia florida	1.09	1.68	0.66	8.23	54.84
Halmyrapseudes cf. bahamensis Heard	0.93	1	0.47	4.9	59.74
Tubificoid Naididae (LPIL)	0.73	0.75	0.4	3.68	63.42
Nemertea (LPIL)	0.56	0.72	0.49	3.55	66.97
Cerapus benthophilus	1.11	0.71	0.39	3.5	70.47
Cyrenoida floridana	0.95	0.68	0.3	3.34	73.81
Apocorophium louisianum	0.94	0.59	0.4	2.89	76.7
Aoridae (LPIL)	0.46	0.42	0.32	2.06	78.76
Actiniaria (LPIL)	0.44	0.33	0.32	1.62	80.39

Group Kings Bay
Average similarity: 28.53

Species	Av.Abund	Av.Sim	Sim/SD	Contrib%	Cum.%
Littoridinops sp.	1.74	3.9	1.12	13.66	13.66
Gammarus sp. B Lecroy	1.34	3.62	1.2	12.69	26.36
Cyrenoida floridana	1.23	2.39	0.68	8.36	34.72
Laeonereis culveri	1.3	2.26	0.65	7.91	42.64
Limnodrilus hoffmeisteri	1.27	2.09	0.52	7.33	49.96
Tubificoid Naididae imm. w/o hair setae (LPIL)	1.06	1.77	0.5	6.19	56.15
Hobsonia florida	1.1	1.39	0.51	4.87	61.02
Grandidierella bonnieroides	0.82	1.31	0.51	4.6	65.62
Cyathura polita	0.76	1.24	0.52	4.35	69.97
Dero digitata complex Milligan	0.98	1.2	0.36	4.19	74.17
Apocorophium louisianum	0.76	1.16	0.52	4.07	78.24
Pristina leidyi	0.87	0.94	0.37	3.3	81.54

Groups Gulf & Crystal River
Average dissimilarity = 90.17

Species	Group Gulf Av.Abund	Group Crystal River Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
Glycinde solitaria	1.43	0	2.47	3.71	2.74	2.74
Aricidea taylori	1.61	0.15	2.4	1.5	2.66	5.4
Mediomastus ambiseta	1.3	0.08	2.08	3.28	2.31	7.71
Ampelisca abdita	0	1.23	2.01	0.91	2.23	9.94
Mooreonuphis nebulosa	1.14	0.1	1.97	1.51	2.18	12.12
Haminoea succinea	1.02	0	1.92	1.43	2.13	14.25
Laeonereis culveri	0.25	1.08	1.83	1.01	2.03	16.28
Ampelisca sp. C LeCroy	1.02	0.22	1.8	1.39	2	18.27
Hobsonia florida	0	1.09	1.77	0.94	1.97	20.24
Fabricinuda trilobata	0.98	0.08	1.7	1.53	1.89	22.13
Acteocina canaliculata	0.93	0.08	1.68	1.34	1.87	24
Cerapus benthophilus	0	1.11	1.65	0.6	1.83	25.83
Streblospio sp.	0.3	1.06	1.65	1.19	1.83	27.66
Halmyrapseudes cf. bahamensis Heard	0.25	0.93	1.56	0.96	1.73	29.39
Scoletoma verrilli	1.04	0.09	1.56	1.54	1.73	31.12
Magelona riojai	1.02	0.1	1.55	1.48	1.72	32.84
Cyrenoida floridana	0	0.95	1.52	0.56	1.69	34.53
Cyathura polita	0	0.88	1.49	1.1	1.65	36.18
Heteromastus filiformis	0.88	0.28	1.48	1.42	1.64	37.83
Monticellina sp.	0.96	0.19	1.46	1.02	1.62	39.45
Apocorophium louisianum	0.25	0.94	1.46	0.55	1.62	41.07
Rhithropanopeus harrisii	0	0.81	1.43	1.08	1.59	42.65
Scoloplos rubra	0.8	0.08	1.4	1.42	1.55	44.2
Aricidea philbinae	0.95	0.18	1.39	1.46	1.55	45.75
Nemertea (LPIL)	1.25	0.56	1.38	1.26	1.53	47.28
Tubificoid Naididae (LPIL)	0.37	0.73	1.33	0.86	1.48	48.75
Leitoscoloplos fragilis	0.66	0	1.14	0.96	1.27	50.02
Aoridae (LPIL)	0.6	0.46	1.12	1.05	1.24	51.26
Sabellinae (LPIL)	0.65	0	1.01	0.97	1.12	52.38
Taphromysis bowmani	0.33	0.28	1	0.72	1.11	53.49
Aricidea catherinae	0.68	0	0.99	0.97	1.1	54.6
Syllis sp.	0.5	0.07	0.98	0.94	1.09	55.68
Maldanidae (LPIL)	0.5	0	0.95	0.92	1.05	56.74
Crepidula fornicata	0.6	0.08	0.95	0.98	1.05	57.78
Actiniaria (LPIL)	0.25	0.44	0.93	0.83	1.03	58.82
Ogyrides alphaerostris	0.62	0.09	0.93	0.97	1.03	59.85
Xenanthura brevitelson	0.25	0.43	0.89	0.81	0.99	60.84
Prionospio heterobranchia	0.55	0	0.89	0.94	0.99	61.83
Cyclaspis varians	0.3	0.41	0.87	0.77	0.97	62.8
Paraprionospio sp.	0.58	0	0.84	0.96	0.93	63.73
Melita nitida complex LeCroy	0.25	0.32	0.8	0.67	0.89	64.61
Liljeborgia sp.	0.25	0.3	0.79	0.77	0.87	65.49
Axiothella sp.	0.43	0	0.75	0.56	0.83	66.32
Angulus versicolor	0.33	0.28	0.74	0.79	0.82	67.14
Lysilla sp.	0.5	0	0.73	0.97	0.81	67.95
Tubificoides sp.	0	0.46	0.71	0.47	0.79	68.74
Eteone heteropoda	0.3	0.21	0.67	0.71	0.74	69.48
Polypedilum scalaenum group Epler	0	0.38	0.65	0.54	0.72	70.2
Crepidula plana	0.25	0.19	0.65	0.64	0.72	70.92
Americorophium ellisi	0	0.3	0.63	0.48	0.7	71.62
Astyris lunata	0.35	0.08	0.6	0.61	0.66	72.29
Transennella conradina	0.25	0	0.57	0.55	0.64	72.92
Nasageneia bacescui	0.41	0	0.57	0.57	0.63	73.55
Bittium varium	0.41	0	0.57	0.57	0.63	74.19
Paradialychone sp.	0.35	0.09	0.57	0.62	0.63	74.82
Americamysis almyra	0	0.33	0.55	0.58	0.62	75.43
Sayella sp.	0	0.34	0.54	0.56	0.6	76.03
Polydora cornuta	0.37	0	0.53	0.57	0.58	76.61
Leptochelia sp.	0	0.28	0.52	0.48	0.57	77.19
Eupolymnia sp.	0.3	0	0.52	0.56	0.57	77.76
Edotia triloba	0	0.36	0.5	0.46	0.55	78.31
Boccardiella sp.	0.25	0.09	0.49	0.6	0.55	78.86
Caridea (LPIL)	0.25	0.07	0.48	0.61	0.53	79.39
Melinna sp.	0.3	0	0.45	0.56	0.5	79.89
Galathowenia oculata	0.25	0	0.43	0.56	0.48	80.37

Groups Gulf & Kings Bay
Average dissimilarity = 98.65

	Group Gulf	Group Kings Bay				
Species	Av.Abund	Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
Littoridinops sp.	0	1.74	2.92	1.32	2.96	2.96
Glycinde solitaria	1.43	0	2.59	3.95	2.63	5.59
Aricidea taylori	1.61	0	2.55	1.57	2.59	8.18
Gammarus sp. B LeCroy	0	1.34	2.32	1.64	2.35	10.53
Mediomastus ambiseta	1.3	0	2.29	6.05	2.32	12.85
Nemertea (LPIL)	1.25	0	2.24	4.53	2.27	15.12
Limnodrilus hoffmeisteri	0	1.27	2.22	0.91	2.26	17.37
Laeonereis culveri	0.25	1.3	2.13	1.1	2.16	19.53
Mooreonuphis nebulosa	1.14	0	2.12	1.6	2.15	21.68
Cyrenoida floridana	0	1.23	2.11	1.12	2.14	23.82
Haminoea succinea	1.02	0	2.02	1.44	2.05	25.88
Ampelisca sp. C LeCroy	1.02	0	1.99	1.51	2.02	27.9
Tubificoid Naididae imm. w/o hair setae (LPIL)	0	1.06	1.94	0.87	1.97	29.86
Fabricinuda trilobata	0.98	0	1.84	1.63	1.87	31.73
Dero digitata complex Milligan	0	0.98	1.84	0.69	1.87	33.6
Hobsonia florida	0	1.1	1.84	0.87	1.86	35.46
Acteocina canaliculata	0.93	0	1.84	1.42	1.86	37.32
Heteromastus filiformis	0.88	0	1.68	1.59	1.7	39.02
Scoletoma verrilli	1.04	0	1.66	1.61	1.68	40.71
Magelona riojai	1.02	0	1.64	1.54	1.67	42.38
Aricidea philbinae	0.95	0	1.53	1.65	1.55	43.93
Pristina leidyi	0	0.87	1.53	0.72	1.55	45.48
Scoloplos rubra	0.8	0	1.52	1.52	1.54	47.01
Monticellina sp.	0.96	0	1.47	0.96	1.49	48.5
Grandidierella bonnieroides	0	0.82	1.47	0.88	1.49	49.99
Cyathura polita	0	0.76	1.32	0.93	1.34	51.33
Apocorophium louisianum	0.25	0.76	1.32	0.99	1.33	52.67
Pyrgophorus platyrachis	0	0.77	1.25	0.52	1.27	53.94
Leitoscoloplos fragilis	0.66	0	1.2	0.96	1.22	55.16
Chironomus sp.	0	0.62	1.07	0.75	1.08	56.24
Syllis sp.	0.5	0	1.06	0.94	1.08	57.32
Sabellinae (LPIL)	0.65	0	1.06	0.97	1.07	58.39
Aricidea catherinae	0.68	0	1.04	0.97	1.05	59.44
Maldanidae (LPIL)	0.5	0	1	0.92	1.02	60.46
Dicrotendipes sp.	0	0.6	0.99	0.75	1	61.46
Aoridae (LPIL)	0.6	0	0.97	0.97	0.99	62.45
Crepidula fornicata	0.6	0	0.97	0.97	0.99	63.43
Psammoryctides convolutus	0	0.55	0.96	0.61	0.97	64.4
Streblospio sp.	0.3	0.44	0.94	0.89	0.96	65.36
Ogyrides alphaerostris	0.62	0	0.94	0.95	0.96	66.32
Prionospio heterobranchia	0.55	0	0.94	0.95	0.95	67.26
Paraprionospio sp.	0.58	0	0.88	0.96	0.89	68.15
Taphromysis bowmani	0.33	0.1	0.86	0.62	0.88	69.03
Procladius (Holotanypus) sp.	0	0.5	0.86	0.75	0.87	69.9
Cerapus benthophilus	0	0.44	0.8	0.6	0.81	70.71
Mytilopsis leucophaeata	0	0.49	0.79	0.62	0.81	71.51
Axiothella sp.	0.43	0	0.79	0.56	0.8	72.31
Lysilla sp.	0.5	0	0.76	0.97	0.77	73.08
Opistocystidae (LPIL)	0	0.34	0.68	0.48	0.69	73.77
Rhithropanopeus harrisii	0	0.38	0.65	0.62	0.66	74.43
Actiniaria (LPIL)	0.25	0	0.61	0.56	0.62	75.05
Liljeborgia sp.	0.25	0	0.61	0.56	0.62	75.66
Halmyrapseudes cf. bahamensis Heard	0.25	0	0.61	0.56	0.62	76.28
Transennella conradina	0.25	0	0.61	0.56	0.62	76.9
Nasageneia bacescui	0.41	0	0.6	0.57	0.6	77.5
Bittium varium	0.41	0	0.6	0.57	0.6	78.11
Polydora cornuta	0.37	0	0.55	0.57	0.55	78.66
Tubificoid Naididae (LPIL)	0.37	0	0.55	0.57	0.55	79.22
Cyclaspis varians	0.3	0.1	0.54	0.65	0.55	79.77
Eteone heteropoda	0.3	0	0.54	0.56	0.55	80.31

Groups Crystal River & Kings Bay
Average dissimilarity = 86.82

Species	Group Crystal River Av.Abund	Group Kings Bay Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
Littoridinops sp.	0.16	1.74	3.49	1.31	4.02	4.02
Cyrenoida floridana	0.95	1.23	3.01	1.05	3.47	7.48
Hobsonia florida	1.09	1.1	2.74	1.18	3.15	10.63
Gammarus sp. B LeCroy	0.07	1.34	2.73	1.59	3.15	13.78
Laeonereis culveri	1.08	1.3	2.7	1.13	3.11	16.89
Limnodrilus hoffmeisteri	0	1.27	2.7	0.91	3.11	20
Ampelisca abdita	1.23	0	2.53	0.93	2.92	22.91
Tubificoid Naididae imm. w/o hair setae (LPIL)	0.11	1.06	2.4	0.89	2.77	25.68
Cerapus benthophilus	1.11	0.44	2.38	0.77	2.74	28.42
Apocorophium louisianum	0.94	0.76	2.34	0.78	2.69	31.11
Dero digitata complex Milligan	0	0.98	2.28	0.69	2.62	33.73
Streblospio sp.	1.06	0.44	2	1.25	2.3	36.03
Grandidierella bonnieroides	0.25	0.82	1.91	0.95	2.2	38.23
Pristina leidyi	0	0.87	1.87	0.71	2.15	40.38
Cyathura polita	0.88	0.76	1.86	1.1	2.14	42.52
Halmyrapseudes cf. bahamensis Heard	0.93	0	1.84	0.8	2.11	44.64
Pyrgophorus platyrachis	0.17	0.77	1.78	0.63	2.05	46.69
Rhithropanopeus harrisii	0.81	0.38	1.75	1.07	2.02	48.71
Tubificoid Naididae (LPIL)	0.73	0	1.5	0.74	1.73	50.43
Chironomus sp.	0	0.62	1.29	0.76	1.48	51.91
Dicrotendipes sp.	0	0.6	1.19	0.75	1.37	53.28
Psammoryctides convolutus	0	0.55	1.16	0.6	1.34	54.62
Polypedilum scalaenum group Epler	0.38	0.29	1.13	0.71	1.3	55.92
Nemertea (LPIL)	0.56	0	1.08	0.91	1.25	57.17
Procladius (Holotanypus) sp.	0	0.5	1.04	0.75	1.19	58.36
Americorophium ellisi	0.3	0.12	1.01	0.58	1.16	59.52
Mytilopsis leucophaeata	0	0.49	0.95	0.63	1.1	60.62
Aoridae (LPIL)	0.46	0	0.95	0.68	1.09	61.72
Cyclaspis varians	0.41	0.1	0.93	0.66	1.07	62.79
Tubificoides sp.	0.46	0	0.89	0.48	1.03	63.81
Opistocystidae (LPIL)	0	0.34	0.85	0.48	0.98	64.8
Actiniaria (LPIL)	0.44	0	0.85	0.65	0.98	65.77
Xenanthura brevitelson	0.43	0	0.84	0.58	0.97	66.74
Taphromysis bowmani	0.28	0.1	0.8	0.53	0.92	67.65
Melita nitida complex LeCroy	0.32	0	0.78	0.48	0.9	68.55
Coelotanypus concinnus group Epler	0.13	0.22	0.78	0.54	0.9	69.45
Edotia triloba	0.36	0.1	0.76	0.56	0.87	70.32
Americamysis almyra	0.33	0	0.7	0.59	0.81	71.13
Leptochelia sp.	0.28	0	0.68	0.48	0.78	71.9
Sayella sp.	0.34	0	0.67	0.57	0.78	72.68
Leptochelia rapax	0.07	0.32	0.67	0.56	0.77	73.45
Liljeborgia sp.	0.3	0	0.66	0.57	0.76	74.21
Tubificoid Naididae imm. w/ hair setae (LPIL)	0	0.26	0.64	0.47	0.74	74.95
Piona sp.	0	0.3	0.63	0.47	0.72	75.67
Angulus versicolor	0.28	0	0.55	0.58	0.63	76.31
Neanthes succinea	0.26	0	0.54	0.48	0.62	76.93
Heteromastus filiformis	0.28	0	0.51	0.48	0.59	77.52
Callianassidae (LPIL)	0.26	0	0.5	0.49	0.58	78.1
Uromunna reynoldsi	0	0.26	0.49	0.48	0.57	78.67
Crassostrea virginica	0.23	0	0.48	0.36	0.56	79.22
Porcellanidae (LPIL)	0.17	0	0.45	0.37	0.52	79.75
Monopylephorus rubroniveus	0	0.23	0.45	0.47	0.52	80.26

Table C-1. Crystal River Macroinvertebrate Data

Twenty-five Taxa Identified by the Primer SIMPER Procedure as Contributing Most to the Dissimilarity Between the Crystal River and Gulf Groups

Average dissimilarity = 90.17 Species	Group - Gulf Average Abundance	Group - Crystal River Average Abundance	Average Dissimilarity	Dissimilarity Standard Dev.	Percent Contribution	Cumulative % Contribution
Glycinde solitaria	1.43	0	2.47	3.71	2.74	2.74
Aricidea taylori	1.61	0.15	2.4	1.5	2.66	5.4
Mediomastus ambiseta	1.3	0.08	2.08	3.28	2.31	7.71
Ampelisca abdita	0	1.23	2.01	0.91	2.23	9.94
Mooreonuphis nebulosa	1.14	0.1	1.97	1.51	2.18	12.12
Haminoea succinea	1.02	0	1.92	1.43	2.13	14.25
Laeonereis culveri	0.25	1.08	1.83	1.01	2.03	16.28
Ampelisca sp. C Lecroy	1.02	0.22	1.8	1.39	2	18.27
Hobsonia florida	0	1.09	1.77	0.94	1.97	20.24
Fabricinuda trilobata	0.98	0.08	1.7	1.53	1.89	22.13
Acteocina canaliculata	0.93	0.08	1.68	1.34	1.87	24
Cerapus benthophilus	0	1.11	1.65	0.6	1.83	25.83
Streblospio sp.	0.3	1.06	1.65	1.19	1.83	27.66
Halmyrapseudes cf. bahamensis Heard	0.25	0.93	1.56	0.96	1.73	29.39
Scoletoma verrilli	1.04	0.09	1.56	1.54	1.73	31.12
Magelona riojai	1.02	0.1	1.55	1.48	1.72	32.84
Cyrenoida floridana	0	0.95	1.52	0.56	1.69	34.53
Cyathura polita	0	0.88	1.49	1.1	1.65	36.18
Heteromastus filiformis	0.88	0.28	1.48	1.42	1.64	37.83
Monticellina sp.	0.96	0.19	1.46	1.02	1.62	39.45
Apocorophium louisianum	0.25	0.94	1.46	0.55	1.62	41.07
Rhithropanopeus harrisii	0	0.81	1.43	1.08	1.59	42.65
Scoloplos rubra	0.8	0.08	1.4	1.42	1.55	44.2
Aricidea philbinae	0.95	0.18	1.39	1.46	1.55	45.75
Nemertea (LPIL)	1.25	0.56	1.38	1.26	1.53	47.28

Table C-2. Crystal River Macroinvertebrate Data

Twenty-five Taxa Identified by the Primer SIMPER Procedure as Contributing Most to the Dissimilarity Between the Kings Bay and Gulf Groups

	Group - Gulf	**Group - Kings Bay**				
Average dissimilarity = 98.65	**Average**	**Average**	**Average**	**Dissimilarity**	**Percent**	**Cumulative**
Species	**Abundance**	**Abundance**	**Dissimilarity**	**Standard Dev.**	**Contribution**	**% Contribution**
Littoridinops sp.	0	1.74	2.92	1.32	2.96	2.96
Glycinde solitaria	1.43	0	2.59	3.95	2.63	5.59
Aricidea taylori	1.61	0	2.55	1.57	2.59	8.18
Gammarus sp. B Lecroy	0	1.34	2.32	1.64	2.35	10.53
Mediomastus ambiseta	1.3	0	2.29	6.05	2.32	12.85
Nemertea (LPIL)	1.25	0	2.24	4.53	2.27	15.12
Limnodrilus hoffmeisteri	0	1.27	2.22	0.91	2.26	17.37
Laeonereis culveri	0.25	1.3	2.13	1.1	2.16	19.53
Mooreonuphis nebulosa	1.14	0	2.12	1.6	2.15	21.68
Cyrenoida floridana	0	1.23	2.11	1.12	2.14	23.82
Haminoea succinea	1.02	0	2.02	1.44	2.05	25.88
Ampelisca sp. C Lecroy	1.02	0	1.99	1.51	2.02	27.9
Tubificoid Naididae imm. w/o hair setae (LPIL)	0	1.06	1.94	0.87	1.97	29.86
Fabricinuda trilobata	0.98	0	1.84	1.63	1.87	31.73
Dero digitata complex Milligan	0	0.98	1.84	0.69	1.87	33.6
Hobsonia florida	0	1.1	1.84	0.87	1.86	35.46
Acteocina canaliculata	0.93	0	1.84	1.42	1.86	37.32
Heteromastus filiformis	0.88	0	1.68	1.59	1.7	39.02
Scoletoma verrilli	1.04	0	1.66	1.61	1.68	40.71
Magelona riojai	1.02	0	1.64	1.54	1.67	42.38
Aricidea philbinae	0.95	0	1.53	1.65	1.55	43.93
Pristina leidyi	0	0.87	1.53	0.72	1.55	45.48
Scoloplos rubra	0.8	0	1.52	1.52	1.54	47.01
Monticellina sp.	0.96	0	1.47	0.96	1.49	48.5
Grandidierella bonnieroides	0	0.82	1.47	0.88	1.49	49.99

Table C-3. Crystal River Macroinvertebrate Data

Twenty-five Taxa Identified by the Primer SIMPER Procedure as Contributing Most to the Dissimilarity Between the Crystal River and Kings Bay Groups

	Group - Crystal River	Group - Kings Bay				
Average dissimilarity = 86.82	**Average**	**Average**	**Average**	**Dissimilarity**	**Percent**	**Cumulative**
Species	**Abundance**	**Abundance**	**Dissimilarity**	**Standard Dev.**	**Contribution**	**% Contribution**
Littoridinops sp.	0.16	1.74	3.49	1.31	4.02	4.02
Cyrenoida floridana	0.95	1.23	3.01	1.05	3.47	7.48
Hobsonia florida	1.09	1.1	2.74	1.18	3.15	10.63
Gammarus sp. B LeCroy	0.07	1.34	2.73	1.59	3.15	13.78
Laeonereis culveri	1.08	1.3	2.7	1.13	3.11	16.89
Limnodrilus hoffmeisteri	0	1.27	2.7	0.91	3.11	20
Ampelisca abdita	1.23	0	2.53	0.93	2.92	22.91
Tubificoid Naididae imm. w/o hair setae (LPIL)	0.11	1.06	2.4	0.89	2.77	25.68
Cerapus benthophilus	1.11	0.44	2.38	0.77	2.74	28.42
Apocorophium louisianum	0.94	0.76	2.34	0.78	2.69	31.11
Dero digitata complex Milligan	0	0.98	2.28	0.69	2.62	33.73
Streblospio sp.	1.06	0.44	2	1.25	2.3	36.03
Grandidierella bonnieroides	0.25	0.82	1.91	0.95	2.2	38.23
Pristina leidyi	0	0.87	1.87	0.71	2.15	40.38
Cyathura polita	0.88	0.76	1.86	1.1	2.14	42.52
Halmyrapseudes cf. bahamensis Heard	0.93	0	1.84	0.8	2.11	44.64
Pyrgophorus platyrachis	0.17	0.77	1.78	0.63	2.05	46.69
Rhithropanopeus harrisii	0.81	0.38	1.75	1.07	2.02	48.71
Tubificoid Naididae (LPIL)	0.73	0	1.5	0.74	1.73	50.43
Chironomus sp.	0	0.62	1.29	0.76	1.48	51.91
Dicrotendipes sp.	0	0.6	1.19	0.75	1.37	53.28
Psammoryctides convolutus	0	0.55	1.16	0.6	1.34	54.62
Polypedilum scalaenum group Epler	0.38	0.29	1.13	0.71	1.3	55.92
Nemertea (LPIL)	0.56	0	1.08	0.91	1.25	57.17
Procladius (Holotanypus) sp.	0	0.5	1.04	0.75	1.19	58.36

Appendix D

USGS Gage Height and SWFWMD Historical Physicochemical Data

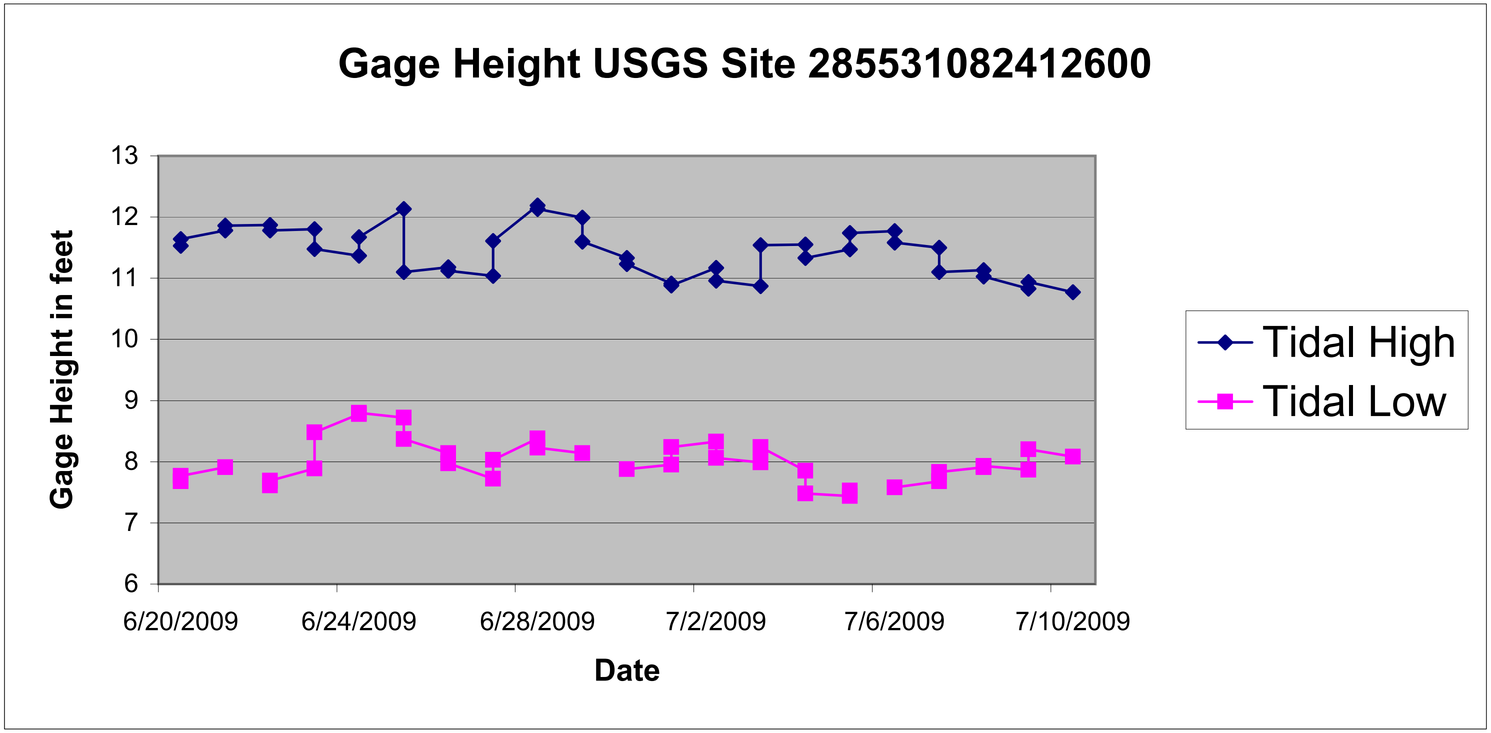


Figure D-1. Daily maxima and minima gage height data recorded for USGS station 285531082412600 at the mouth of the Crystal River for June 20 to July 24 2009.

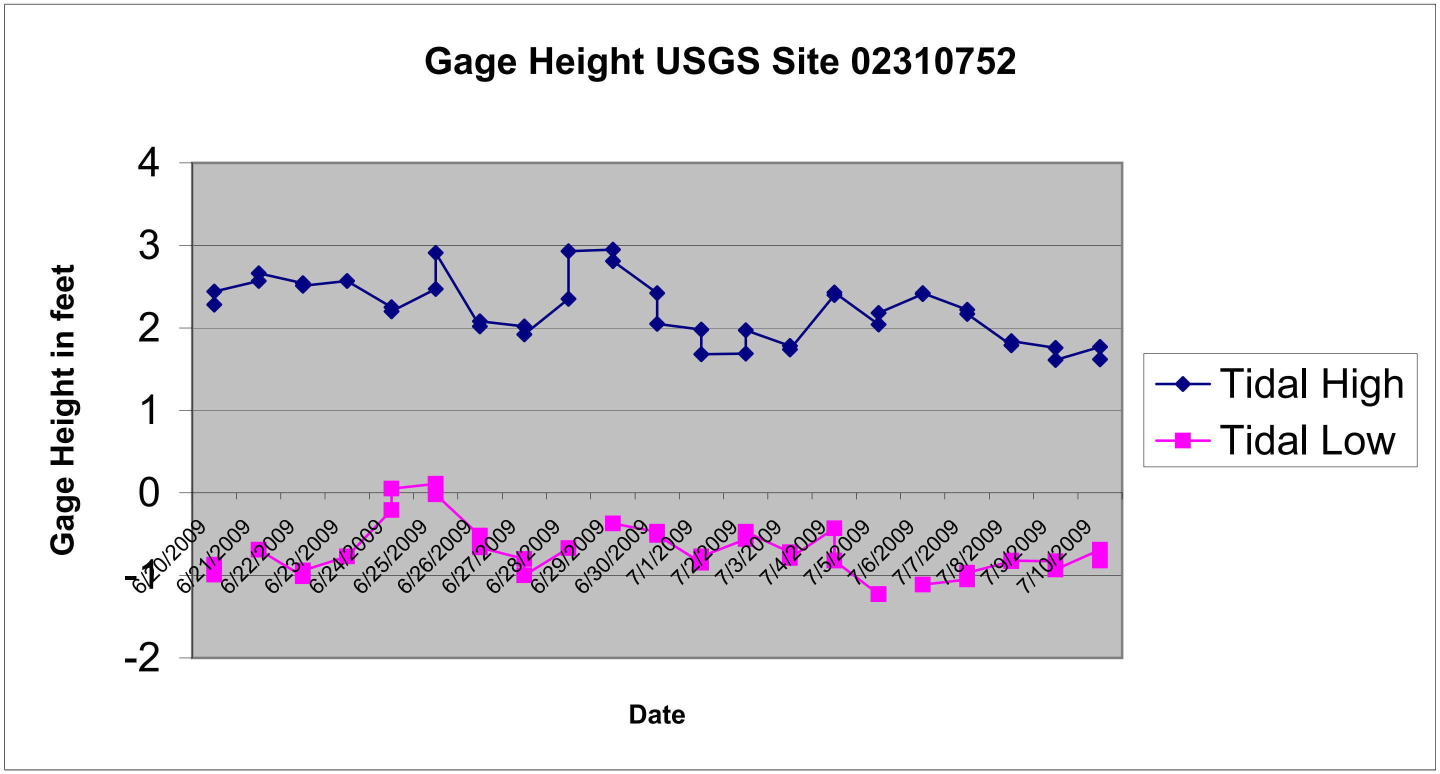


Figure D-2 Daily maxima and minima gage height data recorded for USGS station 02310752 at the mouth of the Salt River for June 20 to July 24 2009.

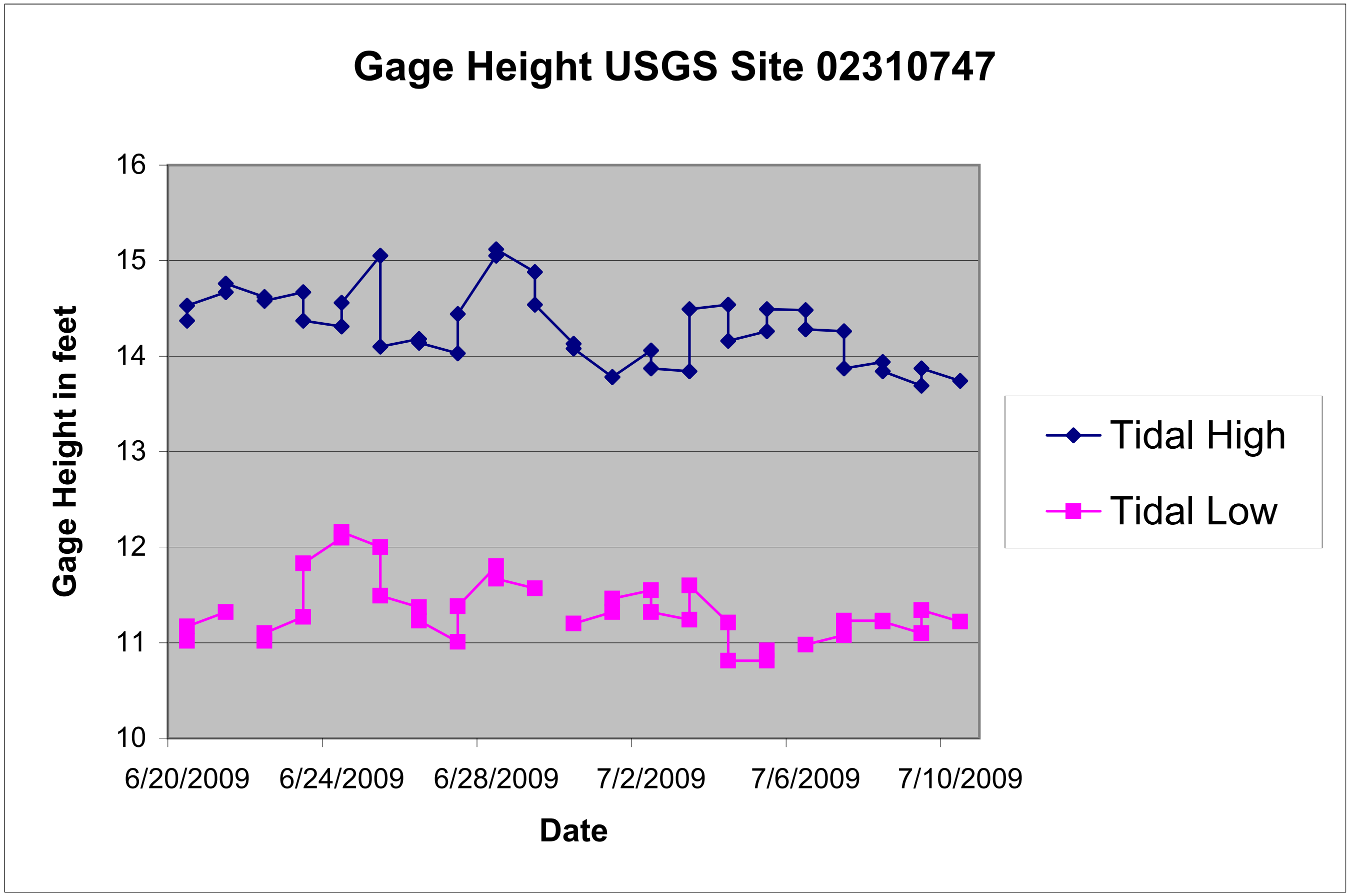


Figure D-3. Daily maxima and minima gage height data recorded for USGS station 02310747 at Bagley Cove in the Crystal River for June 20 to July 24 2009.

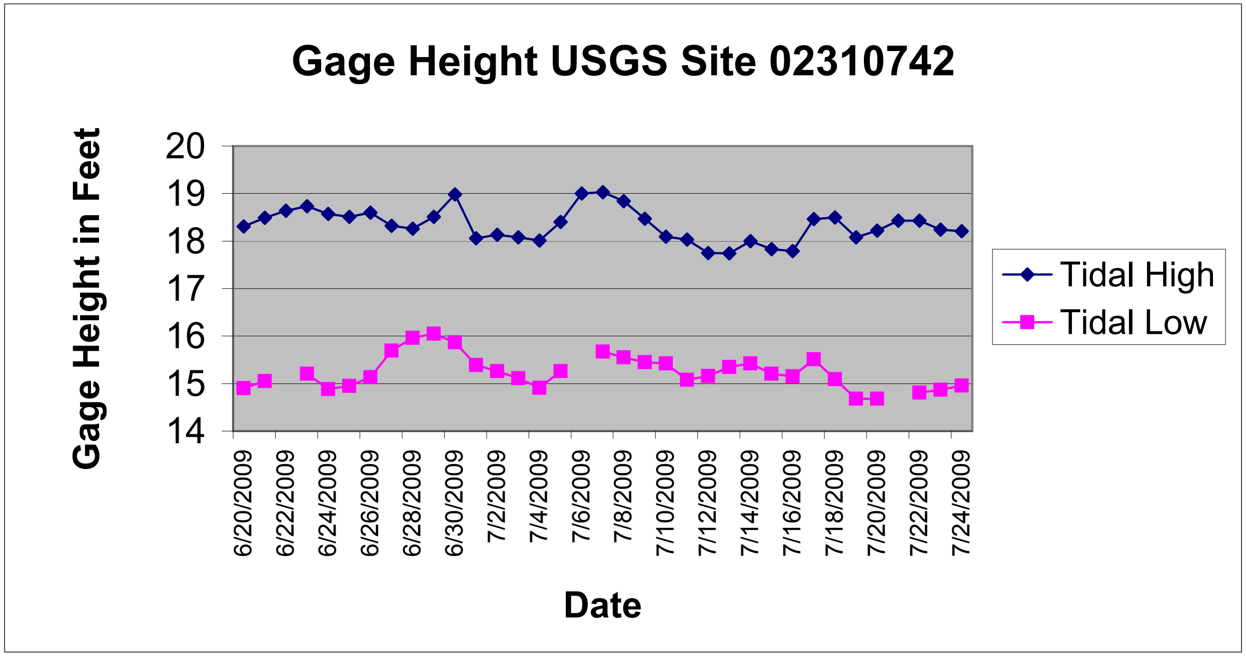


Figure D-4. Daily maxima and minima gage height data recorded for USGS station 02310308 at the mouth of Kings Bay for June 20 to July 24 2009.

Appendix E

Descriptive Statistics

Table E-1. Descriptive statistics for Crystal River bottom and mean profile salinity calculated from data provided by the Southwest Florida Water Management District for April 11 2008 through July 30 2009

Variable		**Mean**		**Minimum**		**Median**		**Maximum**
For all data & by Station	**Number of Observations**		**Standard Deviation**		**First Quartile**		**Third Quartile**	
All Bottom Salinity	79	9.813	7.104	1.17	3.6	7.48	15.16	26.65
All Mean Profile Salinity	79	9.813	7.104	1.17	3.6	7.48	15.16	26.65
1_Bottom Salinity	10	20.93	5.46	6.46	20.51	21.67	23.79	26.65
1_Mean Profile Salinity	10	20.93	5.46	6.46	20.51	21.67	23.79	26.65
2_Bottom Salinity	10	16.51	4.4	8.64	13.9	17.01	19.38	22.63
2_Mean Profile Salinity	10	16.51	4.4	8.64	13.9	17.01	19.38	22.63
3_Bottom Salinity	10	12.62	4.67	3.6	10.42	13.13	15.68	18.9
3_Mean Profile Salinity	10	12.62	4.67	3.6	10.42	13.13	15.68	18.9
4_Bottom Salinity	10	9.57	4.18	3.54	6.09	9.3	13.02	15.75
4_Mean Profile Salinity	10	9.57	4.18	3.54	6.09	9.3	13.02	15.75
5_Bottom Salinity	10	7.691	2.902	2.7	5.46	7.545	9.795	12.65
5_Mean Profile Salinity	10	7.691	2.902	2.7	5.46	7.545	9.795	12.65
6_Bottom Salinity	10	5.035	1.921	1.29	3.805	5	6.493	7.77
6_Mean Profile Salinity	10	5.035	1.921	1.29	3.805	5	6.493	7.77
7_Bottom Salinity	9	2.884	1.775	1.19	1.31	2.74	3.7	6.79
7_Mean Profile Salinity	9	2.884	1.775	1.19	1.31	2.74	3.7	6.79
8_Bottom Salinity	10	2.574	1.273	1.17	1.395	2.37	3.413	5.23
8_Mean Profile Salinity	10	2.574	1.273	1.17	1.395	2.37	3.413	5.23

Table E-2. Descriptive statistics for Crystal River Sediment Data for Samples collected by Water and Air Research, Inc. July 2009 For all Sites and by Sub Area.

Variable		Mean	Minimum			Median		Maximum
	Number of Observations		Standard Deviation		First Quartile		Third Quartile	
%>3 Inch	20	0	0	0	0	0	0	0
% Coarse Gravel	20	0	0	0	0	0	0	0
% Fine Gravel	20	0.025	0.091	0	0	0	0	0.4
% Coarse Sand	20	0.425	0.604	0	0.025	0.2	0.575	2.4
% Medium Sand	20	2.74	6.5	0.2	0.7	1.05	1.5	30.1
% Fine Sand	20	56.06	21.13	0.9	44	63.5	71.08	78.8
% Silt	20	31.37	17.06	13.9	19.6	24.5	37.98	75.1
% Clay	20	9.15	6.18	4	5.63	7.1	11	32.8
% Silt+Clay	20	40.52	20.81	20.2	27.35	33.6	45.18	98.8
Percent Organics	20	4.31	5.77	1	1.9	2.6	4.15	27.5
%>3 Inch_Gulf	4	0	0	0	0	0	0	0
% Coarse Gravel_Gulf	4	0	0	0	0	0	0	0
% Fine Gravel_Gulf	4	0.1	0.2	0	0	0	0.3	0.4
% Coarse Sand_Gulf	4	0.45	0.404	0.1	0.125	0.35	0.875	1
% Medium Sand_Gulf	4	1.7	1.458	0.5	0.625	1.25	3.225	3.8
% Fine Sand_Gulf	4	60.35	4.58	54.1	55.8	61.1	64.15	65.1
% Silt_Gulf	4	25.8	3.98	22.5	22.7	24.7	30	31.3
% Clay_Gulf	4	11.6	1.12	10.2	10.45	11.8	12.55	12.6
% Silt+Clay_Gulf	4	37.4	4.91	33.5	33.55	36.1	42.55	43.9
Percent Organics_Gulf	4	3.625	0.499	3.2	3.225	3.5	4.15	4.3
%>3 Inch_CR	5	0	0	0	0	0	0	0
% Coarse Gravel_CR	5	0	0	0	0	0	0	0
% Fine Gravel_CR	5	0	0	0	0	0	0	0
% Coarse Sand_CR	5	0.62	0.526	0.1	0.2	0.4	1.15	1.4
% Medium Sand_CR	5	1.18	0.876	0.5	0.6	1	1.85	2.7
% Fine Sand_CR	5	69.84	6.7	62.8	63.7	68.6	76.6	78.8
% Silt_CR	5	19.74	4.63	13.9	15.7	18.5	24.4	25.3
% Clay_CR	5	7.68	1.941	6.3	6.55	7	9.15	11.1
% Silt+Clay_CR	5	27.42	4.91	20.2	22.45	29.6	31.3	32.3
Percent Organics_CR	5	2.5	0.663	1.9	1.9	2.5	3.1	3.5
%>3 Inch_KB	11	0	0	0	0	0	0	0
% Coarse Gravel_KB	11	0	0	0	0	0	0	0
% Fine Gravel_KB	11	0.00909	0.03015	0	0	0	0	0.1
% Coarse Sand_KB	11	0.327	0.71	0	0	0.1	0.2	2.4
% Medium Sand_KB	11	3.82	8.74	0.2	0.7	1.2	1.5	30.1
% Fine Sand_KB	11	48.24	25.59	0.9	32.3	50.9	71.9	76.6
% Silt_KB	11	38.68	20.02	17.7	20.2	30.6	56.2	75.1
% Clay_KB	11	8.93	8.19	4	5.2	6.4	9.6	32.8
% Silt+Clay_KB	11	47.61	25.71	22.2	26.6	34.6	66.9	98.8
Percent Organics_KB	11	5.37	7.74	1	1.5	2	6.7	27.5

CR - Crystal River Transect; KB - Kings Bay.

Table E-3. Descriptive statistics for Crystal River Project mean profile physicochemical data for sampling sub-areas calculated from data collected by Water and Air Research, Inc. July 2009.

Variable		Mean		Minimum		Median		Maximum
Variables presented separately by sub-area	**Number of Observations**		**Standard Deviation**		**First Quartile**		**Third Quartile**	
Temperature_Crystal River	5	28.9	0.5	28.2	28.5	28.8	29.4	29.4
pH_Crystal River	5	7.74	0.12	7.56	7.62	7.80	7.83	7.83
Specific Conductance_Crystal River	5	10842	6107	7022	7289	8028	15802	21575
Salinity_Crystal River	5	6.2	3.8	3.9	4.1	4.5	9.3	12.9
Dissolved Oxygen (% Saturation)_Crystal River	5	73.1	6.2	64.5	68.0	71.8	78.9	80.5
Dissolved Oxygen (mg/L)_Crystal River	5	5.42	0.50	4.81	4.94	5.43	5.89	6.05
Total Depth_Crystal River	5	3.4	0.7	2.4	2.8	3.4	4.1	4.2
% Silt+Clay_Crystal River	5	27.4	4.9	20.2	22.5	29.6	31.3	32.3
Temperature_Gulf	4	30.1	0.3	29.8	29.8	30.1	30.4	30.4
pH_Gulf	4	8.02	0.08	7.92	7.94	8.04	8.09	8.09
Specific Conductance_Gulf	4	28421	2123	26472	26543	28265	30456	30684
Salinity_Gulf	4	17.6	1.4	16.2	16.3	17.6	18.9	19.0
Dissolved Oxygen (% Saturation)_Gulf	4	91.0	10.3	78.3	80.4	93.1	99.4	99.5
Dissolved Oxygen (mg/L)_Gulf	4	6.16	0.63	5.37	5.51	6.29	6.66	6.67
Total Depth_Gulf	4	2.1	0.3	1.8	1.9	2.1	2.4	2.4
% Silt+Clay_Gulf	4	37.4	4.9	33.5	33.6	36.1	42.6	43.9
Temperature_Kings Bay	10	28.0	0.9	26.6	27.0	28.0	28.6	29.5
pH_Kings Bay	10	8.4	0.4	8.0	8.2	8.4	8.7	9.1
Specific Conductance_Kings Bay	10	3524	1771	596	2113	3870	4364	6966
Salinity_Kings Bay	10	1.9	1.0	0.3	1.1	2.1	2.4	3.9
Dissolved Oxygen (% Saturation)_Kings	10	113.2	23.1	75.7	100.6	111.5	130.2	155.4
Dissolved Oxygen (mg/L)_Kings Bay	10	8.83	1.80	6.21	7.79	8.54	10.14	12.31
Total Depth_Kings Bay	10	1.8	1.0	0.8	1.0	1.5	2.9	3.3
% Silt+Clay_Kings Bay	10	49.0	26.7	22.2	26.1	40.1	70.9	98.8

Table E-4. Descriptive statistics for all Crystal River Project Unpooled Ponar Metrics.

Variable		Mean		Minimum		Median		Maximum
	Number of Observations		Standard Deviation		First Quartile		Third Quartile	
Number of Taxa	29	17.07	7.61	6	11	16	20	34
Number of Individuals	29	648	2398	24	88	129	325	13068
Margalef's d	29	3.294	1.638	0.95	2.014	3.001	4.036	6.846
Pielou's Evenness	29	0.714	0.1426	0.3487	0.6078	0.6987	0.8446	0.9239
Shannon Diversity (loge)	29	1.975	0.576	0.92	1.496	1.995	2.337	3.044
Shannon Diversity (log2)	29	2.849	0.831	1.328	2.158	2.879	3.372	4.391
Shannon Diversity (log10	29	0.858	0.2502	0.3996	0.6496	0.8666	1.015	1.3218
Simpsons d (1-λ)	29	0.754	0.1358	0.3666	0.6613	0.7647	0.8746	0.9367

Table E-5. Descriptive statistics for all Crystal River Project Stations Pooled Ponar Metrics.

Variable		Mean		Minimum		Median		Maximum
	Number of Observations		Standard Deviation		First Quartile		Third Quartile	
Number of Taxa	9	36.78	16.08	22.00	25.00	32.00	47.50	71.00
Number of Individuals	9	2087.00	4242.00	201.00	312.00	617.00	1310.00	13340.00
Margalef's d	9	5.68	3.08	2.21	3.59	4.98	7.96	11.66
Pielou's Evenness	9	0.68	0.12	0.46	0.61	0.68	0.79	0.87
Shannon Diversity (loge)	9	2.44	0.65	1.43	2.16	2.19	2.99	3.47
Shannon Diversity (log2)	9	3.52	0.94	2.07	3.11	3.16	4.31	5.01
Shannon Diversity (log10	9	1.06	0.28	0.62	0.94	0.95	1.30	1.51
Simpsons d (1-λ)	9	0.83	0.08	0.70	0.77	0.83	0.91	0.96

Table E-6. Descriptive statistics for Crystal River Project unpooled macroinvertebrate Ponar metrics for sampling sub-areas.

Variable		Mean	Minimum			Median		Maximum
Variables presented separately by sub-area	**Number of Observations**		**Standard Deviation**		**First Quartile**		**Third Quartile**	
Number of Taxa_Crystal River	15	16.73	6.73	6.00	11.00	17.00	20.00	32.00
Number of Individuals_Crystal River	15	1011	3337	24	63	123	294	13068
Pielous Evenness_Crystal River	15	0.73	0.12	0.50	0.64	0.74	0.85	0.92
Shannon Diversity (log2)_Crystal River	15	2.88	0.68	1.78	2.34	2.97	3.22	4.30
Number of Taxa_Gulf	4	28.50	7.55	18.00	20.50	31.00	34.00	34.00
Number of Individuals_Gulf	4	101	63	33	43	98	164	177
Pielous Evenness_Gulf	4	0.87	0.06	0.79	0.81	0.88	0.92	0.92
Shannon Diversity (log2)_Gulf	4	4.13	0.25	3.82	3.88	4.15	4.36	4.39
Number of Taxa_Kings Bay	10	13.00	3.71	8.00	9.75	13.00	15.50	20.00
Number of Individuals_Kings Bay	10	321	303	28	121	240	408	1074
Pielous Evenness_Kings Bay	10	0.63	0.15	0.35	0.53	0.63	0.73	0.86
Shannon Diversity (log2)_Kings Bay	10	2.30	0.58	1.33	1.95	2.16	2.72	3.35

Appendix F

July 2009 Salinity and Dissolved Oxygen Data

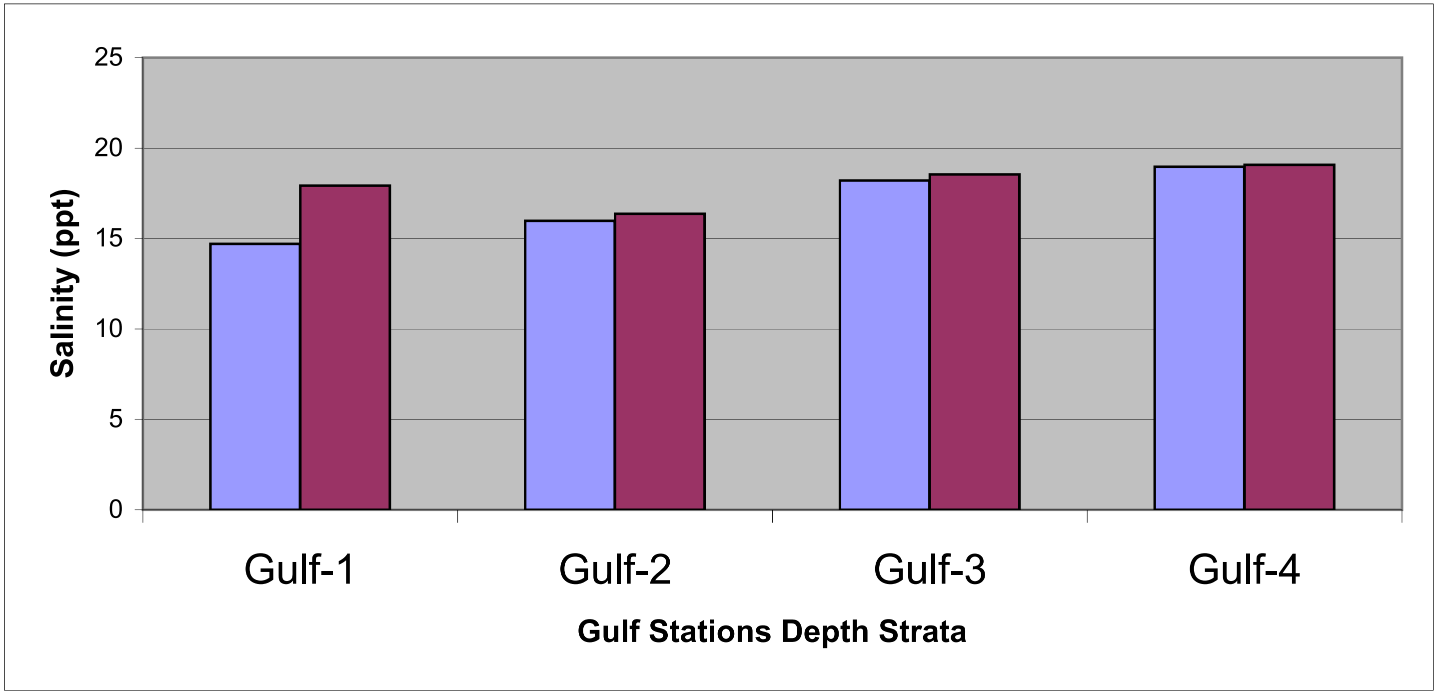


Figure F-1. Top and Bottom Salinity Strata for Gulf Stations July 2009.

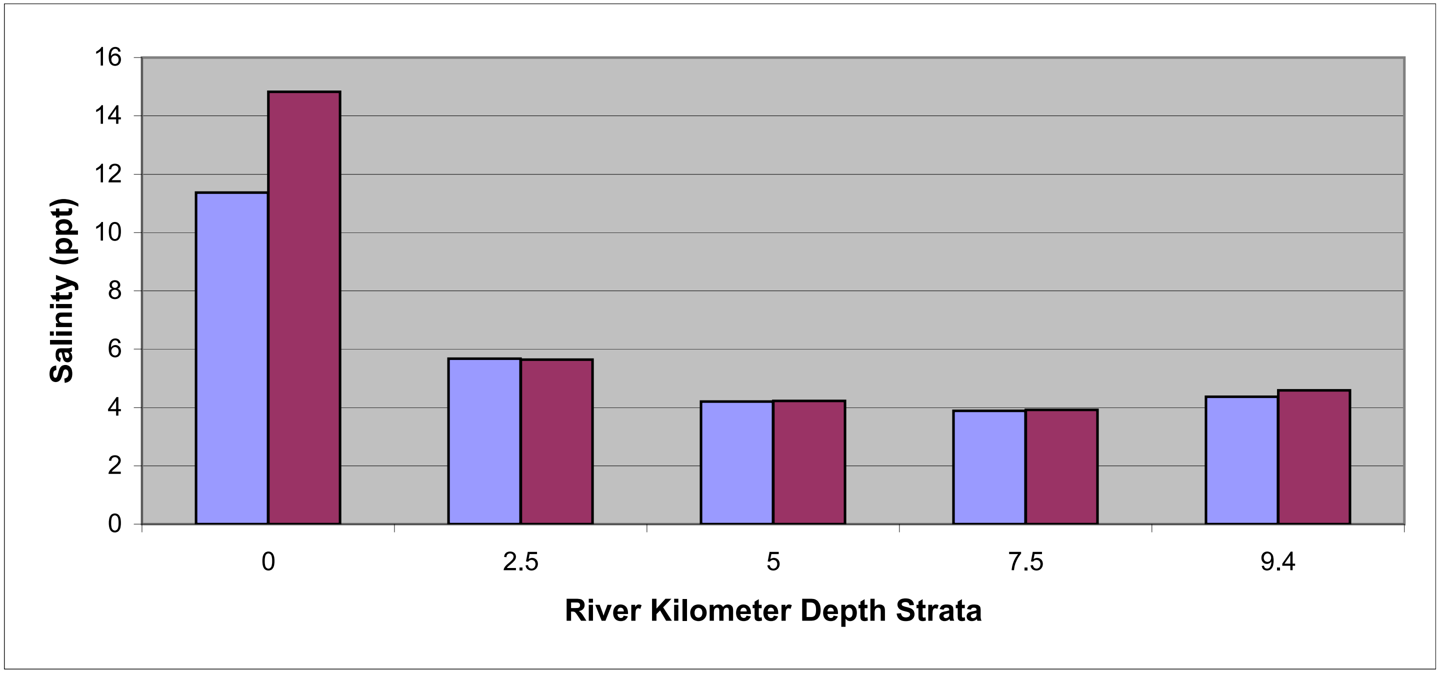


Figure F-2. Salinity for River Kilometer Top and Bottom Strata for the Crystal River July 2009.

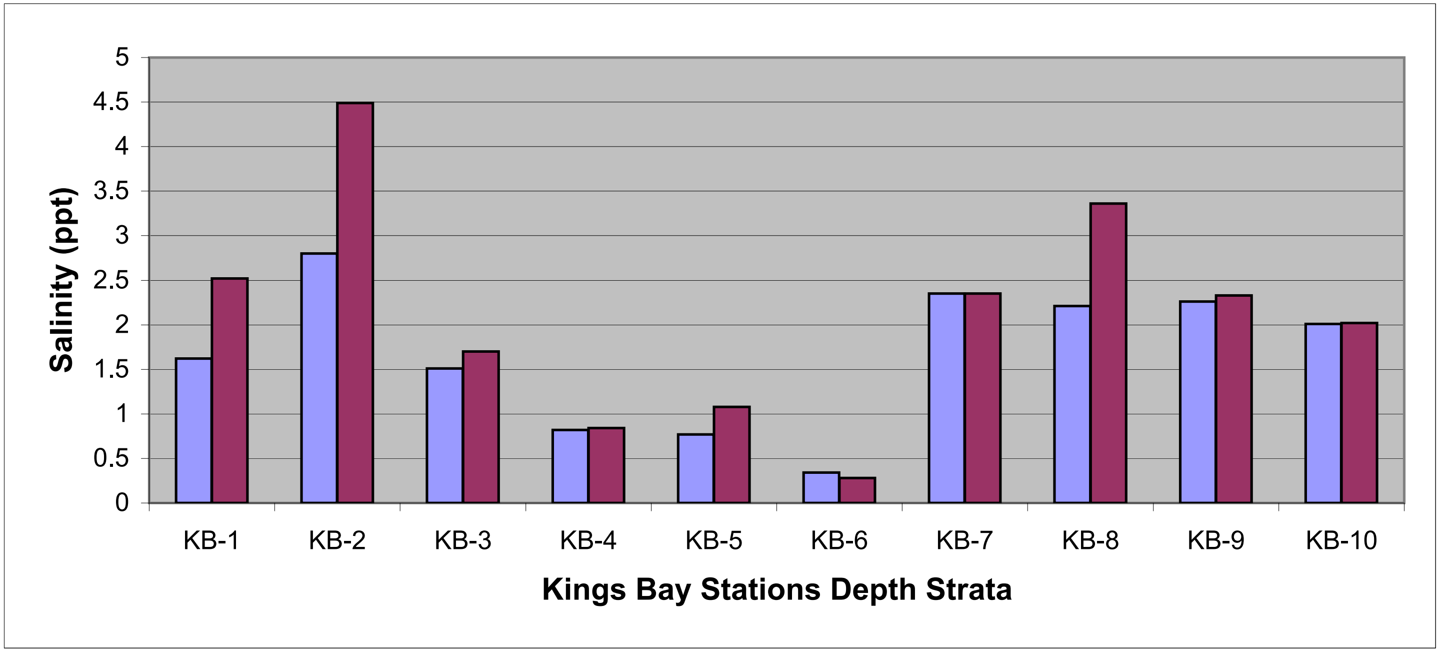
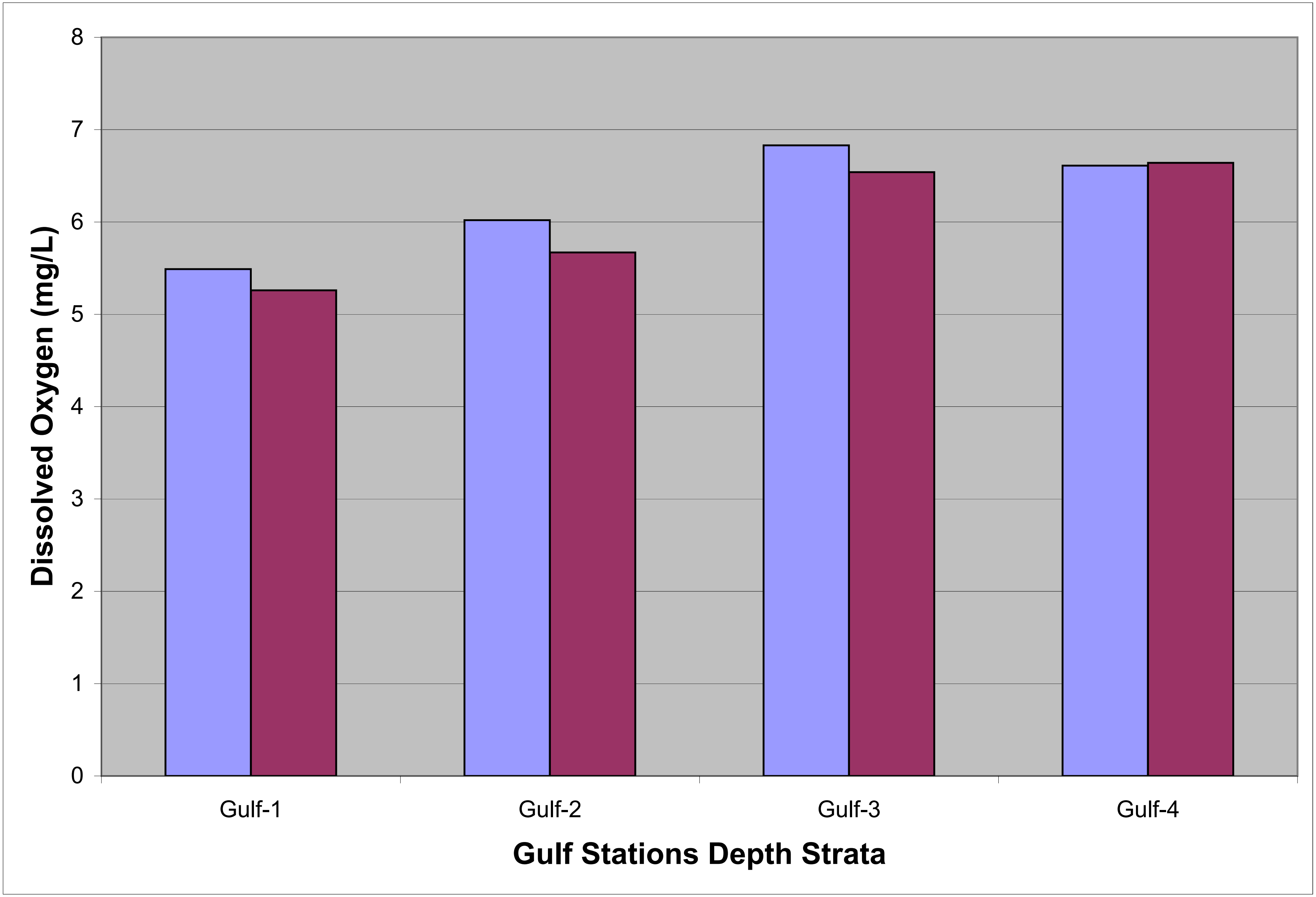


Figure F-3. Top and Bottom Salinity Strata for Kings Bay Stations July 2009.


8
7
6
5
4
3
2
1
0
Dissolved Oxygen (mg/L)
Gulf-1
Gulf-2
Gulf-3
Gulf-4
Gulf Stations Depth Strata

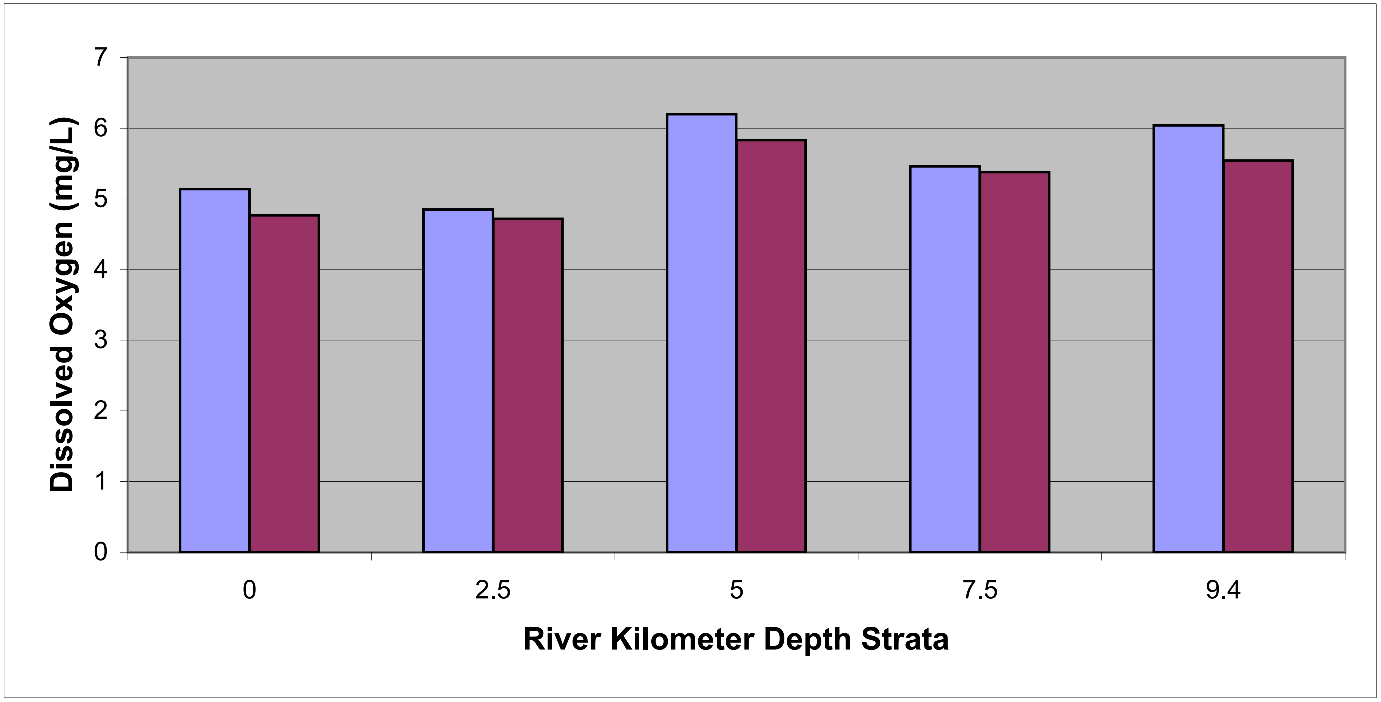


Figure F-5. Dissolved Oxygen for River Kilometer Top and Bottom Strata for the Crystal River July 2009.

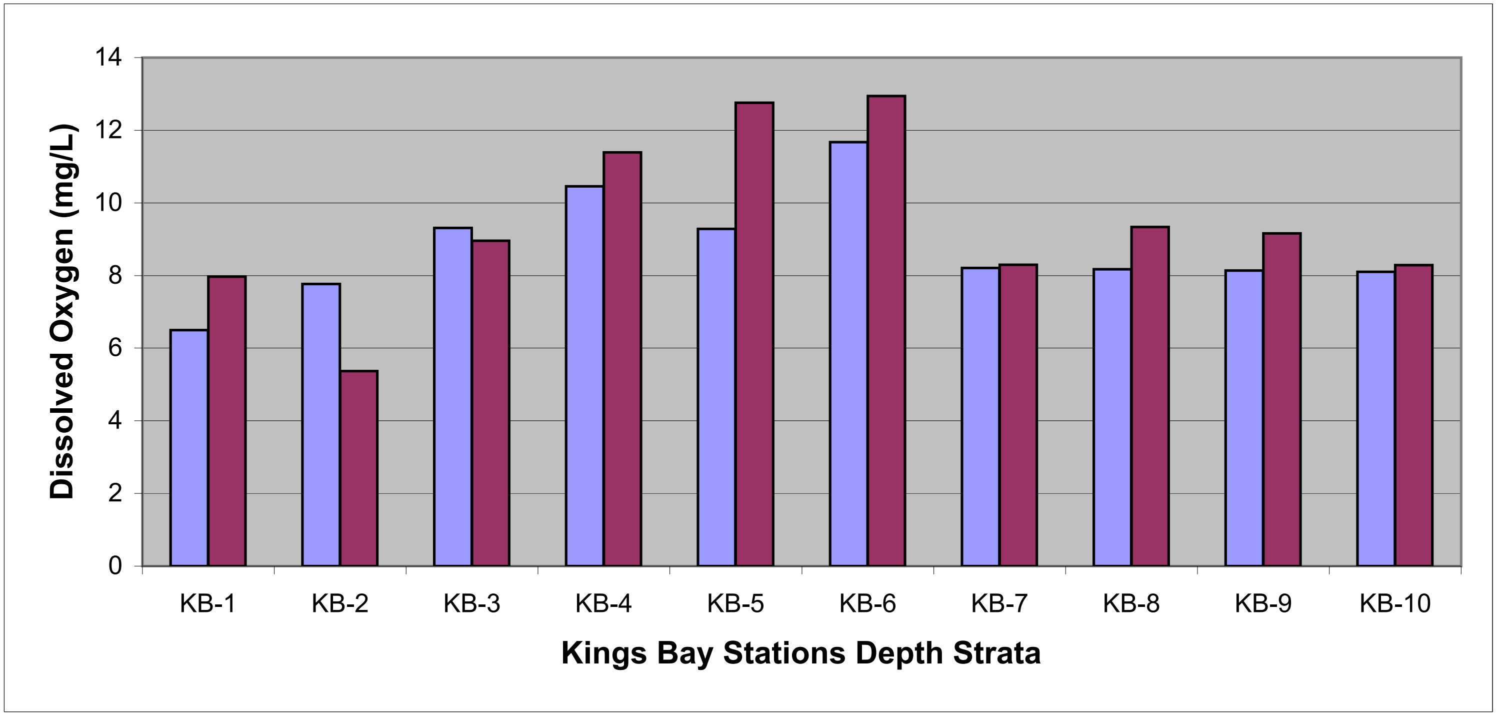


Figure F-6. Top and Bottom Dissolved Oxygen Strata for Kings Bay Stations July 2009.

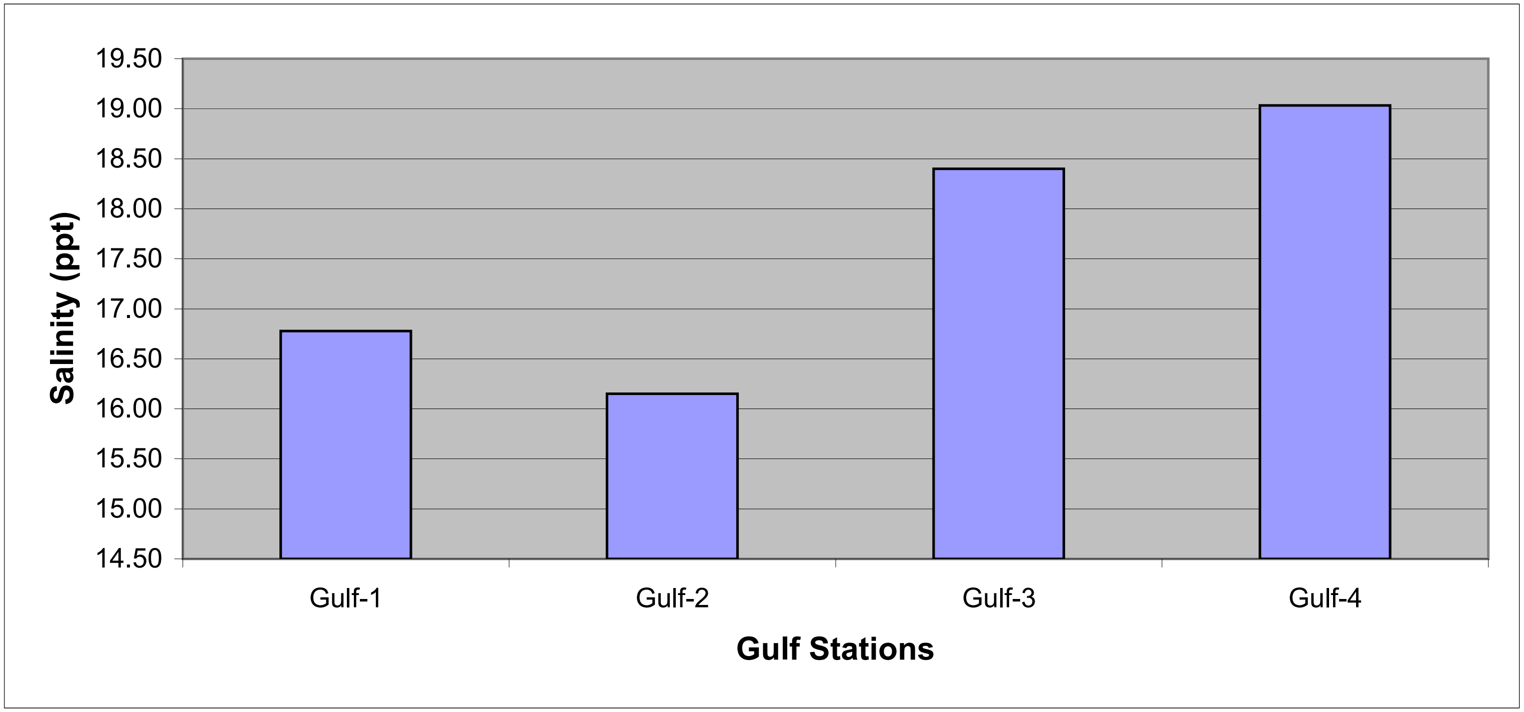


Figure F-7. Mean Water Column Salinity Concentrations for Gulf Stations, July 22, 2010.

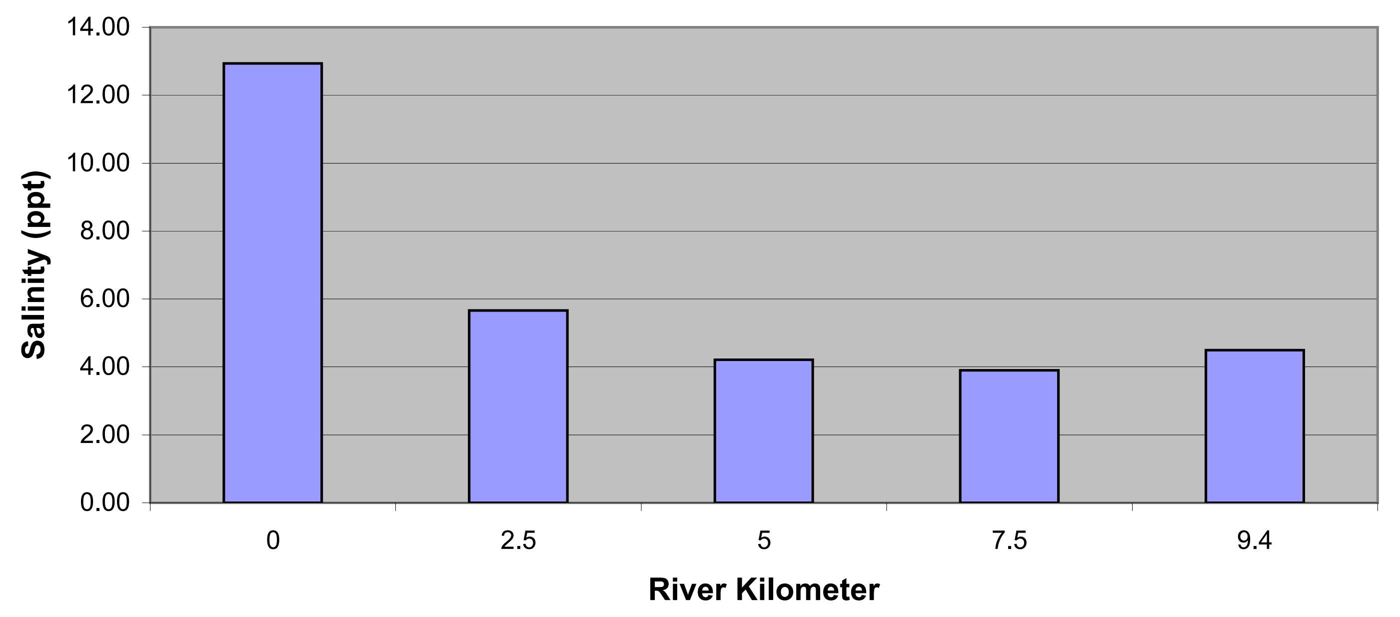


Figure F-8. Mean Water Column Salinity Concentrations in the Crystal River, July 22-23, 2010.

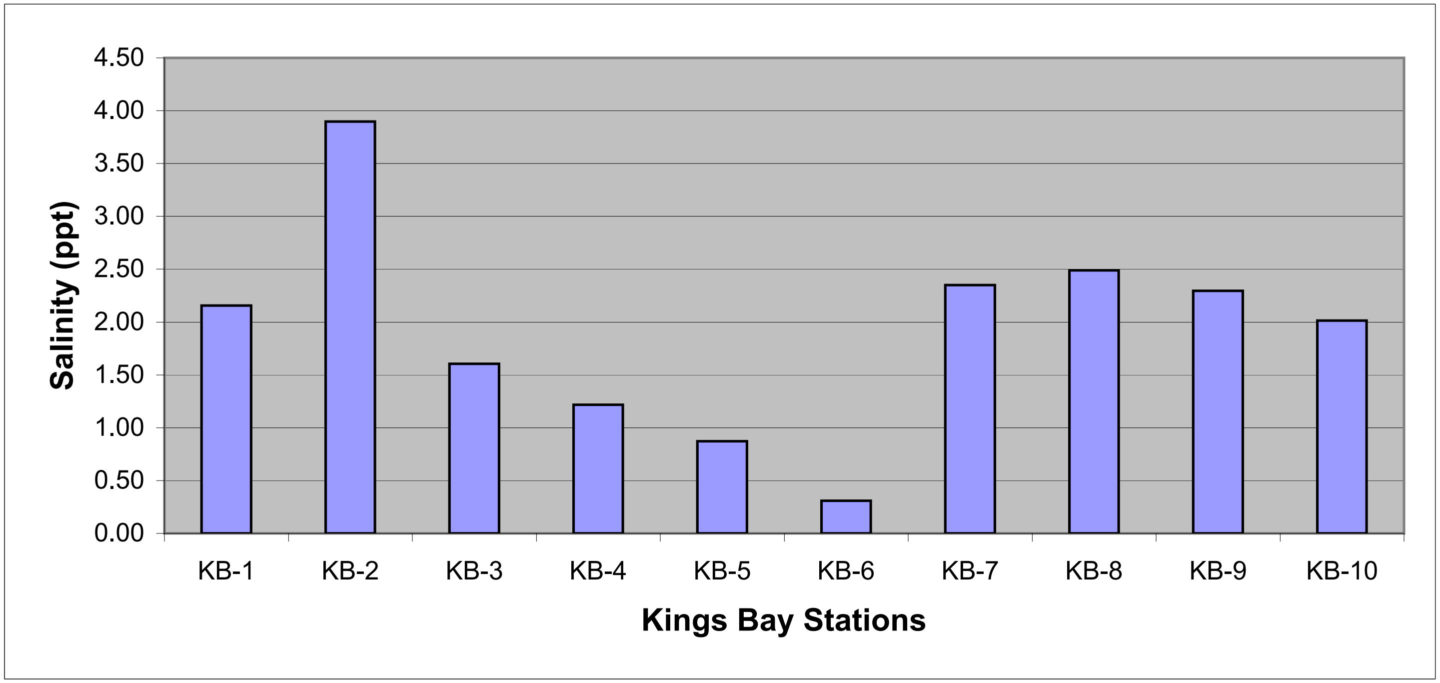


Figure F-9. Mean Water Column Salinity Concentrations for Kings Bay Stations, July 22, 2010.

Table F-1. Physical and Chemical Vertical Profile Data, Crystal River, Florida

Station	Date	Time	Depth (m)	Temperature (C)	pH	Specific Conductance (umho/cm)	Salinity (ppt)	Dissolved Oxygen (% Sat.)	Dissolved Oxygen (mg/l)	Total Water Depth (m)
RK 0.0	7/22/2009	1047	0.10	29.40	7.79	19229	11.37	72.2	5.14	2.40
	7/22/2009	1048	1.00	29.36	7.84	21004	12.61	74.8	5.29	2.40
	7/22/2009	1049	2.00	29.36	7.86	24491	14.83	68.4	4.77	2.40
RK 2.5	7/22/2009	931	0.10	28.74	7.67	10019	5.67	64.9	4.85	3.40
	7/22/2009	932	1.00	28.74	7.67	10052	5.67	65.5	4.87	3.40
	7/22/2009	933	2.00	28.72	7.68	10057	5.66	64.5	4.80	3.40
	7/22/2009	934	3.00	28.71	7.68	9987	5.64	62.9	4.72	3.40
RK 5.0	7/23/2009	1132	0.10	28.83	7.79	7547	4.20	82.7	6.20	3.90
	7/23/2009	1133	1.00	28.82	7.82	7553	4.21	82.2	6.17	3.90
	7/23/2009	1134	2.00	28.79	7.84	7549	4.21	81.4	6.14	3.90
	7/23/2009	1135	3.00	28.78	7.84	7564	4.22	78.8	5.92	3.90
	7/23/2009	1136	3.70	28.75	7.85	7571	4.23	77.4	5.83	3.90
RK 7.5	7/21/2009	1204	0.10	28.23	7.56	7001	3.89	72.0	5.46	3.10
	7/21/2009	1205	1.00	28.22	7.56	7010	3.90	72.2	5.49	3.10
	7/21/2009	1206	2.00	28.24	7.56	7029	3.91	71.0	5.39	3.10
	7/21/2009	1207	3.00	28.25	7.56	7046	3.92	70.9	5.38	3.10
RK 9.4	7/22/2009	1440	0.10	29.44	7.88	7826	4.37	82.0	6.04	4.20
	7/22/2009	1441	1.00	29.38	7.83	7871	4.42	78.9	5.88	4.20
	7/22/2009	1442	2.00	29.29	7.75	8200	4.60	73.9	5.47	4.20
	7/22/2009	1443	3.00	29.33	7.75	8216	4.59	74.7	5.54	4.20
Gulf-1	7/22/2009	1137	0.10	30.14	7.86	22389	14.70	79.3	5.49	2.00
	7/22/2009	1138	1.00	29.66	7.95	28791	17.70	78.4	5.35	2.00
	7/22/2009	1139	2.00	29.66	7.96	29089	17.93	77.1	5.26	2.00
Gulf-2	7/22/2009	1210	0.10	29.86	8.01	26191	15.97	87.8	6.02	1.80
	7/22/2009	1211	1.00	29.87	8.01	26382	16.11	89.3	6.13	1.80
	7/22/2009	1212	2.00	29.89	8.00	26842	16.37	83.5	5.67	1.80
Gulf-3	7/22/2009	1300	0.10	30.41	8.08	29475	18.20	101.9	6.83	2.20
	7/22/2009	1301	1.00	30.36	8.08	29843	18.45	99.1	6.63	2.20
	7/22/2009	1302	2.00	30.33	8.08	30001	18.55	97.4	6.54	2.20
Gulf-4	7/22/2009	1327	0.10	30.34	8.08	30602	18.97	98.4	6.61	2.40

Station	Date	Time	Depth (m)	Temperature (C)	pH	Specific Conductance (umho/cm)	Salinity (ppt)	Dissolved Oxygen (% Sat.)	Dissolved Oxygen (mg/l)	Total Water Depth (m)
	7/22/2009	1328	1.00	30.35	8.09	30680	19.05	100.3	6.69	2.40
	7/22/2009	1329	2.00	30.34	8.09	30770	19.08	99.3	6.64	2.40
KB-1	7/21/2009	1036	0.10	26.47	8.17	3019	1.62	81.9	6.50	3.30
	7/21/2009	1037	1.00	26.38	8.07	3744	2.03	76.7	6.11	3.30
	7/21/2009	1038	2.00	26.83	7.98	4681	2.45	73.1	5.78	3.30
	7/21/2009	1039	3.00	26.87	7.95	4678	2.52	71.0	7.97	3.30
KB-2	7/22/2009	1630	0.10	29.65	8.26	5040	2.80	103.5	7.77	3.20
	7/22/2009	1631	1.00	29.08	7.94	7040	3.97	82.8	6.20	3.20
	7/22/2009	1632	2.00	29.28	7.82	7759	4.33	73.9	5.48	3.20
	7/22/2009	1633	3.00	29.37	7.78	8023	4.49	72.4	5.37	3.20
KB-3	7/23/2009	1301	0.10	28.29	8.55	2800	1.51	120.2	9.31	0.85
	7/23/2009	1302	0.60	27.49	8.50	3154	1.70	114.8	8.96	0.85
KB-4	7/23/2009	1348	0.10	28.39	8.56	1546	0.82	135.3	10.46	0.80
	7/23/2009	1349	0.60	28.16	8.74	1582	0.84	147.4	11.39	0.80
KB-5	7/23/2009	1423	0.10	27.51	8.77	1445	0.77	118.7	9.28	1.90
	7/23/2009	1424	1.00	27.36	8.80	1458	0.77	118.8	9.36	1.90
	7/23/2009	1425	1.70	26.31	9.11	2018	1.08	159.8	12.76	1.90
KB-6	7/23/2009	1446	0.10	27.14	9.13	657	0.34	147.2	11.67	1.20
	7/23/2009	1447	1.00	26.85	9.16	536	0.28	163.5	12.94	1.20
KB-7	7/23/2009	1528	0.10	29.71	8.27	4310	2.35	109.3	8.21	1.00
	7/23/2009	1529	0.80	29.32	8.32	4295	2.35	110.1	8.30	1.00
KB-8	7/23/2009	1558	0.10	28.70	8.32	4049	2.21	107.5	8.17	2.80
	7/23/2009	1559	1.00	28.65	8.32	4051	2.20	109.1	8.31	2.80
	7/23/2009	1600	2.00	27.66	8.27	4023	2.19	101.8	7.87	2.80
	7/23/2009	1601	2.50	26.07	8.22	6069	3.36	117.6	9.34	2.80
KB-9	7/23/2009	1630	0.10	28.48	8.36	4132	2.26	107.8	8.14	1.50
	7/23/2009	1631	1.00	28.34	8.41	4262	2.33	118.9	9.16	1.50
KB-10	7/23/2009	1705	0.10	28.21	8.38	3700	2.01	105.2	8.10	1.50
	7/23/2009	1706	1.00	27.90	8.38	3719	2.02	107.7	8.29	1.50
KB-SR	7/21/2009	1423	0.10	29.23	7.52	10475	5.95	66.9	4.92	1.30
	7/21/2009	1234	1.00	29.23	7.52	10631	6.05	66.2	4.87	1.30

Appendix G

Bray Curtis Matrices

All Pooled Bray Curtis

	Gulf	RK 0	RK 2.5	RK 5	RK 7.5	RK 9.4	KB-1-3	KB-4-6	KB-7-10
Gulf									
RK 0	45.33708								
RK 2.5	25.33452	32.04858							
RK 5	16.22391	22.11763	47.35612						
RK 7.5	14.28511	17.02492	34.70599	46.51858					
RK 9.4	6.983933	6.82146	15.42282	29.13742	34.75751				
KB-1-3	7.037327	7.400856	17.94227	33.54226	36.54127	48.95783			
KB-4-6	2.910049	2.196137	6.689405	17.56353	18.57837	24.63557	54.58124		
KB-7-10	3.713835	4.817416	9.157849	20.15325	25.43987	33.00933	52.20108	52.92951	

All Dipnet Bray Curtis

	KB-3	KB-4	KB-6	KB-7	KB-9	KB-10	KB-SR
KB-3							
KB-4	23.56969						
KB-6	26.01695	22.21103					
KB-7	46.88676	21.44337	16.13197				
KB-9	9.929284	4.330168	6.650076	7.421795			
KB-10	40.78502	31.58046	35.06008	39.21259	11.21492		
KB-SR	15.84965	0	3.247352	16.28047	0	3.326344	

All Unpooled Ponar Bray Curtis

	Gulf-1	Gulf-2	Gulf-3	Gulf-4	RK 0-A	RK 0-B	RK 0-C	RK 2.5-A	RK 2.5-B	RK 2.5-C	RK 5-A	RK 5-B	RK 5-C	RK 7.5-A	RK 7.5-B	RK 7.5-C	RK 9.4-A	RK 9.4-B	RK 9.4-C	KB-1	KB-2	KB-3	KB-4	KB-5	KB-6	KB-7	KB-8	KB-9
Gulf-1																												
Gulf-2	31.87953																											
Gulf-3	36.58435	44.96662																										
Gulf-4	16.2119	43.97166	36.69282																									
RK 0-A	44.52173	47.73684	42.22058	30.74828																								
RK 0-B	9.974883	4.255735	7.255027	11.95238	10.9906																							
RK 0-C	12.52825	10.46893	9.167129	9.135923	11.34445	43.45773																						
RK 2.5-A	6.053824	16.46369	17.38091	18.5058	17.10555	8.090618	10.04066																					
RK 2.5-B	5.97061	7.27588	9.336648	17.14977	13.58466	19.40295	28.49002	20.37126																				
RK 2.5-C	13.04698	26.57622	24.1713	18.32449	27.06629	4.815063	12.30086	65.06537	16.00355																			
RK 5-A	7.922834	6.918684	9.671116	13.54855	14.92455	21.25217	19.72586	46.50809	20.41993	44.05981																		
RK 5-B	9.922257	3.272635	9.210493	8.406264	11.107	19.54004	15.60712	43.32725	11.78497	34.56993	47.60945																	
RK 5-C	3.78421	3.03604	5.915652	7.64146	10.73239	13.12794	7.140167	47.75528	18.69818	39.48565	66.34216	41.57101																
RK 7.5-A	3.040835	3.801143	9.875808	5.116859	9.96472	12.32875	9.354196	32.04251	13.15034	34.13357	43.39191	19.89672	32.4084															
RK 7.5-B	0	0	0	0	0	0	0	4.562114	0	0	0	0	0	19.11116														
RK 7.5-C	6.833959	3.340446	12.3192	8.631296	10.75036	20.15063	11.99567	38.78987	19.62535	38.17636	51.34262	39.43412	48.49821	50.35623	13.58388													
RK 9.4-A	3.891374	0	7.804204	0	7.880347	7.195991	5.247923	23.84714	14.64309	20.78139	43.04248	19.37553	35.61691	41.67197	11.86048	39.26778												
RK 9.4-B	0	0	2.306025	0	0	3.423526	2.909668	5.870083	2.793257	3.599201	10.40874	12.86643	9.213328	14.84797	7.573084	17.71963	11.68146											
RK 9.4-C	0	0	6.977057	6.406371	3.214795	0	0	22.79397	12.59813	20.73226	31.20688	11.86593	30.42548	47.55867	20.78692	29.10734	50.30923	11.79643										
KB-1	0	0	9.677572	4.958967	3.254312	11.87331	9.089658	20.678	12.80118	18.23859	44.01488	15.07505	26.87741	47.20571	9.370964	39.94858	50.47967	17.95298	46.85859									
KB-2	2.90707	0	6.864773	0	3.162615	11.27686	13.10389	19.2933	4.110779	18.34652	25.99976	26.87983	20.37785	28.00741	23.40357	29.00059	25.06929	22.3257	25.40856	41.35636								
KB-3	0	0	7.860684	0	2.63897	8.33	6.856798	19.31437	9.803776	13.70012	34.1603	20.47886	28.80527	40.42991	15.63502	34.24873	40.97886	29.34569	48.88454	56.1092	36.61282							
KB-4	0	0	3.058861	0	0	0	0	11.74503	7.959331	5.082746	14.63802	5.141798	10.29838	25.2327	12.70926	15.30053	15.1469	16.7923	26.30786	39.46644	26.72187	49.22133						
KB-5	0	0	0	0	0	0	0	0	0	0	0	0	5.987759	9.212533	14.7809	6.383473	0	5.610456	26.56013	14.22575	9.089871	23.42562	17.42494					
KB-6	0	0	3.386941	0	0	6.506115	4.871232	0	0	0	9.624786	5.867769	6.778664	0	0	6.034663	0	9.07486	8.768339	34.62131	27.29752	32.17358	45.17575	19.18629				
KB-7	0	0	5.5372	0	2.789533	4.552838	7.373855	11.48512	7.003985	11.81464	23.31009	4.534584	21.67944	25.07039	10.43624	24.69426	28.71949	23.37781	44.44478	48.13218	20.94244	57.2349	35.48082	29.96186	25.88375			
KB-8	0	0	7.318861	0	3.696091	0	0	18.40426	15.18027	18.85742	37.36847	10.8214	30.3993	30.4784	11.46631	29.93871	53.08519	7.557013	57.36737	35.35882	25.02666	45.193	23.58967	19.24082	13.21902	39.37045		
KB-9	0	0	0	0	0	0	0	0	0	0	5.447223	0	0	0	0	0	0	8.337786	5.96709	13.36441	5.789781	17.8942	32.1329	29.86549	16.19568	29.83258	15.7381	
KB-10	0	0	2.555721	0	0	0	3.318795	3.627467	3.168192	4.841121	8.442661	0	4.345324	9.232549	6.74414	4.982551	6.147848	6.008001	5.437526	24.87208	21.41274	22.36615	38.71154	17.06928	33.49852	30.08902	10.37133	33.87378

Appendix H

Important Taxa Bar Graphs

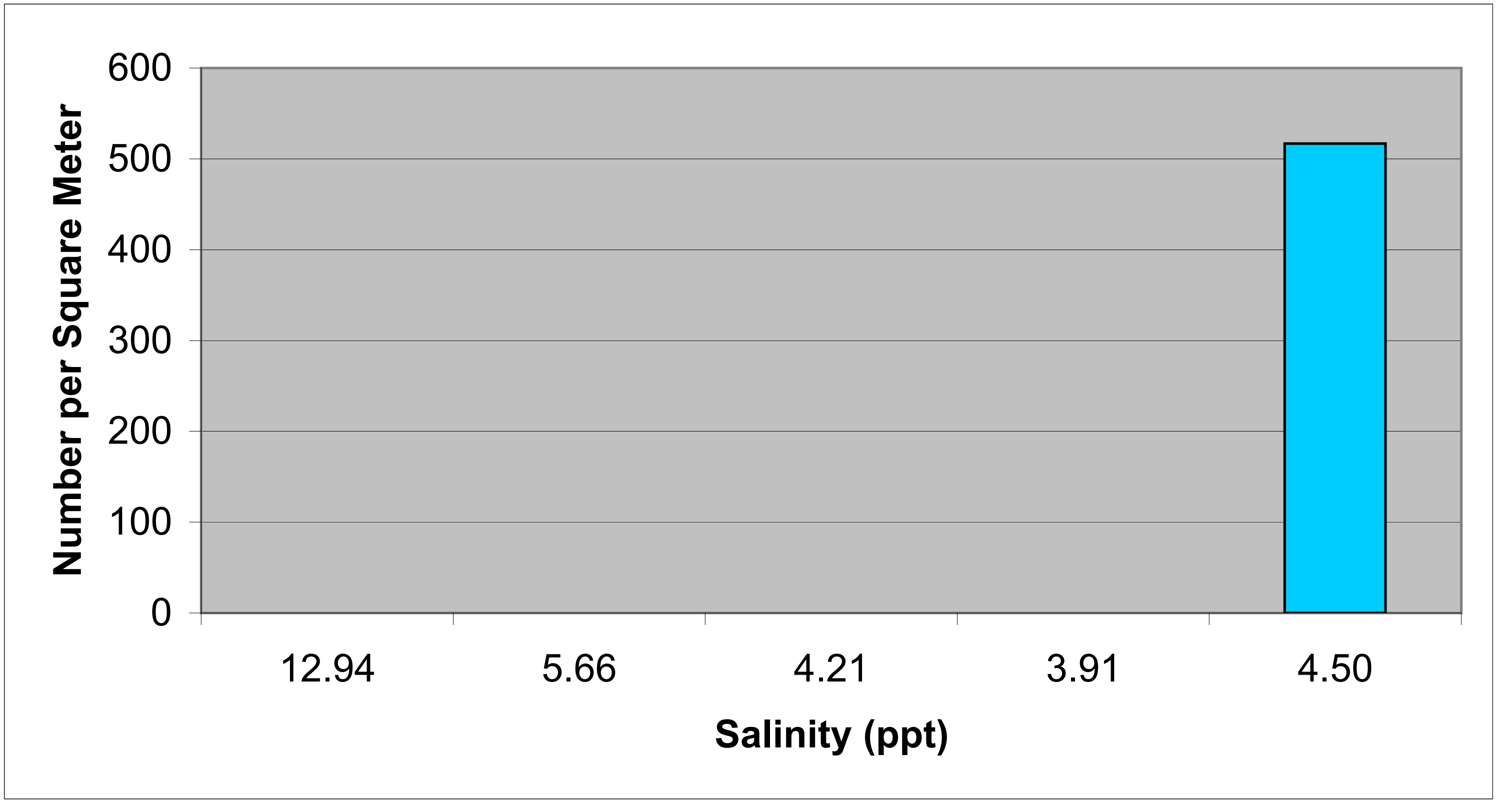


Figure H-1. Distribution of Littoridinops sp. in relation to bottom salinity in the mainstem of the Crystal River, July 2009.

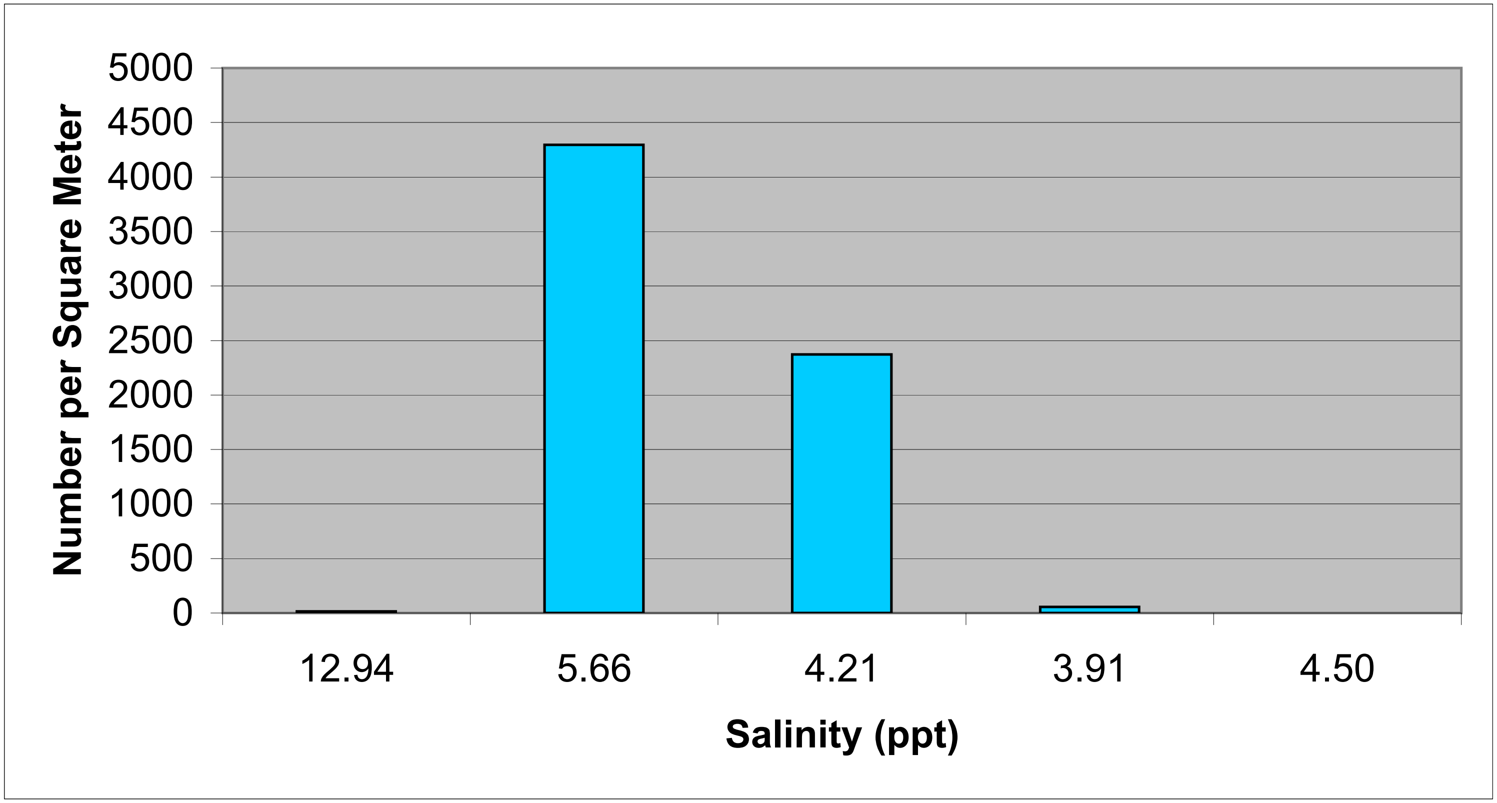


Figure H-2. Distribution of Ampelisca abdita in relation to bottom salinity in the mainstem of the Crystal River, July 2009.

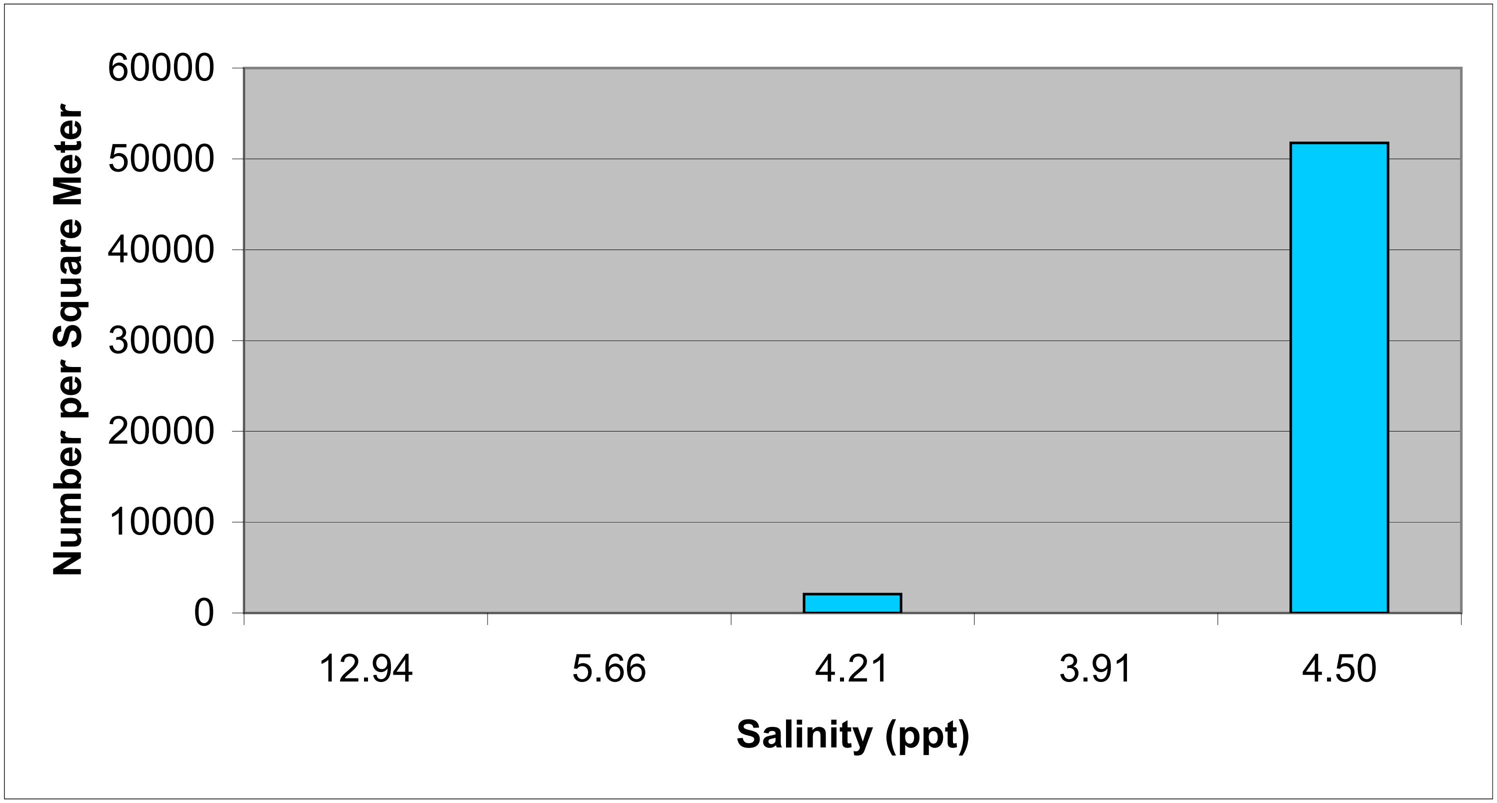


Figure H-3. Distribution of Cerapus benthophilus in relation to bottom salinity in the mainstem of the Crystal River, July 2009.

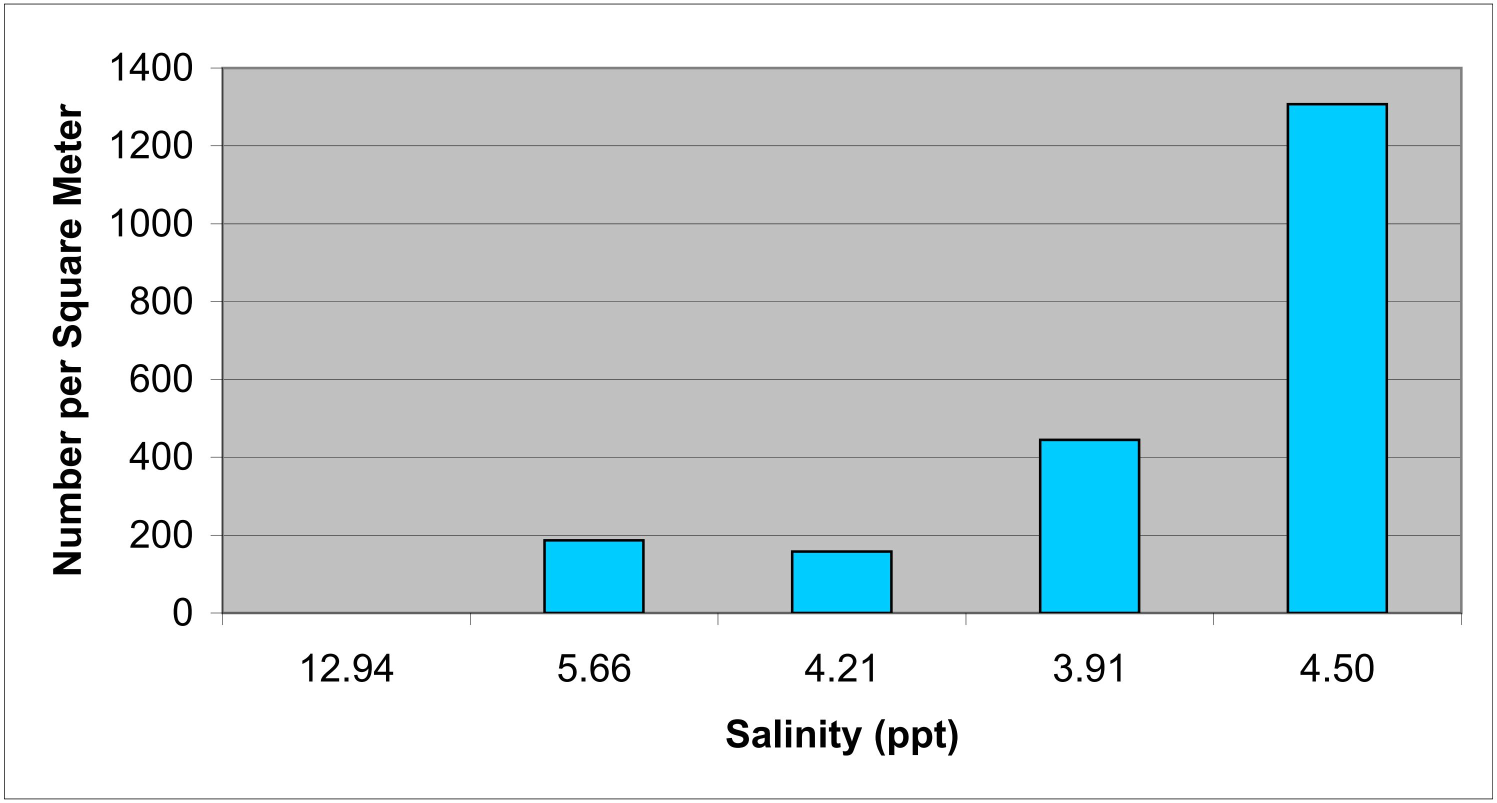


Figure H-4. Distribution of Laeonereis culveri in relation to bottom salinity in the mainstem of the Crystal River, July 2009.

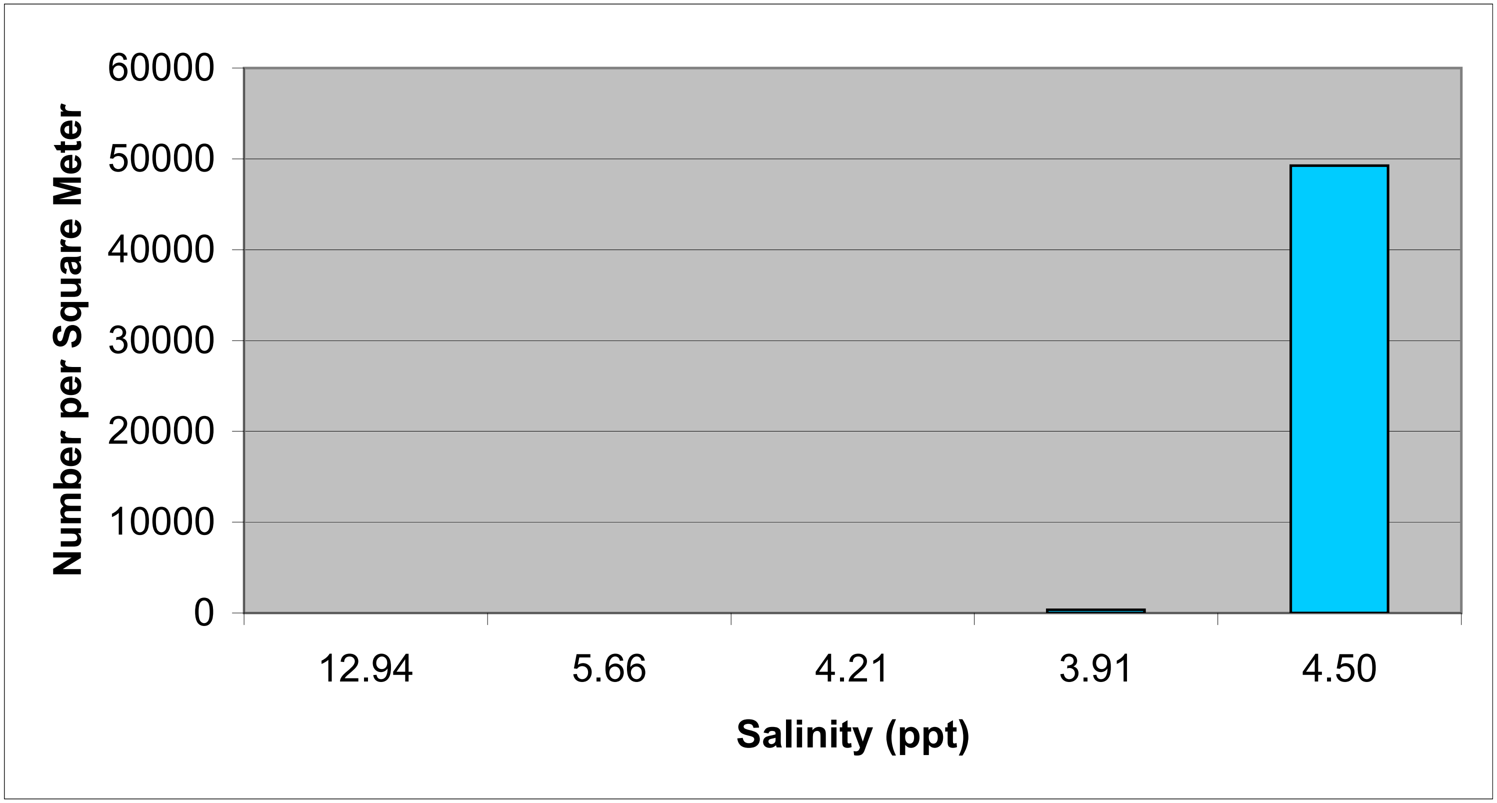


Figure H-5. Distribution of Cyrenoida floridana in relation to bottom salinity in the mainstem of the Crystal River, July 2009.

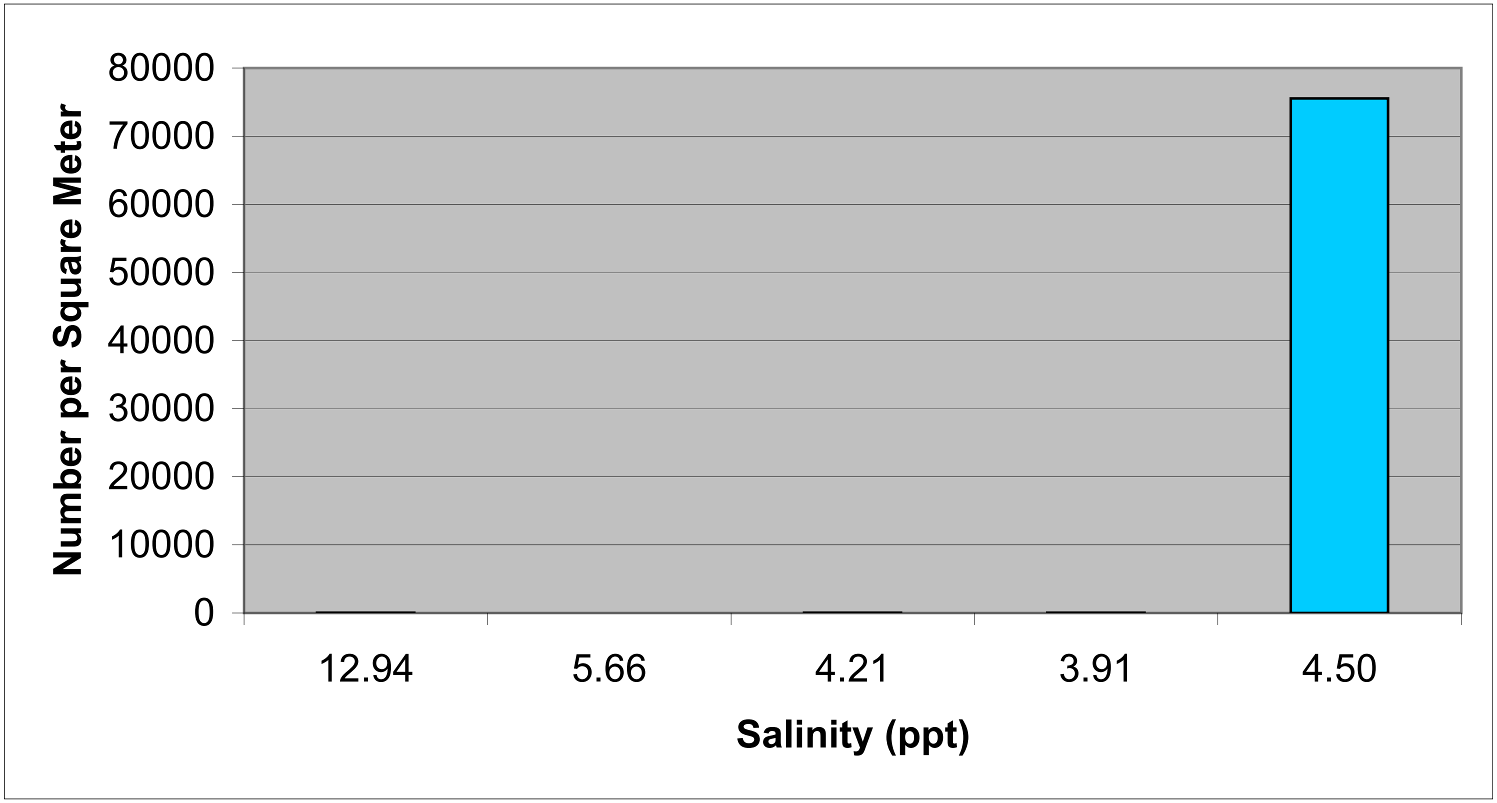


Figure H-6. Distribution of Apocorophium louisianum in relation to bottom salinity in the mainstem of the Crystal River, July 2009.

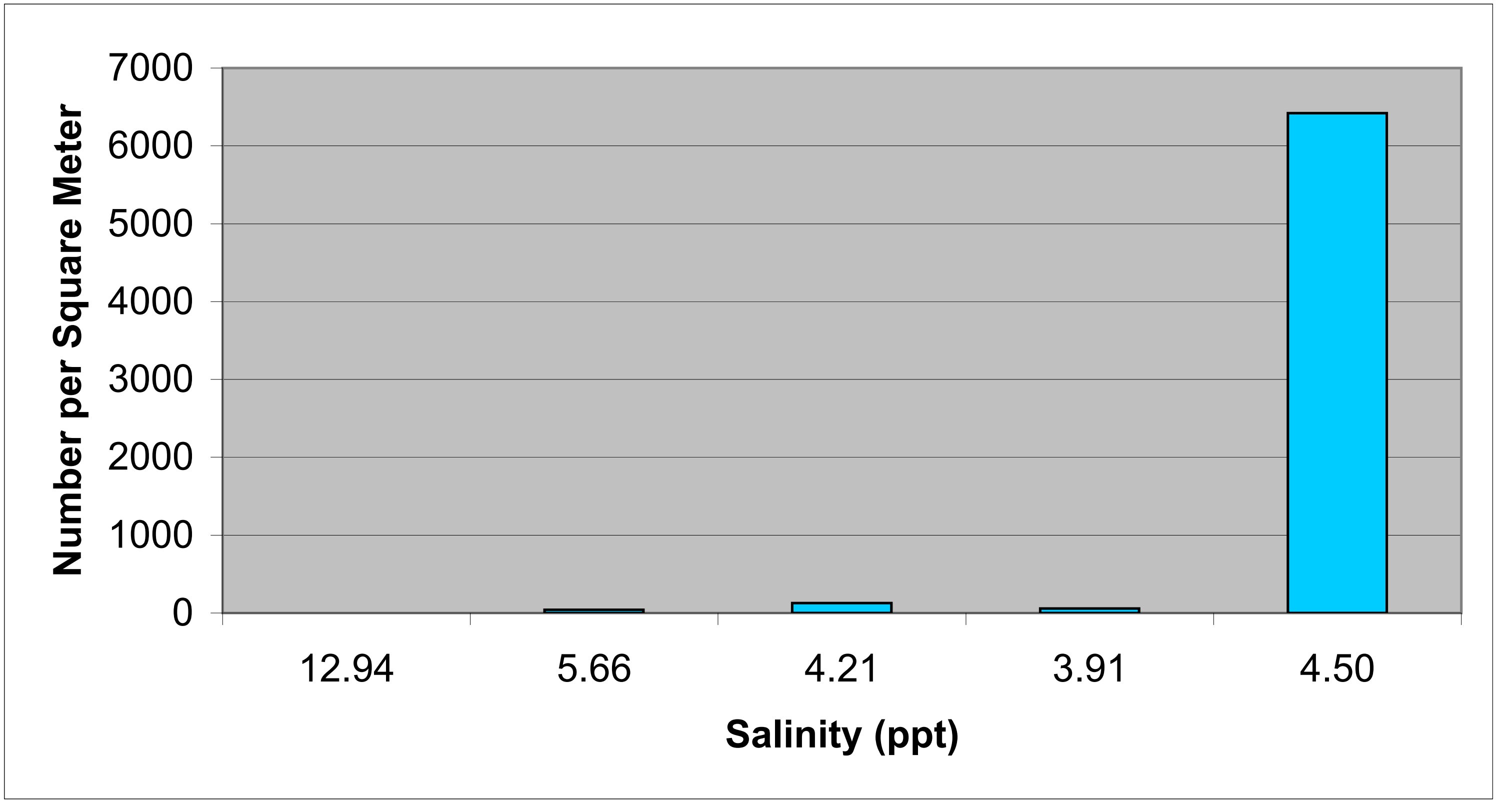


Figure H-7. Distribution of Hobsonia florida in relation to bottom salinity in the mainstem of the Crystal River, July 2009.

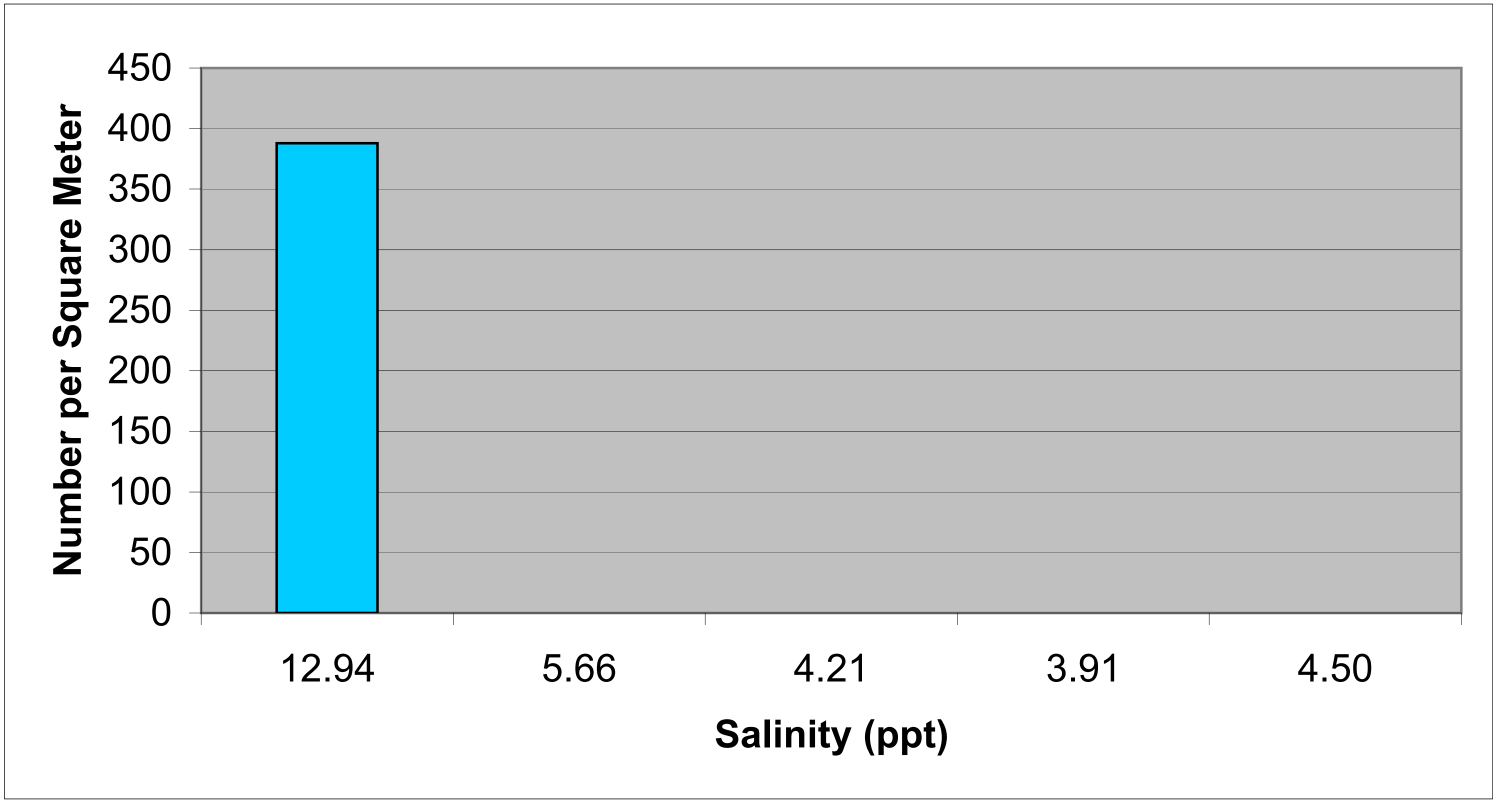


Figure H-8. Distribution of Aricidea taylori in relation to bottom salinity in the mainstem of the Crystal River, July 2009.

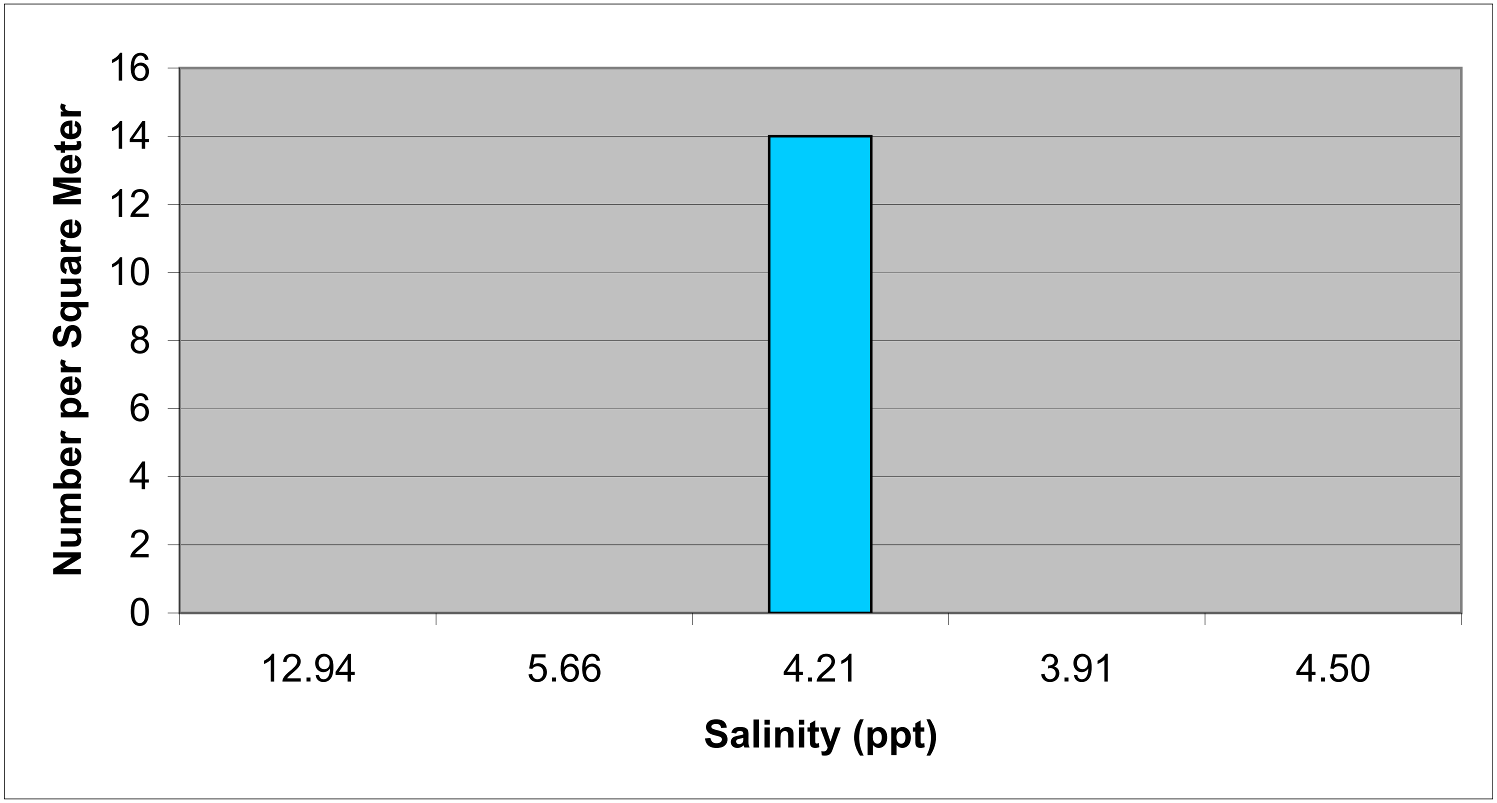


Figure H-9. Distribution of Gammarus sp. B LeCroy in relation to bottom salinity in the mainstem of the Crystal River, July 2009.

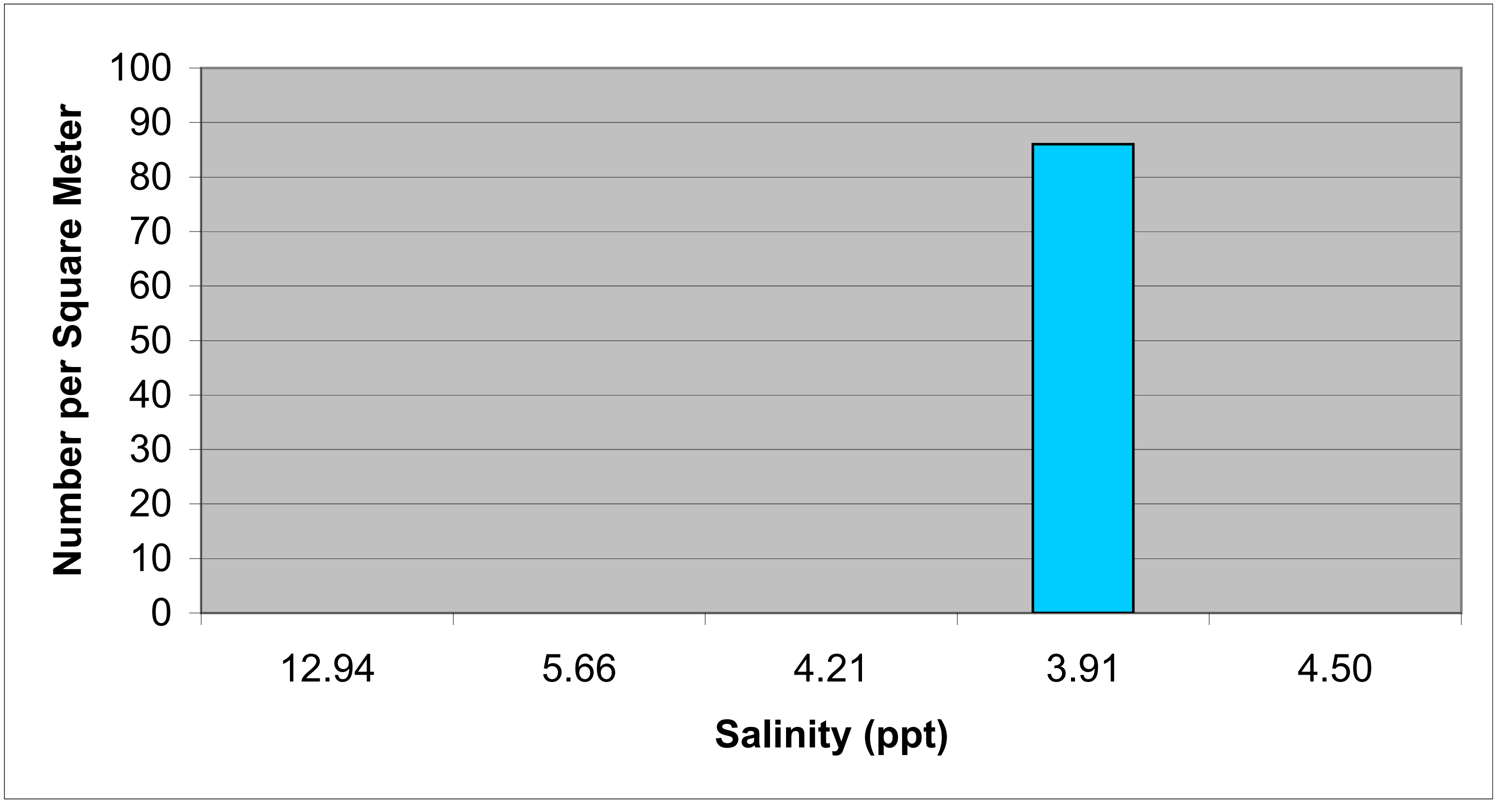


Figure H-10. Distribution of Pyrgophorus platyrachis in relation to bottom salinity in the mainstem of the Crystal River, July 2009.

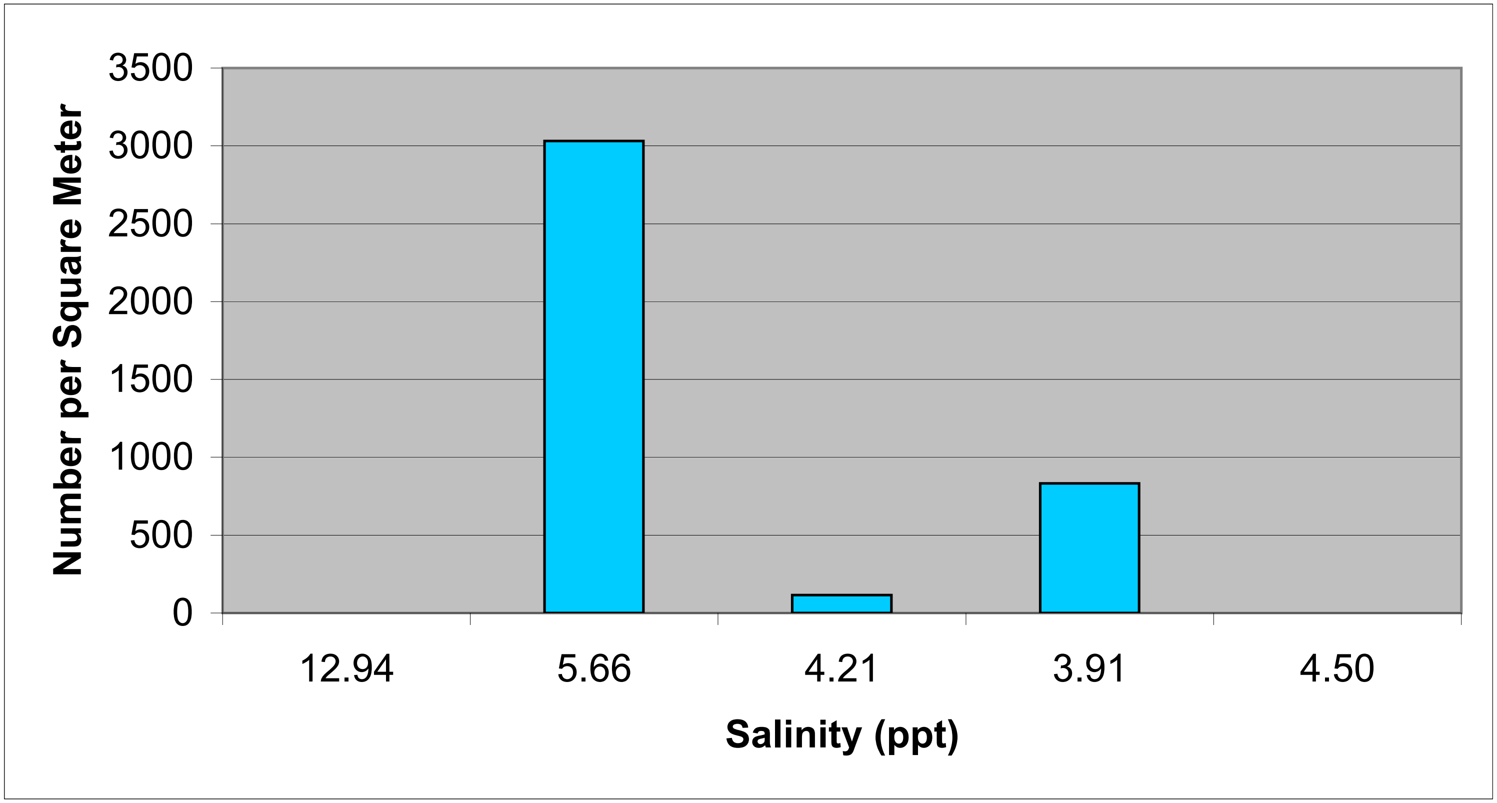


Figure H-11. Distribution of Halmyrapseudes cf. bahamensis Heard in relation to bottom salinity in the mainstem of the Crystal River, July 2009.

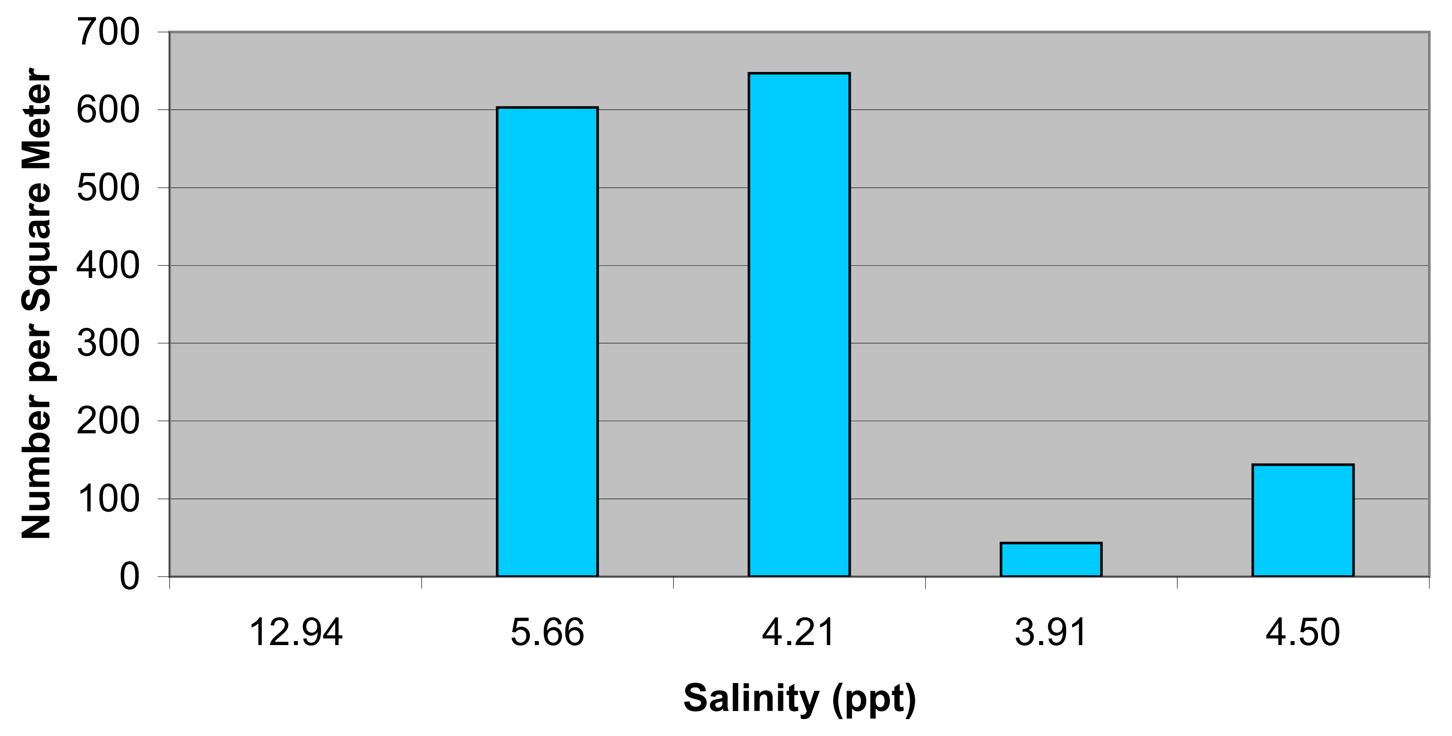


Figure H-12. Distribution of Streblospio sp. in relation to bottom salinity in the mainstem of the Crystal River, July 2009.

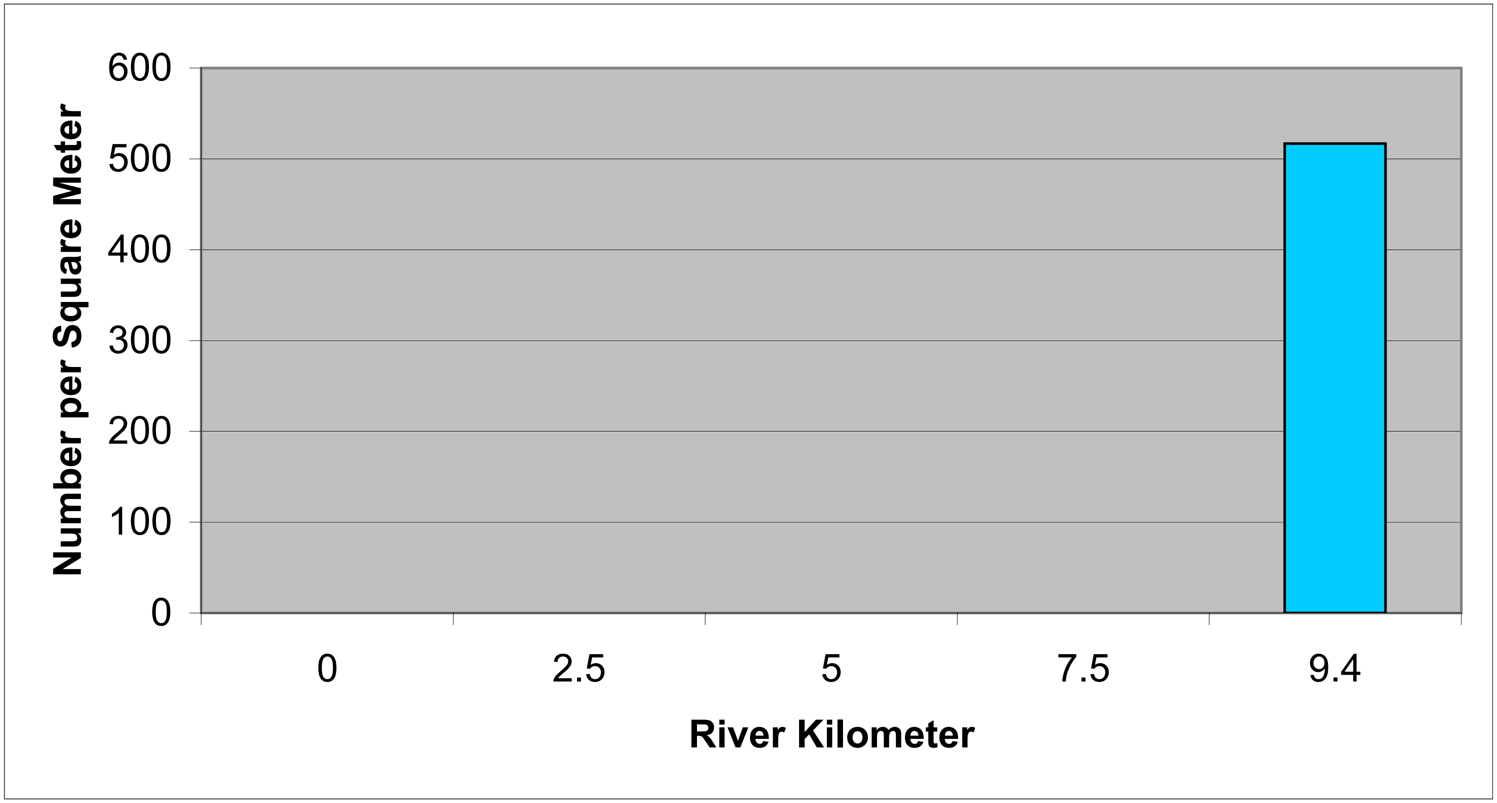


Figure H-13. Longitudinal Distribution of Littoridinops sp. by River Kilometer in the mainstem of the Crystal River, July 2009.

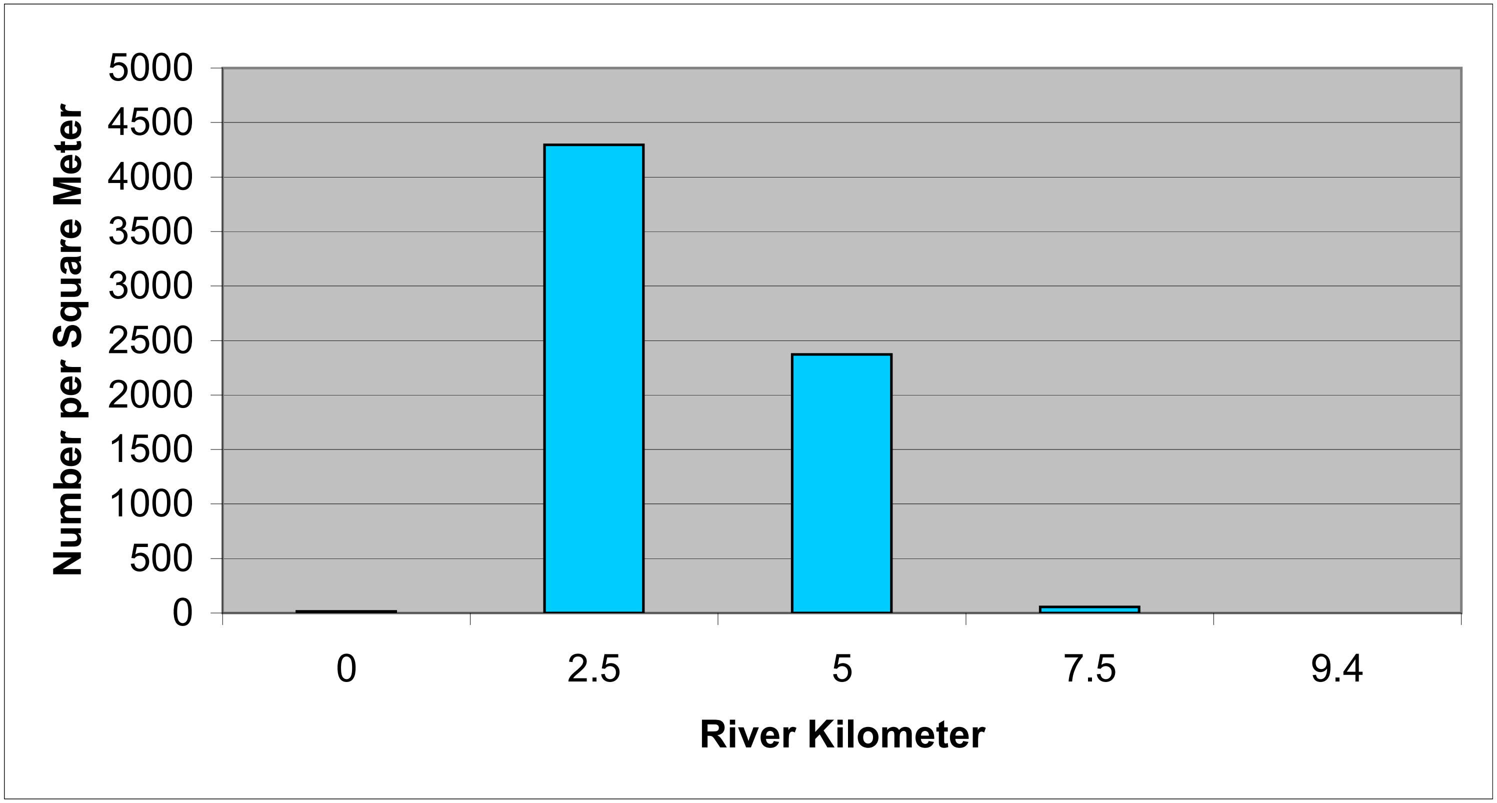


Figure H-14. Longitudinal Distribution of Ampelisca abdita by River Kilometer in the mainstem of the Crystal River, July 2009.

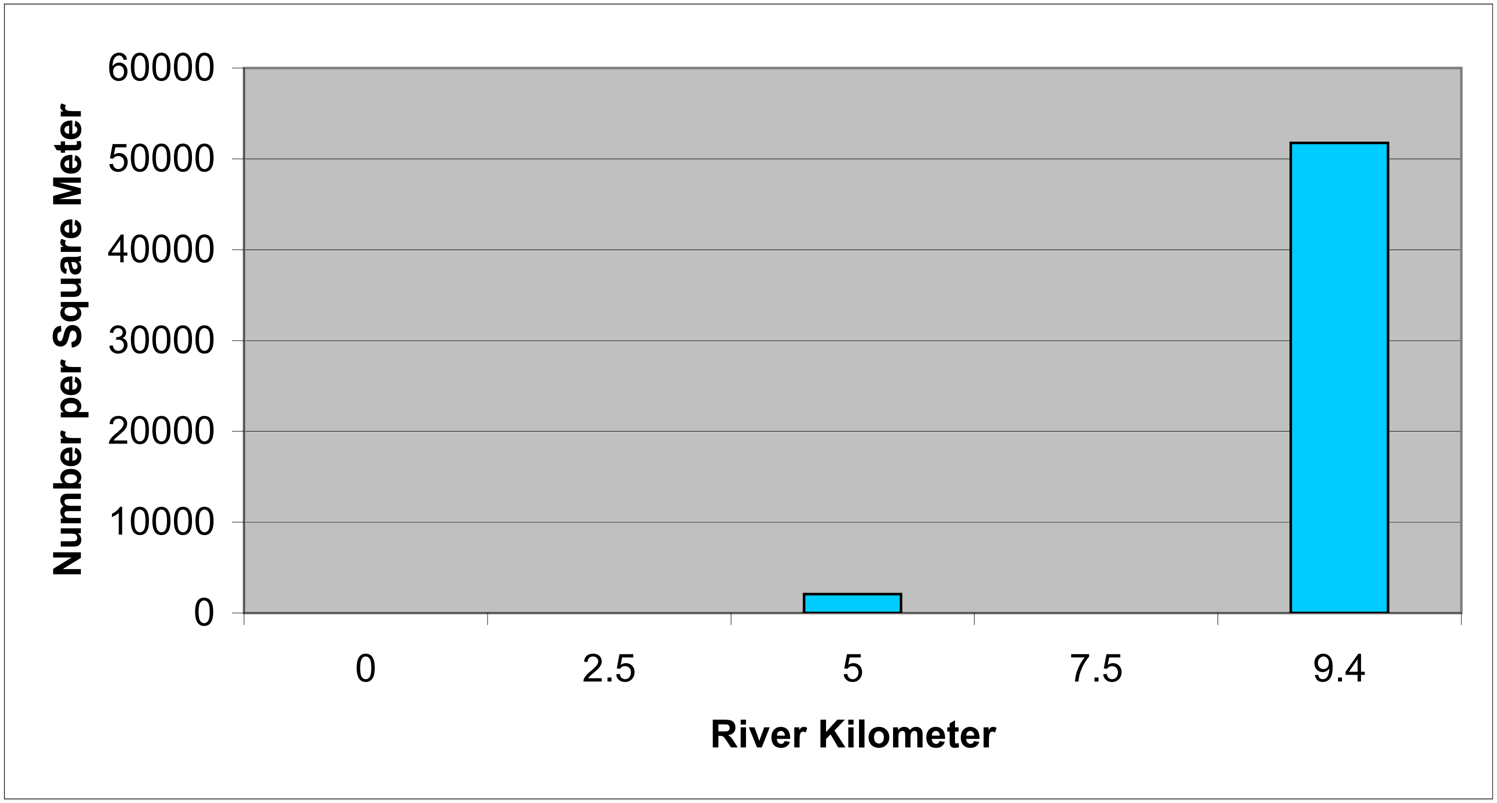


Figure H-15. Longitudinal Distribution of Cerapus benthophilus by River Kilometer in the mainstem of the Crystal River, July 2009.

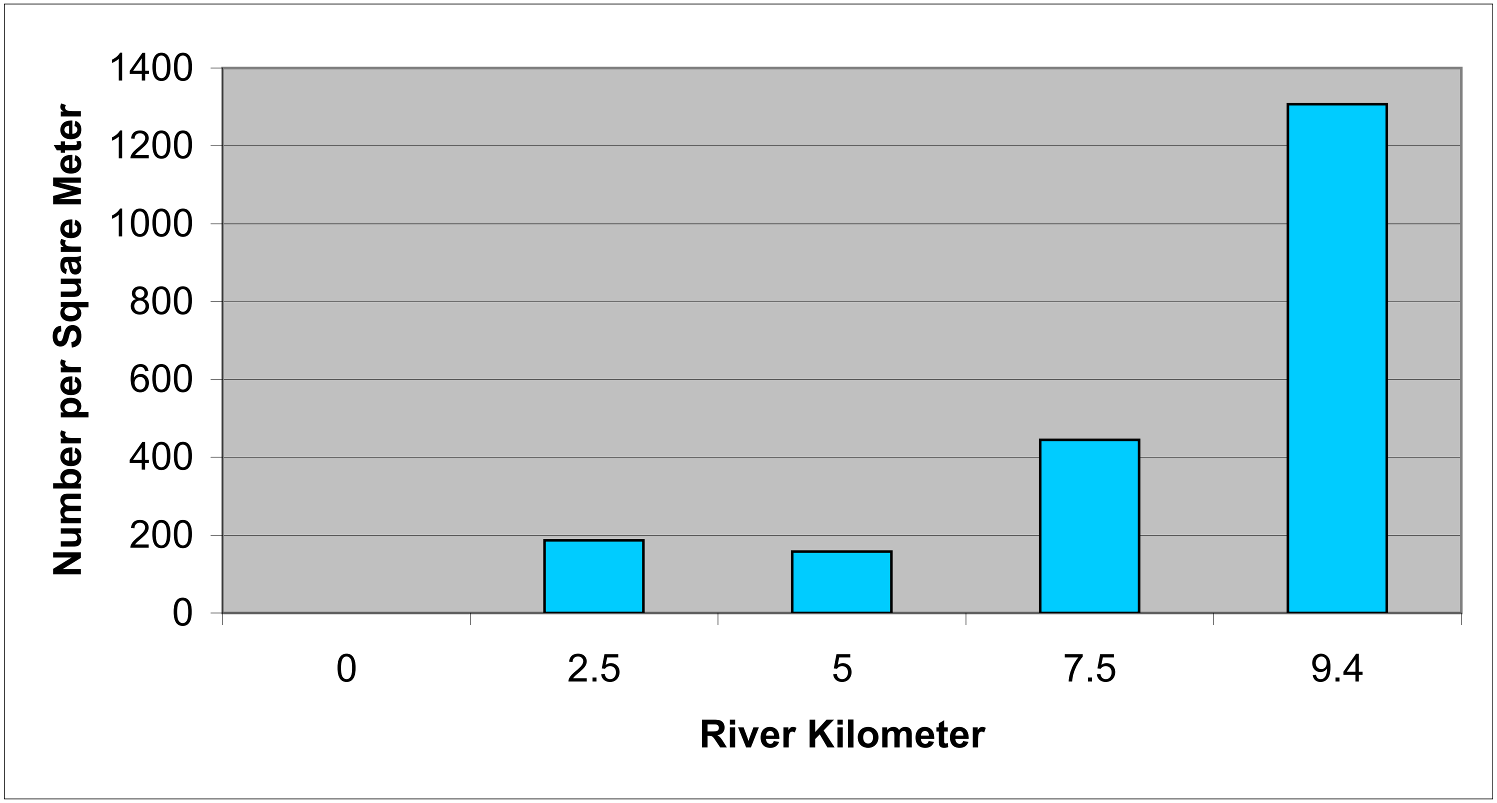


Figure H-16. Longitudinal Distribution of Laeonereis culveri by River Kilometer in the mainstem of the Crystal River, July 2009.

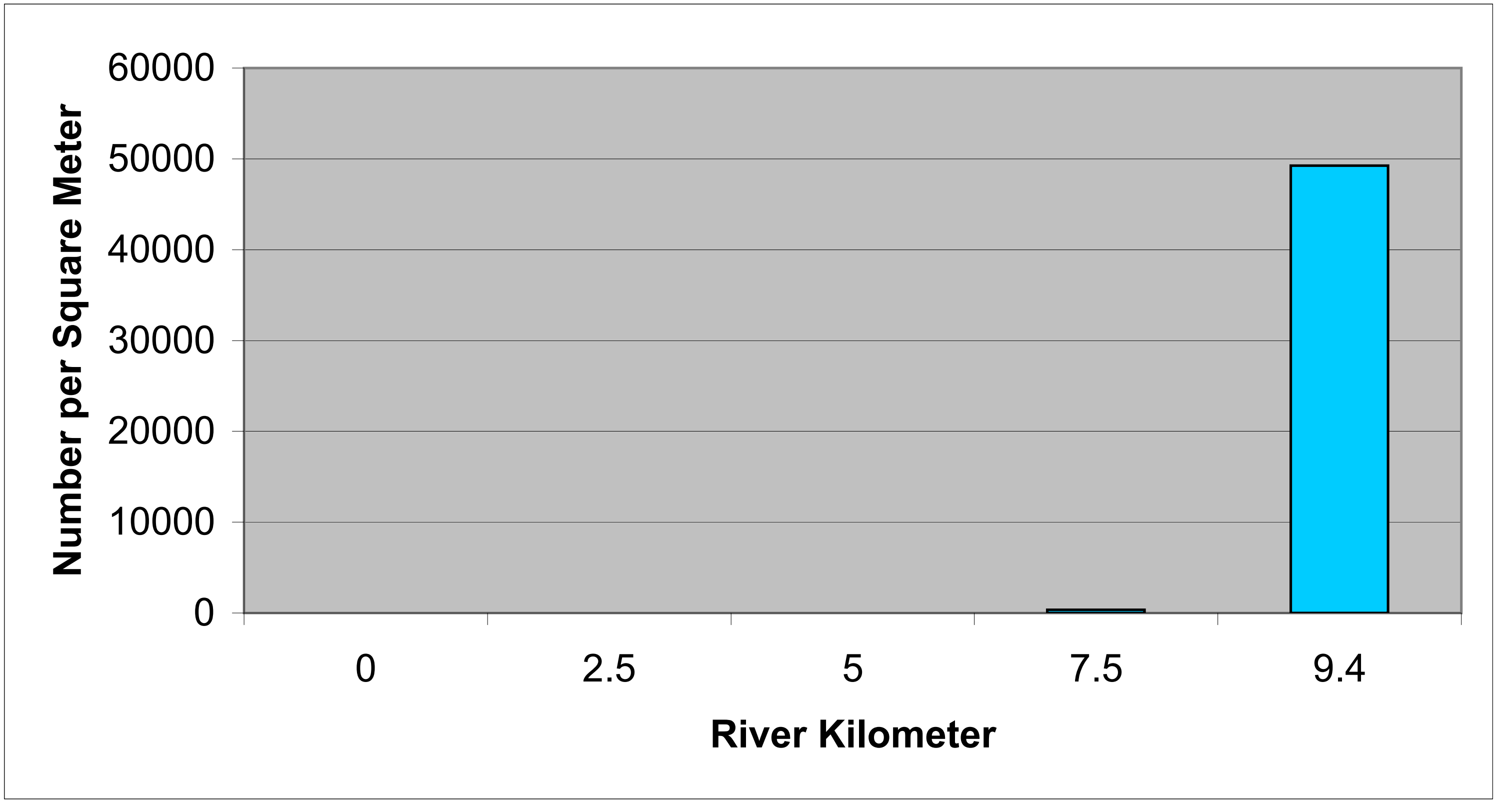


Figure H-17. Longitudinal Distribution of Cyrenoida floridana by River Kilometer in the mainstem of the Crystal River, July 2009.

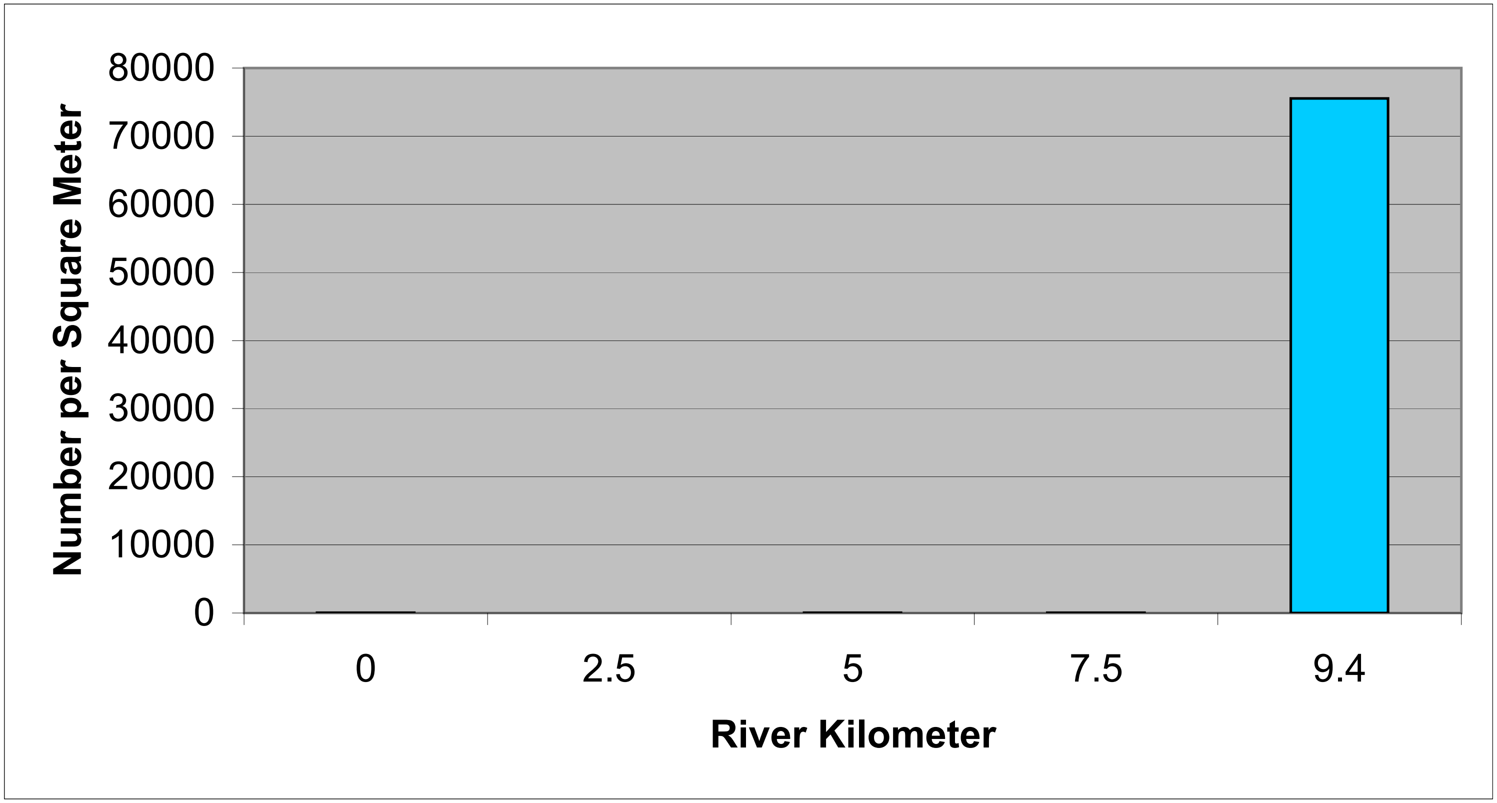


Figure H-18. Longitudinal Distribution of Apocorophium louisianum by River Kilometer in the mainstem of the Crystal River, July 2009.

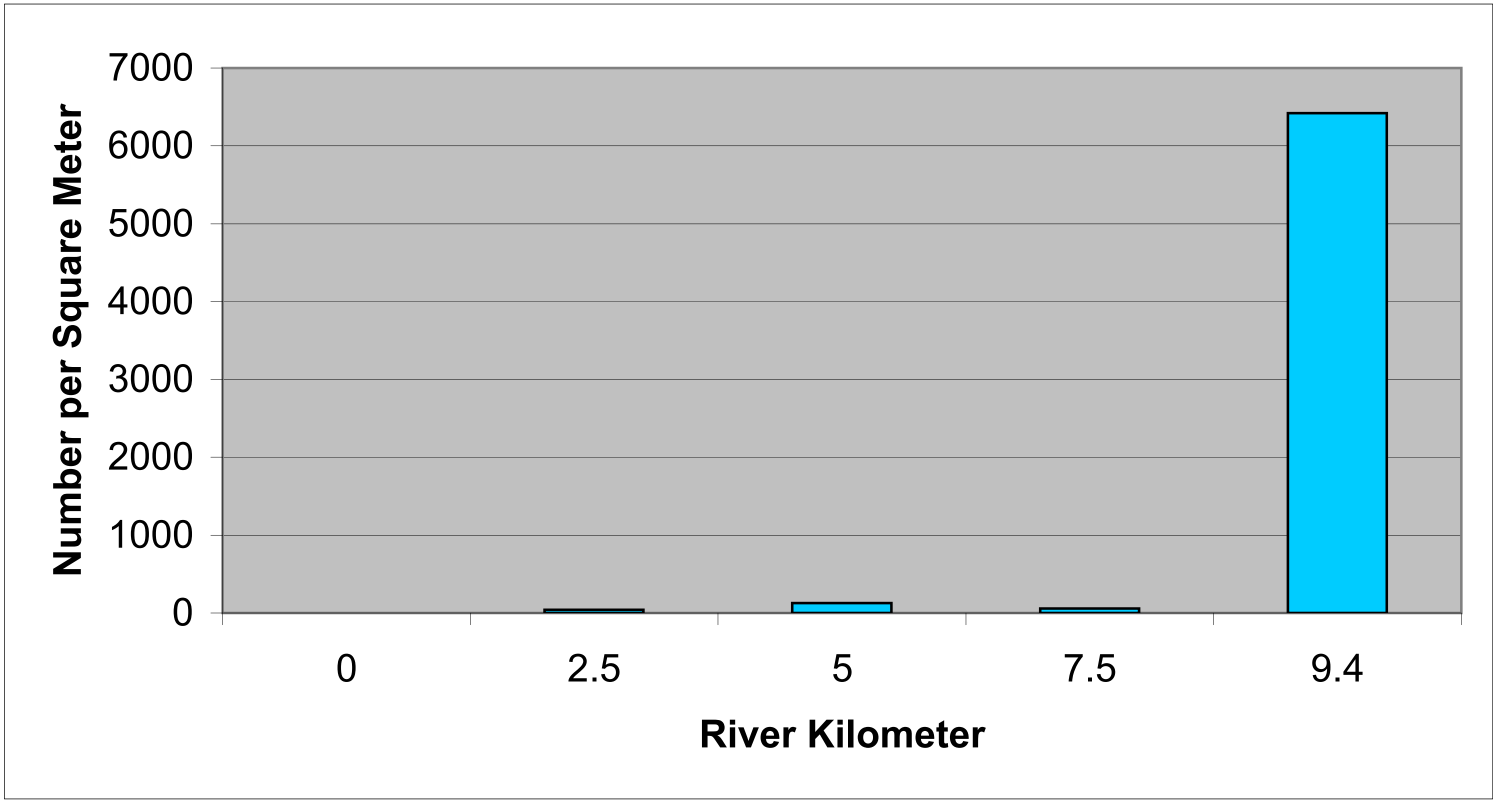


Figure H-19. Longitudinal Distribution of Hobsonia florida by River Kilometer in the mainstem of the Crystal River, July 2009.

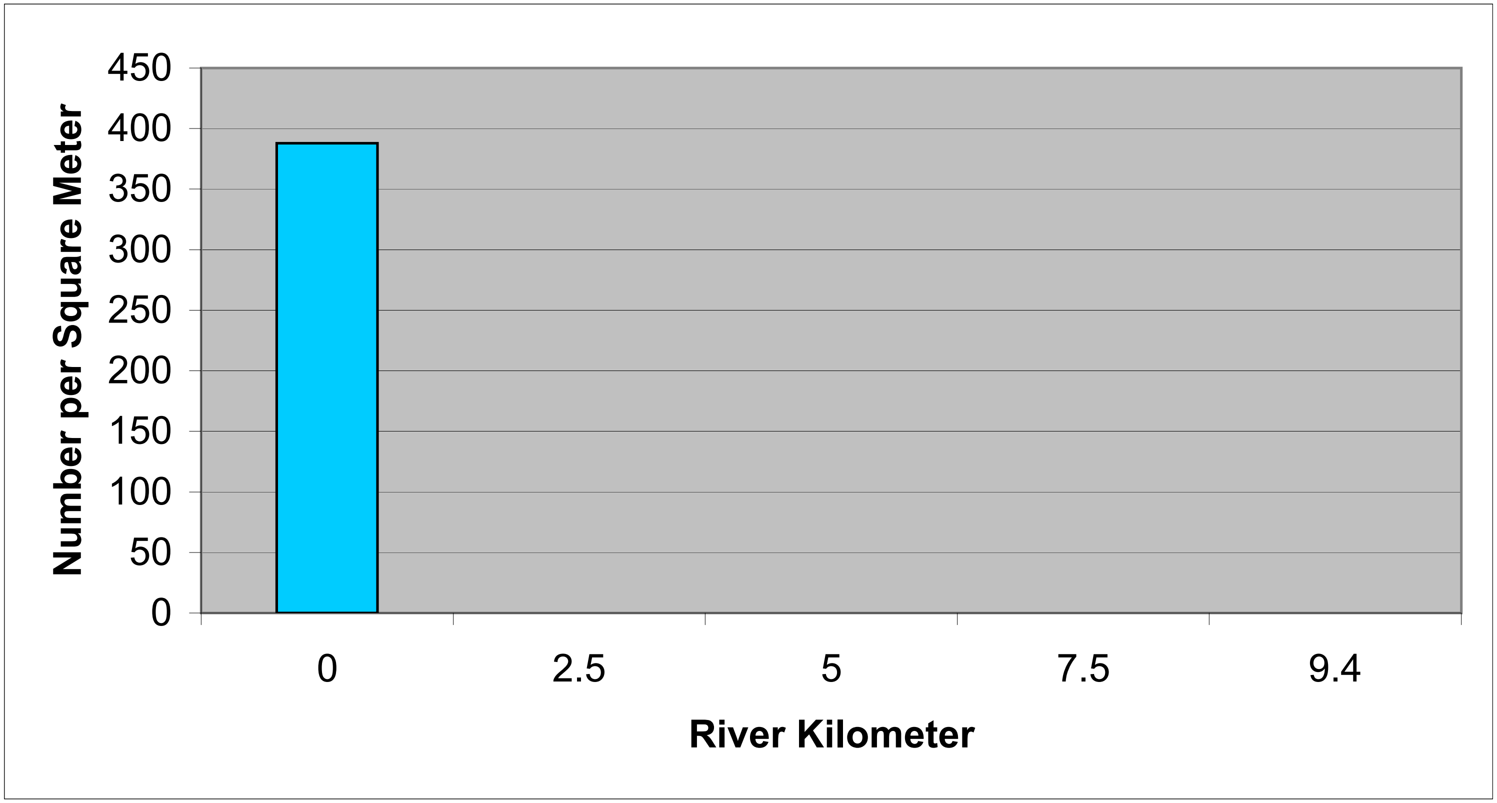


Figure H-20. Longitudinal Distribution of Aricidea taylori by River Kilometer in the mainstem of the Crystal River, July 2009.

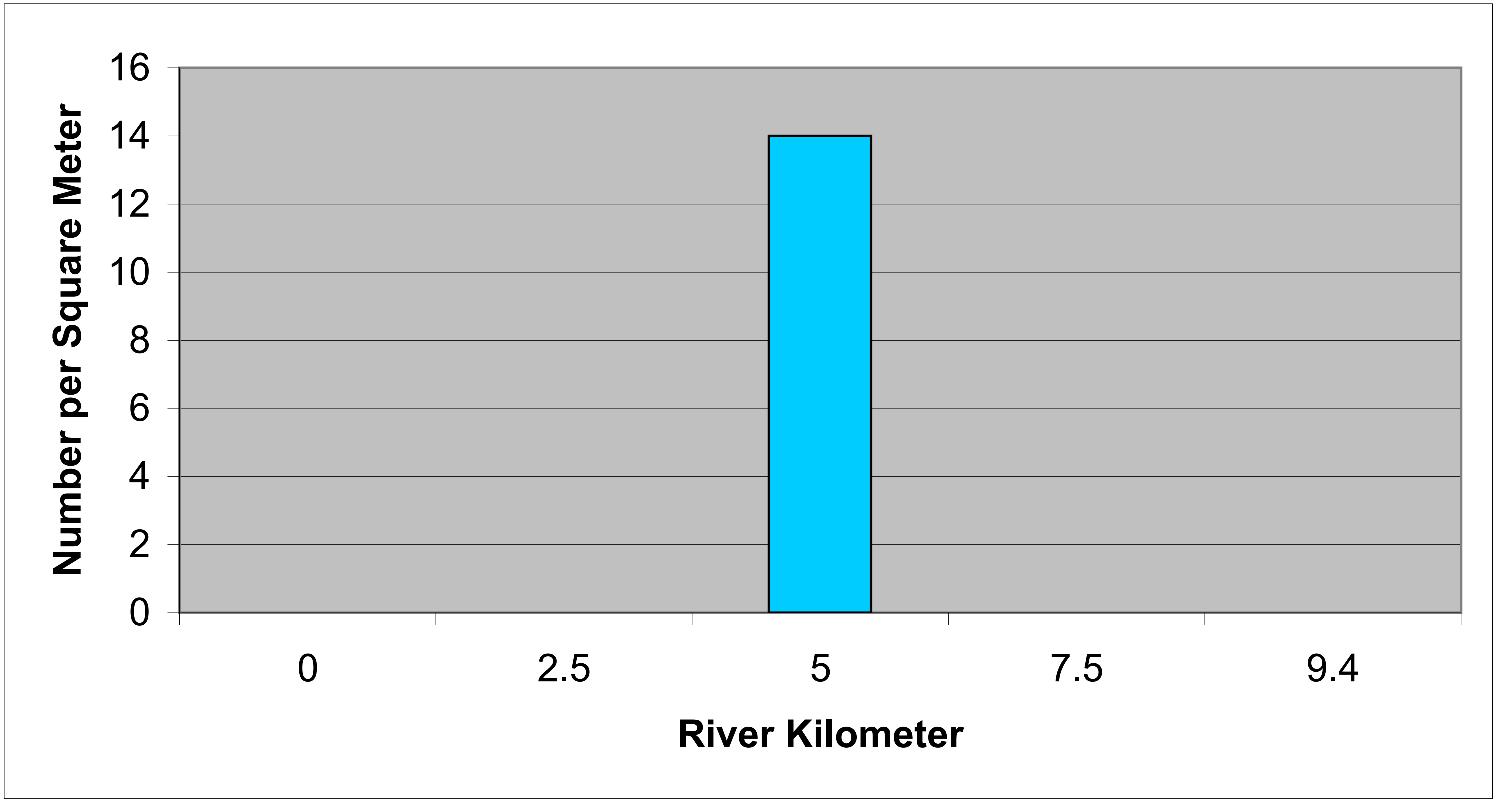


Figure H-21. Longitudinal Distribution of Gammarus sp. B LeCroy by River Kilometer in the mainstem of the Crystal River, July 2009.

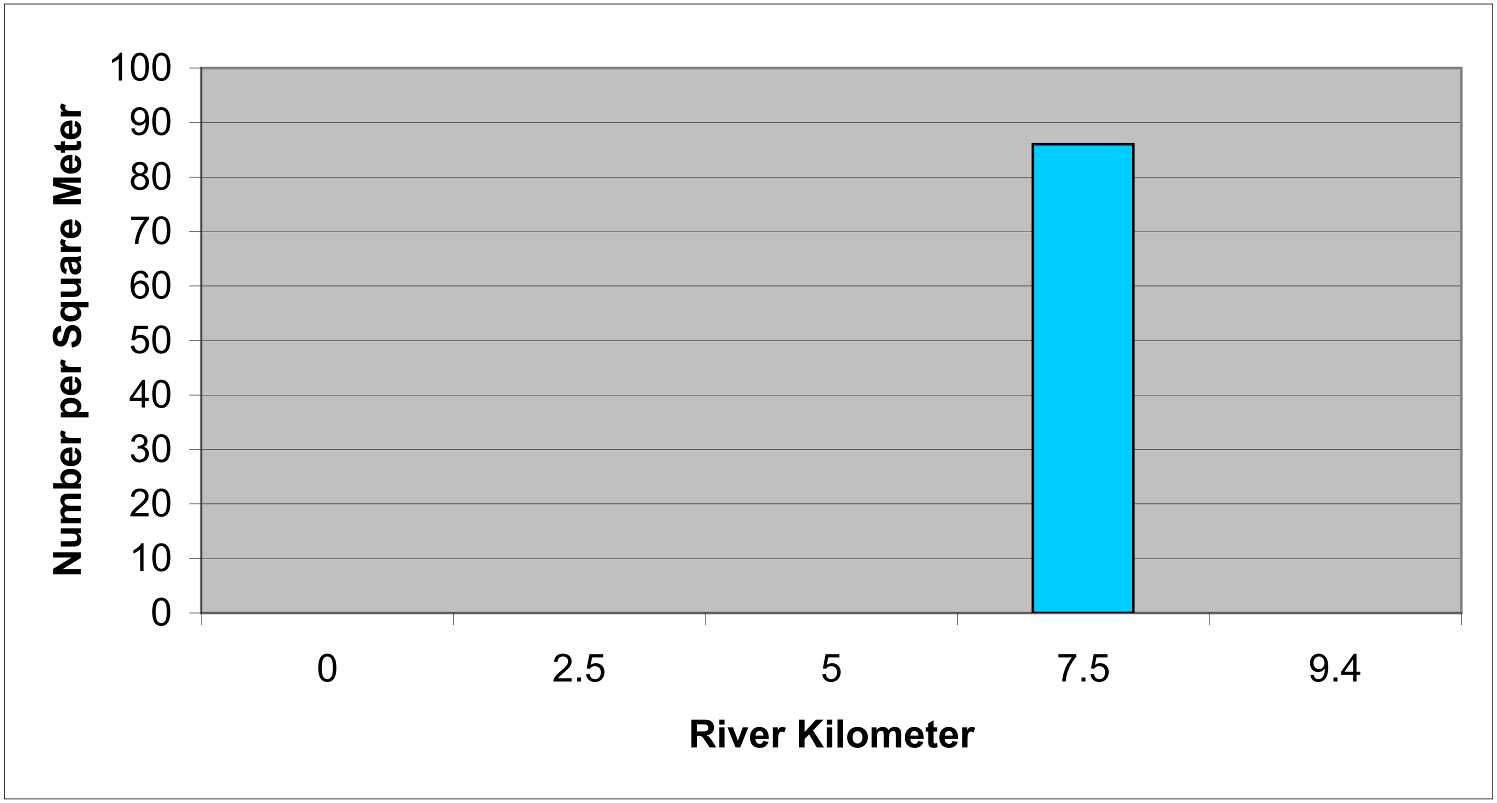


Figure H-22. Longitudinal Distribution of Pyrgophorus platyrachis by River Kilometer in the mainstem of the Crystal River, July 2009.

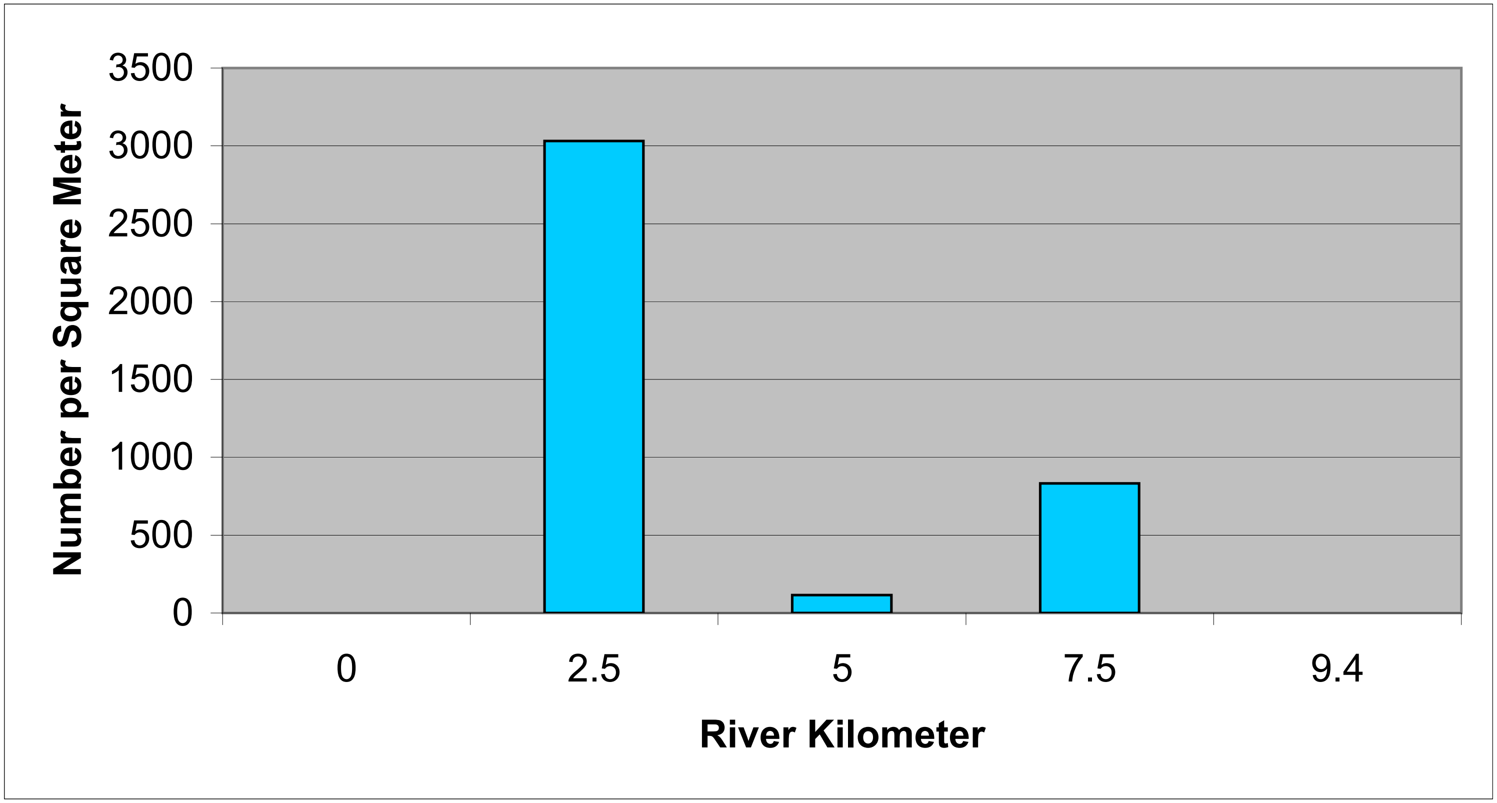


Figure H-23. Longitudinal Distribution of Halmyrapseudes cf. bahamensis Heard by River Kilometer in the mainstem of the Crystal River, July 2009.

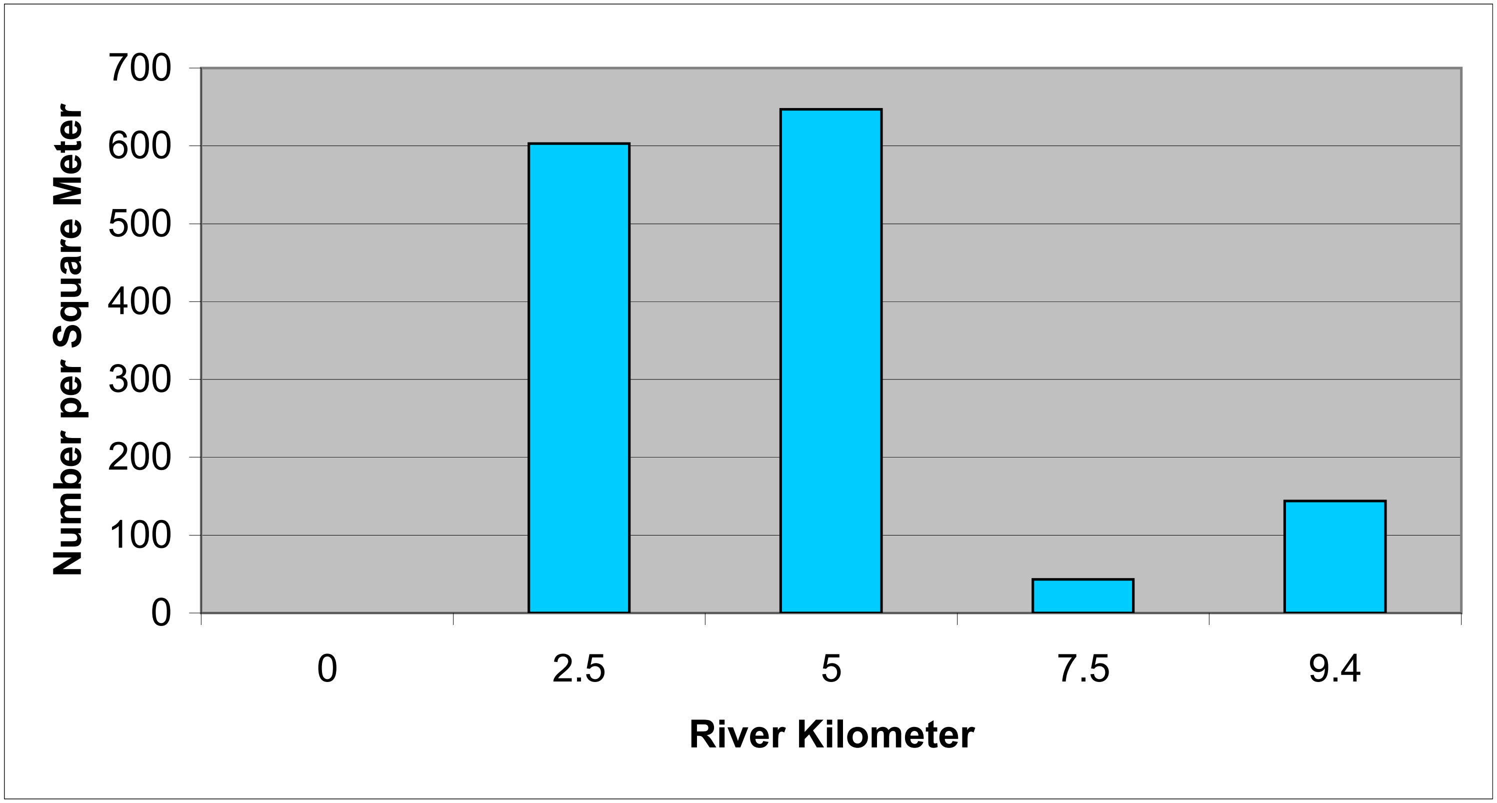


Figure H-24. Longitudinal Distribution of Streblospio sp. by River Kilometer in the mainstem of the Crystal River, July 2009.

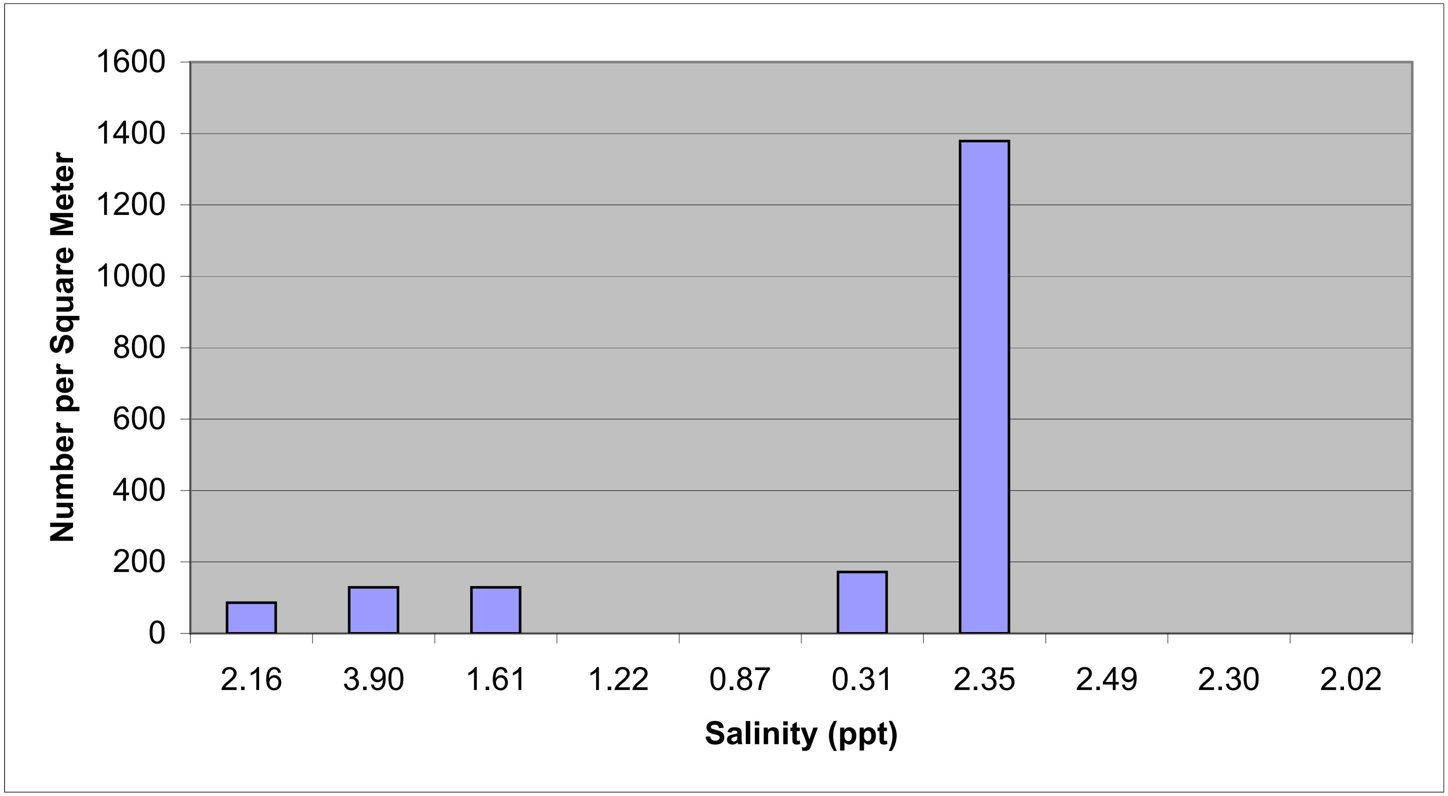


Figure H-25. Distribution of Apocorophium louisianum in relation to bottom salinity in Kings Bay, July 2009.

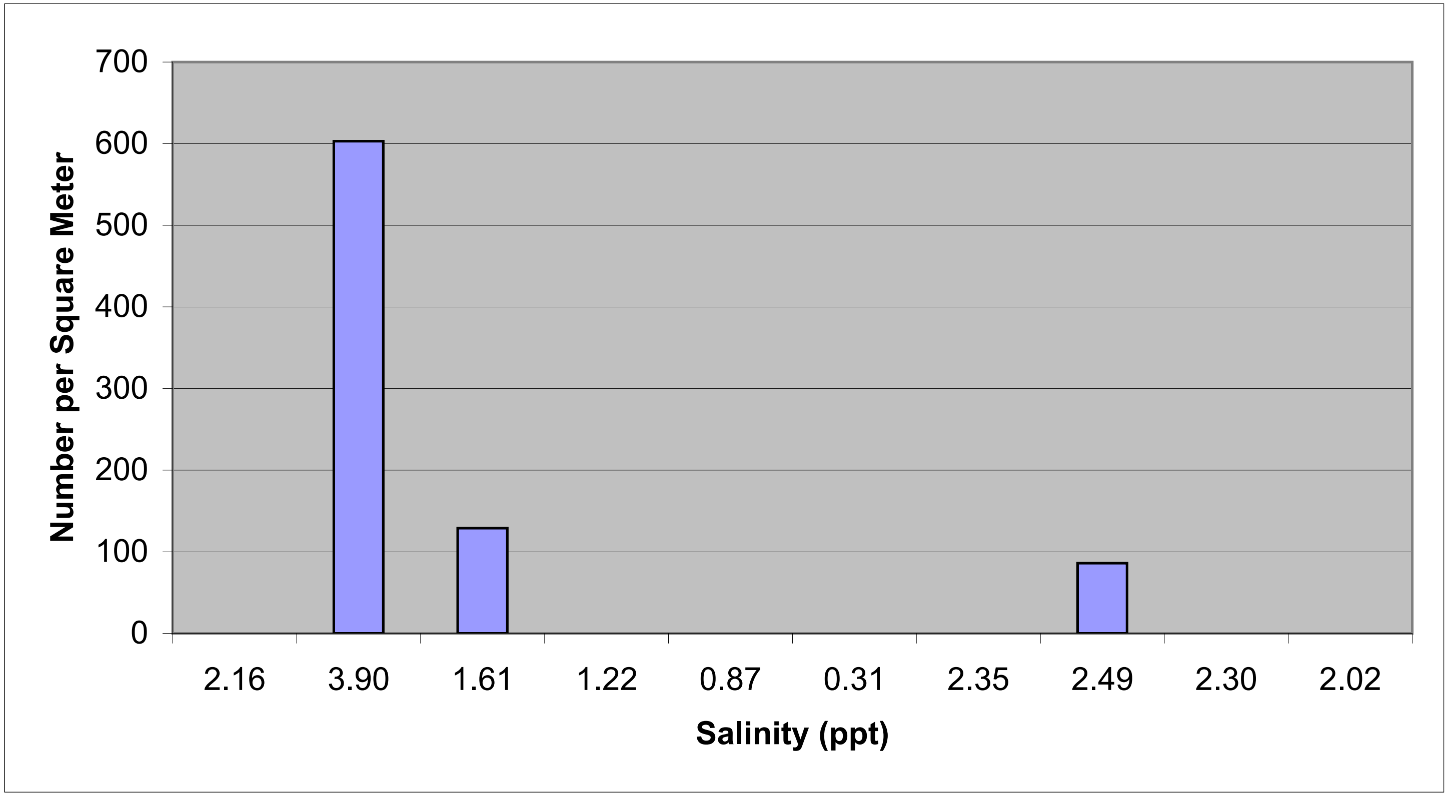


Figure H-26. Distribution of Cerapus benthophilus in relation to bottom salinity in Kings Bay, July 2009.

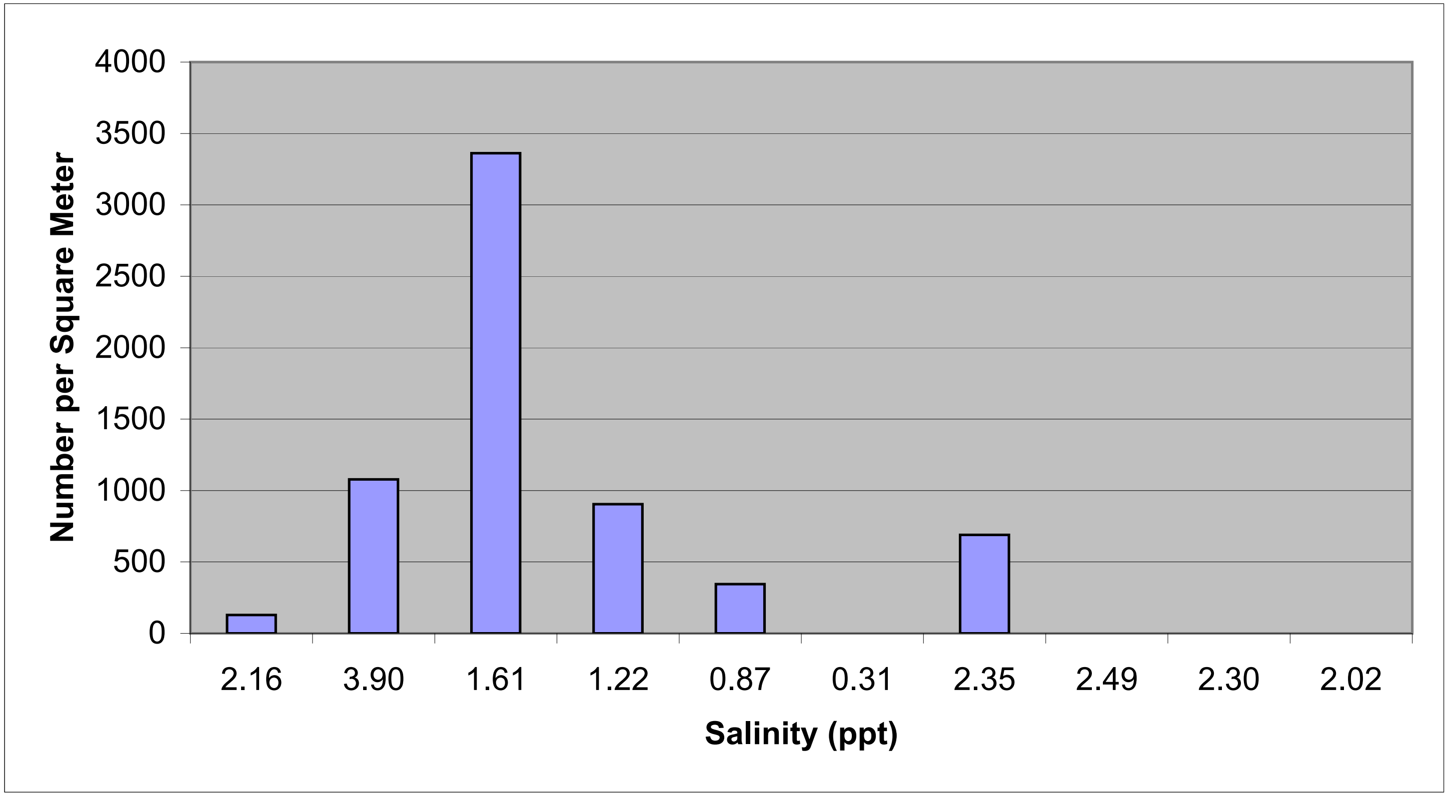


Figure H-27. Distribution of Cyrenoida floridana in relation to bottom salinity in Kings Bay, July 2009.

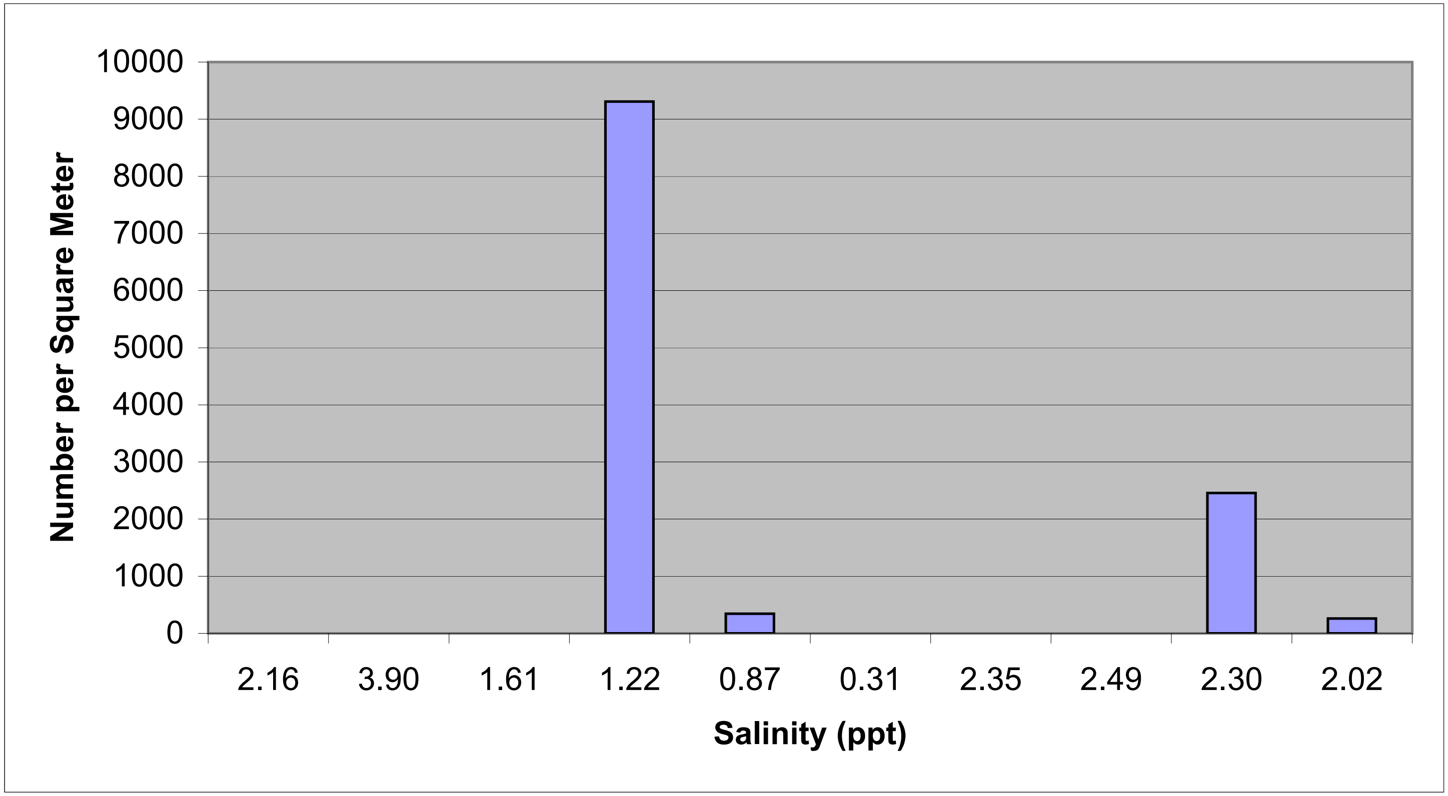


Figure H-28. Distribution of Dero digitata complex Milligan in relation to bottom salinity in Kings Bay, July 2009.

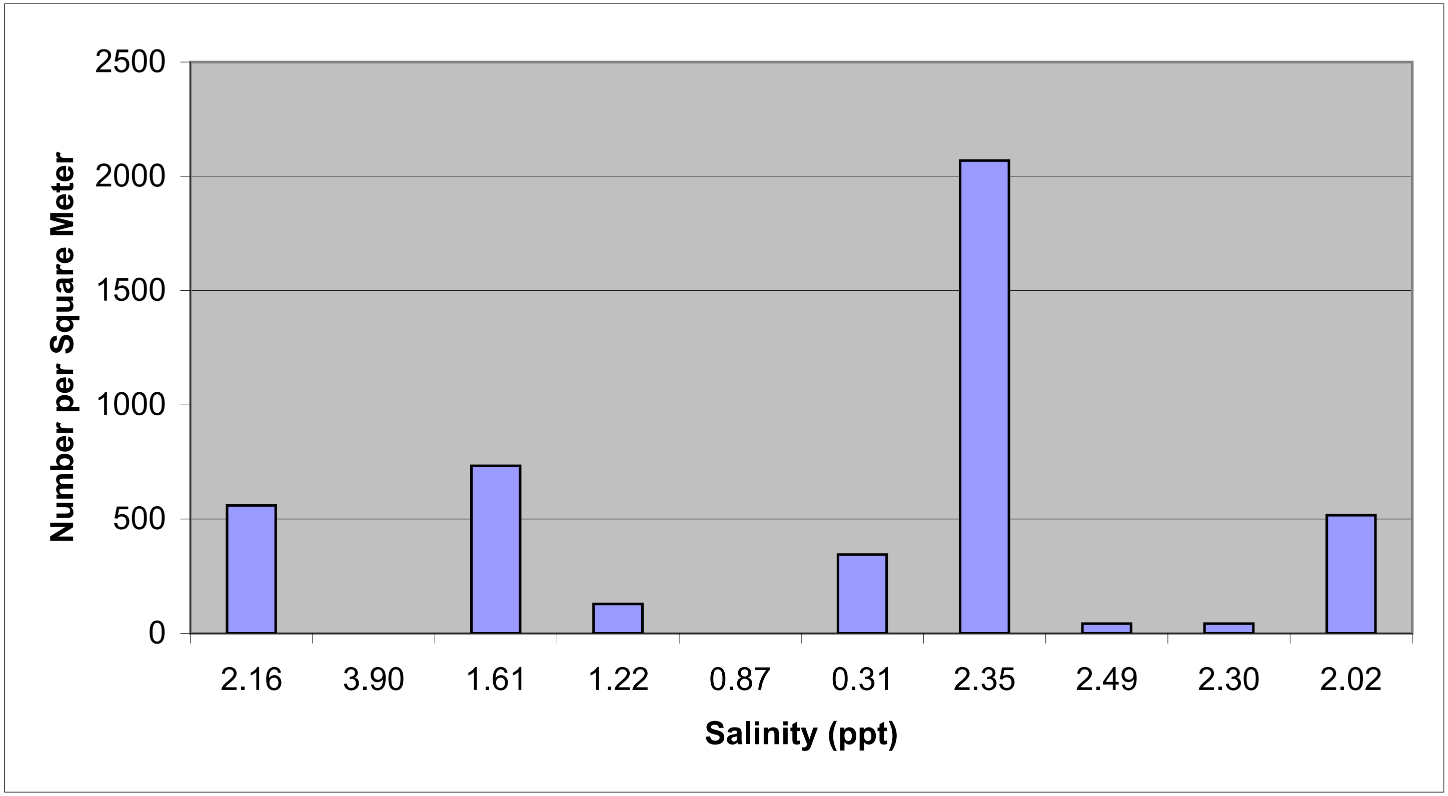


Figure H-29. Distribution of Gammarus sp. B LeCroy in relation to bottom salinity in Kings Bay, July 2009.

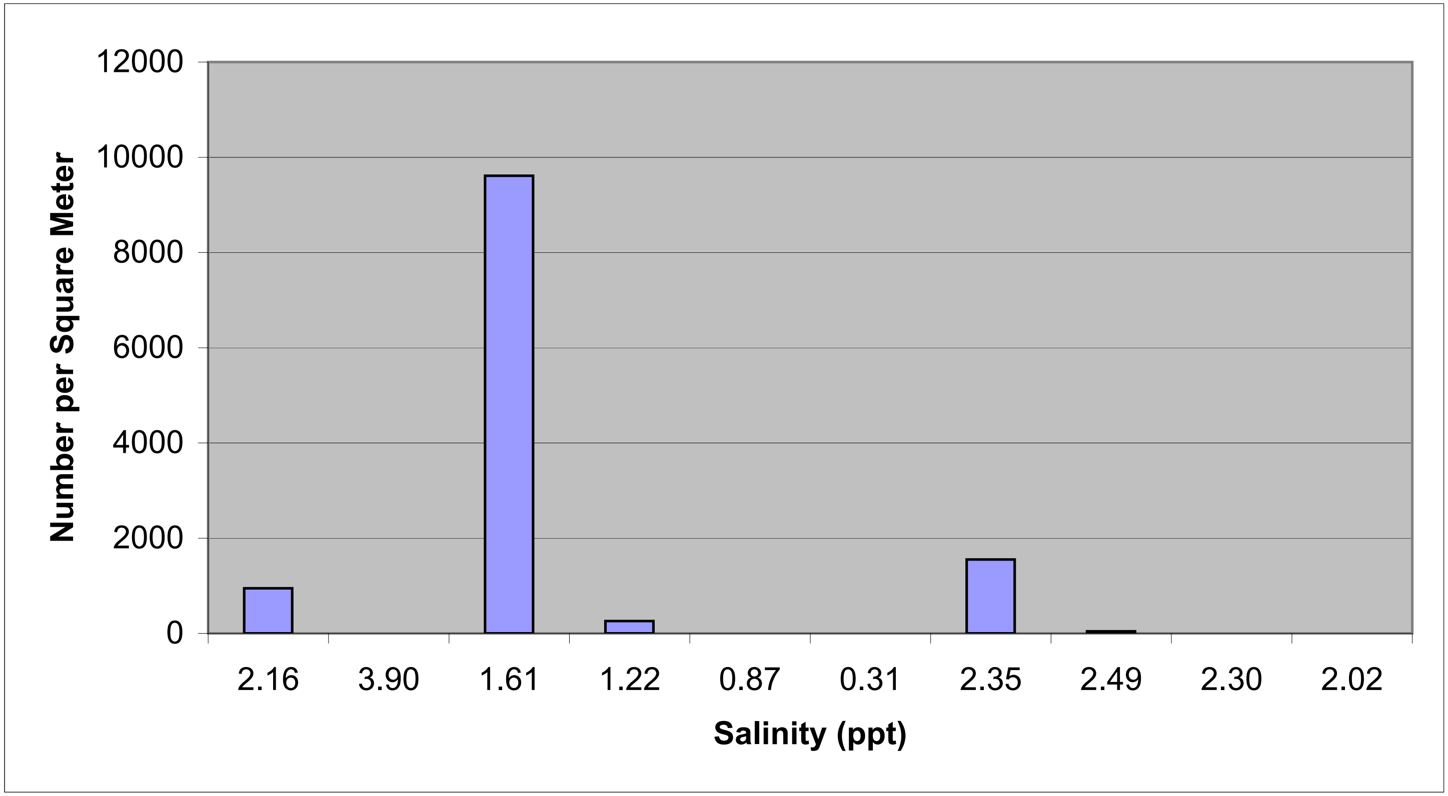


Figure H-30. Distribution of Hobsonia florida in relation to bottom salinity in Kings Bay, July 2009.

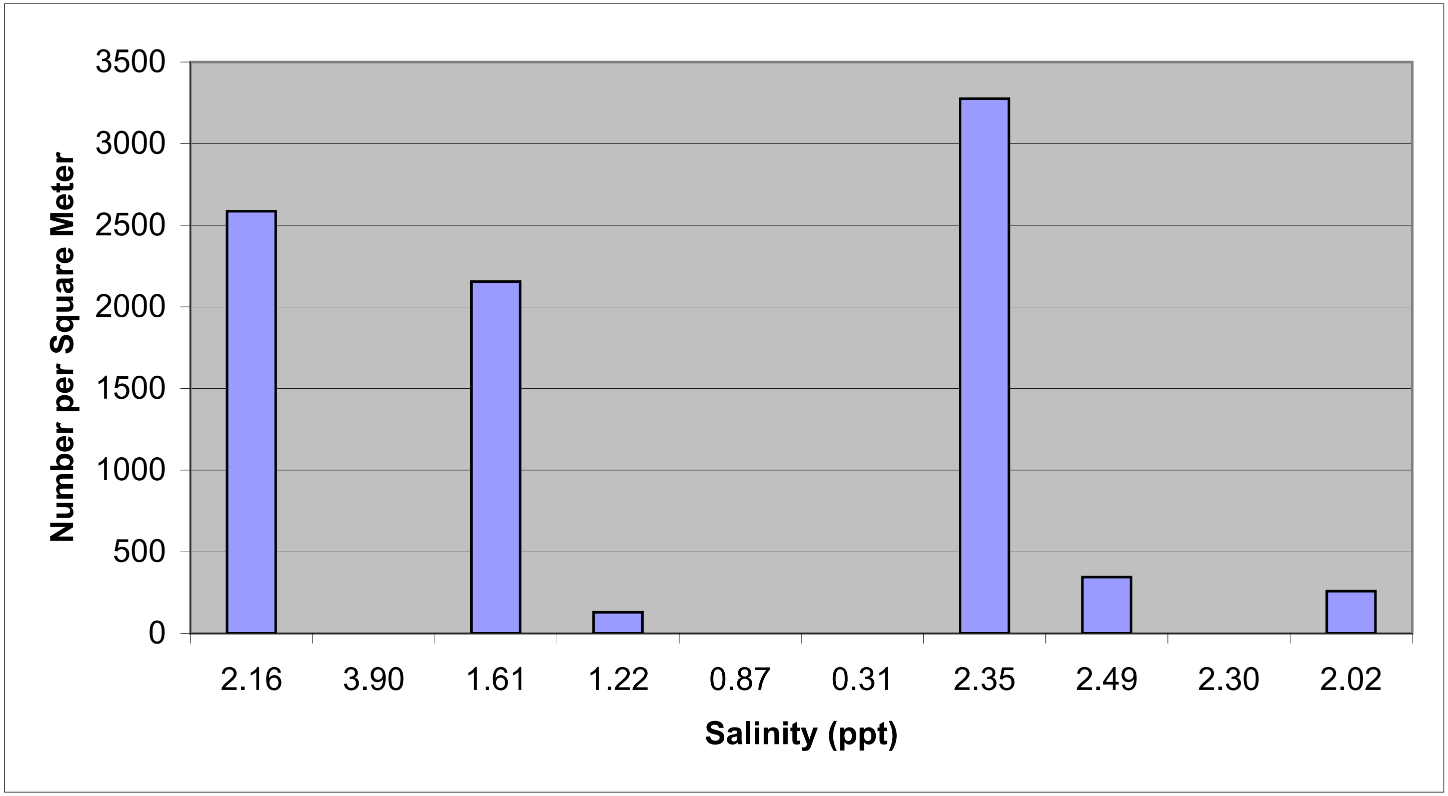


Figure H-31. Distribution of Laeonereis culveri in relation to bottom salinity in Kings Bay, July 2009.

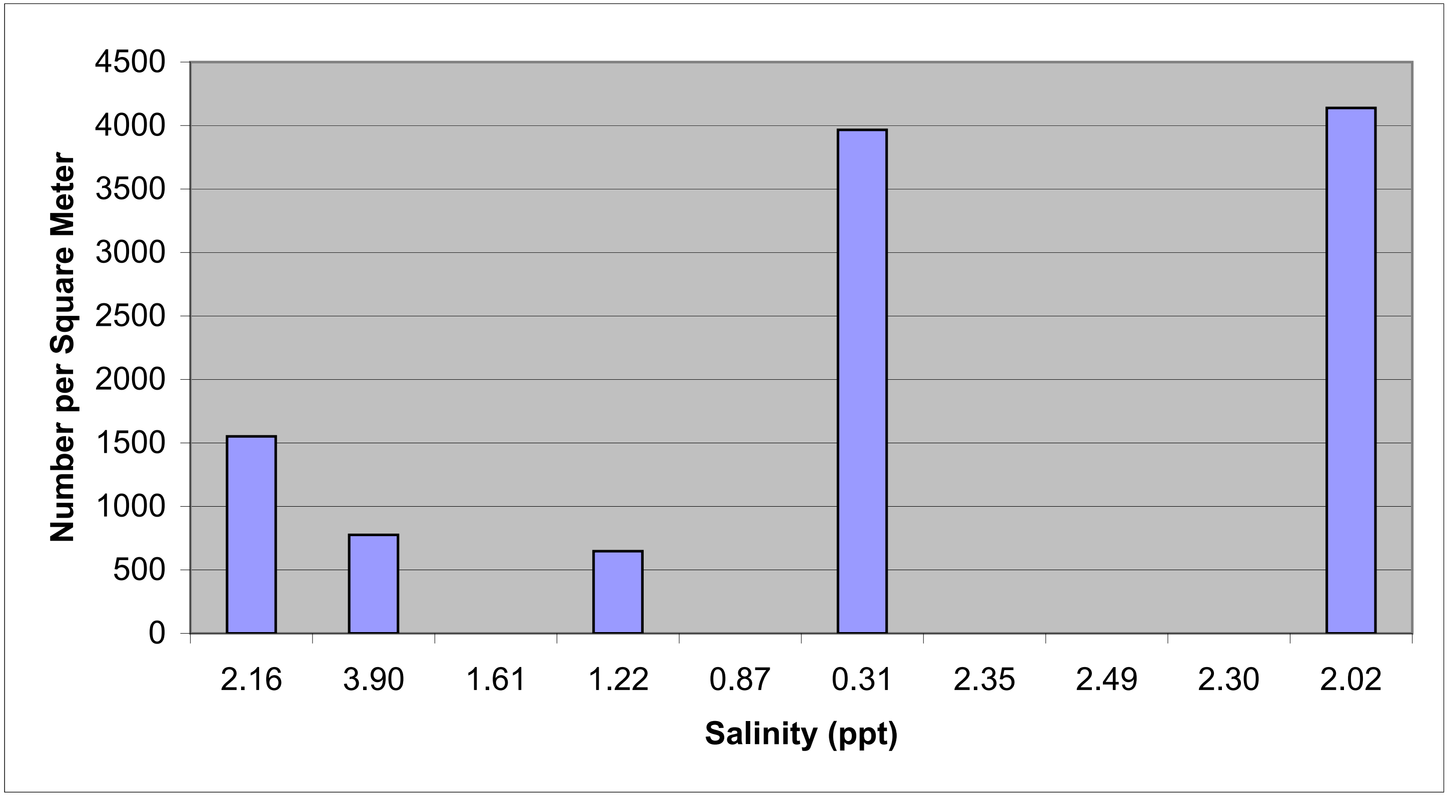


Figure H-32. Distribution of Limnodrilus hoffmeisteri in relation to bottom salinity in Kings Bay, July 2009.

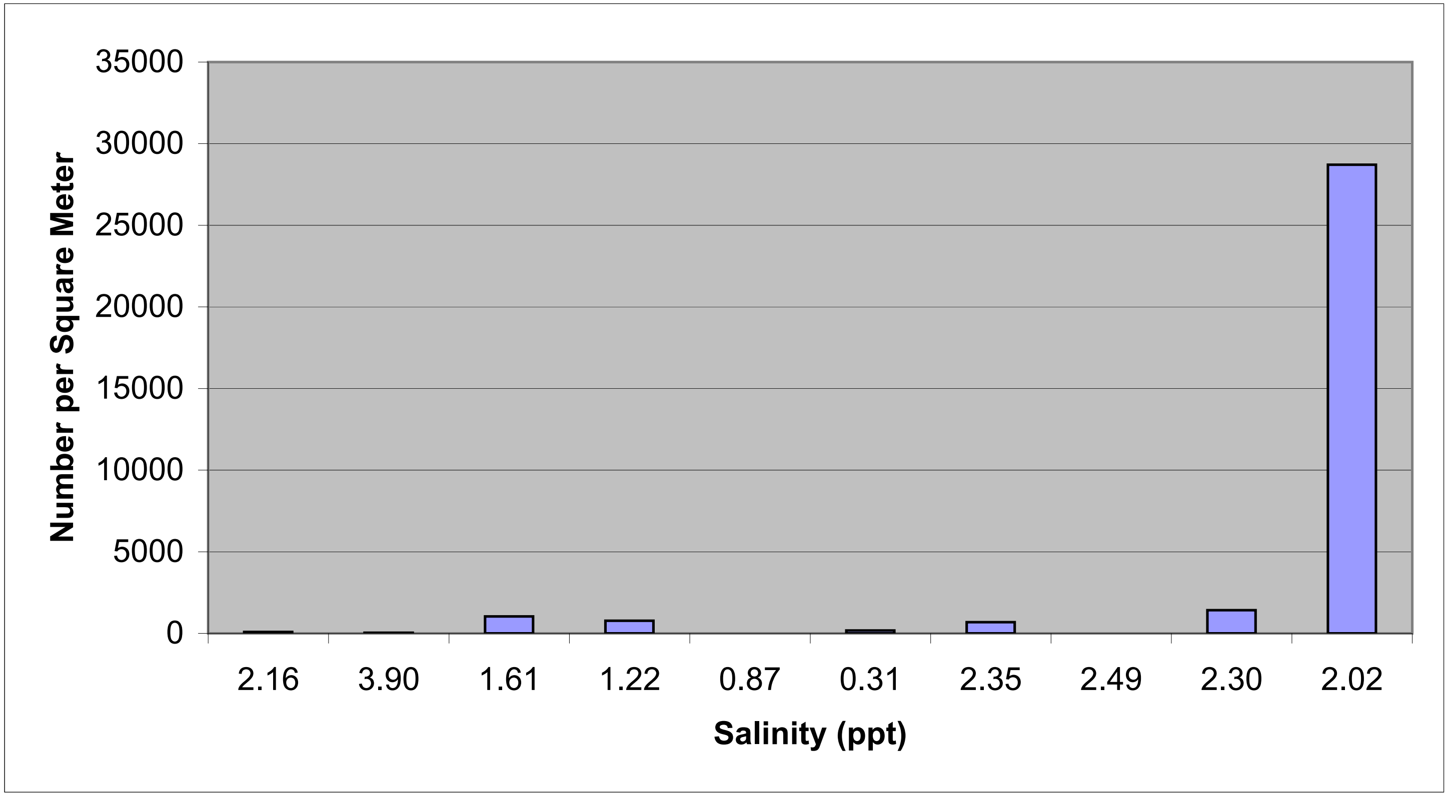


Figure H-33. Distribution of Littoridinops sp. in relation to bottom salinity in Kings Bay, July 2009.

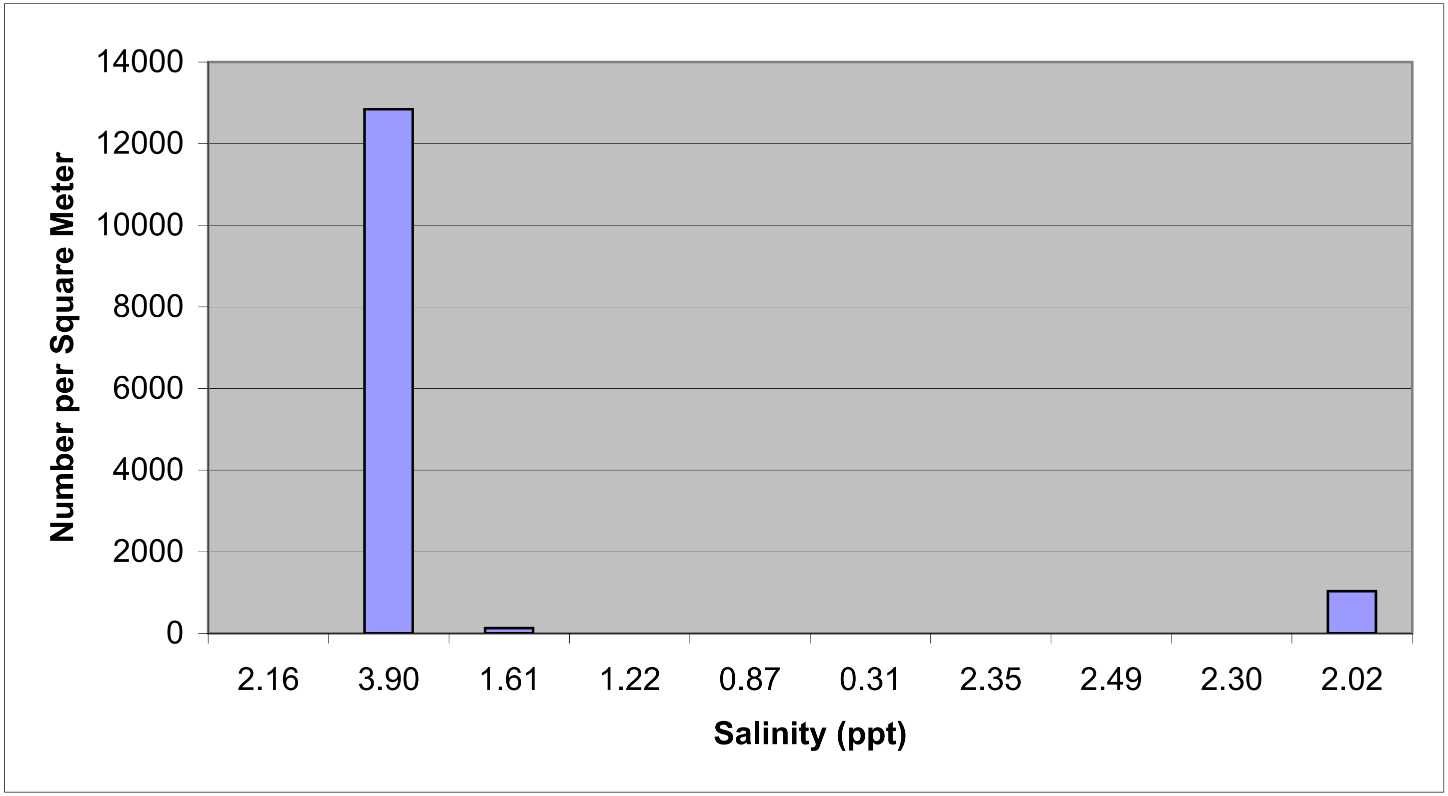


Figure H-34. Distribution of Pyrgophorus platyrachis in relation to bottom salinity in Kings Bay, July 2009.

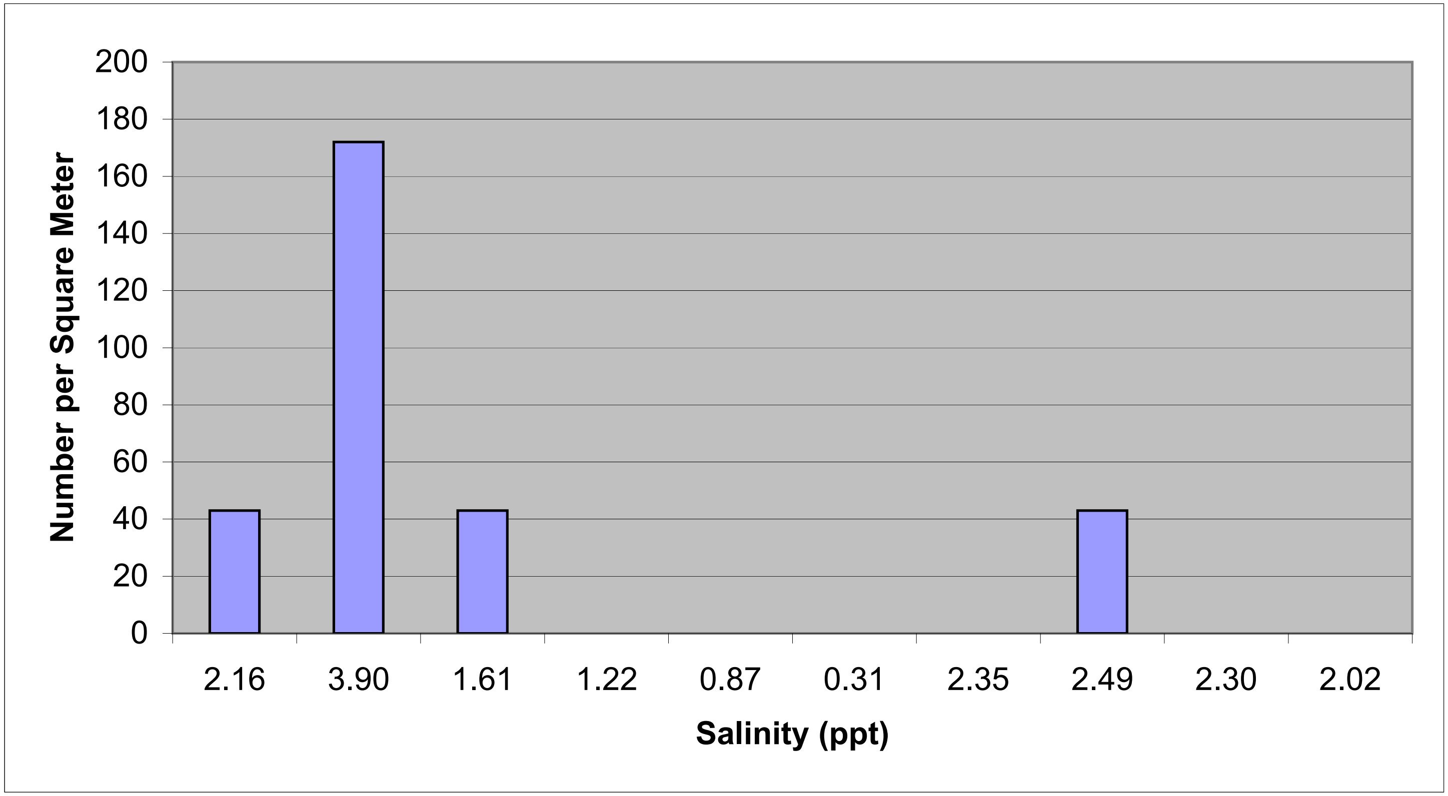


Figure H-35. Distribution of Streblospio sp. in relation to bottom salinity in Kings Bay, July 2009.

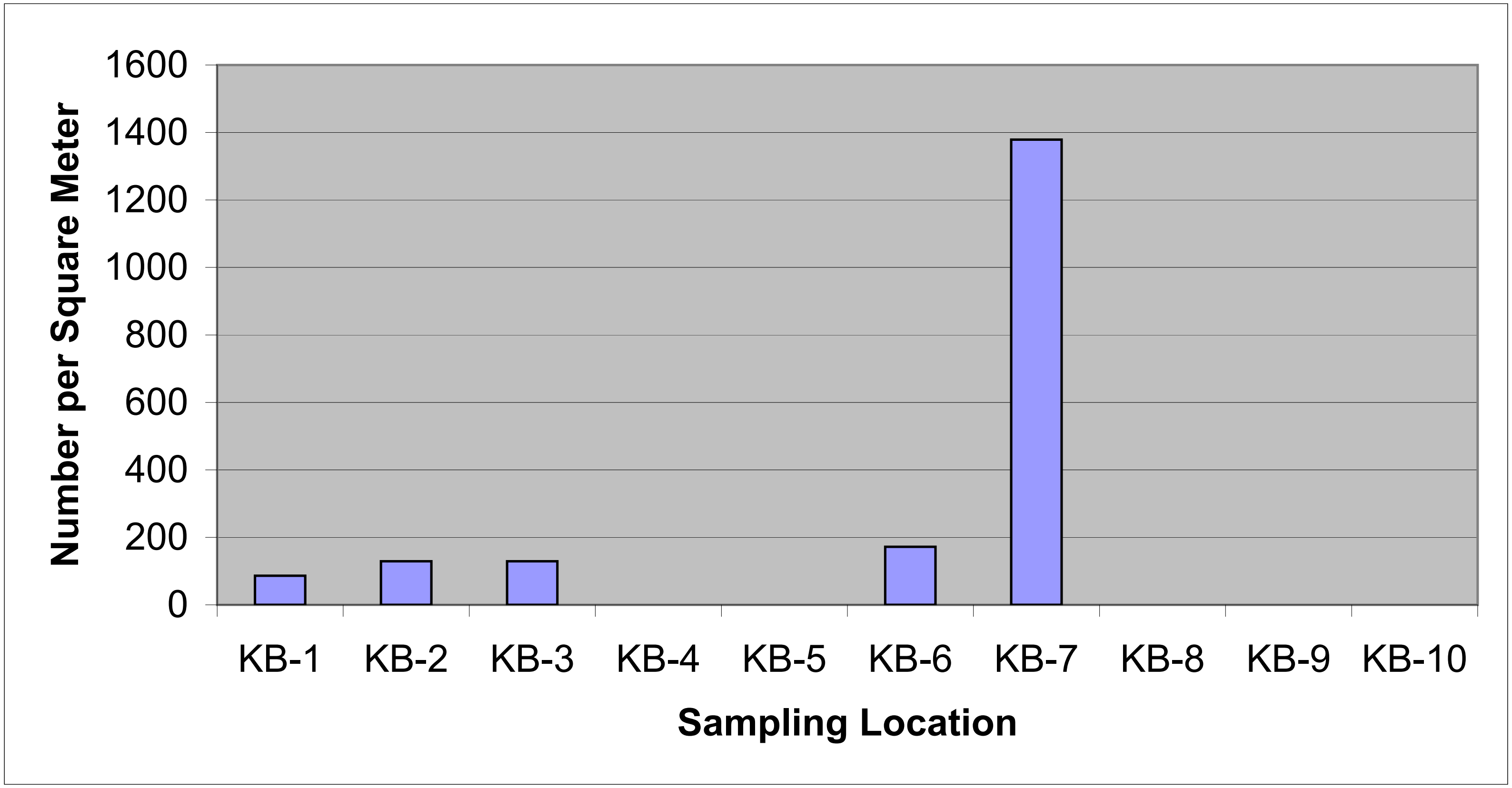


Figure H-36. Density (no. per square meter) of Apocorophium louisianum by sampling location in Kings Bay, July 2009.

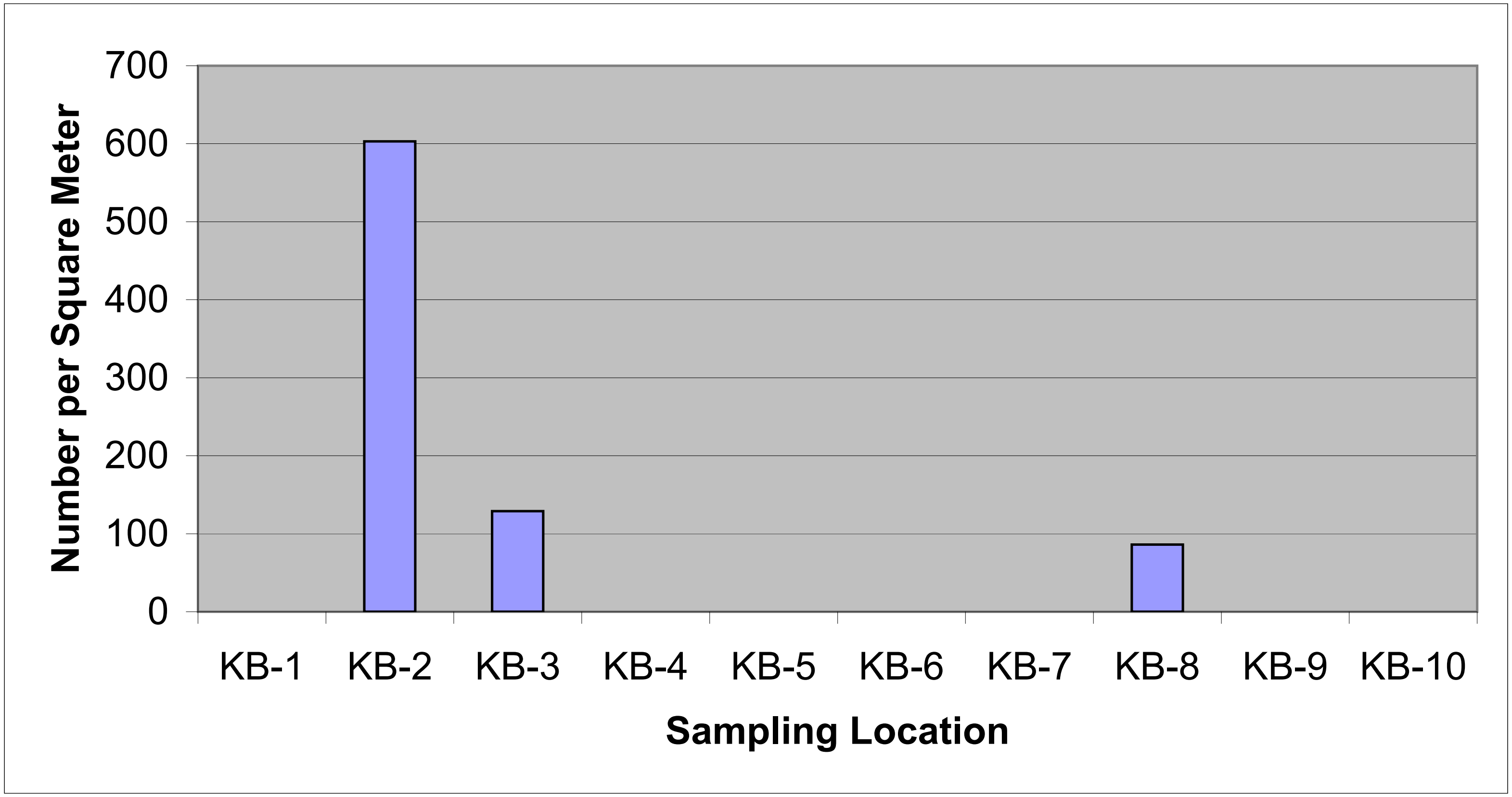


Figure H-37. Density (no. per square meter) of Cerapus benthophilus by sampling location in Kings Bay, July 2009.

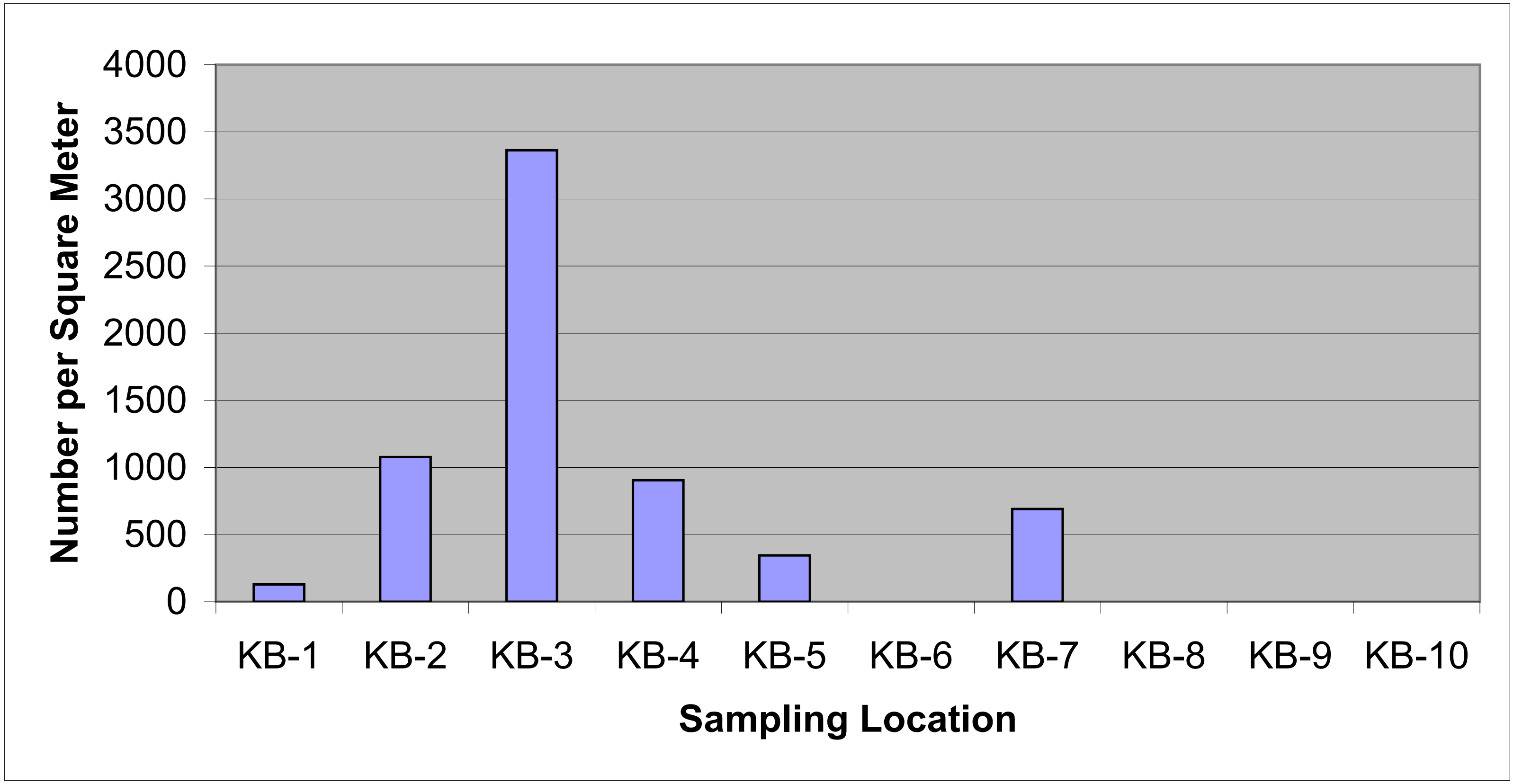


Figure H-38. Density (no. per square meter) of Cyrenoida floridana by sampling location in Kings Bay, July 2009.

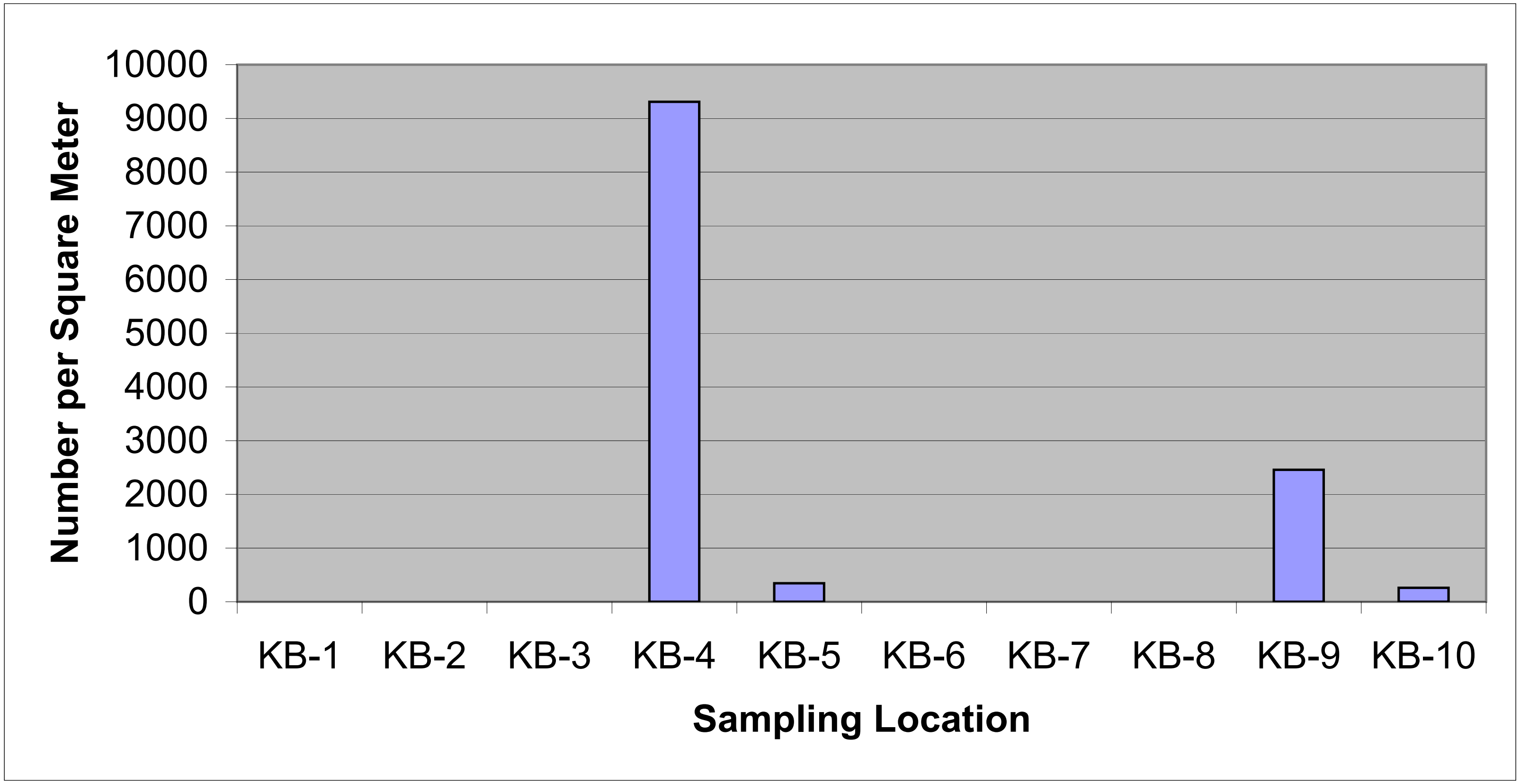


Figure H-39. Density (no. per square meter) of Dero digitata complex Milligan by sampling location in Kings Bay, July 2009.

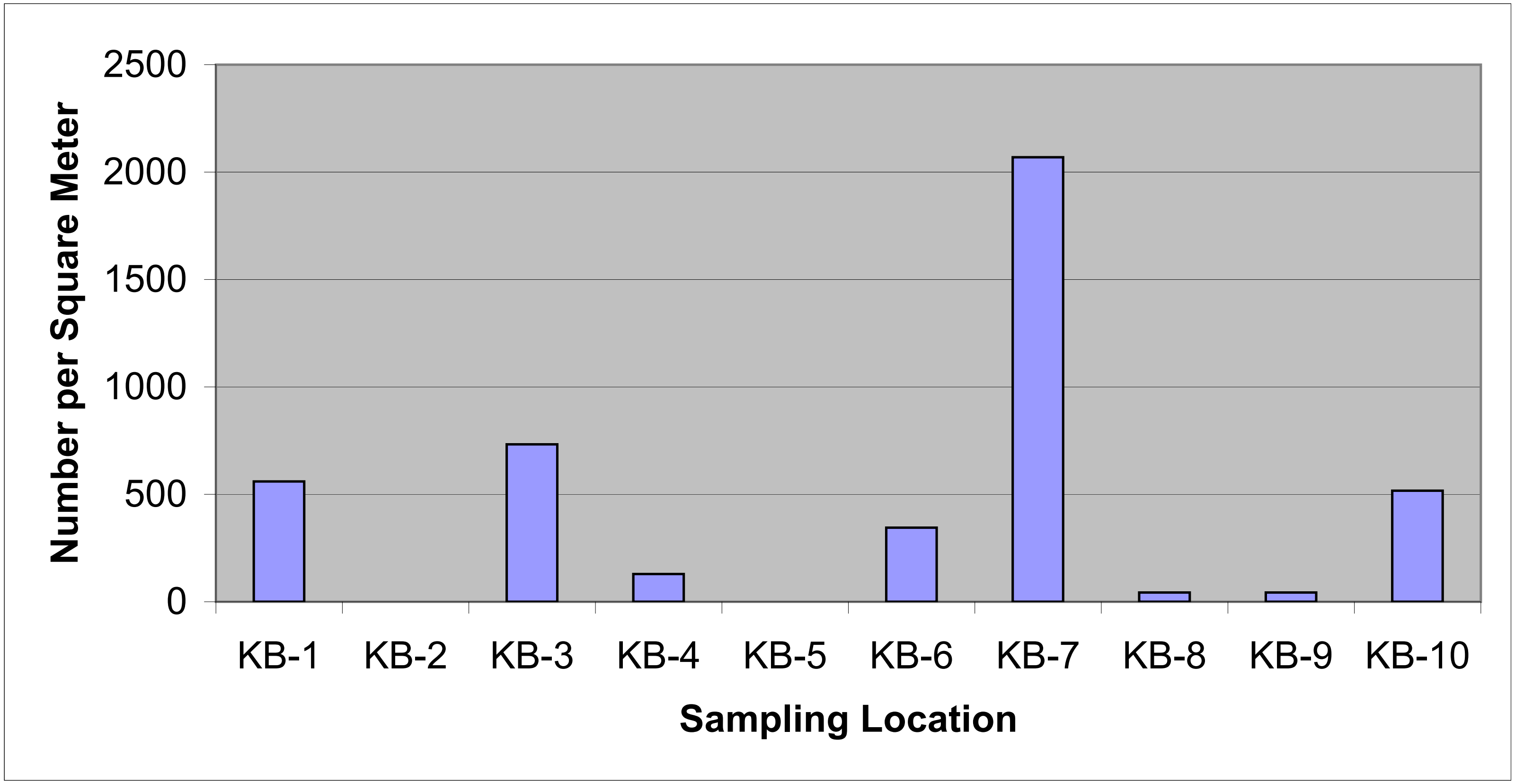


Figure H-40. Density (no. per square meter) of Gammarus sp. B Lecroy by sampling location in Kings Bay, July 2009.

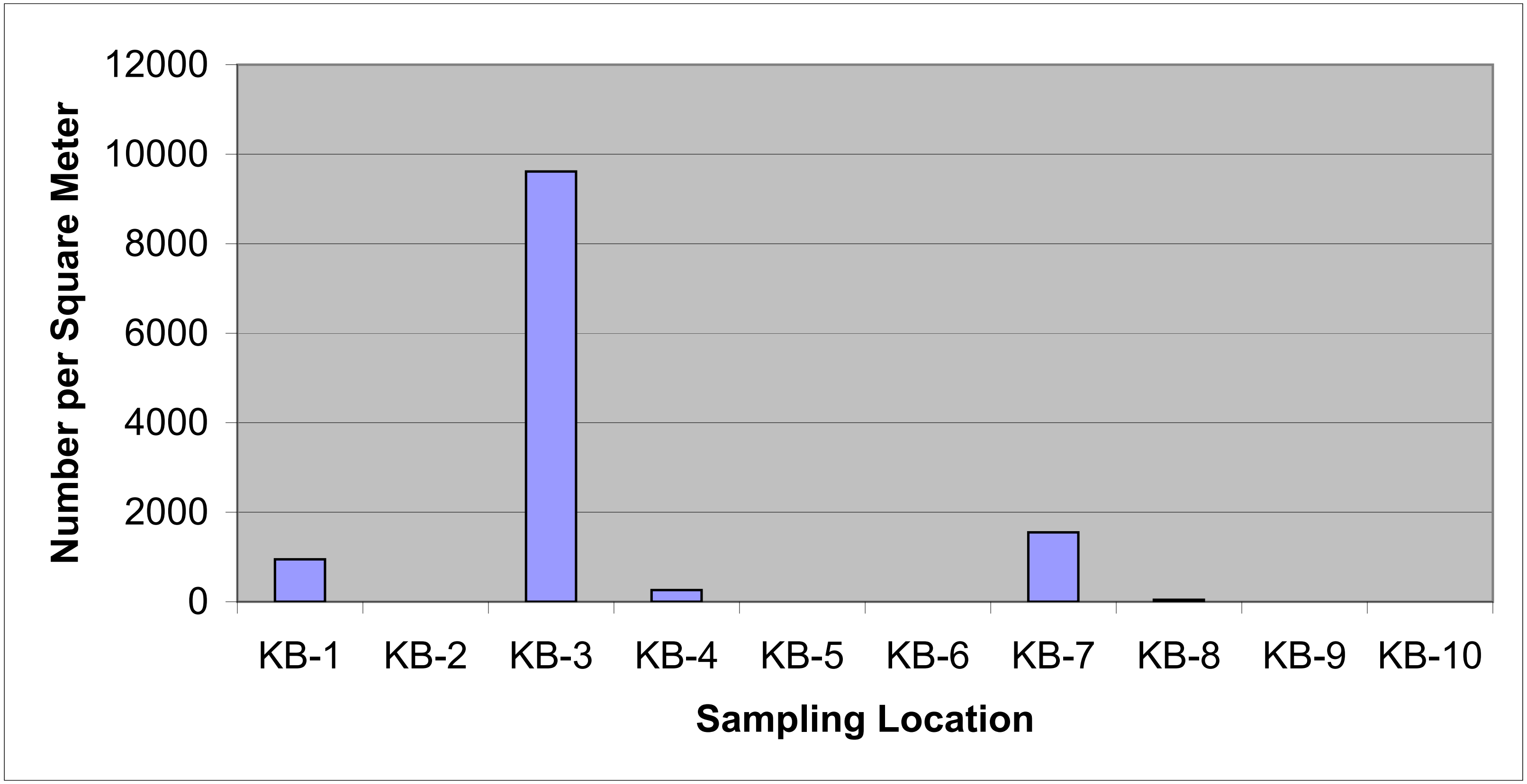


Figure H-41. Density (no. per square meter) of Hobsonia florida by sampling location in Kings Bay, July 2009.

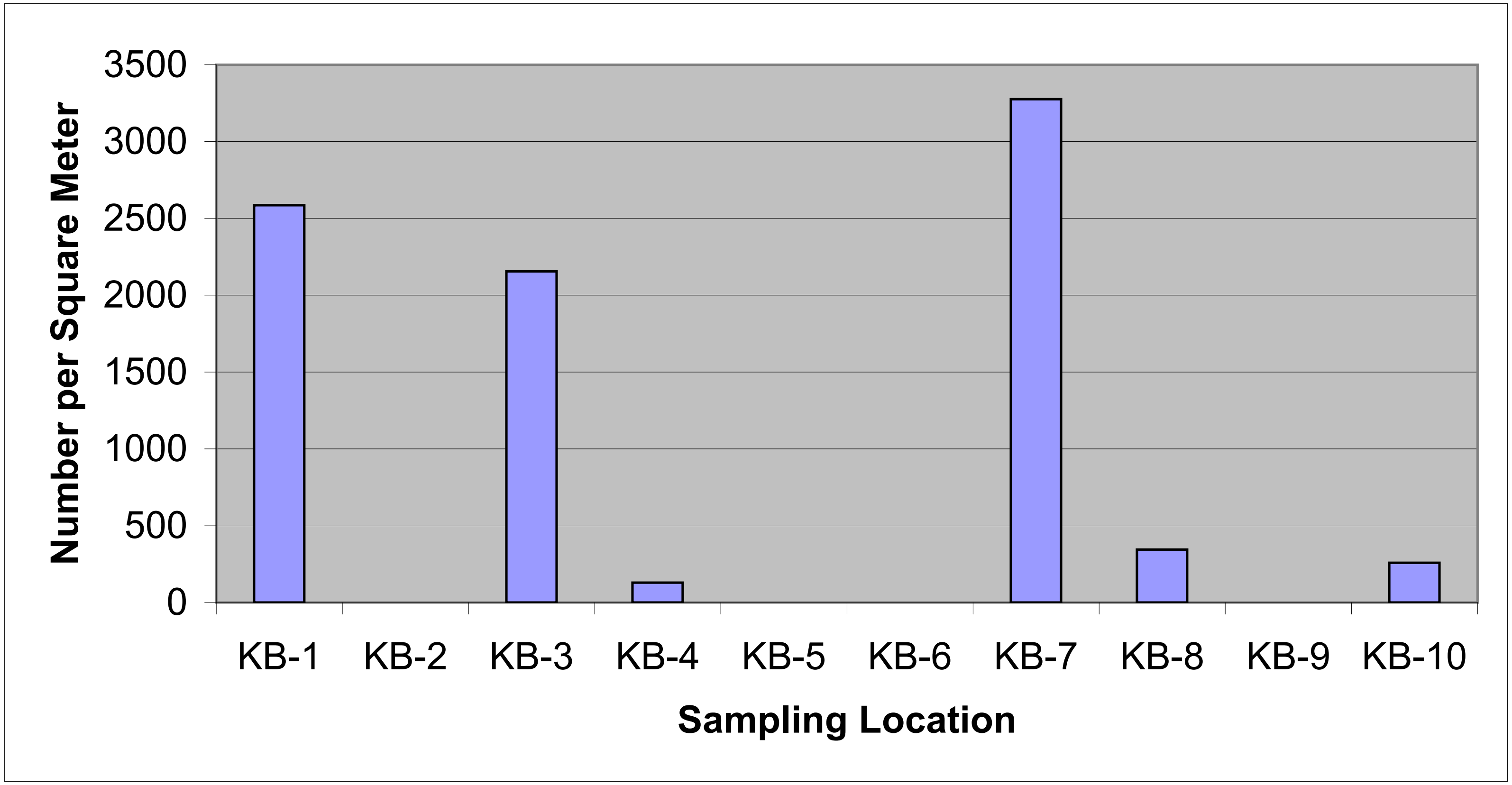


Figure H-42. Density (no. per square meter) of Laeonereis culveri by sampling location in Kings Bay, July 2009.

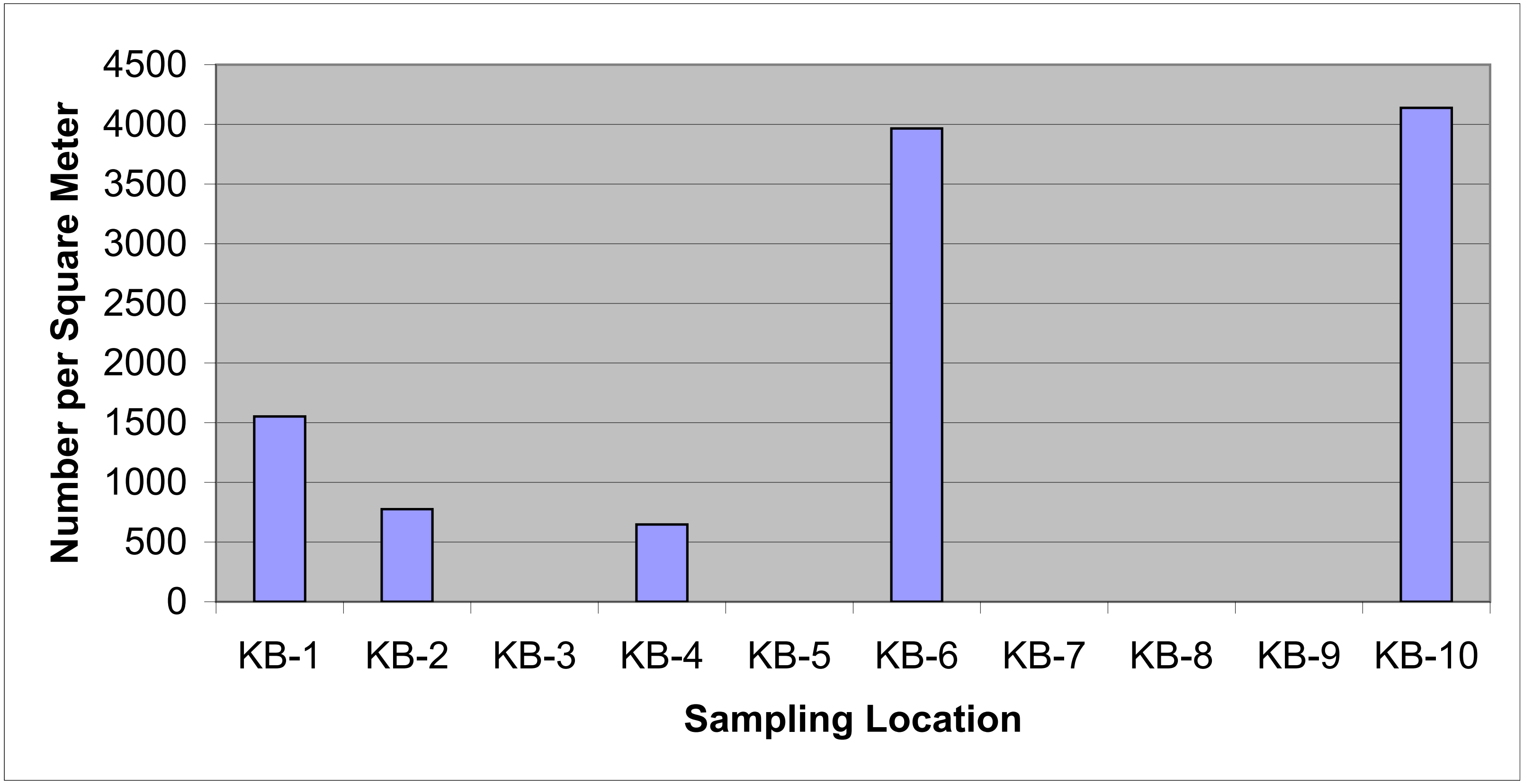


Figure H-43. Density (no. per square meter) of Limnodrilus hoffmeisteri by sampling location in Kings Bay, July 2009.

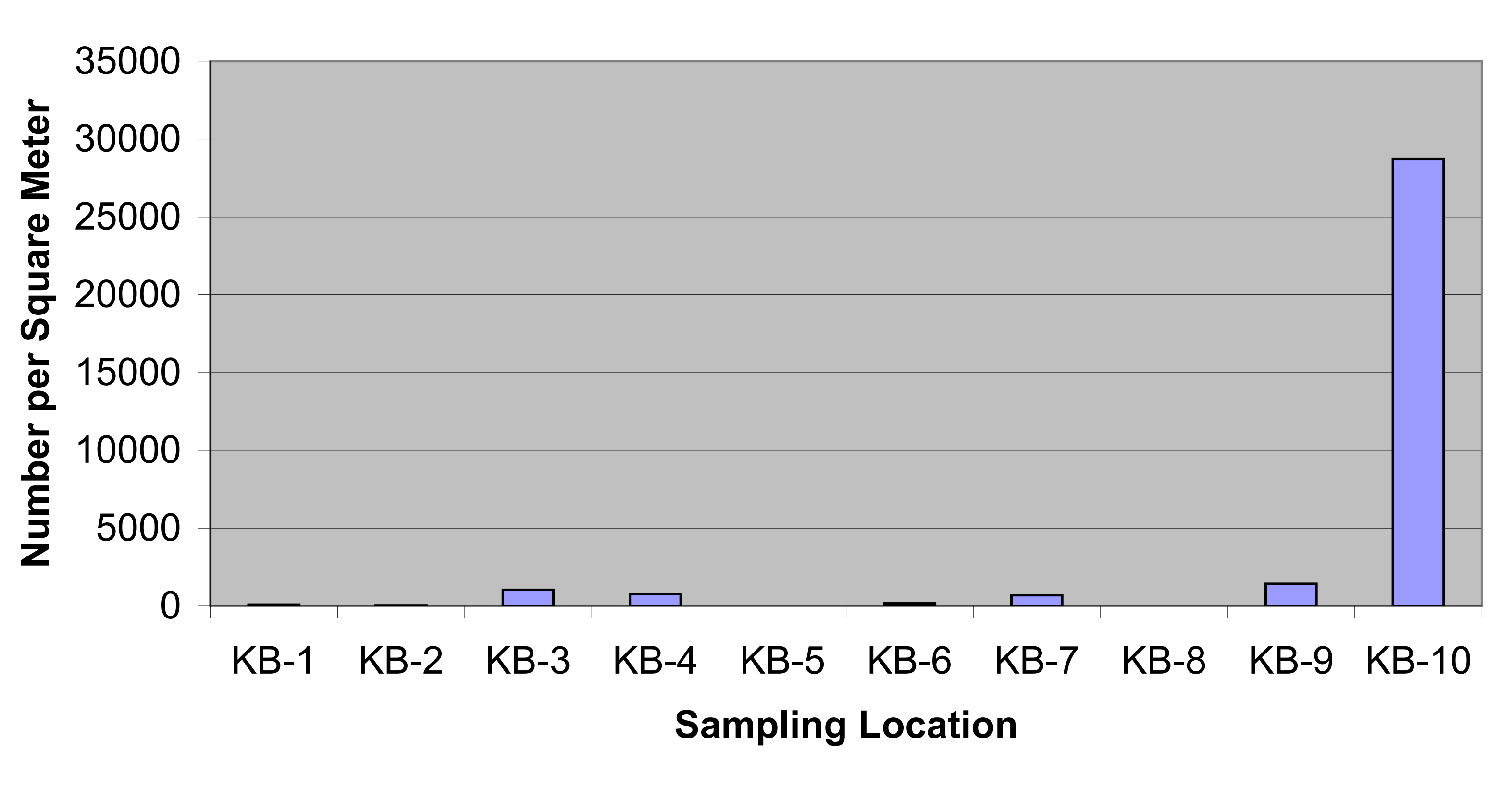


Figure H-44. Density (no. per square meter) of Littoridinops sp. by sampling location in Kings Bay, July 2009.

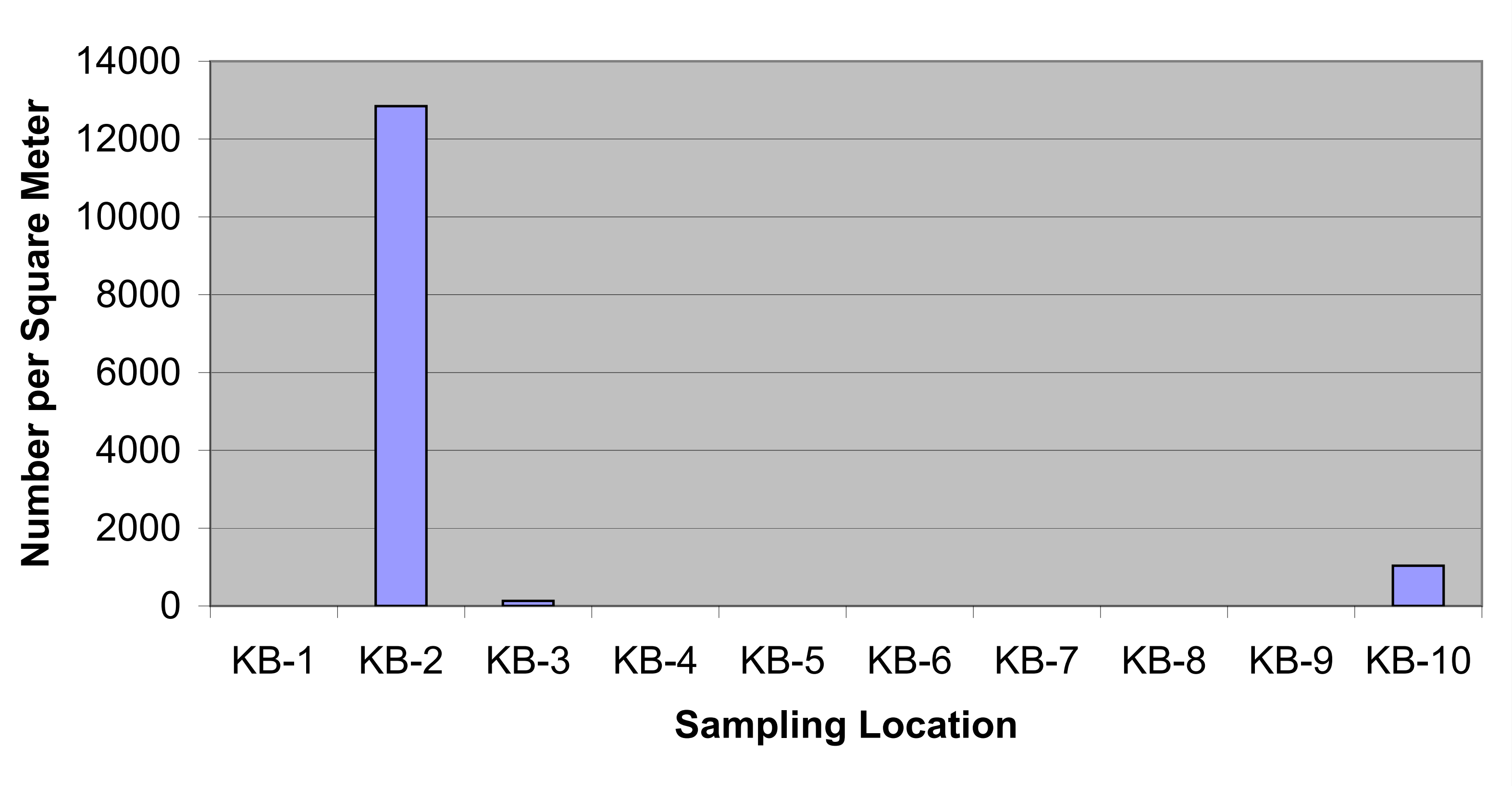


Figure H-45. Density (no. per square meter) of Pyrgophorus platyrachis by sampling location in Kings Bay, July 2009.

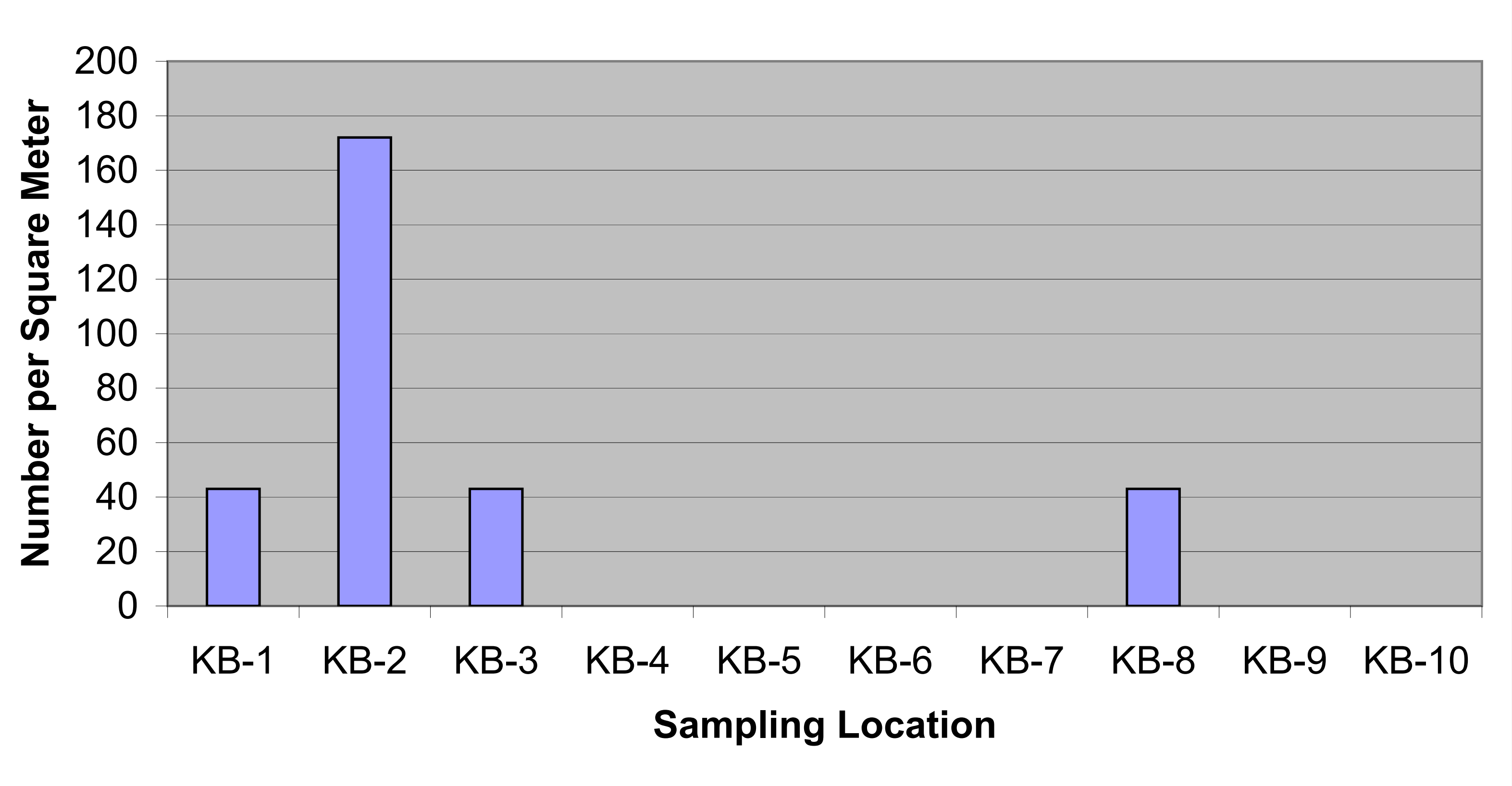


Figure H-46. Density (no. per square meter) of Streblospio sp by sampling location in Kings Bay, July 2009.